WCDMA 시스템에서의 이동체 위치 추정 방안

이 종 찬* · 이 문 호**

Mobile Location Estimation for WCDMA System

Jongchan Lee* · Moonho Lee**

Abstract

In the microcell- or picocell-based system the frequent movements of the mobile bring about excessive traffics into the networks. A mobile location estimation mechanism can facilitate both efficient resource allocation and better QoS provisioning through handoff optimization. Existing location estimation schemes consider only LOS model and have poor performance in presence of multi-path and shadowing. In this paper we study a novel scheme which can increase estimation accuracy by considering NLOS environment and other multiple decision parameters than the received signal strength.

Keywords : WCDMA, Mobile Location, Estimation, Decision Parameter

논문접수일 : 2007년 03월 26일　　　논문게재확정일 : 2007년 06월 19일
* 군산대학교 컴퓨터정보학과
** 교신저자, 청운대학교 멀티미디어학과, (350-701) 충남 홍성군 홍성읍 남장리 산 29번지, e-mail : mhlee@chungwoon.ac.kr

1. Introduction

In a microcell or picocell-based mobile communication network frequent movements of a mobile terminal or host bring about excessive traffics into the network and may degrade the quality of services (QoS) severely. If its location can be estimated, network resources may be more effectively allocated and better QoS can be provisioned with the combination of hand-off optimization. Moreover the location estimation technology may be used in other new applications such as the emergency call for disaster recovery. It will have viable roles in the communication networks of the next generation.

The Global Positioning System (GPS) was initially developed for military purposes but it is also utilized for civil applications such as local traffic information services and geo-location based applications. However incorporating GPS receivers into handsets raises questions of cost, size and power consumption [Djuknic et al., 2001].

Other methods for mobile station are based on radio signal propagation such as signposts, dead reckoning, circular or hyperbolic tri-lateration systems, etc. Many methods and systems have been proposed based on radio signal strength measurement of a mobile object's transmitter by a set of base stations [Hatta et. al., 1980]. Recently, adaptive schemes based on the use of cellular systems and on fuzzy logic [Song, 1994], hidden Markov models [Aycard et al., 1997; Bharadwaj et al., 1999; Nypan et al., 2003] and pattern recognition methods [Kennemann et al., 1994] have been used to estimate the position of mobiles. Time difference of arrival (TDOA) of signals from two base stations is considered in [Rappaport et al., 1996]. TOA scheme and TDOA scheme have been studied for IS-95B where PN code of CDMA system can be used for the location estimation. Enhanced Observed Time Difference (E-OTD) is a TDOA positioning method based on the OTD feature already existing in GSM. The mobile measures an arrival time of each signal from three or more cell sites in a network. In this method the position of a mobile is determined by tri-lateration [Spirito, 2001]. E-OTD, which relies upon the visibility of at least three cell sites to calculate a position, is not a good solution for rural areas where cell-site separation is large. However, it promises to work well in areas of high cell-site density and indoors.

The above-mentioned schemes such as AOA, TOA and TDOA have problems as follows.

- These schemes assume that the cellular system consists of LOS areas. They get good results only under this assumption.
- The microcellular system such as IMT-2000 has NLOS areas which are affected by specific reflections and diffractions. In this situation these schemes have great errors in estimation.
- In the microcellular environment the points of the same average signal strength form not a circular contour but a distorted one. These schemes ignore the fact that the propagation rule is affected by many parameters.

- They rely only on the information related to radio signal such as the signal strength. Their accuracies are affected by short-term fading, shadowing or diffraction.

Recently location estimation schemes to cope with NLOS environments have been studied in [Lee et al., 1999; Lee et al., 2000; Lee et. al., 2003].

In this paper we propose a novel scheme which can consider multiple parameters such as the signal strength, distance between a base station and a mobile, moving direction and previous location in order to enhance the estimation accuracy further. In our scheme a cell is divided into many blocks based on the signal strength, and then the optimal block where a mobile locates is estimated in stepwise.

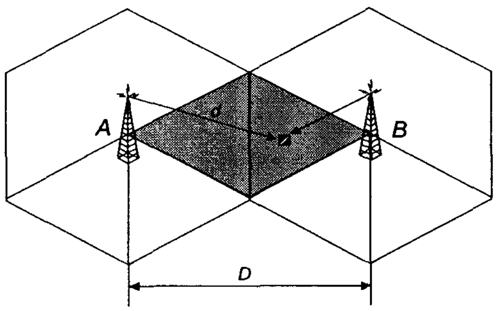
This paper is organized as follows. Section 2 describes the signal measurement and location definition for our system. Using the concepts described in Section 2, our estimation scheme is considered in Section 3. Simulation environment and results are shown in Section 4 in order to compare our scheme with other scheme. Finally concluding remarks are given in Section 5.

2. Signal Measurement and Location Definition

W-CDMA system is considered for our study. It has a downlink frequency of 1.9 GHz, the bandwidth of 5MHz, QPSK modulation and omni-directional antenna. The downlink power control range is 30dB. The mobile station is constantly monitoring signal strengths of pilot channels from neighboring base stations as well as from the serving base station. With the feature of multiple searchers it calculates delay difference of two signals. It has the list of signal strengths for pilot channels from both serving station and neighboring stations, and reports them to the requesting station for update.

