A Modified Profile-Based Location Caching with Fixed Local Anchor for Wireless Mobile Networks

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***Abstract*— Profile-Based Location Caching with Fixed Local Anchor (PCFLA) Strategy can reduce the frequent access to the HLR. As a result, the total management cost is minimized in a wireless mobile network. However, if the MT's information is not found at calling MSC then the HLR is accessed to get that information every time. Middle Location Register (MLR) is located between VLR and HLR. It helps to reduce the heavy load at HLR. Modified PCFLA (MPCFLA) combines the MLR with PCFLA to improve the performance of PCFLA. The analytical results show that our proposed method reduces the overall cost than PCFLA strategy.**

Keyword- **call delivery, location management, location registration, Middle Location Register, Profile-Based Location Caching with Fixed Local Anchor**

I. INTRODUCTION

It is possible for a mobile terminal (MT) to be called by other MTs, or to call other MTs, as it moves in wireless cellular networks such as Personal Communications Service (PCS) networks. When an MT calls another MT then the location of the called MT must be identified before the connection is established. Therefore, a location management strategy is necessary to keep track of the MT's effectively and locate a called MT when a call is initiated [1]. Location management strategy must handle two user location operations efficiently: location registration and call delivery. The former one is the process of informing the network about the MT's current location information; whereas the latter one is the process of determining the serving VLR and the cell location of the called MT prior to connection establishment between the caller and called MTs. There are two common standards used for location management [1]: IS-41and GSM. Both are based on the two-level database hierarchy, which consists of Home Location Register (HLR) and Visitor Location Registers (VLRs). Fig. 1 [9] shows the basic architecture of the wireless mobile networks under this two-level database hierarchy. The parameters used in Fig. 1 are described in Table I.The location information and permanent user profile for each MT is stored and maintained by HLR, and the VLRs are distributed throughout the network to store location information of each MT currently residing in the Registration Area (RA). The task of Mobile Switching Centers (MSCs) is to provide switching functions for the MTs in their associated RAs. In addition, the MSCs of different RAs are connected to a two-level hierarchy of Signaling Transfer Point (STP). This STP is comprised of a Regional STP (RSTP) and Local STPs (LSTP). These STPs are responsible for routing of signaling messages based on their destination addresses. These network elements are interconnected by wireline links.

As the number of the MTs increases, location management under the IS-41 standard has suffered problem like increasing traffic in the network. An extensive work has been done to overcome this problem under the IS-41 [2]-[9]. Among those strategies PCFLA strategy is one of the modern existing strategies [9]. In PCFLA, user profiles are effectively utilized to determine at which sites throughout the networks user's location information should be cached. In this approach, these site lists are prepared based on the long-term call related statistics maintained by the HLR from the callee's user profile. These lists are used to store the callees' location information to some of the most frequently calling VLR caches of the corresponding callees.\

The location information of the called user is obtained at the same VLR if the calling and called users are within the same VLR area during call processing. If the two users are not in the same VLR area then the location query should reach HLR, which causes a serious bottleneck at HLR. To reduce the bottleneck problem, MLR database is proposed in [10] which covers some VLRs. MLR is a multi-stage system. So some MLRs are managed by a next stage MLR. MAIN database is the root of the MLR hierarchy. If the calling and called users are not in the same VLR area then a location query is passed to the corresponding MLR. If the MLR has the information of called user then the query is resolved there. Otherwise, the procedure repeats and finally the MAIN database is accessed. Thus, MLR reduces the heavy load at HLR.

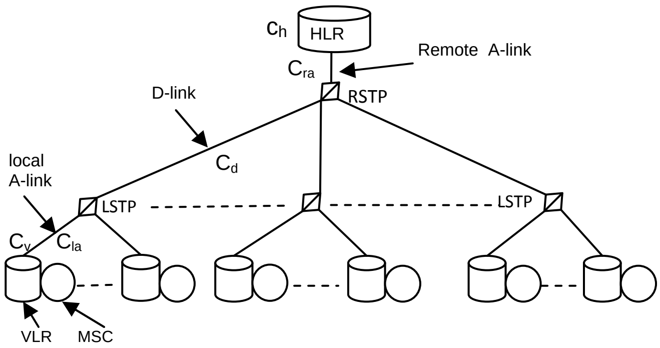


Fig. 1. Network cost model.

In this paper, the MLR system is embedded into the PCFLA strategy. In PCFLA, if the called FLA's information is not cached in calling MSC then HLR is accessed to get the called MT's information. As the numbers of MTs are increasing, this creates heavy load at HLR. If the MLR system is used between HLR and VLR then the MTs location information can be found at MLR. So, the load at HLR will be reduced. As the PCFLA minimizes the total location management cost and MLR system reduces the heavy load at HLR, by combining the MLR with PCFLA, reduces the overall cost and the load at HLR more effectively than PCFLA and MLR.

TABLE I
Description of symbols

Symbol	Description
()	Corresponding message number
[]	Cost for the particular signaling exchange
{}	Cost for accessing the particular database
⟶	Exchange of the particular signaling message
⟵	Acknowledgement of the signaling message

The rest of the paper is organized as follows. Section II provides an overview of the existing related research work. Our proposed approach is described in section III. Section IV provides the analytical modeling. Numerical results and comparison among different approaches based on some experimental results are described in section V. We provide a concluding remark in section VI.

II. EXISTING RELATED WORK

A large number of works have been done reported on location management to reduce the overall location management cost in terms of location registration cost and call delivery cost [2]–[9]. Some of them are basic scheme which are generally used to manage the location irrespective of all the wireless networks. Some others are based on reusing the user location information obtained during the previous call to the user to reduce the call delivery cost. On the other hand, some others manage the local handoff locally, instead of informing the centralized HLR. Thus the location registration cost is reduced. There are also some methods which use the MT's calling statistics from the HLR and replicate its location information to these calling VLR cache. These also manage the local handoff locally instead of accessing the heavily congested HLR. This reduces both the location registration and call delivery cost. Some existing location management strategies are shown in Fig 2– Fig 7. The symbols used in Fig 2– Fig 7 are described in Table I. The signaling and database access costs for the cost analysis is described in Table II. The location management procedures of these strategies are described in the following subsections.

