REPLICATION STRATEGY USING HUFFMAN TREE LIKE STRUCTURE

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Abstract— Replication strategy is mostly useful for replicating the mobile user's profile at selected locations where some callers have higher calling rate. It plays important role in personal communication services (PCS) in order to reduce call setup time and increase the QoS. We have proposed a novel and innovative replication tree which is based on the Huffman tree and there is interrelationship between the replicated sites based on their effective replication probability. In the proposed scheme, the total network traffic statistic data of a mobile user is considered to define effective replication probability.

Keywords—Location Management, Replication Tree, User's Profile Replication, Effective Replication Probability

1. Introduction

In personal communication services (PCS), services to the mobile users are provided irrespective of their location and movement. In order to set up a call, a mobile user should be tracked and located [1, 2, 3, 9, 14]. Keeping the location updated of a mobile user 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 HLR/VLR scheme to update the location of mobile users using HLR and VLR. The two-tier (HLR/VLR) location management scheme is used in Interim Standard 41 (IS-41), Global System for Mobile Communications (GSM) and also adopted by Internet Engineering Task Force (IETF) in mobile IP. There are several enhancements of basic two-tier schemes like per mobile node based location profile caching/replication [8, 9, 10, 13], pointer forwarding schemes [4, 7, 9, 11], and hybrid scheme [5]. But there is no interrelationship among the replicated sited proposed in the prior scheme.

We have proposed a replication tree which is based on the plurality of network traffic statistic data of mobile user. 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 hybrid scheme. Section 5 ends with conclusion and future study.

2. Location Management inHybrid Scheme [5]

Hybrid scheme [5] applies forwarding pointer and user's profile replication strategies together and maintains optimal number of chain length (η) and replicas (k) in order to minimize overall location management cost. When caller mobile user has high call rate (CMR is high), more number of replicas are beneficial in reducing the lookup time of the location of the called mobile user. Otherwise when caller mobile user has high mobility rate (CMR is low), using forwarding pointer technique is beneficial in minimizing the frequent home registration. The **location update** under hybrid strategy [5] proceeds as follows. Whenever there is location registration request by a mobile user, the threshold (η) value of forwarding chain length is checked. If threshold (η) is reached, η is reset and a new chain of VLRs is started and location replica of called mobile node is replicated at k numbers of VLRs. Location of caller mobile node is updated to HLR. Otherwise mobile node registers to the new MSC/VLR (*mobile switching Center/visitor location register*) and new MSC/VLR links with old MSC/VLR in the forwarding chain. The threshold η is incremented by one. The threshold 'η' and 'k' are selected based on value of CMR.

The **call setup in hybrid scheme** [5] takes place as follows. Caller sends call request message to MSC/VLR through BTS(Base Transceiver Station). VLR checks whether it has replica of called user or not. If replica is there, call request is sends to the current VLR of called user through chain of VLRs. Otherwise HLR of called user is requested to provide the location of called user and accordingly call setup is made.

3. **Proposed Huffman Tree like Structure**

We have observed that in most of the prior schemes, specially proposed in [4, 5, 7, 9-13], CMR plays greater importance while selecting a particular scheme. But there are other factors like handover, location update, messages, etc which are also important in deciding the locality of a mobile user. Therefore, we have considered all these factors together in the proposed scheme to define the effective replication probability (ρ_{erp}). Effective replication probability shows that how much weight a site has for profile replication of a mobile user. The number of replication (η) of a mobile user's profile is decided based on the ρ_{erp}.

Replication Strategy:

Suppose a mobile node MN_i is currently under VLR_m and a correspondent node CN_j is under VLR_n. Suppose there are $mtc_{i,j}$ number of calls and $sms_{i,j}$ number of messages from CN_j to MN_i in time period T. Let there are π_h number of handover and π_l number of location update under VLR_m in time T. Following steps are adapted while deciding the replication of mobile node's location profile:

1. HLR periodically accesses the activity of mobile user referred by VLR_n.

2. Now, HLR accesses the total mobile node's location profile reference made in time T by all the MSC/VLRs from which calls and messages are generated to mobile node and HLR decides the effective replication probability (ρ_{erp}) of VLR_n as follows:

$$\rho_{erp} = \frac{mtc_{i,j} + \pi_h + \pi_l + \text{sms}_{i,j}}{\sum_{j=0}^{m} mtc_{i,j} + \pi_h + \pi_l + \sum_{j=0}^{n} sms_{i,j}} \qquad (1)$$

Where, m is the number of callers who have made calls and n is the number of users who have send massages to considered mobile node MN_i.

