Reduction of Location Update Cost Using Hierarchical Architecture in PCS Networks

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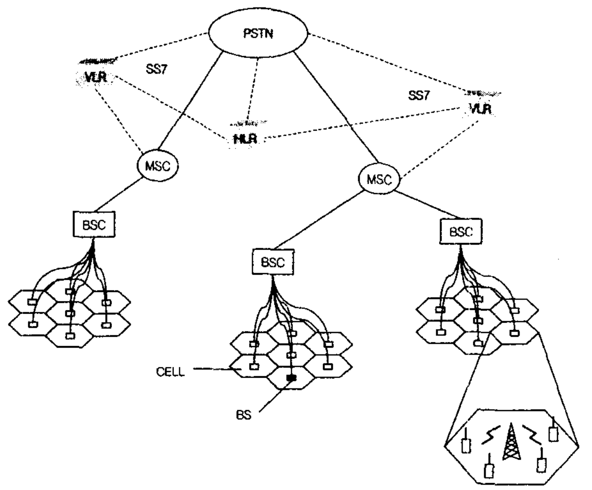
Abstract: Location management schemes dealing with location information of moving terminals play an important role in the personal communications systems (PCS) . Since the location management involves heavy signaling traffics to update the location information, reducing the location update cost becomes a critical research issue. This paper proposes a location management scheme which reduces the location update cost by employing the hierarchical structure in PCS environment. The paper also develops analytical models to evaluate the performance of the proposed scheme. The results obtained from the performance evaluation shows that the proposed scheme outperforms the conventional schemes in terms of the location update rates. Also, the difference in the performance becomes larger as the size of the location area (LA) becomes smaller and as the residual time of the mobile user becomes smaller.

1. Introduction

Mobile communication is very fast growing area in telecommunication industry over the last few years [1]. One of the main research issues in the area is how to manage the information on the location of moving terminals [2-7]. The location management involves two major tasks - *location update* and *paging*. The location update process updates the location information of the terminal whenever it enters a new LA. The paging is the process that sends the page message to the cells in the LA where the called terminal is located. The connection is set up when the called terminal responds to the page message.

The architecture of the PCS networks [8-10] is depicted in Figure 1. The entire service area consists of cells, and several of them are grouped into an LA. The cell site contains a base station (BS) which manages the air interface between the mobile terminal and the BS. Several BSs are wired to a Base Station Controller (BSC) and several BSCs are connected to a mobile switching center (MSC). The MSCs are connected to the backbone wired network such as public switching telephone network (PSTN). The MSC is the control element for the mobile wireless network. It is responsible for switching the call to the cell where the called terminal is located. The MSC communicates with a mobile terminal through BSC and BS.



BS	Base Station
BSC	Base Station Controller
HLR	Home Location Register
VLR	Visitor Location Register
MSC	Mobile Switching Center
PSTN	Public Switching Telephone Network
SS7	Signal System Number7

Figure 1. The Cellular Architecture in PCS

Two databases are used in the system: the home location register (HLR) and the visitor location register (VLR). The HLR keeps track of a subscriber's location, and it also stores information about the subscriber. The VLR keeps track of visiting subscribers that are operating in the specific VLR's territory. The location of a user is known by the subscriber's HLR and the visited VLR by exchanging information with each other. The VLR informs the subscriber's HLR when the subscriber logs on to its system and, in turn, the HLR updates its records, indicating that the subscriber is now located at this particular location. During the logon process, the HLR sends the information about the subscriber to the visited VLR. The protocol used in PCS networks is as follows.

Location update process:

1. A mobile terminal constantly receives the location area identifier (LAI) which is unique for each LA.
2. When the mobile terminal enters a new LA, the mobile terminal receives a different LAI. Then, the terminal sends a registration message to a new VLR.
3. The new VLR sends a registration message to the HLR.
4. The HLR sends a registration cancellation message to old VLR.
5. The old VLR sends a cancellation confirmation message to the HLR
6. The HLR sends a registration confirmation message to the new VLR.

