Novel Database Architecture and Signaling Scheme for IP-Based Heterogeneous Wireless Access Interworking

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ABSTRACT

Next generation heterogeneous wireless networks are expected to interwork with IP-based infrastructures. The IP Multimedia Subsystem (IMS) is an open, standard based solution that merges the Internet with Third Generation (3G) cellular networks. Attainment of a unified logical database is one of the key aspects that promote deployment of IMS. Home Subscriber Server (HSS) as an evolved version of Home Location Register (HLR) is one of the key components of IMS. In deploying HSS as a central repository database, in a fully overlapped heterogeneous network setting, changes of access mode are very frequent and conveying this information to HSS imposes excessive signaling load and delay. In our proposed scheme we introduce an Interface Agent (IA) for each location area that that caches the location and information about the access mode through which a user can be reached. This method results in significant amount of signaling cost savings, hence a better delay performance.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design; C.2.6 [**Computer-Communication Networks**]: Interworking

General Terms

Design, Performance

Keywords

Heterogeneous Access Networks, Home Subscriber Server, IP Multimedia Subsystem, Interface Agent, Unified Logical Database

1. INTRODUCTION

In a transition to the future generation of wireless networks, convergence of IP based core networks with heterogeneous wireless access networks is inevitable. The Internet is composed of different domains operated by Internet Service Providers (ISPs) with different capabilities, policies and access networks. Next Generation Networks (NGNs) will employ standards and architectures that are based on the IP suite. The IP platform can integrate diverse access networks in a common scalable framework, and through IP Multimedia Subsystem (IMS), extend a wide range of multimedia services to subscribers over heterogeneous wireless and wireline access networks. The need for coexistence of diverse applications and wireless access technologies, motivates integration of heterogeneous access networks with IMS. IMS paves the ways to deliver existing services in a more efficient manner while making the creation of new services possible for service providers. These have been pursued by separation of application and service plane from call control plane in IMS. IMS is also based on the vision of single logical view of a central repository database that is called Home Subscriber Server (HSS) and is one of the key components of IMS. To support the heterogeneity, multi-modal mobile devices that provide alternate means to access the Internet are becoming widely available [3]. Interworking architectures are proposed by 3rd Generation Partnership Project (3GPP) that show the interworking of wireless local area network (WLAN) and 3G cellular networks [1] [2]. In today‘s wireless networks each application, service or access network uses its own database for storing end user data. This causes a lot of effort to be done by service providers to coordinate information exchanges across various databases, dealing with different authentication and registration procedures and hence leading to inconsistencies, duplication and data discrepancy. On the other hand, as the future of communication systems merges towards heterogeneity and deployment of multimodal User Equipment (UE), change of access mode (e.g. vertical handovers) within an overlaying network becomes very frequent in a fully overlapped coverage environment. Updating the repository database about current mode of access by mobile users can therefore lead to excessive signaling traffic.
In our novel architecture we address this problem by introducing an Interface Agent (IA) to the 3GPP interworking architecture and proposing an efficient signaling scheme that decreases the signaling cost while improving delay and user experience.

1.1 Location Management in 3G Cellular Systems

Location management is an important issue in mobility management. Mobility management involves call delivery, location management and handover management. It en-

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ables users to roam while simultaneously offering them incoming calls and seamless handovers. Location management involves location registration and call delivery. Call delivery procedure consists of locating a Mobile Terminal (MT) based on the available information in the database when a call to an MT is initiated. Location management also involves the process of discovering the geographical location and current attachment point of an MT. For the purpose of location management, the concept of Home Location Register (HLR) and Visitor Location Register (VLR) is used in the 3G networks. HLR and VLR are used to store the location information of MTs such as account numbers, subscribed features and preferences as well as access permissions and policies. In the literature, several schemes are proposed that are based on centralized database architectures or distributed database architectures [15] [16].

1.2 IP Multimedia Subsystem

The IMS is an overlay network initially defined by 3GPP in the past years and is currently in the development phase. Session Initiation Protocol (SIP) is mainly used in IMS for signaling. Extensions of SIP define several service enablers such as voice over IP (VoIP), multimedia streaming, presence, instant messaging, push to talk, etc. IMS provides an architecture that enables ubiquitous cellular access, convergence of fixed and mobile networks, user mobility, access-agnostic application development and a service centric framework that makes the development of new revenue generating services possible. IMS can be configured to act as the main routing system where all calls to IMS, cellular or Circuit Switched (CS) users are initiated via IMS and IMS makes the routing decision. IMS on the other hand, can act as a serving/visiting entity like Mobile Switching Center (MSC) in the 3GPP. In this model, upon initiation of a call from a 3GPP network, IMS or one of its application servers will be queried to retrieve a routing directory number [3]. Our proposed architecture is based on the strategy where IMS acts as the main routing system.

