

# A New Network Management Scheme for Managing Client Mobility

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## Abstract

One of the most interesting issues of client mobility is location tracking problem, which has ever been discussed for years in telecommunication community. The strategy usually employed is HLR/VLR under IS-41 protocol to locate mobile clients.

Jang [3,4] proposed a Location Server Decision Method (LSDM) based on a single global Network Management Center (NMC) architecture to cope with the problem of client mobility. In this paper, we propose a multiple NMC architecture in order to offer higher service quality, allow mobile clients to move in a wider area, and provide a certain degree of fault-tolerance.

Based on this multiple NMCs architecture, we have criteria to choose a global NMC and local NMCs with minimum cost by computing expected registration cost and location tracking cost according to clients' moving behaviors and called frequencies.

Simulations show that our Multiple Location Server Decision Method (M-LSDM) is able to save up to 49% and 38% of the cost comparing to that of IS-41 in best and average cases, respectively. This is when the value of Call-Mobility Ratio (CMR) is in the range of (1, 100), that means either clients are called with high frequencies or move 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 move with high mobilities, we may save up to 53%, 46%, and 36% costs in best, average, and worst cases, respectively, in comparing to that of IS-41.

Keyword: client mobility management, location registration, location tracking

## 1. Introduction

### 1.1 Previous Work

Jang [4] proposed LSDM, LSDMk, and LSDM with Cache Policy to cope with the problem of client mobility

management. In LSDM, the criteria are used to choose a Home Base Node (HBN) with minimum cost by computing the expected registration cost and location tracking cost according to clients' moving behaviors and called frequencies. In LSDMk, the criteria are used to choose a HBN that minimizes the cost of look-ahead k-step move. In LSDM with Cache Policy, it stores clients addresses into the caches of those HBNs who had ever tracked the clients.

Simulations show that LSDM is able to save up to 45%, 39% and 26% of the cost comparing to that of IS-41 in best, average and worst cases, respectively, when the value of Call-Mobility Ratio (CMR) is in the range of (1, 100). As the value of CMR goes down to the range of (0.01, 1), it saves up to 60%, 50%, and 40% costs in best, average, and worst cases, respectively.

Comparing the simulation results of LSDM and M-LSDM, it shows that even with multiple NMCs, it still keeps a certain degree of performance.

### 1.2 Network Management Facility

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.

(3) Location Directory (LD)

The main propose of LD is to record the information of users' locations. Every record in LD has two entries of data, which are user-ID and user address on the network. As a client moved, we should update the data of user-address stored in LD to make it consistent with the current address of the client.

(4) Location Server (LS)

The main function of LS is to maintain LD and therefore provide services of location registration and location tracking. Location registration is to update the user-address stored in LD and make it consistent with the current client address. Location tracking is to localize where the client to be called is. One of the services provided NMCs is to keep track of the clients' locations. To avoid ambiguity, the NMC which serves as the location server of a NMC area is called a Global NMC (GNMC) and the NMC which serves as the location server of a register area is called a Local NMC (LNMC). Once a NMC is chosen to provide this service, it is called a Global NMC Location Server (GNLS) when it is responsible for client mobility in a whole NMC area, or a Local NMC Location Server (LNLS) when it is responsible for a whole register area.

(5) Register Area (RA)

A register area is a geographical region partitioned by a GNMC. Every register area contains at least one HBN and one local NMC served as a LNLS for a specific mobile client. A mobile client may consider to change his LNLS when he moves to a new RA.

(6) NMC Area

A NMC area is a geographical region partitioned according to the distribution of all GNMCs. Every NMC area is managed by one GNMC, which may serve as a GNLS for a specific mobile client. A mobile client may consider to change his GNLS when he moves to a new RA.

(4) HBN is not reliable enough to service as a location server.

In this study we propose multiple GNMCs architecture to solve these problems. Under this architecture, each GNMC has its own delegated NMC area to manage, workload is decentralized among GNMCs, and the system won't crash since multiple GNMCs can be others backup.

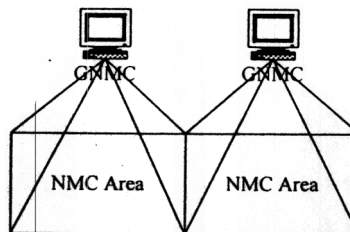


Fig. 1 Overview of system architecture.

