Performance Analysis of Improved Distance-based Location Registration Scheme in Mobility Model

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요 약 본 논문은 이동망에서 위치등록 방식에 따른 성능평가에 관한 것이다. 먼저 거리기반 위치등록 방식을 제안하고, 이를 이동망 모델에 적용하여 성능을 평가하였다. 제안한 방식과 기존의 지역기반 위치등록 방식과의 성능을 비교, 평가한 결과, 거리기반 위치등록 방식은 지역기반 위치등록 방식과 위치등록에 따른 부하는 대동소이하나 주어진 지역내에서 모든 셀들이 고르게 분포하여 주파수 자원이 효율적으로 사용됨을 알 수 있다.

Abstract In this paper, we propose a distance-based location registration scheme and evaluate it's performance in a mobility model. We compare performance of the distance-based registration scheme to that of zone-based registration scheme at the mobility model. Numerical results show that the registration load of the distance-based registration with call arrival is similar to that of the zone-based registration, and is equally distributed to all cells in a location area. So the proposed scheme can be effectively used in the limited radio resources.

Key Words : Registration, Distance-based, Zone-based, Mobility

1. Introduction

Future mobile telecommunication systems are expected to have a microcellular structure to accommodate high subscriber densities. In such environment the signaling traffic due to mobility management and call processing in radio channel would be very heavy. Mobility management consists of two components, one is the location registration that mobile stations notify their positions to the system, and the other is paging. In order to connect a terminating call successfully, the network should maintain the exact location of the terminating station continuously. So the station should register his location to the network whenever it moves to another location area.

Several location registration schemes for mobile telecommunication system have been proposed to reduce the amount of location registration cost. They are zone-based location registration schemes [2][3], distanced-based location registration scheme[4][5], timer-based location registration scheme[6], and movement-based location registration scheme[7][8].

we discuss key issues about zone-based registration, distance-based registration and distance - based registration with call arrival patterns. The zone-based registration requires a mobile station to register his location whenever it moves into a new zone. The registration

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load of the zone-based scheme is concentrated in border cell within the location area. In the distance-based location registration, a mobile station calculates distance between the location of current base station and the base station in which it last registered whenever it moves a certain distance. The mobile station registers his location to the network if the distance exceeds a threshold value.

In this paper, we propose a distance-based location registration scheme and evaluate it's performance in a mobility model. In Section II, introduce an analytical model for zone-based, distance based, and distance-based registration with call arrival. In section III, calculate the optimal location areas of each registration scheme in order to minimize signaling traffics for location registration and paging. In section IV, numerical results are given and compared to each other. Finally, summarize our results.

2. Mobility Model

We define a mobility model to calculate the number of location registrations. The model assumes that i) a subscriber moves to straight with four directions such as upward, downward, forward, backward, ii) the distance, X, between changing directions is exponentially distributed with mean ξ. For the mobility model, we define random variables as follows; S is the distance from the last changing direction point to the zone border, and K is the number of registrations within X.

2.1. Zone-based Scheme

We assume that a zone is rectangular with length d. Fig.1 shows the moving pattern of a mobile station in the zone-based scheme. Due to the independence of mobility, the probability density function (pdf) for X and S is as Eq.(1).[1]

$$f_{X,S}(x,s)=\frac{1}{\xi}e^{-\frac{x}{\xi}}\frac{1}{d}, \qquad x>0, \qquad 0<s<d \tag{1}$$

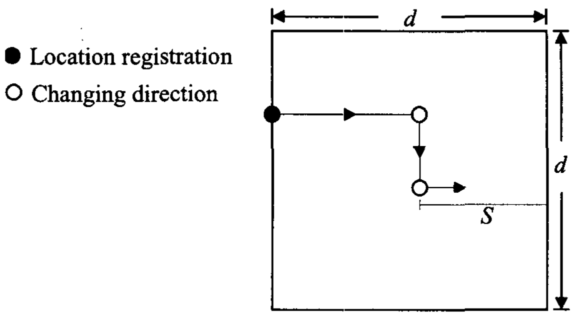

Fig. 1. Mobility patterns in zone-based scheme.

