

Client Location Tracking in Ubiquitous Information Service Network

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Abstract

The objective of this paper is to present a feasible and efficient methodology that improves client mobility management under ubiquitous information service network. We base our system on the Open Integrated Service Network Architecture [3] and propose a hybrid infrastructure with facilities of both a centralized Network Management Center (NMC) and a distributed Home Base Node (HBN). We also have criteria for choosing a HBN with minimum cost by computing the expected registration cost and location tracking cost according to users characteristics and called frequencies.

Running a simulation, results show that our methodology is able to save up to 40% of the cost comparing to that of IS-41 when the value of Call-Mobility Ratio (CMR) is in the range of (1, 100), which means either clients are called with high frequencies or are moving with low mobilities. As the value of CMR goes down to the range of (0.01, 1), which means either clients are called with low frequencies or are moving with high mobilities, we may save up to 50% cost.

1. Introduction

Ubiquitous information service network (UISN) is ideally to provide an information environment such that any user may access information resource via either wired or wireless transportation network anytime and anywhere. The technique we had before allows us to retrieve information from a single resource. If an information system provides us with facility to integrate information from multiple resources, we shall have more precise forecast and make better decisions.

Lien [3] proposed an open service network

architecture, which is appropriate for information providers to build up information for their clients. This architecture follows:

- Rule 1: separation of physical transportation network and logical network (service network).
- Rule 2: adhering to open system architecture.
- Rule 3: decentralized service management for the purpose of reducing workload of centralized service management.

To maximize utilization of UISN, users are expected to be given a variety of mobilities, eg, terminal mobility, personal mobility, physical network mobility, agent mobility and client mobility (or logical network mobility). Client mobility provides logical network independence to users. A client needs only an unique ID number to travel around different logical networks, say Internet and PSDN. No matter where he is, other clients may always reach him by this number. For instance, if client A wants to reach client B and thus, sends a message to him. If B is on a cellular phone, the service network will forward this message to the telephone; while B is on Internet, this message would be sent to him through e-mail.

Current communication network provides no way for a mobile client to communicate with the Internet resource, like Internet phone, through his phone number. The client mobility allows a client, when he was in a car, to use his PDA to send out a message through wireless phone for hotel reservation that is provided by hotel reservation service network. At the time when he gets to office, he can retrieve the reservation result from Internet that is connected to his office PC. What he experienced is doing one thing using different communication devices and transportation networks at different time and different places.

In the upcoming network information age, everyone should go with computer network to do many things in

his daily life. Client mobility would be more important than others, that's why we focus on management of client mobility in this paper. Most of the current researches of mobile communication technology focus on client mobility management of mobile telephone network, like management of mobile stations of cellular phones. However, less researches have referred to management of logical network. In this paper, our management of client mobility is accomplished through the following steps: First, through analyzing a client's moving frequency and called frequency, we compute both the registration cost and location tracking cost for each HBN, then we choose to register to the HBN with minimum joint cost.

The organization of this paper is as follows: we introduce ubiquitous information service system architecture and its components in section two. In section three, we introduce a decision model to determine the optimized HBN for registration. In section four, we compare the total cost of registration and location tracking of our model to that of IS-41. Section five is conclusion and future work.

2. System Architecture

A feasible and effective mobility management system architecture should be associated with a variety of network management facilities. Our system architecture is equipped with the following facilities for real implementation:

(1) Network Management Center (NMC)

NMC is a central facility that supports all non-distributable management functions as well as distributed functions if it is needed. Typical OA&M (operation, administration, and maintenance) functions are client and server registration, authentication, name server, coordination, or client specific services. Although, it looks like a single node, it may actually be a number of nodes distributed over a network. For simplicity, we assume a NMC is a single node. In general, a commercial service network usually needs a NMC for such functionalities as billing, authentication, security, etc.

(2) Home Base Node (HBN)

Even though a mobile client may change its locations from time to time, it usually has a home location and a most frequently used Internet access point such as a personal account on an Internet-connected system or a PC, called Home Base Node. This infrastructure proposes to make use of HBN to share the OA&M workload. Since a mobile terminal device is very vulnerable in a hostile environment, it is not wise to use a mobile device as the

primary information repository. A more reasonable working model for most users is to use their mobile computing devices only for temporary cache and have their HBNs as primary working systems. Further, when a client subscribes to a service network, he can choose to use or not to use his own HBN. A lot of overhead in managing a service network can be saved by using HBNs. A HBN can also offer auxiliary computing resources to help mobile terminals to cope with their residential resource limitation. For example, applications that a HBN can perform are : location register, fax server, answering machine, news filter, etc.

