Proceedings of APCC2008 copyright © 2008 IEICE 08 SB 0083

Interference Tolerant Power Control Algorithm of Ranging Process in IEEE 802.16 Relay System

Doo Hwan Lee and Hiroyuki Morikawa
Department of Frontier Informatics The University of Tokyo
4-6-1, Komaba, Meguroku, Tokyo, Japan
Email: leedh@mlab.t.u-toyko.ac.jp

***Abstract*— This paper considers the ranging process of IEEE 802.16 system in relay system. An interference problem between MS-BS ranging (i.e. ranging between mobile station and base station) and MS-RS ranging (i.e. ranging between mobile station and relay station), which is caused by the introduction of relay systems, is addressed. A solution of the interference problem is provided by proposing a new transmit power control algorithm. Computer simulation shows the performance of the ranging process in relay system, and validates the efficiency of the proposed transmission power control algorithm.**

Keywords; IEEE 802.16; Ranging; Relay; TPC

I. INTRODUCTION

IEEE 802.16e system [1, 2] is based on the orthogonal frequency division multiple access (OFDMA) systems which have advantages due to the spectral efficiency, the capability to cope with inter symbol interference, and the robustness in multipath propagation environment [3-5]. These advantages can be further improved by adopting a relay system [6].

By the introduction of relay systems into IEEE 802.16 system, system throughput improvement and coverage extension can be feasible with the low deployment cost [7]. There exist several contributions in the literature regarding the IEEE 802.16 relay system [8-11]. [8] proposed a new frame structure, and [9] studied on the system throughput of the IEEE 802.16 relay system. [10] developed a new spectrum efficient channel allocation algorithm, and [11] proposed an uplink data traffic scheduling algorithm. However, there is no comprehensive contribution on transmit power control (TPC) algorithm of ranging process for IEEE 802.16 relay system when both MS-BS ranging and MS-RS ranging are transmitted simultaneously.

Ranging process refers to the contention-based wireless random access, and provides a number of functions such as initial network entry, uplink synchronization, power adjustment, and system coordination [12-13]. The conventional ranging process of IEEE 802.16 system has to be optimized under the relay deployed environment. Thus, we propose a new ranging TPC algorithm for IEEE 802.16 relay system, and evaluate the performance. This paper provides following contributions: First, a novel ranging TPC algorithm of IEEE 802.16 relay system is proposed. Second, the performance of ranging process in IEEE 802.16 relay system is analyzed.

The remainder of this paper organized as follow. Section Ⅱ provides background of ranging process, and Section Ⅲ proposes a new ranging TPC algorithm for IEEE 802.16 relay system. Section Ⅳ gives performance analysis of ranging process in IEEE 802.16 relay system. Finally, Section Ⅴ summarizes and concludes this paper.