Based on the pdf for (X, S), we can obtain the pdf of K as

$$\begin{aligned}\Pr[K=k] &= \int_0^d \int_{s+(k-1)d}^{s+kd} f_{X,S}(x,s)\,dx\,ds \\ &= \frac{\xi}{d}\left(1-e^{\frac{d}{\xi}}\right)e^{-\frac{(k+1)d}{\xi}} - \frac{\xi}{d}\left(1-e^{\frac{d}{\xi}}\right)e^{-\frac{kd}{\xi}}, \qquad k \geq 1\end{aligned} \tag{2}$$

The average number of K is calculated by

$$\overline{K}=\sum_{k=0}^{\infty} k \Pr[K=k]=\frac{\xi}{d} \tag{3}$$

Therefore, in the zone-based scheme, the average number ($\overline{N}$) of location registrations per subscriber with constant speed $\overline{V}$ is obtained as

$$\overline{N}=\frac{\overline{V}\overline{K}}{\overline{X}}=\frac{\overline{V}}{d} \tag{4}$$

2.2. Distance-based scheme

In the distance-based scheme, a mobile station informs his location to the base station after moving a certain distance. The base station compares the old location information with the new one. If the distance between the 2 locations is exceed a given value, the location registration is performed.

Detail procedure is outlined in Fig. 2. The location registration is occurred when the mobile station moves the distance r. The figure indicates that the mobile station changed his direction twice and performed 5 location registrations.

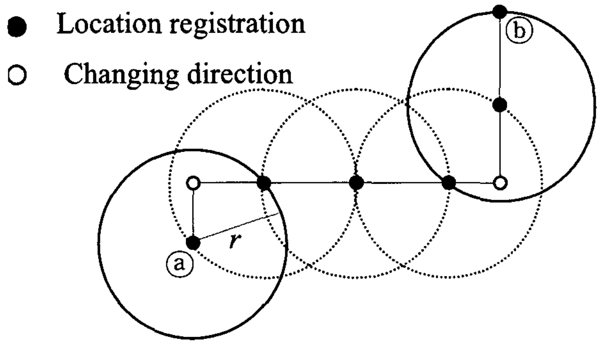

Fig. 2. Mobility patterns in distance-based scheme.

Furthermore, Fig. 3 shows the moving pattern in the location area. As the same manner, the pdf for (X, S) is as Eq.(5).[1]

$$f_{X,S}(x,s)=\frac{1}{\xi}e^{-\frac{x}{\xi}}\frac{2}{\pi r^2}\sqrt{r^2-\left(\frac{s}{2}\right)^2}, \qquad x>0,\ 0\le s\le 2r \tag{5}$$

Fig. 3. Shape of location area in distance-based scheme.

The pdf for the random variable K is then

$$\Pr[K=k]=\int_0^{2r}\int_{s+(k-1)r}^{s+kr}f_{X,S}(x,s)dxds$$
$$=\int_0^{2r}\frac{2}{\pi r^2}\sqrt{r^2-\left(\frac{s}{2}\right)^2}\left(e^{-\frac{s+(k-1)r}{\xi}}-e^{-\frac{s+kr}{\xi}}\right)ds, \qquad k\ge 1 \tag{6}$$

with mean

$$\overline{K}=\sum_{k=0}^{\infty}k\Pr[K=k]=\frac{2}{\pi r^2(1-e^{-\frac{r}{\xi}})}\int_0^{2r}e^{-\frac{s}{\xi}}\sqrt{r^2-\left(\frac{s}{2}\right)^2}ds \tag{7}$$

Hence the average number ($\overline{N}$) of location registrations per subscriber with average speed $\overline{V}$ is calculated as

$$\overline{N}=\frac{\overline{VK}}{\overline{X}}=\frac{\overline{V}}{\xi}\times\frac{2}{\pi r^2(1-e^{-\frac{r}{\xi}})}\int_0^{2r}e^{-\frac{s}{\xi}}\sqrt{r^2-\left(\frac{s}{2}\right)^2}ds \tag{8}$$

2.3. Distance-based scheme considering call arrival

This scheme is based on the distance-based scheme. However, a new location area is constructed whenever a call originates or terminates. Fig. 4 represents the point where a call is originated or terminated. The figure also indicates that 4 location registrations are occurred during 2 direction changes.

