Downlink and Uplink Channel Asymmetry and Novel Handover Ranging Power Adjustment Scheme in OFDMA/TDD Systems

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Abstract—This paper studies the channel asymmetric characteristic between a downlink and an uplink channel in orthogonal frequency division multiple access (OFDMA)/time division duplexing (TDD) systems. To investigate the downlink and uplink channel asymmetry, we derive a propagation loss model and a shadowing model taking into consideration geometrical information and inter-cell interference. Then, the channel asymmetric cases are introduced based on the proposed channel models. Numerical results show that the causes of the uplink and downlink channel asymmetry are mainly due to the coverage of neighbor cells and the usage ratio of uplink and downlink traffic. As coverage of neighbor cells increases, an uplink signal to interference and noise ratio (SINR) becomes lower than that of a downlink SINR. In addition, as uplink traffic of mobile stations (MSs) increases, an uplink SINR decreases. Based on the analysis, we propose the novel handover ranging power adjustment scheme for IEEE 802.16e system which improves the handover performance.

I. INTRODUCTION

Many wireless communication standards including WiMAX, 3GPP LTE, and IEEE 802.16e have adopted orthogonal frequency division multiple access (OFDMA) and time division duplexing (TDD). These systems are appealing for their potential to provide high data rate services [1]–[3]. In TDD systems, a same frequency band is allocated to downlink and uplink channels. For this reason, TDD is widely known for having, when a frame size is smaller than a channel coherent time, channel symmetry between a downlink and an uplink. Accordingly, many physical and medium access control (MAC) layer technologies of OFDM systems, e.g., link adaptation, scheduling, or handover, actively exploit the channel symmetric feature of TDD [4], [5]. However, downlink and uplink channel qualities can be asymmetric due to the different interference and the different traffic characteristics. In practice, the growth of data communications leads to installations of femto-cell BSs and hotspot-zones. Such installations can cause the changing of the cell-deploying and the inter-cell interference. The proliferation of smartphones like the iPhone has brought about a variety of services in the mobile communications. As a result, the usage pattern of the uplink and the downlink traffic can be varied. Therefore, to design effective access technology, engineers must study the channel asymmetry of TDD systems.

Unfortunately, most previous studies on wireless channels have been devoted to modeling, separately, a downlink channel or an uplink channel. The study in [7] derives the downlink channel model of the OFDMA system. It fails, however, to consider the inter-cell interference in the proposed downlink channel model. It also fails to mention the uplink channel. In [6], Moon and et al. propose a downlink channel considering geometric information and the inter-cell interference. The main interest of [6] is to model a downlink channel of code division multiple access (CDMA) systems. Neither the channel symmetry nor the correlation between downlink and uplink channel, still, are mentioned. The channel model in [8] is considered a downlink and uplink signal-to-noise-interference ratio (SINR) in an OFDMA system. This study, nonetheless, considers only the carrier frequency offset effect on an SINR model and these fail to mention the channel asymmetry of the OFDMA systems.

To the best of our knowledge, this work is the first effort to study the channel symmetry of OFDMA/TDD systems. We derive the mathematical models of a downlink and an uplink channel taking into consideration traffic load and inter-cell interferences in an OFDMA/TDD system. Based on the proposed channel models, we show two different cases of downlink and uplink channel asymmetry according to the distance between base stations (BSs) and traffic load of the uplink and downlink. And we propose the novel handover ranging power adjustment scheme for IEEE 802.16e system utilizing the channel asymmetry.

