A Novel Location Management Method Based on Ad hoc Networking

S.M. Saeed Masajedian[1, 2], Hossein Khoshbin[1]

[1]Ferdowsi University of Mashhad
Electrical Engineering Dep.
Mashhad-Iran

[2]Iran Telecommunication Research Center
Mobile Communication Group
Tehran-Iran

masajedian@itrc.ac.ir

***Abstract*—Location Management (LM) as a vital process in every wireless network imposes significant volume of signaling traffic to the network. Different scheme have been proposed to decrease the cost of this signaling. In this paper we propose a new scheme that reduces signaling load specially in the future wireless networks with a great amount of users besides new services. In this method, mobile terminals will be able to communicate with each other via Ad hoc networking. Results of Simulations show that the proposed scheme has better performance compared with Time-based LM method.**

Key Words*—Wireless Cellular Networks, Location Management, Time-base Location Update and Ad hoc networking.

I. INTRODUCTION

During recent years, both number of wireless cellular network subscribers and new services and applications, which require more bandwidth than current ones, have had an exponential growth. Due to the limitation in the available radio spectrum, handling the data and signaling traffic for large number of users will be a challenging issue, specially in next generation networks. On the other hand, obtaining more capacity requires smaller cells, which cause to introduce more signaling traffic during the *mobility management* (MM) process. Therefore, deploying a cost-effective MM protocol in cellular network will be as necessary as ever [1].

Because of free movement and arbitrary mobility rate of mobile terminals within the coverage area of the wireless network, *location management* (LM) is an unavoidable task. LM as an important part of MM is responsible for tracking subscribers, when there is an incoming call for them. LM consists of two phases: *location update* (LU) and *paging*. In LU phase, each terminal informs the network of its exact location and network saves the information of subscriber in a *location database*. Paging phase runs for each particular mobile terminal if there is a new incoming call for it. During paging, the network should search exact current location of users using the information that has acquired during LU stage by polling signals to cells.

The most important criterion in designing a cost-effective LM scheme is the solution of two basic problems: (1) when terminals should inform the network about their locations and (2) how network should search the cells by using previous update location of the mobile terminal, whenever there is an incoming call for it. So, there is a trade off between LU and paging in each LM protocol. If terminals don't inform the network about their current locations during their movements, the cost of LU will be decreased to zero, but when a new call arrives, the network has to search a large number of cells to find the particular user. On the other hand, if LU signals are triggered during cell boundary crossing by users, the cost of paging part approaches to its minimum value, yet the cost of LU is increased specially when the call arrival rate of the particular user is low. Also, because of successive unnecessary LU events, the power of both *base station* (BS) and terminals are wasted.

In current traditional wireless networks like Global System for Mobile Communications (GSM), LM is preformed in static fashion. In these systems the coverage area of network is divided into the separated *Location Areas* (LA) in such a way that each LA includes some certain cells. Whenever a mobile terminal leaves its current LA, LU is necessary and network searches in just certain LA during paging process. The algorithm is performed for different users by different mobility and call arrival rate, equally. Also, users who frequently move between two neighbor LAs, impose unnecessary signaling to the network. Time, Movement and Distance based methods which were introduced as dynamic LM method in [2], overcome the drawbacks of static LM schemes. In these methods each mobile terminal assigned an appropriate parameter based on its characteristics and then informs the network of its current location when the parameter expires. This parameter is Time or the number of movements among cells or Distance threshold, respectively in the three mentioned methods.

Paging process in these algorithms is the same and also when a new call arrives for a user, the network searches the subscriber ring-by-ring. The ring concept in cellular networks is depicted in Fig. 1 for hexagonal cells. The central cell is the location that user has last updated. If the network doesn't find the mobile terminal in this cell (Ring 0), then in next stage the Ring 1 must be searched. This process is continued until the user is found by the network.

