Journal of the Korean
OR/ MS Society
Vol. 20, No. 3, December 1995

Subscriber Grouping for Multi-Layered Location Registration Scheme in Microcellular PCS

Chae Y. Lee · Seok J. Kim*

Abstract

In a microcellular personal communication service(PCS), it is required to minimize the paging and location updating signals. We propose a multi-layered location registration scheme to reduce the paging and updating signals. In this scheme the subscribers are grouped by their characteristics (velocity and call arrival rate) and are served by appropriately sized location registration area. In order to group the subscriber, we define subscriber grouping probelm (SGP). Propostitions are examined to solve the grouping problem. The performance of the proposed subscriber grouping algorithm is tested with examples. Simulation results indicate that the subscriber grouping procedure is effective for designing the multi-layered location registration scheme.

1. INTRODUCTION

The importance of the microcellular system increases in personal communication service (PCS) to accommodate the increasing number of subscribers. Since the cell size is very small, the mobility management of each subscriber are important in PCS microcellular system. One emerging problem of mobility management in the PCS microcellular system is the efficient paging and location updating scheme.

Many paging and location updating schemes are appearing recent research. To reduce the paging signals in one paging area system, Munoz-Rodriguez [1] introduces the cluster paging scheme. In the scheme, a subscriber is first paged within a cluster of base stations including the home location cell. If the subscriber does not exist in the cluster, another

* Dept. of Industrial Management, KAIST

clustered base stations are searched. This procedures is repeated until the subscriber is paged. In the worst case, all the base stations must be searched for the subscriber. Thus, the call setup time in the cluster paging scheme may be greater than that in one paging area scheme.

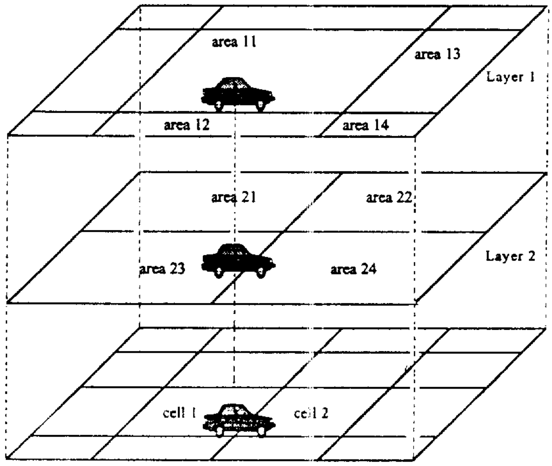
One natural selection to improve the cluster paging scheme is to divide the paging area into fixed subareas [3,4,5,6]. In the fixed location registration (LR) area, it is easy to manage paging and location registration. The location of a subscriber who moves in or out of a particular fixed LR area is updated in the visitor location registration and used for paging. Also in the system, since the location updating procedure is activated when a subscriber leaves out of the fixed area, the updating signal occurs only at a boundary cell of the fixed LR area. Thus in the boundary cells, the shortage of control channels is expected since the occurrence of updating signals is porportional to the amount of traffic. Clearly, the shortage becomes serious when the velocity of each subscriber increases.

To reduce the boundary cell overload, a method with layered LR area is employed by Okasaka et al. [4]. The subscribers are divided into groups and each group is served by an identical layer. In the scheme, each cell is included in one or more layers depending on the amount of traffic at the cell. When a subscriber leaves one area, the location is updated to another area of the same layer or the an area under different layer. The determination of the layer is controlled by the traffic density at each cell.

To minimize the paging and location updating signals, we propose a multi-layered scheme. The multi-layered scheme is illustrated in Figure 1. Each layer is composed of updating signals is proportional to the LR areas which cover all cells in the system and serve subscribers who have similar characteristics. To implement the multi-layered scheme, we first decide the number of layers. Next, we decide the subscriber group which is served by a layer. In each layer the LR area size is determined by the characteristics of the assigned group. Then, each subscriber is served by the layer which has the minimal paging and location updating signal cost.