(3) Location Directory (LD)

Every record in LD has two entries of data, which are user-ID and user address on the network, respectively. As a client moved, we should update the data of user-address to make it consistent with the current address of the client.

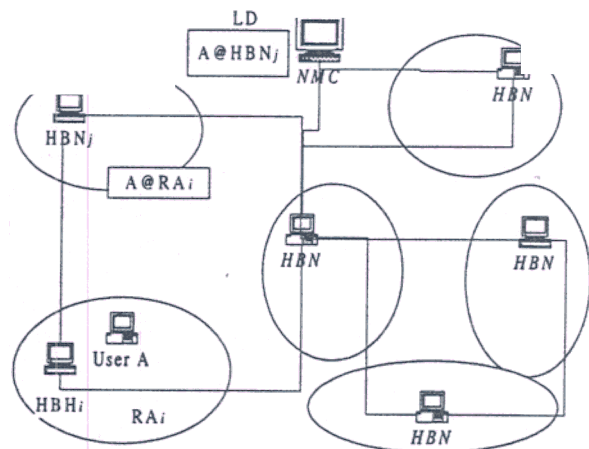


Fig. 2-1 System architecture.

(4) Location Server (LS)

The main functions of LS is to provide services of location registration and location tracking. Location registration is to update the user-address and make it consistent with the current address of the client. Location tracking is to localize where the client to be called is. One of the services provided by HBNs is to keep track of the clients' locations. Once a HBN is chosen to provide this service, it is also called a LS.

(5) Register Area (RA)

A register area is a geographical region partitioned by NMC according to the distribution of all LSs. Every register area is assigned at least one LS. A mobile client

might change a new LS only when he moves to other RA.

Fig. 2-1 is the system architecture which shows a variety of facilities distributed over a network. Where HBNs reside in RAs, mobile clients are allowed to move across RAs, and LDs are stored in both NMC and HBNs for location tracking. In this figure, user A is in HBN_n , HBN_j is the LS of user A, and the LD of HBN_m records the address of user A as $A@RA_j$. The LD of NMC records $A@HBN_j$, which is the LS of user A. Comparing to those facilities of IS-41, NMC corresponds to HLR (Home Location Register) and LS to VLR (Visitor Location Server).

3. Location Server Decision Model (LSDM)

In our system, a client and his LS are allowed to reside in different RAs, e.g., user A and his LS, HBN_j , in Fig. 2-1. Also, all HBNs on the network are possible candidates of a given client's LS. In this section, we propose a decision model to choose one of the HBNs to serve as this given client's LS.

In section 3.1, we define some denotations of matrices and vectors to model a user's moving behavior and called behavior. In section 3.2, we represent a cost function of registration cost and location tracking cost of the user in terms of those matrices and vectors. In section 3.3, we use that cost function to choose a HBN, with minimum total cost, as the user's LS.

3.1 Denotations

In the following definitions, we use matrices and vectors to model length of time a user stays in a RA, probability of a user moves from one RA to another, time spent on network communication between two RAs, cost of using a NMC every unit time, user's called frequency every unit time, and the RA where the caller is in, etc.

N : a set of RAs. One register area belongs to N if and only if either a user A has ever stayed in this area or some other users have ever called user A in this area.

n : the total number of RAs in N .

RA_i : a register area, with index i , that belongs to N , where $N = \{ RA_1, RA_2, \dots, RA_n \}$.

HBN_j : a home base node, with index i , that resides in

RA_j . At a given time, each user would choose a HBN to serve as his LS. Note that the user and his LS are not required to reside in the same RA.

S : a n -dimension vector, $S = (S_1, S_2, \dots, S_n)$. Where S_j , a real number, represents the expected time a user stays in RA_j .

C : a $n \times n$ matrix, $C = [C_{i,j}]_{n \times n}$. Where $C_{i,j}$, an integer, represents expected number of calls come from RA_j per unit time when a user stays in RA_i .

T : a $n \times n$ matrix, $T = [T_{i,j}]_{n \times n}$. Where $T_{i,j}$ represents the network communication time between HBN_j and HBN_i .

T_{NMC} : a n -dimension vector, $T_{NMC} = (T_{NMC,1}, T_{NMC,2}, \dots, T_{NMC,n})$. Where $T_{NMC,i}$, a real number, represents the time spent on network communication between NMC and HBN_j .

