LETTER

Effect of Uncertainty of the Position of Mobile Terminals on the Paging Cost of an Improved Movement-Based Registration Scheme*

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SUMMARY An improved movement-based registration scheme [2] reduces location update cost on conventional movement-based location update scheme [1] but increases uncertainty of the position of a mobile terminal (MT). The effect of this uncertainty of the MT position on the paging cost of the improved movement-based registration scheme is analyzed. We show that the paging cost of the improved movement-based registration scheme in [2] is underestimated, especially for large values of movement threshold. The result shows that the underestimation cannot be ignored.

key words: *movement-based location management, mobility management, location update, paging, personal communication service*

1. Introduction

A movement-based location update scheme with selective paging for a personal communication systems (PCS) was analyzed in [1]. In this movement-based location update scheme, the network performs a location update when the number of cell boundary crossings exceeds a movement threshold. The cost-effectiveness of the proposed scheme under various parameters was demonstrated. In [1], however, if the movement counter of the mobile terminal (MT) reaches the threshold value when the MT revisits the last updated cell, an unnecessary location update is performed.

To overcome this deficiency, Baek and Ryu [2] proposed an improved movement-based registration scheme based on mesh cell configuration. Three steps are proposed in this scheme. First, if the cell ID of a newly entered cell is in the cell ID buffer of the MT, the stored cell ID is removed from its original position in the cell ID buffer. Then, the IDs stored after the original position from which the cell ID was removed are shifted back toward the position of the removed cell ID by one. Finally, the cell ID of the newly entered cell is placed at the last position of the cell ID buffer. In addition, a new paging area is established based on the fact that cells in the corners of each ring of cells cannot be reached at all, even when threshold movement occurs in the conventional mesh cell configuration [2].

Baek and Ryu [2] showed that establishing a new paging area in the conventional movement-based location update scheme yields paging cost reduction and the improved movement-based registration scheme results in the reduction of the location update cost. The paging cost was obtained by assuming that the location distribution of an MT from the last updated cell when an incoming call arrives is the same as that of the conventional movement-based location update scheme. However, as a result of fewer location updates, which results in less contacts with the network, the uncertainty of the MT position increases in the improved movement-bsaed registration scheme [3]. In this letter, we analyze the effect of uncertainty of the MT position on the paging cost of the improved movement-based registration scheme and show that the underestimation of paging cost cannot be ignored.

For the sake of conciseness, we do not repeat the model description in [1], [2] in detail but only analyze the effect of uncertainty of the MT position on paging cost.

2. Effect of Uncertainty of the MT Position on Paging Cost

A mesh cell configuration is considered as shown in Fig. 1

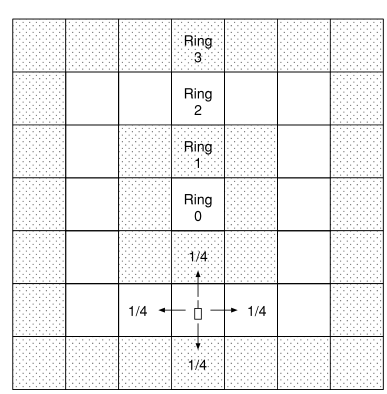

Fig. 1 Mesh cell configuration.

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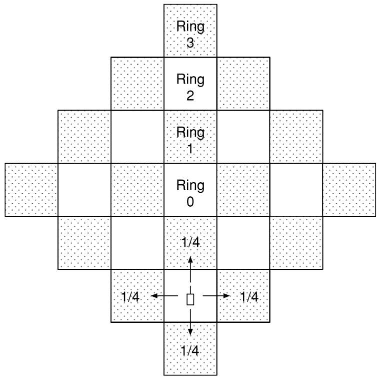

Fig. 2 New mesh cell configuration accommodating new paging area.

[1]. An MT resides in a cell during a generally distributed time interval and moves to one of four neighboring cells. It is assumed that the probability of choosing one of the neighboring cell as a destination when the MT leaves a cell is equal for all four directions and is given by $1/4$. Therefore, the mobility of the MT is modeled as a two-dimensional random walk [4].

In a mesh cell configuration each cell is surrounded by rings of cells. The innermost ring consists of only one cell and is called the center cell. For a given center cell, $r_i(i \geq 0)$ is the set of all cells in the i-th ring. The number of cells in ring i, $g(i)$, is $8i$ in the conventional movement-based location update scheme [1]. In the improved movement-based registration scheme [2], a new paging area is established as shown in Fig. 2 based on the fact that cells in the corners of each ring of cells cannot be reached at all, even when threshold movement occurs. Thus, the number of cells in ring i in the improved movement-based registration scheme is $4i$ [2].