In Section 2, we analyze the paging and location updating signals and propose the multi-layered location area scheme. Subscriber grouping problem is defind and some propositions and the solution procedures to solve the problem are introduced in Section 3. We perform some experiments and analyze the results in Section 4.

Figure 1. Multi-layered LR area Scheme



2. Multi-layered Scheme for Paging and Location Registration

For the purpose of reducing the paging and location updating signals, we propose a multi-layered location registration scheme in this section. Before we propose the multi-layered scheme, we first examine the characteristics of paging and location updating signals.

Consider a simplified cost function of paging and location updating signals of a subscriber. If the radius of an LR area is large, a large number of paging signals is required which is proportional to the number of microcells in the LR area. Thus, the paging cost is propotional to the radius of the LR area. On the other hand, if the radius of the LR area is small, the probability of outgoing the current LR area is large. Thus, the updating cost is inversely proportional to the radius. Therefore, the following paging and location updating cost function is considered.

$$TC(R) = \alpha a R^2 + \beta \frac{v}{R}$$

where R : the radius of the LR area

a : call arrival rate

v : subscriber velocity

α : paging cost coefficient

β : updating cost coefficient

The optimal radius, given the call arrival rate and velocity, is obtained by partial differenciation of R.

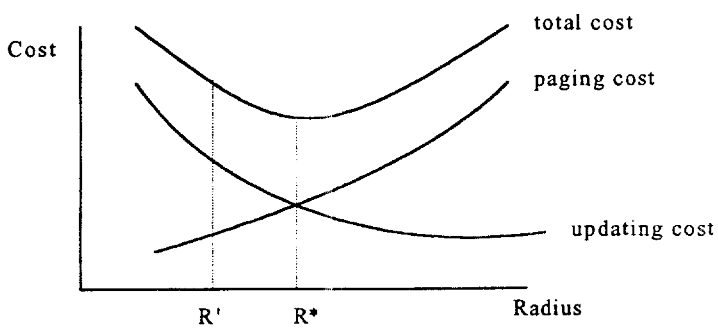
$$R_{opt} = \left(\frac{\beta}{2\alpha}\frac{v}{a}\right)^{\frac{1}{3}}$$

The total cost of the subscriber with R_{opt} then becoms :

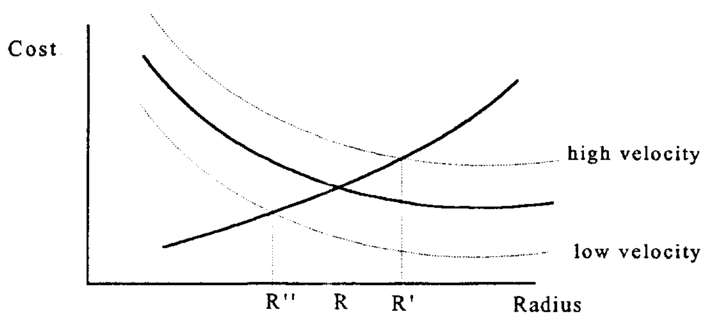
$$TC(R_{opt}) = \alpha a\left(\frac{\beta}{2\alpha}\frac{v}{a}\right)^{\frac{2}{3}} + \beta\left(\frac{\beta}{2\alpha}\frac{v}{a}\right)^{\frac{1}{3}}$$

In the equation the total cost is determined by the ratio of the veloctity to the call arrival rate. In the remaining part of this paper, the v/a ratio is refered to as the subscriber characteristic. To minimize the signal cost, a large LR area has to be considered for a subscriber with high v/a ratio while a small area for a subscriber with low ratio. Figure 2 shows the relationship between the cost and radius of the area with given velocity and call arrival rate. Note in the total cost function that as the velocity of a subscriber increases, the total cost also increases. As a result, the optimal radius of the LR area also increases the optimal radius to minimize the paging and location updating cost. This is illustrated in Figure 4.