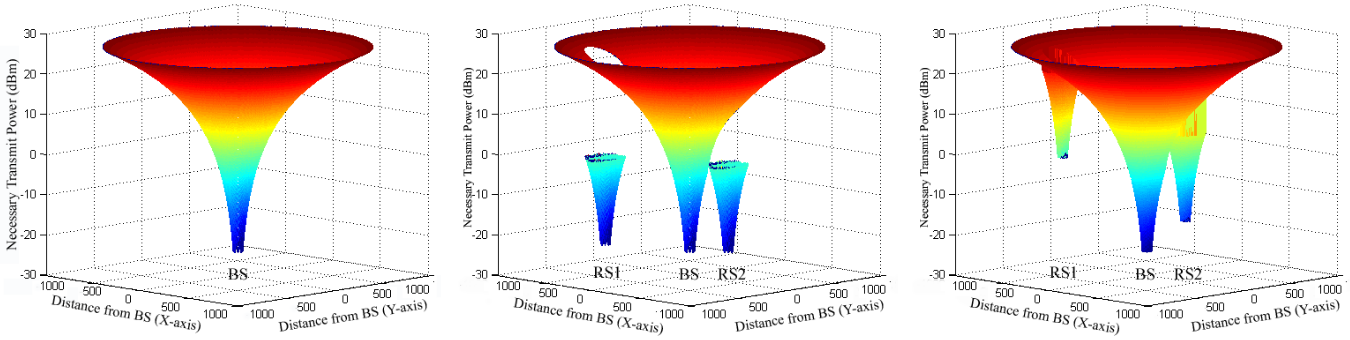
II. BACKGROUND

A. IEEE 802.16e OFDMA System

Among various PHY models, this paper adopts IEEE 802.16e OFDMA system with the time division duplex mode. Downlink and uplink utilize the whole frequency band, and are divided by a transmit/receive transition time gap (TTG/RTG). The base station (BS) manages downlink and uplink channel resources, and it broadcasts the scheduling information through downlink map (DL-MAP) and uplink map (UL-MAP). Data traffics are transmitted through the DL/UL burst channel. One or multiple DL/UL burst(s) can be allocated to a single mobile station (MS) depending on the traffic rate. However, a DL/UL burst should be only allocated to a single MS to prevent interferences among MSs. Ranging subchannel refers to a part of uplink resources which is allocated for ranging process. Ranging subchannel is separated from data channel, and based on the contention-oriented random access. Multiple MSs transmit their ranging signals through ranging subchannel. Once the BS conducts ranging signal detection successfully, it allocates DL/UL burst to the MS for further communication.

B. Ranging Process

Ranging process consists of initial, handover, periodic, and bandwidth request ranging, and it is carried out by the contention-based method. Multiple MSs share the common channel (i.e. ranging subchannel), and transmit mutually exclusive ranging codes simultaneously. The BS performs the contention resolution and the uplink synchronization by ranging code identification and round trip time (RTT) estimation. Multiuser contention resolution (i.e. ranging code identification) and uplink time synchronization (i.e. RTT estimation) are carried out based on the peak detection of the received ranging signals by exploiting the superior correlation property of raging code. Well-known correlation property of ranging codes is given as Eq. (1). Correlation of two ranging codes yields K (peak value) when two codes are matched and RTT is correctly estimated. On the other hand, it yields $1/K$ when two codes are unmatched or RTT is incorrectly estimated.



(a) Conventional TPC algorithm (single cell). (b) Conventional TPC algorithm (relay network) (c) Proposed TPC algorithm (relay network).

Fig. 1 Transmit power distribution of conventional and proposed TPC algorithm.

$$\sum_{i=0}^{K-1}\left[C_m(i)C_n(i)\exp\{j2\pi(f_c+i\cdot f_o)(\Delta t_{RTT}^n-t_{RTT}^m)\}\right] = \begin{cases} K & if\ m=n\ and\ t_{RTT}^m=\Delta t_{RTT}^n), \\ 1/K & otherwise, \end{cases} \quad (1)$$

where $C_m(i)$, $C_n(i)$, t_{RTT}^m, Δt_{RTT}^n, K, f_c, and f_o are the m^{th} user's ranging code, the n^{th} correlated ranging code, the m^{th} user's RTT, the estimated RTT for ranging code $C_n(i)$, ranging code length, center frequency, and subcarrier spacing, respectively.

When multiple MSs transmit ranging codes simultaneously, the BS carries out ranging code identification and RTT estimation with all possible ranging code and RTT value by the peak detection. Assume that, for instance, 3 MSs transmit ranging codes $C_0(i)$, $C_3(i)$, and $C_4(i)$, respectively among total 5 ranging codes, and their RTT are 0.1, 0.2, and 0.5 (*usec*), respectively. Also assume that the maximum RTT is 1 (*usec*) and the resolution of RTT estimation is 0.1 (*usec*). Then, output matrix of ranging detection will be

$$\mathbf{R}(C_n,\Delta t_{RTT}^n)=\begin{bmatrix} \frac{1}{K} & K & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} \\ \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} \\ \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} \\ \frac{1}{K} & \frac{1}{K} & K & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} \\ \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & K & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} & \frac{1}{K} \end{bmatrix}. \quad (2)$$

With matrix **R**, the BS is able to conduct code identification RTT estimation by the peak detection. In the ideal channel, all transmitted ranging codes will be successfully identified and corresponding RTTs will be correctly estimated. However, possibilities of code identification or RTT estimation error exist due to channel, interferences and noise in the practical channel.