TABLE II
Description of cost parameters

Parameter	Description
C_{la}	Cost for sending a signaling message through the local A-link
C_d	Cost for sending a signaling message through D-link
C_{ra}	Cost for sending a signaling message through the remote A-link
C_v	Cost for a query or an update of the VLR
C_f	Cost for a query or an update of the FLA
C_h	Cost for a query or an update of the HLR
C_m	Cost for a query or an update of the MLR
C_{mlr}	Cost for sending a signaling message the MLR
C_{tmlr}	Cost for sending a signaling message to the top MLR from MLR

A. IS-41 Standard

In basic IS-41 standard [1], each MT informs its location information to the HLR during all type of handoff procedures. When a call is initiated, the called MT's location information is searched in the HLR.

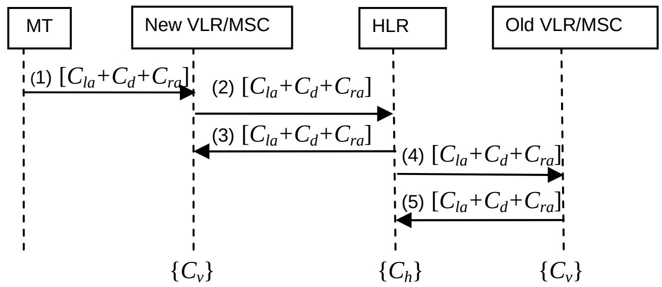


Fig. 2. Location registration under the IS-41 standard.

The location registration procedure of this strategy can be described using the following steps (see Fig. 2).
(1) An MT enters into a new RA and informs its new location to the new MSC through the nearby BTS.
(2) The MSC updates its associated VLR about this newly entered MT. After that, it sends a location registration message to the HLR.
(3) After receiving the location registration message, the HLR updates the MT's record and sends back a registration acknowledgement message to the new VLR.
(4) It also sends a registration cancellation message to the old VLR.
(5) The old VLR removes the record of the MT immediately and sends back a cancellation acknowledgement message to the HLR.

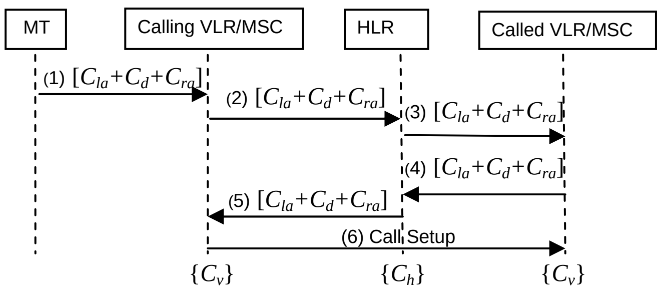
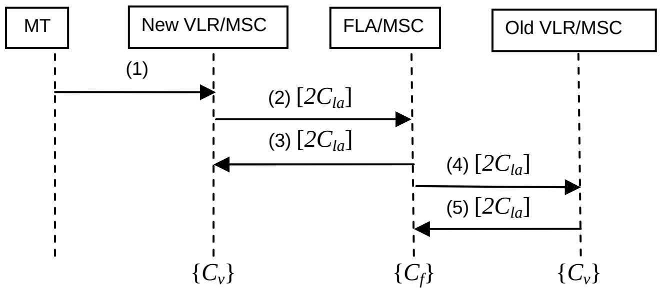


Fig. 3. Call delivery under the IS-41 standard.

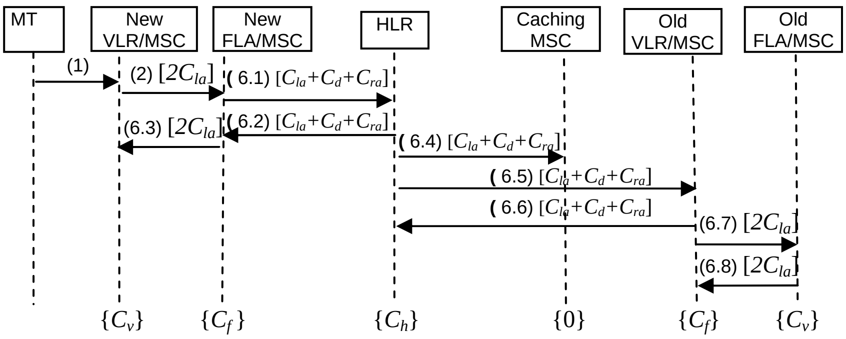
On the other hand, the call delivery procedure under this strategy is described as follows (see Fig. 3).
(1) The calling MT initiates a call and sends a signal to its serving MSC through a nearby base station.
(2) The calling MSC sends a request message to the HLR for the called MT's location information.
(3) The HLR determines the called MT's current serving MSC and sends a location request message to that MSC.
(4) The MSC allocates a Temporary Local Directory Number (TLDN) [9] to the MT and sends back a reply to the HLR together with the TLDN.
(5) The HLR propagates this information to the calling MSC.
(6) The MSC sends a call setup request message to the called MSC through the network shown in Fig. 1.

B. *PCFLA Strategy*

PCFLA strategy [9] is a combination of LC (Location Caching) strategy and FLA (Fixed Local Anchor) strategy. It takes the advantages of both LC strategy and FLA strategy. In PCFLA strategy, each LSTP has a FLA (Fixed Local Anchor) which is actually a specific VLR. The FLA has a table which keeps the current serving VLR for all MTs in its LSTP region. When an MT enters into a new RA then the MSC of the new RA registers the MT's location at the FLA. The HLR then gets the information about the new FLA. The FLA may be the current serving VLR or the other VLR within that RA. However, all the user profiles are stored and manage in the current HLR in the PCS systems which contains the user information such as a user's location, authenticate information, and calling activity log, etc.



(a) Intra- LSTP movement



(b) Inter- LSTP movement

Fig. 4. Location registration under the PCFLA strategy.