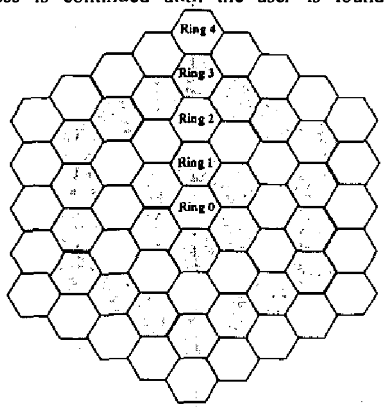


Fig 1: The Ring concept in cellular networks. In paging process the network must search successive ring until the user will be found.

If the particular terminal stays at Ring n, the network must search $3n(n+1)+1$ cells to find it. So, the drawback of these schemes appears in paging stage, because several cells must be searched unnecessarily.

In this paper we show that cost of paging in Time-based LM is minimized by using Ad hoc networking. Ad hoc networks as a candidate to support Pico mobility in fourth generation wireless networks are infrastructureless and mobile terminals can act as a router for other users [3],[4],[5]. Fig. 2 shows an example of such a network in which users 1 and 5 communicate with each other via users 3 and 4 as router.

Users who want to establish a new connection should find their best neighbor via an appropriate algorithm. Routing is the most important issue in Ad hoc networks, because mobile terminals, which work as a router for other users, are free to move in the network. So, in this paper we assume that users have terminals with multi hop communication ability besides the ordinary communication with BS.

In the new LM method when there is a new incoming call for the particular user, the network finds it in cooperation with other mobile terminals which have met it in its trajectory.

The rest of the paper is organized as follows: in section II we propose our new method and discuss it in details. In section III we analytically compare the method with early Tim-based LM scheme. In section IV we present the simulation results and finally in section V we conclude the work.

II. Description of New LM Method

In this new scheme, mobile terminals are able to communicate with each other while they can establish connection with BS like ordinary cellular networks.

The new LM algorithm uses Time-based technique in the LU part. So, in this method mobile terminals periodically inform the network about their location and whenever the user wants to leave its current cell, at first it should obtain ID of next cell, (while it has saved the ID of its current cell) and after then it should search for the most appropriate neighbor mobile terminal which stays at the current cell via an appropriate algorithm. After it finds a good partner, it should send to its partner the information such as its ID, the ID of next cell and the residue of time threshold that has obtained in the last LU event, via Ad hoc communication. So in this system, each mobile terminal has a partner (as an agent) at the cells in its trajectory. When a new incoming call arrives, the network searches the previous update location for mobile subscriber. So, although the subscriber leaves this cell, there is another mobile terminal which knows the particular user's ID and informs the network about the next cell ID of the user. Therefore, in this method the network should searches for mobile terminal cell-by-cell using the agents of subscribers (instead of ring-by-ring paging method).

Because of the existence of a trade off between LU and paging, in the new method the network allocates a longer time threshold to users compared with the optimum time of Time-based LM method.

In a cellular network, users are free to change their current cell with different mobility rates and probability of cell changing for subscribers that are close to the boundary of cell is more than others. In our new scheme these subscribers are used as agent and thus if the mobile terminal changes its current cell, it should send its information in addition to the information which has kept about other users to its appropriate partner, and release the allocated memory. In this condition, every user will have an agent at all cells in its trajectory (between two LU events).

When the timeout occurs for a particular user, LU is performed and all terminals which act as its partner delete the information corresponding to that. This is because they have acquired the residue of the time threshold, when they have communicated with the user.

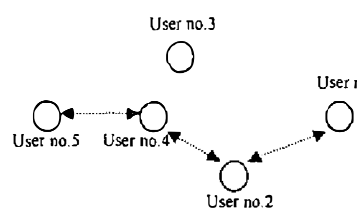


Fig.2: Ad hoc (multi hop) communication. In this network mobile terminal can act as a router for other ones.

In special situation when there is no partner for a mobile terminal, it will leave its current cell without any agent. If the network wants to find the exact location of the particular user, the cells in the trajectory of terminal are searched cell-by-cell, and when there is not any partner in the cell, paging is continued ring-by-ring, while ring 0 is the cell that there is no agent for the particular user. In Fig. 3 the trajectory of the user is presented. The last update location is cell A and the current location of subscriber is cell C and also the user has no agent at cell B. So the network must search ring 1 of cell B after searching of 4 cells in trajectory of user. Clearly, if the network doesn't find any new partner of this ring, ring 2 of cell B must be searched and so on. While in Time-based LM method all of hexagonal cells that depicted in Fig. 3 must be search to find the user.