The rest of this paper is organized as follows. Section II describes the system model used to derive channel models. Section III gives the proposed downlink and uplink channel models which exploit geometric information and inter-cell interference. Section IV provides the numerical results and discussion. Section V VI proposes the novel handover ranging power adjustment scheme and explains simulation results. And
TABLE I

NOTATIONS FOR CHANNEL MODELING

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>Distance between the BS in the center cell and the MS in the neighbor cell</td>
</tr>
<tr>
<td>b</td>
<td>Index of the BS in the center cell</td>
</tr>
<tr>
<td>m</td>
<td>Index of the MS in the center cell</td>
</tr>
<tr>
<td>n</td>
<td>Index of the MS in the neighbor cell</td>
</tr>
<tr>
<td>z</td>
<td>Index of the BS in the neighbor cell</td>
</tr>
<tr>
<td>r_b</td>
<td>Distance between the center and the vertex of a hexagonal cell</td>
</tr>
<tr>
<td>r_e</td>
<td>Radius of an equivalent circle to a hexagonal cell</td>
</tr>
<tr>
<td>R_1</td>
<td>Distance between a BS and an MS in the center cell</td>
</tr>
<tr>
<td>R_2</td>
<td>Distance between a BS in a neighbor cell and an MS in the center cell</td>
</tr>
<tr>
<td>R_3</td>
<td>Distance between a BS in the center cell and an MS in a neighbor cell</td>
</tr>
<tr>
<td>γ</td>
<td>Cell propagation loss factor (= -4)</td>
</tr>
<tr>
<td>ε</td>
<td>Minimum distance between a BS and an MS</td>
</tr>
<tr>
<td>( P_{\text{max,BS}} )</td>
<td>Maximum transmission power of a BS</td>
</tr>
<tr>
<td>( P_{\text{max,MS}} )</td>
<td>Maximum transmission power of an MS</td>
</tr>
<tr>
<td>( \bar{h} )</td>
<td>Shadow fading from BS b to MS m</td>
</tr>
<tr>
<td>( \theta )</td>
<td>Main lobe width of sectored cells</td>
</tr>
<tr>
<td>Δ</td>
<td>Average number of active MSs in a cell</td>
</tr>
<tr>
<td>α</td>
<td>Downlink resource allocation ratio per MS</td>
</tr>
<tr>
<td>β</td>
<td>Uplink resource allocation ratio per MS</td>
</tr>
</tbody>
</table>

Section VII offers our conclusions.

II. SYSTEM MODEL

A. Notations

For modeling the downlink and the uplink channel, we use notations in Table I.

B. Assumption

This paper considers TDD based OFDMA systems where a downlink channel and an uplink channel are multiplexed in a time division manner. Fig. 1 depicts the cell structure considered. In the cell structure, the frequency-reuse factor is assumed to be one and consequently every adjacent cell can cause inter-cell interference for the center cell. All BSs are assumed to be timely synchronized but BSs are not coordinated in resource allocation. So no BS recognizes the traffic its neighbor cells. In addition, MSs are assumed to be uniformly distributed in a cell. Every BS and MS transmit packets with maximum power in any location. To simplify the analysis of the channel modeling, we consider only path loss and shadowing. Under these assumptions, we derive a downlink and an uplink channel model between BS b and MS m located in the center cell in Fig. 1.

C. Path loss

We designed the path loss model referred to in [6]. The distance between a transmitter and a receiver is a dominant factor in determining path loss. As shown in Fig. 1, three different distances are considered to derive a path loss model. \( R_1 \) is for a downlink and an uplink signal path loss, \( R_2 \) is for a downlink interference path loss, and \( R_3 \) is for an uplink interference path loss. The probability density functions for \( R_1, R_2 \) and \( R_3 \) are derived as

\[
f_{R_1}(r) = \frac{2r}{r_e^3}, \tag{1}
\]

\[
f_{R_2}(r) = \frac{\sqrt{4d^2r_e^2 - (d^2 + r_e^2 - r^2)^2}}{\pi r_e^2 d}, \tag{2}
\]

\[
f_{R_3}(r) \approx \frac{2r}{(r_e + d)^2 - (d/2)^2}. \tag{3}
\]

To calculate the average path loss, we derive the \( \gamma \)th moment of distance \( R_1 \) between serving BS b to MS m is derived as

\[
E[{r_{b-m}}^\gamma] = E[{r_{m-b}}^\gamma] = \int_\varepsilon^\infty \frac{2r^{\gamma+1}}{r_e^2} dr. \tag{4}
\]

If the distance between the BS and the MS is less than \( \varepsilon \), then the distance is considered as \( \varepsilon \).

