Timer-Based Location Management to Improve Hit Ratio in Cellular Network Using Cache Memory

Alok Sahelay, Ramratan Ahirwal, and Y. K. Jain

***Abstract*—Location management is essential task in current cellular system. Mobility prediction is widely used to assist handoff management, resource reservation and service pre-configuration. Location management methods are to find out mobile unit current location. Location update and paging have to maintain efficiently to minimize location management cost in cellular network. This paper introduce new timer based algorithm using cache memory for improve hit ratio. This algorithm is based on user's daily predefined moving geographical activities pattern, according to time. Paging decision for user is based on this predicted location for any instance of time interval. This predicated value again sort by higher probability of user finding in any cell for that time duration. This prediction information is saved by mobile unit in its personal cache memory for every fixed time interval. The results confirm the effectiveness of this method compare to existing method for real time in mobile services.**

***Index Terms*—Hit ratio, location update, paging, cellular network, time-slot, mobile switching center (MSC).**

I. Introduction

Personal communication system (PCS) networks offer wireless communication services that enable mobile terminals (MTs) to transfer any information to any location at any instance. To provide the services timely, keeping track the location of mobile users is necessary. Usually this mechanism is referred to as Location management, which is one of the key issues in today's cellular network. This paper introduce new location management scheme based on user's daily routine activity according to time.

Location management refers as how to track the MTs that move from one place to other place in PCS networks [1]-[3]. Two-tier system is used in PCS networks for the location management, one of home location register (HLR) databases and visitor location register (VLR) databases. The HLR contains the permanent data (e.g. profile information) of the MTs whose primary subscription is within the area. For each MT, it contains a pointer to the VLR to assist routing incoming calls. A VLR is associated with a mobile switching center (MSC) in the network as shown in Fig.1. It contains temporary record for all MTs currently active within the service area of the MSC. The VLR retrieves information for handling calls to MT or from a visiting MT. To facilitate the tracking of a moving MT, a PCS network is partitioned into many registration area (RA) or location areas (LAs). Each LA may include tens or hundreds of cells, which is a basic unit of area served by a base station (BS). Each LA is serviced by a VLR. An HLR is associated with tens or hundreds of VLRs. The service area served by an HLR is referred to as service area (SA).

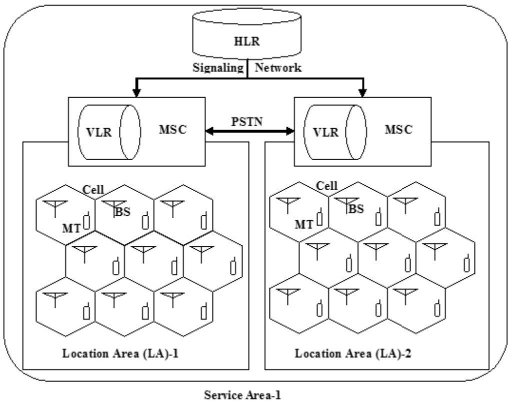

Fig. 1. Cellular network architecture.

Location management handles current position of any mobile user it tracks the mobile terminal during servicing call arrivals and makes sure that the call is shifted without disconnecting the call. Cellular network is based on three major components mobile unit, base station (BS) and location area (LA). MT is an electronic device used for sending and receiving data signals. Service area is divided in to LA and every LA is divided in to BS which has a station for receiving and sending signals for MT. Mobile unit uses pre-assigned radio frequencies [4], [5] set for communicating voice or data signals. Location of MT can be retrieve by registration or location update and paging or polling.

