Mobility Management Scheme for Reducing Location Traffic Cost in Mobile Networks

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Abstract. Even when users are moving, a major problem in such a mobile networks is how to locate Mobile Hosts (MHs). In this paper we propose mobility strategy that minimizes the costs of both operations, the location registration and the call tracking, simultaneously. In numerical results, the proposed method proves that it has more improved performance than the previous methods.

1 Introduction

To effectively monitor the movement of each MH, a large geographical region is partitioned into small Registration Areas (RAs). Figure 1 shows the architecture of a mobile system. Each RA has a Mobile Switch Center (MSC, also called a Base Station (BS)) which serves as the local processing center of the RA. The profiles of MH inside a RA are kept, in the MSC's Visitor Location Register (VLR). On top of several MSC/VLRs is a Local Signaling Transfer Point (LSTP) and on top of several LSTPs again is a Remote Signaling Transfer Point (RSTP). In this way, the whole system forms a hierarchy of station. The LSTP and the RSTP are routers for handling message transfer between stations. For one RSTP there is a Home Location Register (HLR). Each MH must register in a HLR. When a MSC needs to communicate with another MSC. MSC first sends a message to the LSTP on top of it. If another MSC is under the same LSTP as MSC, then the message is forwarded to another MSC without going through the RSTP. Otherwise, the message has to be through the RSTP and then down to a proper LSTP ad then to another MSC. In spite of many advantages available in wireless communication. It is not without difficulties to realize such systems. The first problem is how to locate a Mobile Host (MH) in a wireless environment. The IS-95 strategy is most often referred in resolving this problem. IS-95 used in the United States and GMS [6] used in Europe are examples of this strategy.

Many papers in the literature have demonstrated that the IS-95 strategy does not perform well. This is mainly because whenever a MH moves. The VLR of a Registration Area (RA) which detected the arrival of the host always reports to the HLR about the host's new location.

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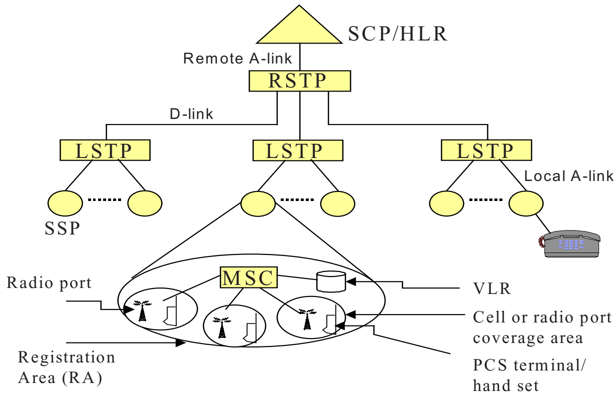

Fig. 1. Architecture of mobile networks

Among them, the Forwarding strategy [4, 5], the Local Anchor (LA) strategy, and the Caching strategy [3,7] are representatives of the old VLR to the new VLR. Update of the client's location to the HLR's database is not always needed to minimize communications to the HLR. To locate a callee however, some extra time is required to follow the forwarding link to locate the host. When the number of the forwarding links is high, the locating cost becomes significant.

In IS-95 scheme, the BS reserves only the resources corresponding to the minimum transmission rate to the mobile. According to the IS-95 strategy, the HLR always knows exactly the ID of the serving VLR of a mobile terminal. We outline the major steps of the IS-95 location registration scheme as follows [6]:

1. The mobile terminal sends a registration request (REGREQ) message to the new VLR.
2. The new VLR checks whether the terminal is already registered. If not, it sends a registration notification (REGNOT) message to the HLR
3. The HLR sends a registration cancellation (REGCANC) message to the old VLR.

The old VLR deletes the information of the terminal and the IS-95 call tracking scheme is outlined as follows:

1. The VLR of caller is queried for the information of callee. If the callee is registered to the VLR, the Search process is over and the call is established. If not, the VLR sends a location Request (LOCREQ) message to the HLR.
2. The HLR finds out to which VLR the callee is registered, and sends a routing request (ROUTREQ) message to the VLR serving the callee. The VLR finds out the location information of the callee.
3. The serving MSC assigns a temporary local directory numbers (TLDN) and returns the digits to the VLR which sends it to the HLR.
4. The HLR sends the TLDN to the MSC of the caller.

5. The MSC of the caller establishes a call by using the TLDN to the MSC of the callee. Among the above 5 steps, the Search process is composed of step1 and step2.

This paper proposes on further improvement the performance by minimizing location traffic. In the proposed method, we define the VLRs that have been linked to by the same LA as the overseen VLRs of this LA, and allow multiple such LAs to be linked together by using forwarding links.

