Study of Location Management for Next Generation Personal Communication Networks

TEERAPAT SANGUANKOTCHAKORN and PANUVIT WIBULLANON

Telecommunications Field of Study
School of Advanced Technologies
Asian Institute of Technology
P.O.Box 4, Klong Luang, Pathumthani 12120
THAILAND
http://www.ait.ac.th

*Abstract:*The main target of location management is to maintain location of users while minimizing the system operation. The process consists of location update, paging, and database consideration. The location update and paging manages the user-network interaction cost as low as possible, while the database maintains user data and manages these data transferred efficiently.

This research studies the scheme combining Velocity Paging (VP) and Timer-based update strategy with Distributed Database (DDB), comparing to the standard strategy, Location Area scheme (LA) with Centralized Database (CDB).

The VP scheme estimates the paging area by the user's velocity and the time span from the last registration. In Timer-based update scheme, Mobile Terminal (MT) updates its location when the timer exceeds the Time Threshold. The performance evaluation of location update, paging, and database is achieved. In LA scheme, a good selection of location area assignment can minimize the total cost. However, when the user's behaviors change, the previous assignment cannot be optimum any more. For VP with Timer-based update scheme, a good selection of Time Threshold can minimize the total cost. Additionally, the Time Threshold can be adapted, according to user's behaviors, to minimize the cost. Meanwhile, the Distributed Database (DDB) can manage the data transferred more efficiently than the Centralized Database (CDB).

Key-Words: Location update, Velocity paging (VP), Timer-based update strategy, Location Area Scheme, Distributed Database (DDB), Centralized Database (CDB).

1 Introduction

The current Personal Communication Network (PCN) uses a cellular architecture. The geographical coverage area is partitioned into cells**,** each served by a base station. MTs are connected to the network via the base stations.

Location management enables the network to track the locations of users. Since MTs can move freely within the coverage area, the network can only maintain the approximate location of each user. When a connection needs to be established for a particular user, the network has to determine the user's exact location within the cell granularity. The operation of informing the network about the current location of the MT is known as *location update* or *location registration*, and the operation of determining the location of the mobile user is called *terminal paging* or *searching*.

In essence, location management for next-generation PCN, has to address the following issues:

- When the MT should update its location to the network?
- When a call arrives, how should the exact location of the called MT be determined within a specific time constraint?
- How should user location information be stored and disseminated throughout the network?

It is well known that there is a trade-off between the cost of location update and paging. If the MT updates its location whenever it crosses a cell boundary, the network can maintain its precise location, thus obviating the need for paging. However, if the call arrival rate is low, the network wastes its resources by processing frequent update information, and the MT wastes its power to transmit the update signal. On the other hand, if the MT does not perform location update frequently, a large coverage area has to be paged when a call arrives, which wastes radio bandwidth. Thus, the problem of location management is to devise algorithms that minimize the overall cost of location update and paging.

An Individual Location Area (ILA) management with Distributed Database (DDB) has been presented in [5]. The main disadvantage is that ILA has to be changed every time the users' parameters change. In [1], the users follow repetitive patterns that can be profiled and predicted with reasonable cost, allowing users to send update occasionally and not on every move. However this method considered only Registration Cost. In [4], only Paging Cost has been considered, and this does not guarantee paging delay. In [8], the different methods of location update and paging are presented but no mention about the performance of the combination of the location update and paging method.

In this research, Velocity Paging (VP) and Timer-based update method are used together to reduce the cost of location update.

Database structure is also an important one, which stresses on how the location of the users can be known. Even though the widely used database architecture, CDB, could maintain locations of the users, the excessive signaling traffic leads to poor performance. Other two problems concerning the database have emerged. One is if Home Location Management (HLR) is overloaded or unavailable, the system will lead to failure. Another is even though the callee is in the same area with the caller but far away from HLR, the searching for the callee has to be done at HLR.

CDB has a bottleneck in HLR while DDB has distributed information along the network. Therefore, DDB seems to be the next generation mobile database architecture.

