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MOBILITY MANAGEMENT USING PROFILE REPLICATION BASED ON TOTAL NETWORK TRAFFIC STATISTIC DATA

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Abstract- Location management is most important aspect in personal communication services (PCS) to keep track of mobile users. Most of the location management schemes are designed based on certain assumptions and few factors like call-to-mobility ratio (CMR). But many other factors like location update, handover, paging, sms (short message services), etc. are excluded, which are important enough to be considered. In the proposed paper, we have proposed a mobility management scheme using profile replication based on total network traffic statistic data of mobile user instead of using single factor CMR. The proposed scheme is more realistic in determining the replication of mobile user's profile as compared to the prior schemes.
Keywords- Mobility Management, Profile Replication, Replication Factor (RF)

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Introduction

In personal communication services (PCS), services to the mobile users are provided irrespective of their location and movement. A mobile user should be tracked and located in order to set up a call [1-3, 13]. Location tracking operation in a PCS networks is expensive because many signal flows and database queries are needed to achieve the task. A well-known basic and simple scheme is two-tier Home location register/Visitor location register (HLR/VLR) scheme to update the location of each mobile user using HLR and VLR.

Many location management schemes are developed in the manner which tries to minimize one cost and tends to increase the other cost but tries to optimize the aggregate cost. These schemes can be classified as static and dynamic [9, 11]. Most of the schemes proposed for location management are developed based on the notion of call-to-mobility (CMR) factor and some schemes, generally forwarding pointer schemes exploit the mobility pattern of mobile nodes to reduce the signaling cost to query the HLR. Recent advancements in location management schemes focus on per-user-based scheme in which location update and searching of mobile nodes can be adapted dynamically based on users' call and mobility patterns. For example, when the frequency of incoming calls is higher than the mobile user's mobility rate, that is, when the CMR value is high, the caching/replication schemes [4, 7] is effective but when CMR is low, the forwarding pointer schemes as proposed in [20] is effective. Therefore, under the notion of per-user-based location management schemes, the better schemes can be selected based on the value of CMR. There is another scheme called hybrid scheme proposed in [5, 13] that combines replication and forwarding techniques.

Most of the prior schemes is based on certain intuitions and assumptions and hence might not correctly model real system. Since the mobile users' mobility behavior in a wireless communication system is complicated and some of these prior schemes are oversimplified and they only specifically focus on certain factors like CMR. Also these schemes do not consider factors like total location update, handover, paging, etc. These factors are important enough to be considered while designing the mobility management scheme. Therefore, the prior mobility management schemes (caching, replication, and hybrid) lack adequate mobility parameters in consideration and thus lack accuracy to reflect the real mobility behavior of mobile users.

The proposed scheme relies on the plurality of network traffic statistic data. We use expression “mobile node” and “mobile user” interchangeable in this paper. The rest of this paper is organized as follows. Section 2 contains the location management procedure involved in hybrid scheme [5]. Section 3 elaborates the proposed scheme. Section 4 contains the performance evaluation of proposed scheme and existing scheme (Hybrid). Section 5 ends with conclusion and future study.

Location Management in Hybrid Scheme [5]

Under hybrid scheme [5], the communication system applies the optimal number of replicas and the optimal forwarding chain length in order to minimize the total signaling cost. A lookup table is built up and applied to all mobile nodes at runtime to identify the optimal number of replicas and the optimal forwarding chain length to be used for each mobile node. The lookup table is kept at HLR to reduce the runtime overhead of determining the optimal number of replicas and forwarding chain length of a mobile. But this scheme adds more processing at HLR and also creates complexity by adding look up tables for mobile nodes at HLR.

A location update under hybrid strategy [5] proceeds when mobile node enters a new RA. The value of threshold K is checked. In case of threshold (K) is reached new chain is started and h replications of mobile node’s profile are made otherwise new MSC/VLR links with old MSC/VLR and K is incremented. The call delivery in hybrid scheme [5] takes place as follows. The caller VLR/MSC checks whether it has replica of called mobile node or not. If replica of called node found, it sends call request to the first VLR/MSC in the forwarding chain. Otherwise the caller VLR/MSC sends location request message to the HLR of called mobile node and gets the routing information. HLR sends the routing information which includes the first VLR/MSC of the forwarding chain. The caller VLR/MSC contacts the current VLR/MSC of the called mobile node through first VLR/MSC in the forwarding chain and call setup is made.