III. Comparison Between Time-based LM and The New Scheme

In this section, we analyze our new scheme and compare its overall cost per call arrival with Time-based LM method. Due to the use of Time-base LU process in

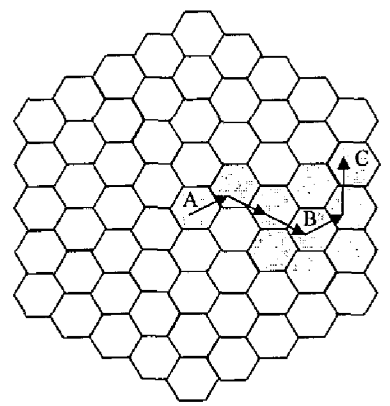


Fig 3: The cells that must be searched for the user whom its last update location is A, and current location is C, the user has no agent at cell B.

the proposed method, it is reasonable to compare it with Time-based LM method. So, in the same threshold of time, the difference in total costs depends on paging phase.

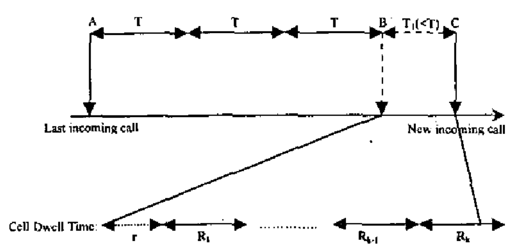


Fig. 4: The time diagram in Time-based LU strategy

According to the two-dimensional *random walk* mobility model [7], we assume that each mobile terminal enters one of its six neighboring hexagonal cells with a probability of 1/6. Also new call arrives based on Poisson process with rate λ_c. The cell dwell time defines the time that mobile terminal stays in a particular cell and may has gamma (or exponential) distribution [8], [9], that is independent and identically distributed for all cells. For the sake of simplicity we assume that cell dwell time follows an exponential distribution with parameter λ_m and $f_R(t)$ is its probability density function (pdf). As mentioned, mobility and call arrival rates are two parameters that determine time threshold in Time-based LU strategy and thus, it is reasonable to define Call to Mobility Ratio parameter (CMR) equal to λ_c / λ_m and compare two methods under the same CMR. Under these assumptions we can calculate the overall cost of LU and Paging per call arrival for both of algorithms. Also, let the costs for each LU and Paging of a cell event to be U and P, respectively.

According to Fig. 4 cost of the LU per call arrival includes the number of LUs which have happened during two successive incoming calls, while the paging cost is in direct relation to the number of movements of the user between cells after the last LU event. In the figure T is time threshold and R_i is the cell dwell time at ith cell. T_l is the random variable that defines the elapsed time in the interval between the last LU event and a new call enters. So, its pdf is calculated by the following equation

$$f_{T_l}(t) = \begin{cases} \dfrac{\lambda_c e^{-\lambda_c t}}{1 - e^{-\lambda_c T}} & 0 \le t \le T \\ 0 & otherwise \end{cases} \quad (1)$$

According to the random observer property [10] we have the following distribution for r as the elapsed time after the last incoming call until new LU event,

$$f_r(t) = \lambda_m \int_{\tau = t}^{\infty} f_R(\tau) d\tau = \lambda_m [1 - F_R(t)]. \quad (2)$$