The two basic operations involved in location management mechanism are location update and paging [6]. Location update is concerned with the reporting of current cell location by the mobile user. When an incoming call arrives for a mobile user, the network searches the user by sending polling signals in a cell or a number of cells, where the mobile user is most likely to be found [7] this searching process is known as paging. In static location management, cells are constant in shape and size, and identical for every mobile user. Every mobile user moving through them follows same set of location management rules. Three basic static location update schemes are always-update, Never-update and static interval-based update. Practically, the third of these schemes is most commonly used [8]. It is a good method for location updating. Cells may differ in shape and size, and may not be identical for every mobile user. Three basic dynamic location update schemes are time-based, movement-based and distance-based update [9]. To get access of current location

Manuscript received May 12, 2012 and revised July 18, 2012.
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DOI: 10.7763/IJIET.2012.V2.188

as soon as possible, various methods of paging have been proposed in which most basic method used is simultaneous paging. In this method every cell for user's location area is paged at the same time in order to find current location. An another scheme is Sequential paging, where each cell within a location area is paged, with one common theory suggesting the polling of small cell areas in order of decreasing user dwelling probability [10]. The total location management cost (C_{Total} LM) can be calculated by adding location update operation cost (C_{Update}) and paging operation cost (C_{Paging}).

$$C_{Total}\, LM = C \times C_{Update} + C_{Paging}$$

Here C_{Total} is the total location management cost [10]. C_{Update} is the number of LU messages generated C_{Paging} is the number of cells paged. C is constant representing the relative cost of update to pages and is taken as 1, roughly representing the approximate size and number of signaling messages required by LU as compared to paging message. Generally speaking, Location update (LU) costs are higher than paging costs. The network can require more frequent LUs, in order to reduce paging costs. Conversely, the network could only require rare LUs, storing less information about users to reduce computational overhead, but at a higher polling cost. To reduce the total location management cost, it is necessary to provide a good tradeoff between the paging and location update operations [7].

II. Previous Work

The static interval-based update algorithm [8] attempts utilize the mobility history of the subscriber to dynamically create LA for individual subscribers. This algorithm dynamically determines the most probable paging areas by maintaining the time duration for which a subscriber stayed in the cell, for all the cells in the current LA. Many LM schemes use previous record of MT to predict a set of probable current locations of goal MT. MT is located by predefined set of cell ID based on time according user's moving pattern, it minimize paging cost, by using predefined set of cell ID based scheme reduce great average location management cost. To reduce the total location management cost, it is necessary to provide a good trade-off between the paging and location update operations [7]. In another method MT is searched simultaneously in the set of predicted cells wherever if it is found then called a page hit otherwise it is a page miss and in this case, MT is searched at the same time in all the left over cells of its present LA. If system can predict user's location exactly then the paging cost is reduced a lot [11] this method is very efficient to minimize total cost of location management. Another method gives better LM scheme by dynamic location management scheme using user speed based algorithm [12]. Another latest research done objective of this research is to propose, validate and evaluate the performance of location update scheme using fuzzy logic technique [13] for cellular radio system. The results of using fuzzy logic technique show that location management cost reduction using Fuzzy logic in cellular radio network using fuzzy logic is decreased about 2% and outperforms the conventional mechanism. New work done based on geometric location proposed in Geometrical positioning approached for mobile location estimation method [14]. This paper illustrates hybrid proposed schemes that combine time of arrival (TOA) at three BSs and angle of arrival (AOA) information at the serving BS to give a location estimate of the MS. This method achieved better accuracy when compare with Taylor series algorithm (TSA) and the hybrid lines of position algorithm (HLOP). Study of timer based method for location management with the blocking probability is very helpful for new work in this field [15]. A good time based method is given in paper [16] proposes an activity based mobility prediction technique that uses activity prediction and Markov modeling techniques (AMPuMM) to devise a prediction methodology that could make accurate predictions than existing techniques.

The research in the area of mobile location management is speed based adaptive method [12]. This technique keeps track record of user movement with its moving speed and LA is defined according to mobile user's speed. Time based dynamic algorithm [10] is find MT location according to its time period prediction which gives very optimum result for working days.

III. Time-Based Location

Through various surveys it had been observed that most of user activities occur only at particular locations, for fixed time periods. The geographical activities of individual are found to be steady over longer periods of time while the time-sequence of stay and repeatability has a shorter life span. Based on these facts this paper proposes a time based location prediction scheme for that time slot could reflect changes in user's behavior earlier than other pattern based techniques and could provide accurate predictions on MT's future locations [17].