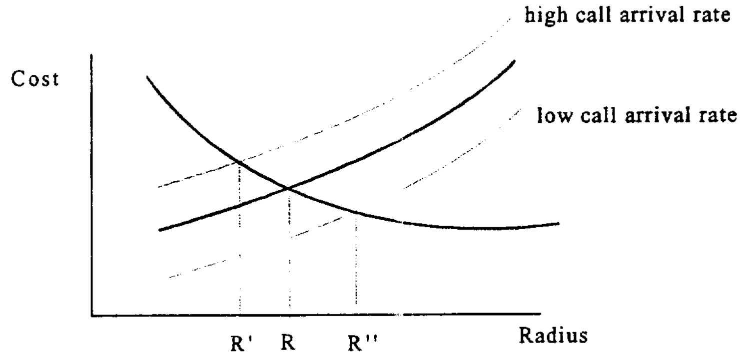
〈Figure 2〉 The Relationship between Cost and Radius of the Area



〈Figure 3〉 The Change of Optimal Radius with Different Velocities



〈Figure 4〉 The Change of Optimal Radius with Different Call Arrival Rates



If we know the subscriber characteristic, we can construct an optimal LR area for each subscriber. However, this individual based approach is impossible due to the limited database capacity and time for location updates. Therefore, we are interested in construction multi-layered LR area. Each layer represents a group of subscribers who have similar characteristics in view of velocities and call arrival rates. Thus the microcells are partitioned in each layer such that signal cost of the group is minimized. We suppose that the optimal radius of a LR area of a subscriber is R^* as in Figure 2. Also suppose that the subscriber is served by a layer and the radius of the layer is R'. Then the paging and location updating cost in the layered system increases compared to the individual cost function. Thus, grouping of subscribers in necessary to reduce the signal cost in the multi-layered system.

Each group of subscribers are charaterized by velocity and call arrival rate. Each subscriber is then served by an appropriate layer in which the LR area is determined by the group by an appropriate layer in which the LR area is determined by the group characteristic. Since the subscriber characteristic is time variant, the change of velocities and call arrival rates has to be reflected by changing the layer. The LR area updating and paging procedure in multi-layered scheme is as follows:

Multi-Layered LR Scheme

UPDATING : If a subscriber leaves out of current LR area,

i) check the current velocity and call arrivals, v/a

ii) if v/a belongs to the current group, updating the LR area in the same layer

otherwise, find the group to which v/a belongs and update to the corresponding layer which serves the group

PAGING : If paging request for the subscriber arrives,

i) check the layer to which the subscriber belongs

ii) page the subscriber in the area of the layer

3. Subscriber Grouping Problem(SGP)

As we mentioned in the previous section, subscribers must be grouped such that they have similar characteristics. To define the subscriber grouping problem, we consider two types of location registration cost of multi-layered scheme. One is location updating and paging signal cost ($C_2(L)$: L is the numbr of layers) which is discussed in the previous section. The other is layer management cost ($C_1(L)$). The layer management cost is composed of two parts. One is database management cost which is proportional to the number of layers. It includes the memory and scanning cost of the database. The other part is signal cost which occurs when each base station broadcasts the LR area identification to its cell. The number of LR area identification of one cell is same as the number of layers. The broadcast signal cost is also proportional to the number of layers. Thus, the layer management cost is assumed linear to L and the number of subscribers in the system. Then, the layer managment cost function is as follows.

$$C_1(L) = \sum_{i=1}^{N} \theta L = \theta N L$$

where θ is the unity layer management cost and N is the number of subcribers.

We assume that a subscriber with velocity v_i and call arrival rate a_i is in the jth group, and that all subscribers are partitioned into L groups. Each group is represented with a particular v/a ratio, and assumed to be served by the LR area computed with that ratio. Let the v/a ratio of jth group be r_j and the set of subscriber characteristic ratios in jth group be I_j. Then, the paging and updating cost of the subscriber i in group j is computed as follows;

$$TC_i = \alpha a_i \left(\frac{\beta}{2\alpha} r_i\right)^{\frac{2}{3}} + \beta v_i \left(\frac{\beta}{2\alpha} r_j\right)^{-\frac{1}{3}}$$

