Multi-States Based Hybrid Location Update Strategy in Wireless Communication System

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Abstract— **In this paper, we propose a multi-state based hybrid location update scheme, which integrates the time-based and the movement-based methods. In the proposed scheme, a mobile terminal updates its location after n cell boundary crossing and a time interval of T[sec]. We derive an analytical solution for the performance of the hybrid scheme with exponential cell resident time and evaluate it numerically with time-varying random walk mobility model, which we model as multi-states Markov chain. Furthermore, we also evaluate the scheme for arbitrary cell resident times by simulation. From the numerical analysis and the simulation results, we prove that the proposed scheme significantly outperforms the time-based and the movement-based methods, when implemented alone, more accurately adapting to the time-varying user mobility.**

I. Introduction and Motivation

Location management and call setup protocol play an important role in the wireless or PCS network[1], [2]. Location search of a mobile terminal is a procedure related to both call setup and location management, and reducing search cost effects performance of wireless network.

Several papers have proved that mobile users' movement characteristics affect the performance of wireless network[4], [5], [6]. Generally, the movement characteristics of a mobile user are that once the user begins to move, the user moves until the user arrives at destination and then, the user remains there until the user finishes some job. For example, an office worker goes to his office in the morning, he works there throughout the day and then comes back home in the evening. Or he may visit somewhere, and stays there for a while to meet someone or do something, then leaves for the next destination. Also when he moves to any place, the speed is affected by some circumstances, such as traffic conditions, by walk or driving car.

Using these characteristics, we propose a hybrid location management method which combines time-based and movement-based location update method based on the mobility characteristics of mobile user as mentioned before. It gives improvement of location management cost and mobile terminal search cost.

There are three basic dynamic strategies in which the mobile users transmit update messages according to their movements[1], [7].

The simple dynamic strategy is the time-based update in which each mobile user updates its location periodically every T units of time, where T is a parameter. It is not difficult to realize that from an implementation point of view, the time-based strategy is the simplest since the mobile users need to follow only their local clocks. But in this strategy, even though the mobile user does not move from an location area and stays at one cell for a long time, the mobile terminal should updates its location periodically every T, which is not changed. It seems to be a waste of control channels, which could be used for other jobs.

Another dynamic strategy is the movement-based update in which each mobile user counts the number of boundary crossing between cells incurred by its movements and when this number exceeds a parameter M it transmits an update message. This is more difficult to implement since the mobile users must know the boundaries between cells when they cross them. And in this strategy, if the mobile user walks up and down between two cells, although the mobile user does not actually move to a new cell, the mobile terminal might update the location because the crossing numbers may exceed the threshold, M.

The last dynamic strategy considered is the distance-based update in which each mobile user tracks the distance it moved since last transmitting an update message, and whenever the distance exceeds a parameter D it transmits an update message. The implementation of this strategy is the most difficult one since the mobile users need information about the topology of the wireless network. Therefore, it is impractical to consider in real wireless or PCS networks.

We focus on a question. Which is better between time-based location update method and movement-based location update method ? Or, does any other method combining the two method show better performance? The time-based registration method leads to an improvement over simpler movement-based method especially at higher mobile terminal velocities since the optimal paging algorithm is affected only by location uncertainty and not directly by the terminal velocity. Currently, users register when they change location area, which is a group of locations all of which are paged when an incoming call is directed to the user, based on the movement-based update strategy[6]. Time-based methods, as opposed to movement-based methods, do not require the user to record and process location information during the time between location updates. This feature might be desirable for minimizing mobile transceiver use during idle periods.

We have that one case, time-based method is better, and the

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other case, movement-based method is better, according to the mobility of mobile user. In this paper, we propose the hybrid location update method that combines time-based method and movement-based method according to mobility of mobile user. In the proposed hybrid method, we get the optimal values of time period T and the optimal value of cell crossing number M to minimize the location management cost.

II. Related Works

Many researches have anlayzed performance of time-based location update method and movement-based location update method and there are many studies that improves these schemes adaptively based on user mobility patterns[2], [3], [6], [8].

