Antenna Selection Based Initial Ranging Method for IEEE 802.16m MIMO-OFDMA Systems

Yongpeng Shi, Yujie Xia
Department of Physics & Electronics Information
Luoyang Normal University
No.71, Longmen Road, Luoyang, Henan, 471022
CHINA
shiyongpeng@163.com

Abstract: - An antenna selection based initial ranging method is proposed in orthogonal frequency division multiple access (OFDMA) networks with multiple-input multiple-output (MIMO) for IEEE 802.16m standard. In the proposed scheme, the initial ranging signal processing is selected by the antenna selection at the base station, where the receive antenna with the largest received signal-to-interference-and-noise ratio (SINR) is chosen. The active initial ranging users and the timing offset estimation can easily obtain by means of the adaptive threshold. Simulation results show that the proposed initial ranging scheme can achieve a much better initial ranging performance than the noncoherent antenna combining method, and dramatically improve the initial ranging efficiency for a large number of active RSSs simultaneously to access into networks.

Key-Words: - orthogonal frequency division multiple access (OFDMA); initial ranging; antenna selection (AS); multiple-input multiple-output (MIMO); IEEE 802.16

1 Introduction

Orthogonal Frequency Division Multiple Access (OFDMA) is a promising multiple access scheme and has been adopted by several wireless communication system standards to provide efficient broadband wireless access to subscribers. Multiple subscriber stations with different timing transmit simultaneously in the uplink channel of OFDMA systems, synchronization can be achieved by a random access process referred to as initial ranging (IR) in the IEEE 802.16m standard [1]. In the IR process, a new ranging subscriber station (RSS), transmits a randomly chosen frequency-domain ranging code on ranging subchannel in specific ranging time-slot (one or several OFDMA symbol intervals). However, the initial ranging performance degrades with the ranging channel frequency selectivity and the magnitude of RSSs since the correlation properties of the ranging codes are affected by the channel frequency selectivity resulting in large multiuser access interference (MAI) which is amplified by the larger number of active RSSs.

The IR methods in OFDMA systems generally fall into two categories. The first category [2]-[13] is discussed for single receive antenna at the base station (BS). The IR methods [2]-[5] are based on the IR codes correlations in either the frequency or the time domain, but the performance of these methods severely deteriorate because of treating the MAI as noise. In order to combat the harmful impact of the ranging channel frequency selectivity, the methods in [6]-[13] are proposed to suppress the MAI effect. The works [6]-[9] are proposed by using a new ranging code structures and associated ranging subchannel allocation, but these schemes are different from that of the IEEE 802.16m standard. Following the IEEE 802.16m standard, the literatures [10]-[13] present a successive multiuser detection and interference cancellation methods in the frequency selective channels. However, the complexity of those methods is very high, and the accumulated residual MAI degrades the IR performance and limits the number of RSSs simultaneously accessing into the network.

The second category on the IR scheme [14]-[16] is presented for the multiple receive antennas equipped at the BS. The works [14] and [15] discuss the multiuser diversity and multiantenna diversity gains by utilizing the IR subchannel allocation. Each of the IR subchannel is allocated with a little number of adjacent subcarriers, and most of the RSSs are expected to transmit on different IR subchannels. Those methods work well by exploiting the channel state information (CSI) at the transmitter side in time division duplex (TDD) model. However, the adjacent subcarriers allocation increases the sensitivity to residual carrier frequency offsets (CFOs). In addition, the subchannel allocation scheme is different from the IEEE 802.16m standard for the IR. The literature [16] presents a noncoherent antenna combining (NAC) initial synchronization scheme in Long Term Evolution (LTE) systems, However, when the receive antennas experience fading independent, the NAC method degrades the IR performance duo to the MAI of each receive antenna.

In this work, we proposed an antenna selection based IR scheme for the IEEE802.16m MIMO-OFDMA systems. In the proposed method, the IR signal processing is selected by the antenna selection, and the selection is based on the received signal-to-interference-and-noise ratio (SINR), where the receive antenna with the largest received SINR is chosen. The active initial ranging users and the timing offset estimation can easily obtain by means of the adaptive threshold. The performance of the IR by the proposed scheme is highly improved compared to NAC method.