1.3 Home Subscriber Server

HSS is a key component of IMS which is an evolved version of HLR. In the current wireless networks, HLR is the essential component that provides access to mobile users in conjunction with the VLR and MSC. It also enables roaming within other networks. Although HLR stores the majority of subscribers' information, yet it is not a comprehensive database that stores all users profile information. HSS on the other hand provides a much wider range of features and is meant to act as a central master repository database. HSS not only takes on many of similar roles as HLR but it also provides routing information, maintains/tracks the location of a subscriber and keeps track of network resources. For the above mentioned reasons, the industry consensus is the deployment of a single logical repository database for all user related information.

Migration from HLR to HSS practically can be done by initially enhancing the existing HLR elements to support additional end user requirements and interfaces with IMS network elements. HSS functionality will be more extensive and having such a repository database in a single location may not be feasible. HSS physical nodes may therefore need

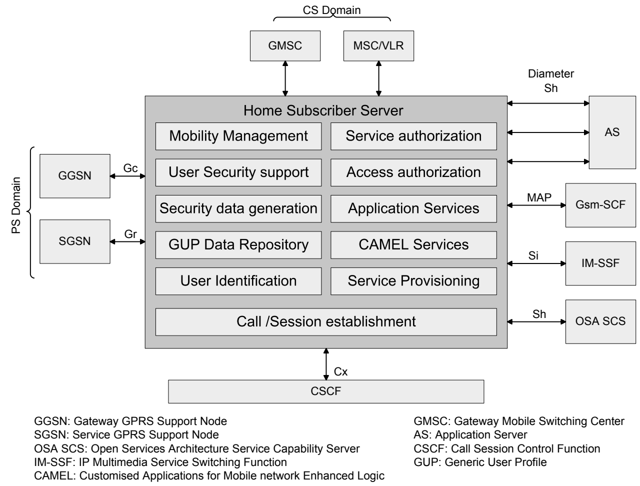

Figure 1: Functionality of HSS node at logical level across multiple domains

to be deployed in a more distributed (geographically) manner although HSS will logically be seen as a single repository network element. Figure 1 shows the interworking of HSS with different domains [5].

This paper is organized as follows. Section 2 briefly explains the previously proposed methods in location management. In section 3 we show our proposed architecture. Section 4 provides analytical modeling on the signaling cost followed by numerical results for cost comparison between our proposed method and a typical base scenario. We then explain some technical challenges and future research directions in section 5. Section 6 concludes this paper.

2. RELATED WORK

For location management and call delivery the database architectures are divided into two categories of centralized and distributed.

Centralized architecture

An example of a centralized architecture is dynamic hierarchical structure [11]. One of the strategies in the centralized category is called *per-user location caching strategy* that is based on a *multiple-copy location information strategy*. In this method the user profiles are replicated in multiple databases [12]. Another strategy in centralized architecture is *pointer forwarding* strategy in which the user location reporting can be eliminated by setting up pointers from old VLR to the new VLR [13]. A similar approach called *k-step pointer forwarding* is also proposed in [14].

Distributed architecture

This approach involves having multiple databases across different networks and can be considered as an extension of multiple-copy method. In this approach the location databases are connected in a tree form where multiple levels can be defined. The root at the highest level and leaves at the lowest level. Each MT is associated with a leaf [11].

Towards the integration of heterogeneous networks, one possible approach is to deploy a common HLR that interacts with VLRs in different access networks. However, the problem with this approach is that each individual network