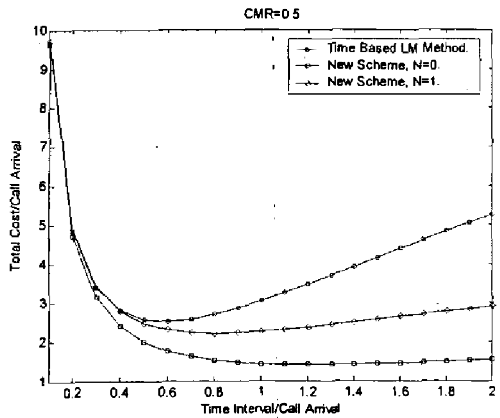
We define $\alpha(K)$ as the probability that there are K boundary crossings between two incoming calls. Also we denote $\beta(n,K)$ as the probability that the user arrives ring n by crossing K boundaries. Based on the above-mentioned assumptions and [11] $\alpha(K)$ can be calculated by following equations,

$$\alpha(K) = \frac{\lambda_m^K \lambda_c}{K!(1 - e^{-\lambda_c T})} \int_0^T e^{-(\lambda_m + \lambda_c)t} t^K dt. \quad (3)$$

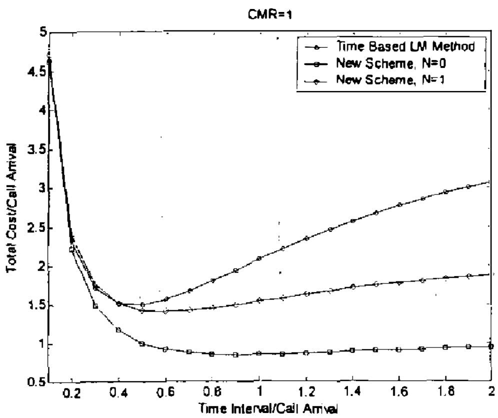
Where $\beta(n,K)$ is calculated via the mentioned algorithm in [7].

If we consider π_n as the probability that the mobile terminal is at ring n when a call arrives for it, we can write

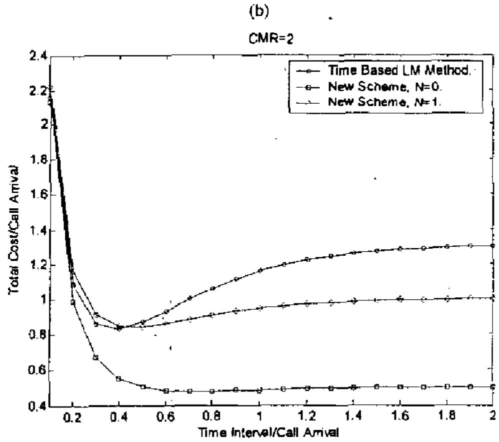
$$\pi_n = \sum_{K=0}^{\infty} \alpha(K) \beta(n,K). \quad (4)$$



(a)



(b)



(c)

Fig.5: Comparison between new scheme and Time-based LM algorithm for three values of CMR.

So the expected paging cost for ordinary Time-based LM method is derived as,

$$C_P^T = P\sum_{n=0}^{\infty}(3n(n+1)+1)\pi_n . \qquad (5)$$

And expected paging cost for the new LM method is,

$$C_P^N = P\sum_{K=0}^{\infty}\alpha(K)\times K . \qquad (6)$$

If we denote N as the cost of each Ad hoc communication, C_A as the total cost of signaling over the infrastractureless network can be written as:

$$C_A = N\sum_{K=0}^{\infty}\alpha(K)\times K . \qquad (7)$$

Since the call arrival events follow the Poisson distribution, the probability of having w LU events during two successive call arrivals is calculated as below,

$$P_w = e^{-\lambda_c wT} - e^{-\lambda_c (w+1)T} . \qquad (8)$$

Now, the expected LU cost per call arrival is,

$$C_U = U\sum_{w=0}^{\infty} wP_w . \qquad (9)$$

Finally, if we denote C_{Total}^T, C_{Total}^N as the overall cost per arrival in Time-based LM and New LM algorithms respectively we have,

$$C_{Total}^T = C_U + C_P^T , \qquad (10)$$
$$C_{Total}^N = C_U + C_P^N + C_A$$

The goal is selection of an appropriate time threshold that minimizes the cost function in (10).