The rest of this paper is organized as follows. We introduce the IR description and signal models over multipath channel in Section 2. The IR scheme is presented in detail in Section 3. The IR performance and simulation results are given in Section 4 and 5. Finally, we conclude paper in Section 6.

2 System Description and Signal Models

2.1 IR procedure

IR process is the first step of wireless initial access for each active RSS, and it contains IR signal transmission, IR detection, and resource allocation. If some RSSs transmit their IR signals at the same time, the BS will recognize each RSS by its specific ranging code. As a result of different locations and mobility, each RSS has its specific transmission time delay (TTD). The BS must execute uplink time synchronization by the IR process to compensate TTD of each RSS. The IR procedure based on the IEEE 802.16 standard can be described as follows:

Step 1) each RSS first acquires downlink synchronization and uplink transmission parameters from downlink control frames.

Step 2) each RSS randomly chooses an IR time-slot and an IR code and then transmits it on the IR channel.

Step 3) BS detects IR codes and estimates its timing and power from the received IR signal. BS broadcasts an IR response message which advertises the received IR code and the IR time-slot where the IR code has been identified. The IR response message also contains all the adjustment information (e.g., timing and power adjustment) and a status notification (e.g., success, continue).

Step 4) if an RSS receives the success notification and its IR process is completed; otherwise, the RSS repeats its IR process at the following IR attempts.

2.2 IR signal models

We consider a multiantenna wireless communication system, and each RSS transmits the IR signal with single antenna and the BS receives the IR signals with R_x receive antennas. According to the IEEE 802.16m standard [1], a typical OFDMA uplink has N subcarriers, and an IR time-slot consists of N_R ranging subcarriers with index $\{J_k; k=0,\cdots,N_R-1\}$ over two OFDMA symbols. Each RSS selects an available IR code which is randomly chosen from a predefined code set $\{\mathbf{C}_1,\cdots,\mathbf{C}_u,\cdots,\mathbf{C}_{N_c}\}$, where N_c is the total number of IR codes.

Assume that all RSSs perform frequency synchronization based on downlink control channel before initiating the ranging process and the conflict of more than one RSS using the same IR code is not considered in this paper. Suppose that the u^{th} RSS transmits $\mathbf{C}_u=\{C_u(l), l=0,1,\cdots,N_R-1\}$ on the ranging channel. The vector of $\mathbf{C}_u$ is mapped onto an OFDMA symbol $\mathbf{X}_u=[X_u(0),\cdots,X_u(k'),\cdots,X_u(N-1)]$ and its corresponding element $X_u(k')$ is given by

$$X_u(k') = \begin{cases} C_u(k), k' = J_k, k = 0,\ldots,N_R-1 \\ 0, \quad otherwise \end{cases} \tag{1}$$

After the inverse discrete Fourier transform (IDFT) and cyclic prefix (CP) insertion, the samples of the u^{th} RSS in the time domain are transmitted over two consecutive OFDMA symbols, and they are expressed by

$$x_u(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N_R-1} C_u(k) e^{j2\pi J_k n/N}, -N_g \le n \le 2N + N_g - 1 \tag{2}$$

where N_g is the length of CP.

Let K_R be the number of RSSs that are simultaneously active on the one IR time slot. The fading channel between the transmit/receive antenna pair is assumed to be frequency selective, and multipath Rayleigh fading channels for different RSSs are independent. The received IR signal at the BS is given by

$$\mathbf{y}(n)=[y^{(1)}(n),\cdots,y^{(m)}(n),\cdots,y^{(R_x)}(n)]^T \tag{3}$$

where $y^{(m)}(n)$ is the received sample at the m^{th} antenna and can be expressed as

$$y^{(m)}(n)=\sum_{u=1}^{K_R}\sum_{l=0}^{L-1}h_{u,l}^{(m)}x_u\left(n-l-d_u\right)+z^{(m)}(n) \tag{4}$$

where $h_{u,l}^{(m)}$ is the fading coefficient of the u^{th} RSS for the l^{th} path at the m^{th} receive antenna and L is the channel length (normalized by the sampling period T_s). d_u represents the round-trip delay and which is related to the different distances between the RSS and the BS. The maximum value for a RSS located at the cell boundary is given by $d_{R,\max}=2R/(cT_s)$ with R being the cell radius and c denoting the speed of light. $\{z^{(m)}(n)\}$ are independent and identical distributed complex Gaussian random variables with variance $\delta_z^2=E[\left|z^{(m)}(n)\right|^2]$ at the m^{th} receive antenna.