Using the above cost function, we define the paging and location updating cost of all subscribers in the system as follows.

$$C_2(L) = c_1 \sum_{j=1}^{L} \left(r_j^{\frac{2}{3}} \sum_{i=I_j} \alpha_i\right) + c_2 \sum_{j=1}^{L} \left(r_j^{-\frac{1}{3}} \sum_{i \in I_j}^{L} v_i\right)$$

where $c_1 = \alpha(\frac{\beta}{2\alpha})^{\frac{2}{3}}$, $c_2 = \beta(\frac{\beta}{2\alpha})^{-\frac{1}{3}}$

Then, the subscriber grouping problem (SGP) is formulated as follows:

$$Min \left\{ \theta NL + c_1 \sum_{j=1}^{L} (r_j^{\frac{2}{3}} \sum_{i \in I_j}^{L} a_i) + c_2 \sum_{j=1}^{L} (r_j^{-\frac{1}{3}} \sum_{i \in I_j}^{L} v_i) \right\}$$

where $c_1 = \alpha(\frac{\beta}{2\alpha})^{\frac{2}{3}}$, $c_2 = \alpha(\frac{\beta}{2\alpha})^{-\frac{1}{3}}$

In the formulation, we must decide the optimal number of layer L and grouping of the subscriber characteristics simultaneously. Since traditional methods can not be applied easily, we suggest the following algorithm to solve the mininiization problem.

Algorithm SGP

Step 0) let $L=2$, $min = BIGM$ and $best-groups = I(1)$

Step 1) solve the problem minimize $C_2(L)$

Step 2) if $C_1(L) + C_2(L) < min$

$min = C_1(L) + C_2(L)$

$L = L+1$

$best-groups = I(L)$

if $C_2(L) + C_2(N) < \theta N$ goto Step 3

else goto Step 1

Step 3) optimal group = *best-groups*

optimal cost = *min*

terminate

In the Algorithm SGP, the termination criterions $C_2(L) + C_2(N) < \theta N$. Since the decreament by the increasing the number of layers is smaller than increament of the layer management cost, we can not reduce the cost. Thus, we must stop algorithm.

To solve the minimization problem of $C_2(L)$, we introduce the following propositions.

Proposition 1 There is no subscriber who satisfies the following condition in the optimal grouping, i.e, the subscriber groups are divided into mutually disjoint intervals of the v/a ratios.

$$\frac{v_{i_1}}{a_{i_1}} > \frac{v_{i_2}}{a_{i_2}} \quad \text{and } i_1 \in I_{j_1},\ i_2 \in I_{j_2}\ (r_{j_2} < r_{j_2})$$

Proof We first define the cost of two subscribers.

$$TC_{i_1} = \alpha a_{i_1}\left(\frac{\beta}{2\alpha} r_{i_1}\right)^{\frac{2}{3}} + \beta v_{i_1}\left(\frac{\beta}{2\alpha} r_{i_1}\right)^{-\frac{1}{3}}$$

$$TC_{i_2} = \alpha a_{i_2}\left(\frac{\beta}{2\alpha} r_{i_2}\right)^{\frac{2}{3}} + \beta v_{i_2}\left(\frac{\beta}{2\alpha} r_{i_2}\right)^{-\frac{1}{3}}$$

Exchanging the group of the two subscribers $i_1 \in I_{j_2}$, $i_2 \in I_{j_1}$ $(r_{j_1} < r_{j_2})$, the changing cost are calcuated as follows.

$$(TC_{i_1} - TC'_{i_1}) + (TC_{i_2} - TC'_{i_2}) = \alpha a_{i_1}\left(\frac{\beta}{2\alpha}\right)^{\frac{2}{3}} (r_{j_1}^{\frac{2}{3}} - r_{j_2}^{\frac{2}{3}}) + \beta v_{i_1}\left(\frac{\beta}{2\alpha}\right)^{-\frac{1}{3}} (r_{j_1}^{\frac{1}{3}} - r_{j_2}^{\frac{1}{3}})$$
$$+ \alpha a_{i_2}\left(\frac{\beta}{2\alpha}\right)^{\frac{2}{3}} (r_{j_2}^{\frac{2}{3}} - r_{j_1}^{\frac{2}{3}}) + \beta v_{i_2}\left(\frac{\beta}{2\alpha}\right)^{\frac{1}{3}} (r_{j_2}^{\frac{1}{3}} - r_{j_1}^{\frac{1}{3}})$$