The location registration procedure under the PCFLA strategy is described in the following steps (see Fig. 4 (a)).
(1) An MT sends a location update registration signal to the new MSC through the nearby BS after entering to the new RA.
(2) The MSC sends a location registration message to its designated FLA in its LSTP region to check whether it has the MT's profile.
(3) If the MT has just moved into a new LSTP region then MT's record will not be found in the FLA. In that case, go to step (6). On the other hand, if the FLA contains the MT's record then, it updates the MT's previous record with the new one which indicates the associated new VLR. The FLA then sends a registration acknowledge message to the new MSC together with a copy of the MT's current record.
(4) After that, The FLA sends a message to the old MSC to remove the MT's record.
(5) The old MSC removes the move- out MT's information from its associated VLR and sends an acknowledge message to the FLA to inform that the deletion is complete. (Location registration by intra-LSTP movement is complete. Do not continue to the next step).
(6) If there is no MT's record in FLA then the following steps are performed (see Fig. 4 (b)).

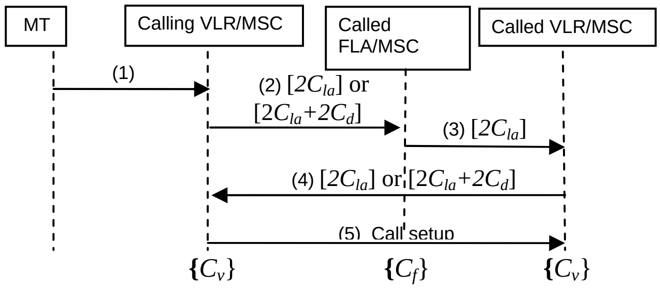
6.1) The MSC associated with the MT's new FLA sends a message to the HLR for location registration.

6.2) As the MT moves to a new FLA, the HLR updates the MT's record with that information and sends a copy of the MT's updated profile to the new FLA.

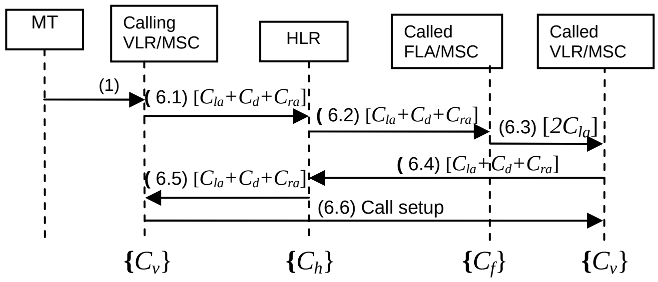
6.3) The FLA updates its table by the MT's record to indicate that the associated new VLR and sends a copy of the MT's profile with a registration acknowledgment message.

6.4) All the MSCs those have location cache for the MT should be updated. For this reason, the HLR sends location cache update messages to those MSCs.

6.5) The HLR sends a message to the MT's old FLA to cancel the registration of the MT, which then removes the MT's record.
6.6) In response of the registration cancellation message from the HLR, the old FLA sends a registration cancellation acknowledgment message back to the HLR.
6.7) The old FLA sends a registration cancellation message to the MT's old VLR in order to remove the MT's obsolete record.
6.8) After removing the MT's record, the old VLR sends a registration cancellation acknowledgment message back to the old FLA (Location registration by inter-LSTP movement is complete).



(a) When calling MSC has location cache for the called FLA



(b) When calling MSC does not have location cache for the called FLA

Fig. 5. Call delivery under the PCFLA strategy.

The call delivery procedure under the PCFLA strategy is described as follows (see Fig. 5 (a)).
(1) The calling MT initiates a call and sends a signal to its serving MSC through the nearby base station.
(2) The calling MSC checks its cache for the location of the called MT's FLA. If the location is found then it sends a location request message to the called FLA. Otherwise, go to the step (6).
(3) The called FLA then forwards the location request message to the called MSC for the called MT.
(4) The called MSC allocates TLDN to the MT and sends a reply back to the calling MSC together with the TLDN.
(5) The calling MSC sends a message for call setup to the called MSC through the network show in Fig. 1 (Call delivery is complete. Do not continue to the next step).
(6) If the calling MSC's cache does not contain the location of the called FLA, the following occurs (see Fig. 5 (b)).
6.1) The calling MSC sends a request message to the HLR for the location of called MT.
6.2) The HLR sends a location request message to the called FLA.
6.3) The called FLA then forwards this message to called MSC.
6.4) The called MSC allocates TLDN to the MT and reply back to the HLR together with the TLDN.
6.5) After receiving this information, the HLR forwards it to the calling MSC.
6.6) The calling MSC send a message for call setup to the called MSC through the network shown in Fig. 1 (Call delivery is complete).

C. MLR Strategy

Fig. 6 shows the hierarchical structure of MLR system[10]. Here some VLRs are managed by a MLR. This MLRs are connected to top level MLR which in turn is managed by immediate top level MLR. MAIN is the top level database of the MLR system. Actually MLR is one kind of cache. Generally it manages the location information of users in the MLR area. Even if the calling and called users are not in the same VLR area, the location query needs not to be connected to HLR since MLRs are added to manage the location information in the middle stage and removes the search messages between VLR and HLR [10]. The total cost for the normal scheme using HLR is calculated as $2*C_{VLR}+C_{HLR}$. However, the total cost of the MLR system can be calculated using $2*C_{VLR}+C_{MLR+}\ P_{Cross}*C_{MLR}$. Where P_{Cross} is the probability that the called MT and calling MT are not in the same MLR area. Fig. 7 shows the two call delivery situations.

(1) Called and calling MTs are not in the same MLR areas (fat dotted circle containing two short arrows).
(2) Two MTs are in the same MLR area (thin dotted circle containing a long arrow).

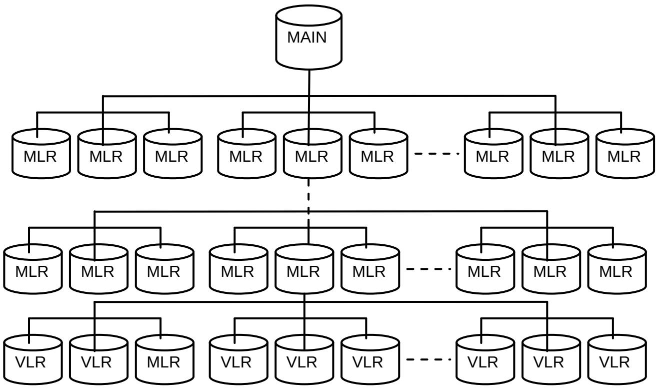


Fig. 6. Hierarchical structure of MLR system.