C. IEEE 802.16 Relay System

In IEEE 802.16 relay system, the main purpose of the introduction of the relays is *coverage extension* and *throughput enhancement*. In *coverage extension* case, BS's signal does not reach the MS due to the long distance or geometrical obstacles. Thus, the relay station (RS) delivers data packets in the middle of the BS and MS to extend the coverage. In *throughput enhancement* case, the RS is introduced where the BS's signal strength is weak and low MCS (modulation and coding scheme) level is adopted. The RS enhances the throughput by maintaining signal strength strong and by allowing high MCS level adopted. In both cases, the BS-centric resource allocation and link adaptation are conducted. The BS schedules resource allocation for all links including BS-RS, BS-MS, and RS-MS links and broadcasts channel allocation information through DL-MAP (downlink map) and UL-MAP (uplink map) messages. The RS conveys BS's broadcast message to the MS, and delivers data packets between the BS and MS. The MS communicates with the BS or RS according to DL-MAP and UL-MAP. Although the MS does not necessarily distinguish the BS and RS for data transmission and reception, the MS has to recognize the BS and RS for TPC to reduce the effect of interferences.

III. PROPOSED RANGING ALGORITHM IN IEEE 802.16 RELAY SYSTEM

A. Problem Statement of the Conventional Ranging Transmission Power Control Algorithm

This subsection describes the problem statement of the conventional TPC algorithm in IEEE 802.16 relay system. Conventional TPC algorithm of ranging process is conducted based on open-loop power control exploiting the reciprocity of downlink and uplink. Channel coherence time of IEEE 802.16e OFDMA system, which operates on the 2.5 *GHz* with the mobility support up to 60 km/h, is approximated as 3.6 *msec* [3]. It is reasonable to determine that downlink and uplink channel are reciprocal because the BS's broadcast

Table 1. System parameters of IEEE 802.16 relay system.

Parameter	Value	Parameter	Value
Cell radius (BS)	1 *Km*	Frame size	5 *ms*
Cell radius (RS)	100 *m*	Noise figure	5 dB
Carrier frequency	2.5 *GHz*	Max BS transmit power	46 dBm
Total bandwidth	10 *MHz*	Max RS transmit power	36 dBm
Subcarrier spacing	10.9375 *KHz*	Max MS transmit power	23 dBm
Total number of sub-carriers	1024	$EIP_X P_{IR,max}$	-116 dBm
Number of ranging sub-carriers	144	Path loss model	Modified COST 231 Hata model
Fading model	Rayleigh fading model [14] (Urban Microcell & Macrocell)	Log normal shadowing standard deviation	8 dB

signal slots and ranging signal slots are less than 3 *msec* apart [1-2].

Fig. 1(a) shows the transmission power distribution of the conventional TPC algorithm in a single cell which is given as Eq. (3). XY-plane shows the distance from the BS and Z-axis shows the ranging transmission power.

$$P_{TX\_IR\_MAX} = EIP_X P_{IR,max} + BS\_EIRP - RSS_{BS,MS} \tag{3}$$

where $P_{TX\_IR\_MAX}$, $EIP_X P_{IR,max}$, BS_EIRP, and $RSS_{A,B}$ are the maximum transmission power, the maximum equivalent isotropic received power (obtained from the DCD), BS transmission power (obtained from the DCD), and measured received signal strength of *A* at *B*, respectively. Each MS adjusts ranging transmission power according to the difference between the original BS transmission power and the received BS signal strength. Basically, it is based on the distance between the BS and each MS. Ranging transmission power increases as the distance between the BS and MS increases.

Fig. 1(b) shows the transmission power distribution when the conventional TPC algorithm is adopted in relay system. Since the conventional TPC algorithm is based on the path loss which is highly relies on the distance between the BS and MS or RS and MS, transmission power of MS-RS ranging is set to relatively lower than that of MS-BS ranging. As confirmed by Fig. 1(b), MS-RS ranging signal gets severe interference from MS-BS ranging signal.