Many studies have been worked optimal location update scheme based on mobile user location prediction idea and heuristic algorithm. Bejerano and Cidon [9] combined the concept of location areas with the location prediction idea based on traffic flow theory and predicted mobile user's location using traffic flow theory. Wang and Akyildiz proposed how to estimate the user mobility by incorporating the aggregate history of mobile users and system parameters in [10]. They used zone partition to predict each user's position, considered each mobile user's movement directions, residence time, and path information to predict the future position of mobile user. In this scheme, the estimation is adjusted dynamically to reduce the computational complexity .

Other work has put efforts toward reducing the registration cost by introducing methods to partition the optimal location area and paging area. Varsamopoulos and Gupta [5] insisted the problem that statically defined registration area cannot cover the entire movement pattern of the mobile terminal efficiently, and used dynamically overlapped registration areas based on monitoring the aggregate mobility and call pattern of the user during each reconfigurable period and adapting to the mobility and call pattern by either expanding or shrinking registration areas at the end of each reconfiguration. Zhu et al [11] proposed cell layered scheme that partitions all the cells of each location area into layers and pages the cell layers one layer after another in order of the probabilities from large to small instead of pages the whole location area simultaneoulsy. Whereas Gau and Haas proposed nonblocking paging scheme to concurrently search for a number of mobile users in a mobile network, and gave significantly reducing the cost of locating mobile users[12]. Cayirci and Akyildiz [13] focused on selecting the optimal set of cells for each static location area, and developed optimal location area design in wireless systems based on intercell traffic prediction and traffic-based cell grouping are used to select the optimal set of cells for location areas. They applied the intercell traffic prediction scheme to determine the expected intercell movement patterns of mobiles.

In [4], Hwang et al proposed the location update scheme using a mobile node's velocity, where the update process is triggered by the change of mobile node's velocity using time and distance, used stepwise paging scheme using the mobile node's velocity, and compared the method with distance-based scheme.

In [14], Li et al introduced dynamic HLR(Home Location Register) location management scheme, a dynamic copy of location information of a mobile terminal is made in the nearest HLR which can be accessed for location management and table lookup procedure for determining the current HLR easily.

III. The Proposed Scheme

We propose a combined method of movement-based and time-based location update methods in wireless or PCS networks. In this method, location of a mobile terminal is updated after a timer expiration of T and thereafter n cell boundary crossings or inversely n cell boundary crossings and thereafter a timer expiration of T. That is, one location update period is

$$T + \sum_{i=0}^{n-1} m_i, \tag{1}$$

where T is time interval, n is cell crossing number, and m_i is the i'th cell resident time. We find the optimal values of n and T. The method includes time-based method and movement-based method as its edges (when $n = 0$, it is the time-based, and when $T = 0$, it is the movement-based).

The detailed scenarios are as follows.

- **Update procedure** : we consider two types of update procedures.
  - *T and n type* : A mobile terminal waits until the timer T expires and, thereafter counts the number of cell boundary crossings of the mobile terminal. At the time of the n'th cell boundary crossing, the mobile terminal updates its location of the cell it just entered. The update procedure repeats. If a call arrival occurs before the location update, the system pages the mobile terminal and the mobile terminal restarts the update procedure.
  - *n and T type* : It is the same except the order of timer expiration and n cell boundary crossings. In this type, a mobile terminal counts n cell boundary crossings and then waits until the timer T expires.
- **Paging procedure** : When the system routes an incoming call to a mobile terminal, it first pages the center cell which is the recently registered location of the mobile terminal. If it does not succeed in finding the mobile terminal, it pages next surrounded ring. The paging goes on until it finds the mobile terminal.

Strong points of the scheme are as follows.

- The hybrid method is simple compared to the other complicated methods based on individual user's mobility characteristics.
- The hybrid method adapts the mobile user's mobility characteristics.
- The hybrid method can replace existing time-based or movement-based scheme easily with better performances.

