A Location Management Scheme for Heterogeneous Wireless Networks

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Abstract **-** One of the most challenging problems in global mobility management is location management which consists of keeping track of mobile users who leave their home network and roam into foreign networks that use different technologies and protocols. In this paper, we propose a model which improves location management efficiency in heterogeneous wireless networks. Such a model essentially consists of adding at the boundary location area between two different subsystems a specialized equipment called LR-ING (*Location Register and Internetworking Gateway*) which is connected to the Home Location Register (HLR) of both subsystems. Numerical results reveal that the proposed scheme enables to significantly reduce the signaling cost generated by the databases.

KEY WORDS - Global roaming, heterogeneous wireless network, location management, signaling cost.

I. INTRODUCTION

In heterogeneous wireless networks, mobile users are able to move from one subsystem to another while maintaining access capability to their subscribed services, which refers to global mobility or global roaming [1]. One of the most challenging problems in global roaming management is location management which consists of keeping track of mobile users who leave their home network and roam into foreign networks that use different protocols. In this context, locating a user requires interoperability between several fixed and mobile subsystems that do not necessarily implement the same technology, which may increase the signaling traffic and decrease the network performance. In this paper, we propose a model which improves the efficiency of location management in heterogeneous wireless networks in terms of signaling traffic generated during global roaming.

The rest of the paper is organized as follows. Section 2 introduces basic concepts and background related to location management. Section 3 presents the proposed location management scheme, as well as related procedures for intersystem registration, update and paging processes. Section 4 evaluates the performance of the proposed model in terms of total signaling costs, whereas Section 5 presents some concluding remarks.

II. BASIC CONCEPTS AND BACKGROUND

In a mobile network, the service area is divided into *location areas* (LA), and each LA covers several cells. In principle, whenever a mobile terminal enters a new LA, it must update its location information, which allows the network to know its current LA at any time [10]. Implementing LA-based methods for *mobility management* requires the use of a *home location register* (HLR) and several *visitor location registers* (VLR) [3], [8]. In fact, when a mobile user first subscribes to wireless services, a permanent record of his profile is created in the HLR. Since this user may move from one LA to another, his current location is usually maintained in a VLR, and must be identified before the setup of any connection.

Global roaming considers subscribers' movements between heterogeneous networks using different technologies. In this context, intersystem location update concerns updating the location information on a mobile terminal performing intersystem roaming, whereas intersystem paging is aimed at searching for the called terminal roaming between different service areas. It turns out to be important to develop a strategy which facilitates interoperability between heterogeneous subsystems in the context of intersystem location management.

Recently, a number of methods have been proposed to analyze the impact of global roaming on network performance [2], [4]-[9], [12]. Among them, conventional methods do not use any equipment to interconnect adjacent heterogeneous subsystems, as location management is made by means of signaling messages directly exchanged between the subsystems. However, new approaches for intersystem location management use specialized equipments to interconnect subsystems using different technologies. In particular, the approach presented in [7] is based on the user profile to manage global mobility. This approach implements intersystem update process by using dynamic regions called *Boundary Location Areas* (BLA). Intersystem paging is based on a boundary location register (BLR) which is connected to each MSC/VLR of both subsystems, and contains data from users who cross a BLA. It has been proven in [10] that this approach may reduce the signaling costs for high-mobility users. However, it contains several drawbacks. First, it does not specify how the registration process is set up when the mobile user turns on his terminal after arriving at the visited subsystem. Furthermore, since a BLR is connected to each MSC/VLR of both subsystems, intersystem paging process requires the network to consult the HLR of both involved subsystems, which may increase the signaling traffic generated during the process.

III. THE PROPOSED SCHEME

In this section, we present an architectural model which improves network performance in the context of intersystem location management. We also introduce related procedures for intersystem location registration, update and paging management.