2 Preliminary

2.1 Location Update and Paging

The wireless network is modeled after a generic personal communication system. Cells are assumed to be hexagons of equal size. All cells together define the coverage area of the system. Calculations include the Location Area (LA) scheme (both registration and paging), the Timer-based registration scheme, and the basic Velocity Paging (VP) scheme. Registrations are also performed when the MT is powered up and down.

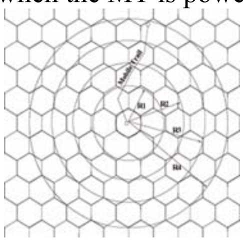


Figure 2.1: Illustration of Circular Area Approximation [7]

2.1.1Timer-based Update Scheme

Each MT updates its location every T time units (e.g. T = 1 hour). The incoming call traffic is assumed to be constant so that we can consider the value of T which is the most matches to the VP scheme. For a real implementation, T should be adaptive due to the incoming load.

To keep track of individual mobile's movement, some form of velocity information has to be obtained. To cooperate with the VP scheme, following attributes are needed in the mobile's database:

- The last known location
- The last registration time
- Number of cells crossed during time threshold T

In the second attribute, each MT keeps a counter of moves and increases it every time it moves to another cell. Therefore an individual mobile's velocity is obtained in term of cell/hour or cell/minute by the formula:

$$X = \frac{\text{Number of cell crossed during T (cells)}}{\text{Time threshold T (hour or minute)}} \qquad (2.1)$$

2.1.2 Velocity Paging (VP) scheme

The VP mechanism will be invoked when the system tries to deliver a call to a standby MT:

1. The system asks the database for the MT's last known location, last registration time, and number of cells crossed during time threshold.

2. The system calculates the velocity (cell/hour or cell/minute) of the MT from Eq. (2.1). Then the system calculates the maximum distance the MT could have traveled since the last registration by using formula:

$$R = X \cdot t \qquad (2.2)$$

Where, R is the maximum distance (cells). X is velocity of the MT (cell/hour). t is time span from the last registration by using the current time minus the last registration time (hour).

2.2 Cost Function

The following cost functions, which will be used here as the evaluation criteria, have been derived and shown in details in [5][6][7].

(i) Paging Cost of Location Area (LA) scheme.
(ii) Registration Cost of Location Area (LA) scheme.
(iii) Paging Cost of Velocity Paging (VP) scheme.
(iv) Registration Cost of Timer-based Update scheme.

2.3 Call Traffic and Mobility Model

Call arrival process is modeled as Poisson process. The mean holding time of users has negative exponential distribution.

MTs move within the geographical area covered by the system. Each MT is associated with a movement class (as described in Table 2.1). Its speed follows the normal distribution defined in the movement class.

Movement destinations are randomly selected according to cell traffic loads. The data transfer algorithm of the CDB and DDB is described in [3].

Table 2.1: Movement classes for two systems [7].

(a). High mobility system

Movement Class	Velocity (km/hr) (95% Class Index)	User Percentage
MC_1	0-10	50%
MC_2	15-35	48%
MC_3	40-80	2%

(b).Low mobility system

Movement Class	Velocity (km/hr) (95% Class Index)	User Percentage
MC_1	0-10	25%
MC_2	35-80	74%
MC_3	110-150	1%

2.4 Simulation Model

The simulation time of every simulation is 2 hours. In the simulation, the 8 UIN (UMTS Information Nodes) symmetry DDB is generated. Exponentially distributed service times are assumed and independent of each other. The following assumptions are made concerning the rules for routing the DDB queries [7].

- The query is viewed as a search along the DDB directory to localize the node containing the UMTS data required.
- Each query regarded as a job generated in an UIN, moves from one node to another until it reaches the queue representing the node in which the query is satisfied.
- No query transits through the same queue more than once.
- Only transition between adjacent levels in the tree hierarchy is allowed.
- Transition toward upper level means that the information being sought has not been found in the subtree from which the query has come. Transition toward lower level implies a refinement of the search made in the root of the subtree toward which the query is forwarded.
- When a query starts to propagate down the tree, it has to continue propagating downward, as this implies that the subtree with the UIN containing the information being sought has been identified.