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IV. Model of Hybrid Movement-Time-Based Location Update Strategy

First, we consider cell structure for the proposed method. In the hexagonal cellular network, each cell is surrounded by rings of cells. The innermost ring(*ring 0*) consists of only one cell and we call it center cell. The center cell is the recently registered cell to the system. *Ring 0* is surrounded by *ring 1* which in turn is surrounded by *ring 2*, and so on. We assume that the call arrivals follow Poisson process. We assume random walk mobility model with equal probability $1/6$ for a mobile terminal to move to each one of six neighboring cells.

- **Definition of** $\beta(j, K)$: probability that a mobile terminal is j rings away from the center cell given that K cell boundary crossings are performed. It is obtained easily from computer programming (see the table in Figure 1).

V. Performance Evaluation of Hybrid Location Update Scheme

A. Hybrid Scheme with Exponential Cell Resident Time

In this section, we make a numerical analysis for hybrid location management scheme of a mobile terminal with exponential call resident time. In the case of the mobility with exponential cell resident time, "*n and T type*" method and "*T and n type*" method give the same results due to the memoryless property of exponential distribution.

We assume that call arrival is Poisson process with mean λ_c (interval between two consecutive calls is denoted by a random variable c). And the cell resident time is random variable m which is exponential distribution with mean $\frac{1}{\lambda_m}$, pdf $f_m(t) = \lambda_m e^{-\lambda_m t}$ and the Laplace Transform(LT) of pdf $F_m^*(s) = \frac{\lambda_m}{s+\lambda_m}$.

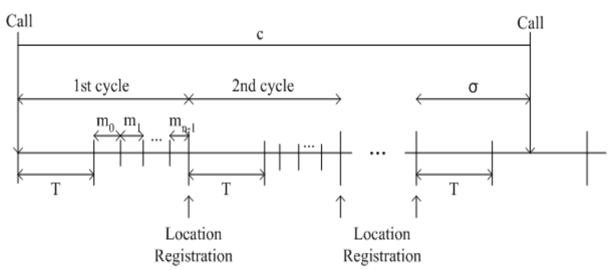

Fig. 2. The time diagram in the hybrid location update mechanism

1) Numerical Analysis: From the figure 2, m_i is the cell residence time at i'th cell and be the i.i.d random variable with the same distribution as m. σ represents the time interval from the recent registration time to the next call arrival. In σ, there can be some cell boundary crossings of a mobile terminal. Let $\alpha(K)$ be the probability that the mobile terminal moves across K cells during σ . Let the costs for performing a location update and for paging a cell be U and V, respectively. These costs account for the wireless and wireline bandwidth utilization and the computational overheads in order to process the location update and the paging. Let C_u be the expected location update cost in the hybrid update method per call arrival. The expected paging cost per call arrival in the hybrid update method is denoted by C_v.

At first, we derive the expected cost for location update. We let q_h be the probability that there are h update messages between two successive calls. We also let g be the probability that there are no location update messages between two successive calls. Therefore, g can be expressed as

$$g = P[c < T + m_0 + m_1 + \cdots + m_{n-1}]. \tag{2}$$

And we have

$$q_0 = g. \tag{3}$$

g is divided into two cases. The first case is that a call arrives within T. The probability of the case is

$$g_0 = P[c < T] = 1 - e^{\lambda_c T}. \tag{4}$$

The other case is that a call arrives after T. The probability of the case is as in equation 5 on the next page.

Note that the probability of no Poisson arrivals(with parameter λ) on a random variable x is $F_x^*(\lambda)$ where $F_x^*(s)$ is the Laplace Transform of the pdf of x.

