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A CONTEXT-AWARE FUZZY-BASED HANDOVER SYSTEM FOR WIRELESS CELLULAR NETWORKS AND ITS PERFORMANCE EVALUATION

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Presently, the wireless mobile networks and devices are becoming increasingly popular to provide users the access anytime and anywhere. The mobile systems are based on cellular approach and the area is covered by cells that overlap each other. In mobile cellular systems the handover is a very important process to maintain the desired Quality of Service (QoS). Many handover algorithms are proposed in the literature. However, to make a better handover and keep the QoS in wireless networks is very difficult. During handover decision in cellular networks, there is a risk of making incorrect decision based on incomplete or outdated information. For this reason, we use Fuzzy Logic (FL) which can operate with imprecision data. The context-triggered actions are carried out based on simple IF-THEN rules. In different from other works, we use Random Walk (RW) model and FL to design a new handover system, which is able to avoid ping-pong effect and has a good handover decision. The performance evaluation via simulations shows that proposed system can avoid ping-pong effect and has a good handover decision.

Keywords: Wireless networks, cellular networks, fuzzy theory, handover.

1 Introduction

During the last few years wireless multimedia networks have been a very active research area [1,2]. The QoS support for future wireless networks is a very important problem. To guarantee the QoS, a good handover strategy is needed in order to balance the call blocking and call dropping for providing the required QoS [3,4]. In the future, the wireless networks will adopt a micro/pico cellular architecture. However, smaller cell size naturally increases the number of handoffs a Mobile Station (MS) is expected to make. As the new call arrival rate or load increases, the probability of handoff failure increases. This phenomenon combined with the large number of handoffs before completion of a call increases the forced termination probability of calls [5,6].

Many metrics have been used to support handover decisions, including Received Signal Strength (RSS), Signal to Interference Ratio (SIR), distance between the mobile and Base Station (BS), traffic load, and mobile velocity, where RSS is the most commonly used one. The conventional handover decision compares the RSS from the serving BS with that from one of the target BSs, using a constant handover threshold value (handover margin). The selection of this margin is crucial to handover performance. If the margin is too small, numerous unnecessary handovers may be processed. Conversely, the QoS could be low and calls could be dropped if the margin is too large. The fluctuations of signal strength associated with shadow fading cause the ping-pong effect [7].

Recently, many investigations have addressed handover algorithms for cellular communication systems. However, it is essentially complex to make handover decision considering multiple criteria. Sometimes, the trade-off of some criteria should be considered. Therefore, heuristic approaches based on Neural Networks (NN), Genetic Algorithms (GA) and Fuzzy Logic (FL) can prove to be efficient for wireless networks [8,9,10,11]. In [10], a multi-criteria handover algorithm for next generation tactical communication systems is introduced. The handover metrics are: RSS from current and candidate base transceivers, ratio of used soft capacity to the total soft capacity of base transceivers, the relative directions and speeds of the base transceivers and the mobile node. In [11], a handover algorithm is proposed to support vertical handover between heterogeneous networks. This is achieved by incorporating the mobile IP principles in combination with FL concepts utilizing different handover parameters.

In wireless cellular networks, where mobile applications suffer from the limitation and variation of system resources availability, its is desirable for the system to adopt the behavior based on the resources availability. In order that mobile applications operate efficiently in a mobile environment, mobile systems have to perform two tasks: sensing the current context of the environment, and react effectively to the current context to optimize the system performance.

Context-aware computing is a mobile computing paradigm in which applications and systems can discover and take advantage of contextual information. The contextual information can be divided in three categories: *Computing Context*, such as network connectivity, communication costs, and communication bandwidth; *User Context*, such as the user's profile and location; *Physical Context*, such as noise levels, signal levels and traffic conditions.

The role of context for better decision-making has been a topic of significant research efforts over the years. The more ambiguous decision situation, the bigger advantage is there to provide the decision-maker with support in modeling and learning the context for better understanding of decision parameters and implications of selecting particular decision alternatives. Most of real-time decisions are mainly based on access to real-time data or information that can support the decision-making process. For handover decision in cellular networks, there is a risk of making incorrect decision based on incomplete or outdated information.

For this reason, we propose a FL-based approach for handover in cellular networks, which can operate with imprecision data. The context-triggered actions are carried out based on simple IF-THEN rules. In different from other works, in the proposed system, we use Random Walk (RW) model and FL. The performance evaluation shows that the proposed system can avoid ping-pong effect and has a good handover decision.

The structure of this paper is as follows. In Section 2, we present the handover decision problem. In Section 3, we give a brief introduction of RW model. In Section 4, we introduce the proposed system. In Section 5, we discuss the simulation results. Finally, some conclusions are given in Section 6.

2 Handover Decision Problem

Handoffs which are consistently both accurate and timely can result in higher capacity and better overall link quality than what is available with today systems [12,13,14]. Now with increasing demands for more system capacity, there is a trend toward smaller cells, also known as microcells. Handoffs are more critical in systems with smaller cells, because for a given average user speed, handoff rates tend to be inversely proportional to cell size [5]. The main objectives of handover are link quality maintenance, interference reduction and keeping the number of handoffs low. Also, a handover algorithm should initiate a handoff if and only if the handoff is necessary. The accuracy of a handover algorithm is based on how the algorithm initiates the handover process. The timing of the handoff initiation is also important. There can be deleterious effects on link quality and interference if the initiation is too early or too late. A timely handover algorithm is one which initiates handoffs neither too early nor too late.

Because of large-scale and small-scale fades are frequently encountered in mobile environment, it is very difficult for handover algorithm to make an accurate and timely decision. Handover algorithms operating in real time have to make decisions without the luxury of repeated uncorrelated measurements, or of future signal strength information. It should be noted that some of handover criteria information can be inherently imprecise, or the precise information is difficult to obtain. For this reason, we propose a FL-based approach, which can operate with imprecision data and can model nonlinear functions with arbitrary complexity.