Proposed Profile Replication Scheme

We have proposed a novel per user’s profile replication scheme which is based on the total network traffic statistic data of the mobile user. We have observed that in most of the existing schemes, especially in [4-5, 7, 20] CMR plays greater importance. It is very much obvious that CMR represents a ratio only, which barely shows whether a mobile node is more active in calling or moving. But there are other factors like handover, location update, paging, SMS, etc which are also important in deciding the locality of a mobile user. Therefore, all these factors are considered together in the proposed scheme in order to predict the optimal replication probability (r_{orp}). The number of replication of a mobile user’s profile is decided based on the r_{orp}.

We have defined the entity called replication factor (RF) in terms of number of mobile terminated calls ($mtc_{i,j}$), number of handover (p_h), number of location update (p_l), number of paging (p_p), and number of SMS ($sms_{i,j}$) within a certain time period recorded by VLR/HLR of a mobile node.

$$RF = mtc_{i,j} + \pi_h + \pi_l + \pi_p + sms_{i,j} \qquad (1)$$

Where, $mtc_{i,j}$ is the number of mobile terminated calls to mobile node i from mobile node j and $sms_{i,j}$ is the number of SMS to mobile node i from mobile node j

Replication Strategy:

Suppose a mobile node MN_i is currently under VLR_m and a correspondent node CN_j is under VLR_n. There are $mtc_{i,j}$ calls and $sms_{i,j}$ from CN_j to MN_i in time period T. There are p_h number of handover, p_l number of location update, p_p number of paging under VLR_m in time T. Following steps are adapted while deciding the replication of mobile node’s working profile:

1. HLR periodically accesses the replication factor (RF) in time T of a mobile node referred by VLR_n.
2. Now, HLR accesses the total mobile node’s working profile reference made in time T by all the MSC/VLRs from which calls and SMSs are generated to mobile node and HLR decides the optimal replication probability (r_{orp}) of VLR_n as follows:

$$\rho_{orp} = \frac{mtc_{i,j} + \pi_h + \pi_l + \pi_p + sms_{i,j}}{\sum_{j=0}^{m} mtc_{i,j} + \sum \pi_h + \sum \pi_p + \sum \pi_l + \sum_{j=0}^{n} sms_{i,j}} \qquad (2)$$

$$= \frac{mtc_{i,j} + \alpha(\lambda_m + mtc_{i,j} + moc_{i,j} + \delta) + \beta(\lambda_m + \varepsilon) + \gamma(mtc_{i,j} + \phi) + sms_{i,j}}{\sum_{j=0}^{m} mtc_{i,j} + \sum_{j=0}^{m} \alpha(\lambda_m + mtc_{i,j} + moc_{i,j} + \delta) + \sum_{j=0}^{n} sms_{i,j}}$$

Where,

- m is the number of calls to the considered mobile node from different users and n is the number of SMSs to considered mobile node from different users
- a is the handover computation factor applied on mobility rate (l_m), MTC (mobile terminated call), MOC (mobile originated call), and other cause d.
- b is the location update computation factor applied on mobility rate and other cause e.
- g is the paging computation factor applied on MTC and other cause f.

3. If VLR_n has higher optimal replication probability (suppose r_{orp} ³ 0.5) then working profile of mobile node is replicated to VLR_n and such records (Replication Table) are kept at HLR.

The proposed system model has been shown in Fig. 1. Working profile (WP) of a mobile user is replicated at h VLRs by HLR. This replication is done periodically, for example once in a day. Replication is done only when the total cost of accessing a HLR is more than the cost of maintenance user’s profile by a VLR for certain time period. Suppose there are w number of HLR access by a VLR for certain mobile user in time T and cost of maintaining the user’s working profile (WP) is u_{wp}, then as per the cost details given in section 4,

$\mathbf{fu_{wp} \leq wz}$ and $\mathbf{N'u_{wp}}$ is within the bearable limit of storage capacity of a VLR

Where N, f, and z are the total number of working profiles of different mobile users maintained by the VLR, the cost of accessing other network elements except HLR, and the cost of accessing HLR and getting location information of a mobile user.