At the BS, removing the CP and after fast Fourier transform (FFT) for the received symbol, the IR signal of the m^{th} receive antenna on the k^{th} IR subcarrier is

$$\begin{aligned}\mathbf{Y}^{(m)}&=[Y^{(m)}(0),\cdots,Y^{(m)}(k),\cdots,Y^{(m)}(N_R-1)]^T\\&=\sum_{u=1}^{K_R}\sum_{l=0}^{L-1}h_{u,l}^{(m)}\mathbf{\Lambda}_{d_u+l}\mathbf{C}_u+\mathbf{Z}^{(m)}\end{aligned} \tag{5}$$

where $\mathbf{\Lambda}_{d_u+l}=diag\{\Lambda_{d_u+l,0},\cdots,\Lambda_{d_u+l,k},\cdots,\Lambda_{d_u+l,N_R-1}\}$ is a diagonal matrix with diagonal element $\Lambda_{d_u+l,k}=e^{-j2\pi J_k(d_u+l)/N}$.

$\mathbf{Z}^{(m)}=[Z^{(m)}(0),\cdots,Z^{(m)}(k),\cdots,Z^{(m)}(N_R-1)]^T$ is a $N_R\times 1$ complex Gaussian vector with covariance matrix $\delta_z^2 I_{N_R}$, and $Z^{(m)}(k)=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}z^{(m)}(n)e^{-j2\pi J_k n/N}$.

Define $M_t=d_{R,\max}+L$ as the maximum number of resolved path for each RSS, equation (5) can be considered as a linear combination of M_t possible path signals for every active RSS. Equation (5) can be further rewritten as

$$\overline{\mathbf{Y}}^{(m)}=\mathbf{Y}^{(m)}=\sum_{u=1}^{K_R}\sum_{\alpha=0}^{M_t-1}h_{u,\alpha}^{(m)}\mathbf{\Lambda}_{\alpha}\mathbf{C}_u+\mathbf{Z}^{(m)} \tag{6}$$

When the path $\{u,\alpha\}$ is present in the observation vector $\overline{\mathbf{Y}}^{(m)}$, the path is valid and $h_{u,\alpha}^{(m)}\neq 0$; otherwise, the path is invalid and $h_{u,\alpha}^{(m)}=0$.

3 Proposed IR Scheme

In this section, we propose a novel IR scheme with multiple receive antennas and derive the threshold setting in detail.

3.1 Proposed IR Algorithm

To derive conveniently, $\{v,\tau\}$ denotes the path of the IR codes with index $v\ (v\in[1,N_c])$ and the timing offset $\tau\ (\tau\in[0,M_t])$. For correlation-based detection, the BS correlates the received signal in the frequency domain with the signal of path $\{v,\tau\}$, separately in each receive antenna output. For the m^{th} receive antenna, the correlation output of path $\{v,\tau\}$ is

$$R_v^{(m)}(\tau)=\mathbf{C}_v^H\mathbf{\Lambda}_\tau^H\overline{\mathbf{Y}}^{(m)} \tag{7}$$

