Field Evaluation on High or Low Mobile Terminal Velocity Decision Algorithm Using Doppler Spread Detection

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Abstract—**In layered cellular networks, to avoid the frequent handovers (HOs) that occur between small cells when a high velocity mobile terminal (MT) travels through these small cells in a short period of time, an inter-layer HO control policy that connects an MT traveling at a high velocity to the macro-cell layer and an MT traveling at a low velocity to the small-cell layer, is effective. To realize such inter-layer HO control policy the authors investigate an MT velocity decision algorithm using Doppler spread detection as a candidate technique for MTs where GPS function has been manually disabled by the user. This paper evaluates the high or low MT velocity decision algorithm in practical radio propagation environment.**

Index Terms— Layered cellular network, Doppler spread, velocity estimation, inter-layer handover.

1. Introduction

Recently, in order to deal with the rapidly increasing mobile traffic, layered cellular networks, where small cells with low transmission power are overlaid onto the hot spot areas of existing macro-cell coverage area, are receiving much attention [1]. However, when a large number of small cells are irregularly and densely deployed in the layered cellular networks, and a mobile terminal (MT) traveling at a high velocity moves through small cells in a short period of time, frequent handovers (HOs) between the small cells occur leading to communication interruption during their HO procedures. To avoid the frequent HO problem, it is effective to introduce an inter-layer HO control policy where MTs travelling at high velocities are connected to base stations (BSs) in the macro-cell layer and MTs travelling at low velocities are connected to BSs in the small-cell layer [2]. To realize such inter-layer HO control policy in the layered cellular networks, it is required to estimate the velocity of each MT and connect the MT to the optimal cell-layer by comparing the estimated velocity to a velocity threshold and deciding whether the MT is traveling at a high or a low velocity with respect to the velocity threshold.

The authors' previous research investigated an MT velocity estimation scheme with Doppler spread detection for MTs where the GPS function has been manually disabled by the user, developed a field experimental system, and evaluated the velocity estimation accuracy of the scheme in a non-line-of-sight (NLOS) practical radio propagation environment through field experiments using our field experimental system [3]. This paper focuses on a high or low velocity decision algorithm based on the MT velocity estimation scheme and a velocity threshold for the inter-layer HO control policy. Then it evaluates the decision accuracy in a heterogeneous practical propagation environment mixed with line-of-sight (LOS) and NLOS propagation through field experiments.

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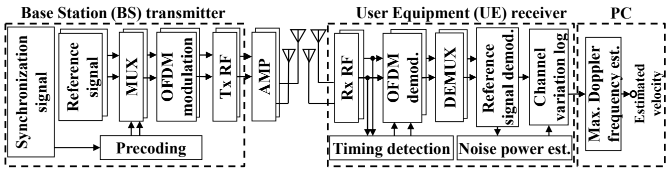

Fig. 1. Transceiver structure of experimental system.

TABLE I

Number of antennas		Tx: 2, Rx: 2
Antenna specifications	BS	±45° dual-polarization diversity antenna (16 dBi sectorized antenna, Horizontal beamwidth : 90 °, Antenna height : 90 m)
	MT	Vertically-polarized space diversity antenna (2.7 dBi sleeve antenna, Antenna separation: λ/2, Antenna height : 3 m)
Baseline system		3GPP LTE Release 8 Extended Cyclic Prefix (CP) specification
Carrier frequency		3.3 GHz band
Transmission power		43 dBm / antenna
Transmission scheme		OFDM (Subcarrier spacing : 15 kHz)
Number of sub-carriers		600 (Transmission bandwidth : 9 MHz)
Symbol duration		66.67 μs + CP 16.67 μs
Subframe/Frame length		1 ms / 10 ms
Reference signal		Cell-specific reference signal based on 3GPP LTE
Channel measurement		Measurement bandwidth : 180 kHz, Measurement time duration : 0.5 ms (Sampling frequency: 2 kHz)

2. Experimental System

This section describes our field experimental system. Fig. 1 illustrates the wireless transceiver structure of the experimental system and TABLE I summarizes its major specifications. As shown in Fig. 1, the system consists of a BS and MT corresponding to the transmitter and receiver sides, respectively. The radio frame structure of the system is the same as 3GPP LTE Release 8 extended cyclic prefix (CP) specification [3].