Furthermore, the HBN doesn't stable enough to service as a location server in a register area. Only NMC have the functionality of location management. In Jang[4], he employees HBN as a location server of a register area. In order to guarantee the service quality, we use NMC to service as a location server in a register area and release the HBN's functionality of mobile management.

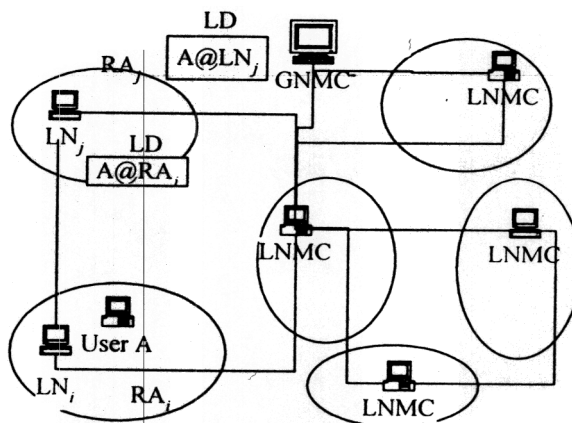


Fig. 2 System architecture specialized in a NMC area.

1.3 Single GNMC vs. Multiple GNMC

The system architecture proposed in [3,4] is based on a single global Network Management Center (GNMC) architecture. Though those strategies save lots of cost than that of IS-41 by choosing a HBN with minimum cost. But they still have several disadvantages.

- (1) When the number of mobile clients is getting larger, it will be more difficult for a single GNMC architecture to maintain high service quality.
- (2) Single GNMC architecture doesn't fit for serving clients when they move in a wild area.
- (3) There is no fault tolerance, once the single GNMC is shutdown all system will crash.

1.4 System Architecture of Multiple GNMC

Fig. 1 is an overview of the system architecture. There are multiple GNMCs in our system. Every NMC area has a GNMC and mobile clients are allowed to move across NMC areas.

Fig. 2 is the system architecture specialized in a NMC area, which shows a variety of facilities distributed over a network. Where LNMCs reside in RAs, mobile clients are allowed to move across RAs, and LDs are stored in both GNMCs and LNMCs for location tracking. In this figure, user A is in RA<sub>i</sub> and set his LNLS and GNLS to LN<sub>j</sub> and GN<sub>j</sub>, respectively.

The LD of LN<sub>j</sub> records the address of user A as A@RA<sub>i</sub>. The LD of GNMC records A@LN<sub>j</sub>, which is the LNLS of

user A. Comparing to those facilities of IS-41, GNMC corresponds to HLR (Home Location Register) and LNLS to VLR (Visitor Location Server). In Fig. 2,  $GN_x$  and  $LN_j$  are called user A's GNLS and LNLS, respectively.

To illustrate the records stored in different LDs, we simplify Fig. 2 and reduce it to Fig. 3. We use arrows, one from  $LN_j$  to  $LN_i$  and another from  $GN_x$  to  $LN_j$ , to show that the LD of  $LN_j$  records the address of user A as  $A@RA_i$  and the LD of  $GN_x$  records the LNLS address of A as  $A@LN_j$ , respectively.

The organization of this paper is as follows: In section two, we introduce our decision model to both optimize registration cost and reduce location tracking cost. In section three, we compare the total costs of registration and location tracking of our model to that of IS-41. Section four is conclusion and future work.

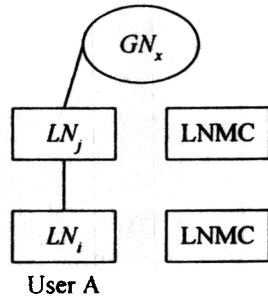


Fig. 3 Flow of records stored in different LDs.

## 2. Multiple Location Server Decision Model (M-LSDM)

All LNMCs and GNMCs on the network are possible candidates of a given client's LNLS and GNLS, respectively. In our system, a client, his LNLS and GNLS are allowed to reside in different NMC areas. Hence, every client can choose proper LNMC and GNMC to serve as his LNLS and GNLS in order to reduce register and location tracking cost. In this section, we propose a decision model to choose one of the LNMCs and one of the GNMCs with minimum cost to serve as this given client's LNLS and GNLS, respectively.