W : a $n \times n$ matrix, $W = [W_{i,j}]_{n \times n}$. Where $W_{i,j}$, a real number, represents the cost spent on network communication between HBN_j and HBN_i every unit time.

W_{NMC} : a n -dimension vector, $W_{NMC} = (W_{NMC,1}, W_{NMC,2}, \dots, W_{NMC,n})$. Where $W_{NMC,i}$, a real number, represents the cost spent on network communication between NMC and HBN_j .

All the above matrices and vectors are recorded in the mobility profile of a mobile user, say user A. Besides, this profile also includes the following information:

- (1) user-IDs, calling times, and calling locations of all those users who communicate with user A.
- (2) a names directory of user A. He might choose only respond to those users' calls whose names are listed in the directory.

3.2 Location Registration, Location Tracking and Cost Evaluation

In this section, we propose a strategy for mobile users' location registration and location tracking; and then use a cost function to compute the total cost.

3.2.1 Initial Location Registration

When a mobile client sends a "ask register" request to a service network at the first time, either NMC or the client himself will choose and set up a HBN as his LS. The client will then send his user-ID together with user-address to that LS. Receiving these information, the LS forwards client's user-ID and LS-address to NMC.

The strategy proposed for mobile users' location registration and location tracking is described in section 3.2.2 and 3.2.3.

3.2.2 Evaluation of Registration Cost

Assuming that user A resides in RA_i with HBN_m as his LS. When he moves to RA_j and changes his LS to HBN_n , then the registration cost can be evaluated in two cases. In the first case, when new LS is different from old LS, that is, $HBN_n \neq HBN_m$, where $n \neq m$; the other case is both of these LSs are the same, that is, $HBN_n = HBN_m$, where $n=m$.

Case1 : $n \neq m$, user A moves from RA_i to RA_j and changes his LS from HBN_m to HBN_n (see Fig. 3-1).

Step0 : user A sends "ask register" message to HBN_j and writes his user-ID and user-address into HBN_j 's LD. Since both user A and HBN_j are in the same RA, communication cost between user A and HBN_j can be ignored.

Step1 : HBN_j sends "ask register" message to HBN_n and writes user A's user-ID and user-address ($A@RA_j$) into HBN_n 's LD. Cost of this step is $T_{j,n} \times W_{j,n}$.

Step2 : HBN_n sends "ask register" message to NMC and writes its LS-address ($A@HBN_n$) and user-ID into NMC's LD. Cost of this step is $T_{NMC,n} \times W_{NMC,n}$.

Step 3 : NMC sends "ask de-register" message to HBN_m to delete user A's registration record ($A@RA_j$). Cost

of this step is $T_{NMC,m} \times W_{NMC,m}$

Summing up all the costs from step0 to step3, we have:

$$T_{j,n} \times W_{j,n} + T_{NMC,n} \times W_{NMC,n} + T_{NMC,m} \times W_{NMC,m}$$

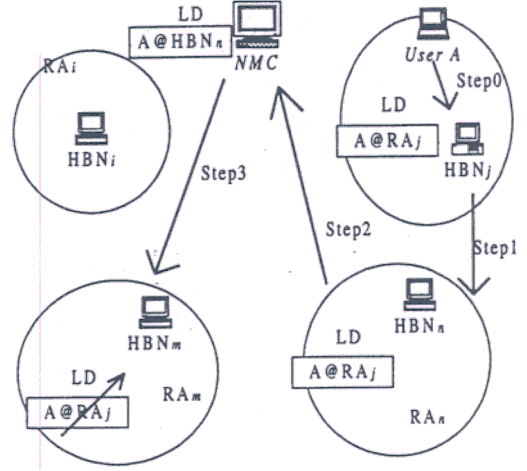


Fig. 3-1 User A moves from RA_i to RA_j and changes his LS from HBN_m to HBN_n .

Case 2 : $m=n$, user A moves from RA_i to RA_j with the same LS ($HBN_n = HBN_m$).

Step 0 : similar to the step0 of Case1, cost of this step can be ignored.

Step1 : similar to the step1 of Case1, cost of this step is $T_{j,n} \times W_{j,n}$.

Step2 : since user A doesn't make any change to the record ($A@HBN_n$) in NMC's LD, cost of this step can be ignored.

Step3: since HBN_n and HBN_m are the same, cost of this step can be ignored.