3 RW Model

The Monte Carlo (MC) method is a technique that uses random numbers and probability to solve problems. It is often used when the model is complex, nonlinear, or involves more than just a couple uncertain parameters.

The MC method can be used for analyzing uncertainty propagation, where the goal is to determine how random variation, lack of knowledge, or error affects the sensitivity, performance, or reliability of the system that is being modeled. MC simulation is categorized as a sampling method because the inputs are randomly generated from probability distributions to simulate the process of sampling from an actual population. The data generated from the

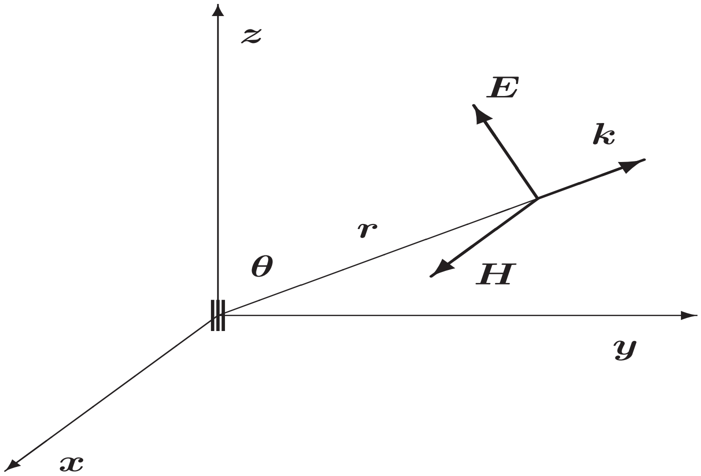

Fig. 1. Dipole antenna.

simulation can be represented as probability distributions (or histograms) or converted to error bars, reliability predictions, tolerance zones, and confidence intervals.

We use the MC method for realizing RW model. We consider a 2-dimensional field. The initial position is considered as a origin point and we decided based on MC method the moving pattern for each walk. If we consider n user movements, when the angle θ and distance d for each walk are generated by general or Gaussian distribution, and the movement changes in x and y directions are Δx and Δy, respectively, then we have the following relations.

$$\Delta x_n = d_n cos\theta_n, \quad \Delta y_n = d_n sin\theta_n \tag{1}$$

$$x_{n+1} = x_n + \Delta x_n, \quad y_{n+1} = y_n + \Delta y_n \tag{2}$$

BS position can be expressed by Cartesian coordinates. By converting Cartesian coordinates to polar ones, we can calculate the angle θ.

We consider that in the cellular system each cell has a hexagonal shape and the BS is located in the center of the cell. The angle θ between Dipole Antenna (DA) and vector $\boldsymbol{r}$ is $D(\theta) = \sin\theta$. If we consider the transmission power as W, the antenna radiation intensity can be calculated as follows:

$$\boldsymbol{E} = \sqrt{45W}\sin\theta\frac{e^{-j\kappa r}}{r^n}\boldsymbol{u_0} \tag{3}$$

where, the DA gain is $G = 1.5$ and $\boldsymbol{u_0}$ is the unit vector that shows DA direction. In Fig. 1 $\boldsymbol{u_0}$ is in Z direction.

In Eq.(3), when $\theta = 90°$, the E value will be maximal in horizontal direction. However, in real situations, the direction of antenna is set up as shown in Fig. 2 in order to cover better the cell area. If we consider the beam tilting angle and the distance, the E can be calculated by the following equation.

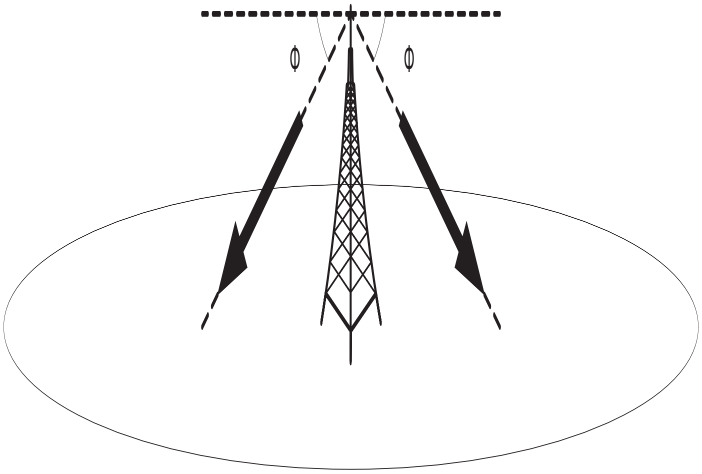

Fig. 2. Beam tilting.

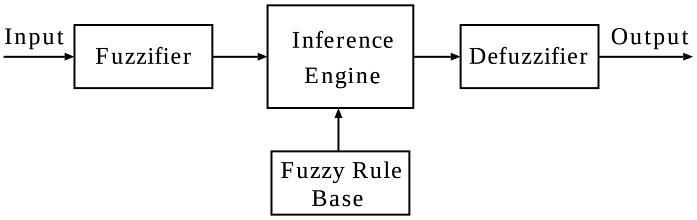

Fig. 3. FLC structure.