Location Update in Proposed Scheme

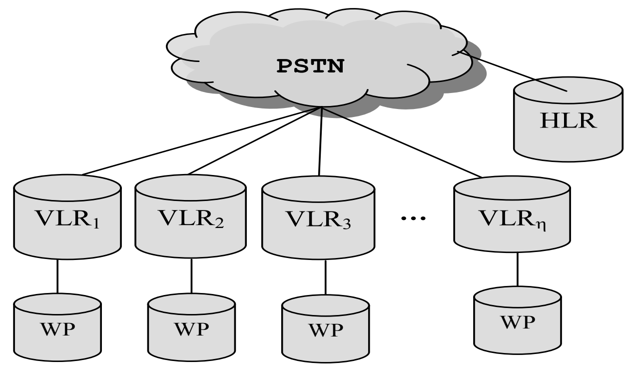

Fig. (1) Proposed Replication Model

- The location of a mobile node is updated as follows:
- The mobile node sends a location update message to the serving BTS.
- The serving BTS sends message to serving MSC/VLR.
- The serving MSC/VLR forwards it to the mobile node's HLR.
- The HLR updates the location of the mobile node and sends location deregistration message to old VLR.
- HLR sends an update message to all VLRs where mobile node's profile replica is stored. All VLRs update the mobile node's profile replica.

Call Setup in Proposed Scheme

The call setup is carried out asas shown in Fig. (2). The calling user sends call request (RQ-Call) to its VLR/MSC via BTS. The VLR/MSC checks whether it has working replica of called mobile user or not. If replica is there, it contacts the VLR/MSC of called mobile user directly. Otherwise it gets (RQ-LO) routing information (Routing-Info) from HLR of the called mobile user and call setup is made thereafter.

Performance Analysis

The variables/references and values used [5, 11, 18] are given in Table 2.

Table 2-

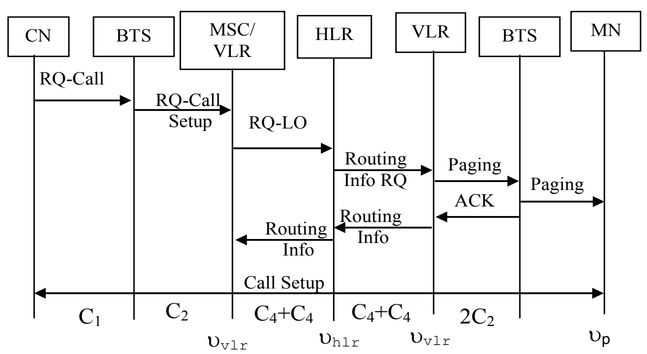

Fig. (2) Call Setup in Proposed Scheme

Location Management Cost of Proposed Scheme

Variable/ Reference	Description	Value Used
C_1	Cost of message transfer between mobile node and BTS	0.1
C_2	Cost of message transfer between BTS and MCS/VLR	1.5
C_{th}	Cost involved in accessing/Updating threshold K	0.01
C_3	Cost of message transfer between two VLRs	2
C_4	Cost of message transfer between VLR and HLR	5
u_p	Cost of paging in a registration area (RA)	2
u_{vlr}	Cost of updating location by a VLR	0.1
u_{hlr}	Cost of updating/accessing user profile by HLR	0.2
u_{ptr}	Cost involved in setting up the pointer to next VLR	2
h	Number of VLRs to be replicated	5, 50, 51
K	Number of VLRs in the chain (Threshold value) in Hybrid scheme	1, 2, 3, …, 10
K¢	Number of VLRs to be traveled to reach Current VLR in the chain	1, 2, 3, …, 10
p_h	Number of handover in time T	5, 10, 15, 20
p_l	Number of location updates in time T	1, 5, 10, 20
p_p	Number of paging in time T	10, 50, 100, 200
p_s	Number of SMS in time T	1, 5, 10, 20
$mtc_{i,j}$	Number of mobile terminated calls to mobile node i from mobile node j	5, 10, 50, 100
$moc_{i,j}$	Number of mobile originated calls to mobile node i from mobile node j	5, 10, 50, 100
$sms_{i,j}$	Number of SMS to mobile node i from mobile node j	1, 2, 3, 5
l_c	Number of mobile terminated calls in time T	5, 10, 17
l_m	Number of mobility in time T	5, 10, 15, 20
r_{orp}	Optimal replication probability of a mobile node's profile	10% - 99%
r_{rep}	Probability of a mobile node's profile to be replicated in a VLR	10% - 99%

We assume that the location update proceeds in the same way as in IS-41/GSM but the replication update to the VLRs where replication by HLR takes place in *T* time.

1. Cost of Location Update:

$$p_L = C_1+C_2+2C_4+2u_{vlr}+u_{hlr} + h(C_4+u_{wp}) \quad (3)$$

And the call setup (mobile terminated call to a particular mobile node) cost per call is given in equation (4).

$$p_c = C_1+C_2+r_{orp}(2C_2+2C_3+u_p+u_{vlr})+ (1-r_{orp})[C_4+u_{vlr}+r_{orp}(C_4+u_{wp}) +(1-r_{orp})(2C_2+3C_4+u_p+u_{vlr}+r_{orp}{´}u_p)] \quad (4)$$

Suppose there are l_c numbers of mobile terminated calls in time *T*.