We have the relation

$$g = g_0 + g_1 = 1 - e^{\lambda_c T}(\frac{\lambda_m}{\lambda_c + \lambda_m})^n. \tag{9}$$

q_h has geometric distribution with parameter g. Then we have

$$q_h = g(1-g)^h. \tag{10}$$

The expected cost for location updates for the period between two consecutive calls, C_u is

$$C_u = U\sum_{h=0}^{\infty} hq_h = U \cdot g \cdot \sum_{h=0}^{\infty} h(1-g)^h = U(\frac{1}{g} - 1). \tag{11}$$

Now, we derive the expected cost for paging cells. To get the probability $\alpha(K)$, we divide it into two cases. The first case is that the mobile terminal moves across K cells when a call arrives within T. The probability of the case is denoted by $A_0(K)$. The other case is that the mobile terminal moves across K cells when a call arrives after T. The probability of the case is denoted by $A_1(K)$. Thus we have the relation

$$\alpha(K) = A_0(K) + A_1(K). \tag{12}$$

Since the number of cell boundary crossings is distributed by Poisson process, we can get $A_0(K)$ as shown in equation 6.

As Δt_1 approaches zero, we have

$$A_0(K) = \int_0^T \frac{(\lambda_m t_1)^K}{K!} e^{-\lambda_m t_1} \cdot \frac{\lambda_c e^{-\lambda_c t_1}}{g} dt_1 = \frac{1}{g}B(K). \tag{13}$$

where

$$B(K) = \int_0^T \frac{(\lambda_m t_1)^K}{K!} e^{-\lambda_m t_1} \cdot \lambda_c e^{-\lambda_c t_1} dt_1. \tag{14}$$

$B(K)$ can be transformed for easy calculation as in equation 7

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j \ K	1	2	3	4	5	6	7	8	9	10	· · ·
0	0	0.166666	0.055555	0.069444	0.046296	0.043724	0.036008	0.032632	0.028839	0.026268	· · ·
1	1	0.333333	0.416666	0.277777	0.262345	0.216049	0.195794	0.173039	0.157611	0.143491	· · ·
2		0.5	0.333333	0.379629	0.324074	0.310570	0.282064	0.263760	0.244555	0.228969	· · ·
3			0.194444	0.203703	0.243055	0.245627	0.249507	0.245456	0.240529	0.233761	· · ·
4				0.069444	0.100308	0.131944	0.151234	0.165387	0.174489	0.180219	· · ·
5					0.023919	0.043981	0.064664	0.082218	0.097018	0.109192	· · ·
6						0.008101	0.018004	0.029535	0.041137	0.052227	· · ·
7							0.002722	0.007058	0.012822	0.019400	· · ·
8								0.000910	0.002689	0.005362	· · ·
9									0.000304	0.001005	· · ·
10										0.000101	· · ·
· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	

Fig. 1. Value of $\beta(j, K)$

$$\begin{aligned} g_1 &= P[T \leq c < T + m_0 + m_1 + \cdots + m_{n-1}] \\ &= P[\textit{no calls within } T] \cdot P[\textit{one or more calls arrives within } m_0{+}m_1{+}\cdots{+}m_{n-1}] \\ &= (1-g_0)(1 - P[\textit{Thereafter, no calls within } m_0{+}m_1{+}\cdots{+}m_{n-1}]) \\ &= e^{-\lambda_c T}(1 - P[\textit{no calls within } m]^n) \\ &= e^{-\lambda_c T}([-F_m^*(\lambda_c)^n] = e^{-\lambda_c T}[1 - (\frac{\lambda_m}{\lambda_c + \lambda_m})^n]. \end{aligned} \tag{5}$$

$$\begin{aligned} A_0(K) &= P[\textit{K cell crossings when a call arrives within } T|(c < T + m_0 + m_1 + \cdots + m_{n-1})] \\ &= \sum_{all\ t_1 \in T} (P[\textit{There are K cell crossing in } t_1] \cdot \\ &\quad P[\textit{a call arrives during } (t_1, t_1+\Delta t_1) \textit{in } T|(c < T + m_0 + m_1 + \cdots\ m_{n-1})]) \\ &= \sum_{all\ t_1 \in T} (P[\textit{There are K Poisson events with rate } \lambda_m \textit{ in } t_1] \cdot \\ &\quad P[\textit{a call arrives during } (t_1, t_1+\Delta t_1) \textit{in } T|(c < T + m_0 + m_1 + \cdots\ m_{n-1})]) \\ &= \sum_{all\ t_a \in T} [\frac{(\lambda_m t_1)^K}{K!} e^{-\lambda_m t_1}] \cdot [\frac{\lambda_c e^{-\lambda_c t_1} \Delta t_1}{g}]. \end{aligned} \tag{6}$$