IV. Results and Discussion

We have studied the results of applying the above calculations under the different of CMR. Due to the existence of a trade off between LU and Paging cost, U and P can have any arbitrary value so, we set them to one for simplicity. The value of N depends on some parameters like congestion, the environment, signaling and data traffic, number of existing users per cell, size of cells and etc. It is obvious that setting the value of N to one we assume weak conditions for ad hoc communications. There is a discussion about choosing the value of N in other work [12]. However, to analyze the signaling of main (infrastructure) network it is reasonable to set the N to zero. In Fig.5-(a) the comparison between two algorithms has been depicted in CMR=0.5.

This result shows the proposed scheme reduces the total cost per arrival in a considerable value compare with Time-based LM method. As we have predicted before, in the new method the optimum value of T is larger than that in Time-based LM. The value of optimum T is 0.6, 0.8 and 1.2 for Time-based, new LM scheme for N=1 and N=0, respectively, and for other values of CMR we can observe the same results.

V. Conclusion

In this paper we introduced a new LM scheme to reduce the cost of signaling in fourth generation cellular networks, where users can communicate with each other by multi hop communications. Our method forced subscribers to use terminals supporting Ad hoc communications which will be available in fourth generation mobile terminals and so, using the proposed scheme doesn't increase complexity of the system.

In the new scheme each subscriber which is leaving its current cell should informs its appropriate neighbor at the same cell, about the next cell which is going t●. The mobile terminals which play the role of the partner, help network in finding different users when there is an incoming call for them. The new scheme reduces the total cost of signaling in the network with a noticeable volume compare with Time-based LM method. It is reasonable that optimum time threshold is increased in this scheme. This new scheme is a basic method in LM process and more studies on this field are expected. We prop●se the name of *Cooperative Location Management* for our LM method.

VI. References

[1]. I.F. Akyildiz, J. McNair, J.S.M. Ho, H. Uzunalioglu, and W. Wang, "Mobility Management in Next-Generation Wireless Systems,"*Proc. IEEE*, vol. 87, no. 8, pp. 1347-1384, Aug. 1999.

[2]. A. Bar-Noy, I. Kessler, and M. Sidi, "Mobile users: To update or not to update?," *ACM-Baltzer J.Wireless Networks*, vol. 1, no. 2, pp. 175–186, July 1995.

[3]. Mobile Ad-hoc Networks (manet) WG, Mobile Ad-hoc Networks (manet) Charter, IETF, 1999; C. http://www.ietf.org/html.charters/manet-charter.html

[4]. Rose, "Minimizing the average cost of paging and registration:A timer-based method," *ACM Wireless Networks*, vol. 2, no. 2, pp.109–116, June 1996.

[5]. C. Perkins and P. Bhagwat, "Highly Dynamic Destination Sequenced Distance-vector Routing (dsdv) for Mobile Computers," *Comp. Commun. Rev.*,Oct. 1994, pp. 234–44.

[6]. S.M.S.Masajedian, H. Khoshbin, M. Khansari, "Ad hoc networks or novel revolution in telecommunication", *NCC 2002 conf.*, Mashhad, Iran, pp. 233-246, Dec. 2002.

[7]. I.F. Akyildiz, J. Ho, and Y. Lin, "Movement-base● location update and selective paging for PCS networks," *IEEE/ACM Trans. Networking,* vol.4, pp. 629–638, Aug. 1996.

[8]. M.M. Zonoozi and P. Dassanayake, "User mobility modeling and characterizati●n of mobility patterns", *IEEE J. Select. Area in Commun.*, vol. 15, No. 7, pp 1239-1252, Sept. 1997.

[9]. D.J. Lee and D.H. Cho, "On optimum timer value of area and timer-based location registration scheme", *IEEE Comm. Let.* V●l. 5, No. 4, Apr. 2001.

[10]. S.M. Ross, Stochastic processes. pp. 67-69, John Weily & Sons, 1983

[11]. Goo Yeon Lee and Yong Lee, "Numerical analysis of optimum timer value for time-based location registration scheme", *IEEE Commu. Let.* , vol. 6, No. 10, pp 431-433, Oct. 2002.

[12]. S.M.S. Masajedian, A. Rostami and H. Khoshbin, "On the performance analysis of cooperative location management method", preprint.