Reducing Database Sizes in Implicit Deregistration for Personal Communicatio Networks

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Abstract

Mobility management schemes that reduce signaling traffic load and connection setup time play a pivotal role in designing future personal communication services (PCS) network. It concerns users' Quality of Service (QoS) requirements and the efficient use of network resources. In recent years, many mobility management schemes have been proposed for the reduction of signaling traffic and network load. Regardless of the specific protocol, all such technologies must support two fundamental mechanisms. One is location management (knowing where the users are) and the other is handover management (making the transition between cells smooth . In location management, a mobile user has to register when entering a new registration area (RA) and to deregister when leaving. To reduce the signaling cost in registration and deregistration, Lin and Noerpel proposed an implicit deregistration scheme. That is, a mobile will not perform der egistration when leaving a RA. As a result, there are two consequences First, we need a large registration database. Second, even with a large database, it will become full eventually. Then we have to select a record to delete when a new mobile moves into the RA. In the original implicit deregistration scheme, the oldest record is deleted. In this paper, we propose two more reasonable and effective criteria to determine which record should be deleted from the database when a new mobile moves into an RA and the database is full. The purpose is t o decrease the database size and ensure a low probability that a valid record wil l be replaced at the same time. The two parameters used are call-to-mobility ratio (CMR) and average call arrival interval. When the database is full, the proposed method will delete the record that has the lowest CMR or that will have to wait for the longest time for an expected call arrival. Simulation results show that the modified approach has significant improvements on the database sizes.

Keywords: *Personal Communication Networks, Location Management*

1. INTRODUCTION

Mobility management algorith s enable wireless networks to support mobile users, while simultaneously serving incoming calls, data packets, and/or other services. Presently, there exist a wide range of technologies for supporting mobile users. Examples include cellular telephony, Personal Communication Services (PCS), and mobile Internet Protocol (IP). Regardless of the specifi protocol, in connection-oriented networks, mobility management consists of location management (tracking mobiles and locating them prior to establishing an incoming call), and handover management (reroutin connections, on which the mobile user was communicatin while moving, with minimal loss of user data).

Two standards currently exit for PCS location management: IS-41 [4,8,9], and GSM [10]. The IS-41 is commonly used in North America while the GSM is popular in Europe. Both the IS-41 and the GSM are based on a two-level database hierarchy. Two types of databases, home location register (HLR) and visitor location register

(VLR), are used to store the locat ion information of the mobile terminals. Figure 1 shows the basic architecture of a PCS network under this two -level hierarchy. The whole PCS network is divided into cells. Mobile terminals within a cell communicate with the network through a base station. These cells are grouped together to form larger areas called registration areas (RA's). All base stations belonging to a giving RA are wired to a mobile switching center (MSC) which serves as the interface between the wireless part and the wired part of the PCS network.

In Figure 1, assume that each MSC has a VLR and all MSCs are interconnected by the public switched telephone network. (PSTN). The HLR stores the user profiles of its assigned subscribers. These user profiles contain information such as the type of services subscribed, the quality of service (QoS) requirements and the current location of the mobile terminals. Each VLR stores replications of the user profiles of the subscribers currentl residing in its associated RA.

In the Personal Communication Services (PCS) Network, registration is used to report the mobile 's current location to the system. This occurs when a mobile moves into a new registration area (RA) or it turns on its power in an RA. The main operations are registering its current location to Visitor Location Register (VLR) correspondin to the RA and updating the new location in Home Location Register (HLR). Once the mobile leaves this RA, the resources such as temporary local directory numbers (TLDN) and database space in VLR allocated to the mobile should be released. In I -41 and several other protocols, explicit deregisteration is needed to infor m previous RA when mobile leaves.

Explicit deregistration incurs additional and significant signaling traffic in the PCS network and can not deregister a mobile that is shut off, broken, or otherwise disabled for a significant period of time. Timeout deregistration [1] has been proposed to solve the problem. A mobile will be deregistered after a default inactive time period. A different approach called implicit deregistration is proposed in [2] to eliminate signaling traffic due to deregistration. The implicit approach assumes that the record registered in the database earliest is obsolete when the database is full and a new mobile arrives at a RA. This method increases the probability that a valid record is forced to deregister for a new incoming mobile. Thus, the database size must be large enough to prevent that a valid record is replaced improperly.

In this paper, we use the implicit dereg isteration approach and propose a more reasonable and effective method to determine which record should be deleted from the database when the database is full and a new mobile moves into an RA. In order to decrease the database size and ensure a low probability that a valid record will be replaced, we use two different parameters as the criteria. One is call-to-mobility ratio (CMR) and the other is average call arrival interval. When the database is full, the proposed method will delete the record that has the lowest CMR or that will have to wait for the longest time for an expected call arrival. Simulation results show that the modified approach has significant improvements on the database sizes.