$$B(K) = \frac{\lambda_c/\lambda_m}{(1+\lambda_c/\lambda_m)^{K+1}}[1 - e^{-(1+\frac{1}{\lambda_c/\lambda_m})\lambda_c T} \sum_{i=0}^{K} \frac{((1+\frac{1}{\lambda_c/\lambda_m})\lambda_c T)^i}{i!}]. \tag{7}$$

$$\begin{aligned} A_1(K) &= P[\textit{K cell crossings when a call arrives after } T|(c<T+m_0+m_1+\cdots+m_{n-1})] \\ &= \sum_{i=0}^{min(K,n-1)} \{P[(\textit{no calls in } T{+}m_0{+}m_1{+}\cdots{+}m_{i+1}) \textit{ and } (\textit{a call arrives in } m_i) \\ &\quad |(c < T + m_0 + m_1 + \cdots + m_{n-1})] \cdot P[\textit{there are } K{-}i \textit{ cell crossings in } T]\} \\ &= \sum_{i=0}^{min(K,\ n-1)} f_i \cdot P[\textit{there are } K{-}i \textit{ cell crossings in } T] \\ &= \sum_{i=0}^{min(K,\ n-1)} f_i \cdot \frac{(\lambda_m T)^{K-i}}{(K-i)!} e^{-\lambda_m T} \\ &= \sum_{i=0}^{min(K,\ n-1)} \frac{e^{-\lambda_c T}}{g} F_m^*(\lambda_c)^i (1 - F_m^*(\lambda_c)) \cdot \frac{(\lambda_m T)^{K-i}}{(K-i)!} e^{-\lambda_m T}. \end{aligned} \tag{8}$$

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We can also get $A_1(K)$ as follows. Let f_i be the probability that on condition that a call arrives, the call falls on $m_i(0 \leq i \leq n-1)$ duration in the time diagram of figure 2. Then we have

$$f_i = e^{-\lambda_c T} F_m^*(\lambda_c)^i (1 - F_m^*(\lambda_c)) \qquad (0 \leq i \leq n-1). \quad (15)$$

f_i is also the probability that there are i cell boundary crossings after the time expiration T. Therefore, $A_1(K)$ is as in equation 8.

Let π_j be the probability that the mobile terminal is located in a ring j cell when a call arrival occurs. Then we have

$$\pi_j = \sum_{K=0}^{\infty} \alpha(K)\beta(j, K). \quad (16)$$

Given that the mobile terminal is residing in ring j, let ω_j be the number of cells from ring 0 to ring j.

$$\omega_j = 1 + \sum_{i=1}^{j} 6i = 1 + 3j(j+1). \quad (17)$$

The paging cost for the hybrid location update for the period between two consecutive calls, C_v is expressed as

$$C_v = V \sum_{j=0}^{\infty} \pi_j \omega_j. \quad (18)$$

The expected total cost for location updates and paging per call arrival, C_T in the hybrid location update method is

$$C_T = C_u + C_v. \quad (19)$$

2) Results: From the above analysis, we made lots of graphs by varying call-to-mobility($CMR : \frac{\lambda_c}{\lambda_m}$) parameter, U, and V values. However, we conclude that the movement-based method seems to have better performance than the time-based and hybrid methods, that is the optimal costs occur at *T=0*. Two of the graphs are listed in Figures 3 and 4. In figure 3, the minimum total cost is *8.619* at *n=2, T=0*. In figure 4, we can see that the minimum total cost is *5.714* at *n=3, T=0*. These figures are normalized by $1/\lambda_c$.