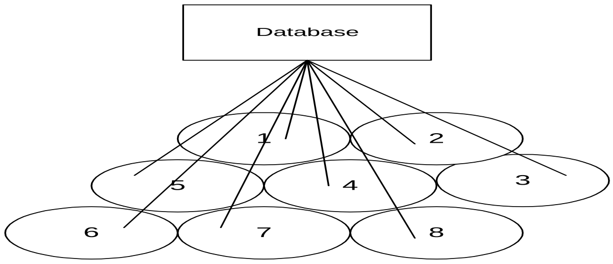


Figure 2.1: Simulation Model

- The database (both DDB and CDB) has 8-leave node. Each node is responsible for 19 cells. (Because in analytical, the best LA scheme has N_{LA} = 19).
- Call initiations and Location updates are the query traffic entering corresponding UIN 1 to 8.
- When a call initiation enters the database, it computes the time span from the last registration in order to use this value in the analysis of Paging Cost (for VP scheme).
- The performance of the database is evaluated as the query load and the average search time. Two Types of processing time are considered according to [2]:

(i) 5ms for all actions related with data retrieval and update from a DDB node.
(ii) 10ms when a record is read, deleted or written.

We assume the exponential distribution of service time for

- UIN with mean 10 ms.
- DIN (Directory Information Nodes) with mean 5 ms. (DINs contain only the directory data not the UMTS data)
- VLR and HLR with mean 10 ms.

The LA and VP scheme uses CDB and DDB respectively as its database. The average search time and query load in each node of the database are obtained by the simulation program.

2.5 Performance Comparison

Table 2.2: System Parameters [7].

Parameter	Value	Remark
α	30%	Mobile terminating call
N_{sub}	150,000	Number of subscribers
β	80%	Power up probability
T_{call}	2	Average call duration
C'_{pag}	1	Paging Cost for LA scheme
C'_{reg}	2	Registration Cost for LA
C_{pag}	1.1	Paging Cost for VP scheme
C_{reg}	2.2	Registration Cost for VP

The performance of VP with Timer-based update is evaluated and discussed by selecting the LA scheme as the performance benchmark. The commonly used parameters are as shown in Table 2.2.

3 Simulation Results

3.1 An Investigation of Cost Function in LA Scheme

3.1.1 Location Update Cost in LA Scheme

There are three core parameters determining the cost of LA-based update method: mean velocity of MTs, number of cells in one location area N_{LA}, and cell size r.

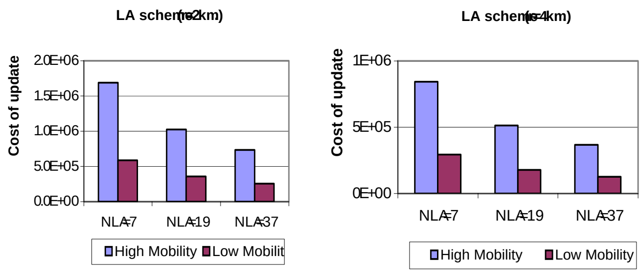
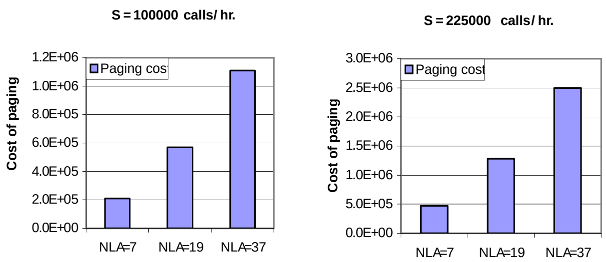


Figure 3.1: Cost of LA-based update scheme with cell radius

Figure 3.1 (a) shows that, for larger location area, the cost of LA-based update become lower, because MTs cross the larger location area's boundary at lower rate than the smaller location area. Figure 3.1 (b) shows that the system with larger cell radius, r, will has lower Registration Cost than the system with smaller r under the same number of cells in the area.

