Locality based Location Tracking using Virtually Hierarchical Link in Personal Communications Services

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ABSTRACT : Personal communications services (PCS) should support a number of users that is several times larger than that of cellular systems. Using the fact that many call patterns in PCS have the locality between the callers and callees, the proposed mobility management strategy is able to track the user locations efficiently in a hierarchically distributed fashion. In the proposed structure, the larger number of nodes per parent node shows better results. The virtually hierarchical link is used for fast call set up, which is useful especially in the international roaming. The locality consideration effectively reduces the HLR query processings compared to otherwise.

I. Introduction

Database (DB) maintains the information for the location of mobile station and personal profile in Personal Communications Services (PCS) system. When a user moves to a new location, DB gets the information about the new user location and updates the related DB entries.

The IS-41 and GSM based mobility management techniques which record all the movements of users in one centralized DB, Home Location Register (HLR), is questionable due to the fact that keeping track of lots of users in real time is not simple task. A centralized DB scheme may raise the bottleneck in signalling network.

The centralized DB management scheme that is based on IS-41 and GSM registers and traces the user location using a centralized DB. This scheme is simple and suitable for small-size system. But this scheme heavily depends on HLR. Frequent query and update processings will cause the bottleneck in the signalling network, which will in turn degrade the system performance [5, 6, 9].

If PCS using this scheme are supported in a real environment, the following problems may occur.

(1) To connect a call, a remote query to the callee's HLR for checking the callee's profile should be always performed. If a callee is close to the caller and the callee's entry is not in the caller's Visitor Location Register (VLR), the system always queries to HLR to get the ID number of callee's VLR. So the signalling traffic would be heavily increased.

(2) If a callee is close to a caller's registration area and the callee's HLR is far away (i.e., in other nation), an international signal transfer may occur in order to query to the callee's HLR in connecting a call. Even though we want a local signal transfer, we have to tolerate some more signal transfer time. Moreover, a call cannot be connected in the case of an international signalling link problem.

(3) It is often difficult to adopt a location independent numbering plan.

In this paper, the DB nodes are distributed hierarchically in order to solve the above problems. Using the functions of the distributed DB nodes in signalling network, PCS system traces the user location and translates user's personal number to physical location number.

II. Call tracking in hierarchically distributed structure

In a hierarchically distributed structure, DBs are distributed according to the Service Control Points (SCPs) and SCPs communicate the call control messages to each other using the related links in [Fig. 1].

In [Fig. 1], SCPs manage the user's service profile, and they maintain the relations among each other to track the user's current location. A leaf node has VLR and HLR functions based on IS-41 and GSM standards. A leaf node can be implemented inside Mobile Switching Center (MSC) or outside MSC. In this case, the leaf node can serve several location areas.

Each node maintains HDB (Home DB) and VDB (Visiting DB). The following shows the call tracking algorithm in the proposed structure shown in [Fig. 1].

Caller request call to MS_A
Send message(request call) to $MSC_{caller\ site}$ //PSTN→$MSC_{caller\ site}$
Send message(request loc) to Node //MSC_{caller}→$Node_{leaf\ node}$
While not exist entry(MS_A) in VDB or HDB //1st phase
  Send message(request loc) to Node //$Node_i$→$Node_{i+1}$
End //end of while
While $Node_{current}$ is not leaf node //2nd phase

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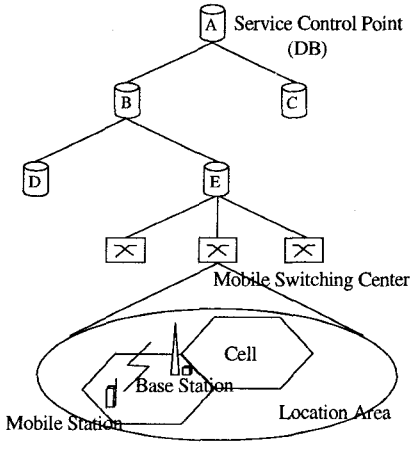
Send message(request loc) to Node // $Node_I \rightarrow Node_{i-1}$
End
send message(request status) to $MSC_{callee\ site}$
if MS_A is power(on) and status(idle)
then connect call
else cancel call
end if