Let $a_{i_1} = a_{i_2}$ then $v_{i_1} > v_{i_2}$ $(v_{i_1} = v_{i_2} + \theta \ : \ \theta > 0)$.

$$(TC_{i_1} - TC'_{i_1}) + (TC_{i_2} - TC'_{i_2}) = \beta\left(\frac{\beta}{2\alpha}\right)^{\frac{1}{3}} (r_{j_1}^{-\frac{1}{3}} - r_{j_2}^{-\frac{1}{3}}) > 0$$

If the above condition is satisfied, we can reduce the cost by exchanging the subscriber groups. □

Proposition 2 Given L and I_j $(j = 1, \cdots, L)$, the optimal ratio in r_j in group j is

$$\frac{(\sum_{i=1}^{N} v_i)/N}{(\sum_{i=1}^{N} a_i)/N}.$$ (where N is the number of subscribers in the jth group.)

Proof To minimize the cost, we must decide the optimal radius R of the group. Since

$$\sum_{i=1}^{N} (\alpha a_i R^2 + \beta \frac{v}{R}) = (\alpha \sum_{i=1}^{N} a_i) R^2 + (\beta \sum_{i=1}^{N} v_i) \frac{1}{R}$$

where N is the number of subscribers in the group.

If take the partial differentiaiton over R, and set it to zero, then

$$2(\alpha \sum a_i) R - (\beta \sum v_i) \frac{1}{R^2} = 0$$

$$R_{opt} = \left(\frac{\beta \sum_{i=1}^{N} v_i}{(2\alpha \sum_{i=1}^{N} a_i)}\right)^{\frac{1}{3}} = \left(\frac{\beta(\sum_{i=1}^{N} v_i)/N}{(2\alpha \sum_{i=1}^{N} a_i)/N}\right)^{\frac{1}{3}} = \left(\frac{\beta}{2\alpha} r_j\right)^{\frac{1}{3}}$$

Thus, the optimal ratio of the group j is $\dfrac{(\beta \sum_{i=1}^{N} v_i)/N}{(2\alpha \sum_{i=1}^{N} a_i)/N}^{\frac{1}{3}}$. □

Proposition 3 Given L and ratios $r_1, r_2, \cdots, r_n$, the optimal boundary point between group j and $j+1$ is $\dfrac{(r_j^{\frac{1}{3}} + r_{j+1}^{\frac{1}{3}})\, r_j^{\frac{1}{3}}\, r_{j+1}^{\frac{1}{3}}}{2}$.

Proof Consider a subscriber whose subscriber characteristic value satisfies $r_j \le \frac{v}{a} \le r_{j+1}$. We determine which layer serves each subscriber.

By proposition 1, since the subscribers are grouped into mutually disjoint intervals, we can know the boundary points by knowing which layer serves the suscribers. Let the cost of subscriber i in group j be $TC_i^{(j)}$. Then from the above function.

$$TC_i^{(j)} = c_1 a R^2 + c_2 \frac{v}{R} = c_1 a\left(\frac{c_2}{2c_1} r_j\right)^{\frac{2}{3}} + c_2 v\left(\frac{c_2}{2c_1} r_j\right)^{-\frac{1}{3}}$$

If the subscriber is satisfied $TC_i^{(j)} = TC_i^{(j+1)}$, then the subscriber is on the boundary point of the interval j and $j+1$.

