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An Improved Location Tracking Mechanism using Call Locality Relation 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 to support the call locality, which is useful especially in the long-distant roaming. The locality consideration effectively reduces the database queries compared with otherwise.

1. 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.

The centralized DB management scheme 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 is 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, a long-distant 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 bottleneck problem in the centralized DB management scheme and to track a call efficiently. 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.

2. Call tracking in hierarchically distributed structure

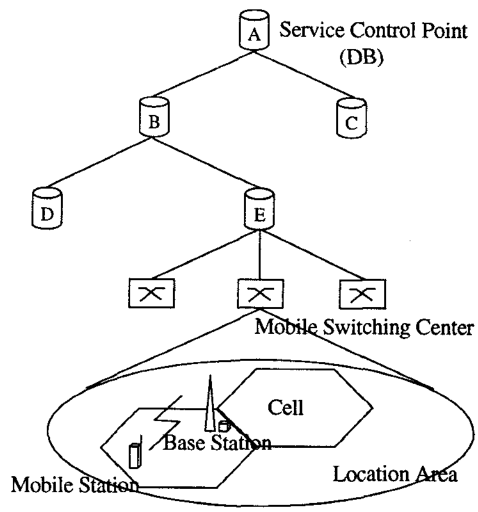
In a hierarchically distributed structure, DBs are distributed according to the Service Control Points (SCPs) and SCPs communicate the call control messages to each other. In [Fig. 1], SCPs manage the user's service profile and maintain the relations among each other to track the user's current location. Each node maintains HDB (Home DB) and VDB (Visiting DB) which are like VLR and HLR functions in IS-41 and GSM standards. A leaf node can be implemented inside Mobile Switching Center (MSC) or outside MSC. The leaf node can serve several location areas. In this structure, the call tracking steps can be described below.

The leaf node which serves the caller queries to its VDB. If the entry doesn't exist in VDB, the leaf node queries to its HDB. If the entry doesn't exist in HDB or the entry of the callee's TID is marked as move-out, the leaf node sends a query request to its parent node. The parent node first queries to its VDB. If the entry exists in VDB, it sends a signal to its child node which sent the query request. If the entry exists in HDB, the node sends a signal to its child node in the entry. If the entry exists in neither VDB nor HDB, the node sends a request to its parent node again.

The node which receives a signal from its parent node gets the location using the same manner described above. The leaf node which receives a signal from its parent node finds the MSC which serves the callee and sends the routing information to its parent node. Each node in routing path relays the routing information in turn to the caller node. The caller node connects a call using this routing information.

The following shows the pseudocode for call tracking algorithm described above.

```
Call_Tracking( )
   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
      Send message(request loc) to Node // Node_l→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
```

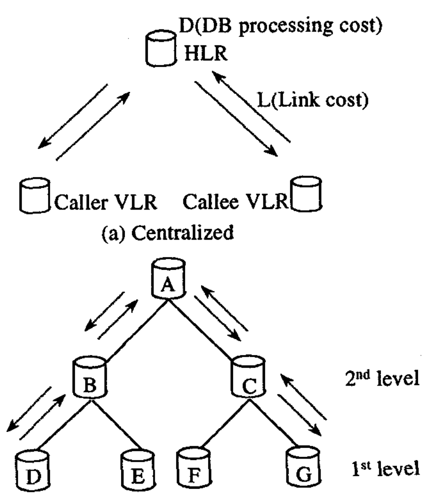


[Fig. 1] Hierarchically distributed structure

3. Virtually hierarchical 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 model and the distributed model.



[Fig. 2] Signalling network system models

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

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

In hierarchically distributed model, the total tracking cost is different according to 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 parent node of the leaf 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 generalized as in (2).

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

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, where $\sum_{i=1}^{n} P_i = 1$. The total tracking cost (C_d) in the hierarchically distributed model is in (3).