Summing up all the costs from step0 to step3, we have:

$$T_{j,n} \times W_{j,n}$$

In summary, the registration cost (register_cost) of user A spent on moving from RA_i to RA_j and changing his LS from HBN_m to HBN_n , is as follows:

when $m \neq n$

$$\text{register_cost}(n, j, m, T, W) =$$

$$T_{j,n} \times W_{j,n} + T_{NMC,n} \times W_{NMC,n} + T_{NMC,m} \times W_{NMC,m}$$

when $m = n$:

$$\text{register_cost}(n, j, m, T, W) = T_{j,n} \times W_{j,n}$$

where m , n , and j represent user A's old LS, current LS, and current RA indices, respectively.

3.2.3 Evaluation of Location Tracking Cost

Assuming that user A is in RA_j with current LS, HBN_n , and user B is in RA_i . Once user B wants to track the current location of user A, there are three steps to be taken (see Fig. 3-2):

Step 0 : user B sends "ask query" message to HBN_i .

HBN_i checks its LD to see if there is user A's current address. If it is found, then there are two possible cases:

Case1 : the record in HBN_i 's LD shows that user A is not in RA_j , and user A sets HBN_j as his current LS. The address found in HBN_i 's LD is user A's current location.

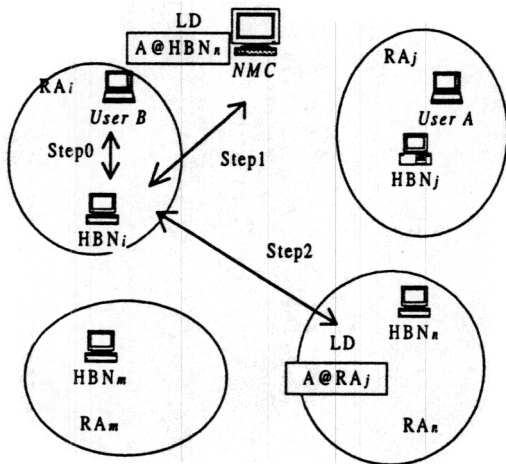


Fig. 3-2 User B tracks the location of user A.

Case2 : the record in HBN_i 's LD shows that user A is in RA_j . At this time, HBN_i broadcasts to every user that is in RA_j . If user A is actually in RA_j , then user A is found ; otherwise, it indicates that user A had ever stayed in RA_j , but moved to other RA. HBN_i would then delete this record and go to step1. Since HBN_i needs not communicate with other HBNs and NMC, the cost of step0 can be ignored.

Step1 : HBN_i sends "ask query" message to NMC to check user A's current LS. NMC would then check and send the address of user A's current LS back to HBN_i . Cost of this step is: $2 \times T_{NMC,i} \times W_{NMC,i}$

Step2 : now, user B has the address of user A's current LS, HBN_n . At this time, user B sends "ask query" message from HBN_i to HBN_n to retrieve user A's current location. As HBN_n received this query, it returns user A's current location back to HBN_i . Cost of this step is: $2 \times T_{i,n} \times W_{i,n}$

In summary, the cost of location tracking (location_cost) is:

when $i \neq j$ and $i \neq n$

$$\text{location_cost}(i, j, n, T, W) = 2 \times T_{NMC,i} \times W_{NMC,i} + 2 \times T_{i,n} \times W_{i,n}$$

when $i = j$ or $i = n$

$$\text{location_cost}(i, j, n, T, W) = 0$$

where i and j are indices of user B's and A's current RAs, respectively ; n is the index of user A's HBN.

3.2.4 Total Cost of Registration and Location Tracking

In the previous subsections, we evaluate the costs of registration and location tracking. Here, we define a total cost function as follows: the registration cost is the cost that a user, say user A, spent on moving from old RA to new RA, and the location tracking cost is the cost spent by other users who call user A, when he moves to a new RA. The registration cost can be evaluated by the same register_cost function, but the location tracking cost can't

be just apply *location_cost* function since it depends on all the calls made by all callers instead of a single caller.

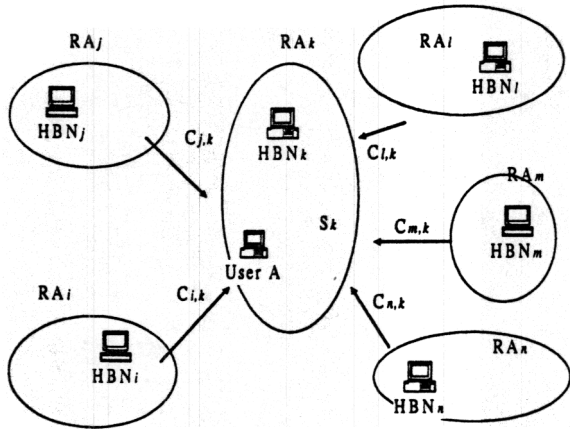


Fig. 3-3 Number of calls arrived every unit time.