Location finding process:

1. Call to a PCS user is detected at the local switch
2. If the called party is the in the same LA, then return.
3. Switch the query to the HLR
4. The HLR queries to the VLR in which the called party is registered.
5. The VLR returns the location of the called party to HLR
6. The HLR returns the location to the calling switch
7. The calling switch connects the called party using the location information received

The location update cost consists of the update cost of HLR and that of VLR. Since the HLR is connected to many VLRs as shown in Figure 1, reducing the traffic with the HLR becomes an important issue to reduce the whole location update costs. The paper proposes a location management scheme which reduces the location update cost using hierarchical architecture for LAs. The proposed scheme is presented in Section 2. The paper also develops analytical models to evaluate the performance of the proposed scheme. The performance evaluation is shown in Section 3. Finally, Section 4 concludes the paper.

2. The Proposed Scheme

The proposed scheme employs a *super location area* (SLA) which is a group of LAs. The paper assumes that the SLA consists of seven LAs. Also, the structure of LAI is modified as shown in Figure 2.

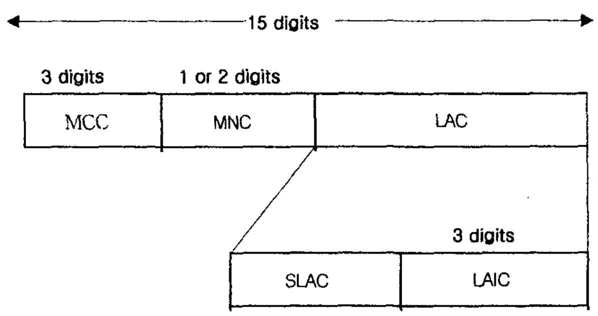


Figure 2. The Hierarchical Structure of the LAI

The LAI originally consists of 3 parts: the mobile country code (MCC), the mobile network code (MNC), and the location area code (LAC). The proposed scheme employs a hierarchical structure by dividing the LAC into two parts: the super location area code (SLAC) and the location area identification code (LAIC). The modified cellular architecture for the proposed scheme is depicted in Figure 3.

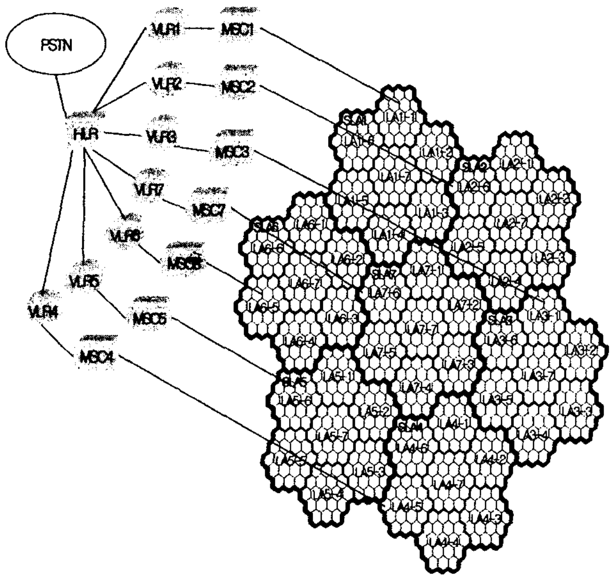


Figure 3. The Cellular Architecture Employing SLA

In the service area, the thickest line represents a boundary of a SLA while the second thickest line represents that of an LA. The thin line represents the boundary of the cell. The figure shows seven SLAs each of which, in turn, contains seven LAs. Each LA contains 19 cells. The notation LA*i-j* represents the cell belonging to LA *j* in SLA i. As in the conventional system, the mobile terminal receives a different LAI when the terminal enters a new LA. Then the terminal sends registration message to the corresponding MSC. The MSC reads the SLAC in the LAI and determines whether the new LA belongs to the same SLA or not. If the new LA belongs to the same SLA, only the VLR is updated in the proposed scheme while both HLR and VLR is required to be updated in the conventional system. The proposed scheme requires the HLR updates only when the mobile terminal enters a new SLA. Figure 4 shows an example of a user path. The terminal starts from location A belonging to LA6-7 which means the seventh LA in SLA 6. It moves to location D through B and C. The location of D is LA6-1 which is the first LA in SLA 6. Thus, the VLR is updated while the HLR is not. Since the conventional scheme does not employ any hierarchy, it should update not only the VLR but also the HLR. The whole update process is depicted in Table 1. The comparison depicted in Table 1 shows the reduction of the location update cost using the proposed architecture in this paper.