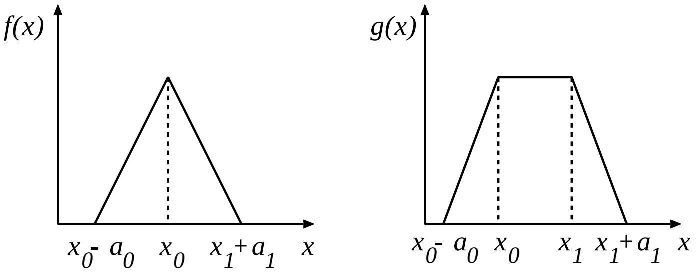

Fig. 4. Membership function shapes.

$$\boldsymbol{E} = \sqrt{45W} \sin(\theta - \phi) \frac{e^{-j\kappa r}}{r^n} \boldsymbol{u_0} \tag{4}$$

4 Proposed System Model

The Fuzzy Logic Controller (FLC) is the main part of the proposed system and its basic elements are shown in Fig. 3. They are the fuzzifier, inference engine, Fuzzy Rule Base (FRB) and defuzzifier. As membership functions, we use triangular and trapezoidal membership functions because they are suitable for real-time operation [15]. They are shown in Fig. 4 and are given as:

$$f(x; x_0, a_0, a_1) = \begin{cases} \frac{x-x_0}{a_0} + 1 & \text{for } x_0 - a_0 < x \leq x_0 \\ \frac{x_0-x}{a_1} + 1 & \text{for } x_0 < x \leq x_0 + a_1 \\ 0 & \text{otherwise} \end{cases}$$

$$g(x; x_0, x_1, a_0, a_1) = \begin{cases} \frac{x-x_0}{a_0} + 1 & \text{for } x_0 - a_0 < x \leq x_0 \\ 1 & \text{for } x_0 < x \leq x_1 \\ \frac{x_1-x}{a_1} + 1 & \text{for } x_1 < x \leq x_1 + a_1 \\ 0 & \text{otherwise} \end{cases}$$

where x_0 in $f(.)$ is the center of triangular function; $x_0(x_1)$ in $g(.)$ is the left (right) edge of trapezoidal function; and $a_0(a_1)$ is the left (right) width of the triangular or trapezoidal function.

Let us consider the time that a MS is in a cell. In our system, we consider hexagonal cell shape, but for simple calculation let consider a circular cell shape. The distance that a MS moves in a cell can be expressed as follows:

$$D = 2\sqrt{(r^2 + x^2)} \tag{5}$$

where, $0 \leq x < r$.

If the speed of the MS will be V, the time that MS is in a cell is:

$$T_D = \frac{D}{V} = \frac{2\sqrt{(r^2 + x^2)}}{V}. \tag{6}$$

The average distance that a MS is in a cell can be calculated by Eq. (7).

$$\overline{D} = \frac{4\int_0^r \sqrt{(r^2 + x^2)}dx}{2r} = \frac{\pi r}{2} \tag{7}$$

Then, the average T_D time will be:

$$\overline{T_D} = \frac{\overline{D}}{V} = \frac{\pi r}{2V}. \tag{8}$$

The proposed fuzzy model is shown in Fig. 5. The $Node\_B$ shows the wireless transmitter and receiver of BS and RNS indicates Radio Network System.

In this paper, we consider mobility-based services, which make use of some characteristics or context parameters that change with mobility. As contextual parameters we consider: Signal Strength from the Present BS (*SSP*), Signal Strength from the Neighbor BS (*SSN*), and the distance of MS from BS (*D*). These parameters are used as the input parameters for FLC. The output linguistic parameter is Handover Decision (*HD*).

The term sets of *SSP*, *SSN* and *D* are defined respectively as:

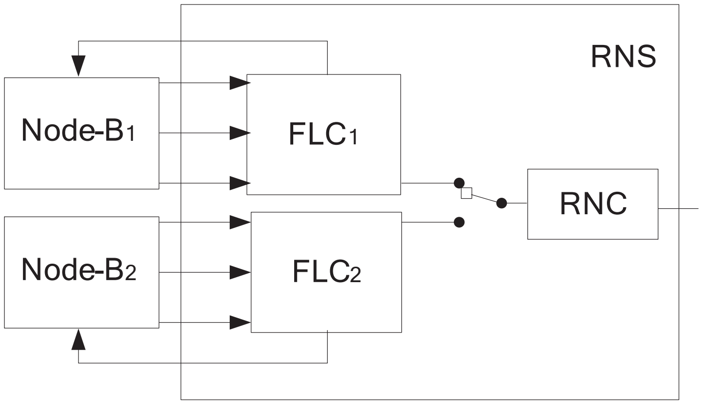

Fig. 5. System model.

$$
\begin{aligned}
T(SSP) &= \{Weak, Not\ So\ Weak, Normal, Strong\} \\
&= \{W1, NSW1, N1, S1\}; \\
T(SSN) &= \{Weak, Not\ So\ Weak, Normal, Strong\} \\
&= \{W2, NSW2, N2, S2\}; \\
T(D) &= \{Near, Not\ So\ Near, Not\ So\ Far, Far\} \\
&= \{NR, NSN, NSF, FA\}.
\end{aligned}
$$

The output linguistic parameter $T(HD)$ is defined as $\{Very\ Low, Low, Little\ High, High\}$ $= \{VL, LO, LH, HG\}$.

The membership functions of FLC are shown in Fig. 6. The FRB forms a fuzzy set of dimensions $|T(SSP)| \times |T(SSN)| \times |T(D)|$, where $|T(x)|$ is the number of terms on $T(x)$. The FRB is shown in Table 1 and has 64 rules. The control rules have the following form: IF "conditions" THEN "control action". The context-triggered actions are carried out based on these simple IF-THEN rules.

5 Simulation Results

5.1 RW model results

The cell shape is hexagonal and the coordinates of BSs are indicated as shown in Fig. 7. In Fig. 8 is shown the power distribution for one transmission antenna when the BS is located in the center of the cell, the transmission antenna power is 10 W, and cell radius is 2 km. In Table 2 are shown the simulation parameters.

We carried out many simulations, but for the sake of space, we considered two scenarios: un-necessary handover and enforced handover. As scenario of un-necessary handover, we consider the case when the MS moves in the boundary of cells. While, as enforced handover we consider the case when MS moves inside the cells.

