Performance Optimization of an Improved Movement-Based Location Update Scheme in Real PCS Networks

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Abstract. In this paper, an improved movement-based location update (iMBLU) scheme is proposed to reduce the location update (LU) cost of the conventional movement-based location update (CMBLU) scheme. The main idea is that instead of simply keeping counts of the number of cell boundary crossings, the counter of a mobile station (MS) stores the distance information between the currently residing cell and the last registered cell and an LU is performed whenever the counter value reaches a predefined threshold, called movement threshold. Unnecessary LUs are avoided when the MS moves around the recently visited cells. Simulation results demonstrate that the iMBLU scheme has achieved a considerable reduction in LU cost compared to other schemes under irregular cell configuration in real personal communication service (PCS) networks.

Keywords: Movement-based location update, Movement threshold, PCS networks.

1 Introduction

Location management (LM) is a critical component to effectively deliver network services to mobile users. One basic operation of LM is location update (LU). LU is the process through which an MS periodically sends LU messages to notify the network to reregister its location information in the database in order to make the network efficiently deliver incoming calls to the MS.

There are three essential dynamic LM schemes, namely, time-based [1], distance-based [2], and movement-based [3]-[7] schemes. Because the movement-based location update (MBLU) scheme is the most cost-effective and easy to implement in the PCS networks [3], we in this paper focus on the MBLU scheme and contribute on reducing the number of LUs.

In the conventional movement-based location update (CMBLU) scheme, the value of each MC is compared to a movement threshold D to trigger an LU. When the number of cells visited by an MS exceeds D, the MS performs an LU. However, the MS increases its MC value even when the MS reenters the cell already visited, which may give rise to unnecessary LUs. The scheme in [5] was proposed to reduce the

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unnecessary LUs. However, unnecessary LUs still exist when an MS moves around the recently visited cells. In [6] and [7], two dynamic movement-based location update schemes, called DMBU (dynamic movement-based update) scheme and iDMBU (improved dynamic movement-based update), respectively. The iDMBU scheme [8] is infeasible with the network topology expansion. A main deficiency of the two schemes is that the characteristic of the network is unavailable in reality.

In this paper, we present an improved movement-based location update (iMBLU) scheme which can be easily deployed in real PCS networks to overcome the shortcomings of the DMBU and the iDMBU schemes by determination the distance between the newly moved-in cell and the last registered cell. Simulation results demonstrate that the iMBLU scheme outperforms the DMBU and CMBLU schemes in the real PCS networks.

The rest of this paper is organized as follows. Scheme description is presented in Section 2. Section 3 presents the performance comparisons between the iMBLU scheme and other schemes. Section 4 concludes the paper.

2 iMBLU Scheme

In this section we describe an iMBLU scheme, which can be successfully implemented in the real PCS networks and result in less LU cost than the CMBLU scheme.

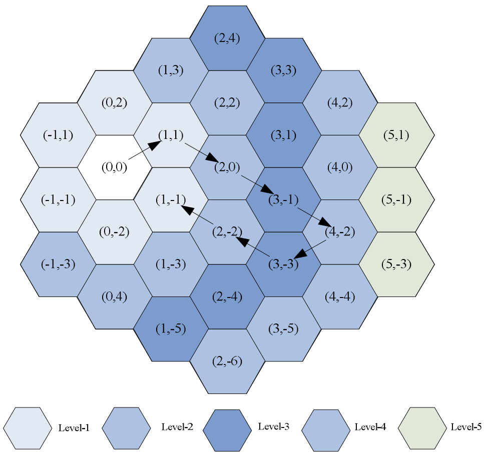

Fig. 1. An example path of an MS

Firstly, we briefly introduce the DMBU and iDMBU schemes, both of which are assumed under the hexagonal cell configuration. The network topology in the two schemes is known. As illustrated in Fig.1, the coordinate (x, y) indicates cell identification (ID). Each cell is surrounded by rings of cells. The level-i cells is a set of cells of which the distance from the last registered cell is i and $i = 0, 1, 2 \cdots$. For example, let the ID of the last registered cell be (0, 0), which is surrounded by ring level-1 which in turn is surrounded by ring level-2 and so on. All distances are measured in terms of the number of rings.