<Call tracking algorithm >



[Fig. 1] Hierarchically distributed structure

III. Virtually hierarchically link for call locality

3.1 Threshold analysis

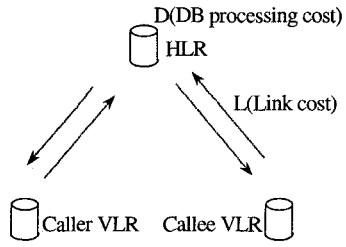
To estimate the locality effect, we simplify a centralized model and a hierarchically distributed model shown in [Fig. 2]. The call tracking cost is mainly composed of the DB cost for query processing denoted by D and the link cost for signal transfer denoted by L. We assume that D and L are same in both the centralized and the distributed models.

In the centralized model, The total tracking cost (C_c) is in (1).

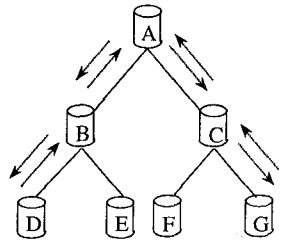
$$C_c = 4L + 2D \qquad (1)$$

In hierarchically distributed model, the total cost is different on the level difference between the caller node and callee node. For example, one D is enough to track the location if caller and callee reside in the same leaf node. If the callee's location is founded in the leaf's parent node, three D and four L are needed. Otherwise, the upper node of its parent node will be queried. In this case, five D and eight L are needed for location tracking. This can be expressed as follow.

$$C_n = D + (4L + 2D)(n - 1) \qquad (2)$$



(a) Centralized



(b) Hierarchically distributed

[Fig. 2] Signalling network system models

In (2), C_n is the required cost when callee's location is founded in the n-th level node. Let P_n be the probability that the callee's location is founded in the n-th level node. The total tracking cost (C_d) in the hierarchically distributed model is in (3).

$$C_d = \sum_{i=1}^{n} P_i C_i \qquad (3)$$

$$\frac{C_d}{C_c} = \frac{\sum_{i=1}^{n} P_i C_i}{4L + 2D} < 1 \qquad (4)$$

[Table. 1] Tracking cost ratio ($\frac{C_d}{C_c}$) and probability threshold

Dominant Cost		Cost Ratio	Probability Threshold
N = 3	D Cost	$(5-4P_1-2P_2)/2$	$2P_1+P_2 \geq 1.5$
	L Cost	$2 - 2P_1 - P_2$	$2P_1+P_2 \geq 1$
N=4	D Cost	$(7-6P_1-4P_2-2P_3)/2$	$3P_1+2P_2+P_3 \geq 2.5$
	L Cost	$3 - 3P_1 - 2P_2 - P_3$	$3P_1+2P_2+P_3 \geq 2$

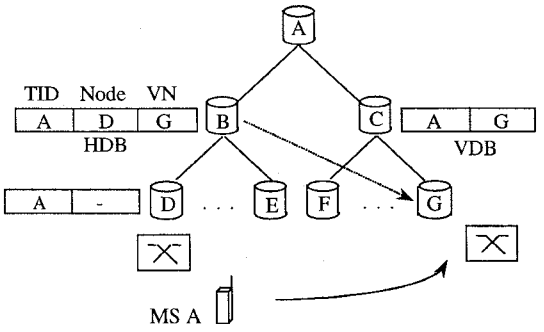
[Table. 1] shows the cost ratio and the probability threshold for the cost ratio ≤ 1, where the depths of the hierarchically distributed system are 3 and 4. The larger degree of the locality implies that the hierarchically

distributed system shows better cost effect compared to the centralized system.