In Fig. 3-3, we assume that user A moves into RA_k and changes his LS from HBN_j to HBN_i, the registration cost is

$$register_cost(l, k, j, T, W) = \dots\dots\dots(1)$$

N is the collection of all RAs in Fig. 3-4, so we have $N = \{RA_i, RA_j, RA_k, RA_l, RA_m, RA_n\}$. S_k is expected time user A stays in RA_k.

C_{i,k}, C_{j,k}, C_{l,k}, C_{m,k}, C_{n,k} represent expected number of calls every unit time made by callers from RA_i, RA_j, RA_k, RA_l, RA_m, RA_n, respectively.

Altogether, we have (C_{i,k} + C_{j,k} + C_{l,k} + C_{m,k} + C_{n,k}) × S_k number of calls arrived during the time when user A stays in RA_k.

Specifically, C_{i,k} × S_k represents number of calls come from RA_i, and the cost of location tracking by calling from RA_i is

$$C_{i,k} \times S_k \times location_cost(i, k, l, T, W).$$

The costs from other RAs can be computed similarly. Summing up all the costs, we have user A' location tracking cost as:

$$\sum_{RA_x \in N} C_{x,k} \times S_k \times location_cost(x, k, l, T, W) \dots\dots(2)$$

From (1) and (2), we have user A's total cost function as follows:

$$Total_cost(l, k, j, T, W, C, S) = register_cost(l, k, j, T, W) + \sum_{RA_x \in N} C_{x,k} \times S_k \times location_cost(x, k, l, T, W)$$

where l, k, and j are indices of user A's current LS, current RA; and old LS.

3.3 Decision Method for Choosing HBN to Register

3.3.1 Background Description

We define the ratio of number of calls arrived every unit time to moving frequency from one RA to another as Call-Mobility-Ratio (CMR). When a user is in RA_j, the value of CMR can be expressed as follow :

$$CMR = \frac{\sum_{RA_i \in N} C_{i,j}}{1/S_j} = S_j \times \sum_{RA_i \in N} C_{i,j}$$

That is, the value of CMR is equal to the multiplication of expected unit time one user stays in RA_j and number of calls arrived every unit time. A low CMR indicates either the expected time one user stays in a RA is short (high mobility) or number of calls made by others every unit time is low. A high CMR indicates either the expected time one user stays in a RA is long (low mobility) or number of calls made by others every unit time is high. In choosing a HBN as a LS, the best candidate would be the one belonging to the RA that maximize the value of CMR, which will reduce the location tracking cost.

3.3.2 Decision Method

When a user moves from RA_i to RA_j and changes his LS form HBN_m to an unknown HBN_x. The total cost is Total_cost(x, j, m, T, W, C, S) Where j and m are constants and T, W, C, S are constant matrices and vectors that recorded in users' mobility profiles. Hence, Total_cost function can be defined in terms of x. F(x)=Total_cost(x, j, m, T, W, C, S). Applying all HBNs of RAs belonging to N into F(x), we would have the total costs of each HBN that serves as user A's new LS. Our decision method would choose the HBN, say HBN_{opt}, that satisfies F(opt) = Min{F(x) | RA_x ∈ N}, as user's

new LS.

4. Implementation and Result Analysis

4.1 Simulation

In the simulation of decision model, we assume that every RA has exactly one HBN. Let $W_{i,j}=1$, where $i, j=1, 2, \dots, n$. S_j is chosen from a uniform random variable between 1 and 100 ; $C_{i,j}$ is chosen from a uniform random variable between 1 and 10.

The distributions of HBNs are on a xy-plane. The x and y coordinates range from -1000 to 1000, respectively. The (0,0) is chosen as NMC's coordinate. Let the network communication time between two HBNs be the distance between them. For example, HBN_i locates at (X_i, Y_i) and HBN_j locates at (X_j, Y_j) , then $T_{i,j} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$, similarly, we have $T_{NMC,i} = \sqrt{X_i^2 + Y_i^2}$. In the following, we compute the total cost of registration and location tracking of a user's ten-step movement.