3. If VLR_n has higher effective replication probability then location profile of mobile node is replicated to VLR_n.

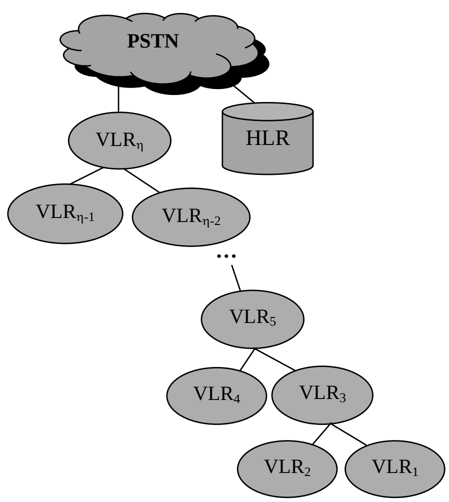

Fig. 1 Proposed Replication Tree Model

The proposed replication tree model has been shown in Fig. 1. The profile of a mobile user is replicated at ηVLRs by the HLR. A replication tree is constructed from the replicated VLRs which is similar to the Huffman's tree notion (Algorithm 2). This replication is done periodically (say time period T), for example once in a day. Replication is done only when the cost of accessing a HLR is more than the accessing cost of user's profile by VLRs in the tree. The root VLR_η maintains a table which contains all the VLRs under itand the mobile nodes under these VLRs. The information stored in this table is used for forwarding the location of mobile nodes.

3.1 **Creation of Replication Tree**

Suppose there are ηVLRs namely VLR_1, VLR_2, VLR_3, …,VLR_η where user's profile is to be replicated and effective replication probabilities of these VLRs are ρ_1, ρ_2, ρ_3, …, ρ_η respectively.

Algorithm 2: *Create-Replication-Tree*

1. Sorting of effective replication probabilities in ascending order such that $\rho_1 \le \rho_2 \le \rho_3 \ldots \le \rho_\eta$ (2)
2. Initialize counter i=1 and repeat for $i \le \eta$
   (a) Make i^{th}VLR and $(i+1)^{th}$VLR are children of $(i+2)^{th}$VLR
   (b) i = i+2
3. Make VLR_η as the root of tree.
4. Exit

3.2 **Location Update in Proposed Scheme**

Whenever there is change in the location of a mobile node, it registers its location to new MSC/VLR. The new MSC/VLR informs the root VLR. The location update of mobile node is carried out as given below:

Location Update Procedure:

1. The mobile node sends a location update (RQ-LU) message to the serving BTS.
2. The serving BTS sends location update message (RQ-LU) to serving MSC/VLR.
3. The serving MSC/VLR informs (INFO-LU) to its root VLR (VLR_η).
4. The root VLR update the location of the mobile node.
5. The current VLR sends location deregistration message to old VLR. If old VLR is not in the tree, the root VLR informs the HLR.

3.3 **Call Setup in Proposed Scheme**

The call setup is carried out as per following algorithm:

Algorithm 3: *Call-Setup*

1. The calling user sends a call request message to its MSC/VLR through current BTS.

2. If the serving MSC/VLR stores a location replica of called node, it contacts the called node's serving MSC/VLR directly and gets the routing information. Otherwise

(a) The current MSC/VLR sends a location request message to its root VLR.

(b) If root VLR stores mobile node's location information then forwards it to thecalling MSC/VLR. Otherwise

(c) The calling MSC sends a location request message to the HLR of called mobile node.

(i) HLR transmits a location request message to the current serving MSCof the called mobile node.

(ii) The MSC of called mobile node locates the called mobile node andassigns a temporary location directory number (TLDN) for it and sends the TLDN to the HLR.

(iii) The HLR forwards the TLDN to the calling MSC/VLR.