This section proposed a new LM scheme in which current location of MT is predict by previous data stored at VLR in form of table called mobility data table (MDT). MDT has maintained particular user's location within every time slot. Here we are considering time slot of one hour, so MT have cache memory in mobile unit to keep record cell ID for every hour. At starting of every time slot MT store its current cell ID in corresponding time slot in form of MDT at MT side in its cache memory. This MDT send to VLR database to keep all day location information for this MT. VLR side MDT gets updated by sending of MDT through MT at mid night when channel become ideal and control signal can be transmitted for better resource utilization. Due to mid night MDT transmission, frequent registration is not required, hence registration cost become near about constant or very low. If this data transmitted in day time then it can consume resource which is used for data transmission and average LM cost could increase, MT store cell ID at every time slot interval and store in its cache memory, at mid night this whole information is transferred to VLR for updating VLR data in VLR side MDT as Table 1. MDT maintains user information according the time, time is divided into slot for every hour and VLR keeps record of every cell ID according time slot. This table can be given as follow:

TABLE 1. MOBILE DATA TABLE (MDT)

Slot No.	Hours	Prediction sets
0	00:00 to 01:00	[]
1	01:00 to 02:00	[]
-	-	-
-	-	-
23	23:00 to 24:00	[]

Initially prediction sets having only one cell ID which is MT's home cell ID for each time slot. When call is arrived for MT, VLR selects set by corresponding time slot at which time call is arrived and then get first index cell ID of that set because this slot maintain most prior cell at index 1 by applying automatic sorting on set. If MT not found in index 1 ID of predicted set than traditional paging applied and current cell ID is inserted into prediction set if user again found in this ID again at same time slot than this ID is swapped with nearest left cell ID. Now next time this shifted ID becomes at index 1 and paged first on call if arrived in this time slot. This table is maintained by MT with help of cache memory at MT.

The second column of MDT holds an entry for each hour of the day whereas subsequent column indicates the set of predicted cells where the MT can probably be present. Initially, the network has no mobility information of MT therefore second column is fully empty and in this situation. Overall location management cost can be calculated by registration cost and paging cost. Above registration method can explain easily by following timer based registration algorithm

When call arrives and VLR searches for Mobile terminal then paging process will call and search for MT (let us say between time [T] to [T+1]) then whole LA will be paged simultaneously and the cell-id of the cell where MT is found (lets us say C3) will be inserted in the corresponding time in MDT as follow: [T] to [T+1] → [C3]. Next time when a call arrives for this MT between duration [T] to [T+1] then firstly MT will be first searched in cell C3 and if MT is found (page hit occurs) then no update will take place in MDT prediction set for this duration ([T] to [T+1]). MDT is updated only when a page miss occurs. Let us assume that MT was present in cell C5 when next call arrived and a page miss occurred. Now MDT will add C5 as the last (rightmost) entry in its prediction set. [T] to [T+1] → [C3, C5], For example at any time a call arrives for MT, then firstly it will be searched only in cell C3, C5. If a page hit occurs then no changes are made in MDT but if a page miss occurs then all the remaining cells in the LA will be searched simultaneously to locate MT.

IV. PROPOSED ALGORITHM

A. Algorithm for Timer-Based with Cache Registration Scheme

Following steps are for registration scheme.

1. When a mobile terminal is turned on
   a) It updates its current location to VLR
   b) Store current location id in its cache memory for current time slot at first index.
   c) Sets the cell movement cell_counter=1 for this time slot.
   d) Store default cell ID for every time slot in mobile cache MDT.
2. When a mobile user enters new cell
   MT checks current cell ID in cache MDT for current time slot-
   If the ID is not found in MT's MDT then
   i) MT inserts this new cell ID for this time slot.
   ii) Increment the value of cell_counter by 1.
   Else if the ID is found in its cache MDT then
   i) Checks position of this ID in cache array.
   ii) Swap its position by nearest left cell ID.
3. When the value of time is 00:00(mid-night)
   a) MT updates its current location.
   b) Copies the contents of the cache to the VLR.
4. When a mobile terminal enters to new VLR then,
   a) New VLR sends the de_registration message to the old VLR.
   b) Old VLR forwards the mobility information of the mobile terminal to the new VLR.
   c) Old VLR deletes all records of this MT after receiving acknowledgment
   d) New VLR updates the mobility information of this mobile user.