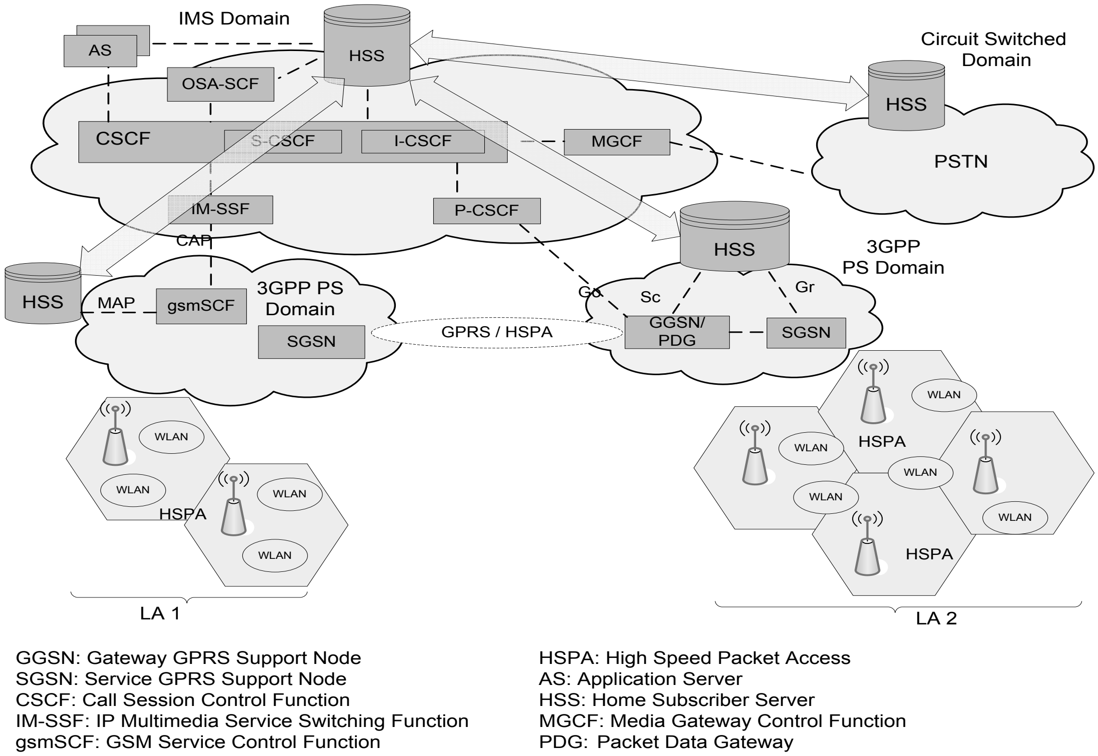

Figure 2: Interworking architecture that shows the physical distribution of HSS

uses a different signaling format, authentication procedure and registration method [7]. To make roaming among different wireless access networks possible, the idea of Boundary Location Register (BLR) is proposed [9]. It involves some boundary interworking units that are connected to MSCs. This method is designed for networks with partial overlaps at boundaries and may not be suitable for multiple networks that are fully overlapped [10].

In a heterogeneous network environment where multiple access networks fully overlap in their coverage, the following issues become important:

- Through which access network the user profile information, location and access mode should be updated
- In which network should the user profile be stored
- How the database repositories (physical nodes) can be managed and distributed.

The fully overlapped setting enables efficient ways to improve the capacity and quality of mobile users. To address the problem of heterogeneous access networks with different authentication procedures and registration operations the multi-tier HLR (MHLR) approach is proposed [10]. In the MHLR approach two methods of registration are introduced: Single Registration (SR) and Multiple Registration (MR). Under the SR method, the MT would only register through the lowest tier, whereas in MR method the MT would be able to concurrently register with multiple tiers. Detailed explanation of SR and MR is given in [7].

In a fully overlapped network setting, to solve the earlier mentioned problem about choosing the access network through which the MT can update its location, one possible approach would be updating the location information through all subscribed networks. However, this approach would make the task of call delivery more complex as it causes more data discrepancy. On the other hand it is not clear for the call delivery procedure that which one of the replicas is most recently updated and valid.

3. PROPOSED ARCHITECTURE

Our assumptions for the proposed model is based on the interworking architecture shown in figure 2 where we also demonstrate the physical distribution of HSS [8]. The basic idea is to introduce an Interface Agent (IA) that stores the information about active interfaces for the users in a LA in its cache. The IA is a SIP entity that is co-located with the P-CSCF at the edge of the IMS, running on the same host as P-CSCF. IA can interact with other entities within P-CSCF directly through internal SIP transport since TCP/UDP, IP, MAC and Physical layers are bypassed. Some of the advantages of such approach are less processing time and more reliability. In the context of this work, we define the LA as a set of clusters or coverage areas that can be covered by different service providers and have different converges fully overlapped as we will explain later. In order to explain how our proposed scheme function, we use the fully overlapped network setting which is a general and yet a more realistic and challenging case. In a LA there might be WLAN, WiMax and High Speed Packet Access (HSPA) coverage at the same time. A multimodal device is able to have multiple interfaces activated at the same time according to user‘s preference or automatically controlled by the UE based on available bandwidth and power criteria.

In deploying HSS as a central repository database, one possible approach can be that all HSS nodes of individual access networks would store all user related information such as user identification, account number, subscription data, preferences, location as well as current mode of access that the user can be reached at.

The aforementioned approach may not be suitable for a fully overlapped network setting environment where multiple access coverages coexist. Mobile users often move within or outside a Location Area (LA). In either case, due to mobility of users, change of primary access mode can be very frequent and this may result in excessive signaling traffic for updating the database.

In our proposed architecture, the role of IA is to store the information about active interfaces for the users in that LA in its cache. It interacts directly with the HSS physical node of that LA. Once the user moves outside the LA of a corresponding IA, the record for that user will be removed from the cache.

Our proposed architecture utilized the deployment of a single logical database that communicates with the IA. This single database can apply user profiles and store users‘ locations across all domains. Figure 2 shows the interworking architecture with HSS physical nodes distribution at an abstract level.

In the following we explain how our proposed method works.

As mentioned earlier, in the context of IMS, HSS is the central repository database that stores user related information that includes user profile data (e.g. identification, contact information, preferences, security information, subscription information, etc.) It furthermore, includes the HLR functionalities. HSS is the industry consensus as a single logical database to store network and user related data. It does not however know about the access mode through which a user can be reached. It knows the LA in which the user is residing and with the help of Interrogating Call Session Control Function (I-CSCF) and Subscriber Locator Function (SLF) can locate the Proxy-CSCF(P-CSCF)and the IA for that LA. Table 1 summarizes the role of CSCF and core elements of IMS in the context of registration [4] [5]. In this manner the updates for change of access mode are not conveyed to the HSS or the core IMS network. In addition, it facilitates the access agnosticism of access mode from the core network.