B. *Transmission Power Control Algorithmon*

This subsection proposes a novel ranging TPC algorithm for IEEE 802.16 relay system. The basic concept of the proposed ranging TPC algorithm is to increase the MS-RS ranging power to overcome the interference of MS-BS ranging. Fig. 1(c) shows the transmission power distribution of the proposed ranging TPC algorithm when two RSs are deployed. MS-RS ranging transmission power is dynamically adjusted depending on the location of the RS to suppress the interference from MS-BS ranging. Suggested algorithm is given in Eq. (4). In Eq. (4), MS_{TX_MAX} is the maximum transmission power of the MS, and $thres_{BS}$ and $thres_{RS}$ are predefined threshold defined as below.

$$\begin{aligned} thres_{BS} &= EIP_X P_{IR,max} + BS\_EIRP - MS_{TX\_MAX}, \\ thres_{RS} &= EIP_X P_{IR,RS} + RS\_EIRP - MS_{TX\_MAX}. \end{aligned} \tag{5}$$

The MS is able to identify the BS and RS by distinct BS ID format and RS ID format, and the MS is also able to distinguish between $RSS_{BS,MS}$ and $RSS_{RS,MS}$. Basically, MS-BS ranging is set to have the higher priority than MS-RS ranging. Thus, the MS performs MS-BS ranging when $RSS_{BS,MS}$ surpasses $thres_{BS}$ regardless of $RSS_{RS,MS}$ and $thres_{RS}$. Only when MS-BS ranging is infeasible and $RSS_{RS,MS}$ surpasses $thres_{RS}$, the MS conducts MS-RS ranging. In the case that both MS-BS and MS-RS ranging are infeasible, the MS transmits ranging signal to the BS with maximum transmission power. Furthermore, each RS should set $EIP_X P_{IR,RS}$ properly in order to minimize interferences between MS-BS and MS-RS ranging. We propose $EIP_X P_{IR,RS}$ to be set as Eq. (6).

$$EIP_X P_{IR,RS} = EIP_X P_{IR,max} + BS\_EIRP - RSS_{BS,RS} - P_{loss}(r) \tag{6}$$

where $P_{loss}(r)$ is a path loss with the variable *r* (the coverage of RS). $P_{loss}(r)$ will be given in Section 4. Eq. (6) can be interpreted as follow: MS-BS ranging transmission power is adjusted for received MS-BS ranging signal power at the BS and MS-RS ranging signal power at the BS to be maintained equivalent regardless of the location of the RS.

IV. PERFORMANCE EVALUATION

A. *Simulation Parameters*

Simulation parameters are chosen from [1, 2], and details are

---

$$P_{TX\_IR\_MAX} = \begin{cases} EIP_X P_{IR,max} + BS\_EIRP - RSS_{BS,MS}, & if\ RSS_{BS,MS} \geq thres_{BS}, \\ EIP_X P_{IR,RS} + RS\_EIRP - RSS_{RS,MS}, & if\ RSS_{BS,MS} < thres_{BS}\ and\ RSS_{RS,MS} \geq thres_{RS}, \\ MS_{TX\_MAX} & , otherwise. \end{cases} \tag{4}$$

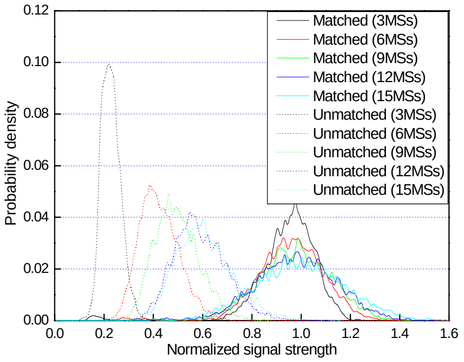


Fig. 2 Dist. of R_D and R_U at BS (conv. TPC).