2.1 Signal Strength

In this section we describe the radio propagation environment which influences signal strength measurement. Signal levels change rapidly and unpredictably due to multi-path and shadowing. Troubles in signal reception occur with abrupt changes in moving velocity or direction, signal blockages by buildings, and "corner effects" in the microcellular environment. In this situation the radio propagation environment can be explained by either LOS (Line of Sight) model or NLOS (Non Line of Sight) model [Austine et al., 1996; Fau et al., 1996]. We consider the signal propagation environment as shown in <Figure 1>. It is assumed that a base station locates at the



〈Figure 1〉 The signal propagation environment center of each cell and mobiles are distributed evenly in each cell. Each mobile receives periodically from both the present base station and its neighboring station.

The signal level $r(t)$ received by a mobile from the station is given by Equation (1) [Lee, 1985].

$$r(t) = p(t) \times f(t) \quad (1)$$

$p(t)$ indicates the local mean of path loss and shadowing in the signal power of pilot channel received by the mobile, and it has the log-normal distribution. $f(t)$ indicates the signal component of multi-path fading and has Rayleigh or Rician local average power. The signal component of multi-path fading can be eliminated by a low pass filter or time-averaging. We consider log-normal fading and path-loss only [Austine et al., 1993; Gudmundson, 1991]. Therefore the local average power of the signal received at the mobile is given by Equation (2) [Vijayan et al., 1992; Zhang. et al., 1996].

$$\begin{aligned} p_A(d) &= k_1 - k_2 \times \log(d) + u(d) \\ p_B(d) &= k_1 - k_2 \times \log(D-d) + v(d) \end{aligned} \quad (2)$$

In Equation (2) D indicates the distance between two base stations, and d the distance between the base station A and the mobile. k_1 is proportional to the transmission power of the station and k_2 has the offset value depending on the radio propagation environment. Two random signals $u(d)$, $v(d)$ represent power distributions of signals received at a distance d from the station A and from the station B respectively. They have i.i.d (identical independent distribution) with Gaussian distribution of $N(\mu(d), \sigma)$. In our study the signal attenuation in NLOS environment is estimated based on the distance in LOS model, and this result is reflected in the block object information. Changes in the LOS and NLOS environment are depicted by k_2.

As the received signal strength changes arbitrarily at a place, it cannot be accurately defined with a single measurement. It is desirable to define the signal strength at a place as the average of values measured several times in a fixed interval. The strengths of a pilot signal are measured repeatedly and the average of these values is calculated by Equation (3). This result is defined as the final estimated value. In this equation $PSS(t_s)$ denotes the strength of the base station's pilot signal as perceived by the mobile station at the moment t_s, where t_s is the sampling period and i is a positive integer. The average of N sample values is calculated for estimation. The average signal strength PSS_{ea} is given by the expression below [Senarath et al., 1995].

$$PSS_{ea}(t_0 + t_s) = \frac{1}{N}\sum_{i=0}^{N-1} PSS(t_0 - i \times t_s) \quad (3)$$

2.2 Defining Location

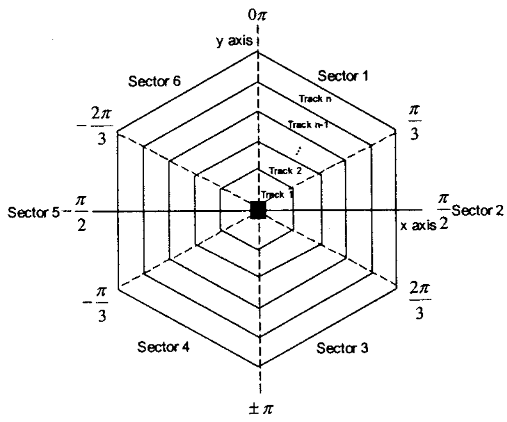
We can define the location of a mobile within a cell by dividing each cell into sectors, tracks and blocks, and then by relating these to the signal level received at that point. It is done automatically in three phases : sector definition, track definition and block definition. With these results we can construct the location definition database. They are performed at the system initialization before the location estimation is executed.

The sector definition phase divides a cell into sectors, and assigns a sector number to blocks belonging to each sector. The track definition phase divides each sector into tracks, and assigns a track number to blocks belonging to each track. The block definition phase assigns a block number to each block. After the completion of this phase each block has a set of three numbers. A location relative to the origin in the map can be indicated in two ways. The rectangular coordinate indicates the location by a horizontal distance x from a base station and a vertical one y. The polar coordinate indicates the location by a distance from the origin to a mobile and an angle from the positive horizontal axis toward counter-clockwise. In our study, as we need the direction information to identify a sector relative to a base station and the relative position of a block, we use the polar coordinate that is converted from the rectangular coordinates.

(1) Sector Definition

The sector definition phase divides a cell into six sectors and assigns a sector number to blocks belonging to each respective sector as shown in <Figure 2>.