3.1.2 Paging Cost in LA Scheme

The two main parameters determining the Paging Cost in LA scheme are: number of cells in a location area N_{LA}, and number of call attempt in the system S.



(a) S=100,000 calls/hr (b) S=225,000 calls/hr

Figure 3.2: Paging Cost in LA scheme with number of call attempt.

Figure 3.2 (a) shows that the larger the number of cells in a location area, the higher the Paging Cost, because the system pages larger coverage area. Figure 3.2 (b) shows that the Paging Cost also depends directly on S. If the system has more call attempted, the Paging Cost will be higher.

3.1.3 Total Cost Function

In this section, the LA, which shows the best performance, will be selected as a benchmark to compare with VP scheme.

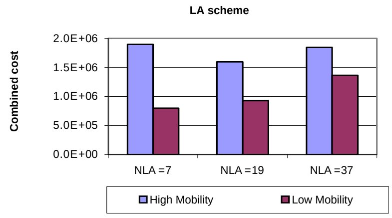


Figure 3.3: Combined Cost of LA scheme (S = 100,000 calls/hr; r = 2 km)

From Figure 3.3, it is obvious that the LA with N_{LA} = 19 has the lowest cost in high mobility system and the cost in low mobility system is slightly higher than the LA with N_{LA} = 7.

At N_{LA} = 19 offers the best performance and will be used as a comparison to VP scheme.

● Location update and Paging Cost are trade off to each other. Only a good selection of LA assignment can minimize them.

● Even though, LA offers trade off between registration rate and paging traffic, in low mobility system, paging seems to have much more influence on the total cost. Total cost appears to be an increasing function of paging and thus decreasing function of N_{LA}.

● In large LA, where the paging coverage area is large, Paging Cost is dominant.

3.2 An Investigation of Cost Function in VP scheme

3.2.1 Timer-based Update Cost

The main parameter determining the Registration Cost is Time Threshold T. Parameter for VP scheme is S = 100,000 calls/hr. Parameters for LA scheme is S = 100,000 calls/hr., N_{LA} = 19, and r = 2km.

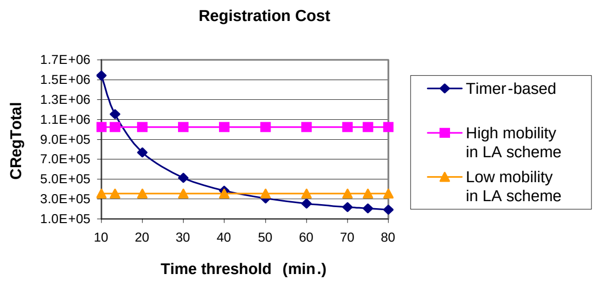
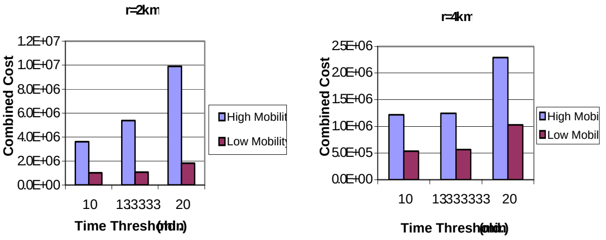


Figure 3.4: Cost of location update in LA scheme and Timer-based update scheme

Figure 3.4 shows that, for small Time Threshold T, the Registration Cost in Timer-based update scheme is high because MTs perform frequent update.

3.2.2 Relationship between Paging Cost, Time Threshold, and Cell Size



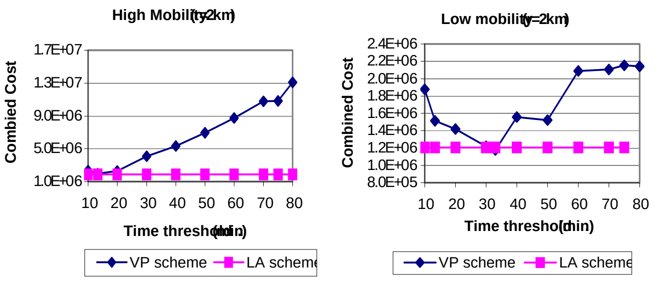
(a) 2 km (b) 4 km

Figure 3.5: Paging Cost in VP scheme (S= 225,000 calls/hr).