The role of IA is to cache the user data about the access mode that the user can be reached at. The final decision will be made by the P-CSCF and the network based on user‘s preferences or availability of network resources. This method improves the user experience, while eliminating data discrepancy and duplication. It also enables a faster call delivery and service time.

Our proposed architecture best suits situations where multiple coverage coexist in a LA. It performs best when users roam within a LA. In designing the LAs, one should consider the upper limits on the number of LAs and therefore the number of HSS physical nodes and the way they are distributed. We will demonstrate later in our analysis that the proposed architecture reduces the signaling cost while users

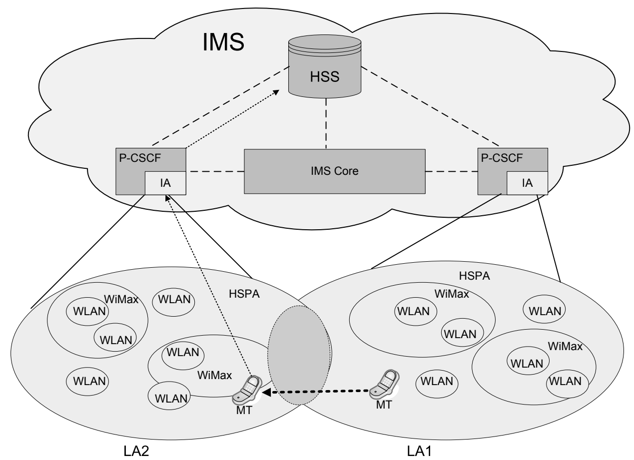

Figure 3: User movement and registration procedure

roam within a LA or outside a LA to a different or adjacent LA. Yet, the performance will be indifferent if this architecture is deployed in an environment where only single mode of access exists. However, in the future generation of wireless access networks, multimodal devices will be widely used and fully overlapped multiple coverage settings will exist. Therefore, the proposed method can be practically adapted for use in the future converged architectures. In the next section we demonstrate a user registration scenario based on the proposed architecture.

3.1 User Registration

In figure 3,we show the scenario for movement of a user from LA1 to LA2 in a situation where the two LAs may partially overlap if the LAs are covered by two different service providers. In this section we consider three situations for location update and registration:

1. *When the MT is moving away from LA1*: When the user is in the overlapping area of the two LAs the process of registration in the new LA will be performed. In the meanwhile, the old IA (in LA1) will be notified and the entry for that user will be removed from cache.

2. *When the MT enters LA2*: Once the MT enters LA2, along the registration procedure, information about the available access modes will be conveyed to the IA. If this is a new entry to the IA‘s cache, then HSS will be notified of the current location of the user.

3. *When a MT resides in a LA*: While residing in a LA, the MT might detect WLAN coverage or prefer to change the primary mode of access to WiMax, HSPA or WLAN. It is possible through deployment of multihomed clients in which the primary IP address can be changed at any point in time. This only requires an update to the IA and not to the HSS. Multihoming can be made possible through deployment of Stream Control Transmission Protocol (SCTP) as the transport layer protocol. Furthermore, it is possible to consider the case of an SCTP association between the two end points (MT and P-CSCF or IA).

Table 1: **Role of core elements of IMS**

Network Element	Functionality and Behaviour
S-CSCF	Acts as a **Registrar**,**Proxy Server** & **User Agent**. As a registrar it stores user registration information in HSS
I-CSCF	Acts as a **Proxy Server**, **User Agent**. Locating/Assigning the S-CSCF to/for the subscriber
P-CSCF	Acts as a **Proxy Server**. Forwards SIP resister request to the I-CSCF

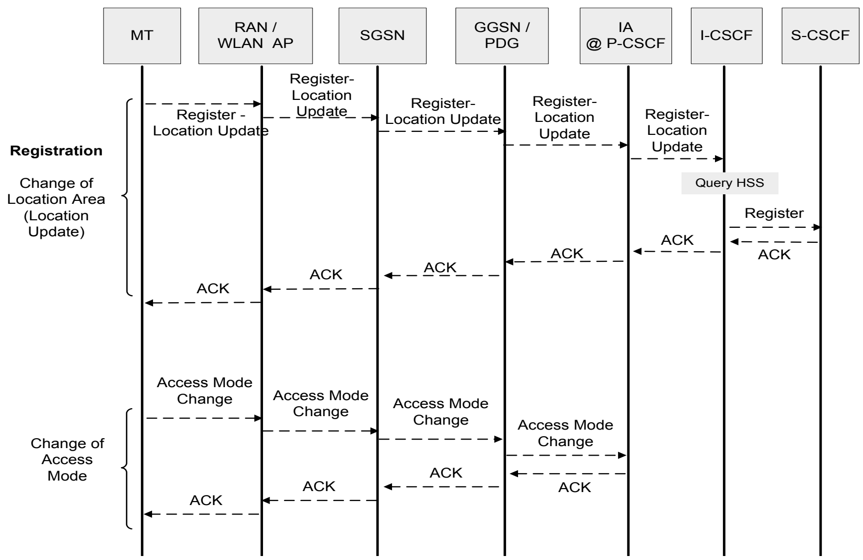

Figure 4: Signaling diagram for location update and access mode update in HSPA and WLAN

Figure 4 shows the signaling diagram for the cases of location update and access mode update in HSPA and WLAN coverage. As shown in the figure, the difference between the two tasks of location update and change of access mode is that querying the HSS is eliminated in the later.