B. Algorithm for Timer-Based With Cache Paging Process Scheme

Following steps are for paging scheme.

1. When an incoming call arrives
   a) The system retrieves the record which has the mobility information MDT for the target MT in the VLR database.
   b) Performs the timer-based paging to current time slot cells in the list of the MDT.
2. Once record fetched then
   a) Target MT is searched in first entry of MDT at VLR for current time slot.
   b) If not found in first entered cell ID then Check for all next entry in this time slot.
3. If the target mobile terminal is not found in timer-based paging process then normal traditional location area paging is performed again to find the target mobile terminal.

The proposed LM scheme inserts a new cell-id at N^{th} position because from here, this cell can be removed from first paging phase and this position can be occupied by a more frequently visited cell in only one shift operation. The left shift in already existing cell makes its position nearer to N each time a call arrives, thus the most frequently visited cells are always paged in first phase of paging without increasing the number of predicted cells.

In the next section, it is shown that the proposed scheme adapts the predictions according to call arrival rate and mobility history of MT. It is found that it performs well which reduces the total paging cost significantly.

V. SIMULATION AND RESULTS

A. Network Model

For simulation purpose, a 15×15 network model is used. Each cell is assigned a unique number and is used as its cell-id. There are 225 cells in the network, which are partitioned into 9 LAs shown with different levels. Each LA consists of 25 cells could be understood as given below:

- First LA consists of Cell IDs 0, 1, 2, 3, 4, 15, 16, 17, 18, 19, 30, 31, 32, 33, 34, 45, 46, 47, 48, 49, 60, 61, 62, 63, and 64.
- Second LA consists of Cell IDs 5, 6, 7, 8, 9, 20, 21, 22, 23, 24, 35, 36, 37, 38, 39, 50, 51, 52, 53, 54, 65, 66, 67, 68, and 69.
- Such as ninth LA consists of Cell IDs 160, 161, 162, 163, 164, 175, 176, 177, 178, 179, 190, 191, 192, 193, 194, 205, 206, 207, 208, 209, 220, 221, 222, 223, and 224.

Initially all the prediction sets are empty, which are gradually filled depending upon the call arrival frequencies and mobility patterns of each MT. We have simulated the network with 500 MTs for duration of eleven days. An MT triggers a location update on changing the LA. For evaluation purpose, we have examined proposed scheme on various parameters. For mobility model, we assume the daily worker mobility pattern [7] for time 08:00am to 05:00pm after which, user can move at semi-random. MT travels almost the same route everyday between home, gymnasiums and work locations from 05:00am to 11:00pm, the user may move randomly.

B. *Number of Page Hit against AMPuMM*

MT is searched simultaneously in the set of predicted cells wherever if it is found then called a page hit otherwise it is a page miss and in this case, MT is searched at the same time in all the left over cells of its present LA.As mention in above section proposed algorithm keeps hit ratio high. As well as Fig. 2 compare result with existing method activity based mobility prediction using Markov modeling (AMPuMM) [16]. This comparison shows efficiency of predictions made by proposed scheme. Proposed algorithm give somehow less ratio for initial days but due to keeping most prior cell ID at first index for latter days it gives batter result continuously.

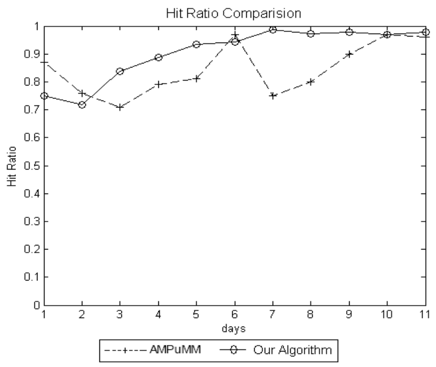

Fig. 2. Comparing hit ratio proposed algorithm with AMPuMM.