The rest of this paper is organized as follows. In Section 2, we briefly review prior work on location management. Then we introduce our modified implicit deregisteration method in Section .. Simulation results and discussions are included in Section 4. Finally, we will make some conclusions and suggest some future studies in Section 5.

2 Previous Work

IS-41 is a standard for location management. The scheme consists of using a two -level hierarchy of location registers called home location registers (HLR's) and visitor location registers (VLR's) to track mobile locations by registration messages. When a user subscribes to the services of a mobile communications system, a user profile is created in the system's database called HLR. The HLR is the location register to which a mobile identit is assigned for recording mobile user information (e.g. directory number, profile information, current location, validation period). An HLR record is assigned to a mobile based on its permanent address. A VLR record, usually located with a mobile switching center (MSC), is assigned to a mobile based on the current location of the mobile. When the mobile user visits another registration area (RA) other than the home RA, a temporary record for the mobile user is created in the VLR. The VLR is used to retrieve information for handling of calls to or from a visitin mobile user. To improve this basic architecture, there are "flat" schemes and "hierarchical" schemes.

The former uses a single-level hierarchy of location registers and the latter uses tree structures for location registers. In the flat scheme, when the HLR receives a location request, it assigns a temporary address based on the VLR/MSC at which the callee is located. The mobile's permanent address is tunneled in the call setup message, which the temporary address is used to route the connection from the caller's switch to the callee's current switch.

The hierarchical scheme uses a hierarchy of location registers to localize both mobile tracking and mobile locating messages. The registration message is propagated up the hierarchy until it reaches a location register beyond which there is no change of information regarding the mobile's location. The call setup message (or an explicit location query) is sent up the hierarchy until it reaches a location register that knows the location of the mobile, from which point the hierarchy is traced downward to reach the exact switch where the mobile is located.

The flat scheme results in lower computation costs, but incurs larger communication costs in comparison to the hierarchical scheme. Using a tree structure for location registers can decrease the need for "long-distance" signaling messages to HLR. On the other hand, the location query needs to be stopped and processed on many location registers in order to determine the location of a mobile. This will increase the computation costs. In contrast, the flat scheme increases the signaling communication costs since registrations and location queries need to be sent "long-distance" to the HLR. However, it decreases the computation costs since processing is needed only at one node for both registrations and location queries. The flat scheme also results in a lower delay due to the one hop location query processing. To balance the computation and communication costs, there are many other improved schemes [1-7, 9, 1 -15] between these two extremes. [11] introduced a cache scheme which reduces the signaling cost for call delivery by reusing the cached information about a callee's location from a previous call. In [12], a threshold scheme is introduced that dynamically determines the time when a cache record becomes obsolete. In [3, 13-15], a location forwarding strategy is proposed to reduce the signaling cost for location registration. Local anchoring [4] reduces the number of location registration messages between the HLR and the VLR's in a way that location change is reported to a nearby VLR called the local anchor (LR) instead of to the HLR.

3. Criteria for Selecting a Record to Delete

Our proposed method is based on implicit deregistration [2]. Since registration/deregistration is required in a PCS network when a mobile terminal moves between registration areas, the deregistration may create significant traffic in the network. Implicit deregistra ti scheme totally eliminates network traffic due to deregistration. If the database is full when a mobile terminal arrives at an RA, the implicit scheme assumes that the record with the oldest timestamp (i.e., the time when the mobile registered in the database) is obsolete and it is deleted. Although there may exists multiple VLRs that keep the record of a mobile terminal, only one record is valid. This won't affect the tracking of the mobile terminal. Because when the mobile terminal moves, its HLR record is updated to point to the VLR which contains the valid record. When the system attempts to locate the mobile terminal, the HLR record is accessed to find the valid VLR record, and the system will never be confused by multiple obsolete records. The only impact of the obsolete records is that they are not deleted immediately, which increases the probability that a valid is replaced and the correspondin mobile terminal is forced to deregister. Thus, the size of a registration database must be sufficientl large to ensure a low probability (say 10^{3}) that a valid registration record is replaced.

The original implicit deregistration scheme uses the oldest timestamp to be the criterion for selecting an obsolete record to replace. This is a rather crude method. In this paper we propose two more reasonable and effective criteria to determine which record should be deleted from the database when a new mobile moves into an R and the database is full. These two parameters are call-to-mobilit ratio (CMR) and average call arrival interval. The details of these two approaches are described below.