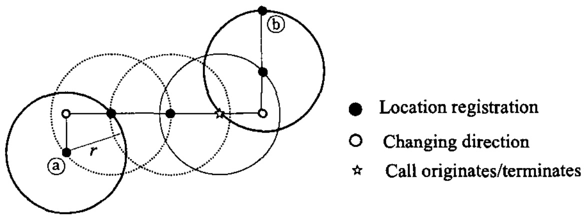

Fig. 4. Mobility patterns in distance-based scheme considering call arrival.

Assuming the time between call arrival/departures is exponentially distributed with mean $1/\lambda_C$, and constant speed υ, then the distance (Z) between call arrival/departures has a exponential distribution with mean υ/λ_C. The pdf for (X, Z, S) is obtained as

$$f_{X,Z,S}(x,z,s)=\frac{2\lambda_c}{\pi r^2\xi v}\exp\left[-\left(\frac{x}{\xi}+\frac{\lambda_c z}{v}\right)\right]\sqrt{r^2-\left(\frac{s}{2}\right)^2},\quad x>0,\ z>0,\ 0<s<2r \tag{9}$$

To calculate the pdf for the number of location registrations, the relationship among random variables X, Z, and S is outlined in Fig. 5. The number within the circle indicates the total number of location registrations in the given range. Based on the figure, we can obtain the pdf for K as follows.

$$\begin{aligned}\Pr[K=k]&=\int_0^{2r}\int_0^{s}\int_{z+kr}^{z+(k+1)r} f(x,z,s)dxdzds+\int_0^{2r}\int_s^{\infty}\int_{z+(k-1)r}^{z+kr} f(x,z,s)dxdzds\\&\quad+\int_0^{2r}\int_{s+(k-1)r}^{s+kr}\int_x^{\infty} f(x,z,s)dxdzds\\&=\alpha_1\left[\int_0^{2r} f(s)ds-\frac{\pi r^2}{2}\right]+\alpha_1\int_0^{2r} f(s)ds+\alpha_2\int_0^{2r} f(s)ds,\quad k\ge 1\end{aligned} \tag{10}$$

The average number of location registrations is calculated as

$$\overline{K}=\sum_{k=0}^{\infty} k\Pr[K=k] \tag{11}$$

Then the average number of location registrations per subscriber is calculated by

$$\overline{N}=\frac{\overline{VK}}{\overline{X}} \tag{12}$$

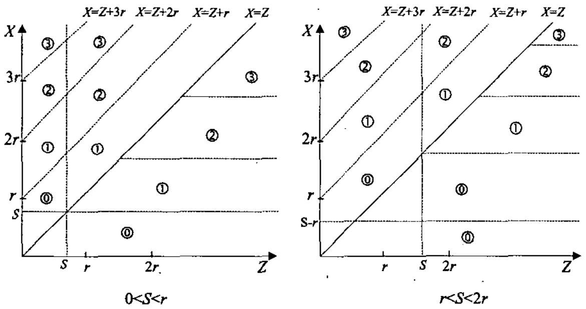

Fig. 5. Relationships among random variables S, Z and X.

3. Optimal Location Registration Area

In general, the signaling traffic for terminal paging is increased as the location area becomes larger but the signaling traffic for location registration is decreased. There is a trade-off between paging and location registration signaling information according to the size of location area. Therefore, there is an optimal location area minimizing signaling traffic for paging and location registration. To calculate optimal location area, we define following parameters.

- λ_C : originating and terminating call arrival rates(calls/hour)
- ρ : density of mobile terminal(MSs/km^2)
- d_{cell} : radius of a cell(km)
- C_p : signaling traffic per one paging
- C_u : signaling traffic per one location registration

The signaling traffics for terminal paging through down-link are equal to the number of base stations within a location area, but only one paging response message is transferred to network through up-link. In addition, as location registration load is determined by the number of location registration per mobile subscriber, $\overline{N}$, the signaling traffic per mobile subscriber required for paging and location registration can be defined by Eqs. (13) and (14). Eq.(13) is the total cost function of the zone-based scheme per unit time, and Eq.(14) is that of the distance-based and distance-based scheme with call arrival per unit time.

$$C_{sub}^{Z}=\overline{N}\times C_U+\frac{\lambda_c}{2}\times\left(\frac{d^2}{d_{cell}^2}+1\right)\times\frac{C_P}{2} \tag{13}$$

$$C_{sub}^{D}=C_{sub}^{DA}=\overline{N}\times C_U+\frac{\lambda_c}{2}\times\left(\frac{\pi r^2}{d_{cell}^2}+1\right)\times\frac{C_P}{2} \tag{14}$$