The \( \gamma \)th moment of distance \( R_2 \) from neighbor BS \( z \) to MS \( m \) served by BS b using (2) is derived as

\[
E[{r_{z-m}}^\gamma] = \int_{d-r_e}^{d+r_e} \frac{r^{\gamma}}{\pi r_e^2} \cdot \frac{\sqrt{4d^2r_e^2 - (d^2 + r_e^2 - r^2)^2}}{d} dr. \tag{5}
\]

where \( r_e \approx r_h = d/\sqrt{3} \). From (3), the \( \gamma \)th moment of distance \( R_3 \) from MS \( n \) in a neighbor cell to serving BS b is derived as

\[
E[{r_{n-b}}^\gamma] = \int_{d/2}^{d+r_e} \frac{2r^{\gamma+1}}{(r_e + d)^2 - (d/2)^2} dr. \tag{6}
\]
D. Shadowing

The shadowing model is modeled on a log-normal distribution with zero mean. The expectation of a log-normal distributed random variable with a mean of \( m_\xi = 0 \) and a variance of \( \sigma_\xi^2 \) is derived as

\[
E[10^{-\xi/10}] = 10^{-m_\xi/10} \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_\xi^2 / 2\right\} = \exp\left\{\frac{\ln 10}{10} \cdot \sigma_\xi^2 / 2\right\}.
\]

(7)

III. DOWNLINK AND UPILNK CHANNEL MODEL

A. Downlink channel model

From (4) and (7), the expectation of the received signal power at the desired MS \( m \) from the serving BS \( b \) is derived as

\[
E[P_{b-m}^{(r)}] = P_{\text{max,BS}}^{(r)} \cdot \bar{\alpha} \cdot E[r_{\gamma}^{(r)}] \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}
\]

\[
= P_{\text{max,BS}}^{(r)} \cdot \bar{\alpha} \cdot \int_{e}^{\infty} 2 \pi r^{2+1} dr \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}.
\]

(8)

In OFDMA systems, users can share tones in a frame. Subsets of tones are assigned to each user based on the resource allocation algorithms. Therefore the downlink resource allocation ratio, \( \bar{\alpha} \), is different from each user and it affects the received power of a downlink channel. The expectation of the received interference power from neighboring BSs at the desired MS \( m \) is written as

\[
E[I_{m}^{(r)}] = \frac{\theta}{360^\circ} \cdot \sum_{b \neq m} \sum_{n = 1}^{N_b} \left( P_{\text{max,BS}}^{(r)} \cdot E[\beta_n] \cdot E[r_{\gamma}^{(r)}] \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}\right).
\]

(9)

The MS \( n \) uses the same carrier frequency as the MS \( m \). Thus the first \( \bar{\alpha} \) of \( \bar{\alpha}^2 \) denotes the received interference power portion of the maximum transmitting power of BS. The other \( \bar{\alpha} \) denotes the probability of receiving interference from neighboring cells. The probability of receiving interference increases proportionally with the increasing of \( \bar{\alpha} \), indeed, the probability increases that the user is using the same resource as other users in neighbor cells.

Using (8) and (9), the downlink SINR at the desired MS \( m \) is derived as

\[
\Gamma_{b-m}^{(r)} = \left[ P_{\text{max,BS}}^{(r)} \cdot \bar{\alpha} \cdot \int_{e}^{\infty} 2 \pi r^{2+1} dr \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}\right] \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}
\]

\[
= \left[ P_{\text{max,BS}}^{(r)} \cdot \bar{\alpha} \cdot \int_{e}^{\infty} 2 \pi r^{2+1} dr \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}\right] \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}.
\]

(10)