Upon the first entry of an MT in a LA, in addition to conveying the location update to the HSS, it is also necessary to partially retrieve the user profile from HSS to determine the access networks that the user is subscribed to. A Policy Decision Function (PDF) is incorporated in P-CSCF and a Policy Enforcement (PE) module can also be incorporated in Gateway GPRS Support Node (GGSN). Policy enforcement decisions are conveyed to PE by PDF. PE and PDF can communicate in two possible modes of communication namely *push mode* and *pull mode*. In the push mode, communication is initiated by PDF and the decision is sent to PE module. In the pull mode communication is initiated by the PE module where a decision is requested [3]. The subscriber information about permitted access network types is cached to PDF of P-CSCF by HSS. Once the user enters a LA, it might need to authenticate itself to be granted access to its preferred available network. It therefore requires the PE module to operate in the pull mode and initiate a decision request from PDF. In this manner, the IA shall be informed by the P-CSCF about the current access mode through which the user can be reached.

In the context of access mode permissions, in our proposed architecture the following two approaches can be realized: The access modes that a subscriber is allowed to connect can be conveyed to the IA and cached upon the first entry of an MT in a LA. Yet, it might impose some unnecessary load on IA that requires more processing power and caching costs. It might not be necessary for the IA to know about all subscribed access networks that a user is permitted to connect because in some LAs chances are that some coverage such as WLAN or WiMax are not available.

On the other hand, the IA can pull the decision from the PDF of the P-CSCF upon the first occurrence of a user attempt to connect to a different Access Network (AN). This would happen if the UE detects such coverage and the user preferences allow initiation of access grant request. This approach is preferred because it imposes less amount of load on the IA node. To deploy this strategy we demonstrate a sample procedure for a scenario as described below.
A subscriber is roaming within a LA where HSPA, WiMax and WLAN coverage are available. Upon its first entry to the LA, the user has registered with HSPA network. The user has subscribed to all ANs and should be granted access to any of them upon its request and availability of resources. Currently, the IA has a record of this user to be accessible via HSPA. As the MT moves, it initiates a request to GGSN/PDG (Packet Data Gateway) to be connected to a WLAN AN. As the IA does not have any previous record of this user to be connected to a WLAN AN, it will initiate a request to P-CSCF. The PDF would make a decision and query HSS if needed. Should the access permission be granted, the PDF will then push the decision to the PE module in the GGSN. In this scenario, PDF and PE communicate in push mode. If successful, the current point of

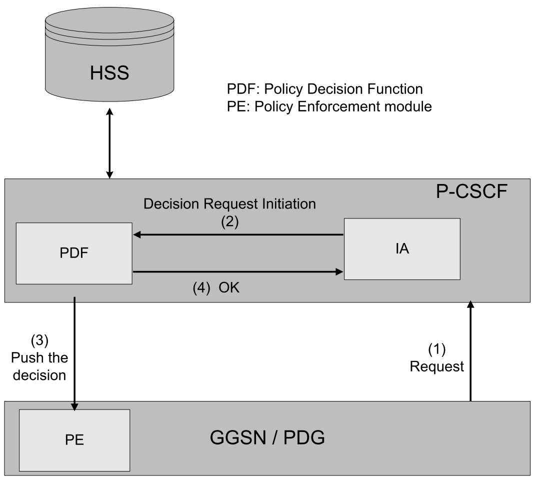

Figure 5: Communication of policy decisions for access mode grant permission

attachment would be cached at the IA. Figure 5 demonstrates the above mentioned procedure.

4. SIGNALING COST ANALYSIS

For the purpose of analysis in this work, we make the assumption that upon the first entry of a user in a LA, if authentication required by the network, the subscriber‘s profile information will be retrieved from HSS to determine the access networks that the user has subscribed. In the following, we model the cost of querying the IMS core and HSS based on the probability of user mobility within a LA and moving to an adjacent or different LA. In this analysis we only take the forced handovers into account (e.g. vertical handover from WLAN to HSPA when a user moves out of WLAN coverage to an area where WLAN coverage does not exist anymore). For the purpose of cost analysis we assume that LAs do not share any coverage (i.e there is no WLAN hotspot that crosses the boundary of a LA). We furthermore assume one HSS physical node per LA.
We start the analysis by presenting the cost analysis for a typical base scenario. In a typical base scenario, all changes such as location change and access mode change will be conveyed to the HSS. Figure 6 shows the signaling diagram.