3. A connection is established from the calling MSC to the called MSC by using the received TLDN.

4. Performance Analysis

The variables/references and values [5, 10] used in the performance analysis are given in Table 1.

Table 1:

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_3	Cost of message transfer between two VLRs	2
C_4	Cost of message transfer between VLR and HLR	5
υ_p	Cost of paging in a registration area (RA)	2
υ_{vlr}	Cost of updating/accessing location by a VLR	0.1
υ_{hlr}	Cost of updating/accessing user profile by HLR	0.2
C_{th}	Cost involved in accessing/Updating threshold K	0.01
υ_{ptr}	Cost involved in setting up the pointer to next VLR	2
C_{Rep}	Cost of replicating mobile node profile to one VLR	0.01
η	Number of VLRs to be replicated	Varies
K	Number of VLRs in the chain (Threshold value) in Hybrid scheme	Varies
K'	Number of VLRs to be traveled to reach Current VLR in the chain	Varies
π_h	Number of handover in time T	5, 10, 15, 20
π_l	Number of location updates in time T	1, 5, 10, 20
π_p	Number of paging in time T	10, 50, 100
$mtc_{i,j}$	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	5, 20, 50, 100
ρ_{erp}	Effective replication probability of a mobile node's profile	Varies
$\rho_{erp,i}$	Effective replication probability of a mobile node's profile for VLR_i	Varies
ρ_{hit}	Probability of a mobile node to be in replication tree	Varies

The probability P_l that a mobile node stays in a RA isexpressed as given in [7, 10] as follows:

$$\rho_l = \frac{\lambda_c}{\lambda_m + \lambda_c} = \frac{CMR}{1 + CMR} \quad (3)$$

We assume that k and N are the VLRs under the proposed tree where location profile of a mobile user has been replicated and total number of VLRs in the foreign network respectively. We define the probability (ρ_{hit}) that next movement of MN is under the same proposed tree in terms of k and N as follows:

$$\rho_{hit} = \frac{k-1}{N} \quad (4)$$

It is discussed earlier that the proposed replication tree system is useful when the cost of accessing the HLR is less than the cost of cost of accessing the root VLR and updating k VLRs in the proposed tree. Other constraints like bandwidth, processing load on root VLR should be also taken into consideration. We assume that root VLR has enough storage and processing capacity. So, subject to the bandwidth constraint, the value of threshold (k) imposed on number of VLRs in the proposed tree can be calculated as follows:

$$k \le \frac{3C_4 + 2\upsilon_{hlr} + C_3}{C_3 + \upsilon_{vlr}} \quad (5)$$

4.1 **Location Management Cost of Proposed Scheme**

We assume that the location update proceeds in the way as discussed in section 3.2. Various costs are calculated as follows:

Cost of Location Update:

$$\Omega_l = C_1 + C_2 + 2C_3 + \left(1 - \rho_{erp}\right)(C_4 + \upsilon_{hlr}) + \upsilon_{vlr} \quad (6)$$

And the **call setup cost** is calculated as follows:

$$\Omega_c = C_1 + C_2 + \rho_{erp}(2C_2 + 2C_3 + \upsilon_p + 2\upsilon_{vlr}) + \left(1 - \rho_{erp}\right) \times \begin{Bmatrix} C_3 + \upsilon_{vlr} + \rho_{hit}(C_3 + \upsilon_{vlr}) \\ +(1 - \rho_{hit})(2C_2 + 4C_4 + \upsilon_p + \upsilon_{vlr} + \upsilon_{hlr}) \end{Bmatrix} \quad (7)$$

The **total cost**is calculated as follows:

$$\Omega_t = 2(C_1 + C_2 + C_3) + \rho_{erp}(2C_2 + 2C_3 + \upsilon_p + 2\upsilon_{vlr}) + \upsilon_{vlr} + \left(1 - \rho_{erp}\right) \times \begin{Bmatrix} C_3 + C_4 + \upsilon_{hlr} + \upsilon_{vlr} + \rho_{hit}(C_3 + \upsilon_{vlr}) \\ +(1 - \rho_{hit})(2C_2 + 4C_4 + \upsilon_p + \upsilon_{vlr} + \upsilon_{hlr}) \end{Bmatrix} \quad (8)$$