$$c_1 a\left(\frac{c_2}{2c_1} r_j\right)^{\frac{2}{3}} + c_2 v\left(\frac{c_2}{2c_1} r_j\right)^{-\frac{1}{3}} = c_1 a\left(\frac{c_2}{2c_1} r_{j+1}\right)^{\frac{2}{3}} + c_2 v\left(\frac{c_2}{2c_1} r_{j+1}\right)^{-\frac{1}{3}}$$

$$\text{or } c_1\left(\frac{c_2}{2c_1}\right)^{\frac{2}{3}} a r_j^{\frac{2}{3}} + c_2\left(\frac{c_2}{2c_1}\right)^{-\frac{1}{3}} v r_j^{-\frac{1}{3}} = c_1\left(\frac{c_2}{2c_1}\right)^{\frac{2}{3}} a r_{j+1}^{\frac{2}{3}}$$

$$+ c_2\left(\frac{c_2}{2c_1}\right)^{-\frac{1}{3}} v r_{j+1}^{-\frac{1}{3}}$$

Let $c_1\left(\frac{c_2}{2c_1}\right)^{\frac{2}{3}} = c'_1$, $c_2\left(\frac{c_2}{2c_1}\right)^{-\frac{1}{3}} = c'_2$, and $r_j^{\frac{1}{3}} = t_j$, then since we have

$$c'_1 a(t_{j+1}^2 - t_j^2) + c'_2 v(t_{j+1}^{-1} - t_j^{-1}) = 0$$

$$\frac{v}{a} = -\frac{c'_1}{c'_2}\,\frac{t_{j+1}^2 - t_j^2}{t_{j+1}^{-1} - t_j^{-1}} = \frac{1}{2}(t_{j+1} + t_j)t_{j+1}t_j = \frac{(r_j^{\frac{1}{3}} + r_{j+1}^{\frac{1}{3}})\, r_j^{\frac{1}{3}}\, r_{j+1}^{\frac{1}{3}}}{2}.$$

$$\text{where } \frac{c_1}{c_2} = \frac{c_1\left(\frac{c_2}{2c_1}\right)^{\frac{2}{3}}}{c_2\left(\frac{c_2}{2c_1}\right)^{-\frac{1}{3}}} = \frac{c_1\frac{c_2}{2c_1}}{c_2} = \frac{1}{2}$$

If the subscriber characteristic is higher than $\dfrac{(r_j^{\frac{1}{3}} + r_{j+1}^{\frac{1}{3}})\, r_j^{\frac{1}{3}}\, r_{j+1}^{\frac{1}{3}}}{2}$, the subscriber is served by the layer $j+1$, otherwise layer j. Thus, the two groups j and $j+1$ are divided by $\dfrac{(r_j^{\frac{1}{3}} + r_{j+1}^{\frac{1}{3}})\, r_j^{\frac{1}{3}}\, r_{j+1}^{\frac{1}{3}}}{2}$ □.

Using the above propositions, we introduce a procedure to solve the minimization problem of paging and location updating as follows

```
Procedure Optimal C2(L)

Begin
While (there exists cost change after one iteration)
  For j=1 to L
          Determine the optimal ratio r_j (Proposition 2)
  end For
  For j=1 to L-1
          Determine the optimal boundary of the groups j, j+1(Proposition 3)
  end For
end While
end.
```

4. Computational Results and Discussion

To examine the performance of the algorithm SGP for multi-layered scheme, we consider a square cell structure. We assume that the length of each cell is 200m and the shape of a LR area is a $(k \times k)$ square. In the model of Section 2, the unit paging and updating cost is assumed to be $\alpha = 1$ and $\beta = 10$ as in [2]. With a given velocity v and call arrival rate a the updating and paging rate are obtained by the following equations as in [2].

$$Updating\ Rate = \beta \frac{4v\mathrm{v}}{\pi kl} = 10 \frac{4\pi}{\pi\ 2R\ 0.2} = 31.83 \frac{v}{R}$$

$$Paging\ Rate = \alpha a k^2 = 4aR^2$$

where $k = 2R$

Then, the cost function of the paging and updating signals is given as follows:

$$TC(R) = 4aR^2 + 31.83 \frac{v}{R}$$

The examine the performance of the algorithm SGP, example problems are tested which respectively has 20, 30, 40, 50 and 100 subscribers. Optimal solutions are obtained by the branch and bound method and results are average over 5 instances of each problem. The experiments are performed on the IBM PC 486 33MHz machine and coded in C language. The results are shown in Table 1. As noted in Table 1, the error bound of algoritm SGP is less than 0.05% and the computational time is less than 0.2 seconds.