### 2.1 Denotations

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

$NA$  : a set of NMC areas. One NMC area belongs to  $NA$  if and only if either a user A has ever stayed in this area or some other users have ever called user A from this area. Furthermore, we define  $|NA|$  as the total number of NMC areas in  $NA$  and  $na$  is equal to  $|NA|$ .

$NA_i$ : a NMC area, with index  $i$ , that belongs to  $NA$ , where

$NA = \{NA_1, NA_2, \dots, NA_{na}\}$ .

$GN_i$ : a GNMC, with index  $i$ , that resides in the  $NA_i$ .

$RAS$  : a set of RAs. For all register areas contained in all NMC areas, one register area belongs to  $RAS$  if and only if either a user A has ever stayed in this area or some other users have ever called user A from this area.  $ra$  is equal to  $|RAS|$ .

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

$LN_i$ : the LNMC resides in  $RA_i$  and serves as a client's LNLS. At a given time, each user would choose a LNMC to serve as his LNLS. Note that the user and his LNLS are not required to reside in the same RA.

$INA$  : a  $na$ -dimension vector,  $INA = \{INA_1, INA_2, \dots, INA_{na}\}$ .  $INA_i$  is the index of NMC area which  $RA_i$  resides in.

$S$  : a  $ra$ -dimension vector,  $S = \{S_1, S_2, \dots, S_{ra}\}$ . Where  $S_i$ , a real number, represents the expected time a user will stay in  $RA_i$  per unit time.

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

$M$  : a  $ra \times ra$  matrix,  $M = [M_{ij}]_{ra \times ra}$ . Where  $M_{ij}$ , a real number, represents the probability of a user's movement from  $RA_i$  to  $RA_j$ .

$TL$  : a  $ra \times ra$  matrix,  $TL = [TL_{ij}]_{ra \times ra}$ . Where  $TL_{ij}$ , a real number, represents the network communication time between  $LN_i$  and  $LN_j$ .

$TNL$  : a  $na \times ra$  matrix,  $TNL = [TNL_{ij}]_{na \times ra}$ . Where  $TNL_{ij}$ , a real number, represents the time spent on network communication between  $GN_i$  and  $LN_j$ .

$TN$  : a  $na \times na$  matrix,  $TN = [TN_{ij}]_{na \times na}$ . Where  $TN_{ij}$ , a real number, represents the network communication time between  $GN_i$  and  $GN_j$ .

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

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

### 2.2 Location Registration and Location Tracking 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.

#### 2.2.1 Evaluation of Registration Cost

Assuming that user A resides in  $RA_i$  with  $LN_m$  and  $GN_x$  as his LNLS and GNLS. When he moves to  $RA_j$  and changes his LNLS and GNLS to  $LN_n$  and  $GN_y$ , then the registration cost can be evaluated as follow ( see Fig. 4):

e in the same RA, communication cost between user A and  $LN_j$  can be ignored.

Step1 :  $LN_j$  sends "ask register" message to  $LN_n$  and writes user A's user-ID and user-address ( $A@RA_j$ ) into  $LN_n$ 's LD. We use one arrow from  $LN_n$  to  $LN_j$  to show this step. Cost of this step includes,  $TL_{j,n}$ , the communication time between  $LN_j$  and  $LN_n$ . Cost of this step is  $TL_{j,n}$ .

Step2 :  $LN_n$  sends "ask register" message to  $GN_y$ , and writes its LNLS-address ( $A@LN_n$ ) and user-ID into  $GN_y$ 's LD. Cost of this step is  $TNL_{y,n}$ .

Step 3 :  $GN_y$  sends "ask de-register" message to  $GN_x$  to delete user A's registration record ( $A@LN_m$ ) ( as shown in the dotted arrow from  $GN_x$  to  $LN_m$ ) and writes record ( $A@GN_y$ ) into the LD of  $GN_x$ . Cost of this step is  $TN_{y,x}$ .