In Fig. 9 is showing the walking pattern for a MS when $iseed = 100$ and $nwalk = 5$, while in Fig. 10 for $iseed = 200$ and $nwalk = 10$. In Fig. 9, the MS moves in the cells: (0,0)→(2,-

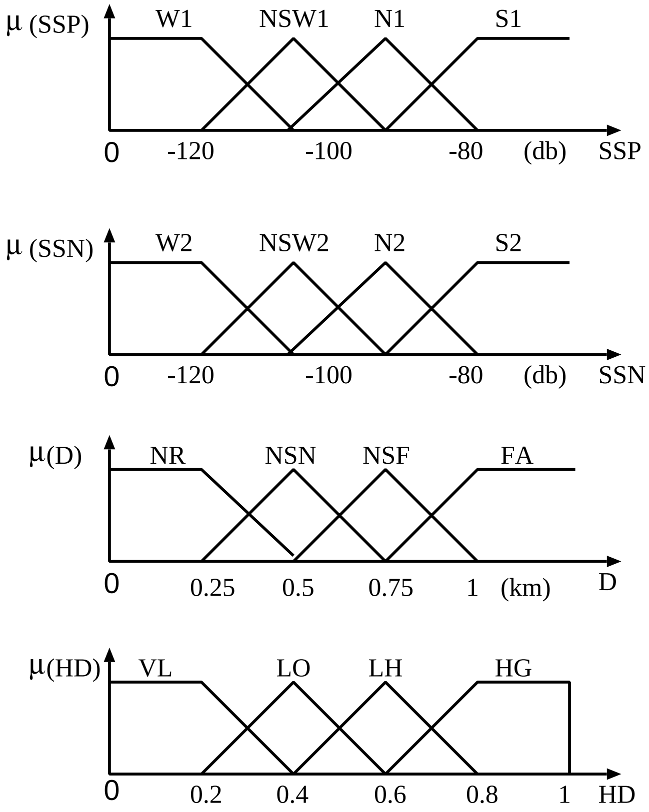

Fig. 6. Membership functions.

1)→(0,0)→(1,-2), while in Fig. 10 in the cells: (0,0)→(-1,2)→(-2,1)→(-1,2). In Fig. 9, the ping-pong effect happens, because the MS is moving in the cells boundary (un-necessary handover). While in Fig. 10, the handover process is necessary (enforced handover).

In Fig. 11 is showing the aggregate received power of MS for the case when $iseed = 100$. In Fig. 12, Fig. 13 and Fig. 14 is showing the received power from the BS(0,0), BS(2,-1), BS(1,-2), respectively.

In Fig. 15, we show the aggregate received power of MS for the case when $iseed = 200$, while in Fig. 16, Fig. 17 and Fig. 18 is showing the received power from the BS(0,0), BS(-1,2), BS(-2,1), respectively.

As can be seen from these figures, when the MS is going far from the BS the received power is decreased, while when the MS is approaching neighbor BS the received power from these BSs is increased.

Table 1. FRB.

Rules	SSP	SSN	D	HD	Rules	SSP	SSN	D	HD
1	W1	W2	NR	VL	33	N1	W2	NR	VL
2	W1	W2	NSN	VL	34	N1	W2	NSN	VL
3	W1	W2	NSF	VL	35	N1	W2	NSF	LO
4	W1	W2	FA	LO	36	N1	W2	FA	LO
5	W1	NSW2	NR	LO	37	N1	NSW2	NR	LO
6	W1	NSW2	NSN	LO	38	N1	NSW2	NSN	LO
7	W1	NSW2	NSF	LO	39	N1	NSW2	NSF	LH
8	W1	NSW2	FA	LH	40	N1	NSW2	FA	LH
9	W1	N2	NR	LH	41	N1	N2	NR	LH
10	W1	N2	NSN	LH	42	N1	N2	NSN	LH
11	W1	N2	NSF	HG	43	N1	N2	NSF	LH
12	W1	N2	FA	HG	44	N1	N2	FA	HG
13	W1	S2	NR	LH	45	N1	S2	NR	LH
14	W1	S2	NSN	LH	46	N1	S2	NSN	LH
15	W1	S2	NSF	LH	47	N1	S2	NSF	LH
16	W1	S2	FA	HG	48	N1	S2	FA	HG
17	NSW1	W2	NR	VL	49	S1	W2	NR	VL
18	NSW1	W2	NSN	VL	50	S1	W2	NSN	VL
19	NSW1	W2	NSF	LO	51	S1	W2	NSF	VL
20	NSW1	W2	FA	LO	52	S1	W2	FA	VL
21	NSW1	NSW2	NR	LO	53	S1	NSW2	NR	VL
22	NSW1	NSW2	NSN	LO	54	S1	NSW2	NSN	VL
23	NSW1	NSW2	NSF	LH	55	S1	NSW2	NSF	VL
24	NSW1	NSW2	FA	LH	56	S1	NSW2	FA	LO
25	NSW1	N2	NR	LH	57	S1	N2	NR	LO
26	NSW1	N2	NSN	LH	58	S1	N2	NSN	LO
27	NSW1	N2	NSF	LH	59	S1	N2	NSF	LO
28	NSW1	N2	FA	HG	60	S1	N2	FA	LH
29	NSW1	S2	NR	LH	61	S1	S2	NR	LO
30	NSW1	S2	NSN	LH	62	S1	S2	NSN	LO
31	NSW1	S2	NSF	LH	63	S1	S2	NSF	LH
32	NSW1	S2	FA	HG	64	S1	S2	FA	LH

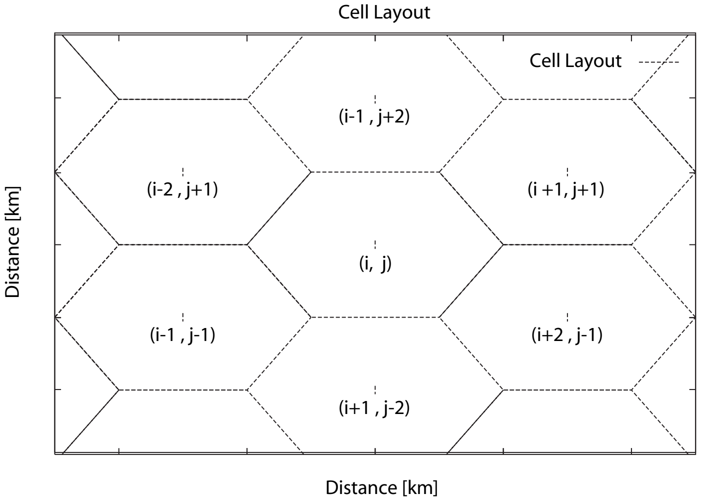

Fig. 7. Cell layout.