All blocks belonging to the same sector have a same sector number. In order to identify



〈Figure 2〉 Dividing a cell into sectors and tracks

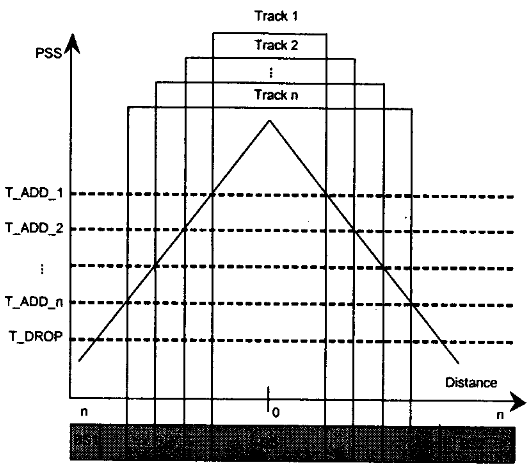
which blocks belong to which sector, we utilize the direction information of a vector which shows the direction of a block from the origin of the base station.

The sector definition procedure is summarized as follows.

a. Divide a cell into six sectors of a size.
b. Assign an angle for each sector at the interval of $\pi/3$ respectively.
c. Compare the direction information of a block with the angle of each sector, and then determine which sector it belongs to.
d. Assign the corresponding sector number to each block.

(2) Track Definition

The track definition phase divides each sector into tracks, and assigns a track number to the blocks belonging to each respective track as shown in <Figure 2>. This definition phase can be described with two different algorithms depending on LOS model and NLOS model. Each cell is divided into n tracks, with each track classified by PSS threshold as shown in <Figure 3>.



〈Figure 3〉 Track definition with PSS

The following algorithm summarizes the track definition procedure for LOS model.

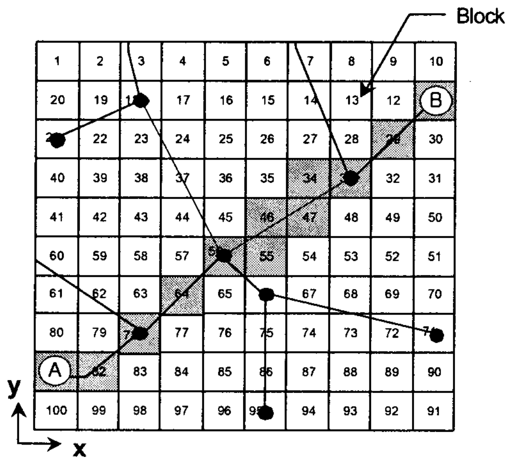
a. Select each threshold by considering PSS.
b. In order to map the signal strength onto the direction information, determine the distance function for each threshold with Equation (2).
c. Classify tracks using the distance function.
d. Assign a same track number and a PSS threshold to all blocks that belong to a same track.

But the above algorithm for LOS is not sufficient in the environment where blocks have a building or a hill. The boundary line for identifying each track of the same signal strength is severely distorted due to shadowing and diffraction. Further refinement with NLOS data is required as shown below.

a. Identify tracks by above LOS algorithm.
b. From blocks belonging to the same track, select blocks which need NLOS offset. As shown in <Figure 4>,
c. Assign NLOS offset, k_2, of Equation (2) to the blocks selected.
d. Find the difference between k_2 and PSS threshold which is determined by LOS model.
e. Define new tracks by using the above difference as a new PSS.

(3) Block Definition

In the block definition phase a block number is assigned to each block as shown in <Figure 4>.



〈Figure 4〉 Identifying a block using a vector.

In order to indicate the location of each block within a cell, we use vector data obtained by converting the rectangular coordinate of a block to the polar coordinate with the origin of the base station [Cichon et al., 1996]. Each vector has the information on a distance and an angle. If the mobile moves along the path (from A to B), the vector data indicates the location of the block that the mobile passes through within the cell. In order to represent the location of a block relative to the base station, we assign a 2-dimensional vector (d, a) to each block.

The collection of this block information is called the *block object*. The *block object* contains the following information : the sector number, the track number, the block number, the vector data (d, a), the maximum and minimum value of average PSS for LOS block and the compensated value for NLOS block, etc.

3. Mobile Location Estimation Based on Multi-Criteria Decision Parameter

In this section we consider location estimation scheme for estimating the mobile location in NLOS environment by utilizing the concepts described in Section 2.

3.1 Multi-Criteria Decision Making

Two schemes mentioned in [Lee et al, 1998; Lee et al, 2000; [Lee et al, 2003] utilize the information relating to the radio signal only, and their estimation accuracies are therefore affected by short term fading, shadowing and diffraction.

In mobile tracking using the multi-criteria decision making [Kuo et al., 1996; Yeh et al., 1997] Decision function D is defined by combining the degree of satisfaction for multiple evaluation parameters, and the decision is made on the basis of this function. The evaluation parameter can be seen as a proposition. A compound proposition is formed from multiple evaluation parameters with a connective operator, and the total evaluation is performed by totaling the values for the multiple parameters with connective operators. In this method errors in the evaluation parameters impose milder changes on the total evaluation value than in binary logics. This method can also consider multiple inaccurate and insufficient evaluation parameters simultaneously and can compensate for them. This results in the optimal decision. In our study the measure of the ratio was used for indicating the evaluation parameter and a weight was imposed according to the degree of importance of each evaluation parameter.