Depending on whether the path $\{v,\tau\}$ is present in the observation vector $\overline{\mathbf{Y}}^{(m)}$, equation in (7) can be expressed as

$$R_v^{(m)}(\tau)=W_v^{(m)} \tag{8}$$

for $m=1,\cdots,R_x$, for the MAI-plus-noise hypothesis (H_0), where $W_v^{(m)}=\sum_{\substack{u=1\\u\neq v}}^{K_R}\sum_{\alpha=0}^{M_t-1}h_{u,\alpha}^{(m)}\mathbf{C}_v^H\mathbf{\Lambda}_\tau^H\mathbf{\Lambda}_\alpha\mathbf{C}_u+\mathbf{C}_v^H\mathbf{\Lambda}_\tau^H\mathbf{Z}$ is the MAI-plus-noise on the m^{th} receive antenna, and

$$R_v^{(m)}(\tau)=h_v^{(m)}(\tau)N_R+W_v^{(m)} \tag{9}$$

for $m=1,\cdots,R_x$, for the signal-plus-noise hypothesis (H_1).

The problem of the IR detection is to test the MAI-plus-noise hypothesis against a signal-plus-noise hypothesis, given R_x observations in (7) at the BS. The binary hypothesis test can be formulated as

$$H_0: R_v^{(m)}(\tau)=W_v^{(m)} \tag{10}$$

$$H_1: R_v^{(m)}(\tau)=h_v^{(m)}(\tau)N_R+W_v^{(m)} \tag{11}$$

To alleviate the fading impairment, the IR signal processing is selected by the antenna selection criteria, and the selection is based on the receive SINR, where the receive antenna with the largest received SINR is chosen. Thus, even if some of the received versions are deeply faded, it is probable that not all copies are faded. The block of the proposed IR scheme is depicted in Fig.1.

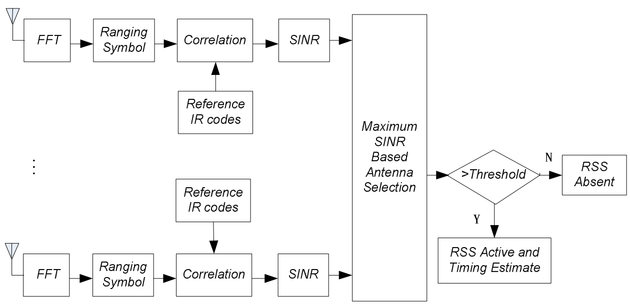

Fig. 1. Block of the Proposed IR scheme

The MAI can be considered as an independent Gaussian random variable with zero mean and unknown power $(\sigma_{MAI}^{(m)})^2$, and is independent for different antennas. Hence, $W_v^{(m)}$ is a Gaussian variable with power $(\sigma_v^{(m)})^2 = (\sigma_{MAI}^{(m)})^2 + N_R \delta_z^2$. From (6), for given H_0, the power of the MAI plus noise on the m^{th} receive antenna is obtained as

$$(\sigma_v^{(m)})^2 = E[(W_v^{(m)})^H W_v^{(m)}) = (\bar{\mathbf{Y}}^{(m)})^H \bar{\mathbf{Y}}^{(m)} \tag{12}$$

From (7), the signal power of path $\{v,\tau\}$ on the m^{th} receive antenna under H_1 is estimated by

$$\hat{y}_v^{(m)}(\tau) = \left|R_v^{(m)}(\tau)\right|^2, \tau = 0,\cdots,M_t \tag{13}$$

The estimated signal-to-interference-and-noise ratio (SINR) of path $\{v,\tau\}$ on the m^{th} receive antenna is obtained as

$$\gamma_v^{(m)}(\tau) = \hat{y}_v^{(m)}(\tau) / \hat{\sigma}_{m,v}^2 = \left|R_v^{(m)}(\tau) / \sigma_v^{(m)}\right|^2 \tag{14}$$

The most possible timing offset for the v reference code on the m^{th} receive antenna is estimated by

$$\hat{\tau}_v^{(m)} = \arg\max_{0\le\tau\le M_t-1} \gamma_v^{(m)}(\tau) \tag{15}$$

A receive antenna is selected by

$$\hat{m} = \arg\max_{0\le m\le R_x} \gamma_v^{(m)}(\hat{\tau}_v^{(m)}) \tag{16}$$

If $\gamma_v^{(\hat{m})}(\hat{\tau}_v^{(\hat{m})}) \ge \lambda$ where λ is a predefined threshold which is set according to the false alarm probability acceptable at the BS, the path $\{v,\hat{\tau}_v^{(\hat{m})}\}$ is valid, so the RSS with code index v is declared present and $\hat{\tau}_v^{(\hat{m})}$ is the estimated timing offset for the active code v. Otherwise, the path $\{v,\hat{\tau}_v^{(\hat{m})}\}$ is invalid and the v^{th} RSS is assumed to be absent.