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

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

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

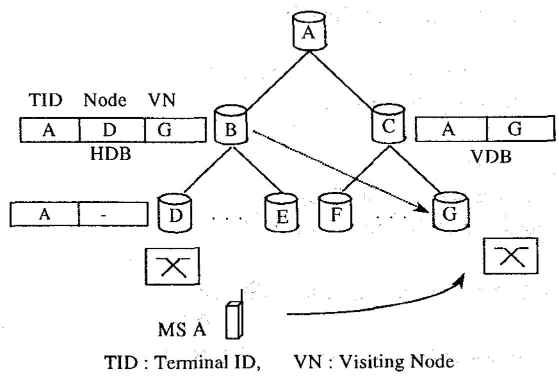
Dominant Cost		Cost Ratio	Probability Threshold
N = 3	D Cost	$(5-4P_1-2P_2)/2$	$2P_1+P_2 \geq 1.5$
	L Cost	$2 - 2P_1 - P_2$	$2P_1+P_2 \geq 1$
N=4	D Cost	$(7-6P_1-4P_2-2P_3)/2$	$3P_1+2P_2+P_3 \geq 2.5$
	L Cost	$3 - 3P_1 - 2P_2 - P_3$	$3P_1+2P_2+P_3 \geq 2$

[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, respectively. As shown in (4), the cost ratio mainly depends on the probability P_n that the callee is found in n-th level node. Since we note that the small value i in P_i implies high degree of the call locality, the higher degree of the locality means that the hierarchically distributed system is cost effective compared with the centralized system.

3.2 Setting 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 which is far from his home location. There are much more calls which originate from his home location or its neighboring locations than those originated from the new location. We use a virtually hierarchical link (VHL) to adopt the locality relation in tracking the callee's location efficiently. In setting 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 the VHL, which reduces the signalling overhead for searching the home location of the terminal.

Using VHL, we can set up calls which are originated from the locations which are adjacent to the callee's home location in an efficient way. We can set the VHL in 1st or 2nd level, according to the density of user per registration area and the degree of the call locality. In [Fig. 3], the VHL is set in 2nd level of the structure.



[Fig. 3] Setting the VHL in 2nd level

3.3 Simulation Results

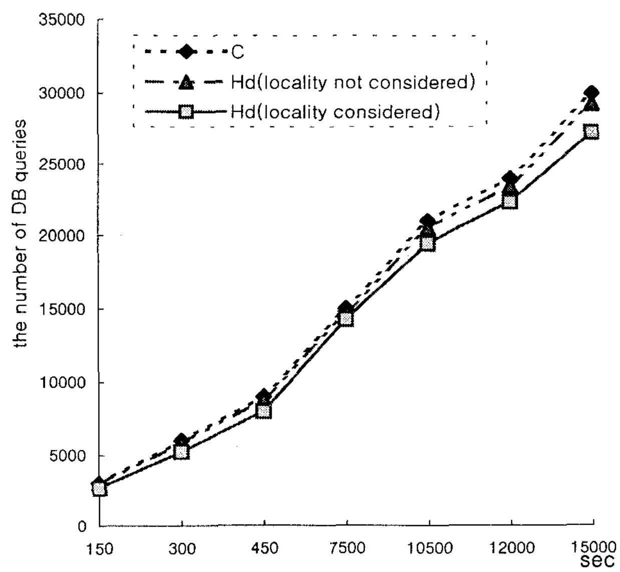
To estimate the traffic in signalling network, we simplify a centralized model and a hierarchically distributed model.

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

The number of records in leaf node level is 85 which is same as the one of registration areas. Each record consists of node id, upper-node id, and neighboring-node id. The number of records in upper node level is 18 – 17 for parent nodes of the leaf nodes and 1 for root node –. Each record except the one of root node consists of node id, upper-node id, and lower-node id.



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 with the centralized system. And the consideration of the call locality shows better result than otherwise.

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 the VHL is set. If the call pattern in PCS system shows the high degree of the locality, we can get the better performance setting the VHL in leaf node level.

Described above, we set the VHL in 2nd level to increase the probability to find the callee's location using VHL. In this case, one more DB query in 2nd level is needed to use the VHL but the number of calls in which the VHL can be used to track the callee's location is increased. So according to the call patterns and the level in which the VHL is set, the performance can be varied.

4. 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 systems based on IS-41 and GSM standards.

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 long-distance roaming. The hierarchically distributed system using the VHL reduces the signalling traffic compared with the centralized system. Consideration of the call locality shows the improved performance compared with otherwise. If PCS users display a high degree of locality in their call reception patterns, we can get the better results.

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