2.1 DMBU Scheme

Park, et al. [6] proposed a DMBU scheme to reduce the LU cost. In the DMBU scheme, an MS has one MC and three memory elements i.e. UPDATE, HISTORY, and CURRENT. The UPDATE stores the ID of the cell where the last LU is performed. The HISTORY stores the ID of the cell after leaving which the MC will increase. The CURRENT stores the ID of the cell where the MS is currently residing. The MC tallies the number of cell boundary crossings for an MS and it will increase when the MS moves out of the last registered cell or moves farther from the cell of which the ID is not stored in the HISTORY. When the value of the MC reaches the movement threshold D, an LU is performed. Table 1 depicts the DMBU scheme under the path in Fig.1.

Table 1. An Example Illustration of the DMBU Scheme

UPDATE	HISTORY	CURRENT	MC
(0,0)	—	(0,0)	0
(0,0)	(0,0)	(1,1)	1
(0,0)	(1,1)	(2,0)	2
(0,0)	(2,0)	(3,-1)	3
(0,0)	(3,-1)	(4,-2)	4
(0,0)	(3,-1)	(3,-3)	4
(0,0)	(3,-1)	(2,-2)	4
(1,-1)	—	(1,-1)	0

As presented in Table 1, an MS performs the last LU in cell (0, 0) and (0, 0) is stored in the UPDATE. The current cell ID(0, 0) is stored in the CURRENT. In cell (0, 0), the HISTORY is NULL and the MC is initialized to zero. The MC is increased by one when the MS leaves cell (0, 0) and the ID(0, 0) is stored in the HISTORY.

Two situations should be considered then: i) If the newly moved-in cell ID is neither stored in the HISTORY nor a neighboring cell ID of the cell IDs stored in the HISTORY, the MC is increased by one. And then the ID of the cell from which the MS enters the new cell stores in the HISTORY. ii) If the newly moved-in cell ID is stored in the HISTORY or a neighboring cell ID of the cell IDs stored in the HISTORY, the MC remains unchanged and the HISTORY will not be changed, either. In this way, unnecessary LUs can be avoided as shown in Fig.1 and Table 1.

It is assumed that $D = 5$. We can find from Table 1 that an LU will be performed when the MS crosses five cell boundaries i.e. enters cell (3, -3) for the CMBLU scheme and for the DMBU scheme the MS performs an LU when it is in cell (1, -1) with seven cell boundary crossings. Obviously, the number of the LUs for the DMBU scheme is less than that of the CMBLU scheme.

Note that the DMBU scheme can also be implemented without the network topology. But an MS should know the IDs of the currently residing cell and its neighbors.

2.2 The Infeasible of iDMBU Scheme

Beak, et al. [7] proposed an iDMBU scheme to enhance performance of the DMBU, in which more memory space in an MS is required to store more cell IDs. The difference from the DMBU scheme is that the HISTORY in iDMBU scheme stores IDs of the visited cells and their neighboring cells. The cell IDs in the HISTORY are arranged in increasing order of levels. When a cell and its neighboring cells are added to the HISTORY, each existing duplicated cell is stored in the lower level of the HISTORY. The MC equals to the value of the level and changes according to whether the newly moved-in cell is in the HISTORY or not.

For concision purpose, it is assumed that an MS enters cell- j which is a level- k cell from cell- i .When the ID of cell- j is not stored in the HISTORY, the MC increases by one. Otherwise, there are two situations for the MC. 1) if cell- j is a level- k cell, the MC remains unchanged. 2) if cell- j is a level-($k-1$) cell, the MC is decremented by one. For all the cases, the IDs of cell- i and its neighboring cells are stored in the HISTORY in increasing order of levels. If MC= D , an LU is performed and it is initiated with the cell.

As presented in Fig.1, cells with same colors belong to the same level in the HISTORY. When an MS moves from (0, 0) to (1, -1), the MS is back to level-1 cells i.e. the distance between the currently residing cell and the last registered cell is one. So the MC=1. The main idea of the iDMBU scheme is that the MS stores the cell distance in terms of rings and the MC is equal to the value of the rings, which changes according to the history information. Under this idea, only when the MS enters the cell which is in level- D , an LU is performed. So the number of LUs is greatly reduced. However, the scheme cannot be successfully implemented in the current networks, for two reasons contributing to it.