A. The architectural model

Figure 1 gives an example of interconnection of two adjacent subsystems in accordance with the proposed architecture. This interconnection is based on a specialized equipment called LR-ING (Location Register and INternetworking Gateway) which interconnects the HLR of both subsystems. In fact, the LR-ING is a bridge that facilitates interoperability between the subsystems by converting information exchanged between them and reducing signaling traffic in the context of intersystem location management. Furthermore, it contains a database which enables to collect and register user profile, as well as information related to the sessions of users who change subsystems. As a result, during the paging process, the LR-ING uses its database to recover the mobile terminal in a visited subsystem, which enables to decrease the packet loss rate and paging delay during intersystem handoff.

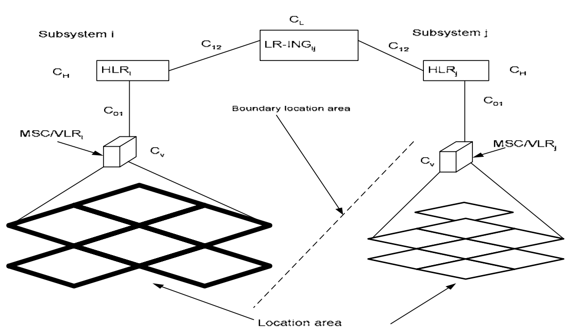

Fig. 1. Interconnection of two subsystems with an LR-ING

Moreover, the proposed approach defines a boundary location area (like in [11]) to guarantee that the location update procedure is executed before entering the visited subsystem. This area is dynamic, *i.e.* configurable according to the user profile. To evaluate the approach performance, we define the following parameters:

C_{01}: the transmission cost from an MSC/VLR to the HLR;
C_{12}: the transmission cost from the HLR to the LR-ING;
C_v: the access cost to the MSC/VLR;
C_H: the access cost to the HLR;
C_L: the access cost to the LR-ING.

B. Procedures for intersystem registration, handoff and location update

Consider two adjacent subsystems *i* and *j*. When a subscriber of subsystem *i* turns on his terminal for the first time in subsystem *j*, he has to register in *j*. As shown in Figure 2, the registration process is triggered by MSC/VLR_j which detects the presence of an unknown user in its LA, then sends an authentication request to HLR_j. The whole process is executed as follows:

1. The user sends an authentication request to MSC/VLR_j;
2. MSC/VLR_j transfers this request to HLR_j;
3. HLR_j transfers the same request to $LR\text{-}ING_{ij}$;
4. $LR\text{-}ING_{ij}$ registers the subscriber profile in its database, then sends an update request to HLR_i;
5. HLR_i updates its database and sends a confirmation message to $LR\text{-}ING_{ij}$;
6. $LR\text{-}ING_{ij}$ sends a response to MSC/VLR_j so that it registers the subscriber in its database.

At the end of the process, the user can be served by subsystem *j* that uses the LR-ING to keep track of each mobile user coming from other subsystems.

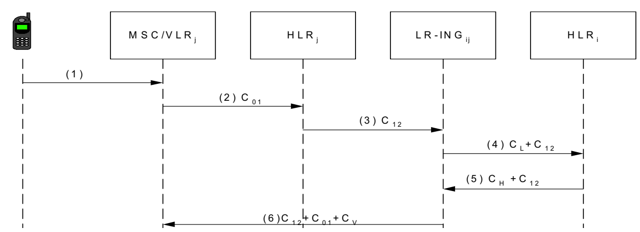

Fig. 2. Registration procedure with the LR-ING

Moreover, when a subscriber from subsystem *i* moves into subsystem *j* during a communication, an intersystem handoff is engaged to allow the user to maintain the connection and access his services from subsystem *j*. Such a procedure is illustrated in Figure 3 and decomposed as follows:

1. The mobile terminal sends a request to MSC/VLR_i to notify that it moves into subsystem *j*;
2. MSC/VLR_i transfers the request to HLR_i;
3. HLR_i sends the same request to $LR\text{-}ING_{ij}$;
4. $LR\text{-}ING_{ij}$ creates an entry to the mobile user in its database, then sends a connection request to HLR_j;
5. HLR_j sends to $LR\text{-}ING_{ij}$ information required to maintain the connection, such as bandwidth, available channels;
6. $LR\text{-}ING_{ij}$ transfers such information to MSC/VLR_j;
7. $LR\text{-}ING_{ij}$ transfers such information to the mobile terminal via MSC/VLR_i.