[Table 1]. Result of small sized subscriber grouping problems

Problem Size	Optimal Solution			Algorithm SGP			
	Cost	CPU second	# of groups	Cost	CPU second	# of groups	Error Bound
20	4726.32	4.00	2	4727.94	0.05	2	3.42e-4
30	7666.52	20.51	2	7667.89	0.05	2	1.79-4
40	9744.71	65.18	2	9745.24	0.06	2	5.4e-5
50	11790.77	160.37	3	11790.95	0.06	3	1.6e-5
100	23833.56	7284.48	3	23833.85	0.11	3	1.6e-7

Next, we consider four types of problem with 1000 subscribers. Each problem has different type of the subscriber characteristic as summarized below.

Type Ⅰ : The distribution of call arrival rates and velocities are uniform over [0.1, 5.0] and [1, 50], respectively.

Type Ⅱ : The distribution of call arrival rates is uniform over [0.1, 0.5] and [2.0, 3.0] and that of velocitites is uniform over [1, 5] and [20, 30].

Type Ⅲ : The distribution of call arrival rates is uniform over [0.2, 5.0] and that of velocities is uniform over [1, 5] and [20, 30].

Type Ⅳ : The distribution of call arrival rates and velocities ae uniform over [0.1, 0.5] and [1, 10], respectively.

To investigate the effect of the layer management cost, experiments are performed on Type Ⅰ problem. See Figure 5, the unit layer management costs are assumed to be 0, 0.1, 0.5, 1.0, 2.0 and 5.0, respectively. Table 2 shows the relationship between the optimal number of layers with lower weight of layer management cost is larger than that with higher weight of layer management cost. In the rest part of this paper, we assume the layer management cost θ is 2.0.

Table 2. Optimal number of layers and layer management cost

Layer Management Cost θ	0	0.1	0.5	1.0	2.0	5.0
Optimal Number of Layers	Infinite	11	8	7	4	3

〈Figure 5〉 The Relationship between Layer Management Cost and Optimal Number of Layers

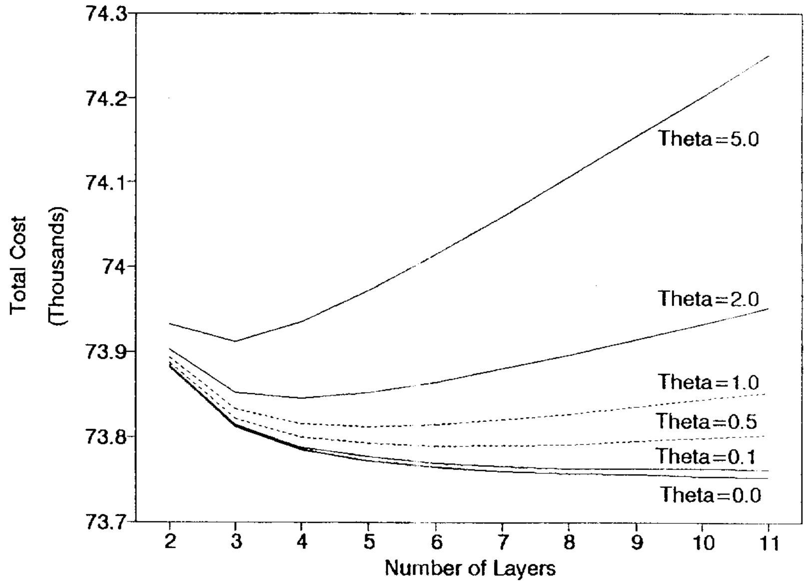


Table 3 shows optimal subscriber groups and v/a ratio of each problem. The grouping of subscriber characteristic of Type Ⅱ is intuitively divided into three groups due to v/a ratio in the data. Also distribution of Type Ⅲ is divided into two groups. Thus, the effectiveness of algorithm. SGP is partly verified by problems of Type Ⅱ and Type Ⅲ.