3.2 Threshold Setting

Let $q_v^{(m)}(\tau) = R_v^{(m)}(\tau)/\sigma_v^{(m)}$, for given H_0, $q_v^{(m)}(\tau)$ is a complex Gaussian random variable with zero mean and unit variance. Equation (14) can be written as

$$\gamma_v^{(m)}(\tau) = \left|q_v^{(m)}(\tau)\right|^2 \tag{17}$$

$\{\gamma_v^{(m)}(\tau), \tau = 0,\cdots M_t - 1, m = 1,\cdots,R_x\}$ follow central Chi-square distribution with 2 degree of freedom, and the probability density function (PDF) of $\gamma_v^{(m)}(\tau)$ is

$$p_{\gamma_v^{(m)}(\tau)}(\eta) = e^{-\eta}, \eta \ge 0 \tag{18}$$

In the proposed IR method, the RSS will pick the antenna with the largest SINR defined in (16). Define

$$Z_i = \max\{\gamma_v^{(m)}(\tau), \tau = 0,\cdots M_t - 1, m = 1,\cdots,R_x\} \tag{19}$$

The cumulative distribution function (CDF) of Z_i is

$$\begin{aligned} P[Z_i \le \lambda | H_0] &= [\int_0^\lambda p_{\gamma_v^{(m)}(\tau)}(\eta) d\eta]^{M_t R_x} \\ &= (1 - e^{-\lambda})^{M_t R_x} \end{aligned} \tag{20}$$

A false alarm could happen if one or more invalid paths reach the threshold λ for all R_x receive antennas and N_c referenced IR codes at the BS. The probability of false alarm P_{fa} acceptable at the BS can be determined as

$$P_{fa} = 1 - (1 - e^{-\lambda})^{M_t R_x N_c} \approx M_t R_x N_c e^{-\lambda} \tag{21}$$

From (21), the threshold λ is determined as

$$\lambda = \ln(M_t R_x N_c / P_{fa}) \tag{22}$$

4 Performance analysis

In this section, the probability of correct detection is analyzed for the proposed IR scheme, and the computational complexity is compared with the NAC IR method.

4.1 Probability of Correct Detection

For H_1, when $\{v,\hat{\tau}_v^{(\hat{m})}\}$ is the valid path for the v^{th} active RSS where $\hat{m}$ is the index of selected antenna, the decision variable is given by

$$\begin{aligned} s &= \gamma_v^{(\hat{m})}(\hat{\tau}_v^{(\hat{m})}) = |R_v^{(\hat{m})}(\hat{\tau}_v^{(\hat{m})}) / \sigma_v^{(\hat{m})}|^2 \\ &= |\, h_v^{(\hat{m})}(\hat{\tau}_v^{(\hat{m})}) N_R / \sigma_v^{(\hat{m})} + W_v^{(\hat{m})} / \sigma_v^{(\hat{m})}\, |^2 \end{aligned} \tag{23}$$

Due to $W_v^{(\hat{m})}/\sigma_v^{(\hat{m})}$ is a complex Gaussian random variable with zero mean and unit variance, so s is a non-central Chi-square random variable with 2 degree of freedom. The PDF of s is given by

$$p(s) = e^{-(s+\beta^2)} I_0(\sqrt{4\beta^2 s}) \tag{24}$$

where $\beta = h_v^{(\hat{m})}(\hat{\tau}_v^{(\hat{m})}) N_R / \sigma_v^{(\hat{m})}$, and $I_0(\cdot)$ the zero-order modified Bessel function of the first kind.