5.2 Evaluation of Proposed Fuzzy Handover System

For evaluation of the proposed FL-based handover system, we carried out the measurement for 3 points, where the MS is in the boundary of the 3 cells. In Fig. 19 and Fig. 20 are

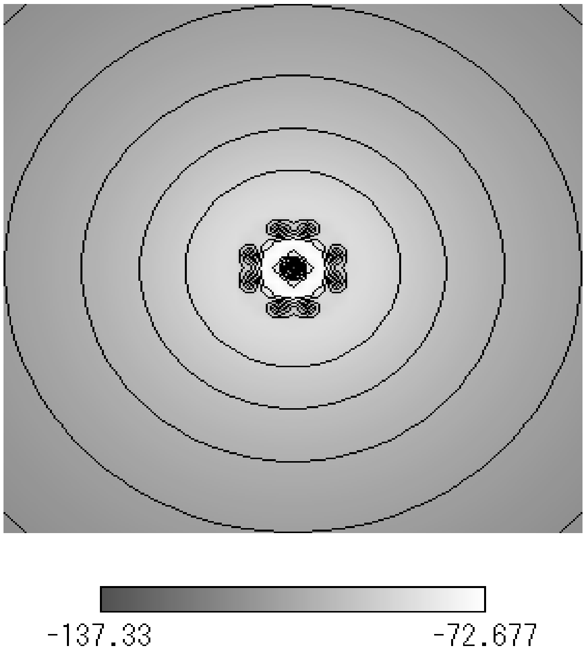

Fig. 8. Power distribution for one antenna.

Table 2. Simulation parameters.

Distribution Law	Gaussian Distribution
Number of Walks	5, 10
Random Types	100, 200
Cell Radius	1km, 2km
Transmission Power	10W, 20W
Frequency	2000MHz
Transmission Antenna Beam Tilting	3°
Transmission Antenna Height	40m
Receiving Antenna Height	1.5m
Average Value for a Walk	0.6km
n	1.1

shown the measurement points for $iseed = 100$ and $iseed = 200$, respectively. In Fig. 19, the handover should not be carried out, because we will have the ping-pong effect, while in Fig. 20 the handover is necessary because the MS is moving inside the neighbor cells.

In our system, we consider that the handover is carried out when the output value is bigger than 0.7. We assume that during the RW for each 10 km/h the signal strength is decreased 2 db. We carried out many simulations and calculated the average values. The simulation results for $iseed = 100$ and $iseed = 200$ are shown in Table 3 and Table 4, respectively.

In the case when $iseed = 100$, the MS moves in the boundary of cells. Thus if the handover will be carried out, we will have the ping-pong effect. As shown in Table 3, for most of the cases when the MS moves in the boundary between two cells, the proposed system can avoid

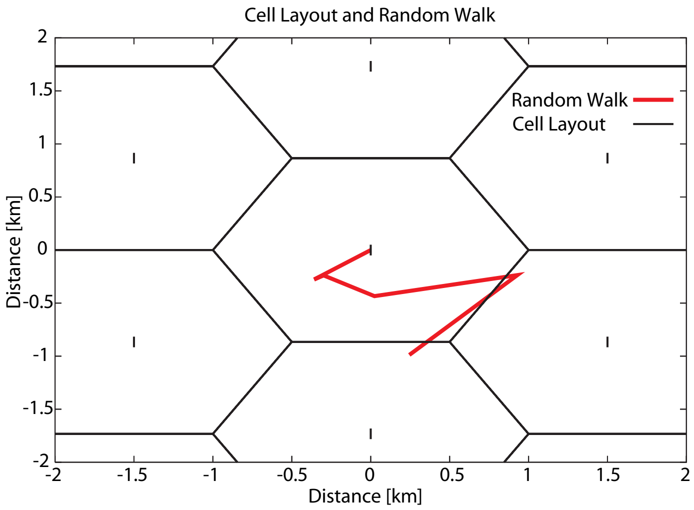

Fig. 9. RW pattern for $iseed = 100$.

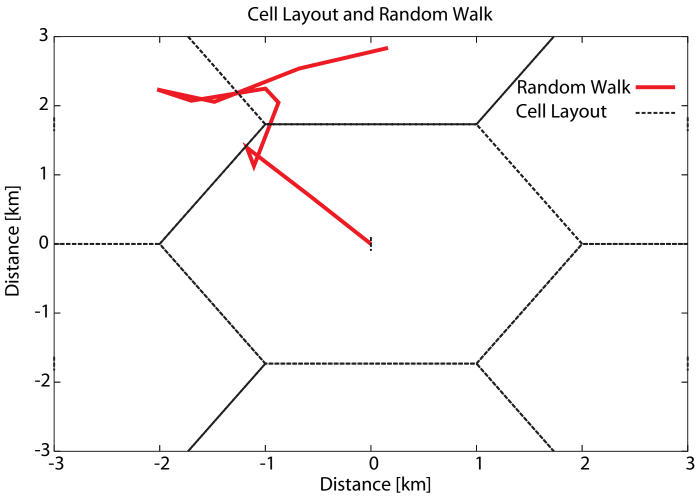

Fig. 10. RW pattern for $iseed = 200$.

the ping-pong effect.

In the case when $iseed = 200$, the MS is moving inside the neighbor cells, so the handover should be carried out 3 times. In the results of Table 4, the proposed system in all cases has done 3 handovers. This shows that the proposed system has a good handover decision.