First, the iDMBU scheme is implemented in the PCS networks with assumption of the hexagonal cell configuration. Real cellular networks have irregular cell configuration. Second, the coordinate, as shown in Fig.1, is assumed under the condition that the distance for an MS between the last registered cell and its surrounding cells is already known by the PCS networks, which is not corresponding to the characteristic of the real PCS networks. That is to say, the real networks do not have the coordinate network topology and the storage mode in the HISTORY cannot be implemented.

2.3 iMBLU Scheme

Based on the study of the above schemes, we present a more realistic scheme in this paper, which is not only can be implemented in the real PCS networks but achieves a significant reduction in the LU cost.

Similar to the two schemes in [6] [7], in our scheme, each MS has three memory elements (UPDATE, HISTORY, CURRENT) and one MC. The difference is that the three memory elements store the cell information (CI). The CI contains two components, namely, cell ID and the distance information (DI). The cell ID is to identify a cell and the DI is the distance information between the last registered cell and its surrounding cells. The storing way when an MS leaves a cell is as follows:

Denote the CIs of the visited cells and unvisited cells which are stored in the HISTORY by H_n and $\mathrm{H}_n^{'}$, respectively. Here n is the detailed value of the DI and $n = 0,1,2\cdots$. As known, the distance of two neighboring cells is one. Assuming that a cell DI is $\mathrm{H}_k (k = 0,1,2\cdots)$, the CIs of its neighboring cells are $\mathrm{H}_{k\pm1}$. The MC value equals to n and it changes (incremented, maintained, decremented, or reset) at each step according to our scheme. For demonstration purpose, we assume mesh configuration cells are rectangle shaped but with different size and different numbers of neighbors which is much like realistic networks as shown in Fig.2 which shows the storing method in the HISTORY.

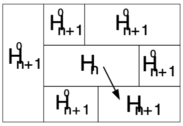

Fig. 2. An example Illustration for storing

As shown in Fig.2, an MS enters cell H_{n+1} from cell H_n. After the CI of the newly moved-in cell is determined, the CIs of H_n and its neighboring cells denoted by $\mathrm{H}_{n+1}^{'}$ which has not been visited by the MS are stored in the HISTORY. A specific example is to demonstrate the iMBLU scheme in Fig.3.

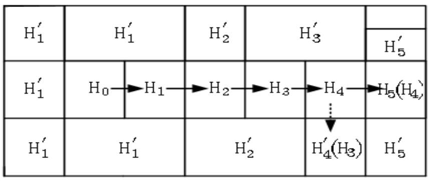

Fig. 3. An example path of an MS for the iMBLU scheme

Fig.3 shows an example path of an MS with mesh configuration cells which are irregular rectangle shaped. As shown in Fig.3, the MS performs the last LU in cell H_0. The CURRENT and HISTORY is NULL and the MC is set to zero. When the MS enters a new cell, the cell must be a neighbor of cell H_0 and denote it by H_1.

The MC is set to one. Denote by H_1' the other neighbors of cell H_0 and store cell H_1 and H_1' s in the HISTORY. For the second step, the MS first checks whether the CI of the cell is in the HISTORY or not. We can see that the cell CI is not in the HISTORY and then compare the DIs of its neighboring cells i.e. (H_1, H_1') stored in the HISTORY. The minimal distance is one. So the CI of the currently residing cell is H_{1+1} i.e. H_2. The MC is set to two. After that, the CIs of cell H_1 and its neighboring cells which are not stored in the HISTORY are stored in the HISTORY, denoted by H_2' as shown in Fig.3. Similarly, for the fifth step as the solid line shown, the DI should be the minimal index of (H_4, H_3', H_4') plus one i.e. $3+1=4$ and as the dotted line shown, the DI should be the minimal index of (H_4, H_3, H_2') plus one i.e. the CI should be H_3. However, because the cell is in the HISTORY, the final CI of the cell is min(H_4', H_3) i.e. H_3.The MC and the HISTORY is set following the above way as shown in the figure. In the way, an LU is performed only when the value of the distance between the currently residing cell and the last registered cell reaches the movement threshold. Unnecessary LUs are avoided when the MS moves around the recently visited cells.