We assume the value of following parameters as table 1. Where origination traffic is the same as termination traffic and the C_p -to- C_u ratio is assumed as 10.[1]

Table 1. Input Parameter Values

λ_C	2.88(calls/hour)	$C_p : C_u$	1 : 10
d_{cell}	0.2(km)	$\overline{V}$	3(km/hour)
ξ	0.2(km)	ρ	1500(MSs/km^2)

Figure 6 shows the values of Eq. (13) according to the d in zone-based scheme. In Figure 6, the signaling traffic for terminal paging is increased and that of location registration is decreased as d increases. By selecting the appropriate value for d, C_{sub} can be reduced to the minimum value. We represent the optimal size of cell as $d^*$and the optimal total cost per mobile subscriber as C^*_{sub}. If the value of d^* is 0.941(km), the optimal total cost, C^*_{sub}, is 48.5396.

Figure 7 shows the values of Eq. (14) according to the radius of cell, r, in the distance-based scheme. By selecting the appropriate value for r, C_{sub} can be reduced to a minimum value. We represent the optimal size of cell and the optimal total cost per mobile subscriber as r^* and C^*_{sub} respectively. If the value of $r^*$is 0.567(km), the optimal total cost, C^*_{sub}, is 53.4330. Finally, figure 8 shows the values of Eq. (14) according to the radius of cell, r, in distance-based scheme with call arrival. If the value of r^* is 0.557(km), the optimal total cost, C^*_{sub}, is 48.7879.

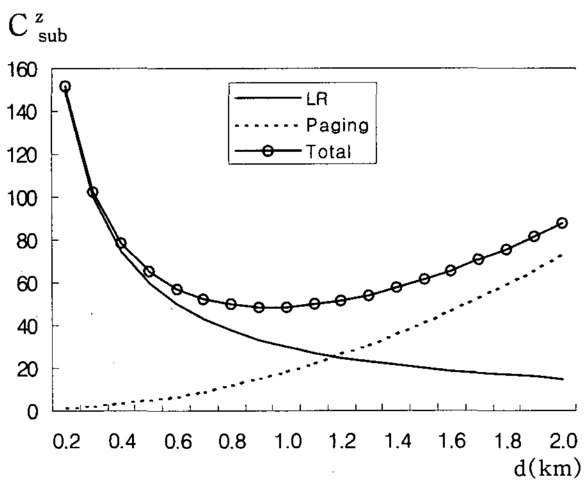

Fig. 6. Comparison of two signaling traffics in the zone-based scheme.

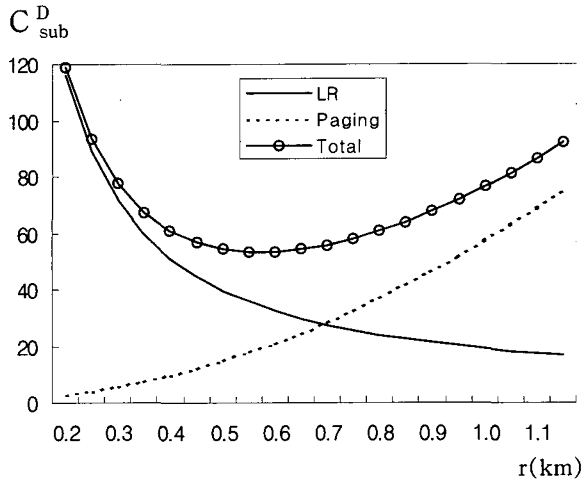

Fig. 7. Comparison of two signaling traffics in the distance-based scheme.

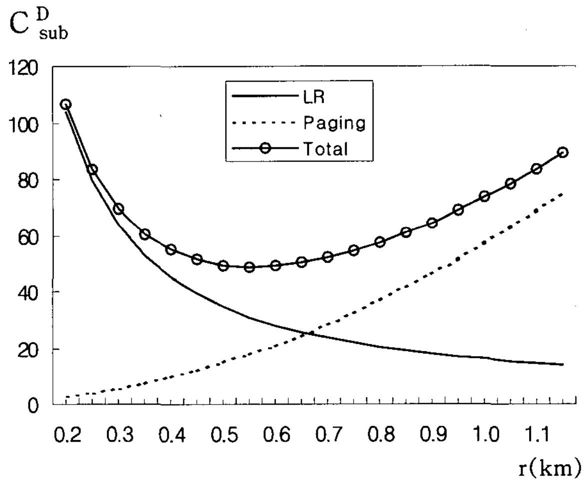

Fig. 8. Comparison of two signaling traffics in the distance-based scheme with call arrival.