3.2 Multi-Criteria Decision Parameters

In our study, the received signal strength, the distance between a mobile and a base station, previous location, and moving direction are considered as decision parameters. The received signal strength has been used in many schemes, but it has very irregular profiles due to the effects of radio environments. The distance is considered because it can explain the block allocation plan; however, it may also be inaccurate due to the effect of multi-path fading, etc. It is not sufficient by itself. We consider the previous location. It is normally expected that the estimated location should be near the previous one. Therefore, if the estimated location is too far from the previous one, the estimation may be regarded as inaccurate. We also consider the moving direction. Usually the mobile is most likely to move forward, less likely to move rightward or leftward, and least likely to move backward more than one block. A low-speed mobile (a pedestrian) has a smaller moving radius and a more complex moving pattern, while a high-speed mobile (a motor vehicle) has a larger radius and a simpler pattern.

3.3 Membership Function

The membership function with a trapezoidal shape is used for determining the membership degree of the mobile because it provides more versatile degree between upper limit and lower one than the membership function with a step-like shape.

The membership function of PSS_i, $\mu_R(PSS_i)$, is given by (4). PSS_i is the signal strength received from the base station i, s_1 is the lower limit, and s_2 is the upper limit [Lee et al., 2003].

$$\mu_R(PSS_i) = \begin{bmatrix} 0, & PSS_i < s_1 \\ 1-\dfrac{PSS_i - s_1}{|s_2 - s_1|}, & s_1 \le PSS_i \le s_2 s \\ 1, & PSS_i > s_2 \end{bmatrix} \quad (4)$$

Now we define the membership function of the distance. The membership function of the distance $\mu_R(D_i)$ is given by (5), where D_i is the distance between the base station i and the mobile, d_1 is the upper limit, and d_2 is the lower limit.

$$\mu_R(D_i) = \begin{bmatrix} 1, & D_i < d_1 \\ 1-\dfrac{|D_i - d_2|}{|d_1 - d_2|}, & d_1 \le D_i \le d_2 \\ 0, & d_i > d_2 \end{bmatrix} \quad (5)$$

The membership function of the previous location of the mobile $\mu_R(L_i)$ is given by (6), where L_i is the vector information of its current location, $E_i \cdots E_4$ is the vector information of the previous location, and g_i is the physical difference between them.

$$\mu_R(L_i) = \begin{bmatrix} 0, & L_i < E_1 \\ 1-\dfrac{L_i - E_1}{|g_i|}, & E_1 \le L_i \le E_2 \\ 1, & E_2 \le L_i \le E_3 \\ 1-\dfrac{L_i - E_3}{|g_i|}, & E_3 \le L_i \le E_4 \\ 0, & L_i > E_4 \end{bmatrix} \quad (6)$$

The membership function of the moving direction $\mu_R(C_i)$ is given by (7). C_i is the vector information of the moving direction, PSS_1, $\cdots$, PSS_4 is the pilot signal strength, and o_i the physical difference between the previous location and the current one.

$$\mu_R(C_i) = \begin{bmatrix} 0, & C_i < PSS_1 \\ 1-\dfrac{C_i - PSS_1}{|o_i|} & PSS_1 \le C_i \le PSS_2 \\ 1 & PSS_2 \le C_i \le PSS_3 \\ 1-\dfrac{C_i - PSS_3}{|o_i|} & PSS_3 \le C_i \le PSS_4 \\ 0, & C_i > PSS_4 \end{bmatrix} \quad (7)$$

3.4 Location Estimation

(1) Sector Estimation Based on Multi-Criteria Parameters

The decision parameters considered in the Sector Estimation step are the signal strength, the distance and the previous location. The mobile is estimated to be located at the sector neighboring to the base station whose total membership degree is the largest. The sector estimation is performed as follows.

Procedure 1 Membership degrees are obtained using the membership function for the signal strength, the distance and the previous location.

Procedure 2 Membership degrees obtained in Procedure 1 for the base station neighboring to the present station are totalized using the fuzzy connective operator as shown in (8).

$$\mu_i \mu_R(PSS_i) \cdot \mu_R(D_i) \cdot \mu_R(L_i) \tag{8}$$

We obtain (9) by imposing the weight on μ_i. The reason for weighting is that the parameters used may differ in their importance.

$$\omega\mu_i = mj_R(PSS_i) \cdot W_{PSS} + \mu_R(D_i) \cdot W_D + \mu_R(L_i) \cdot W_L \tag{9}$$

where W_{PSS} is the weight for the received signal strength, W_D for the distance, and W_L for the location. Also $W_{PSS} + W_D + W_L = 1$, and $W_{PSS} = 0.5$, $W_D = 0.3$ and $W_L = 0.2$ respectively.

Procedure 3 Blocks with the sector number estimated are selected from all the blocks within the cell for the next step of the estimation. Selection is done by examining sector number in the block object information.