B. Hybrid Scheme with Multi-States Exponential Residence Time

In this section, we assume that call arrival is distributed Poisson process with mean λ_c and cell resident time is multi-states exponential distribution with time-varying cell-resident time. To explain the mobility characteristics of mobile user, we assume that mobility of a mobile user has multi states, for example, for some period a mobile user does not move, then the mobile user moves slowly for next some period, and then the mobile user moves fast, and next, the mobile user does not move again, and so on. Figure 5 shows a general diagram of multi-states exponential cell resident time. In this figure, we assume the followings.

- Cell resident time is exponential distribution and call arrival is Poisson process.

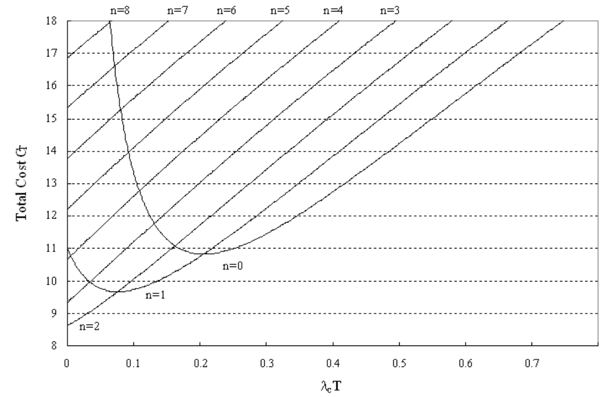

Fig. 3. Expected total location update cost for exponential cell resident time by varying call-to-mobility: CMR=λ_c/λ_m = 0.1, V=1, U=1

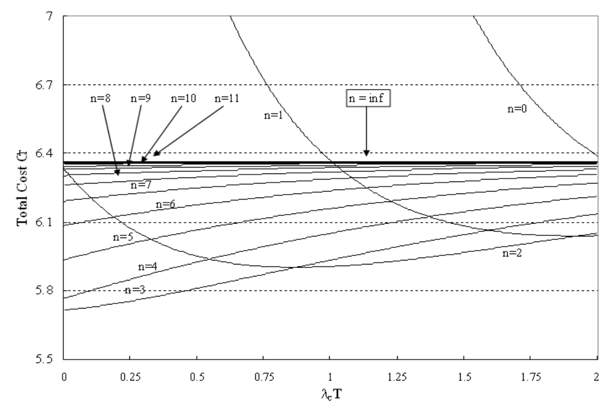

Fig. 4. Expected total location update cost for exponential cell resident time by varying call-to-mobility: CMR= λ_c/λ_m = 1, V=1, U=10

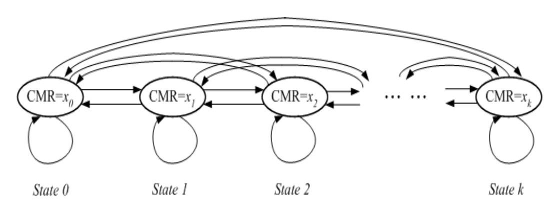

Fig. 5. A diagram of Multi-states exponential cell resident time.

- *CMR* = x : average cell resident time is x unit time.
- State transitions occur at *cell boundary crossings*.
- If the average call arrival interval is fixed without loss of generality, then we can estimate an average state staying time to determine a mobile terminal's state.

This figure shows that a mobile terminal has *k* states of mobility. For example, after the mobile terminal stays at *state 0* for a cell resident time with exponential distribution, the mobile terminal moves to another state according to change of its mobility rate. In *k* states, for simplicity, we assume that call arrival rate is 1 unit time and only mobility rate of the mobile terminal could be changed. We can estimate the average state staying time for each state.