B. Uplink channel model

The expectation of the received signal power at the serving BS \( b \) from the desired MS \( m \) is expressed as

\[
E[F_{m-b}^{(r)}] = \frac{P_{\text{max,BS}}^{(r)} \cdot \bar{\beta} \cdot E[r_{\gamma}^{(r)}]}{\exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\} \cdot E[10^{-\xi_{\gamma}}/10]}.
\]

(11)

And the expectation of the received interference power from MSs in neighbor cells at the serving BS \( b \) is derived as

\[
E[I_{b}^{(r)}] = \left[ \frac{\theta}{360^\circ} \cdot \sum_{n = 1}^{N_b} P_{\text{max,BS}}^{(r)} \cdot \bar{\beta} \cdot E[r_{\gamma}^{(r)}] \right] \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}, (d \leq 2r_e).
\]

(12)

\[
E[I_{b}^{(r)}] = \left[ \frac{\theta}{360^\circ} \cdot \sum_{n = 1}^{N_b} P_{\text{max,BS}}^{(r)} \cdot \bar{\beta} \cdot E[r_{\gamma}^{(r)}] \right] \cdot \exp\left\{\frac{\ln 10}{10} \cdot \sigma_{\xi_{\gamma}}^2 / 2\right\}, (d > 2r_e).
\]

(13)

We fix the value of \( r_e \) and vary only the cell radius of adjacent cells. So, when \( d \) is larger than \( 2r_e \), adjacent cells can overlap.
MSs in the overlapping area are assumed to be served by the nearest BS. $\bar{\beta}$ affects the received signal and interference power as $\bar{\alpha}$.

From (11), (12) and (13), the uplink SINR of the desired MS at the serving BS $b$, $\Gamma_{m\rightarrow b}^{(i)}$, is derived as

$$
\Gamma_{m\rightarrow b}^{(i)} = \left[p_{\text{max,MS}}^{(i)} \cdot \frac{\bar{\beta}}{360^\circ} \cdot \int_{\alpha}^{\beta} \frac{2^{p_r+1}}{r_c^2} dr \cdot \exp\left\{\ln\left(\frac{10}{\sigma_{\text{foe-b}}}/2\right)\right\}\right]
$$

$$
\cdot \exp\left\{\ln\left(\frac{10}{\sigma_{\text{foe-b}}}/2\right) + N_\theta\right\},
$$

$$
(d \leq 2r_c),
$$

$$
(14)
$$

$$
\Gamma_{m\rightarrow b}^{(i)} = \left[p_{\text{max,MS}}^{(i)} \cdot \frac{\bar{\beta}}{360^\circ} \cdot \int_{\alpha}^{\beta} \frac{2^{p_r+1}}{r_c^2} dr \cdot \exp\left\{\ln\left(\frac{10}{\sigma_{\text{foe-b}}}/2\right)\right\}\right]
$$

$$
\cdot \exp\left\{\ln\left(\frac{10}{\sigma_{\text{foe-b}}}/2\right) + N_\theta\right\},
$$

$$
(d > 2r_c).
$$

$$
(15)
$$

**IV. CHANNEL ASYMMETRIC CASES AND DISCUSSION**

In this section, we introduce various numerical results according to the variation of the value of the principal parameters in the proposed channel model. Subsequently, we discuss based on the numerical results, notable channel asymmetric cases.

In (10), (14) and (15) the value of the downlink SINR or the uplink SINR is affected by various parameters such as $\alpha, \beta, r_c, d, \sigma_\xi, \gamma, N_\theta, P_{\text{max,BS}}^{(i)}$, and $P_{\text{max,MS}}^{(i)}$. Among these parameters, some have a fixed value and others, according to how users or the type of service application are distributed, have an instantaneously variable value. Especially, some variable parameters affect differently the downlink SINR and the uplink SINR. Therefore we classify these parameters into fixed values and variable values.