6 Conclusions

Many investigations have addressed handover algorithms for cellular communication systems. However, it is essentially complex to make handover decision considering multiple criteria.

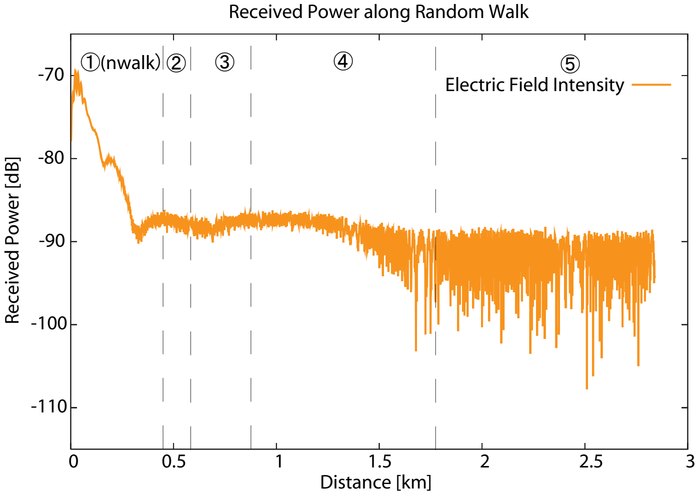

Fig. 11. Aggregate received power ($iseed = 100$).

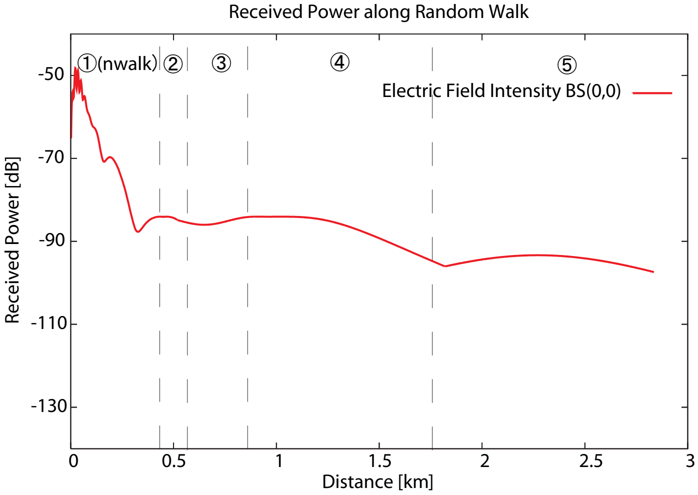

Fig. 12. Received power from BS(0,0) ($iseed = 100$).

Sometimes, the trade-off of some criteria should be considered.

Because of large-scale and small-scale fades are frequently encountered in mobile environment, it is very difficult for handover algorithm to make an accurate and timely decision. Handover algorithms operating in real time have to make decisions without the luxury of repeated uncorrelated measurements. Some of handover criteria information can be inherently imprecise, or the precise information is difficult to obtain.

During handover decision in cellular networks, there is a risk of making incorrect decision based on incomplete or outdated information. For this reason, we use Fuzzy Logic (FL) which can operate with imprecision data. As contextual parameters we considered *User*

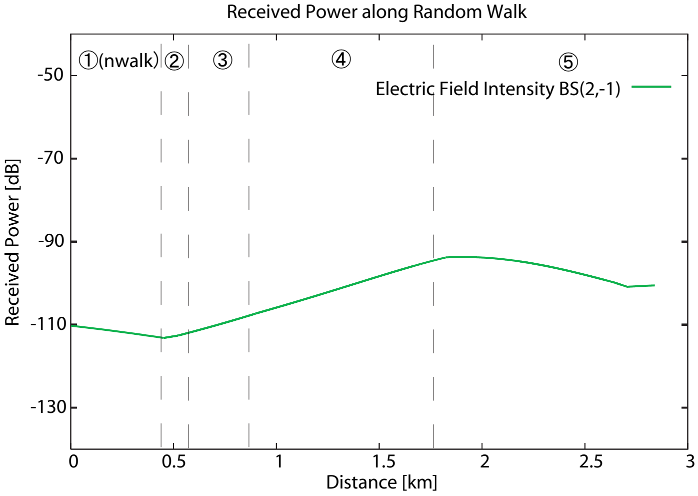

Fig. 13. Received power from BS(2,-1) ($iseed = 100$).

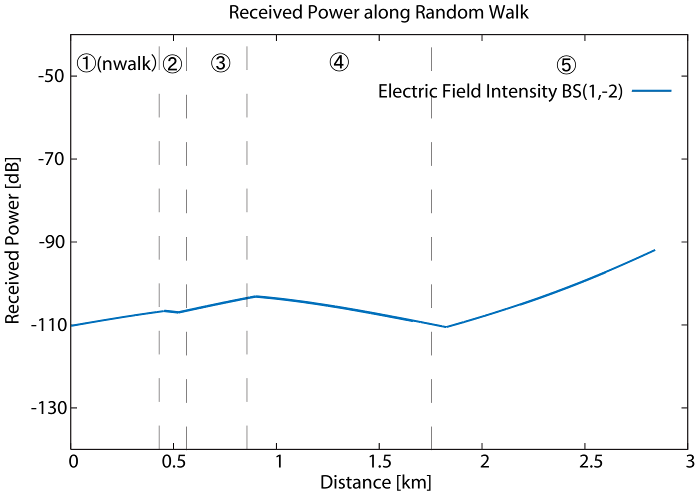

Fig. 14. Received power from BS(1,-2) ($iseed = 100$).

Context and *Physical Context* parameters such as signal levels and distance from the BS. The context-triggered actions are carried out based on simple IF-THEN rules.