(2) Track Estimation Based on Multi-Criteria Parameters

The decision parameters considered in the Track Estimation step are the signal strength, the distance and the moving direction. From the blocks selected in the sector estimation step, this step estimates the track of blocks at one of which the mobile locates using the following algorithm.

Procedure 1 Membership degrees are obtained using the membership function for the signal strength, the distance and the moving direction.

Procedure 2 Membership degrees obtained in Procedure 1 is totalized using the fuzzy connective operator as shown in (10).

$$\mu_i = \mu_R(PSS_i) \cdot \mu_R(D_i) \cdot \mu_R(C_i) \tag{10}$$

We obtain (11) by imposing the weight on μ_i.

$$\omega\mu_i = \mu_R(PSS_i) \cdot W_{PSS} + \mu_R(D_i) \cdot W_D + \mu_R(C_i) \cdot W_c \tag{11}$$

where W_{PSS} is assumed to be 0.6, W_D 0.2 and W_C 0.2 respectively.

Procedure 3 Blocks that belong to the track estimated above are selected for the next step. It is done by examining the track number of blocks selected in the sector estimation.

(3) Block Estimation Based on Multi-Criteria Parameters

The decision parameters to be considered in the Block Estimation step are the signal strength, the distance and the moving direction.

From the blocks selected in the zone estimation step, this step uses the following algorithm to estimate the block in which the mobile may be located.

Procedure 1 Membership degrees are obtained using the membership function for the signal strength, the distance and the moving direction.

Procedure 2 Membership degrees obtained in Procedure 1 are totalized using the fuzzy connective operator as shown in (12).

$$\mu_i = \mu_R(PSS_i) \cdot \mu_R(D_i) \cdot \mu_R(C_i) \qquad (12)$$

We obtain (13) by imposing the weight on μ_i.

$$\omega\mu_i = \mu_R(PSS_i) \cdot W_{PSS} + \mu_R(D_i) \cdot W_D + \mu_R(C_i) \cdot W_C \qquad (13)$$

where W_{PSS} is assumed to be 0.6, W_D 0.1 and W_C 0.3 respectively.

Procedure 3 The selection is done by examining the block number of blocks selected in the track estimation.

4. Performance Evaluation

4.1 Simulation Parameters

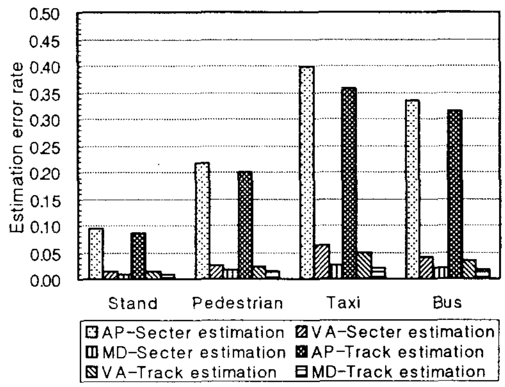
The moving path and the mobile velocity are affected by the road topology. The moving pattern is described by the changes in moving direction and velocity. In our study we assume that low speed mobiles, pedestrians, occupy 60% of the total population in the cell and high-speed mobiles, vehicles do 40% of the population. One half of the pedestrians are assumed to be still and another half moving. Also the private owned cars occupy 60% of the total vehicle, the taxi 10% and the public transportation 30%. Vehicles move forward, leftward/rightward and U-Turn. The moving velocity is assumed to have a uniform distribution. The walking speed of pedestrians is 0~5 Km/hr, the speed of private cars and taxis 30~100 Km/hr, and buses 10~70 Km/hr. The speed is assumed to be constant during walking or driving. <Figure 4> shows the road used in our simulation to consider traffic environments. The black circle indicates the branch of the road, and the shaded areas are blocks that the road passes through. Each block is a square and its side is assumed to have the length of 30 m. The time needed for a high speed mobile to pass through a block is calculated from $BT=r/v$ where r is the length of the road segment crossing at each block and v the mobile speed. As shown in <Figure 4>, BT is dependent on r. We can consider four different values - r, $n\sqrt{2}m$ (crossing diagonally, e.g. block number 64), $\frac{3n}{4}\sqrt{2}m$ (3/4 crossing, e.g. block number 37), $\frac{n}{2}\sqrt{2}\ m$ (2/4 crossing, e.g. block number 46) and $\frac{n}{4}\sqrt{2}m$ (1/4 crossing, e.g. block number 28) - according to which portion of a block each road segment crosses through. In order to reflect more realistic information into our simulation, it is assumed that the signal strength is sampled every 0.5 sec, 0.2 sec, 0.1 sec, 0.1 sec and 0.05 sec for the speed of $\leq$ 10km/h, $\leq$ 20km/h, $\leq$ 50km/h, $\leq$ 70km/h and $\leq$ 100km/h respectively. If BT is too small, we cannot obtain enough samples to calculate the average signal strength. We consider the following simulation parameters regarding the received signal strength. The value of k_2, which indicates the changes in LOS/NLOS environments, is in the range of 20 through 50. The mean signal attenuation by the path-loss is proportional to 3.5 times the propagation distance, and the shadowing has a log-normal distribution with a standard deviation of $\sigma = 6dB$. A value of received signal strength less than -16 dB is regarded as an error, which is therefore excluded from the calculation.