So we have,

$$\lambda_c = \sum_{j=0}^{n} mtc_{i,j} \quad (5)$$

pT = (1+lc)(C1+C2) + 2C4 + 2uvlr+uhlr +h(C4+uwp)+ lc[rorp (2C2+2C3+up+uvlr) +(1-rorp) {C4+uvlr+rorp(C4+uwp)+ (1-rorp) (2C2+3C4+up+uvlr+rorp´up)}] (6)

And the average cost involved in location management per call is obtained as given in equation (7).

$$\pi_{avg} = \frac{\pi_T}{\sum_{j=0}^{n} mtc_{i,j}} = \frac{\pi_T}{\lambda_c} \quad (7)$$

The Cost of Location Management Involved in Hybrid Scheme [5]

The location update cost of hybrid scheme as discussed in section 2, is calculated as follows. Suppose y_{LH} is the location update cost. First we determine the probability of crossing a RA which is a crucial factor involved in building and maintaining the chain. Let r_K is the probability of crossing K registration area (RA), so using the proposal given in [18, 21], we have

$$\rho_K = \frac{\lambda_c}{\lambda_c+\lambda_m}\left(\frac{\lambda_m}{\lambda_c+\lambda_m}\right)^K \quad \text{for K=0, 1, 2, …} \tag{8}$$

So,

$$\psi_{LH} = C_1+C_2+C_{th}+\rho_K\begin{bmatrix}(2\eta+4)\times C_4+\\ \eta\times C_{\mathrm{Rep}}+C_{th}\end{bmatrix}+(1-\rho_K)\left(2C_3+\upsilon_{vlr}+\upsilon_{ptr}+C_{th}\right) \tag{9}$$

The cost of call setup in hybrid scheme as discussed in Section 2 is as follows:

$$\psi_{CH} = C_1+C_2+\upsilon_{vlr}+\frac{C_3}{\eta}+\left(\frac{\eta-1}{\eta}\right)\times\begin{bmatrix}2C_4+K' C_3+\frac{C_3}{\eta}+\frac{(\eta-1)}{\eta}\\ \times(2C_4+\upsilon_{hlr})\end{bmatrix}+C_3$$

$$=C_1+C_2+\upsilon_{vlr}+\frac{(\eta+1)C_3}{\eta}+\left(\frac{\eta-1}{\eta}\right)\times\left[2C_4+\left(\frac{\eta K'+1}{\eta}\right)\times C_3+\frac{(\eta-1)}{\eta}\times(2C_4+\upsilon_{hlr})\right] \tag{10}$$

Therefore, the total cost involved in location management in hybrids scheme is given in equation (11).

$$\psi_{TH} = 2(C_1+C_2)+C_{th}+\rho_K\begin{bmatrix}(2\eta+4)\times C_4+\\ \eta\times C_{\mathrm{Rep}}+C_{th}\end{bmatrix}+(1-\rho_K)\left(2C_3+\upsilon_{vlr}+\upsilon_{ptr}+C_{th}\right)$$

$$+\upsilon_{vlr}+\frac{(\eta+1)C_3}{\eta}+\left(\frac{\eta-1}{\eta}\right)\times\left[2C_4+\left(\frac{\eta K'+1}{\eta}\right)\times C_3+\frac{(\eta-1)}{\eta}\times(2C_4+\upsilon_{hlr})\right] \tag{11}$$

Where K¢ =1, 2, 3, …, K

And the average cost involved in location management is obtained as given in equation (12).

$$\psi_{avg} = \frac{\psi_{TH}}{\sum_{j=0}^{n} mtc_{i,j}} = \frac{\psi_{TH}}{\lambda_c} \tag{12}$$

The cost comparisons of hybrid and proposed location management schemes have been shown in Fig. (3), Fig. (4), Fig. (5), and Fig. (6). Referring to Fig. (3), probability factors r_{rep} and r_{orp} range from 0.1 to 0.99 (10% to 99%) and the number of replications, calls are considered equal and fixed. The number of VLRs accessed to reach current VLR in the chain in hybrid scheme is kept at the best, i.e. K¢=1. Referring to Fig. (4), the probability factors r_{rep}, and r_{orp} are kept fixed at 50% and number of calls (l_c) is fixed at 5. But the number of replications (h) varies from 1 to 10. Referring to Fig. (5), the probability factors r_{rep}, and r_{orp} are kept fixed at 50% and number of replications (h) is fixed at 5, but number of calls (l_c) and threshold (K) vary from 1 to 10. Referring to Fig. (6), the probability factors r_{rep}, and r_{orp} are kept fixed at 50% and number of replications (h) is fixed at 5, but number of calls (l_c) and K¢ vary from 1 to 10.