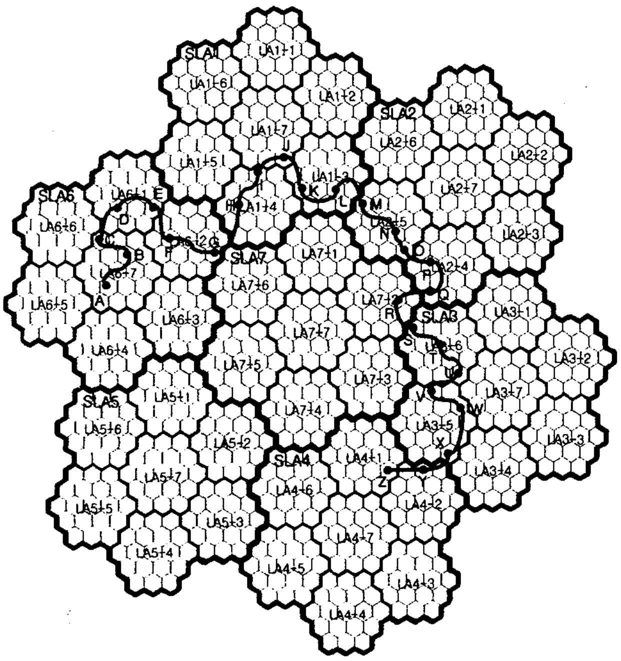


Figure 4. Path of a Mobile Terminal

Table 1. Comparison of The Location Update Cost

	Path	Registered LA	PCS	The Proposed Scheme
			Register Update	Register Update
1	A→B	LA6-7	None	None
2	B→C	LA6-7	None	None
3	C→D	LA6-1	VLR, **HLR**	VLR
4	D→E	LA6-1	None	None
5	E→F	LA6-2	VLR, **HLR**	VLR
6	F→G	LA6-2	None	None
7	G→H	LA1-4	VLR, **HLR**	VLR, **HLR**
8	H→I	LA1-4	None	None
9	I→J	LA1-7	VLR, **HLR**	VLR
10	J→K	LA1-3	VLR, **HLR**	VLR
11	K→L	LA1-3	None	None
12	L→M	LA2-5	VLR, **HLR**	VLR, **HLR**
13	M→N	LA2-5	None	None
14	N→O	LA2-5	None	None
15	O→P	LA2-4	VLR, **HLR**	VLR
16	P→Q	LA2-4	None	None
17	Q→R	LA7-2	VLR, **HLR**	VLR, **HLR**
18	R→S	LA3-6	VLR, **HLR**	VLR, **HLR**
19	S→T	LA3-6	None	None
20	T→U	LA3-6	None	None
21	U→V	LA3-5	VLR, **HLR**	VLR
22	V→W	LA3-5	None	None
23	W→X	LA3-5	None	None
24	X→Y	LA4-2	VLR, **HLR**	VLR, **HLR**
25	Y→Z	LA4-1	VLR, **HLR**	VLR

3. Performance Evaluation

We have developed analytical models to compare the update cost of the proposed scheme with that of the conventional scheme used in PCS networks. The followings are assumed in the model.

1. The service area is divided into hexagonal cells of equal size.
2. A mobile user moves to one of neighboring cells with probability 1/6.
3. The movements of mobile users are probabilistic and independent of one another.
4. The dwell time in any cell for a mobile user is an exponentially distributed random variable with the average value, $\overline{T_d}$.

The size of an LA is represented by the number of rings of cells, *d*, forming the LA. The rings of this LA are numbered 1, 2, ..., *d* from innermost (the center cell) to outermost. The notations used in the model are depicted in Table 2.

Table 2. The notations used in the model

$\overline{K}$	The average number of mobile users in a cell
d	The size of an LA
$\overline{T_d}$	The average dwell time
N	The total number of mobile users in an LA
N_c	The number of cells in an LA : $3d^2-3d+1$
N_{bc}	The number of boundary cells in an LA
N_S	The total number of mobile users in a SLA
N_{Sc}	The number of cells in a SLA
N_{Sbc}	The number of boundary cells in a SLA
$\overline{R_{LA}}$	The average location update rate for the given LA
$\overline{R_{SLA}}$	The average location update rate for the given SLA
$\overline{R_{MS}}$	The average location update rate per mobile user

The analytical models are presented as follow without derivation due to the space limit.