4.2 **The Location Management Cost of Hybrid Scheme**

The location update cost of hybrid scheme as discussed in section 2, is calculated as follows. Suppose μ_{hl} is the location update cost. Let ρ_K is the probability of crossing K number of RA, so using the proposal given in [14], we have,

$$\rho_K = \frac{\lambda_c}{\lambda_m + \lambda_c}\left(\frac{\lambda_m}{\lambda_m + \lambda_c}\right)^i = \rho_p\left(\frac{1}{1 + CMR}\right)^i \quad (9)$$

where i=0, 1, 2, 3…

$$\mu_{hl} = C_1 + C_2 + C_{th} + \rho_K\{(2\eta + 4)C_4 + \eta C_{Rep} + C_{th}\} + (1 - \rho_K)(2C_3 + \upsilon_{vlr} + \upsilon_{ptr} + C_{th}) \quad (10)$$

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

$$\mu_{hl} = C_1 + C_2 + \upsilon_{vlr} + \frac{(\eta+1)C_3}{\eta} + \left(\frac{\eta-1}{\eta}\right) \times \left\{2C_4 + \left(\frac{\eta K' + 1}{\eta}\right)C_3 + \left(\frac{\eta-1}{\eta}\right)(2C_4 + \upsilon_{vlr})\right\} \quad (11)$$

The total cost involved in location management in hybrid scheme is as follows:

$$\mu_{ht} = 2C_1 + 2C_2 + C_{th} + \upsilon_{vlr} + \rho_K\begin{Bmatrix}(2\eta + 4)C_4 + \\ \eta C_{Rep} + C_{th}\end{Bmatrix} + (1 - \rho_K)(2C_3 + \upsilon_{vlr} + \upsilon_{ptr} + C_{th}) + \frac{(\eta+1)C_3}{\eta} + \left(\frac{\eta-1}{\eta}\right) \times \left\{2C_4 + \left(\frac{\eta K' + 1}{\eta}\right)C_3 + \left(\frac{\eta-1}{\eta}\right)(2C_4 + \upsilon_{vlr})\right\} \quad (12)$$

Where K′ =1, 2, 3, …, K

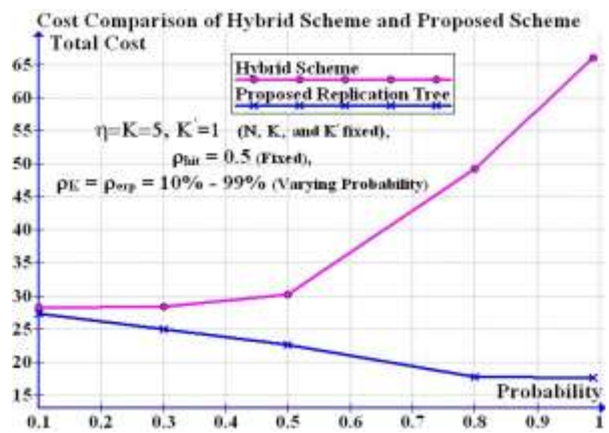

Fig. 2 Total Cost Comparison Varying Probability

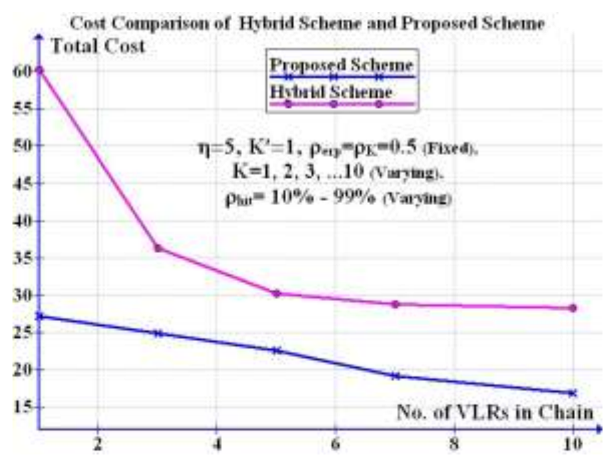

Fig. 3 Total Cost Comparison Varying No. of VLRs

The cost comparisons of hybrid and proposed schemes have been shown in **Fig. 2**, **Fig. 3**, **Fig.4**, and **Fig.5**. Referring to **Fig. 2**, probability factors ρ_{hit} has been fixed (50%) and $\rho_K$and ρ_{erp} range from 0.1 to 0.99 (10% to 99%). The number of replications (η) and number of VLRs in the chain has been fixed at 5. It is clear from the Fig. 4 that total cost in proposed scheme is decreasing and total cost in hybrid scheme is increasing as probability increases.