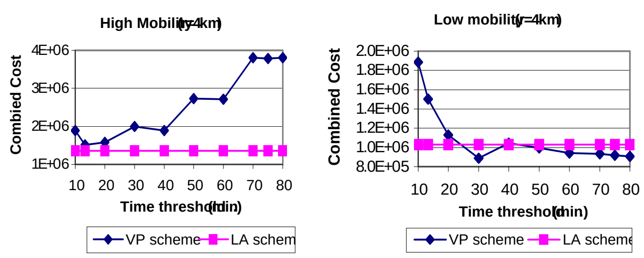
Figure 3.5 (a) shows that the larger Time Threshold, the higher Paging Cost. Since VP scheme estimates larger coverage paging area due to the fact that MTs update their location less frequent. In high mobility system, Paging Cost is higher than that of low mobility system, because VP scheme estimates larger paging area due to their higher velocity.

In Figure 3.5 (b), for larger cell size r, MTs cross fewer cells during the Time Threshold. Less velocity (in term of cell/hr.) is then recorded into the database. When paging action is required, the smaller paging area is polled. Therefore, Paging Cost is less.

3.2.3 Total Cost Function

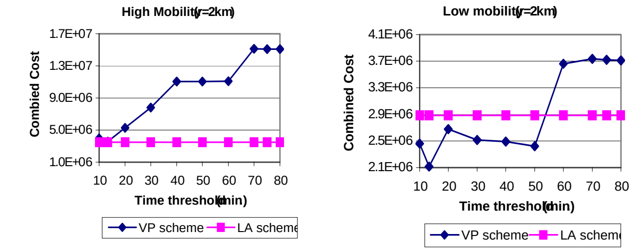


(a) 2 km (b) 2 km

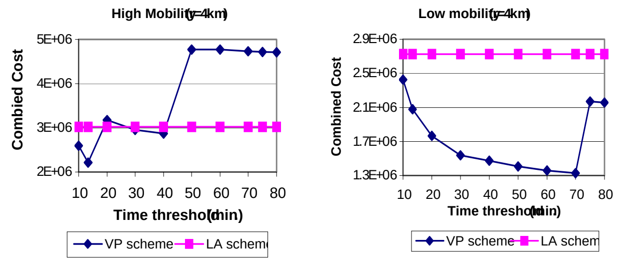


(c) 4 km (d) 4 km

Figure 3.6: Combined Cost in VP scheme (S = 150,000 calls/hr).



(a) 2 km (b) 2 km



(c) 4 km (d) 4 km

Figure 3.7: Combined Cost in VP (S = 450,000 calls/hr).

Comparing Figure 3.6 with 3.7, the following statements can be made.

- VP scheme works well for a large number of call attempt in the system.
- Location update and Paging Cost are trade off to each other. A good selection of T can minimize the Total Cost.
- Registration Cost in Timer-based update scheme is independent of velocity of the MTs, and the cell radius r.
- In VP scheme, for high mobility system, frequent registration is needed. From Figure 3.4, the cost of frequent update (T=10 min. and T=13.33 min.) is much higher than that of LA scheme and also VP scheme suffers from 10% increment cost over the LA scheme. The 10% of the large number have a significant influence for VP scheme. These are the reasons why VP scheme does not show better performance than LA scheme in the high mobility system.
- The number of calls attempted and cell radius have much influence to VP scheme. The more value of these parameters, the better performance of the VP scheme is.