3.2 Set up Virtually Hierarchical Link

We note that the call pattern of the PCS user has a strong locality. Suppose that a user moves to a new location area which is far from his home location area. There are much more calls which originate from his home location area or its neighboring location areas than those from the new location area. We use a virtually hierarchical link (VHL) to adopt the locality relation in tracking the callee's location efficiently. In setting up VHL, the preserved information about the home location of the terminal is used. A leaf node uses this information to let the home node set up the VHL, which reduces the signalling overhead for searching the home location of the terminal.

It is possible to set up calls fast which are originated from the location areas which are adjacent to the callee's home location. We can set up a VHL in the leaf nodes or their parent nodes, according to the number of location areas and the degree of the call locality. We can set up the VHL in 1st or 2nd level, according to the degree of the locality. In [Fig. 3], the VHL is set up in 2nd level of the structure.



TID : Terminal ID, VN : Visiting Node

[Fig. 3] VHL set up in 2nd level

3.3 Simulation Results

To estimate the traffic in signalling network, we simplify a centralized model and a hierarchically distributed model.

We assume a simple mobility model for PCS users. In the model, the direction of movement is uniformly distributed over [0, 2π]. And the PCS users are uniformly populated with a density of ρ. The rate of registration area crossing, R is $\frac{\rho v L}{\pi}$ where the average velocity of users is v and registration area boundary is of length L[7].

Now, we simply model the proposed hierarchically distributed structure as follows.

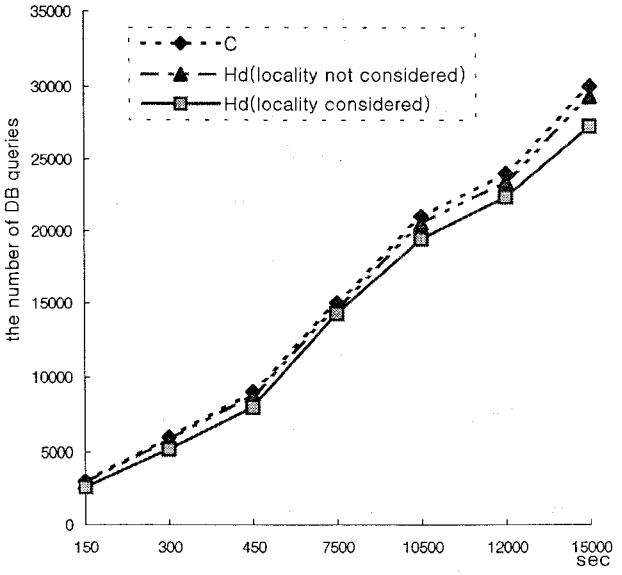
1) 85 leaf nodes

2) 17 parent nodes of the leaf nodes where the number of branches per parent node is 5

3) 3 level structure

If a call request and an update processing occur simultaneously, the update processing is processed first. The costs for DB query are calculated in simulation.

In hierarchically distributed model, the cost for the DB query processing is different on the level of the node in which the callee is found. That is, the cost effect varies according to the level in which a VHL is located.



C : Centralized Hd : Hierarchically distributed

[Fig. 4] Comparison of the tracking costs of the two systems

In [Fig. 4], the number of DB query for call tracking when the call locality relation between caller and callee is considered is compared with otherwise. The hierarchically distributed system reduces the signal traffic compared to the centralized system. And the consideration of the call locality shows better result than otherwise.

IV. Conclusions

This paper mainly focuses on reducing the signalling traffic to track PCS users. Using the call locality relationship between caller and callee, we provide a preliminary solution to the call tracking in the hierarchically distributed SCP structure. The proposed mechanism can solve the traffic bottleneck which may occur in the centralized system.

In the proposed mechanism, we use VHL to support the call locality. By using VHL, the fast call set up is possible

especially in the international roaming. Consideration of the call locality between the caller and callee shows the improved performance in the hierarchically distributed system compared to otherwise.

The simulation result shows that the proposed mechanism significantly reduces the signalling traffic load in PCS system. If PCS users display a high degree of locality in their call reception patterns, we can get the better results. In the traffic model, the ratio of the number of leaf nodes to one parent node, δ, is the important factor in performance evaluation. The larger δ shows better performance.

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