Referring to **Fig. 3**, probability factors ρ_{erp} and ρ_K have been fixed (50%) and ρ_{hit} ranges from 0.1 to 0.99 (10% to 99%). The number VLRs in forwarding pointer chain (K) varies from 1 to 10. The number of replications (η) is fixed at 5. The total cost in both the schemes is decreasing but total cost in proposed scheme is less than the total cost in hybrid scheme.

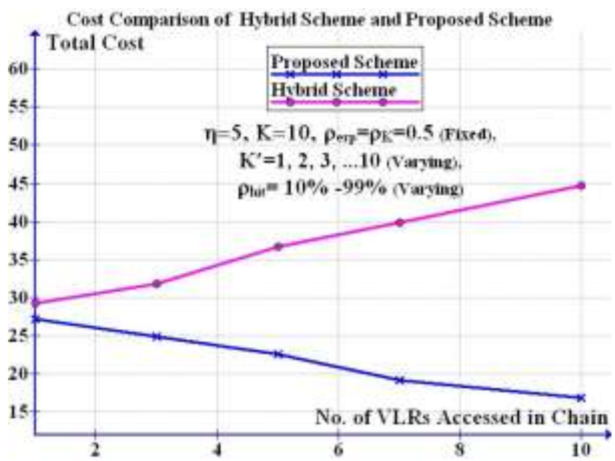

Fig. 4 Total Cost Comparison

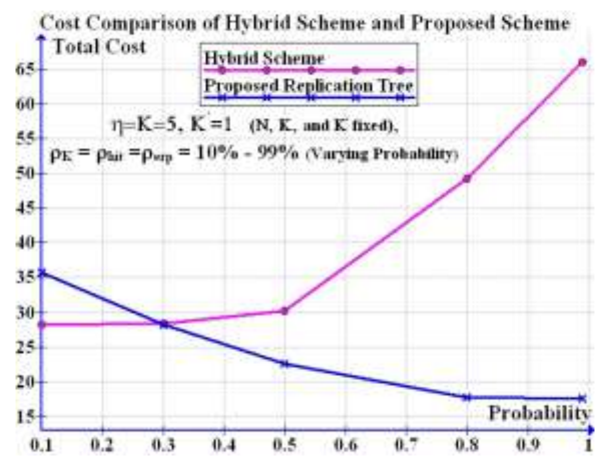

Fig. 5 Total Cost Comparison

Referring to **Fig. 4**, probability factors ρ_{erp} and ρ_K have been fixed (50%) and ρ_{hit} ranges from 0.1 to 0.99 (10% to 99%). The number VLRs accessed in forwarding pointer chain (K′) varies from 1 to 10. The number of replications (η) and number of VLRs in the forwarding pointer chain are fixed at 5 and 10 respectively. The total cost in both the schemes is decreasing but total cost in proposed scheme is less than the total cost in hybrid scheme.

Referring to **Fig. 5**, probability factors ρ_{hit}, ρ_K and ρ_{erp} range from 0.1 to 0.99 (10% to 99%). The number of replications (η) and number of VLRs in the chain has been fixed at 5. The number of VLRs accessed in the forwarding pointer chain is 1. Initially, total cost in proposed scheme is higher than hybrid but as probability increases.

5. Conclusion and Future Scope

It has been observed from the illustrations shown in Fig. 2, Fig. 3, Fig. 4, and Fig. 5 that the proposed replication tree scheme out performs the prior scheme (Hybrid Scheme) for probability factor 10% to 99%. Further, the proposed replication tree scheme is more realistic while considering the effective replication probability (ρ_{erp}) as compare to the factor CMR used in hybrid scheme. We believe that the effects of number of replications (number of VLRs in the replication tree) over total location management cost in proposed replication tree scheme can be considered for further research.

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