VI. Conclusion

The timer based location management to improve hit ratio in cellular network using cache memory is free from maintaining large user history. This paper presented a new location management scheme using mobility information of users in cellular mobile networks, which adapts the prediction for locating mobile users according to their mobility patterns and call arrival frequency. During simulation, user movements were kept neither fully random nor fully predefined and results prove that the proposed scheme predicts user location with high accuracy. This scheme keeps hit ratio high as in comparison shown. High hit ratio minimizes total paging cost because most of the time user found in its prediction cell location which helps to maintain paging cost. So the total cost also becomes less as compare to other method.

References

[1] T. X. Brown and S. Mohan, "Mobility management for personal communications systems," *IEEE Trans. Vehicular Technology*, vol. 46, no. 2, pp. 269-278, May 1997.

[2] Y. Fang, I. Chlamtac, and Y. Lin, "Portable movement modeling for PCS Networks," *IEEE Trans. on Vehicular Technology*, vol. 49, no. 4, pp. 1356-1363, July 2000.

[3] Y. Fang, I. Chlamtac, and H. Fei, "Analytical results for optimal choice of location update interval for mobility database failure restoration in PCS networks," *IEEE Trans. on Parallel and Distributed Systems*, vol. 11, no. 6, pp. 615-624, 2000.

[4] J. Gil and Y. Chan, C. Hwang, D. Park, J. Shon, and Y. Jeong, "Restoration Scheme of Mobility Databases by Mobility Learning and Prediction in PCS Networks," *IEEE J. Selected Areas in Comm*., vol. 19, no. 10, pp. 1962-1973, 2001.

[5] E. Cayirci and I. F. Akyildiz, "User Mobility Pattern Scheme for Location Update and Paging in Wireless Systems," *IEEE Trans. Mobile Computing*, vol. 1, no. 3, pp. 236-247, 2002.

[6] K. W. Shum and C. W. Sung, "Kalman-filter based predictive location management for PCS networks," in *Proc. of the IEEE Vehicular Technology Conference (VTC Spring 2003)*, 2003, pp. 2701-2705.

[7] B. D. Beheshti, "Review of location management in cellular networks," in *Proc. of LISAT 2007*, 2007, pp.1-6.

[8] B. Sidhu and H. Singh, "Location management in cellular networks," in *Proc. of WASET 2007*, 2007, pp. 314-319.

[9] I. F. Akyildiz and J. S. M. Ho, "On location management for personal communications networks," *IEEE Communications Magazine*, vol. 34, no. 9, pp. 138-145, Sept. 1996.

[10] V. Bhatt and D. S. Khatri, "Timer based dynamic location management," in *Proc. of 2004 Wireless Telecommunications Symposium*, 2004, pp. 66-60.

[11] S. Akoush and A. Sameh, "The use of bayesian learning of neural networks for mobile user position prediction," in *Proc. of the 7th International Conference on Intelligent Systems Design and Applications*, pp. 441-446, 2007.

[12] A. Goel, N. Gupta, and P. Kumar, "A speed based adaptive algorithm for reducing paging cost in cellular networks," in *Proc. of ICCSIT 2009*, 2009, pp. 22-25.

[13] C. Ing-Ray, "Quantitative Analysis of a Hybrid Replication with Forwarding Strategy for Efficient and Uniform Location Management in Mobile Wireless Networks," *IEEE Trans. on Mobile Computing*, vol. 2, no. 1, pp. 3-15, 2003.

[14] C. Chien-Sheng, S. Szu-Lin, and L. Chyuan-Der, "Geometrical positioning approached for mobile location estimation," in *Proc. of ICIME 2010* , 2010, pp. 268-272.

[15] E. Martin, "A Graphical study of the timer based method for location management with the blocking probability," in *Proc. of WiCOM 2011*, 2011, pp. 1-4.

[16] R. V. Mathivaruni and V. Vaidehi "An activity based mobility prediction strategy using markov modeling for wireless networks," presented at WCECS, 2008.

[17] M. S. Sricharan, V. Vaidehi, and P. P.Arun, "An activity based mobility prediction strategy for next generation wireless networks," presented at Int. Conf. on Wireless and Optical Communications Networks, 2006.