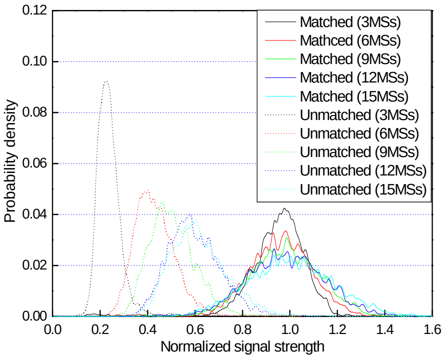


Fig. 3 Dist. of R_D and R_U at BS (prop. TPC).

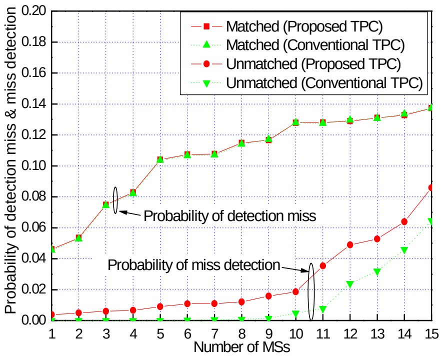


Fig. 4 *Detection miss* and *miss detection* at BS.

given in Table 1. The cell radius of the BS and RS are set to 1 *Km* and 100 *m*. Carrier frequency of 2.5 *GHz* with total bandwidth 10 *MHz* model is considered. The total number of subcarrier and number of ranging subcarrier are 1024 and 144, which indicates that ranging code length *K* in Eq. (1) is equal to 144. The modified COST 231 Hata path loss model is adopted. For the realistic analysis, the path loss model includes Urban Macrocell and Urban Microcell scenarios with both LOS (line of sight) and NLOS (non line of sight) cases simultaneously as below.

$$P_{loss}(r) = \begin{cases} P_{loss,Urban\ Micro}(r), & r \le 300m, \\ P_{loss,Urban\ Macro}(r), & r > 300m. \end{cases} \tag{7}$$

where *r* is the distance between the MS and BS or the MS and RS. $P_{loss,Urban\ Micro}(r)$ and $P_{loss,Urban\ Macro}(r)$ are the path loss model of Urban Macrocell and Urban Microcell scenario [14]. Probability of LOS in an Urban Micro cell is given as below.

$$P_{LOS}(r) = \begin{cases} 1 & , r < 15m, \\ 1-\left[1-\left(1-(1.56-0.48\log_{10}(r))^3\right)\right]^{1/3} & , r > 15m. \end{cases} \tag{8}$$

We assume that all channels of Urban Macrocell model are NLOS. Rayleigh fading channel model with 20 tabs and log normal shadowing with 8 dB standard deviation model are also adopted. The maximum transmit power of the BS, RS, and MS are set to 46 dBm, 36 dBm, and 23 dBm, respectively. Noise figure at the BS and RS is set to 5 dB and $EIP_X P_{IR,max}$ is set to -116 dBm.

B. Ranging Detection Miss and Miss Detection

To analyze the performance of the ranging process in IEEE 802.16 relay system, we define two metrics: 1) *ranging code detection miss*, 2) *ranging code miss detection*. For convenience, they will be noted as *detection miss* and *miss detection*, respectively. *Detection miss* occurs when the peak detection output of the matched code (i.e. transmitted code by MS) is not identified by the BS as transmitted code. *Miss detection* occurs when the peak detection output of unmatched code (i.e. not transmitted code by MS) is identified as the transmitted code. Let R_D and R_U denote the peak detection output of the matched code and the unmatched code, respectively. Then, *detection miss* and *miss detection* are given as below.

$$detection\ miss = pr(R_D < \alpha),\ miss\ detection = pr(R_U > \alpha), \tag{9}$$

where α is the predefined ranging detection threshold.

C. Simulation Results

Fig. 2 and Fig. 3 show distribution of R_D and R_U at the BS with conventional and proposed TPC algorithm, respectively. X-axis is the normalized ranging signal strength, and Y-axis is the probability density. The number of MSs is set to 3, 6, 9, 12, and 15. Solid lines and dotted lines represent R_D and R_U, respectively. In both cases, R_D shows similar distribution while R_U has right-shifted distribution as the number of MSs increases. To guarantee the stable ranging performance up to 15 MSs, we set α to 0.8.