4.2 Performance Analysis

To evaluate the error probability of our schemes in each estimation stage, the mobile population in the track boundary and sector boundary is generated according to a Poisson distribution. All the mobiles generated above are assumed to cross the sector boundary lines and track boundary lines. Also the curved path passes through the handoff area. Stationary mobiles appear at sector boundary areas and track boundary areas and remain still at those points. Pedestrian mobiles appear at sector and track boundary areas and move toward the neighboring sector or track. Private passenger cars and buses appear at track boundary areas and move toward the neighboring track.

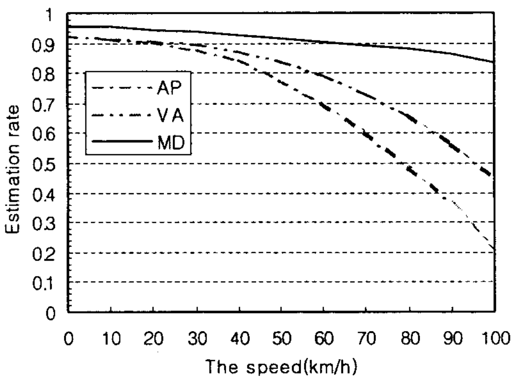
According to simulation results, we found that most estimation errors occurred when mobiles passed through sector and zone boundary lines or in a curved path. Estimation errors for low speed mobiles were mostly observed while they were moving through a curved path. On the other hand estimation errors for high-speed mobiles were observed when they were moving through either sector boundary lines or a curved path.

<Figure 5> shows error rates of our schemes in the sector estimation stage. When high speed mobiles such as passenger cars and buses pass through the sector boundary, the rate of estimation error in Area Partitioning (AP) scheme[Lee et al., 1998] is near to 0.4 in total, but it becomes drastically reduced in Virtual Area (VA) scheme[Lee et al., 2000; Lee et al., 2003]. Moreover it is much further reduced in Multi-criteria Decision (MD) scheme which considers other information than the received signal strength additionally. As we can see in <Figure 5>, track estimation error



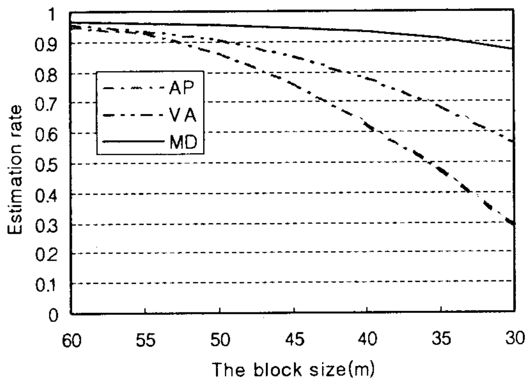
〈Figure 5〉 Sector and Track estimation error rate is lower than sector estimation error. The track estimation is performed using PSS of the base station which the mobile belongs to. The shadowing in sector estimation is same as in track estimation. The path-loss error in track estimation is smaller than in sector estimation, therefore the track estimation error is smaller than the sector estimation error.

<Figure 6> shows estimation rates or accuracies of our proposed schemes depending on the mobile speed. The accuracy of AP becomes lower rapidly due to the signal measurement error as the mobile speed increases. In VA the effect of mobile speed increase is smaller. Further the performance of MD is least affected by the mobile speed increase because information such as moving direction and previous location are considered in MD.



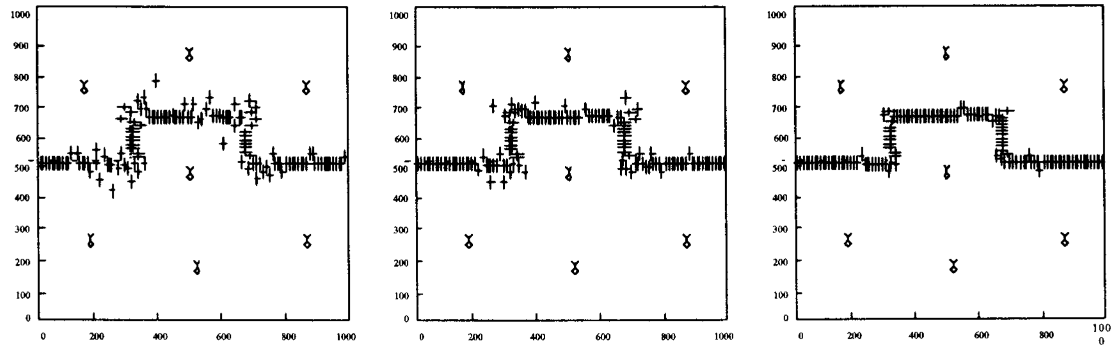
〈Figure 6〉 The estimation accuracy versus the mobile speed

<Figure 7> shows the effect of block size on the estimation performance of our schemes. As the block size becomes smaller, the accuracies of AP and VA are decreased rapidly. On the other hand the performance of MD is least affected by the block size increase because it utilizes previous location and distance between mobile and base station additionally for estimation.