The communication environment and the form of system deployment determine $\gamma, N_\theta, \sigma_\xi, r_c$, and $d$. We assume that every wireless path has the same environment. So the path loss exponent factor, the noise and the shadowing distribution factor are fixed as $\gamma, N_\theta, \sigma_\xi$ in Table II. $r_c$ and $d$ are determined by the deployment of BSs. The deployment of BSs can be changed according to the local communication load or the installation of the femto-cell BS. Thus $r_c$ and $d$ are varied occasionally. However $\alpha$ and $\beta$ have an instantaneously variable property in accordance with the service. For example, the mobile web surfing service has more downlink traffic than uplink traffic. So if a user uses the mobile web surfing service then $\alpha$ has a larger value than $\beta$. On the other hand, if a user uploads UCC (User Created Contents) then the uplink traffic is heavier than the downlink traffic and $\beta$ has a larger value than $\alpha$.

For these reasons, we find two main parameters which cause the channel asymmetry among previously explain-ed parameters. First, the channel asymmetry can be caused by $d$. The changing of channel models can be found according to the variation of $d$ when $\alpha$ and $\beta$ are the same. In (8), the downlink signal model has the integral region as $r_c$ and (10), which is the downlink interference model, also has the integral region as $2r_c$ difference between $d + r_c$ and $d - r_c$. On the other hand, integral regions of (12) and (13) which are uplink interference models are varied in proportion to $d$. As $d$ increases, in the downlink case, the transmission power of neighbor BSs increase, causing downlink interference to increase. Only one factor affects the downlink SINR. In the uplink case, however, two factors affect the uplink SINR. The transmission power of MSs in neighbor cells and the region of interference increase and these factors cause the increment of the uplink interference. Therefore the uplink SINR decreases, according to increment of $d$, more than the downlink SINR. Consequently, the channel asymmetry can be caused by the difference of channel models of the downlink and the uplink.

For the simulation, parameters are set as Table II. And the power control scheme is not applied to a cell. But $P_{\text{max,BS}}$ and $P_{\text{max,MS}}$ are adjusted to receive the constant value at the BS from the MS which is in the edge region of the cell, and vice versa. Therefore, when $r_c$ is fixed and $d$ increases, $P_{\text{max,BS}}$ and $P_{\text{max,MS}}$ increase in proportion to the $\gamma$th power of the neighbor cell coverage.

Fig. 2 shows the downlink SINR and the uplink SINR according to the increase of $d$. The uplink SINR is higher than the downlink SINR by 6dB when $d = 1.5r_c$. The uplink and downlink SINR, however, are same when $d = 2r_c$ and the uplink SINR is lower than the downlink SINR when $d = 3r_c$ by 6dB. The downlink SINR and the uplink SINR both decrease in accordance with andy increase of $d$. This happens because the effect of increased $P_{\text{max,BS}}$ and $P_{\text{max,MS}}$ is larger.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.01</td>
<td>$P_{\text{max,BS}}^{(i)}$</td>
<td>39,42, 48 dBm</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.01</td>
<td>$P_{\text{max,MS}}^{(i)}$</td>
<td>27,30,36 dBm</td>
</tr>
<tr>
<td>$\theta$</td>
<td>120°</td>
<td>$\sigma_\xi$</td>
<td>8 dB</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>$\frac{4}{3}$</td>
<td>$\varepsilon$</td>
<td>$\frac{4}{3}$</td>
</tr>
<tr>
<td>$N_\theta$</td>
<td>-174dBm</td>
<td>$\delta$</td>
<td>100</td>
</tr>
</tbody>
</table>
than the path loss effect. However the uplink interference increases more than the downlink interference. Therefore the uplink SINR decreases more rapidly than the downlink SINR according to how $d$ increases and whether the reversal of the uplink SINR and downlink SINR occurs. Finally it means that the channel asymmetry is caused by the distance between BSs.