Fig. 4 shows *detection miss* and *miss detection* at the BS when α equals to 0.8. X-axis is the number of MSs, and Y-axis is the probability of *detection miss* and *miss detection.* Solid lines and dotted lines represent results of proposed and conventional TPC algorithm, respectively. Probability of *detection miss* shows almost same results in both cases, and probability of *miss detection* in proposed TPC algorithm is slightly higher than that of conventional TPC algorithm.

From results in Fig.2, 3, and 4, it is concluded that proposed TPC algorithm for MS-RS ranging does not severely degrade the performance of conventional MS-BS ranging. It comes from the fact that proposed TPC algorithm increases MS-RS ranging power not to interfere existing MS-BS ranging as sated in the previous section.

Fig. 5 and Fig. 6 show distribution of R_D and R_U at the RS with the conventional and the proposed TPC algorithm, respectively. X-axis is the normalized ranging signal strength, and Y-axis is the probability density. Distance between the BS and RS is set to 300 *m*, 500 *m*, 700 *m*, and 900 *m*. Solid lines and dotted lines represent R_D and R_U, respectively. The number of MSs is set to 5. In the case of conventional TPC

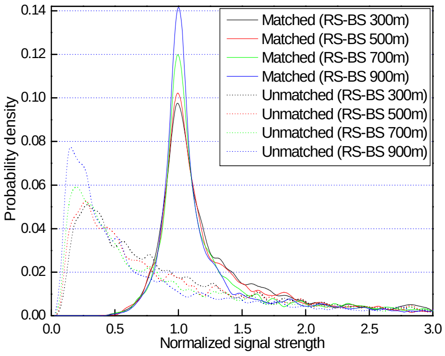


Fig. 5 Dist. of R_D and R_U at RS (conv. TPC).

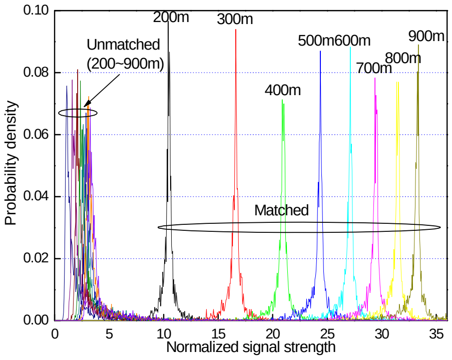


Fig. 6 Dist. of R_D and R_U at RS (prop. TPC).

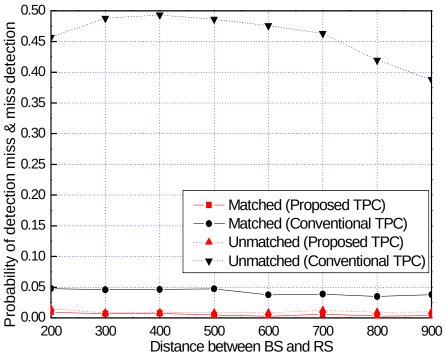


Fig. 7 *Detection miss* and *miss detection* at RS (5MSs).

algorithm, a large part of R_D and R_U are overlapped, which causes severe performance degradation. On the other hand, R_D and R_U are clearly separated in the case of proposed TPC algorithm, which improves the performance of MS-RS ranging. In particular, R_D and R_U show right-shifted distribution in Fig. 6 as the distance between the BS and RS increases. It is derived from the fact that proposed TPC algorithm increases MS-RS ranging power based on $RSS_{BS,RS}$, which highly depends the distance between the BS and RS.

Fig. 7 shows *detection miss* and *miss detection* at the RS when 5 MSs exist. α of conventional TPC algorithm is set to 0.8, and α of proposed TPC algorithm is set as Eq. (10) to compensate for the increased MS-RS ranging power. .

$$\alpha = 0.8\cdot\{35\log(d_{BS,RS}) - 35\log(r)\}, \qquad (10)$$

where $d_{BS,RS}$ and r are distance between the BS and RS and the coverage of the RS, respectively. In particular, the number 35 is obtained from $P_{loss,Urban\ Macro}(r)$ [14]. Solid lines and dotted lines represent results of *detection miss* and *miss detection*, respectively. In both cases, MS-RS ranging with proposed TPC algorithm shows better performance than that with conventional TPC algorithm. In particular, the probability of *miss detection* is significantly improved by the proposed TPC algorithm. With these simulation results, it is confirmed that the proposed TPC algorithm enhances the performance of MS-RS ranging with the negligible performance degradation of MS-BS ranging.