Step 4 :  $GN_y$  sends "ask de-register" message to  $LN_m$  to delete user A's registration record ( $A@RA_i$ ). Cost of this step is  $TNL_{y,m}$ .

Summing up all the costs from step0 to step4, we have:

$$\text{register\_cost}(m, x, j, n, y, TL, TNL, TN) = TL_{j,n} + TNL_{y,n} + TN_{y,x} + TNL_{y,m}$$

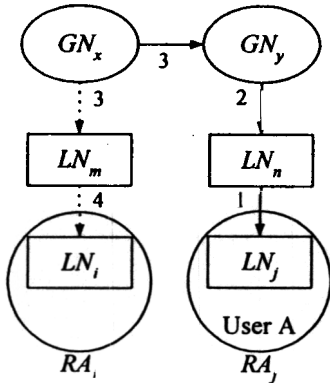


Fig. 4 User A moves from  $RA_i$  to  $RA_j$  and changes his GNLS from  $GN_x$  to  $GN_y$ , and LNLS from  $LN_m$  to  $LN_n$ .

where  $x, y, m, n,$  and  $j$  represent user A's old GNLS, current GNLS, old LNLS, current LNLS, and current RA indices, respectively. As a concise denotation, we use  $\text{register\_cost}(m, x, j, n, y)$  as a substitute for  $\text{register\_cost}(m, x, j, n, y, TL, TNL, TN)$ .

### 2.2.2 Evaluation of Location Tracking Cost

Assuming that user A is in  $RA_j$  with current GNLS and LNLS,  $GN_y$  and  $LN_n$ , respectively. User B is in  $RA_i$ , which resides in  $NA_x$  where  $x = INA_i$ . Once user B wants to track the current location of user A, there are six steps to be taken ( see Fig.5) :

Step 0 : user B sends "track user A" message to  $LN_i$ .  $LN_i$  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  $LN_i$ 's LD shows that user A is not in  $RA_j$ , and user A sets  $LN_i$  as his current LNLS. The address found in  $LN_i$ 's LD is user A's current location.

Case2 : the record in  $LN_i$ 's LD shows that user A is in  $RA_j$ . At this time,  $LN_i$  broadcasts to every user that is in  $RA_i$ . 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.  $LN_i$  would then delete this record and go to step1.

Since  $LN_i$  needs not communicate with other LNMCs and GNMCS, the cost of step0 can be ignored.

Step1 :  $LN_i$  sends "track user A" message to  $GN_x$ . In Fig. 5, we use dotted arrows to express each track steps. If  $x = y$ ,  $GN_x = GN_y$ , go to step3 , otherwise, go to step2. Cost of this step is :  $TNL_{x,i}$

Step2 :  $GN_x$  forwards "track user A" message to  $GN_y$ . Cost of this step is  $TN_{x,y}$ .

Step3 :  $GN_y$  forwards "track user A" message to  $LN_n$ . Cost of this step is  $TNL_{y,n}$ .

Step4 : After receiving "track user A" message,  $LN_n$  sends user A's current address to  $GN_x$ . Cost of this step is  $TNL_{x,n}$ .

Step5 :  $GN_x$  updates the record of LD of user A's GNLS to user A's current GNLS,  $GN_y$ , and forwards user A's current address to  $LN_i$ . Cost of this step is  $TNL_{x,i}$ .

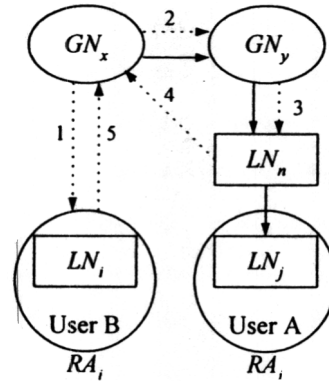


Fig. 5 User B tracks user A.

In summary, the cost of location tracking ( $\text{location\_cost}$ ) is:

$$\text{location\_cost}(i, x, n, y, TL, TNL, TN) = 2 \times TNL_{x,i} + TN_{x,y} + TNL_{y,n} + TNL_{x,n}$$

where  $i$  and  $j$  are indices of user B's and A's current RAs, respectively ;  $n$  is the index of user A's LNLS ;  $y$  is the index of user A's GNLS ;  $x$  is the index of user B's NMC area. As a concise denotation, we use  $\text{location\_cost}(i, x, n, y)$  as a substitute for  $\text{location\_cost}(i, x, n, y, TL, TNL, TN)$ .