Secondary parameters of the channel asymmetry are $\alpha$ and $\beta$. The uplink and the downlink SINR model are in inverse proportion to $\alpha$ and $\beta$, respectively. $\alpha$ and $\beta$ can have asymmetry according to the service characteristics. In (8) and (11), The downlink and uplink signal power are proportional to $\alpha$ and $\beta$, respectively. This occurs because the MS is allocated more carriers to receive more data and the MS also use more carriers to transmit more data. In (9), (12) and (13), however, the downlink and the uplink interference model is proportional to $\alpha^2$ and $\beta^2$. Because the MS in neighbor cells also uses more carriers to communicate with the BS in neighbor cells and the probability that the desired MS in the center cell uses same frequency as MSs in the neighbor cell increases. When $\alpha$ become larger than $\beta$, the downlink interference power increase more than the uplink interference power. Then the downlink SINR becomes less than the uplink SINR. On the other hand, the uplink SINR becomes lower than the downlink SINR.

Fig.3 shows the uplink and the downlink SINR according to the varied uplink traffic load. When $\alpha = 0.009$ and $\beta = 0.001$, the mean uplink SINR is higher, by 10dB, than the downlink mean SINR. However, when $\alpha = 0.001$ and $\beta = 0.009$, the uplink mean SINR is lower, by 9dB, than the mean downlink SINR. The reversal of uplink and downlink SINR happens according to the increase of the portion of $\beta$. Therefore we can confirm that the channel asymmetry can be caused by service traffic patterns in OFDMA systems.

V. PROPOSED HANDOVER RANGING POWER ADJUSTMENT SCHEME

The IEEE 802.16e standard defines the transmission power of a ranging message as

$$P_{TX_{IR_{MAX}}}(dB) = EIRxP_{IR_{max}} + BS_EIRP - RSS$$ (16)

where $EIRxP_{IR_{max}}$, $BS_EIRP$, and $RSS$ are the maximum equivalent isotropic received power at the BS, the equivalent isotropic radiated power of the BS, and the received signal strength, respectively [1]. This conventional power adjustment algorithm has two weaknesses. First, the transmission power of a ranging message is calculated based on the downlink channel quality, even though the handover ranging message uses the uplink channel. Second, the interference power is not considered when calculating the transmission power. The interference power is a very important factor in the packet error rate in the OFDMA system. The reason is that users in neighbor cells can use the same frequency, and this affects the signal-to-interference-and-noise ratio (SINR). Therefore, handover ranging messages with inadequate power can be dropped, which may cause an additional retransmission delay of the handover ranging message during the handover process. As a result, the probability of handover outage increases.

The proposed scheme uses two factors to calculate the uplink handover ranging power. The first factor is the acceptable target power level of the MS at the target BS, and the second factor is the power attenuation information between the MS and the target BS. We define $EIRxP_{HR_{min}}$ for the acceptable target power level as the minimum equivalent isotropic received power for handover ranging at the BS. Moreover, for the uplink power attenuation information, we also use existing parameters, such as $RSS_{BS}$, $P_{interference}$, and $P_{noise}$ in the standard [1]. These denote the received signal strength at the BS, the uplink interference power level, and the noise power level, respectively. To implement the proposed algorithm, we exploit the existing messages in the IEEE 802.16e system. As shown in Fig.4, the parameters in bold face are added to the existing handover messages of the IEEE 802.16e standard [1]. Neighbor BSs measure $RSS_{BS}$, $P_{interference}$, and $P_{noise}$ of the MS during the scanning process. Then, the serving BS gathers these uplink channel quality factors through an $HO-pre-notification-response$ message from the neighbor BSs, and it forwards these parameters and $EIRxP_{HR_{min}}$ to the MS in a $MOB_{BS}HO-RSP$ message. The MS calculates the
uplink transmission power of the handover ranging message $P_{TX\_HR}$ as

$$P_{TX\_HR}(dB) = EIR_x P_{HR,min} + MS\_EIRP - 10 \log (RSS_{BS}/10 - P_{interference} - P_{noise}) \quad (17)$$

where $MS\_EIRP$ denotes the effective isotropic radiated power level of the MS in the decibel scale. Here, $P_{interference}$ and $P_{noise}$ are expressed in the linear scale. The MS recognizes the uplink channel quality, and it adjusts the handover ranging power to compensate for the signal degradation, interference, and noise to reduce the drop rate of the handover ranging message. In addition, the proposed scheme reduces the uplink interference caused by the handover ranging message to the neighbor BSs because $P_{TX\_HR}$ is based on the minimum acceptable power level. Accordingly, the proposed scheme can reduce the service interruption time.