2 Proposed Strategy

The proposed strategy is designed based on this simple concept. That is, when a call is made, instead of asking the callee's HLR the system will find the callee's VLR and from there the LA and then the callee. To accomplish this, the concept of the past LA strategy is adopted in this work. Depending on whether the caller's VLR statically or determine where to search for the callee. In both of these methods, the callee's profile needs to be kept in his visited VLRs. To serve for this purpose, a data structure named the MH table is defined to save some information of visited mobile users for each VLR. This table maintains for each visited MH the host's ID, a Type and a Pointer. The host's ID has the identifier of the host. Each host is assumed to have a different host's ID. Every VLR maintains a MH table records the information for each MH who has visited this VLR. Whether a VLR is the LA of a mobile client can be examined by using the value of Type in the MH table. The schema of the MH table is quite simple and easy to implement. The size of each record in this table can be as small as eight byte. The size of Type value is two bits and that of a Pointer value is also four bytes. It is easily manageable by any current DBMS. However the size of a MH table grows when more and more clients visited this. This problem can be easily resolved by removing obsolete records from the table when necessary. If from the table the system cannot locate the host, then the system simply asks the HLR of the callee about the current location of the callee.

2.1 Location Registration

We formally present the algorithms in the following subsections. Basically, take of location registration are to save a new record in visiting VLR, and to update location of the MH recorded in the old VLR. We provide for each algorithm to illustrate how the algorithm works.

1. The new VLR learns that the MH is inside its territory and informs the old VLR that MH is in its RA. The MH table of the new VLR is inserted a new record describing the coming MH. If the mobile client visited this new VLR in the past, then the system only updates the Type and the Pointer values.
2. The old VLR replies an acknowledgement to the new VLR.
3. The old VLR informs the LA that the MH has moved to the new VLR. Also the old VLR update its own MH table by replacing the MH's Type value with Visited VLR and the Pointer value with the LA's; location.

4. The LA replies a message to the old VLR, and updates its own MH table. The Type value of the mobile client is not changed. The Pointer value is modified to the new VLR's location.
5. End.

2.2 Call Tracking

We describe the call tracking operation. The algorithm of the call tracking is as follows.

1. When a VLR receives a request of locating a callee, it first checks whether its Mobile Host table has the callee's record. If yes, then sends the locating requite to the LA stated in this record. Otherwise, jump to Step 7.
2. / The caller is currently at a location where the callee visited before./
   if the record of the Mobile Host table of the LA stated in Step 1 says that this LA is a "Visited LA", then goto Step 3. If it says "Latest LA", goto Step 4.
3. The locating request is forwarded to this visited LA. While the request is forwarded to the next LA, the callee's record is again searched from this LA's Mobile Host table. Goto Step 2.
4. The latest LA finds the callee's record from the Mobile Host table. If the value of the Pointer field is NULL, then the callee is right in one of this LA's governing RAs. Hence, a message is forwarded to the caller's VLR to make the connection. Goto step 13. If the value of the Pointer field is not NULL, then it must be a VLR who is currently overseeing the callee. Hence, the call tracking request is sent to the latest VLR to which the Pointer field refers.
5. The latest VLR sends a message to the caller's VLR to make a connection.
6. Goto Step 13
7. / The caller is at a location where the callee has not visited before. Updates of the callee's new location in the LA, VLR, and HLR are associated with this call tracking operation /
8. The HLR forwards the request to the callee's LA.
9. The callee's latest LA forwards the request to the latest. Also, the callee's record in this VLR's Mobile Host table is updated by replacing its Type with "Latest LA" and Pointer with NULL.
10. The callee's VLR acknowledges the receipt of the message to the LA and the LA will then update the callee's record in its Mobile Host table by replacing type with "Visited LA" and Pointer with a pointer to the callee's current residing.
11. The callee's VLR sends a message to the HLR. The HLR updates the callee's new location to the new latest .
12. The HLR forwards the message about the current location (VLR) of the callee to the caller's VLR and the connection between the caller's VLR and the callee's VLR is built.
13. End.

3 Performance Model

We present the cost models that used to evaluate the performance of the proposed strategy. We list the parameters used in the models. Then, we derive the cost functions for the mobility strategies to be compared. The parameters used in our cost models are listed in Fig. 2. The costs of the IS-95strategy, was discussed in the literature [4]. But the environments and the details that were referenced in their derivations are different in many ways. In order to make a fair and reasonable comparison, we make some general assumptions and based on which we derive their cost functions in a uniform way. As the local database processing cost is insignificant comparing to the long communication time, we only consider communication cost in this derivation. Communication cost is dependent on the "distance" between two parties, and is classified into three levels: two parties are under different RSTPs, two parties are under the same RSTP but different LSTPs, and two parties under the same LSTP. Their costs are respectively C_1, C_2, and C_3, we also need to use probability to model the location distribution of two communicating parties. VLR, and two linked LAs. For simplicity, in all three sub-cases we assume that the two communicating parties are arbitrarily distributed.