Table 3. Optimal grouping and v/a ration of the four problems

Layer	Interval	v/a Ratio
1	0.0−3.744752	2.035478
2	3.744752−9.714409	6.629302
3	9.714409−26.705346	14.015875
4	26.705346−500.0	48.749043

(a) Type Ⅰ (Optimal Number of Layers:4)

Layer	Interval	v/a Ratio
1	0.0−3.49993	1.121009
2	3.49993−29.979145	9.635092
3	29.979145−150.0	82.303879

(b) Type Ⅱ (Optimal Number of Layers:3)

Layer	Interval	v/a Ratio
1	0.0 − 28.694513	8.630930
2	28.694513 − 150.0	83.011536

(c) Type Ⅲ (Optimal Number of Layers:2)

Layer	Interval	v/a Ratio
1	0.0 − 8.316945	5.378475
2	8.316945 − 16.742851	12.605234
3	16.742851 − 32.104569	22.046483
4	32.104569 − 100.1	46.053745

(d) Type Ⅳ (Optimal Number of Layers:4)

Finally, we perform a simulation with more practical data of subscribers. The call arrival rates and velocities are assumed to follow Poisson distribtion and normal distribution, respectively. The mean velocity and average call arrivals are also assumed to follow uniform distribution as the Type Ⅳ. Table 4 represents simulation results with multi-layered scheme. From the table, we see that the lowest cost is obtained when the number of layers is four, which corresponds to the result by the proposed algorithm SGP.

Table 4 The simulation results of 7 types of multi-layered scheme

Number of Layer	Number of Layer Change	Total Cost
1	10	980530
2	304	750842
3	568	713336
4	865	655629
5	971	671913
6	1291	725249
7	1312	726894

5. Conclusion

A subscriber grouping problem is defined for the multi-layered paging and location registration scheme. Algorithm SGP is introduced which is based on the properties of the optimal grouping of the subscribers. It is shown that the optimal boundary of the grouping problem can be obtained with subscriber's characteristic ratio that is determined by the velocity and call arrival rate.

To investigate the performance of the algorithm, SGP, experiments are performed with increasing number of subscribers. The paging and location updating cost approaches optimal solution as the number of subscribers increases. Another experiments are performed with different types of subscriber characteristics. In the experiment, it is shown that the optimal number of layers in dependant on the layer management cost. That is as the layer management cost increases, the optimal number of layers also increases. Finally, a simulation is performed to examine the real situation of microcellular PCS system. The results indicate that multi-layered LR area scheme can reduce the paging and location updating costs by using the proposed algorithm SGP.

Future wireless PCS system may be supposed by the intelligent network (IN), by which diverse subscriber's characteristics will be satisfied. In this situation, the multi-layered LR area schemes and the proposed subscriber grouping technnique will be necessary to reduce the paging and location updating signals.

References

[1] Munoz-Rodriguez, D. "Cluster Paging for Traveling Subscribers" IEEE 40th Vehicular Technology Conference(1990)

[2] Xie, H., S. Tabbane and D. J. Goodman, "Dynamic Location Area Management and Performance Analysis," IEEE 43rd Vehicular Technology Conference(1993)

[3] Taketsugu, M and Y. Otheru, "Holonic Locaton Registration/Paging Procedure in Microcellular System," IEICE trans. Fundamentals, Vol. E75-A, No.12(1992)

[4] Okasaka, Sadaatsu, S. Onoe, S. Yasuda and A. Maebara, "A New Location Updating Method for Digital Cellular System," IEEE 41st Vehicular Technology Conference (1991)

[5] Lin, Y. B., "Determining the User Location for Personal Communications Services

Network," IEEE trans. on Vehicular Technology, Vol.43, No.3(1994)
[6] Cimet, I. A., "How to Assign Sevice Areas in a Cellular Mobile Telephone System," Supercomm/ICC(1994)