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Optimal Time-Interval for Time-based Location Update in Mobile Communications

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Abstract

In this paper, we analyze a time-based update method in location management and calculate the optimal time-interval. The probability that an MT is j rings away from the center cell is obtained by computer programming. And using these values, an exact analysis is made for the time-based location management cost. From the result, when the time-based method is applied to location update, we can get the optimal time-interval which minimizes the location management cost.

Keywords : *Time-based Update, Location Management, Optimal Time-Interval*

1. Introduction

Location management and call setup process play an important role in the PCS performance [1,2,3,4]. The whereabouts of a user in mobile communication systems must first be known in order to correctly route an incoming call. A user's location information can be obtained from the registration initiated by the user and the paging issued by the system. However, the registration cost and the paging cost have the relation of inverse coupling in the use of network resources.

Researches has been made about the performance of PCS in the three models; movement-based, distance-based and time-based. However, exact numerical analyses have not been made for the case of time-based model. In this paper, we make an exact numerical analysis of a time-based model and determine the optimal time interval for location update.

2. Time-based Location Update

A simple dynamic strategy in location update is a time-based method in that a mobile terminal(MT) transmits its location update messages periodically every T units of time[5,6]. However, if a call arrival occurs within T interval, the system pages the MT and the MT restarts its timer. The paging mechanism of the time-based method are more complex than the movement-based and distance-based updates in that it is difficult to estimate the paging area because the MT does not update its location until the time interval T expires.

Fig. 1 shows the hexagonal cell structure of the mobile communication system considered in this paper. Each cell is surrounded by rings of cells. The innermost ring(ring 0) consists of only one cell and we call it center cell. Ring 0 is surrounded by ring 1 which in turn is surrounded by ring 2, and so on. When the system routes a incoming call to an MT, it first pages the center cell which is the recently registered location of the MT. If it does not succeed in finding the MT, it pages next surrounded ring. The paging goes on until it finds the MT.

3. Model and Analysis

We denote some notations and assumptions. Call arrival distribution to an MT is Poisson with rate λ_c. Let a random variable t_c be the interval between two consecutive calls to the

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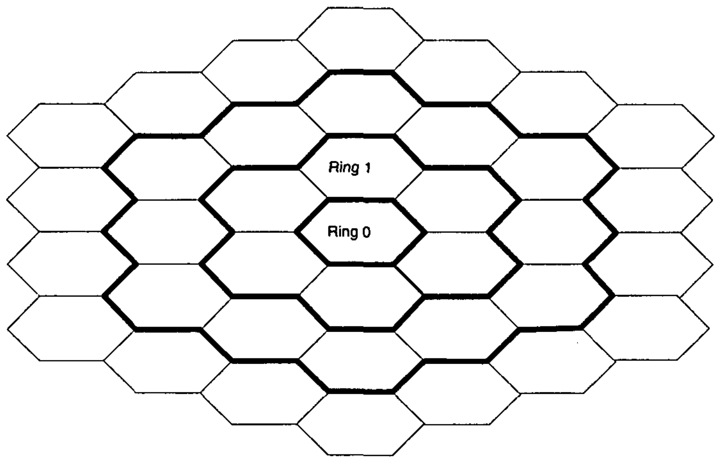

Fig. 1. Hexagonal cell structure

MT. Let m_i be the cell residence time at cell i and be independent identically distributed random variables with a general distribution function $F_m(t)$, a density function $f_m(t)$ and the mean rate λ_m.

Fig. 2 shows a timing diagram of a MT between two consecutive calls. The MT visits another l cells(numbered inversely in the figure) and gets a new call. The MT resides in the intermediate ith $(0 \leq i \leq l)$ cell for a period m_i. In t_c, there are n expirations of T and the remnant σ. r_1 and r are the residual life and the age of m_0, respectively.

Let $\alpha(K)$ be the probability that a MT moves across K cells during the remnant σ. Let $\beta(j, K)$ be the probability that the MT is j rings away from the center cell given that K cell boundary crossings are performed.

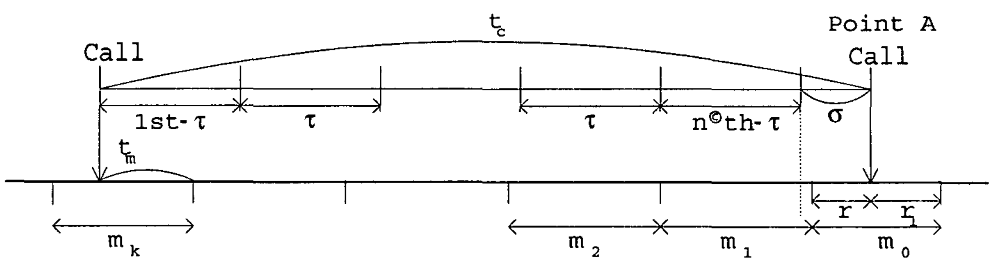

Fig. 2. The time diagram in time-based update mechanism

For the hexagonal cell configuration in Fig. 1, we assume that each MT resides in a cell for a time period then moves to one of its neighbors with equal probability, i.e., 1/6. Therefore, we can get $\beta(j,K)$ from computer programming.