3.1 Call-to-Mobility Ratio (CMR) Approach

Call-to-Mobilit Ratio (CMR) of a user is the average number of calls to a user per unit time, divided b the average number of times the user changes registration areas per unit time [8]. The basic idea of this approach is that most users ha ve a similar moving pattern within a certain time period and the calling pattern also do not has large variation. For example, a user goes to work in the morning and goes home in the evening traveling the same route. When in the office, a user stays in the same building every day. We can calculate the value of each user's CM and record it in the user 's profile. When the database is full and a mobile terminal moves into an RA, we select the user record which has the smallest CMR to rep lace. Because the user with a larger CMR is likelier to have a call arrival before the user moves to another RA. When there are several users having the same value of CMR, then we use the timestam (the time when the mobile terminal registered in the database) as the second criterion. *Simulation results in the next secti show this* modification is more effective than the original implicit deregistration scheme.

3.2 Average Call Arrival Interval Approach

When the database is full and a mobile terminal moves into an RA, a user which has the longest idle time (i.e. no call arrival) may be obsolete. However, this does not imply this user has the smallest call arrival probability since the call ma be coming immediatel . Define the call arrival interval as the time between two calls. We calculate each user's average call arrival interval in the RA and record the last call arrival time. When the database is full, first we select those records with

$T_{Now} - T_{LastCallArrival} > \text{Average\_Call\_Arrival\_Interval}$.

Then we find the record with

$$\mathrm{Max}\left(\frac{(T_{Now} - T_{LastCallArrival}) - \text{Average\_Call\_Arrival\_Interval}}{\text{Average\_Call\_Arrival\_Interval}}\right)$$

and let this record be obsolete, where

$(T_{Now} - T_{LastCallArrival})$ is the idle time of a mobile, and

$[(T_{Now} - T_{LastCallArrival}) - \text{Average\_Call\_Arrival\_Interval}]$ is the excess idle time.

The rationale for the above formula is that if a user has a small Average_Call_Arrival_Interval (meaning that the user receives calls frequently) and his last call is past Average_Call_Arrival_Interval, then this user probably moves out of the registration area. And if a user has a large Average_Call_Arrival_Interval (meaning that the user seldom has calls) and his last call is way before Average_Call_Arrival_Interval, then this user probably moves out of the registration area too.

4. SIMULATION RESULTS AND DISCUSSTIONS

4.1 Database Size

Figure 2 shows the simulation result of three approaches CMR, Average call arrival interval, and timestamp only (i.e the original implicit d eregistration scheme). In the simulation, we assume that there are *N* mobile terminals in an RA on the average. The simulation focuses on the hit rate under different database sizes. We can see that the modified approaches ha ve significant improvement over the original implicit deregistration scheme. In the original implicit deregistration scheme (timestamp only), if the expected number of mobile terminals in an RA is N, then we need a database of size as large as $6N$ to achieve a high hit rate. But in our ap proaches we only need about $4.5N$ to achieve the same hit rate.

4.2 Signaling Cost Analysis

Figure 3 shows the model of RA for simulation of the signaling cost. Assume the HLR is in the cent er. Each hexagon is an RA with an MSC/VLR in it. The number in each hexagon represents the signaling cost form MSC/VLR to HLR.

In the simulation, we calculate the signaling cost of standard IS-41 location registration algorithm and the implicit deregistration scheme. Then we calculate the average relative cost of the two schemes. The simulation result of signal cost analysis is shown is Figure 4. We can see that in the long run the average relative cost approaches 0.5. Therefore, we can say that using implicit deregistration scheme can save about half of signaling cos t on average.

5. Conclusions

In this paper, we propose a modified implicit deregistration scheme based on the statistics of C MR and average call arrival interval . We modify the implicit deregisteration approach by using more effective parameters to de termine which record should be deleted from the database when a new mobile moves into an RA. In order to decrease the database size and ensure the same low probability that a valid record will be replaced, we use two different parameters to fulfill this go al. One is call-to-mobility ratio (CMR) and the other is average call arrival interval. When the database is full, the proposed method tends to delete the record that has the lowest CMR or that will have to wait for the longest time for an expected call arrival. Simulation results show that the modified approach has improvement on the database sizes. The average relative signaling cost analysis shows that using implicit deregistration can save about half of the cost in the long run.

Other considerations of implicit deregistration could be included. Since each user has a primary locality, we can also give these records high priority not to be obsolete in these primary RAs. This criterion can improve localit characteristic to our modified implicit deregistera tion. Furthermore, the cost analysis model can includes various costs, such as physical and logical network cost.