**2.2.3 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. The registration cost can be evaluated by the same `register_cost` function, but the location tracking cost can't simply apply `location_cost` function since it depends on all the calls made by all callers rather than a single caller.

In Fig. 4, user A moves from  $RA_i$  into  $RA_j$  and changes his LNLS and GNLS from  $LN_m$  to  $LN_n$  and  $GN_x$  to  $GN_y$ , respectively.

$$\text{register\_cost}(m, x, j, n, y) \dots\dots\dots(1)$$

When user A stays in  $RA_j$ , the location tracking cost can be calculated as follows.  $RAS$  is the collection of all RAs in Fig. 6, so we have  $RAS = \{RA_i, RA_j, RA_k, RA_l, RA_m, RA_n\}$ .  $C_{ij}, C_{jj}, C_{kj}, C_{lj}, C_{mj}, C_{nj}$  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.  $S_j$  is the expected time user A stays in  $RA_j$ . Altogether, we have  $(C_{ij} + C_{jj} + C_{kj} + C_{lj} + C_{mj} + C_{nj}) \times S_j$  number of calls arrived during the time when user A stays in  $RA_j$ . Specifically,  $C_{ij} \times S_j$  represents number of calls come from  $RA_i$ , and the cost of location tracking by calling from  $RA_i$  is  $C_{ij} \times S_j \times \text{location\_cost}(i, INA_p, n, y)$ . The costs from other RAs can be computed similarly. Summing up all the costs, we have user A' location tracking cost as:

$$\sum_{RA_p \in RAS} C_{pj} \times S_j \times \text{location\_cost}(p, INA_p, n, y) \dots\dots\dots(2)$$

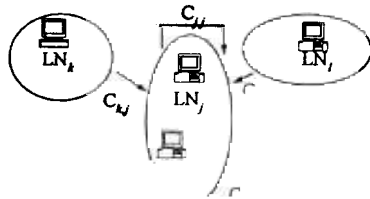


Fig. 6 Number of calls arrived every unit time.

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

$$\begin{aligned} \text{Total\_coat}(m, x, j, n, y, INA, RAS) = & \\ & \text{register\_cost}(m, x, j, n, y) + \\ & \sum_{RA_p \in RAS} C_{pj} \times S_j \times \text{location\_cost}(p, INA_p, n, y) \end{aligned}$$

where  $n, j,$  and  $m$  are indices of user A's current LNLS, current RA, and old LNLS, respectively ;  $x$  and  $y$  are indices of user A's old GNLS and current GNLS, respectively.

**2.3 Decision Method for Choosing LNMC and GNMC for Registration**

When a user moves from  $RA_i$  to  $RA_j$ , changes his LNLS from  $LN_m$  to an unknown  $LN_n$  and GNLS from  $GN_x$  to an unknown  $GN_y$ . The total cost is

$$\text{Total\_cost}(m, x, j, n, y, INA, RAS)$$

Where  $j, x$  and  $m$  are constants and  $INA, RAS$  are constant vectors that recorded in users' mobility profiles. Hence,  $\text{Total\_cost}$  function can be defined in terms of  $n$  and  $y$  as :

$$F(n, y) = \text{Total\_cost}(m, x, j, n, y, INA, RAS)$$

Applying all LNMCs of RAs that belong to  $RAS$  and all GNMCs of NMC areas that belong to  $NA$  into  $F(n, y)$ , we would have total cost of each LNMC and GNMC that serve as user A's new LNLS and GNLS, respectively. Our decision method would choose the LNMC and GNMC, say  $LN_{hls}$  and  $GN_{gnl}$ , respectively, that satisfies  $F(hls, gnl) = \text{Min}\{F(n, y) \mid RA_n \in RAS, NA_y \in NA\}$ , as user's new LNLS and new GNLS.