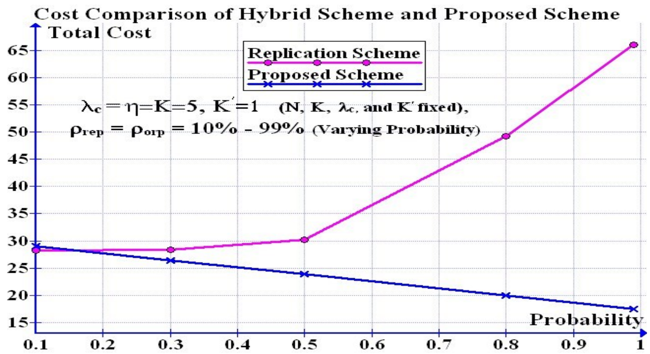

Fig. (3) Total Cost Comparison Varying the Probability (r_{orp}, r_{rep})

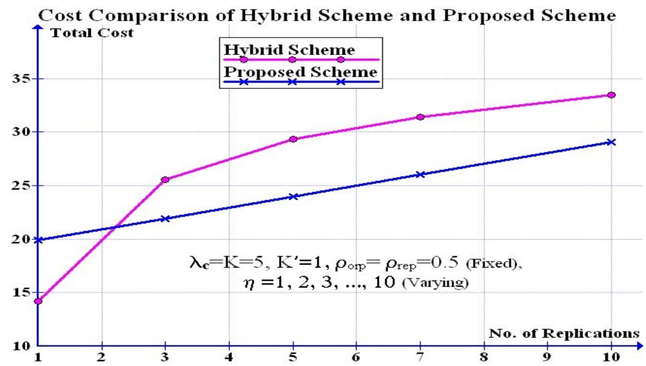

Fig. (4) Total Cost Comparison Varying No. of Replications

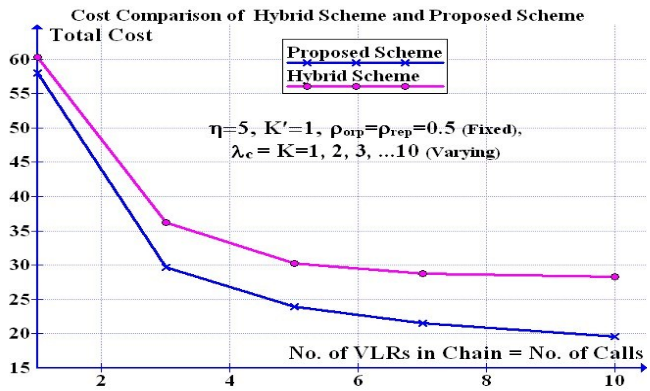

Fig. (5) Total Cost Comparison in Different Scenarios

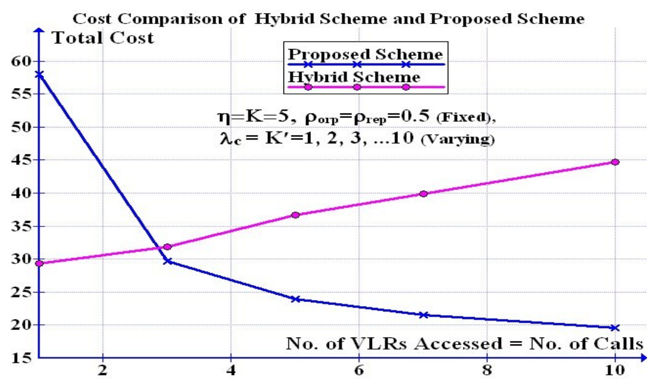

Fig. (6) Total Cost Comparison in Different Scenarios

Conclusion and Future Scope

It is very much obvious from the illustrations shown in Fig. (3), Fig. (4), Fig. (5), and Fig. (6) that the proposed scheme outperforms the prior hybrid scheme. The total cost of location management involved in proposed scheme is less than total cost involved in prior hybrid scheme. The proposed scheme is more realistic while considering the replication factor (RF) as compare to the factor CMR used in prior scheme (replication, caching, and forwarding pointer). We believe that the effects of factor h/l_c over total location management cost in proposed scheme can be considered for further study.

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