Let the costs for performing a location update and for paging a cell be V and U, respectively. At first, we derive the expected cost for location updates. The probability that there are n update messages between two successive calls, p_n, is

$$p_n = e^{-\lambda_c nT}(1-e^{-\lambda_c T}). \tag{1}$$

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

$$C_u = U\sum_{n=0}^{\infty} np_n. \tag{2}$$

Now, we derive the expected cost for paging cells. Let $f_\sigma(t)$, $f_r(t)$ and $f_{r_1}(t)$ be the probability density function of σ, r and r_1, respectively. Then we have

$$\begin{aligned} f_\sigma(t) &= \frac{\lambda_c e^{-\lambda_c t}}{1-e^{-\lambda_c T}} && (0 \le t \le T) \\ &= 0 && \textit{Otherwise} \end{aligned} \tag{3}$$

From the random observer property, we can get

$$f_r(t) = f_{r_1}(t) = \lambda_m[1-F_{m(t)}]. \tag{4}$$

At point A in the Fig. 2, time axis can be displayed reversly as shown in the Fig. 3. We consider the instant, $\sigma = t_1$. Let the probability that the MT moves across K cells during $\sigma = t_1$ be $\alpha(K, t_1)$. Then we have

$$\alpha(K) = \int_0^T \alpha(K, t_1) f_\sigma(t_1)dt_1. \tag{5}$$

We let $b_K = r + m_1 + m_2 + \cdots + m_K = r + \sum_{i=1}^{K} m_i$. Then we can get

$$\alpha(K, t_1) = \int_0^{t_1} [\int_{t_1-t}^{\infty} f_m(t_2)dt_2] b_{K-1}(t)\, dt. \tag{6}$$

From (5) and (6), we can get $\alpha(K)$.

Let π_j be the probability that the MT is located in a ring j cell when a call arrival occurs.

$$\pi_j = \sum_{K=0}^{\infty} \alpha(K)\beta(j,K). \tag{7}$$

Given that the MT is residing in ring j, let ω_j be the number of cells from ring 0 to ring j. The paging cost for the time-based update, C_v is expressed by

$$C_v = V\sum_{j=0}^{\infty} \pi_j \omega_j. \tag{8}$$

The expected total cost for location updates and paging per call arrival in the time-based method is therefore

$$C_T = C_u + C_v. \tag{9}$$

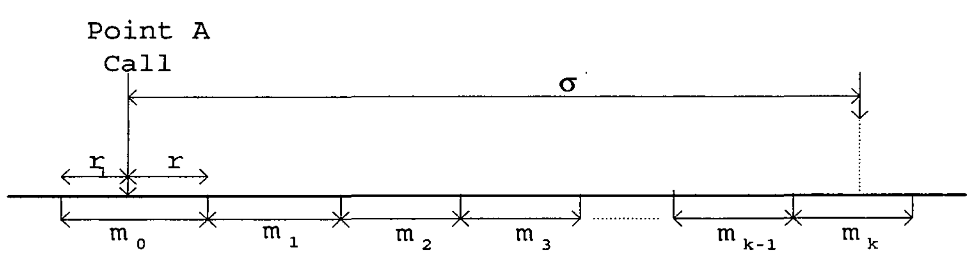

Fig. 3. The reverse time diagram

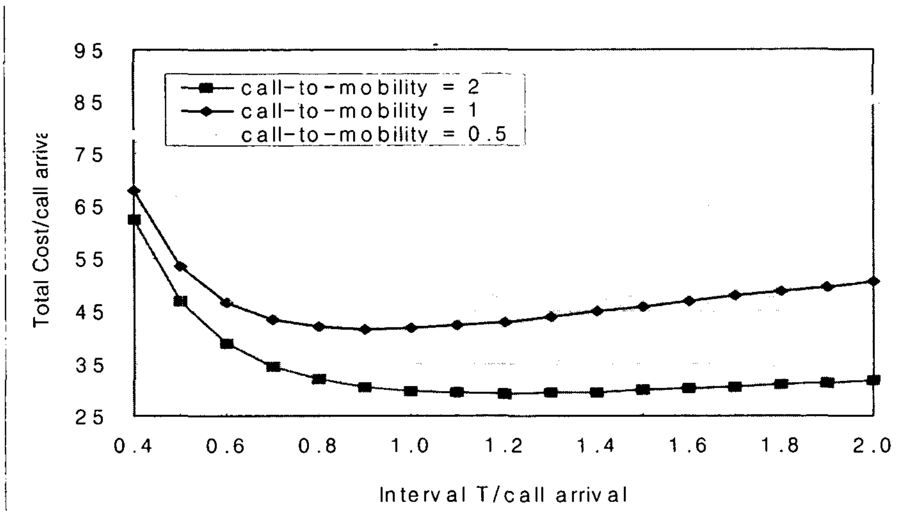

Fig. 4. Total cost versus time interval in the time-based method.

4. Results and Discussion

Fig. 4 shows the values of total cost, C_T as a function of T.

The distribution of cell resident time is gamma distributrion with $\gamma=2$. And U and V are set to one. To demonstrate the effect of call-to-mobility patterns, three call-to-mobility ratio $\frac{\lambda_c}{\lambda_m}$, 0.5, 1.0 and 2.0, are considered.

In the figure, it can be seen that the value of the total cost varies widely as T changes. By selecting the appropriate value of T, the total cost per call arrival, C_T, could be minimal.

In the figure, when the call arrival rate is low and the mobility is large, the optimal T has smaller values than the call arrival interval. In the opposite case, the optimal T has larger values than the call arrival interval. Therefore, we see that as an MT is more mobile, then the location updates should be performed more frequently.

5. Conclusion

In this paper, we analyzed a time-based update method in location management and calculated the optimal time-interval. We obtained the probability that an MT is j rings away from the center cell by computer programming. And using these values, we made an exact analysis for the time-based location management cost.

From the result, when the time-based method is applied to location update, we can determine the optimal time-interval which minimizes the location management cost.

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