The signaling cost of registration and location update, C_{Reg} in the typical base model is:

$$C_{Reg} = 2 \times (C_{UE-AN} + C_{AN-SGSN} + C_{SGSN-GGSN} + C_{GGSN-PCSCF} + C_{HSS-access}) \quad (1)$$

Where C_{x-y}represents transmission costs between network element x and y. We denote $C_{HSS-access}$ as the cost of accessing the HSS through IMS. This would involve communicating with I-CSCF, S-CSCF, SLF and other core elements. Total signaling cost as a result of user mobility within a LA and movement to adjacent LAs can be written as:

$$C_T^{base} = C_{Reg} \times Pr[Intra-LA-mobility] + C_{Reg} \times Pr[Inter-LA-mobility] \quad (2)$$

Where Pr[Inter-LA-mobility] and Pr[Intra-LA-mobility] are probabilities of moving outside a LA and within a LA respectively at a certain period of time and are explained in the following subsections.

4.1 Signaling Cost of Registration & Location Update

The following analysis is based on our proposed architecture and signaling scheme. Figure 4 shows the signaling diagrams. In this analysis we consider the signaling cost of location registration when a MT moves to a different LA. We define C_{Reg} as the cost of registration and location update. Cost of location registration in a new LA, (C_{Reg}) for the cases that the MT enters a HSPA coverage and the case that the MT enters a WLAN hotspot, can be written as:

$$C_{Reg}^{hspa} = 2 \times (C_{UE-RAN} + C_{RAN-SGSN} + C_{SGSN-GGSN} + C_{GGSN-PCSCF} + C_{HSS-access}) \quad (3)$$

$$C_{Reg}^{wlan} = 2 \times (C_{UE-AP} + C_{AP-SGSN} + C_{SGSN-GGSN} + C_{GGSN-PCSCF} + C_{HSS-access}) \quad (4)$$

An MT can move within a LA when it is active (whether it is on a call or not) or move outside a LA to an adjacent LA to LA_i or a WLAN hotspot or a WiMax coverage within LA_i at a certain time period. We define $Pr[Inter-LA-mobility]$ as the probability of an MT moving to an adjacent LA of LA_i. We consider the whole system as M^m LAs that consist of HSPA, WiMax and WLAN coverage. Let L_i^m be the set of LAs adjacent to LA_i, GP_i^m be the set of HSPA coverage inside LA_i, WM_i^m be the set of WiMax coverage inside LA_i and WL_i^m be the set of WLAN hotspots inside the LA_i. Let GP_k^{adj} be the set of HSPA coverage areas adjacent to HSPA coverage k, WM_k^{adj} be the set of WiMax coverage areas adjacent to WiMax coverage k and WL_k^{adj} be the set of WLAN hotspots adjacent to hotspot k [6]. For instance in figure 7, $M^m = 9$, $L_6^m = \{1, 5, 7, 2\}$, $GP_8^m = \{1, 2, 3, 4\}$, $WL_8^m = \{1, 2, 3, 4, 5, 6, 7\}$. The probability that an MT moves to an adjacent LA of LA_i is:

$$Pr[Inter-LA-mobility] = \sum_{j \in L_i^m} p_{ij}^L (\sum_{l \in GP_i^m} P_{jl}^{\alpha} + \sum_{m \in WM_i^m} P_{jm}^{\beta} + \sum_{n \ inWL_i^m} P_{jn}^{\gamma}) \quad (5)$$

where p_{ij}^L is the probability of moving from LA_i to LA_j and P_{jl}^{α} is the probability of entering in HSPA coverage l inside LA_j , P_{jm}^{β} is the probability of entering in Wimax coverage m inside LA_j and P_{jn}^{γ} is the probability of entering in WLAN hotspot n inside LA_j. For simplicity of our analysis however we consider equal cost of location update for HSPA, WiMax and WLAN and we set it to be C_{Reg}. i.e.

$$C_{Reg} \approx C_{Reg}^{hspa} \approx C_{Reg}^{wlan} \approx C_{Reg}^{wimax} \quad (6)$$

Therefore, the total signaling cost for location update is as follows:

$$C_{Reg}^s = Pr[Inter-LA-mobility] \times C_{Reg} \quad (7)$$

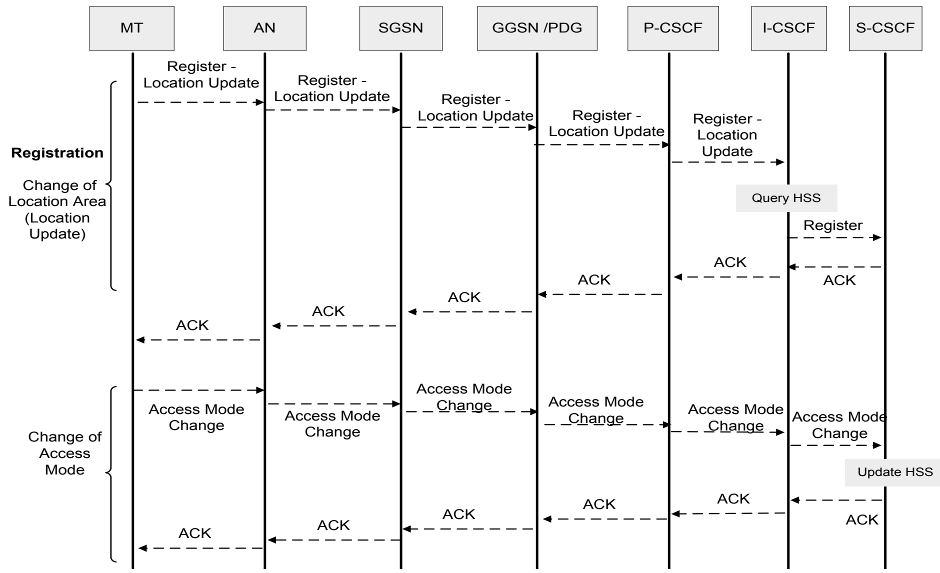

Figure 6: Sinaling diagram for a typical base scenario

4.2 Signaling Cost of Access Mode Update

Now we consider the case where the MT moves only within a LA but as it moves it might cross the boundaries of different coverage areas. For example it might perform a horizontal handover from WLAN hotspot i to an adjacent WLAN hotspot or perform a forced vertical handover from a WLAN hotspot to a WiMax or HSPA connection. In an overlapped network setting, forced handovers are: WLAN → WiMax, WiMax → HSPA or WLAN → HSPA. The cost of vertical handover within an overlaying network of a LA is:

$$C_{ho} = 2 \times (C_{UE-SGSN} + C_{SGSN-GGSN} + C_{GGSN-PCSCF}) \quad (8)$$

We now define the probability of mobility of an MT which is the probability of an MT moving to adjacent coverage or hotspots within a LA or perform vertical handovers within a LA. The probability of mobility, $Pr[Intra-LA-mobility]$ is therefore:

$$Pr[Intra-LA-mobility] = \sum_{l \in WM_k^m} P_{kl}^{WM} + \sum_{n \in WL_k^m} P_{kn}^{WL} + Pr[Forced-Vertical-Handover] \quad (9)$$

where P_{kl}^{WM} is the probability of moving (performing a horizontal handover) from WiMax coverage k to l and P_{kn}^{WL} is the probability of moving from WLAN hotspot k to n. $Pr[Forced-Vertical-Handover]$ can also be defined as follows:

$$Pr[Forced-Vertical-Handover] = \sum_{l \in GP_k^m} P_{kl}^{wimax\to hspa} + \sum_{j \in GP_k^m} P_{kj}^{wlan\to hspa} + \sum_{n \in WM_k^m} P_{kn}^{wlan\to wimax} \quad (10)$$

where $P_{ij}^{X\to Y}$ is the probability of VHO from X coverage i to Y coverage j (e.g. X and Y can be WiMax, HSPA or WLAN).

We define the signaling cost as a result of an MT moving within a LA as follows:

$$C^s_{access-Mode-update} = C_{ho} \times Pr[Intra-LA-mobility] \quad (11)$$

Total cost of signaling in the proposed method is therefore:

$$C_T^{proposed} = C^s_{Reg} + C^s_{access-Mode-update} \quad (12)$$

To obtain the signaling cost savings by using the proposed model, we consider $C_{Reg} = C^s_{db-access}$. We can therefore derive the savings in cost of signaling as follows:

$$\Delta C_{sav} \approx 2 \times C_{HSS-access} \times Pr[Intra-LA-mobility] \quad (13)$$

4.3 Numerical Results

In this section we demonstrate some numerical results to provide a comparison between a typical base scenario and our proposed model in terms of signaling cost. As mentioned earlier we decomposed the probability of mobility into the probability of user mobility within an overlaying LA and outside a LA. In this analysis we considered the ratio of movements within a LA to the movements out of a LA to be 0.8 : 0.2 with the assumption that a movement occurs. Each of the elements in the cost of registration is considered as one unit of cost except the cost of HSS access that is three units of cost. The ratio of mobility within a LA and between different LAs depends on the size of the location area and with the assumption of one physical HSS node per LA, it also indicates the number of HSS physical nodes. We denote $Pr[mobility]$ as the probability that a user is mobile and γ as the ratio of mobility that indicates the portion of roaming within a LA with respect to the roaming to a different LA. We denote the savings in cost ΔC_{sav} as follows:

$$\Delta C_{sav} = C_T^{proposed} - C_T^{base} \quad (14)$$

The graph of figure 8 shows the comparison of signaling cost between a typical base scenario and our proposed

Table 2: Parameters for cost of signaling vs. probability of mobility

Parameters	Value
Probabilty of Mobility	0.1 - 1
Probability of LA changes	0.2
Wireless link costs	1 (unit of cost)
$C_{HSS-access}$	3 (units of cost)

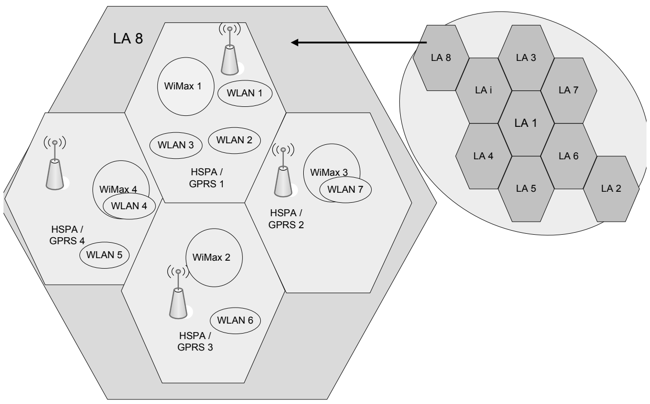

Figure 7: Location areas and possible configuration of coverage within a LA

Table 3: Cost savings as a result of change in ratio of Intra-LA to Inter-LA mobility