At the BS, the synchronization signal for symbol timing detection of the MT, and the reference signal for channel measurement of the MT are multiplexed onto the OFDM transmission signal. At the MT, after demodulating the reference signal, the measured channel fading data and the estimated average interference noise level are obtained. These data are then output to a PC. By Fast Fourier Transform (FFT) analysis of the acquired channel fading data over an observation time window T, the Doppler spectrum is first calculated. Next, the Doppler spread is detected from the effective spectrum components with power levels greater than a threshold based on the estimated average interference noise level of the spectrum. Finally, the MT velocity is estimated from the Doppler spread [4].

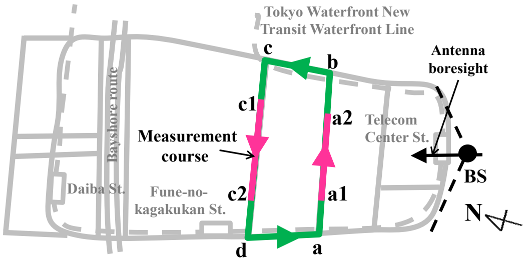

Fig. 2. Experimental environment and measurement course.

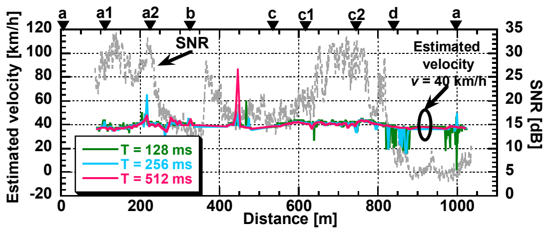

Fig. 3. Example of measurement results in field experiment.

3. Field Experiments

3.1 Field Experimental Environment

By using our experimental system, field experiments were carried out at an urban area in Tokyo, Japan. Fig. 2 shows the experimental environment and the measurement course. As shown in Fig. 2, the BS was located on the roof of a building and the MT was placed within a measurement vehicle. The evaluations were performed by driving the measurement vehicle at a constant velocity (v = 10 km/h or 40 km/h) on the measurement course which consists of LOS and NLOS mixed radio propagation environments as shown in Fig. 2. The points from a1 to a2 and those from c1 to c2 on the course correspond to LOS environment and the remaining parts correspond to NLOS environment.

3.2 Field Experimental Results

This subsection shows the estimated MT velocity using our Doppler spread detection in the practical radio propagation environment and then evaluates the high or low velocity decision algorithm based on the estimated MT velocity and a velocity threshold for the inter-layer HO control policy.

Fig. 3 plots an example of measurement results of the estimated MT velocity v' when v = 40 km/h with time window T as the parameter. As can be seen, v' generally lies within a range of v ± 5 km/h regardless of LOS or NLOS environment. Fig. 4 plots the cumulative distribution function (CDF) of v'. This figure shows that the distribution of v' is concentrated near the actual velocity of the measurement vehicle for both v = 10 km/h and 40 km/h. It also shows that the probability that the estimated velocity is greater than the actual velocity is high, compared to the probability that the estimated velocity is smaller than the actual velocity.

To evaluate the high or low velocity decision accuracy for the inter-layer HO control policy, we define the probability of falsely deciding a low velocity MT as a high velocity MT as $P_{false}^{(L\rightarrow H)}$ and the probability of falsely deciding a high velocity MT as a low velocity MT as $P_{false}^{(H\rightarrow L)}$. We define high or low

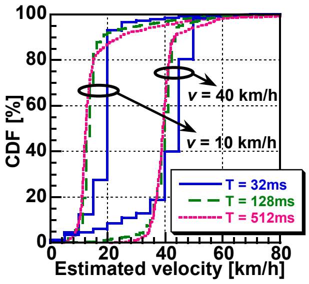

Fig. 4. CDF of estimated velocity.