VI. SIMULATION RESULTS

To evaluate the performance of the proposed handover scheme, we built a simulator using OPNET. We considered the path loss and large-scale fading of the channel mode because fast fading effects are eliminated due to the averaged SINR. We also generated interference from 37 cells which wrap around the serving cell. For uplink interfences, the dummy MSs were randomly distributed over each cell. To mitigate the ping-pong effect, we calculated the moving average of the measured SINR and used the averaged SINR for the handover initiation and decision thresholds. We measured the handover outage probability and the service interruption time during handover. The handover outage probability is the ratio of the number of handover outages to the number of handover trials. The handover outage is defined as the downlink or uplink signal level being lower than the outage threshold for 30 sequential frames, which means that the service interruption time exceeds 150 ms during the handover process. WiMAX limits the system requirement of the service interruption time to 150 ms for seamless communication [6]. The service interruption time is defined as the time during which the MS cannot exchange data packets with any BS.

Fig. 5 describes the results of the handover outage probability in respect to the outage thresholds. The conventional handover scheme uses only the downlink channel information for the handover process. The hybrid handover scheme exploits both the downlink and uplink channel information. The hybrid handover scheme has a lower handover outage probability than the conventional scheme. This means that channel asymmetry exists in the IEEE 802.16e system, and the conventional scheme cannot avoid uplink signal outage when the uplink channel quality is poor, although the downlink channel quality is acceptable. However, the hybrid scheme copes with both uplink and downlink signal degradation. The hybrid handover that includes the proposed ranging power adjustment scheme shows the best performance because it prevents both signal outages and timeout outages. The hybrid handover scheme selects the target BS with good channel quality for both uplink and downlink transmission. Moreover, the proposed scheme reduces the number of retransmissions of handover ranging messages by adjusting the ranging power based on the uplink channel quality. Thus, the proposed scheme prevents handover outages caused by exceeding the allowed service interruption time. As a result, the proposed scheme improves handover outage performance by 12% compared to the conventional
scheme and 4% compared to the normal hybrid handover scheme.

Fig. 6 shows the cumulative distribution function of service interruption time during handover. In the conventional scheme, 83% of the users experienced service interruption time within the 150 ms limit within the given conditions. Some users experienced 180 ms of service interruption time. The increased service interruption time was caused by retransmission of the handover ranging messages. Retransmissions occurred due to the lack of transmission power for handover ranging. A handover ranging message is an uplink message, but the conventional scheme adjusts the handover ranging power based on the downlink channel quality. The hybrid handover scheme satisfies 89% of users within the 150 ms limit. Although the hybrid handover scheme adjusts the handover ranging power based on the downlink channel quality, it chooses the target BS with good uplink channel quality. Thus, there are fewer retransmissions of ranging messages than in the conventional scheme. The proposed hybrid handover scheme allows 100% of users to experience less than 150 ms of service interruption time because it appropriately adjusts the handover ranging power based on the uplink channel quality. Thus, only 6% of users experience handover ranging message retransmission. In all other cases, handover ranging was completed without retransmission.

VII. Conclusion

In this paper, we mathematically derived the wireless channel model for OFDMA/TDD systems. By varying parameters that can be changed in practical mobile communication systems, we also found cases that cause channel asymmetry. As a result, we show that the neighbor cell size and uplink and downlink traffic load can cause the channel asymmetry in an OFDMA system. Based on the analysis, we also proposed the handover ranging adjustment scheme. Simulation results show that the proposed scheme reduces the handover outage probability and the service interruption time during the handover. Like the proposed scheme, consequently, we need new channel quality management schemes adapted for asymmetric channels to improve quality of experience.

References