Location registration procedure in the MLR system is given below which has been proposed in [10].
(1) MSC sends location registration messages to HLR.
(2) HLR sends the messages to MSC. The information in the messages is recorded at VLR.
(3) VLR sends the messages to MLR and Main. The messages have the information of mobile terminal, the location of mobile terminal and VLR. The information is recorded at MLRs and Main. MLR and Main are mapping each other.

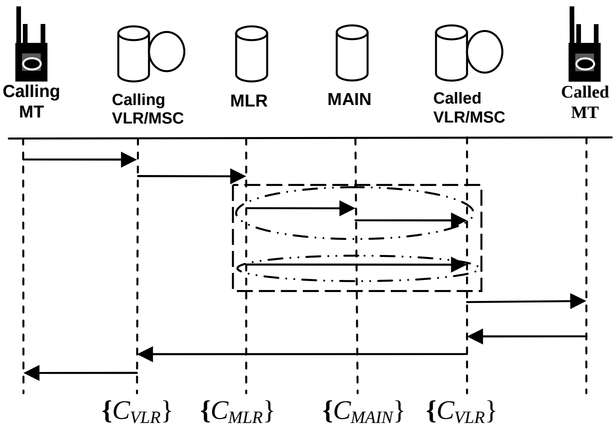


Fig. 7. Call delivery under the MLR system.

The call delivery procedure is as follows (see Fig. 7).
(1) Calling mobile terminal sends a message to MLR to know the location information of the called mobile terminal.
(2) MLR sends location messages of called terminal to MSC if it has the information. If the MLR does not have the location information, the MLR passes the messages to the next stage MLR. At last, the messages are sent to the MAIN to know the location information.
(3) MSC receives messages from MLR. In the reverse order, the call is connected to the called terminal.

III. PROPOSED STRATEGY

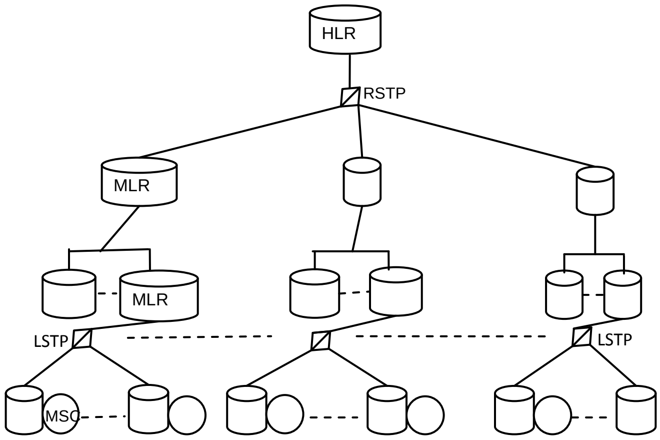
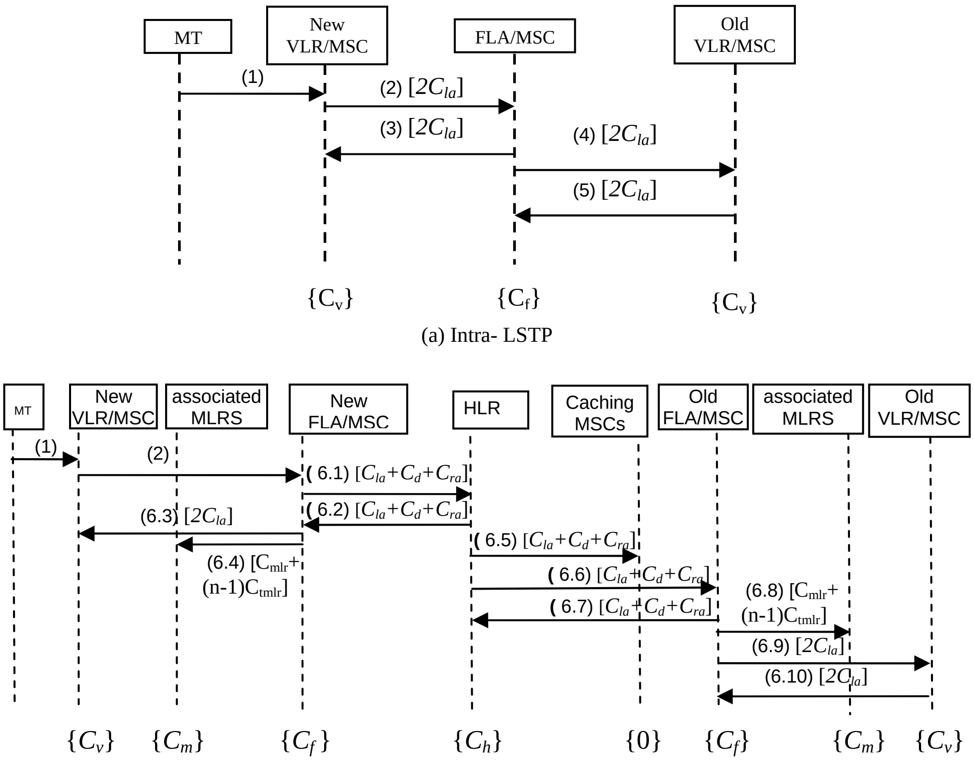


Fig. 8. Network cost model for MPCFLA

In the PCFLA strategy, there is VLRs and HLR database for location management. So when an MT calls another MT and if the calling MT and called MT are not in the same LSTP region then HLR database is the ultimate place to find information about called MT. MLR system is used into existing PCFLA strategy to reduce the load at HLR. If MLR scheme is used then there is no need to go to HLR for information about called MT every time when the called and calling MTs are not in the same LSTP region. Here, the MLR system is added between LSTP and RSTP region. As a result, the signaling cost is reduced during call delivery and total cost is reduced also. If information is not found in a MLR then there is a probability to find the information at top MLR which is indicated by P_{tmlr}. The network cost model for Modified PCFLA (MPCFLA) is shown in Fig. 8.