Parameters	Value
Probability of mobility	0.2, 0.5, 0.9
Probability of LA changes	0.1 - 1

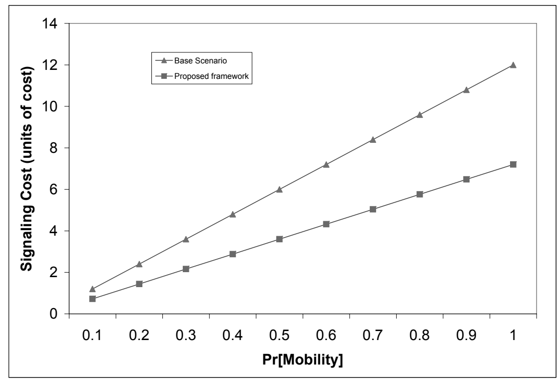

Figure 8: Signaling cost vs. probability of mobility

scheme. It demonstrates a better performance as the probability of user mobility increases. In other words, it shows more signaling cost savings. This graph is based on the assumption that 80% of user movements are within the LA and 20% chance of crossing a LA boundary that leads a location update. Table 2 shows values for the parameters that are used for this graph.

The result of figure 9 shows that as we increase the number of HSS physical nodes or decrease the size of a LA, there are less signaling cost savings. We have demonstrated this scenario for the cases where probability of mobility is 0.9, 0.5 and 0.2. The numerical values are listed in table 3. As shown in the graph as the probability of changing the LA increases, there are less cost savings in signaling traffic. The extreme point in the graph can be interpreted as the situation similar to the cellular networks with only HSPA coverage that users roam within different registration areas. On the other hand the proposed scheme performs better in the areas that there are more heterogeneity of networks. In other words, if there is only single HSPA coverage in some LAs, deployment of an IA under the proposed scheme, would result in an indifferent cost and delay performance as in a typical base scenario.

5. FUTURE WORK & TECHNICAL CHALLENGES

Towards adoption of IMS convergence solutions, service and network providers should migrate from HLRs to HSS. Since HSS is a more extensive database than HLR, it therefore needs to be geographically distributed. It furthermore, needs to support the existing and newly required functionalities, accommodate new subscribers while maintaining high availability and reliability as well as being simply manageable in a highly distributed framework. From the manufacturing point of view, however there may be upper limits on the size of a database. On the other hand, increasing the number of physical nodes may lead to a more complex management system. These can lead to researches on the optimal size of a database and the number of physical nodes.

6. CONCLUSION

In transitioning to the future generation of wireless networks, convergence of IP based core networks with heterogeneous wireless access networks is inevitable. IMS aims at providing a standardized solution for multimedia services in an access agnostic manner within a unified framework. In this paper we looked at the database location management for interworking of wireless heterogeneous networks with IMS. HSS as a key component of IMS will take over the task of HLRs with additional functionalities. The industry‘s consensus is towards deployment of a unified repository database that holds the subscriber profile information across different domains. One of the issues in mobility of users in heterogeneous environments is through which network should the MT update its location and where should the location information and access mode information of subscribers be stored. Location update through all possible access modes to separate databases for each access network can cause excessive delay in call delivery and service time to the users while creating data duplication and discrepancy. It also causes excessive signaling cost on the network. For the future wireless communication systems where multimodal devices deployed, having a single logical database

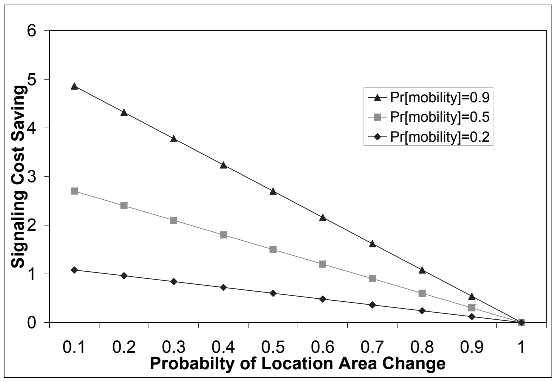

Figure 9: Signaling cost saving vs. probability of LA change

that applies the subscribersŠ profiles for all CS and Packet Switched (PS) domains would be advantageous. In this paper we presented our proposed scheme that was motivated by the idea of a unified logical database. The problem of frequent changes of access mode as a result of high mobility is explained. To reduce the signaling cost as a result of frequent changes of access mode, we proposed the use of an IA to cache the location and mode of access for a user. We demonstrated the performance improvements for situations where user is traveling within and outside a LA. Furthermore, the case for access grant permission and policy decision procedure is illustrated.

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