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Let us consider an example. Figure 6 shows an example of three-states exponential cell resident time. In this figure, mobility rates of the mobile terminal are fast, slow, very slow. Usually, a mobile user has three movement state, such as staying, walking, car driving. From this figure, the time portion of each state is *33.3%*, respectively. In *state 1*, *CMR = 0.01*, it

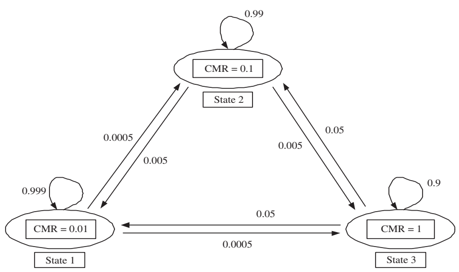

Fig. 6. An example of Three-states exponential cell resident time.

means that the mobility rate of the mobile user is fastest, and the mobility rate of *state 3* is lowest. In *state 1*, the probability that the state goes to *state 2* or *3* is 0.001, and because state transitions occur at cell boundary crossings, the average state staying time is 10 unit time. In *state 2*, the probability that the state goes to *state 1* or *3* is 0.01, and the average state staying time is 10 unit time. Average time portion of each state is same. We analyze the hybrid scheme with multi-states cell resident time numerically and by simulation using Figure 6.

1) Numerical analysis : We get numerical analysis for multi-states cell resident time with exponential cell resident time for each state and Poisson process call arrival. The followings are procedures.

1) Obtain the time portion of each state (e.g. : in figure 6, *state 1: 33.3%, state 2: 33.3%, state 3: 33.3%*).
2) Obtain the paging cost and updating cost of each state using the equations of V-A.1 (e.g. : U_1, V_1 for *state 1*, U_2, V_2 for *state 2*, U_3, V_3 for *state 3* in figure 6).
3) Assuming the average state staying time is much larger (in figure 6, the average state staying time is 10 unit time) than the cell resident time of a mobile terminal, the paging and updating costs of all states in figure 6 can be *approximately* obtained as,

$$0.333V_1 + 0.333V_2 + 0.333V_3 \text{ and}$$
$$0.333U_1 + 0.333U_2 + 0.333U_3.$$

2) Results : In this section, we compare numerical and simulation results for multi-states cell exponential resident time for figure 6. We run two simulations for assumtion of $V = 1$, $U = 1$ and $V = 1$, $U = 10$.

Figure 7 shows that when $V = 1$ and $U = 1$, the minimum total cost of numerical analysis and simulation is *14.4660* at $n = 1$, $\lambda_c T = 0.0575$. That is, the total cost could be minimized when location is updated after time period, $T = 0.0575$ and one cell crossing. In this figure, if the time-based method is applied ($n = 0$), total cost is mimimized as *19.1993* at $T = 0.115$, and this value is larger than the hybrid method. If the movement-based method is applied, we can get the minimum cost of the movement-based method at $n = 5$.

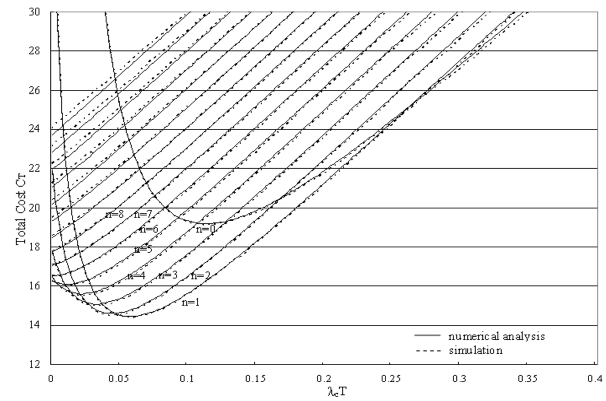

Fig. 7. Total cost comparison between numerical analysis and simulation for three-states cell resident time when $V = 1$ and $U = 1$, and $CMR = 0.01,\ 0.1$ and 1 with same time portion.

The cost is also larger than the hybrid method. As a result, the hybrid method shows better performace than time-based and movement-based method.