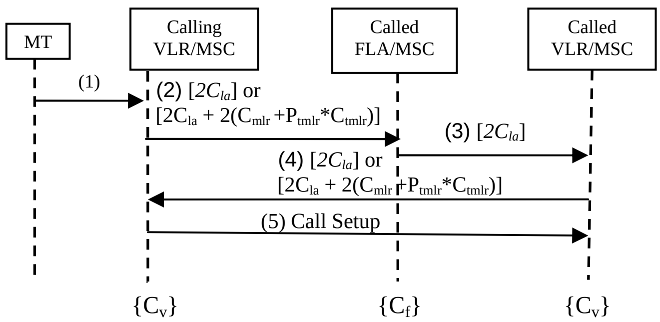
(b) Inter- LSTP movement

Fig. 9. Location registration under MPCFLA

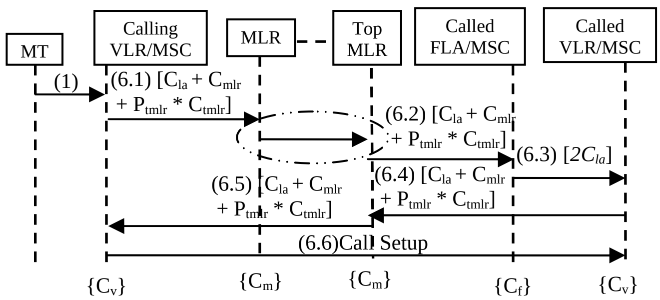
The location registration procedure under the MPCFLA strategy is described as follows (see Fig. 9 (a)).
(1) An MT moves to the new RA and sends a location update registration to the new MSC through the nearby BS.

(2) The MSC sends a location registration message to its designated FLA in its LSTP region.
(3) The FLA checks for the MT's profile. If there is not an MT's record in the FLA, which means that the MT has just to move into a new LSTP region, then go to step (6). Otherwise, it updates the MT's record to indicate the associated new VLR, and sends a registration acknowledge message to the new MSC together with a copy of the MT's profile.
(4) The FLA sends a registration cancellation message to the old MSC.
(5) The old MSC removes the record of an MT at its associated VLR and sends a registration acknowledge message to the FLA. (Location registration by intra-LSTP movement is complete. Do not continue to the next step).
(6) If there is no MT's record in FLA, the followings are performed (see Fig. 9 (b)).

6.1) The MSC associated with the MT's new FLA sends a location registration message to the HLR.
6.2) The HLR updates the MT's record to indicate the MT's new FLA and sends a copy of the MT's profile to the new FLA.
6.3) The FLA also updates the MT's record to indicate that the associated new VLR and sends a registration acknowledgment message to the new VLR together with a copy of the MT's profile.
6.4) The FLA sends the information messages about the MT to all associated MLRs.
6.5) The HLR sends a location cache update message to the MSCs which have location caches for the MT, which updates the location caches to indicate the MT's new FLA.
6.6) The HLR sends a registration cancellation message to the MT's old FLA, which remove the MT's record.
6.7) The old FLA sends a registration cancellation acknowledgment message back to the HLR.
6.8) The old FLA sends a registration cancellation message to the MT's old associated MLRs, which remove the MT's record.
6.9) The old FLA sends a registration cancellation message to the MT's old VLR, which remove the MT's record.
6.10) The MT's old VLR sends a registration cancellation acknowledgment message back to the old FLA (Location registration by intra-LSTP movement is complete)



(a) When calling MSC has location cache for the called FLA



(b) When calling MSC does not have location cache for the called FLA

Fig. 10. Call delivery under MPCFLA

The call delivery procedure under the MPCFLA strategy is described as follows (see Fig. 10(a)).
(1) The calling MT sends a call initiation signal to its serving MSC through the nearby BS.
(2) The calling MSC checks if it has location cache which indicates the FLA of the called MT. If yes, it sends a location request message to the called FLA. Otherwise, go to the step (6).

(3) The FLA forwards the location request message to the called MSC.
(4) The called MSC allocates TLDN to the MT and sends it to the calling MSC.
(5) The calling MSC requests a call setup to the called MSC through the through the network shown in Fig. 8 (Call delivery is complete. Do not continue to the next step).
(6) If the calling MSC does not have location cache for the called FLA, the following occurs (see Fig. 10(b)).
6.1) The calling MSC sends a location request message to the MLR.
6.2) The MLR sends a location request message to the called FLA.
6.3) The called FLA forwards a location request message to called MSC.
6.4) The called MSC allocates TLDN to the MT and sends it to the MLR.
6.5) The MLR forwards this information to the calling MSC.
The calling MSC requests a call setup to the called MSC through the network shown in Fig. 8 (Call delivery is complete).

In Fig. 10, the dotted circle indicates that if the information is not found at calling MLR then the information may be found at top MLRs.

IV. Analytical Model

In this section, a fluid flow mobility model [11] is used to evaluate the performance of our proposed strategy and PCFLA strategy. It is assumed that MTs are moving at an average speed of *v* in uniformly distributed direction over [0, 2*π*] with a view to crossing the LSTP region composed of *N* equal rectangular-shaped and sized RAs [9]. The following parameters used for the MTs' movement rates analysis.

- γ : the MT's movement rate out of an RA
- μ : the MT's movement rate out of an LSTP region
- λ : the MT's movement rate to an adjacent RA within a given LSTP region

According to [12], these parameters are calculated as follows.

$$\gamma = \frac{4v}{\pi\sqrt{S}} \tag{1}$$

$$\mu = \frac{4v}{\pi\sqrt{NS}} \tag{2}$$

$$\lambda = \gamma - \mu = \left(1 - \frac{1}{\sqrt{N}}\right)\gamma \tag{3}$$

Where *v* is the average moving speed of an MT, *S* is the size of the RA, and *N* is the number of RAs within a LSTP region.