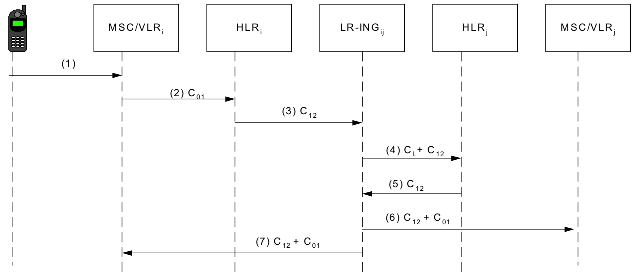

Fig. 3. Procedure for intersystem handoff with the LR-ING

In the same vein, when a subscriber moves throughout the LA of subsystem *j*, he has to update his location in order to be able to receive calls from his home subsystem. Such a procedure is illustrated in Figure 4 and consists of the following operations:

1. The mobile terminal sends a service request to the new MSC/VLR$_j$;
2. The MSC/VLR$_j$ transfers the request to HLR$_j$;
3. HLR$_j$ transfers the same message to LR-ING$_{ij}$;
4. The new MSC/VLR$_j$ sends a cancel message to the old MSC/VLR$_j$ which updates its database;
5. The old MSC/VLR$_j$ sends a notification message to the new MSC/VLR$_j$;
6. LR-ING$_{ij}$ updates its database and sends a notification message to the new MSC/VLR$_j$.

C. Procedure for intersystem paging

In the context of intersystem paging, two possible scenarios for the user location may be identified according to the proposed architecture.

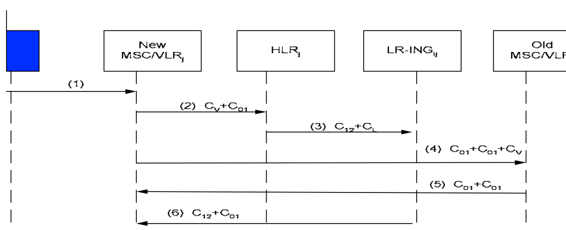

Fig. 4. Procedure for intersystem location update with the LR-ING

Scenario 1: The called terminal is located at the boundary location area of the home subsystem

In this context, the procedure for intersystem paging is illustrated in Figure 5 and consists of the following steps:

1. A call arrives at HLR$_i$ which realizes that the mobile user had already made an intersystem registration request. As a result, HLR$_i$ transfers the request to LR-ING$_{ij}$;
2. LR-ING$_{ij}$ obtains the user location, then notifies to HLR$_i$ that the user is still located at subsystem *i*;
3. HLR$_i$ sends a signaling message to MSC/VLR$_i$ which controls the user location area;
4. MSC/VLR$_i$ finds the user location, assigns a temporary location directory number (TLDN) to the terminal, and transfers this information to HLR$_i$ which forwards it to the calling MSC/VLR.