〈Figure 7〉 The estimation accuracy versus the block size

<Figure 8> shows estimation results of three schemes for the situation where the high speed mobile moves along a straight or curved sector boundary area. In this figure the horizontal and vertical axes represent the relative location of the area observed and the path generated in this simulation. Results are shown for AP, VP and MD from left to right in this figure respectively. As can be seen AP sometimes selects faulty locations far away from the generated path. That is because inaccurate results in sector estimation stage are escalated into track and block estimation. VA has better accuracies for curved path. In our understanding it may be attributed to the fact that the average value of pilot signal strengths sampled by high speed mobile passing through two sectors falls into the range of PSS values of the sector boundary area. The performance of MD is less affected during a left turn or right turn. A left or right turn causes

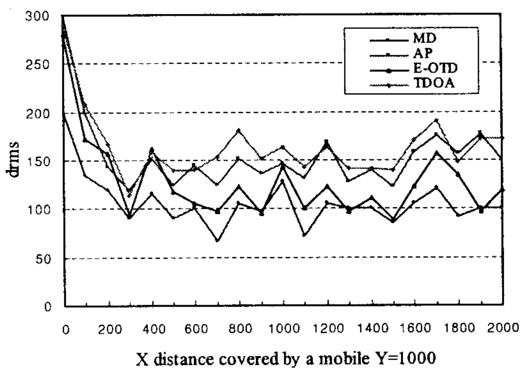


(a) AP (b) VA (c) MD

⟨Figure 8⟩ The estimation results on the move

abrupt signal distortions, but their effects on estimation can be compensated for by using information on previous location and distance to base station. Especially, it can reduce the possibility of selecting a faulty location far away from present location by using information on previous location.

In <Figure 9> we compare our schemes AP, MD with E-OTD and TDOA [Spirito, 2001]. The mobile maintains its y position at 1000m and traverse the x axis from x = 0m to x = 2000m. The y axis means how the drms varies with x position of mobile. In order to get the estimated values for comparison we take the average of 20 random values of the received signal strength for each mobile position. We assume NLOS environment at every position and also assume that the signal level of mobile may change abruptly due to shadowing. Under this assumption the estimation accuracy of each scheme may be changed. E-OTD and TDOA are affected by abrupt change of signal levels in NLOS environment. On the other hand the performance of MD is least affected even by abrupt change of signal level and it has the best accurate estimation result. Its best accuracy may well be attributed to the fact that it imposes less weight on the received signal strength in NLOS area and more weights on other decision parameters (such as the distance between the mobile and the base station, the previous location, and the moving direction).



⟨Figure 9⟩ Comparison of the estimation accuracy

5. Conclusion

In this paper we study novel schemes for estimating the mobile location in the micro-

/picocellular communication system more accurately by considering NLOS environment and other multiple decision parameters than the received signal strength.

AP scheme estimates in stepwise the optimal block at which the mobile locates with the help of the location definition database. It is constructed at the initialization of the base station by mapping the received signal strength, according to NLOS model, onto small blocks divided from each cell. It is, however, prone to errors in the situation where the mobile locates at the boundary of sectors, tracks or blocks. VA scheme reduces these errors by defining "virtual area" at these boundaries and performing the additional estimation steps for these areas. Moreover MD scheme utilizes the fuzzy-based decision making with the consideration of the information such as previous location, moving direction and distance to the base station as well as received signal strength. Error rates in the sector estimation and track estimation of both AP scheme and VA scheme increase rapidly as the mobile speed gets higher or the block size smaller. On the other hand MD scheme is least affected by the increased mobile speed or the decreased block size. According to the comparison of our scheme MD with existing schemes such as AP, E-OTD and TDOA, the performance of MD is least affected by abrupt change of signal level and it has the most accurate result.

The effect of weight factor variation on estimation performance in our MD scheme, and the determination of the optimal weight should be the subject of a future study. Also further researches are required on their implementation and applications to the handoff and channel allocation strategies.

References

[1] Austine, M. D. and Stuber, G. L., "Velocity Adaptive Handoff Algorithms for Microcellular Systems", *Proceedings of ICUPC*, Oct. 1993, pp. 793-797.

[2] Austine, M. D., "Direction Biased Handoff Algorithms for Urban Micro-cells", *Proceedings of VTC'94*, Vol. 1, 1996, pp. 101-105.

[3] Aycard, O., Charpillet, F., Fohr, D., and Mari, J. F., "Place Learning and Recognition Using Hidden Markov Models", *Proceedings of IEEE IROS'97*, Vol. 3, Sep. 1997, pp. 1741-1747.

[4] Bharadwaj, V. K. and Karandikar, A., "Hidden Markov Model Based Resource Estimation and Call Admissions in Mobile Cellular Networks", *Proceedings of IEEE ICPWC'99*, 1999, pp. 321-325.

[5] Cichon, D. J., Becker, T. C. and Dottling, M., "Ray Optical Prediction of Outdoor and Indoor Coverage in Urban Macro- and Micro-cells", *Proceedings of VTC'96*, Vol. 1, May 1996, pp. 41-45.