A continuous-time Markov Chain state transition diagram is used to show an MT's RA movement. It is shown in Fig. 11 which represents the fluid flow mobility model. Each state $i(i \geq 0)$ defines as the RA number of a given LSTP region where an MT can stay and state 0 means the MT stays outside of this region. The state transition $a_{i,j+1}(i \geq 1)$ represents an MT's movement rate to an adjacent RA within a given LSTP region, and $a_{0,1}$ represents an MT's movement rate to an RA of that region from another one. On the other hand, $b_{i,0}(i \geq 1)$ represents an MT's inter-LSTP region movement rate and it is assumed that there are maximum *K* number of such movements. Therefore, from Figure 11, it is obtained that $a_{i,j+1}(i \geq 1) = \lambda$ and $a_{0,1} = b_{i,0} = \mu$, respectively.

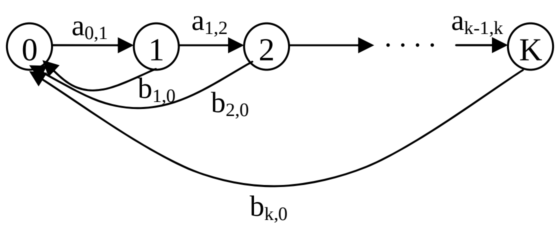


Fig. 11. State transition diagram of an MT's RA movement

On the other hand, assuming that π_i is the equilibrium probability of state *i*, the following equations can be obtained from a continuous-time Markov Chain given in Figure 11.

$$\mu\pi_0 = \mu\sum_{i=1}^{K}\pi_i \quad (4)$$

$$\mu\pi_{i-1} = (\lambda+\mu)\pi_i, \qquad i=0 \quad (5)$$

$$\lambda\pi_{i-1} = (\lambda+\mu)\pi_i, \quad 2 \le i \le K-1 \quad (6)$$

$$\mu\pi_{i-1} = \mu\pi_i, \qquad i=K \quad (7)$$

According to the law of the total probability, the sum of the probabilities of all states is 1. So,

$$\pi_0 + \pi_1 + \pi_2 + \ldots\pi_K = \sum_{i=0}^{K}\pi_i = 1 \quad (8)$$

By substituting (8) into (4), it can be obtained the quilibrium probability of state $0, \pi_0$ .So,

$$\pi_0 = \frac{1}{2} \quad (9)$$

Finally, from (5), (6), (7) and (9), π_i is obtained as follows.

$$\pi_i = \begin{cases} \frac{1}{2} & if\ i=0 \\ \frac{1}{2}\left(\frac{\mu}{\lambda+\mu}\right)\left(\frac{\lambda}{\lambda+\mu}\right)^{i-1} & if\ 1 \le i \le K-1 \\ \frac{1}{2}\left(\frac{\lambda}{\lambda+\mu}\right)^{i-1} & if\ i=K \end{cases} \quad (10)$$

In this section, based on the user mobility model, we derive the location registration costs, the call delivery costs and the total location management costs of the MPCFLA strategy. Table III [9] shows the various parameters used for the cost analysis of MPCFLA strategy.

TABLE III
Parameters used for the cost analysis.

P_l	Probability (caller and callee are located within the same LSTP region)
P_n	Probability (new VLR is the FLA)
P_o	Probability (old VLR is the FLA)
P_f	Probability (callee is located in the FLA area)
P_c	Probability (calling MSC has location cache for the called FLA under the MPCFLA strategy)
q	The MT's CMR (call-to-mobility ratio)
m	The number of the MSCs which have location caches for the called FLA under the MPCFLA strategy (= the number of the most frequently calling VLRs to the specify)

Table II and III describe different parameters that are used in order to calculate location management cost, signaling cost. The following notations are also used to represent the cost of each strategy [9].

- U_X: The average location registration cost of the *X* strategy for an MT staying in an LSTP region.
- S_X: The average call delivery cost of the *X* strategy for an MT staying in an LSTP region.
- T_X: The average total location management cost of the *X* strategy for an MT staying in an LSTP region.
- U_X^Y : the average location registration cost of the *X* strategy generated by movement type *Y* for an MT staying in an LSTP region

From Fig. 11, the average number of unique RAs that an MT visits within a given LSTP for *K* movements which can be represented by the following equation.

$$\Phi(K) = \pi_1 + 2\pi_2 + 3\pi_3 \ldots + K\pi_K = \sum_{i=1}^{K} i\pi_i \quad (11)$$

The average location registration cost under the MPCFLA strategy can be expressed as [9]:

$$U_{MPCFLA} = \pi_0 * U_{MPCFLA}^{inter} + (\Phi(K)-1) * U_{MPCFLA}^{intra} \quad (12)$$

U_{MPCFLA}^{inter} and U_{MPCFLA}^{intra} can be expressed as follows:

$$U_{MPCFLA}^{intra} = p_n * (1 - p_0) M_1 + p_0 * (1 - p_n) M_2 + (1 - p_n)(1 - p_0) M_4 \quad (13)$$

$$U_{MPCFLA}^{inter} = p_n * (1 - p_0) \widehat{M}_1 + p_0 * (1 - p_n) \widehat{M}_2 + p_n * p_0 * \widehat{M}_3 + (1 - p_n)(1 - p_0) \widehat{M}_4 \quad (14)$$

Where M_x and $\widehat{M}_x$ (x ε {1, 2, 3, 4}) mean the location registration costs for intra-LSTP movement and inter-LSTP movement under MPCFLA strategy in case of (x) given in Table IV [9], respectively. And, these costs can be expressed as follows (see Fig. 9(a) and 9(b)):

$$M_1 = M_2 = 2 * 2 * C_{la} + C_v + C_f \quad (15)$$

$$M_4 = 4 * 2 * C_{la} + 2 * C_v + C_f \quad (16)$$

$$\widehat{M}_1 = \widehat{M}_2 = 4*(C_{la} + C_d + C_{ra}) + 4*C_{la} + m*(C_{la} + C_d + C_{ra}) + 2*(C_{mlr} + (n-1)C_{tmlr}) + C_v + 2C_f + C_h + (2 + 2(n-1))C_m \quad (17)$$

$$\widehat{M}_3 = 4*(C_{la} + C_d + C_{ra}) + m*(C_{la} + C_d + C_{ra}) + 2*(C_{mlr} + (n-1)C_{tmlr}) + 2C_f + C_h + (2 + 2(n-1))C_m \quad (18)$$

$$\widehat{M}_4 = 4*(C_{la} + C_d + C_{ra}) + 8*C_{la} + m*(C_{la} + C_d + C_{ra}) + 2*(C_{mlr} + (n-1)C_{tmlr}) + 2C_v + 2C_f + C_h + (2 + 2(n-1))C_m \quad (19)$$

When the inter-LSTP movement of the MT occurs, the MLR should update m location caches for that MT throughout the networks. In this case, we consider the signaling cost for sending cache update messages, but ignore the cache access cost since it is relatively too small as compared to the database access cost [2].