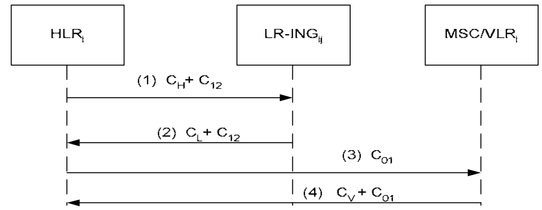

Fig. 5. Procedure for intersystem paging: scenario 1

Scenario 2: The called terminal is located at the visited subsystem

In this context, the procedure for intersystem paging is illustrated in Figure 6 and consists of the following steps:

1. A call arrives at HLR$_i$ which realizes that the mobile user had already made an intersystem registration request. Thus, it transfers the request to LR-ING$_{ij}$;
2. LR-ING$_{ij}$ consults its database to obtain the user location, then notifies to HLR$_j$ that a user from subsystem *i* has to receive a call;
3. HLR$_j$ sends a signaling message to MSC/VLR$_j$ (which controls the current user location);
4. MSC/VLR$_j$ finds the user location, assigns a TLDN to the terminal, and transfers this information to HLR$_i$ via LR-ING$_{ij}$.

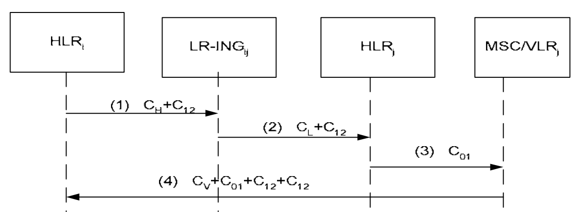

Fig. 6. Procedure for intersystem paging: scenario 2

IV. NUMERICAL RESULTS AND ANALYSIS

To evaluate the performance of the proposed architecture, we have estimated the total signaling costs for the procedures described in Section 3. Afterwards, we have compared the total signaling costs obtained from the proposed architecture with those obtained from the BLR protocol [11].

A. Total signaling costs

To evaluate the total signaling costs, we define the following parameters:

λ_n : number of calls per unit of time to the mobile terminal;

μ: number of times a mobile terminal changes location areas per unit of time;

S_1: cost for paging a terminal using the LR-ING and considering scenario 1;
S_2: cost for paging a terminal using the LR-ING and considering scenario 2;
R_{ij}: cost for intersystem handoff between subsystems *i* and *j* using the LR-ING;
U_T: total cost for location update using the LR-ING;
U: total cost for location update using the BLR protocol;
C_G: total costs for location update and paging procedures using the LR-ING;
C_{11}: transmission cost from an MSC/VLR to the BLR;
C_B: access cost to the BLR;
C: total costs for location update and paging procedures using the BLR protocol.

Let P_s be the probability of intersystem mobility. Then, P_s is given by [7] as follows:

$$P_s = \Pr[\textit{call duration } t_2 \rangle \textit{ sojourn time } T] * \Pr[\textit{a call arrives during } T]$$

As a result, the total cost for location paging S_T using the LR-ING is expressed as follows:

$$S_T = S_1*(1 - P_s) + S_2 * P_s \quad (1)$$

Moreover, the total costs for location update using the LR-ING involve the intersystem handoff process. It is expressed as follows:

$$U_T = \mu R_{ij} \quad (2)$$

As a result, the total costs for location update and paging procedures using the LR-ING are given by:

$$C_G = \mu U_T + \lambda_n S_T \quad (3)$$

Furthermore, to evaluate the costs of procedures defined in Section 3 and illustrated in Figures 3 - 6, it is important to take into account the costs of accessing the databases, as well as the transmission link cost, as illustrated in Figure 1. In particular, Figure 3 enables to evaluate R_{ij} by summing the costs of operations executed in steps 2 – 7 as follows:

2. C_{01}
3. C_{12}
4. $C_L + C_{12}$
5. C_{12}
6. $C_{12} + C_{01}$
7. $C_{12} + C_{01}$

Thus R_{ij} is given by:

$$R_{ij} = 5\,C_{12} + 3\,C_{01} + C_L$$

In the same vein, Figures 5 and 6 enable to respectively evaluate S_1 and S_2 as follows:

$$S_1 = 2\,C_{12} + 2\,C_{01} + C_H + C_L + C_V$$
$$S_2 = 4\,C_{12} + 2\,C_{01} + C_H + C_L + C_V$$

Moreover, the costs for the BLR protocol have the same characteristics as those defined in Figure 1, with the difference that the BLR can communicate with the HLR via the MSC. In this context, the total cost U for location update using the BLR protocol is obtained by summing the costs of all operations executed during the same procedure of intersystem handoff, paging or update. As a result, U is given as follows:

$$U = 6\,C_{11} + C_B \quad (4)$$

Furthermore, the cost S for paging a terminal using the BLR protocol is calculated as follows:

$$S = C_V + C_B + C_H + 3\,C_{11} + 2\,C_{01} + P_s * C_{11} + (1 - P_s) * (C_{11} + 2\,C_{01}) \quad (5)$$

As a result, the total costs C for location update and paging procedures using the BLR protocol are given by:

$$C = \mu U + \lambda_n S \quad (6)$$

For performance comparison, we combine (3) and (6) to define a cost ratio as follows:

$$\frac{C_G}{C} = \frac{U_T + \frac{\lambda_n}{\mu} S_T}{U + \frac{\lambda_n}{\mu} S} \quad (7)$$

where C_G and C are respectively given by (3) and (6), whereas λ_n/μ = CMR (Call to Mobility Ratio) indicates the ratio of the number of calls per unit of time to the number of changes of location areas per unit of time for a mobile terminal.

B. Results analysis

We first consider the case where the link costs are more significant than database access costs, *i.e.* $C_v = C_H = C_L = C_B = 0$, whereas C_{01}, C_{11} and C_{12} are given in Table 1. Figure 7 illustrates the behaviour of the ratio given by (7) for $P_s = 0.3$ and CMR = λ_n/μ. We realize that, when $C_{12} > C_{11}$, the BLR protocol gives better results due to the fact that, for the proposed architecture, all signaling messages sent from an MSC to the LR-ING must transit via the HLR, which increases the link costs. On the other hand, when $C_{12} < C_{11}$, the proposed architecture transmits less signaling messages throughout the network than the BLR architecture. Furthermore, when $C_{12} = C_{11}$, the proposed architecture enables to reduce the signaling costs obtained from the BLR protocol by about 40 %. The decreasing aspect of the curves comes from the fact that, for high values of CMR, mobile users receive more and more calls, as the scenario for location paging becomes more efficient using the proposed architecture. On the other hand, for low-speed users, the improvement is about 45% of the total cost for a mobility probability value of 0.3.

TABLE 1
Link costs for comparison with the BLR protocol

Series	C_{01}	C_{12}	C_{11}
1	1	3	6
2	1	6	3
3	1	6	6

We now consider the situation where the database access costs are more significant than the link costs, *i.e.* $C_{01} = C_{12} = C_{11} = 0$, whereas C_V, C_H, C_B and C_L are given in Table 2. Figure 8 illustrates the behaviour of the ratio given by (7) for $P_s = 0.3$ and CMR = λ_n/μ. For the chosen values of database access costs, we realize that both architectures give the same results. In other words, they are similar in terms of the number of signaling messages processed by the databases. The main difference resides in the interconnection of the added equipment: the LR-ING is connected with the HLR of each subsystem, whereas the BLR is connected with all MSC/VLR in each subsystem, which is financially more expensive for operators and service providers.

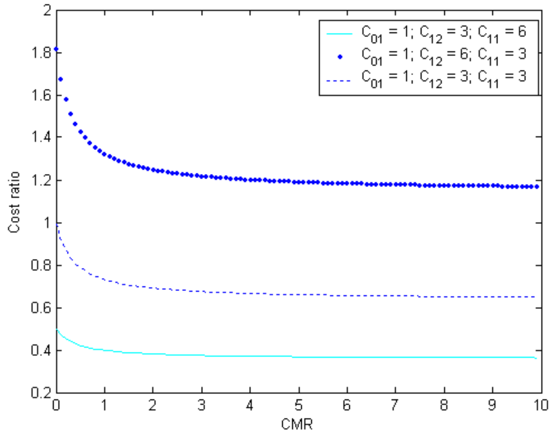

Fig. 7. Comparison with the BLR protocol (database access costs negligible and P_s = 0.3)