4. Numerical Results

4.1 Load per location area

Using the Eq.(13) and (14), the total cost function per location area is represented by equation (15) and (16). Equation (15) is the total cost function of zone-based location registration per hour. Equation (16) is the total cost function of distanced-based location registration and distanced-based location registration with call arrival per hour.

$$C_{LR}^{Z} = \rho \times d^2 \times \left\{ \overline{N} \times C_U + \frac{\lambda_c}{2} \times \left(\frac{d^2}{d_{cell}^2} + 1 \right) \times \frac{C_P}{2} \right\} \tag{15}$$

$$C_{LR}^{D} = C_{LR}^{DA} = \rho \times \pi r^2 \times \left\{ \overline{N} \times C_U + \frac{\lambda_c}{2} \times \left(\frac{\pi r^2}{d_{cell}^2} + 1 \right) \times \frac{C_P}{2} \right\} \tag{16}$$

Using equation (15) and (16), we calculate the load per location area for three registration schemes such as zone-based(ZB), distance-based(DB), and distance-based with call arrival scheme(DAB) with various call arrival rates.

Fig. 9 shows the calculation results of each registration scheme. We see that as call arrival rate increases, the load per location area decreases in all registration schemes. As the call arrival rate becomes higher, then the load decreases rapidly.

Fig. 10 shows the relationship between the load per location area and the moving velocity of a subscriber. As the velocity increases, the load per location area increases rapidly.

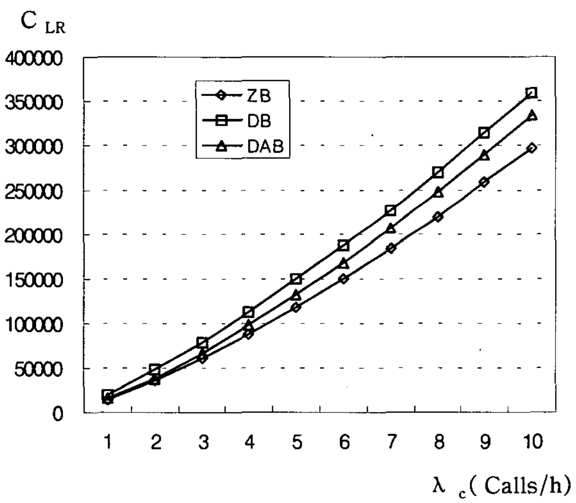

Fig. 9. Relationship between load per location area and call arrival rate.

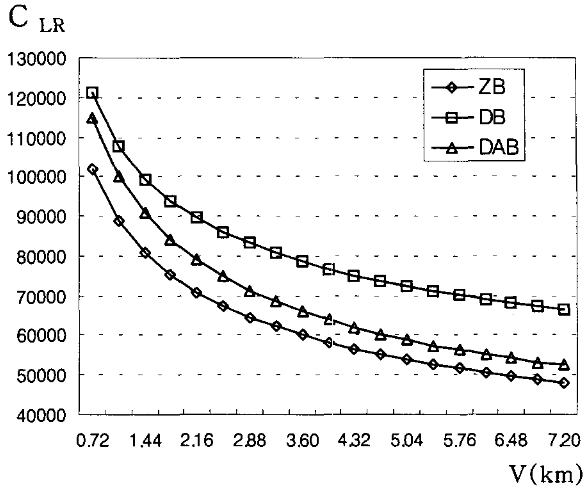

Fig. 10. Relationship between load per location area and velocity.

4.2 Load per cell

To analyze the load per cell in three registration types, we assume that the location area consists of n^2 cells and the shape of a location area is circular. Because the load of distance-based location registration and distance-based registration with call arrival scheme are equally distributed to all cells in a location area, the load of each cell is obtained by dividing total load per location area into n^2.