In different from other works, we used Random Walk (RW) model and FL to design a new handover system. We evaluated the performance of the proposed FL-based handover system by computer simulations. We considered two scenarios: un-necessary handover and enforced handover. As scenario of un-necessary handover, we consider the case when the MS moves in the boundary of cells. While, as enforced handover we consider the case when MS moves inside the cells. The performance evaluation shows that the proposed system in most of the cases of un-necessary handover can avoid ping-pong effect and in the case of enforced

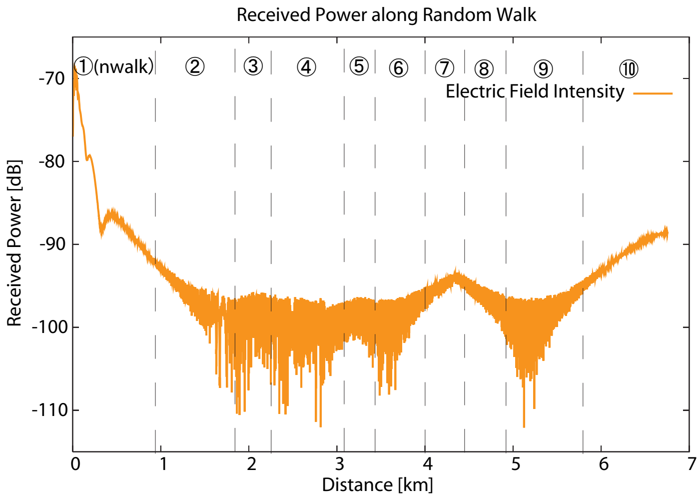

Fig. 15. Aggregate received power (*iseed* = 200).

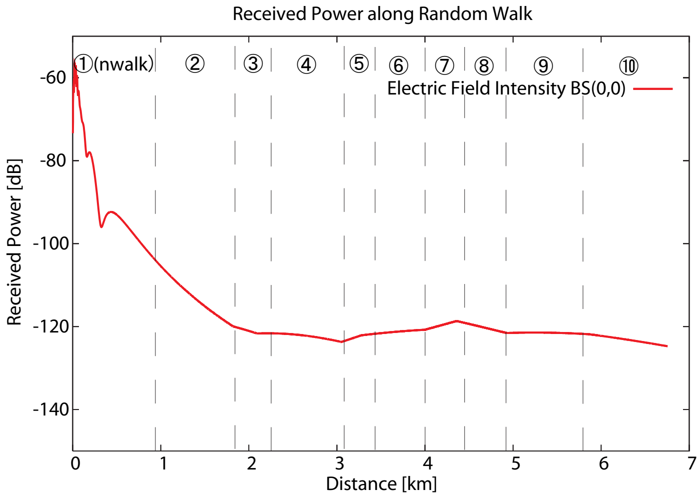

Fig. 16. Received power from BS(0,0) (*iseed* = 200).

handover, it has a very good handover decision.

In the future, we would like to compare the performance of the proposed system with other non-fuzzy-based handover algorithms.

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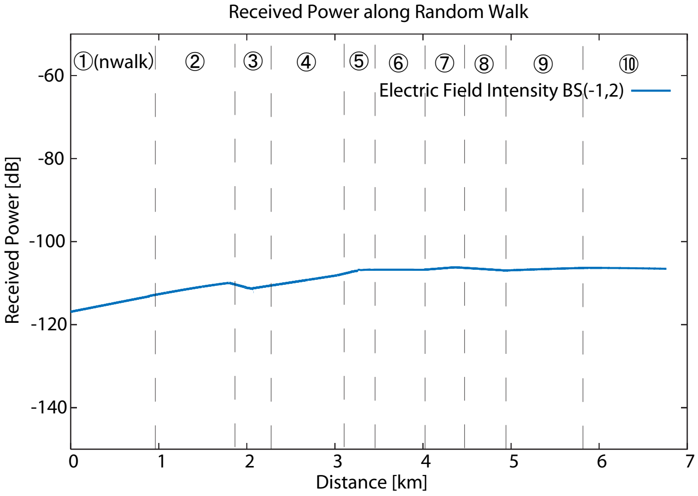

Fig. 17. Received power from BS(-1,2) ($iseed = 200$).

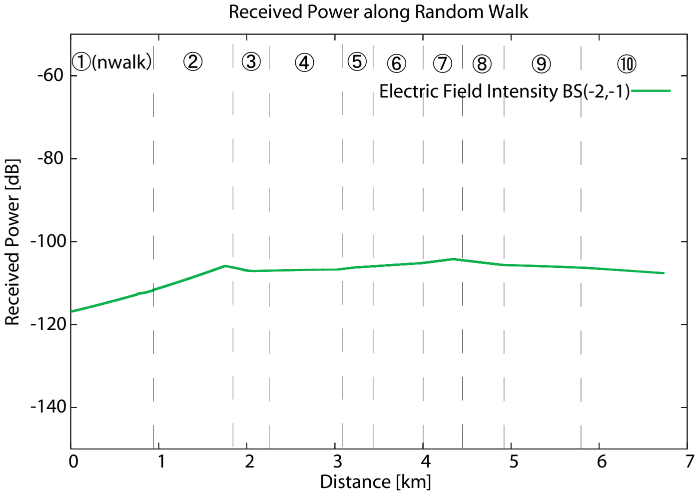

Fig. 18. Received power from BS(-2,1) ($iseed = 200$).

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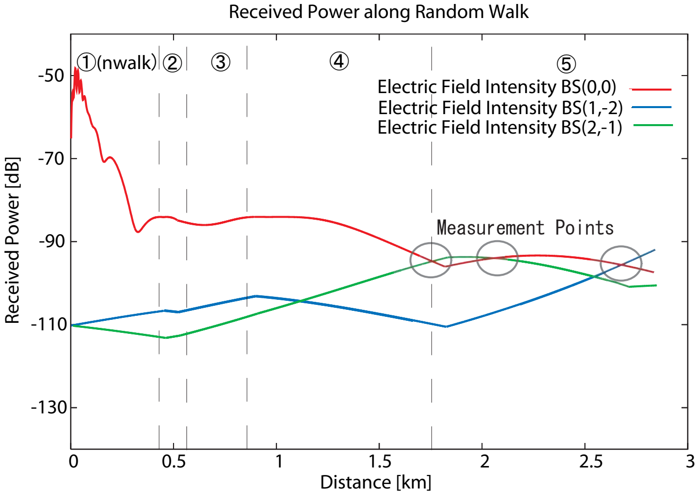

Fig. 19. 3 measurement points for $iseed = 100$.