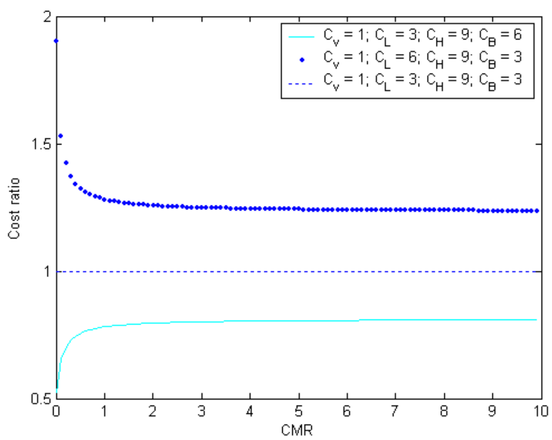

Fig. 8. Comparison with the BLR protocol (link costs negligible and P_s = 0.3)

TABLE 2
Database access costs for comparison with the BLR protocol

Series	C_V	C_H	C_L	C_B
1’	1	9	3	6
2’	1	9	6	3
3’	1	9	3	3

Finally, Figure 9 illustrates the behaviour of the ratio given by (7) for various values of CMR (= λ_n/μ) in function of P_s ($0 < P_s < 1$). The other parameters are chosen as follows: $C_{01} = 1$, $C_{12} = 3$, $C_{11} = 3$, $C_B = 3$, $C_L = 3$, $C_H = 9$ and $C_V = 1$. For such parameters, we realize that, the more the CMR increases, the more the proposed architecture improves results obtained by the BLR protocol. The increasing aspect of the curves comes from the fact that, when P_s increases, the quantity of signaling messages generated by the proposed architecture becomes more important. In fact, each MSC/VLR of the BLR architecture has a direct access to the BLR, which is not the case of the proposed architecture where each MSC/VLR has to pass by the HLR to communicate with the LR-ING. On the other hand, the scenario for intersystem paging induces less signaling messages with the proposed architecture. In fact, when a request for location update is sent to the BLR and the user has not changed subsystem yet, the BLR does not exactly know in which location area to search. Consequently, it sends a signaling message to the HLR so that the latter can find the mobile user. This explains why the proposed architecture gives better results when P_s tends to 0. In general, the improvement reaches 30 % approximately.

V. CONCLUSION

In this paper, we have proposed an architectural model for intersystem location management. Such a model essentially consists of adding at the boundary location area between two adjacent subsystems a specialized equipment called LR-ING which maintains roaming information on mobile users moving between different subsystems. Numerical results reveal that the proposed scheme enables to reduce the signaling cost generated by the databases by about 45% when comparing the proposed architecture with the BLR protocol. Further work should be oriented towards developing new strategies which take into account the user classes in terms of mobility and types of generated traffic.

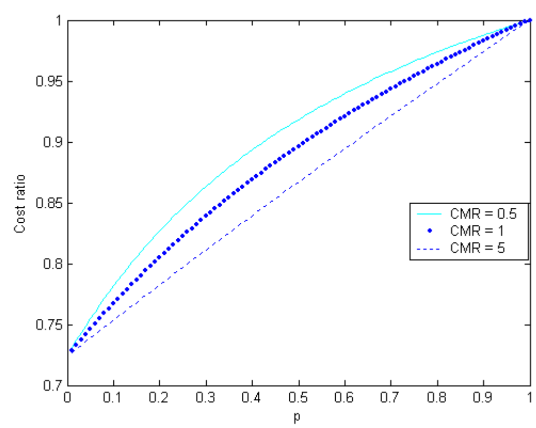

Fig. 9. Comparison with the BLR protocol for various CMR

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