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An Intelligent PCS Location Tracking Strategy

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Abstract

We propose a new method which aims at reduction of signaling overhead resulting from location tracking in PCS (personal communication systems). The key idea is taking the recent user movement information (i.e., last connection's location area and start time of the last connection, etc.), which is called *paging information record*, into account to determine which location area to be paged first. Experimental results show that our method can significantly reduce location management's signaling cost compared with existing methods. The overhead of our approach is the additional storage space required (for storing mobile host profiles and paging information records) in network databases and the additional processing time of profiles and paging information records. However, neither the storage nor the processing time requirements can be considered significant in terms of today's memory capacity and processor speed as far as the reduction of signaling traffic implying more bandwidth available.

Keywords : alternative strategy, classical strategy, location update, location tracking, paging information record, PCS.

1 Introduction

In the second generation mobile communication systems, such as *Global System for Mobile Communications* (GSM) [1], the issue of location tracking [2] is described as follows. A network is divided into geographical areas, called *location areas* (LA) and the location management system keeps track of the current LA of an MH (mobile host). An LA may contain one or more cells. The location information is stored in the network database for location management. In order to maintain the consistency of location information, an update process is triggered whenever an MH crosses LA boundaries. When a call arrives, a query to the location database is conducted to get the location information of the called MH. Then, the location management system will page the cells in the corresponding LA simultaneously.

In the third generation mobile communication systems the same location management approaches may not be applicable. Due to fast growing population of MHs, the signaling load will become too heavy to handle location management, especially in densely populated areas. Our method belongs to the *memory-based* type. The memory-based type emphasizes on the information collecting capability of the network. Based on the movement records of an MH during last observation period, the location management system generates an *LA list*. When there is a call for the MH, the location management system will take the recent short term events and the LA list into account and generate a new list, called *paging list*. The LA list and the paging list are two primary elements of our method for dealing with location management.

This paper is organized as follows. In section 2, we introduce the classical strategy (CS) and the alternative strategy (AS) [3][4], respectively. In section 3, we describe some short term events and our design approach. Then, we evaluate our approach in comparison with CS and AS in section 4. Finally, a few concluding remarks are made in section 5.

2 Existing Methods

In this section, we introduce two representative location management methods, CS [3] and AS [3, 4], respectively. The CS was the most frequently used method in a wireless telecommunication environment. Its policy is simple but may generate too much location management signaling load. To suit for a large number of MHs, the AS were proposed to relieve the signaling load by reducing the frequency of location update. The AS can meet the need of the future, because the size of a cell will become smaller to facilitate frequency reuse. However, the smaller the cell size is, the higher the cell crossing rate is. The location management system will need to spend more

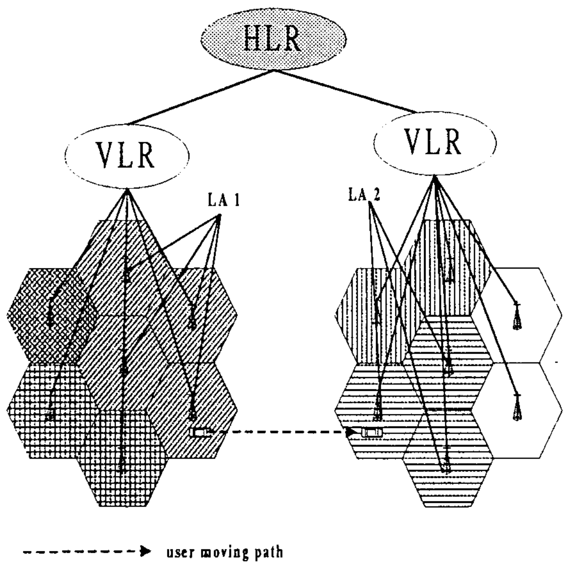

Figure 1: Classical strategy architecture.

radio channels to manage the MH location. The CS is a GSM-like method and is most used in wireless telecommunication systems. The AS is aimed to reduce most of location updates. It is suitable for future need because the base station (BS) coverage will become small for frequency reuse. The smaller the range of an BS is, the higher the location update rate is. In this situation, the location update cost will increase very much and require more channels to maintain the MHs' location information. The AS can reduce location update cost and save channels.

2.1 Classical Strategy

In CS [3], the radio coverage area is partitioned into LAs, as shown in Figure 1. Each LA consists of a group of cells (1, 2 or more cells). The MH tracking is realized by updating its location whenever an MH leaves its current LA. The location management system always knows which LA an MH is in, and therefore, when a call is for the MH, the system pages it over its current LA. The location area identifier (LAI) is recorded in a location pointer stored in a visitor location register (VLR). The address of the current VLR of an MH is kept in the home location register (HLR) of the MH. The major drawback of this method is the very high traffic generated by location updates in the case of an MH which frequently changes its LA. If an MH receives very few calls, then the signaling traffic generated to track it is useless, and the ratio of the traffic generated cost to the number of processed calls is very high. This situation is severer with the growth of customer population and the very limited bandwidth capacity.