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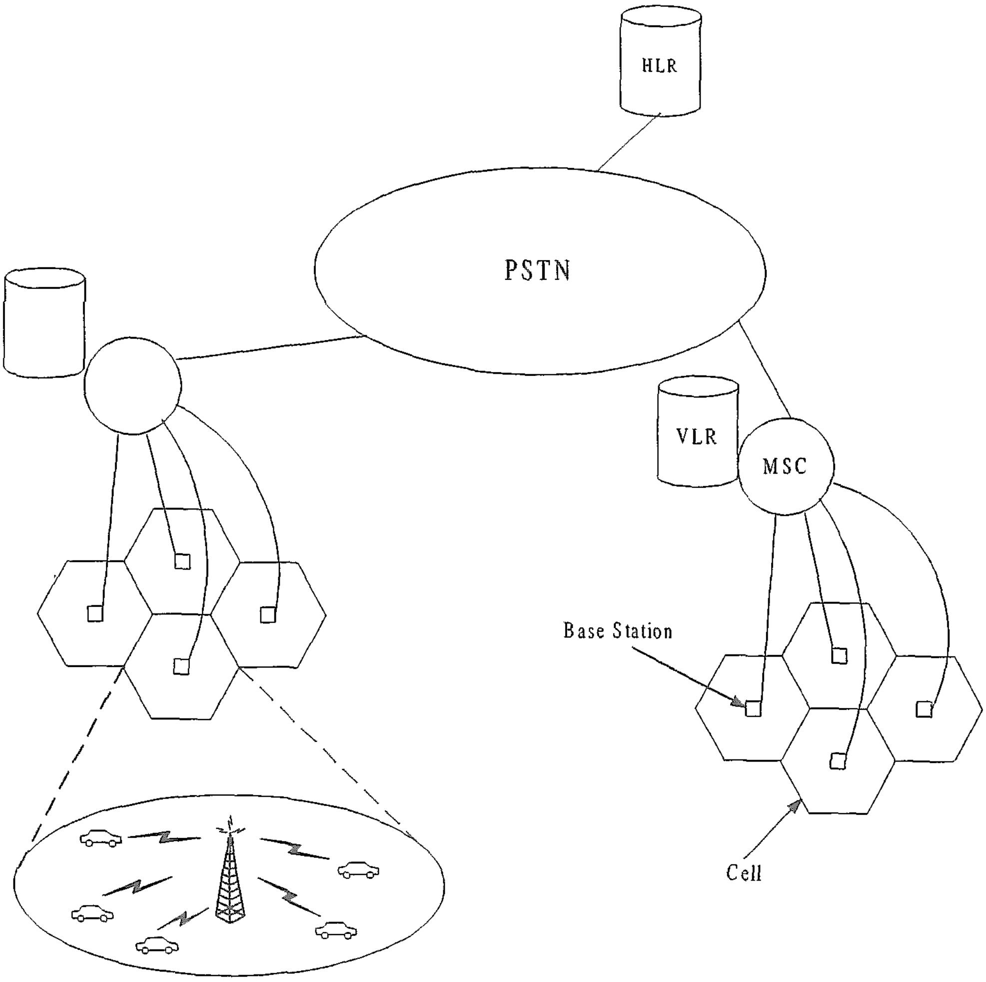

Figure 1. PCS Network Architecture.