V. CONCLUSIONS

This paper proposes a novel ranging TPC algorithm for IEEE 802.16 relay system considering the received signal strength of both the BS and RS to reduce the interference between MS-BS ranging and MS-RS ranging. Computer simulations are conducted to analyze the performance of the proposed TPC algorithm in terms of *detection miss* and *miss detection*. Simulation results validate the efficiency of the proposed TPC algorithm. Achievement of this paper will be beneficial as the guideline for the design of IEEE 802.16 relays system.

REFERENCES

[1] IEEE LAN/MAN Standards Committee, "IEEE Standard for local and metropolitan area networks part 16: Air interface for fixed broadband wireless access systems," IEEE Std 802.16^{TM}-2004, 2004.

[2] IEEE LAN/MAN Standards Committee, "IEEE Standard for local and metropolitan area networks Part 16: Air interface for fixed and mobile broadband wireless access systems amendment 2: Physical and medium access control layers for combined fixed and mobile operation in licensed bands and corrigendum 1," IEEE Std 802.16e-2005 and IEEE Std 802.16-2004/Cor 1-2005, 2006.

[3] R. Nee and R. Prasad, OFDM Wireless Multimedia Communications, Artech House, 1999.

[4] L. J. Cimini, "Analysis and simulations of a digital mobile channel using orthogonal frequency division multiplexing," IEEE Trans. Commun, vol. 33, no. 7, pp. 665-675, Jul. 1985.

[5] T. Keller and L. Hanzo, "Adaptive multicarrier modulation: A convenient framework for time-frequency processing in wireless communications," Proc. IEEE, vol. 88, no. 5. pp. 611-640, May 2000.

[6] R. Pabst, et al. "Relay-based deployment concepts for wireless and mobile broadband radio," IEEE Commun. Mag., vol. 42, no. 9, pp. 80-89, Sep. 2004.

[7] B. Can, M. Portalski, H. Lebreton, S. Frattasi, and H. Suraweera,. "Implementation Issues for OFDM-based multihop cellular networks," IEEE Commun. Mag., vol. 45, no. 9, pp. 74-81, Sep. 2007.

[8] Z. Tao, A. Li, K.H. Teo, and J. Zhang, "Frame structure design for IEEE 802.16j mobile multihop relay (MMR) networks," in Proc. IEEE Global Telecommunications Conference 2007, pp. 4301-4306, Nov. 2007.

[9] Y.Q. Bian, A.R. Nix, Y. Sun, and P. Strauch, "Performance evaluation of mobile WiMAX with MIMO and relay extensions," in Proc. IEEE Wireless Communications and Networking Conference 2007, pp. 1814-1819, Mar. 2007.

[10] E. Liu, D. Wang, J. Liu, G. Shen, and S. Jin, "Performance evaluation of bandwidth allocation in 802.16j mobile multi-hop relay networks," in Proc. IEEE 65th VTC 2007, pp. 939-943, Apr. 2007.

[11] O. Jo and D. Cho, "Traffic adaptive uplink scheduling scheme for relay station in IEEE 802.16 based multi-hop system," in Proc. IEEE 65th Vehicular Technology Conference 2007, pp. 1679-1683, Sep. 2007.

[12] X. Fu, Y. Li, and H. Minn, "A new ranging method for OFDMA systems," IEEE Trans. Wireless Commun., vol. 6, no. 2, pp. 659-669, Feb. 2007.

[13] D.H. Lee and H. Morikawa, "Performance analysis of ranging process in IEEE 802.16e systems," in Proc. IEEE 3rd WiMob, Oct. 2007.

[14] R. Srinivasan et al. "Draft IEEE 802.16m evaluation methodology," IEEE 802.16m-07/02.