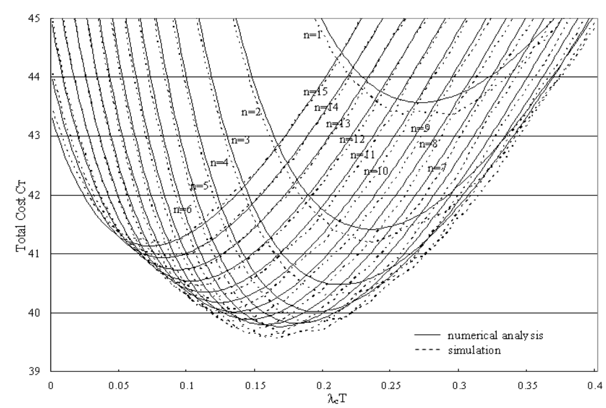

Fig. 8. Total cost comparison between numerical analysis and simulation for three-states cell resident time when $V = 1$ and $U = 10$, and $CMR = 0.01,\ 0.1$ and 1 with same time portion.

In figure 8, we can get the minimum total cost is *39.7662* at $n = 6$, $\lambda_c T = 0.1675$, when $V = 1$ and $U = 10$. That means, a mobile terminal should update its location after 6 cell crossing and $T = 0.1675$. On time-based method ($n = 0$), the total cost is minimized as *51.4317* at $T = 0.4$, and on movement-based method, we could get the minimum total cost, *43.3040* at $n = 15$. The total costs of both cases are larger than the hybrid method.

Let us compare the location update period about three states in figure 8. In *state 1*, the average cell resident time is *0.01* unit time. From the hybrid method and figure 8, we can calculate that the location update period is *0.2275* for $n = 6$ and $T = 0.1675$. In *state 2*, the average cell resident time is *0.1* and we get the location update period, *0.7675*. The location update period in *state 3* with the average cell resident time, *1* is *6.1675*. A mobile terminal with the longer cell resident time, the location update period is longer. From this, we can know that when a mobile user moves slow or stays for a long time(e.g. *state 3*), i.e, the cell resident time is long, location update period must be longer and location might be updated seldomly. Because the mobile user might not go fast and far, we do not need to update location of mobile user frequently and search area for the mobile terminal might be small. Whereas when mobility speed of a mobile user is fast(e.g. *state 1*), i.e, the cell resident time is small, the location should be updated frequently. Because the mobile user moves fast, if location update period is long, search cost for the mobile user might be wider. This characteristics shows the hybrid method efficiently adapts the mobility speed of the mobile terminal.

When the update interval (T and n) gets large, the discrepancy between numerical and simulation results gets large. It is because we assumed in the numerical analysis that the average state staying time is much larger than the cell resident time.

VI. Conclusion

Time-based location update method and movement-based location update method are simple schemes to implement in cellular or PCS networks. Distance-based location update method is impractical to implement in that the mobile terminal should have the knowledge of network topology. From the viewpoint of simple implementation, time-based and movement-based method should be first considered rather than the distance-based method and the other complicated location update methods since simple implementations are also one performance issue to pursue.

In this paper, we proposed a simple location update method which combines movement-based and time-based location update methods, a multi-states based hybrid location update scheme. In the proposed scheme, a mobile terminal updates its location after n cell boundary crossing and then T time interval, or the inverse.

Since the proposed scheme includes time-based method and movement-based method as its edges, the performance of the scheme should be better than the existing two methods. We made numerical analysis and simulation analyses in which we get the optimal T and n which minimize the total costs and compared with two methods.

We defined the multi-states exponential cell resident time for describing the mobility characteristics of mobile user and analyzed the total cost of the hybrid method using multi-states cell resident time. Generally, the mobile user has three states for its movement, such as staying, walking, driving. This multi-states cell resident time based hybrid method reflects the movement characteristics of mobile user and adapts the location update period according to the states of mobility speed. As a results of numerical and simulation analysis, the proposed hybrid method showed better performance than the time-based and movement-based method.

From the study results, we insist that the hybrid movement-time-based location update scheme is worth implementing in cellular networks instead of the time-based or the movement-based methods only.

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