[6] Djuknic, G. M. and Richton, R. E., "Geolocation and Assisted GPS", *IEEE Computer*, Vol. 34, No. 2, Feb. 2001, pp. 123-125.

[7] Fau, R. and Wasch, A., "A Hybrid Propagation Modeling Approach for DCS1800 Macro cells", *Proceedings of VTC'96*, Vol.

3, May 1996, pp. 1628-1632.

[8] Gudmundson, M., "Analysis of Handover Algorithms", *Proceedings of VTC'91*, May 1991, pp. 537-542.

[9] Hatta, M. and Nagatsu, T., "Mobile Location Using Signal Strength Measurements in a Cellular System", *IEEE Transactions on Vehicular Technology*, Vol. VT29, May 1980, pp. 245-252.

[10] Kennemann, O., "Continuous Location of Moving GSM Mobile Stations by Pattern Recognition Techniques", *Proceedings of 5th International. Symposium on Personal, Indoor, Mobile, Radio Communications*, den Haag, Holland, 1994, pp. 630-634.

[11] Kuo, J. Y. and H. W. T., "Fuzzy Decision Making through Relationships Analysis between Criteria", *Fuzzy Systems Symposium, Soft Computing in Intelligent Systems and Information Processing*, 1996, pp. 296-301.

[12] Lee, J. C., Lee M. H., Moon, Y., "Mobile Location Estimation for PCS", *Journal of Korea Information and Communication Society*, Vol. 23, No. 8, Aug. 1998, pp. 2080-2089.

[13] Lee, J. C. and Lee, M. H., "Mobile Location Estimation Scheme Based on Virtual Area Concept", *Journal of the Institute of Electronics Engineers of Korea*, Vol. 37, No. TC-7, July 2000, pp. 423-431.

[14] Lee, J. C. and Lee, M. H., "Mobile Tracking Schemes", *Journal of the Institute of Electronics Engineers of Korea*, Vol. 40, No. TC-4, April 2003, pp. 140-154.

[15] Lee, J. C. Lee, M. H. and Lee, G., "Location Tracking Based on Virtual Area Concept" *Proceedings of International Technical Conference on Circuits/Systems, Computers and Communications*, July 2003, pp. 512-515.

[16] Lee, W. C. Y., "Estimate of Local Average Power of a Mobile Radio Signal", *IEEE Transactions on Vehicular Technology*, Vol. 34, No. 1, 1985, pp. 22-27.

[17] Nypan, T. and Hallingstad, O., "Cellular Positioning by Database Comparison and Hidden Markov Models", *Proceedings of PWC 2003*, Oct. 2003, pp. 277-284.

[18] Rappaport, T. S., Reed, J. H., and Woerner, B. D., "Position Location Using Wireless Communications on Highways of the Future", *IEEE Communications Magazine*, Oct. 1996, pp. 33-41.

[19] Senarath, G. N. and Everitt, D., "Reduction Call Drop-outs during Handoff Using Efficient Signal Strength Prediction Algorithms for Personal Communication Systems", *Proceedings of GLOBECOM'95*, Vol. 3, No. 1995, pp. 2308-2312.

[20] Song, H. L., "Automatic Vehicle Location in Cellular Communication Systems", *IEEE Transactions on Vehicular Technology*, Vol. 43, 1994, pp. 902-908.

[21] Spirito, Y. A., "On the Accuracy of Cellular Mobile Station Location Estimation," *IEEE Transactions on Vehicular Technology*, Vol. 50, No. 3, 2001, pp. 674-685.

[22] Vijayan, R. and Holtzman, J. M., "Analysis of Handoff Algorithms Using Nonstationary Signal Strength Measurements", *Proceedings of IEEE GLOBECOM 1992*,

Vol. 3, 1992, pp. 1405-1409.

[23] Yeh, C. H. and Deng, H., "An Algorithm for Fuzzy Multi-criteria Decision Making", *Proceedings of IEEE ICIPS 1997*, Vol. 2, 1997, pp. 1564-1568.

[24] Zhang, N. and Holtzman, J. M., "Analysis of Handoff Algorithms Using Both Absolute and Relative Measurements", *IEEE Transactions on Vehicular Technology*, Vol. 45, Feb 1996, pp. 174-179.

■ 저자소개

이 종 찬

군산대학교 전자계산학과에서 공학사, 숭실대학교 컴퓨터과학과에서 공학석사와 공학박사를 취득하였으며 한국전자통신연구원에서 선임연구원으로 근무한 후 현재는 국립군산대학교 컴퓨터정보과학과 교수로 재직 중이다. 관심분야는 차세대 이동통신, 센서네트워크, 무선멀티미디어이다.

이 문 호

서울대학교 공과대학에서 공학사, 숭실대학교에서 공학석사와 공학박사를 취득하였으며 한국전자통신연구원과 현대전자(주)에서 근무한 후 현재는 청운대학교 멀티미디어학과 교수로 재직 중이다. 관심분야는 멀티미디어 통신, 차세대 이동통신, 유비쿼터스 컴퓨팅이다

◈ 이 논문은 2007년 03월 26일 접수하여 1차 수정을 거쳐 2007년 06월 19일 게재확정되었습니다.