The location registration load in zone-based location registration is concentrated on the border cell within the location area. The registration cost of the border cell can be obtained as follow.

$$C_{cell}^{Z} = \frac{2\overline{N}\rho d^2}{4n} \times C_U + \rho d_{cell}^2 \times \frac{\lambda_c}{2} \left(\frac{d^2}{d_{cell}^2} + 1 \right) \times \frac{C_P}{2} \quad (n \ge 2) \tag{17}$$

The registration load per cell in distance-based and distance-based location registration with call arrival scheme can be obtained as follow.

$$C_{cell}^{D} = C_{cell}^{DA} = \frac{\overline{N}\rho\pi r^2}{n^2} \times C_U + \rho d_{cell}^2 \times \frac{\lambda_c}{2} \left(\frac{\pi r^2}{d_{cell}^2} + 1 \right) \times \frac{C_P}{2} \tag{18}$$

In Fig. 11, load per cell in zone-based location registration scheme is higher than that of the rest 2 registration schemes regardless of the call arrival rates. However, load per cell in distance-based location registration with call arrival scheme is smaller than that of distance-based location registration scheme. We also know that as call arrival rates increases, the size of optimal location area decreases. So load per cell in each registration scheme increases. Fig 12 shows the relationship between load per cell and velocity variation. In the figure, we see that as velocity variation of mobile station increases, the load per cell also increases.

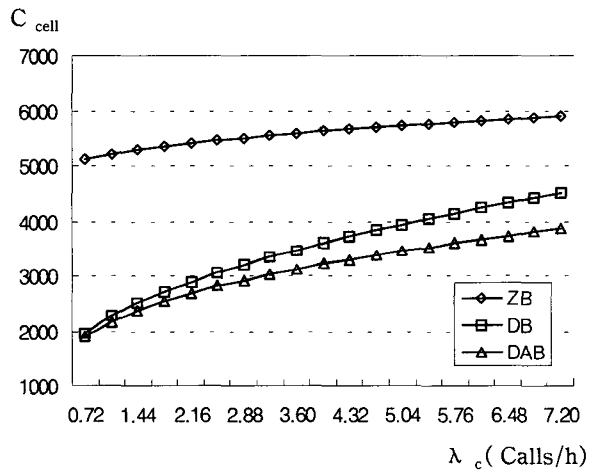

Fig. 11. Relationship between load per cell and call arrival rate.

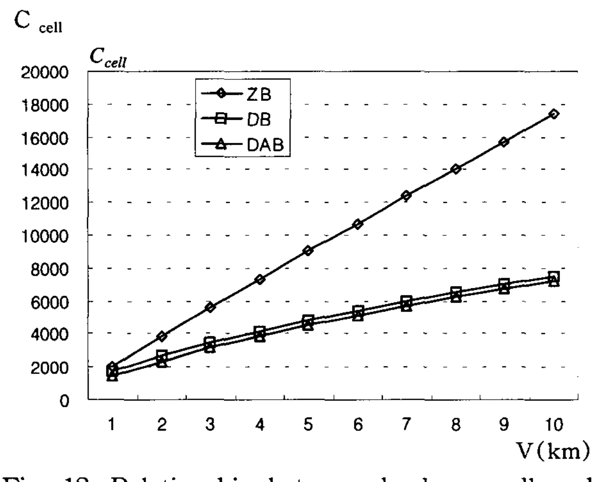

Fig. 12. Relationship between load per cell and velocity.

5. Conclusions

In this paper, we proposed a location tracking mechanism for mobile communication system by combining a distance-based scheme and call arrival patterns. Explained 3 types of location registration scheme such as zone-based, distance based, and distance-based registration with call arrival. An analytical model for the proposed distance-based scheme with call arrival is provided. The performance of proposed scheme is also compared to a zone-based registration and distance-based registration schemes.

Numerical results show that the zone-based and distance-based with call arrival schemes need less number of registration than the distance-based scheme, while the load per cell in the distance-based and distance-based with call arrival schemes are equally distributed to all cells in a location area.

Therefore, the registration load of the distance-based registration with call arrival is similar to that of zone-based registration, and equally distributed to all cells in a location area. So the proposed scheme with call arrival can be used effectively in the limited radio environment.

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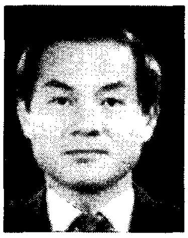

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