TABLE IV
Four possible cases for location registration under MPCFLA strategy.

Case	Description
(1)	New VLR is the FLA, and old VLR is not the FLA.
(2)	Old VLR is the FLA, and new VLR is not the FLA.
(3)	Both new VLR and old VLR are the FLAs.
(4)	Both new VLR and old VLR are not the FLAs.

On the other hand, the average call delivery cost under the MPCFLA strategy is expressed as follows [9]:

$$S_{MPCFLA} = P_c * C_{MPCFLA}^{cache} + (1 - P_c) * C_{MPCFLA}^{nocache} \quad (20)$$

Where C_{MPCFLA}^{cache} represents the call delivery costs under the MPCFLA strategy when the calling MSC has location cache for the called FLA, and $C_{MPCFLA}^{nocache}$ means the call delivery costs when the calling MSC does not have location cache for the called FLA, respectively. There are four possible cases shown in Table V [9].

TABLE V
Four possible cases for call delivery when the calling MSC has location cache for the called FLA under the MPCFLA strategy

Case	Description
(1)	The caller and called MT are located within the same LSTP region, and the called MT is found in the FLA area.
(2)	The caller and the called MT are located within the same LSTP region, and the called MT is found in the other VLR area, not the FLA area.
(3)	The caller and the called MT are located in the different LSTP regions, and the called MT is found in the FLA area.
(4)	The caller and the called MT are located in the different LSTP regions, and the called MT is found in the other VLR area, not the FLA area.

According to the four possible cases given in Table V, these costs are as follows (see Fig. 10(a) and Fig. 10(b)):

$$C_{MPCFLA}^{cache} = p_1 * \{P_f * N_1 + (1 - P_f) * N_2\} + (1 - P_l) * \{P_f * N_3 + (1 - P_f) * N_4\} \quad (21)$$

where N_x (x ε {1, 2, 3, 4}) means the call delivery costs when the calling MSC has location cache for the called FLA under the MPCFLA strategy in case of case (x) given in Table V. These costs can be expressed as follows (see Fig. 10(a)):

$$N_1 = 2 * 2C_{la} + C_v + C_f \quad (22)$$

$$N_2 = 3*2C_{la} + 2*C_v + C_f \quad (23)$$

$$N_3 = 2*\{2*C_{la} + 2*(C_{mlr} + P_{tmlr} * C_{tmlr})\} + C_v + C_f \quad (24)$$

$$N_4 = 2*\{2*C_{la} + 2*(C_{mlr} + P_{tmlr} * C_{tmlr})\} + 2*C_v + C_f + 2*C_{la} \quad (25)$$

$$C_{MPCFLA}^{nocache} = P_f * D_1 + (1 - P_f)* D_2 \quad (26)$$

Where D_1 means the call delivery costs when the called MT is found in its FLA area, and D_2 represents the call delivery cost when called MT is found in the other VLR area, respectively. These costs are as follows (see Fig. 10(b)):

$$D_1 = 4*(C_{la} + C_{mlr} + P_{tmlr} * C_{tmlr}) + (C_v + C_f + C_m) \quad (27)$$

$$D_2 = 4*(C_{la} + C_{mlr} + P_{tmlr} * C_{tmlr}) + (2*C_v + C_f + C_m) + 2*C_{la} \quad (28)$$

Finally, the average total cost of the MPCFLA strategy can be expressed as

$$T_{MPCFLA} = U_{MPCFLA} + q * S_{MPCFLA} \quad (29)$$

V. NUMERICAL RESULTS AND COMPARISONS

In this section, we compare the performance of the MPCFLA strategy with that of the PCFLA strategy. For performance analysis, we define the relative cost of MPCFLA and PCFLA in the following way

Relative cost = T_{MPCFLA} / T_{MIS-41} (30)

Relative cost = T_{PCFLA} / T_{IS-41} (31)

For analysis purpose, N is set to 55. We set $P_n = P_o = P_f = 1/55 = 0.018$ as the number of the RA's per LSTP region is 55 [2], [3], [5]. Similarly, since the number of the LSTPs per region is 160/7 = 23, the value of P_l is 1/23=0.043. For simplicity we assume $P_c = 0.7$, n=2 and m = 5 [9]. We also consider the total cost of IS-41 and MIS-41 is 1 and P_{tmlr} is 0.4.The value of v and S is considered as 5.6 km/h and 20 km^2 [11]. The signaling cost, database access cost and total cost for MPCFLA strategy are compared to PCFLA strategy which is shown graphically in the following subsection by taking values from Table VI and Table VII.

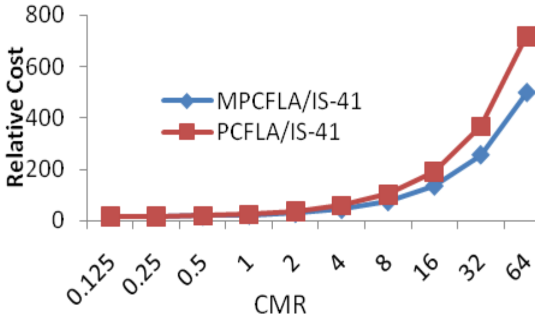
TABLE VI
Signaling costs parameter set.

Set	C_{la}	C_d	C_{ra}	C_{mlr}	C_{tmlr}
1	1	1	1	0.3	0.3
2	1	3	6	1	1

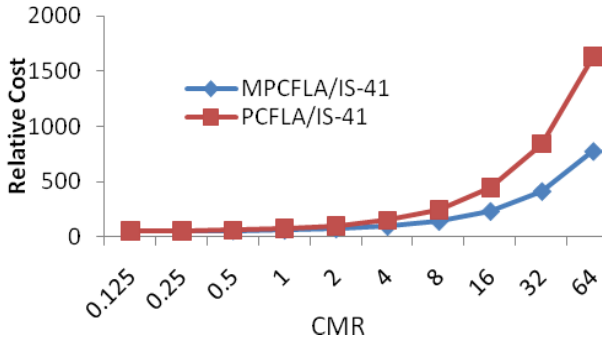
TABLE VII
Database access costs parameter set.