Total cost is defined in two different ways. The first one, *Decesion_cost*, is the cost spent on ten-step movement using LSDM. The second one, *IS-41_cost*, is the cost spent on ten-step movement using the method employed by IS-41.

4.2 Result Analysis

Fig. 4-1 illustrates the ratio of *Decision_cost* to *IS-41_cost* after ten-step movement. Y-axis represents the ratio of *Decision_cost* to *IS-41_cost*, and the x-axis represents the value of user's *CMR*. The maximum, minimum, and average ratios of *Decision_cost* to *IS-41_cost* are 0.738, 0.554, and 0.609, respectively. The zigzag line in Fig. 4-1 represents the real ratios of *Decision_cost* to *IS-41_cost*, and the curve of function $y=4 \times 10^{-6}X^2 - 0.0006 + 0.6258$ is the zigzag line's quadric asymptote. From the curve, we note that when the values of user's *CMR* are in the range of (1,100), changes to the values of *CMR* don't make significant changes to the ratios of *Decision_cost* to *IS-41_cost*. Hence, the ratios are very stable.

In Fig. 4-2, the maximum, minimum, and average ratios of *Decision_cost* to *IS-41_cost* are 0.602, 0.408, and 0.495, respectively. The zigzag line in Fig. 4-2

indicates the real ratio of *Decision_cost* to *IS-41_cost*, and the curve of function $y = 3 \times 10^{-7} - 2 \times 10^{-4}X^2 + 0.4795$ is the zigzag line's quadric asymptote. From the curve, we note that when the values of user's *CMR* are in the range of (0.01,1), changes to the values of *CMR* don't make significant changes to the ratios of *Decision_cost* to that of *IS-41_cost*. Hence, the ratios are very stable.

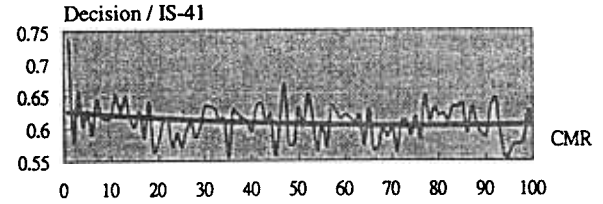


Fig. 4-1 Ratio of *Decision_cost* to *IS-41_cost* ($CMR=1_{..}100$).

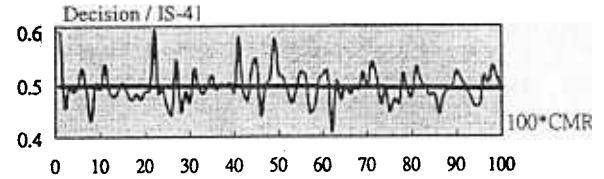


Fig. 4-2 Ratio of *Decision_cost* to *IS-41_cost* ($CMR=0.01..1$).

From these simulation results, we found that use of LSDM can save us at least 40% cost in comparing to that of IS-41. We don't count the computing time in making decision, which is of complexity $O(n^2)$, n is the total number of RAs in N , because the time is much less than the total network communication time, and all the computations are done on users' side.

5. Conclusion and Future Work

In comparing to other strategies of mobility management, the main difference is that we use LSDM to choose the LS with least cost, where a user and his LS are allowed to reside in different RAs. From the simulation results, we see that LSDM saves us up to 40% to 50 % cost less than that of IS-41. This is because of the following three reasons:

- (1) changing frequency of LSs in LSDM is much less than that of IS-41.
- (2) in choosing a LS, LSDM always selects the HBN with minimum location cost, but IS-41 doesn't.
- (3) in LSDM, when either caller and callee; or caller and callee's LS are in the same RA, the location cost

approximates to zero. In IS-41, only if caller and callee are in the same RA, the location cost approximates to zero. Thus, LSDM saves location tracking cost.

The time complexity of our current decision model is of $O(n^2)$, In the future work, we will count the factor of $M_{i,j}$, the probability of a user's movement from RA_i to RA_j , with k-steps look ahead strategy. We hope that it will not increase too much computing time and thus save more registration and location tracking costs. In addition, changing frequency of LSs in LSDM is much less than that of IS-41. So, in the future work, we would like to use a cache policy to cache the locations of users' LSs.

Our system architecture currently has only one NMC. The more the numbers of users or the larger the regions covered, the higher and better performance demands on the service. In the future work, we would consider using multiple NMCs [4,5] or hierarchical architecture [6] to meet users' need.

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