$$N = (3d^2 - 3d + 1)\cdot\overline{K}$$

$$\overline{R_{LA}} = (2d-1)\cdot\overline{K}\cdot\frac{1}{\overline{T_d}}$$

$$\overline{R_{MS}} = \frac{\overline{R_{LA}}}{N} = \frac{2d-1}{3d^2-3d+1}\cdot\frac{1}{\overline{T_d}}$$

$$N_S = 7(3d^2 - 3d + 1)\cdot\overline{K}$$

$$\overline{R_{SLA}} = (6d-3)\cdot\overline{K}\cdot\frac{1}{\overline{T_d}}$$

$$\overline{R_{MS}} = \frac{\overline{R_{SLA}}}{N_S} = \frac{6d-3}{7(3d^2-3d+1)}\cdot\frac{1}{\overline{T_d}}$$

Figure 5 and Figure 6 show the result of the performance evaluation study obtained from the model. In the figures, R-MS represents the HLR update rate with the conventional scheme while R-MS* represents that with the proposed scheme. Figure 5 shows the location update rates according to the size of LA. In the figure, *d* represents the number of cells belonging to the radius of the LA. Thus, LA with *d* value of *1* represents the LA consisting of *1* cell, that with *d* value of *2*, *7* cells, that with *d* value of *3*, *19* cells, and so on. The figure shows that the proposed scheme outperforms the conventional scheme. Also, the difference becomes larger when the size of LA becomes smaller. When the value of *d* is 3 as shown in Figure 4, the update rate of the proposed scheme is 0.11278 while that of the conventional scheme is 0. 26316. Figure 6 shows the location update rates according to the average residual time of mobile users. The figure also shows that the proposed scheme outperforms the conventional scheme. Also, the difference becomes larger as the residual time becomes smaller.

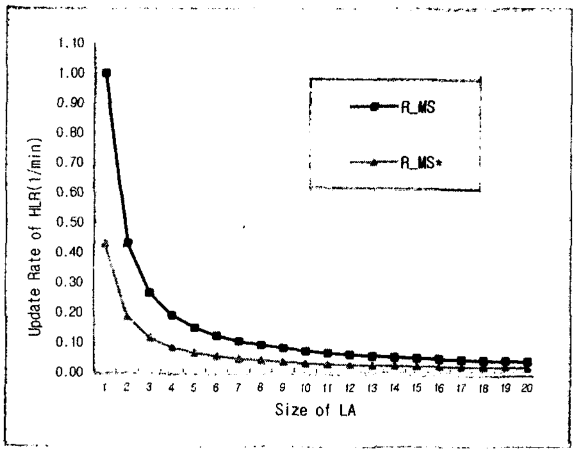


Figure 5. Update Rate of HLR According to the Size of LA

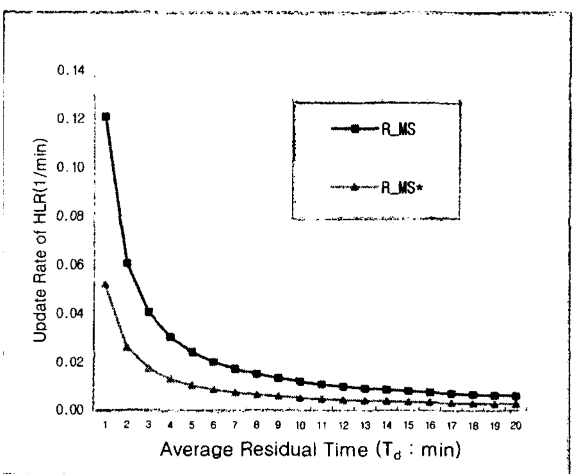


Figure 6. The Location Update Rates According to the Average Residual Time

4. Conclusion

Since the location update process requires heavy signaling traffics, reducing the location update cost becomes a critical research. The paper proposed a new location management scheme which reduces the location update cost by employing a hierarchical structure in PCS networks. The paper also proposed modified cellular architecture and LAI to enable the proposed scheme. We have developed analytical models to compare the performance of the proposed scheme with that of the conventional scheme. The results obtained from the model show that the proposed scheme outperforms the conventional scheme in terms of the location update rates. Also, the difference in the performance becomes larger as the size of the LA becomes smaller and as the residual time of the mobile user becomes smaller. Considering the active mobility of users and the high user density in each LA these days, the proposed scheme can be a good candidate for a location management scheme in the future.

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