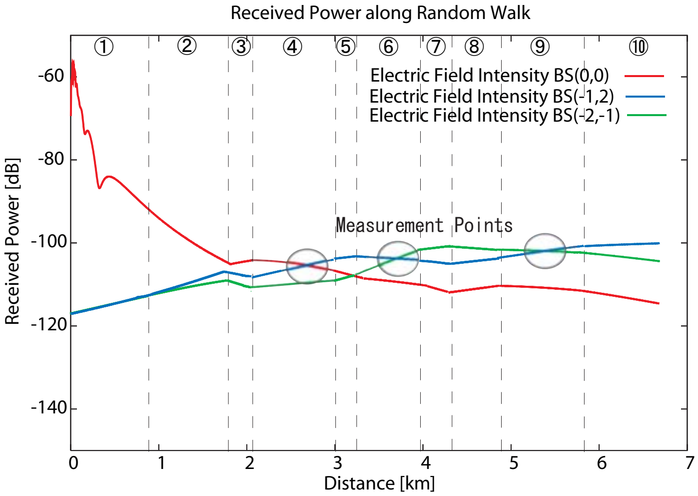

Fig. 20. 3 measurement points for $iseed = 200$.

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Table 3. Simulation results for $iseed = 100$.

Measurement Points	Point 1		Point 2		Point 3	
Speed 0 km/h						
Present BS	−93.06	−94.11	−92.86	−92.47	−94.01	−95.28
Neighbor BS	−93.36	−92.49	−92.77	−93.98	−93.99	−91.28
Distance	0.8804	0.9431	0.8684	0.8466	0.9367	1.0183
System Output Value	0.595	0.629	0.602	0.576	0.623	0.704
Speed 10 km/h						
Present BS	−95.06	−96.11	−94.86	−94.47	−96.01	−97.28
Neighbor BS	−95.36	−94.49	−94.77	−95.98	−95.99	−93.28
Distance	0.8858	0.9431	0.8684	0.8466	0.9367	1.0183
System Output Value	0.598	0.649	0.600	0.578	0.623	0.708
Speed 20 km/h						
Present BS	−97.06	−98.11	−96.86	−96.47	−98.01	−99.28
Neighbor BS	−97.36	−96.49	−96.77	−97.98	−97.99	−95.28
Distance	0.8804	0.9431	0.8684	0.8466	0.9367	1.0183
System Output Value	0.568	0.621	0.572	0.538	0.590	0.696
Speed 30 km/h						
Present BS	−99.06	−100.11	−98.86	−98.47	−100.01	−101.28
Neighbor BS	−99.36	−98.49	−98.77	−99.98	−99.99	−97.28
Distance	0.8804	0.9431	0.8684	0.8466	0.9367	1.0183
System Output Value	0.522	0.585	0.531	0.482	0.542	0.662
Speed 40 km/h						
Present BS	−101.06	−102.11	−100.86	−100.47	−102.01	−103.28
Neighbor BS	−101.36	−100.49	−100.77	−101.98	−101.99	−99.28
Distance	0.8804	0.9431	0.8684	0.8466	0.9367	1.0183
System Output Value	0.534	0.597	0.521	0.497	0.590	0.672
Speed 50 km/h						
Present BS	−103.06	−104.11	−101.86	−104.47	−104.01	−105.28
Neighbor BS	−103.36	−102.49	−102.77	−103.98	−103.99	−101.28
Distance	0.8804	0.9431	0.8684	0.8466	0.9367	1.0183
System Output Value	0.576	0.625	0.566	0.549	0.600	0.668

Table 4. Simulation results for $iseed = 200$.

Measurement Points	Point 1		Point 2		Point 3	
Speed 0 km/h						
Present BS	−105.23	−108.70	−104.64	−107.96	−103.95	−111.93
Neighbor BS	−105.55	−102.07	−103.52	−96.763	−103.85	−88.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.596	**0.706**	0.615	**0.748**	0.601	**0.800**
Speed 10 km/h						
Present BS	−107.23	−110.70	−106.64	−109.96	−105.95	−113.93
Neighbor BS	−107.55	−104.07	−105.52	−98.763	−105.85	−90.442
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.595	**0.715**	0.616	**0.799**	0.601	**0.800**
Speed 20 km/h						
Present BS	−109.23	−112.70	−108.64	−111.96	−107.95	−115.93
Neighbor BS	−109.55	−106.07	−107.52	−100.76	−107.85	−92.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.592	**0.701**	0.699	**0.799**	0.602	**0.800**
Speed 30 km/h						
Present BS	−111.23	−114.70	−110.64	−113.96	−109.95	−117.93
Neighbor BS	−111.55	−108.07	−109.52	−102.76	−109.85	−94.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.632	**0.705**	0.618	**0.733**	0.603	**0.800**
Speed 40 km/h						
Present BS	−113.23	−116.70	−112.64	−115.96	−111.95	−119.93
Neighbor BS	−113.55	−110.07	−111.52	−104.76	−111.85	−96.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.602	**0.711**	0.660	**0.711**	0.647	**0.800**
Speed 50 km/h						
Present BS	−115.23	−118.70	−114.64	−117.96	−113.95	−121.93
Neighbor BS	−115.55	−112.07	−113.52	−106.76	−113.85	−98.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.693	**0.746**	0.694	**0.748**	0.683	**0.800**

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