When an incoming call arrives, the network initiates the paging process to find the called MT and the network must be capable of locating the called MT within η paging times, where η denotes the maximum number of pagings. The residing area of the called MT is partitioned into η subareas and a shortest-distance-first (SDF) partitioning scheme [1] is considered. In the SDF scheme, the residing area of the called MT is partitioned into $l = \min[\eta, \mathrm{d}]$ subareas, where d is the movement threshold. Subarea j is denoted by $A_j (0 \leq j < l)$ and contains rings s_j to e_j where rings s_j and e_j are the indices of the first and the last rings in subarea A_j, respectively. The values for s_j and e_j are given in [1].

In order to obtain the expected location update and paging costs per call arrival, the probability $\alpha(K)$ that there are K movements between two successive incoming call arrivals is derived in [1]. The costs of performing a location update and for paging a cell are U and V, respectively. The expected location update cost per call arrival is obtained as:

$$\begin{aligned} C_u &= U \sum_{j=1}^{\infty} \alpha(j) \sum_{i=1}^{\infty} i\, P(i|j) \\ &= U \sum_{i=1}^{\infty} i \sum_{j=1}^{\infty} \alpha(j) P(i|j), \end{aligned} \tag{1}$$

where $P(i|j)$ is the probability that i location updates occur during j cell movements. In [1], the location update cost is given by:

$$C_u = U \sum_{i=1}^{\infty} i \sum_{j=id}^{(i+1)d-1} \alpha(j). \tag{2}$$

In [2], the location update cost is given by:

$$C_u = U \sum_{i=0}^{\infty} i \sum_{j=id}^{\infty} \alpha(j) \sum_{k=id}^{(i+1)d-1} Pr(N=k|M=j), \tag{3}$$

where M and N represent the number of movements since the last incoming call arrival and the number of movements into new cells that are not in the cell ID buffer, respectively.

The expected paging cost per call arrival is obtained as [1]:

$$C_v = V \sum_{k=0}^{l-1} \Big(\sum_{r_i \in A_k} \pi_i \Big) \Big(\sum_{j=0}^{k} \sum_{r_i \in A_j} g(i) \Big), \tag{4}$$

where π_i is the probability that the MT is located in ring-i cell when a call arrives. The probability π_i can be expressed as:

$$\pi_i = \sum_{z=0}^{\infty} \alpha(z) p_i(z), \tag{5}$$

where $p_i(z)$ denotes the probability that, after z movements, the distance between the current and the initial position is i-rings. The distribution of $p_i(z)$ depends on the location update algorithm of each movement-based location update scheme. If a scheme results in less location updates and thus, less contacts with the network, the uncertainty of the MT position is likely to be increased, and the probability that the MT is found in a remote distance is increased. On the contrary, in the opposite case, the uncertainty is likely to be decreased and the probability that the MT is found in a close distance is increased. The value of π_i is closely related with the paging cost and should be analyzed appropriately.

In [1], the value of $p_i(z)$ was derived based on the conventional movement-based location update scheme. In [2], the value of $p_i(z)$ was obtained based on the conventional movement-based location update scheme accommodating newly established paging area. However, this should be corrected because the value of $p_i(z)$ is not the same if a different movement-based scheme is considered, which was overlooked in the derivation of $p_i(z)$ in [2]. Thus, in this letter, the value of $p_i(z)$ of the improved movement-based registration scheme is obtained based on the improved movement-based registration scheme via simulation.

The expected total cost for location update and paging per call arrival is finally obtained as:

$$C_T = C_u + C_v. \tag{6}$$

3. Simulation Results

For illustrative purpose, the cell residence time and the incoming call arrivals are assumed to follow an exponential

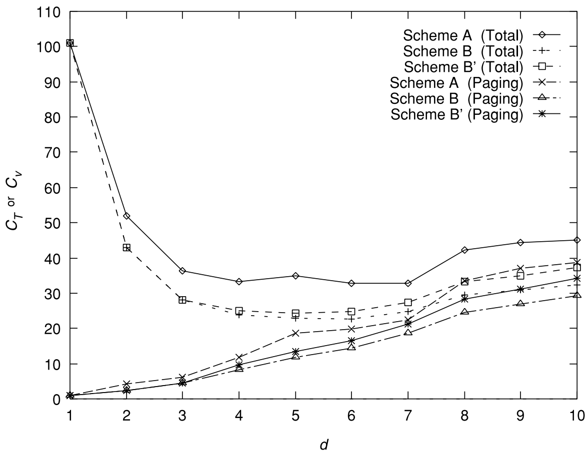

Fig. 3 Cost per call arrival ($\eta = 3$, CMR=0.1).