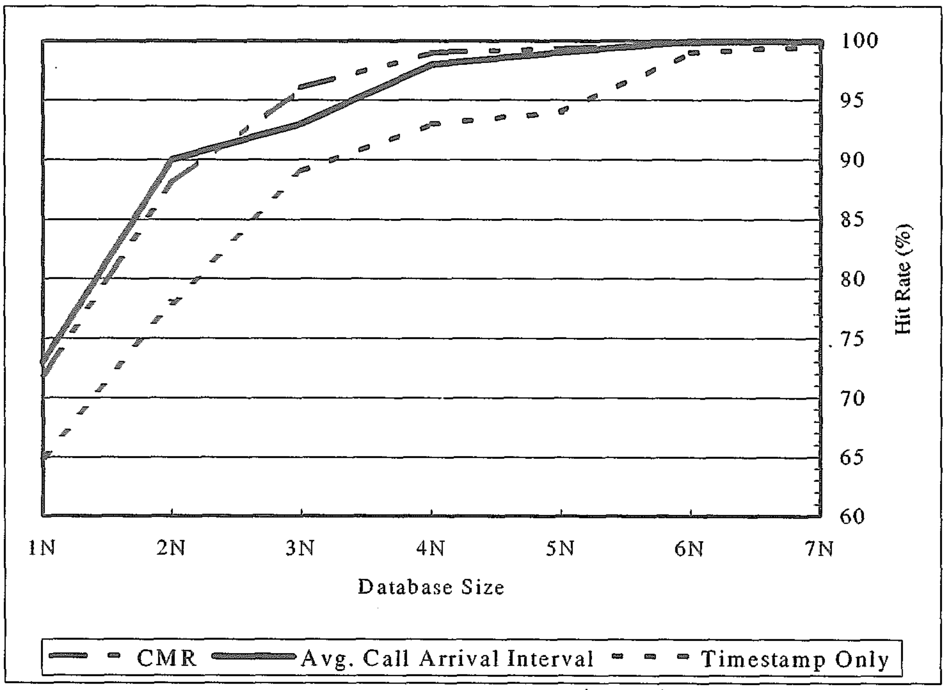

Figure 2. Simulation Results for the Three Approaches

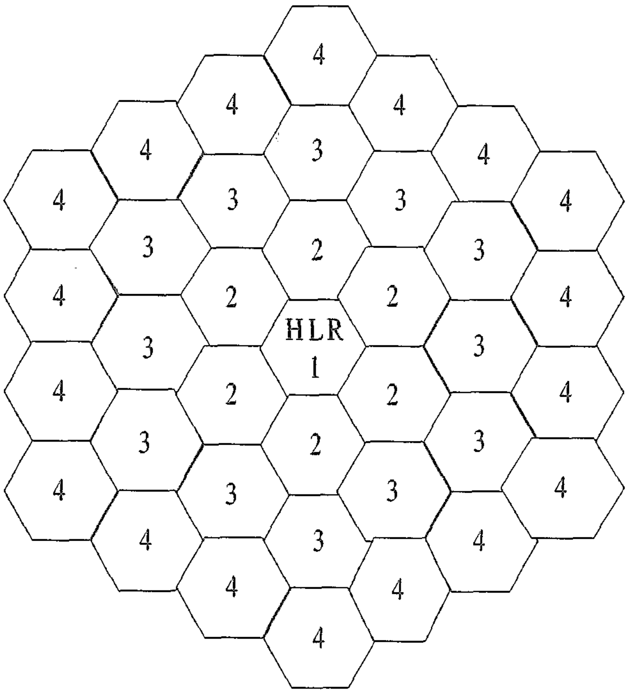

Figure 3. Simulation model of R 's

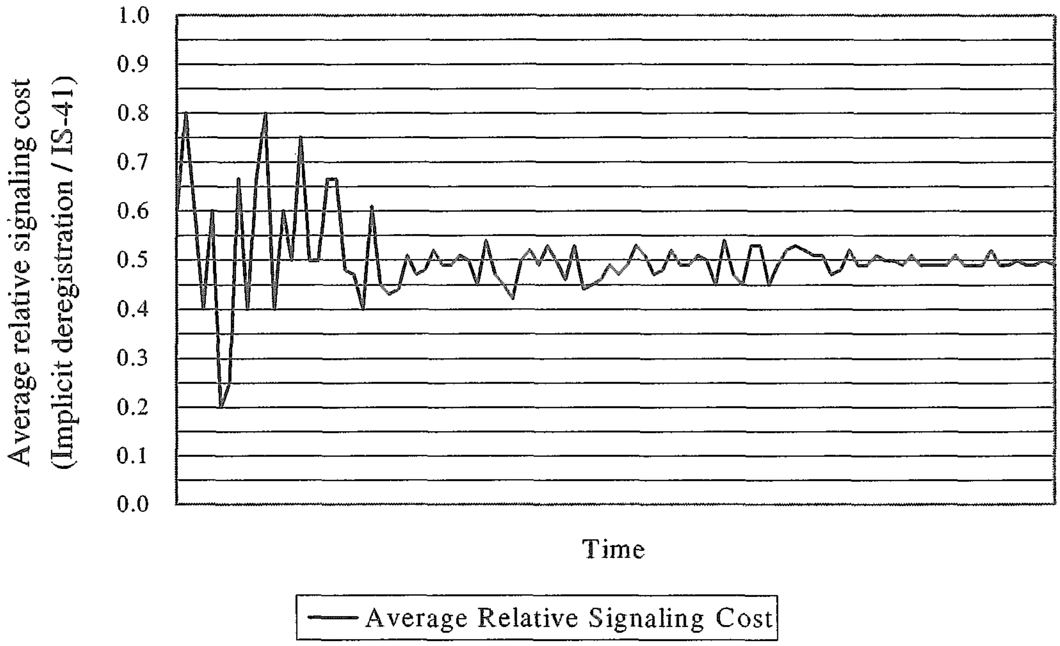

Figure 4. Simulation result of signaling cost