3.2.5 Combined Cost Trend as a Function of Cell Radius

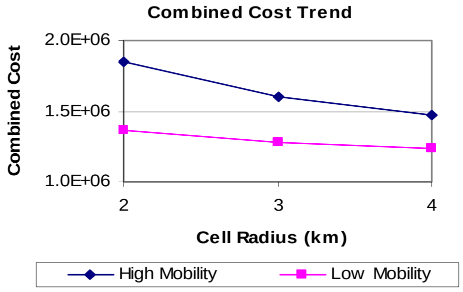


Figure 3.8: Combined Cost Trend as a function of cell radius in LA scheme (S = 100,000 calls/hr)

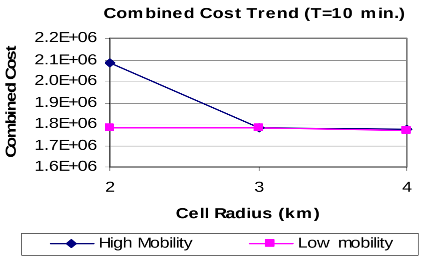


Figure 3.9: Combined Cost Trend as a function of cell radius in VP scheme.

From Figure 3.8 and 3.9, we can summarize the trend of performance as shown in Table 3.1.

Table 3.1: Trend of performance when S, r, T, and N_{LA} are increased.

	LA		VP	
	Update Cost	Paging Cost	Update Cost	Paging Cost
Increase S	-	+	-	+
Increase r	-	0	0	-
Increase T	X	X	-	+
Increase N_{LA}	-	+	X	X

Where, + :The value of performance figure increases.
- : The value of performance figure decreases.
0 : The value of performance figure does not change.
X : The increase value is not used in the scheme.

4 Conclusions

The system under consideration can be divided into two parts. One is Location update and paging strategy, the other is Database. The performance of the location update and paging part and the database part can be evaluated by using the equations derived in [9].

● In designing location update and paging scheme, the minimum cost is obtained when the best trade off between paging and location update is reached.

● In LA scheme, the optimal cost is found by selecting a suitable number of cells in a location area N_{LA}. As N_{LA} becomes larger, the Paging Cost is higher, but the Registration Cost and the database load are lower. The size of LA must be selected according to the MT's velocity.

● In VP scheme, the optimal cost is found by selecting a suitable Time Threshold T and cell size r. As T becomes larger, the Paging Cost is higher, but the Registration Cost and the database load are lower. T must be selected according to the traffic load S and the MT's velocity. However the Registration Cost of Timer-based update scheme does not depend on MT's velocity.

● In our case study, the more traffic load S and the cell size r are, the better performance VP scheme performs. The results show that VP scheme with DDB is much better, especially in low mobility system, than LA scheme with CDB.

References:

[1] Adly, N. and El-Nahas, A., "A Profile-based Hierarchical Location Management Scheme for Future PCS", *Proceeding on 11th International Workshop IEEE*, 2000, pp.204-208.
[2] Casares, V., Paradells, J., and Crespo, A., "Evaluation Studies of DDB Architecture with Hierarchical Structure", *IEEE International Conference on Universal Personal Communications*, 1994, pp.345-349.
[3] MONET61,"Implementation Aspects of the UMTS Database", *CEC Deliverable R2066/PTT NL/MF1/DS/P/061/b1*.
[4] Rose, C. and Yates, R., "Minimizing the Average Cost of Paging under Delay Constraints", *ACM/Baltzer Journal Wireless Networks*, vol.1, no.2, July 1995, pp. 211-219.
[5] Tabbane, S., "An Alternative Strategy for Location Tracking", *IEEE Journal on Selected Area in Communications*, vol.13, Issue 5, June 1995, pp. 880-892.
[6] Thomas, R., Gilbert, H., and Mazziotto, G., "Influence of the Moving of the Mobile Stations on the Performance of a Radio Mobile Cellular Network", *Proc. 3rd Nordic Seminar on Digital Land Mobile Radio Communications, 1998*
[7] Wan, G. and Lin, E., "Cost reduction in Location Management Using Semi-realtime Movement Information", *Baltzer Journals* February 10, 1998.
[8] Wong, V. W. –S. and Leung, V. C. M., "Location Management for Next-Generation Personal Communications Networks", *IEEE Network*, September/October 2000, pp18-24.