**3. Result Analysis — M-LSDM**

Fig. 7 illustrates the ratio of M-LSDM\_cost to IS-41\_cost after ten-step movement. Y-axis represents the ratio of M-LSDM\_cost to IS-41\_cost, and the x-axis represents the value of user's  $CMR$ . The maximum, minimum, and average ratios of M-LSDM\_cost to IS-41\_cost are 0.990, 0.518, and 0.621, respectively. The zigzag line represents the real ratios of M-LSDM\_cost to IS-41\_cost, and the curve of function  $y = 2 \times 10^{-5} X^2 - 0.0021X + 0.6682$  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 M-LSDM\_cost to IS-41\_cost. Hence, the ratios are very stable.

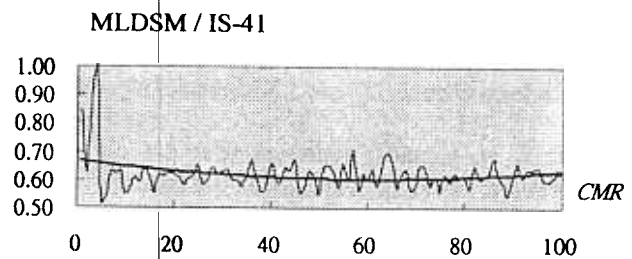


Fig. 7 Ratio of M-LSDM\_cost to IS-41\_cost (CMR=1..100).

In Fig. 8, the maximum, minimum, and average ratios of M-LSDM\_cost to IS-41\_cost are 0.646, 0.472, and 0.548, respectively. The zigzag line indicates the real ratio of M-LSDM\_cost to IS-41\_cost, and the curve of function  $y = 9 \times 10^{-6} X^2 - 0.0012X + 0.5786$  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 *M-LSDM\_cost* to that of *IS-41\_cost*. Hence, the ratios are very stable.

From these simulation results, average ratios of *M-LSDM\_cost* to *IS-41\_cost* are 0.621 and 0.548 when values of *CMR* are in the range of (1, 100) and (0.01, 1), respectively. Hence, we conclude that use of *M-LSDM* can save us at least 38% average cost in comparing to that of *IS-41*. We don't count the computing time in making decision, which is of complexity  $O(n^2)$ , because the time is much less than the total network communication time, and all the computations are done on users' side.

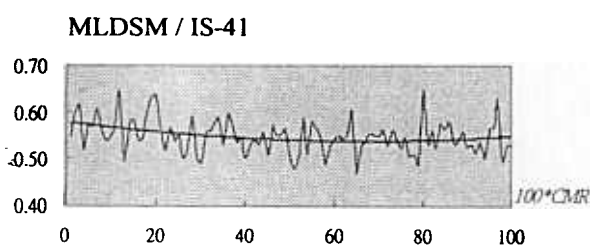


Fig. 8 Ratio of *Decision\_cost* to *IS-41\_cost* (*CMR*=0.01..1).

#### 4. Conclusion and Future work

Lin [5] suggested that distributing HLRs in several areas can prevent HLRs from coming to a bottleneck in the network. In that study, he uses forwarding pointers to make use of distributed HLRs more efficient. However, a drawback of the strategy is that the length of forwarding chains may become too long. The length of forwarding chains will increase by one if user changes his RA. Knowing that the changing frequency of RA is much greater than that of GNLS. Hence, the length of forwarding chains of our strategy is shorter.

Simulations show that our methodology is able to save up to 49% and 38% of the cost comparing to that of *IS-41* in best and average cases, respectively, when the value of *CMR* is in the range of (1, 100). As the value of *CMR* goes down to the range of (0.01, 1), we may save up to 53%, 46%, and 36% costs in best, average, and worst cases, respectively, in comparing to that of *IS-41*. This is because of the following reasons:

- (1) the changing frequencies of LNLSs in *M-LSDM* are less than those in *IS-41*.
- (2) *M-LSDM* always selects the LNMC and GNMC with minimum location cost in choosing a GNLS and LNLS, but *IS-41* won't.
- (3) using *M-LSDM*, when either caller and callee; or caller and callee's LNLS 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, *M-LSDM* saves location tracking cost.

In our register and location tracking policy, we do not consider what to do if network disconnect, servers break

down, and other inevitable accidents. In the future work, we would use intelligent agent to carry the "ask query" and "ask tracking" messages, so that every message will carry its mission through.

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