Cost Function: The tasks of location management include managing location registration and call tracking. Hence, the location management cost is computed according to these two operations. As the ratio of the number of calls to mobility and defined as

$$Total\cos t = \frac{1}{CMR}\cdot \mathrm{Re}gistration\ \cos t + Call\ tracking \cos t.$$

Cost of IS-95: The total cost of the IS-95 strategy can be represented as follows.

$$C_{IS-95}^{total} = (\frac{1}{CMR})\cdot C_{IS-95}^{R} + C_{IS-95}^{T}$$

The registration cost and the call tracking cost of the IS-95 strategy is therefore.

$$C_{IS-95}^{R} = 2\cdot C_1, \quad C_{IS-95}^{T} = 4\cdot C_1.$$

Cost of Proposed Method: From the previous discussion, we understand that the difference of the registration operation between the proposed strategy and the Static LA strategy is that the MH record of a host is saved in the VLRs that the client has visited, whereas it's not in the LA strategy. Therefore, the registration cost of those two strategies should be the same. That is,

$$C_{proposed}^{R} = P_L\cdot(2\cdot C_3) + P_R\cdot(2\cdot C_2) + (1-P_L-P_R)\cdot(2\cdot C_1)$$

For the call tracking operation, two cases are involved: The caller is at a VLR that the callee has never visited. The caller is at a VLR that the callee visited before.

$$C_{prooposed}^{T} = (1-\sum_{i=0}^{k} p_i)\cdot C_{LA}^{T} + \sum_{i=0}^{k}(p_i\cdot(i\cdot C_{proposed\ -link}).$$

Symbol	Meaning
C_1	The cost of sending a message from VLR to another VLR under a different RSTP
C_2	The cost of sending a message from VLR to another VLR under a different LSTP but the same RSTP
C_3	The cost of sending a message from VLR to another VLR under the same LSTP
P_L	The probability of a mobile client's moving into a new RA which is under the same LSTP as the last RA that the client just left
P_R	The probability of a mobile client's moving into a new RA which is under the same RSTP as the last RA that the client just left
CMR	The call-to-mobility ratio
P_i	The probability that a caller's request is issued from LA_i and its overseeing VLRs

Fig. 2. Symbols of the parameters

4 Performance Analysis

From the above discussion, we see two important factors that affect the performance of the proposed strategy: K and P_i. Both of these parameters help to indicate how many calls could be from a VLR that the callee has visited in the past. For such callers, the locating cost could be cheap. But the tradeoff is that a long LA link will increase the cost for traversing through the LAs. Hence, we study the effect of these two factors. Also, we vary the ratio C_1 /C_3, which represents varying region size of a RSTP versus a LSTP. This is a general factor which affects all strategies. The default values of the parameters used in our evaluation are given ; C_1, C_2, and C_3 are 4, 2, 1, respectively, P_L is 0.7, P_R is 0.2, *CMR* is 0.5, *Ks* is 6, and P_i is 0.05. P_i is the probability that a caller places a call from a VLR that happens to be under one of the linked LAs of the callee. When this occurs, the call tracking cost is cheap. We vary P_i from 0.01 to 0.16. As the default K is 6, the total probability of a call from the VLR under a linked LAs is actually 0.06~0.96. The result given in Fig. 3 shows. However, for the proposed method a dramatic decrease of the cost when P_i increases. Although in general P_i may not be large for every kind of MHs, it could definitely be so for a certain type of users. Our performance result shows that the proposed strategy is especially good for managing MH of this kind. Figure 4 shows the result by varying length of this link K. A large K means that many VLRs that are under the linked LAs can locate a callee through the providing links of LAs, which helps to reduce the locating cost. Hence, the higher the *K*, the lower the cost of the proposed strategy. The improvement of the proposed strategy over the IS-95 strategies is very significant.

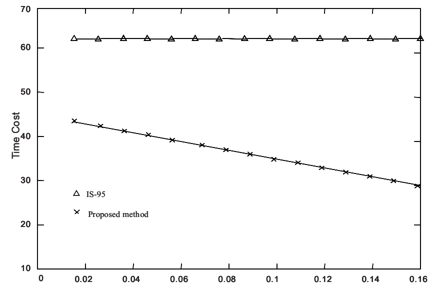

Fig. 3. Probability from LA_i

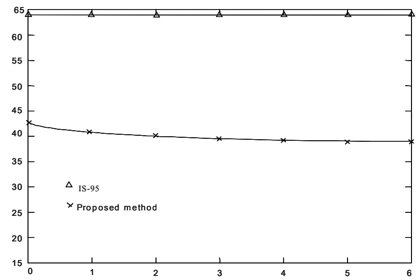

Fig. 4. Length of link

5 Conclusions

In this paper the proposed strategy could be reduced location traffic cost. The proposed strategy avoids updating the host's location to the HLR when the client moves to a new VLR. The host's new VLR always updates the host's location to the LA. We also derived the cost models of the proposed strategies and several other methods. Our analysis results reveal that in most case the proposed strategy performs better than the IS-95 strategies.

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