Set	C_v	C_f	C_h	C_m
3	1	1	1	0.5
4	1	2	3	1

A. Signaling cost



(a) Set (1)



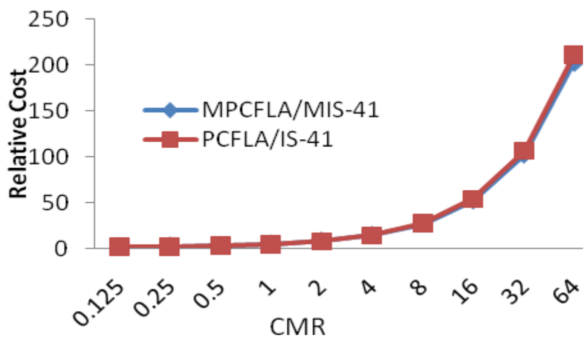
(b) Set (2)

Fig. 12. Signaling Costs

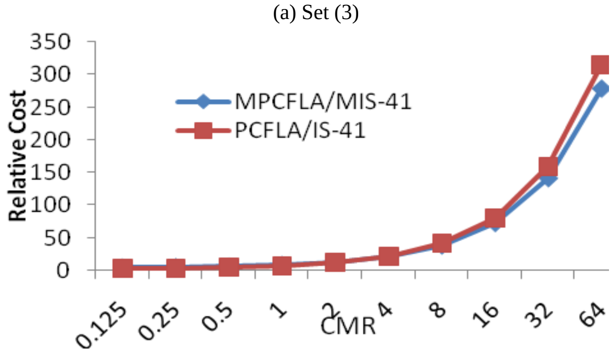
At first we determine the signaling cost which dominates by setting the database access cost parameters, C_h, C_v, C_f and C_m to be 0. Set (1) and (2) from Table VI is used to calculate signaling costs for both MPCFLA and PCFLA. As MLR system resides between VLR and HLR. So, C_{mlr} and C_{tmlr} must be less than C_d. Here two MLR is used. For this reason $C_{mlr} = 0.3$ and $C_{tmlr} = 0.3$ is considered. Fig. 12 shows the comparison of Signaling costs between MPCFLA and PCFLA. It shows that the relative cost of MPCFLA is less than PCFLA. The difference increases with increasing the CMR value. In MPCFLA, the information can be found at MLR and HLR access is not needed so our proposed approach results better output.

B. Database access cost

For calculating database access cost we assume signaling cost is zero. We consider the set (3) and set (4) from Table VII to calculate Database access cost by setting C_{la}, C_d, C_{ra}, C_{mlr} and C_{tmlr} to zero.



(a) Set (3)



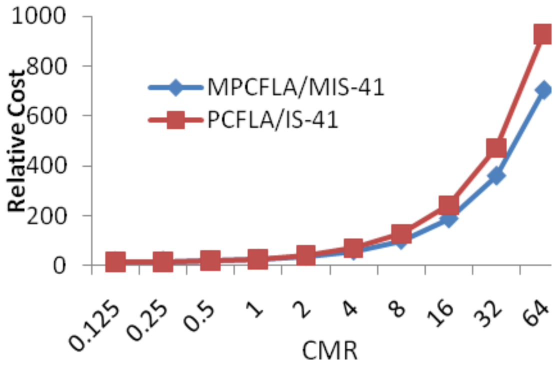
(b) Set (4)

Fig. 13. Database Access Costs

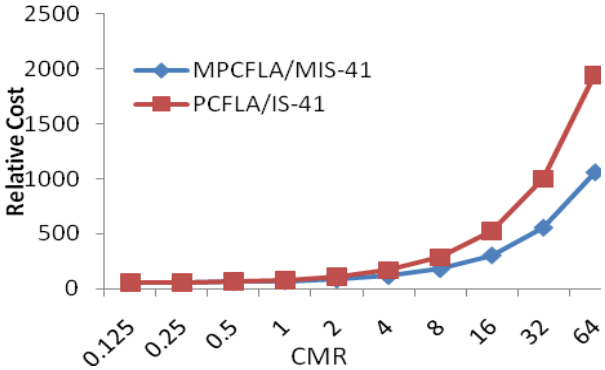
Fig. 13 shows that the database access cost remains almost same for set (3) for all CMR values. But for set (4), it remains same at first but with increasing CMR value the difference is evident and it is clear that the cost of MPCFLA is less than PCFLA. The MLR is one type of cache so the cost is very low for updating the MLR so we set C_m is 0.5 (set 3) and 1 (set 4). As compared with HLR database the access cost of MLR database is very small that is why our proposed approach gives better result than PCFLA.

C. *Total cost*

The total cost is determined by considering set (1) and set (3) in Fig. 14(a) and set (2) and set (4) in Fig. 14(b). In both cases MPCFLA shows better result than PCFLA. When the CMR value is small then the output of MPCFLA and PCFLA is approximately same. But MPCFLA performs well than PCFLA with increasing the CMR value. The signaling cost and database access cost is reduced because of the MLR system that is embedded in PCFLA strategy. Thus, the total cost is reduced in MPCFLA than PCFLA.



(a) Set (1) and Set (3)



(b) Set (2) and Set (4)

Fig. 14. Total Costs

VI. Conclusion

Now a days, Location management in wireless mobile networks is one of the most important and challenging issues in the current world. To perform efficient location management an effective strategy called MPCFLA is proposed in this paper. This strategy uses MLR system with PCFLA strategy. It reduces the access of HLR when the information of a called user is not found at calling MSC. As a result, it minimizes the total location management cost in terms of location registration cost and call delivery cost regardless of the CMR. The numerical results show that proposed MPCFLA strategy outperforms the PCFLA strategy irrespective of the MT's calling and mobility pattern.

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