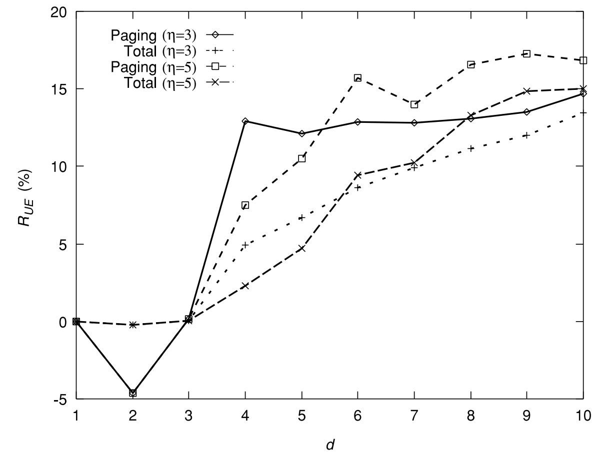

Fig. 4 R_{UE} performance versus d, comparing $\eta = 3$ with $\eta = 5$ ($\text{CMR} = 0.1$).

distribution with λ_m and a Poisson process with λ_c, respectively. It is also assumed that $U = 10$ and $V = 1$ as applied in [1], [2]. For notational convenience, the conventional movement-based location update scheme by Akyildiz et al. [1] and the improved movement-based registration scheme by Baek and Ryu [2] are denoted as *Schemes A* and *B*, respectively. In addition, the improved movement-based location registration scheme with corrected paging cost is denoted as *Scheme* B' for notational convenience but it is noted that basically, it is not any new scheme.

Figure 3 shows the paging and total costs per call arrival for the three schemes for varying the values of movement threshold, d for $\eta = 3$ and call-to-mobility ratio (CMR) $= 0.1$. CMR is introduced to represent the relative frequency of call rate and mobility and is defined as $\frac{\lambda_c}{\lambda_m}$. Paging cost increases as d increases due to the increased movement of the MT. On the contrary, total cost decreases for small values of d due to a decrease in location update cost. For large values of d total cost increases slowly due to an increase in paging cost. As expected, the paging and total costs for the *Schemes B* and B' are less than those of the *Scheme A*, and the cost for the *Scheme* B' is higher than for the *Scheme B*.

The underestimation of the cost of the *Scheme B* with respect to the *Scheme* B' is illustrated in Fig. 4 for $\eta = 3$ and 5 and CMR = 0.1, and an underestimation ratio, R_{UE}, is defined as:

$$R_{UE}(\%) = 100 \times \frac{Cost(B') - Cost(B)}{Cost(B')}, \qquad (7)$$

where $Cost(B)$ and $Cost(B')$ represent the cost of *Schemes B* and B', respectively. The $Cost(B)$ and $Cost(B')$ can be either paging costs or total costs. If they represent paging costs, then R_{UE} becomes the underestimation ratio for paging cost. On the other hand, if they are total costs, then R_{UE} is the underestimation ratio for total cost.

The figure shows that the underestimation generally becomes serious as d increases although there are some fluctuations because of a high probability that the MT is found in a distant location from the last updated cell in the *Scheme* B'. *Scheme* B', however, results in a lower paging cost than for *Scheme* B for $d = 2$ because the probability that the MT is found at the center cell is higher in *Scheme* B' than for *Scheme B* for $d = 2$. This is due to the fact that, in *Scheme* B', location update can be performed at ring 1 cells as well as both center cell and ring 2 cells but in *Scheme B*, the location update is performed only at both center cell and ring 2 cells. Thus, the probability of finding an MT at the center cell when an incoming call arrives is higher in the *Scheme* B' than for the *Scheme B*. This results in a lower paging cost because in selective paging scheme with $d = 2$ the paging cost (i.e., expected number of paging cells before locating an MT) decreases if the probability that the MT is found at the center cell increases based on Eq. (4). The maximum underestimation ratio for paging cost is about 15% and 17% for $\eta = 3$ and 5, respectively. This underestimation cannot be ignored.

4. Conclusions

In this letter, we analyzed the effect of the uncertainty of the position of an MT on the paging cost of the improved movement-based registration scheme. It is shown that the paging cost of the improved movement-based scheme is underestimated, especially for large values of movement threshold. The results show that the underestimation cannot be ignored.

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