Note that in all the schemes above, it is assumed that an MS receives beaconing signals from the corresponding BS containing IDs for the BS's own and its neighboring cells within the coverage area [6] [7]. Note also that our scheme is applicable to any cell configurations.

3 Simulation Results and Performance Analysis

We will show that the LU cost of our scheme is less than that of the DMBU and CMBLU schemes through simulation results. Due to the determination of the cell distance, the performance of the DMBU and CMBLU schemes are improved considerably. We can obtain the following LU costs formula between call arrivals [1] [5]:

$$C=\frac{U\lambda_m}{N(D)\lambda_c}. \quad (1)$$

Where C represents the LU cost, $N(D)$ is the average number of movements for an MS, and U denotes the unit LU cost required for one LU. The cell residence time and the incoming call arrivals are assumed to follow an exponential distribution with λ_m and a Poisson process with λ_c respectively. We define CMR (call to mobility ratio) as λ_c/λ_m. For showing the real characteristic of the PCS networks, irregular cell configuration is assumed.

Table 2. The Average Number of Movements of Three Schemes

	D	1	2	3	4	5	6
CMBLU	$N(D)_1$	1	2	3	4	5	6
DMBU	$N(D)_2$	1.00	2.97	5.35	7.50	9.81	12.00
iMBLU	$N(D)_3$	1.00	3.18	13.33	32.66	100.63	129.64

Table 2 shows the average number of movements of CMBLU, DMBU and iMBLU schemes compared to the corresponding conventional movement threshold D with CMR=0.1 through simulation. In this table, we can see clearly that in both the DMBU and iMBLU schemes, an MS can move more steps than it does in the CMBLU scheme to trigger an LU. Especially in the iMBLU scheme, only when the MC value which is the distance between the last registered cell and the currently residing cell equals to the movement threshold, an LU is triggered no matter how many cells the MS crosses. In this case, the number of LUs is significantly reduced when the MS moves around to the recently visited cells and the LU cost is accordingly decreased.

Fig.4 shows the LU cost of DMBU, CMBLU and iMBLU schemes for different CMRs with varying movement threshold values. The CMR is set to 0.1 and 0.05, respectively. It is also assumed that $U = 10$, as in [7]. We can see that the LU cost of iMBLU scheme is obviously significantly reduced as the movement threshold value increased in contrast to the DMBU and CMBLU schemes when the CMR maintains the same. It is also derived that the LU cost is in inverse proportion to the CMR when other parameters are fixed from formula (1). As shown in Fig.4, the LU cost of all of the three schemes is reduced as CMR increases. Note that this result is achieved in irregular cell configuration which is close to the reality of the real PCS networks. From fig.4 we can find the LU cost of the iMBLU scheme is the lowest in these three schemes. Hence, we prove that the performance of the iMBLU scheme is better than the DMBU and CMBLU schemes.

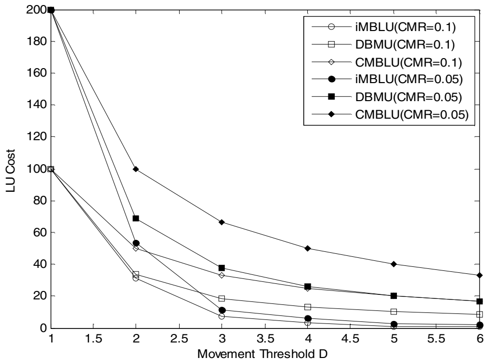

Fig. 4. LU cost of three schemes for different CMR values with varying movement threshold values

4 Conclusions

In this paper, an improved version of movement-based location update scheme was proposed. When the distance information rather than the movements kept in the MC reaches a certain value, an LU will be performed. The iMBLU scheme outperforms the CMBLU scheme. Simulation results show that a considerable reduction in the LU cost is gained in the iMBLU scheme. One of the biggest advantages of our scheme is that we can implement it in the real PCS networks, which is a challenge in the research of the mobility management. The proposal of our scheme is important to the implementation of the CMBLU scheme in the real PCS networks.

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