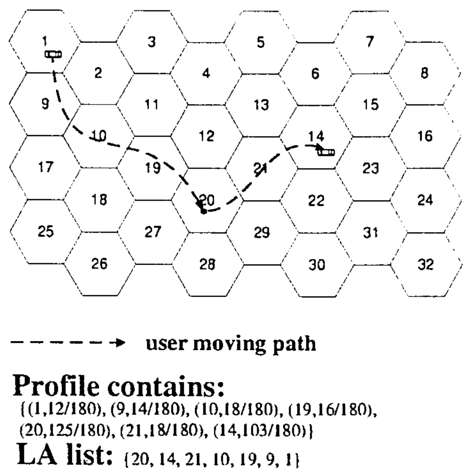

Figure 2: Alternative strategy.

2.2 Alternative Strategy

The main goal of the AS [3, 4] is to reduce the location update (registration) cost by predicting users' movement patterns. It is based on the human movement habit. Most people move the same path as usual. In this situation, we can predict an MH's movement path to avoid most of location updates. In the AS, the system handles a profile for each user, where each user's mobility pattern is recorded. The structure and elements of this profile [3, 4] are as follows:

For an MH:

1. In a period of time $[t_i, t_j]$, it crosses a set of LAs.
2. The profile consists of two elements : (a_f, α_f) with $1 \leq f \leq k$ (the number of LAs).
   where a_f is the identifier of the fth LA that an MH can be located;
   α_f is the resident probability that the MH is located in a_f, with $\alpha_1 \geq \alpha_2 \geq \cdots \geq \alpha_k$.

When an MH updates its profile, the location management system will generate an *LA list*. The LA list is the set of LAs that appeared in the profile and the sequence of the list is according to the probability of an MH that may reside in an LA. The profile of each user is stored in the HLR. If an MH is called, the location management system will first page it over LA a_1. If it is not there, the system will page it over LA a_2 up to LA a_k (the last LA in the LA list). The location management system should keep all the possible areas

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(at most k areas) where an MH may be there. If an MH moves away from the LAs in the LA list, the MH should do registration to add a new LA to the profile and the LA list. As an example, in Figure 2, an MH moves from LA 1 to LA 20, and then to LA 14. After the MH updates its profile, the location management system generates an LA list in the order of the MH resident probability. If there is a call for the MH, the location management system will first page LA 20.

The AS reduces most of the signaling traffic by decreasing the times of registration. An MH usually moves in the same track because of the same destination (i.e., office, school, home and etc.) and the same placement of the highway in the ordinary days. The location management cost can be saved by getting high predictable moving patterns. However, sometimes an MH may change its destination due to some short term events. In this case, we may have a different path and some new LAs where the MH never visits during the last period. Under this condition, the location management system will spend more paging cost to locate an MH because it should page over all LAs in the LA list first. To avoid consuming too much network resources in this respect, we will propose a new method which takes short term events into account.

3 Design Approach

The AS is based on long-term observation patterns and it analyzes the patterns to produce an LA list which is the collection of an MH ever visited during the observation period. For short term events the AS must spend more location tracking (paging) cost, so we propose a new method to improve the AS.

3.1 Short Term Event Scenarios

In the AS, when an MH is in the LA list, the location management system will get its new location information only when it generates a call or after it was paged. An MH may not interact with the location management system very often, because it does not make a call or receive very few calls. The location management system does not have enough information about the MH's short term events. First, we consider the situation when an MH is called and the time from the last connection to now is short. According to this information, the probability of the MH staying in the same LA is large. In the AS, we should page the MH from a_1 up to a_k in the LA list and it would waste much paging cost. Instead, we should show the MH over the LA where the MH last appeared. Secondly, an MH may change his movement habit or move around some LAs (boundary crossing). The LAs where the MH visited may not be the frequently visited LAs (not in the first several LAs of the LA list). So the location management system must page the first several LAs in the LA list, and it results in high paging cost.

LAI	Time	Tag

LAI : **location area identifier**
Time : **start time of this connection**
Tag : **a mark indicates if the LA has been paged successfully**

Figure 3: The data structure of paging information record.

3.2 Paging Information Records

Before describing how our intelligent location tracking strategy works, the data structure of *paging information records* must be defined first. The paging information record stores the information about an MH communicating with the location management system. In Figure 3, the three fields of the paging information record are explained as follows.

1. *LAI*: The location area identifier (LAI) identifies the LA where an MH communicated with the location management system during the last period. The short term events, including the MH entering a new LA, the MH having a call to deliver, and a call for the MH, must be recorded.

2. *Time*: This is the start time (last connection time) when an MH had a connection with the location management system. This is an important parameter for us to decide which LA to page first for call delivery.

3. *Tag*: This is a mark (1:successful; 0:unsuccessful) to let us know if an LA has ever been successfully paged during the observation period before an MH updates its profile in the system. If there are i 1s in the *Tag* field of the paging information record, the offset (W) is defined as:

$$W = i \cdot w \tag{1}$$

where w is an adjusting constant. W indicates the offset that the location management system should add to α_f of the LAs in the paging information records when it rearranges the LA sequence in the LA list.