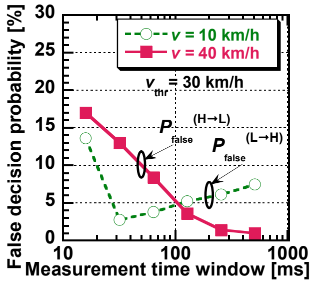

Fig. 5. Relation between T and $P_{false}^{(L\rightarrow H)}$ and $P_{false}^{(H\rightarrow L)}$.

MT velocity state when the actual velocity exceeds or falls below a velocity threshold v_{thr}. Fig. 5 shows the high or low MT velocity decision accuracy based on the estimated MT velocity and v_{thr} is set to, for example, 30 km/h. The horizontal and the vertical axes represent the time window T and $P_{false}^{(L\rightarrow H)}$ and $P_{false}^{(H\rightarrow L)}$, respectively. Note that, in this evaluation, v = 40 km/h is defined as a high velocity MT and v = 10 km/h is defined as a low velocity MT. In Fig. 5, the solid line represents $P_{false}^{(H\rightarrow L)}$ for v = 40 km/h, and the dashed line represents $P_{false}^{(L\rightarrow H)}$ for v = 10 km/h. From Fig. 5, it is found that both the $P_{false}^{(L\rightarrow H)}$ and $P_{false}^{(H\rightarrow L)}$ fall below 10% for T ≥ 64 ms. For v = 40 km/h, the $P_{false}^{(H\rightarrow L)}$ decreases with increase in T. This is due to the increase in the frequency resolution of the Doppler spectrum with T. For v = 10 km/h, in the range T ≤ 32 ms, the $P_{false}^{(L\rightarrow H)}$ decreases with increase in T. This is due to increase in the Doppler frequency resolution. However, in the range T > 32 ms, the $P_{false}^{(L\rightarrow H)}$ increases with T. One of the factors that lead to false decision for a low velocity MT is the presence of moving scatterers such as passing-by vehicles around the MT. Thus, although the Doppler frequency resolution increases with T, the probability of observing the moving scatterers within the time window T increases, leading to a larger $P_{false}^{(L\rightarrow H)}$.

4. Conclusion

This paper investigated a high or low MT velocity decision algorithm using Doppler spread detection for the inter-layer handover (HO) control policy to avoid the frequent HOs in layered cellular networks. The field evaluation results clarified the decision accuracy of the algorithm in a mixed LOS and NLOS practical radio propagation environment.

REFERENCES

[1] A. Damnjanovic et al., "A survey on 3GPP heterogeneous networks," *IEEE Wireless Commun.*, vol.18, no.3, pp.10–21, June 2011.

[2] N. Kanazawa, S. Nabatame, D. Ogata, and A. Nagate, "System Performance Evaluation for Inter-Layer Handover Control Based on UE Speed for Layered Cell Configuration," *IEICE Tech. Report*, RCS2016-10, Apr. 2016 (in Japanese).

[3] S. Maiti, K. Hoshino, M. Mikami, "Experimental Evaluation on Terminal Velocity Estimation Algorithm Based on Doppler Frequency Detection in An NLOS Outdoor Propagation Environment,"in *Proc. 2015 IEICE Society Conf.*, B-5-33, p. 295, Sept. 2015 (in Japanese).

[4] S. Maiti, K. Hoshino, and M. Mikami, "An investigation on velocity estimation of mobile terminal for cellular mobile radio communication systems," *IEICE Tech. Report*, RCS2014-274, Jan. 2015 (in Japanese).