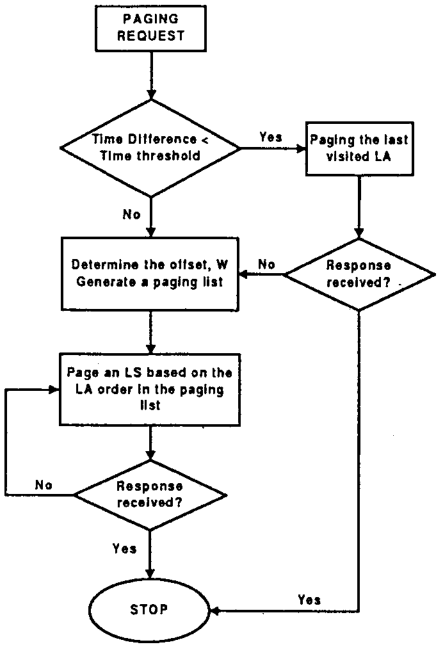

Figure 4: The flow chart of our intelligent location tracking strategy.

3.3 Our Intelligent Location Tracking Strategy

To reduce the paging cost under the scenarios described in section 3.1, we should pay attention to recent short term events. Based on the AS, we add a new component and store it in the HLR. The new component is called *paging information record*, which has been described in the last section. The flow chart of our intelligent location tracking strategy is described in Figure 4. When an MH is called, the location management system will not page it according to the original LA sequence in the LA list. First, we obtain the *time difference* (δ_t) between the last connection time and the call arrival time. If there are more than one records in the paging information records, we just compute the time difference of the last record because its time difference is the smallest. Then, we determine if the time difference is smaller than the *time threshold*, which is defined as the maximum resident time that an MH is still in the last visited LA. Otherwise, the system w ill rearrange the LA sequence in the LA list first by taking the paging information records into account. Those LAs that appear in the paging information records will increase their resident probability by an offset, W. The system will sort the LA sequence in the LA list and the sorted list is called a *paging list*. The system will page the LAs according to the new LA sequence in the paging list until paging is successful. The offset is intended to reflect the events that happened during this observation period. The larger the offset is, the higher the probability of an MH in the LAs of the paging information records.

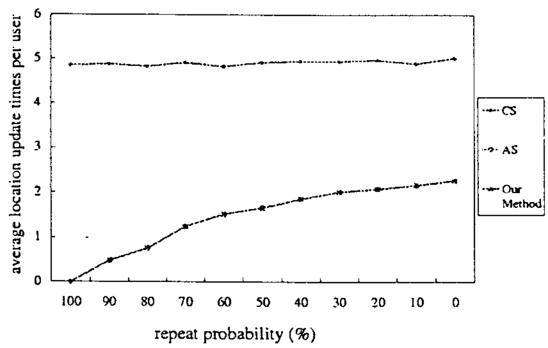

Figure 5: Location update cost among CS, AS and our method.

4 Experimental Results

Our simulation model is based on a city zone area model [5][6] . In Figure 5, it shows that the update cost of the AS and our method is much less than the CS with the variance of repeat probability. Repeat probability is the probability of the MH moving in the same path as the last period of time. If the repeat probability is 100%, it means that the MH moving in the same path as the last period of time and the times of location update is zero. As the repeat probability decreases, the location update cost will increase. This is because the MH will change its moving path and it will stay in some LAs that was not visited in the last period of time.

In Figure 6, we can see our approach is much better than AS on location tracking cost. When the repeat probability increases, the location tracking cost of the AS will increase faster than that of our method. According to the estimated size of the SS7 message from [4], we can compare the total location management cost among these three strategies. Simulation results show that our method can save 14% - 55% location management's signaling cost compared with the CS, and save 6% - 39% signaling cost compared with the AS under different repeat probabilities.

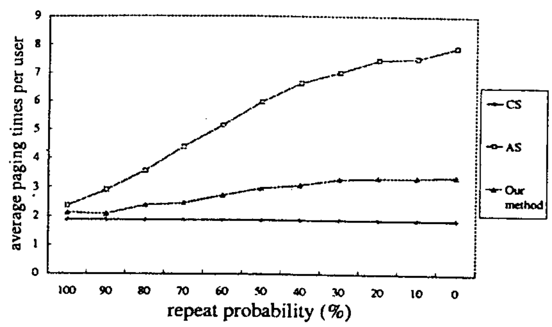

Figure 6: Location tracking cost among CS, AS and our method.

5 Conclusions

We have presented an efficient location tracking method for PCS and have shown that it is better than existing methods: CS and AS. The AS, which has been proposed for improving the CS for location management, is suitable for the cases of high mobility rate and small LA size because it can reduce most of location update cost. Our approach further reduces most of location tracking cost in comparison with the AS without increasing location update cost. It just needs extra storage space and some simple computations. Since the advancement of memory capacity and processor speed is higher than the availability of radio channels, this overhead is very low. Our method can reflect an MH's moving behavior by generating a dynamic paging list. If an MH performs some actions that it seldom or never did during the last period, our approach will increase the offset for its paging information record. In this way, our location management system may respond to the MH's behavior quickly before the MH updates its profile.

6 Acknowledgement

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