The probability of the correct detection is given by

$$P[s \ge \lambda | H_1] = 1 - \int_0^\lambda p(s) ds = Q_1(\sqrt{2}\beta, \sqrt{2s}) \tag{25}$$

where $Q_1(a,b) = \int_b^\infty x e^{-(x^2+a^2)/2} I_0(ax) dx$.

4.2 Computational Complexity

Consider that a complex multiplication (CM) is equivalent to four real multiplications (RMs) plus two real additions (RAs), a complex addition (CA) is translated into two RAs, and $|\ |^2$ represents two RMs and one RA. Because a RM takes much more hardware resources than that of a RA, computational complexity of the proposed scheme is evaluated in terms of the number of the RMs.

Let N be the number of subcarriers for an OFDMA symbol, N_c, M_t, and R_x are the number of the reference IR codes, the maximum number of resolved path for each RSS, and the number of receive antennas, respectively. For the proposed IR method, the correlation detection can be performed by the N-point FFT operation, so it needs about $2N_cR_xN\log_2N+N_cM_tR_x$ RMs, while the NAC scheme is $4N_cR_xN_RM_t+2N_cM_tR_x$. In general, the number of N is large, thus, computational complexity of the proposed method is lower than that of the NAC scheme.

5 Simulation Results

We consider an IR system with multiple antennas at the BS, and the system parameters are specified in the IEEE 802.16m [1]. The number of subcarriers in OFDMA system is 1024, and the length of CP is 128 samples. The sample rate is 11.2MHz and the carrier frequency is 2.5GHz. The cell radius is set to 3km, and the maximum round-trip delay is 224 samples. In the IR procedure, an IR time-slot consists of 144 non-contiguous subcarriers over two OFDMA symbols and the number of codes reserved for IR is 32.

The main tasks of the IR process at the BS are multiuser IR code detection and multi-user timing estimation. The timing requirement according to [1] is that all uplink OFDMA symbols for each RSS should arrive at the BS within an accuracy of 1/8 of the length of CP, and which indicates that the timing offset should be within 16 samples. If a RSS is correct detected with timing offset estimation within 16 samples, the RSS receives the success response and its IR process is completed. If a RSS is detected with timing offset estimate beyond the range of 16 samples, the RSS receives the retransmission response and repeats its IR process at the following IR attempts. When a RSS is not detected by the BS, a missed detection event occurs.

In the simulation, the fading channel is simulated by the WINNERII-B1 channel model and the mobile speed is 60km/hr. Comparisons are made between the proposed method and the NAC scheme under the false alarm probability is limited within 10^{-3}.

Fig.2 shows the probability of correct detection versus number of active RSSs in one IR time-slot, where the SNR for each RSS is equal to 9 dB. It is shown that the correct detection probability of the proposed method is much better than that of the NAC method under the same receive antennas R_x condition. With the number of active RSSs increasing, the probability of correct detection by two methods drops, but the proposed method still has a good correct detection performance compared to the NAC method. As expected, with R_x increasing, the probability of correct detection of the proposed method is dramatically superior to that of the NAC method.

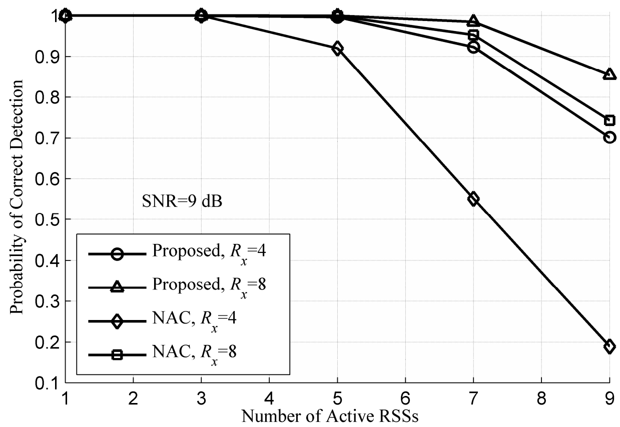

Fig. 2. Probability of correct detection vs. number of active RSSs

Fig.3 shows the standard deviation of timing offset estimation versus number of active RSSs in one IR time-slot at SNR equal to 9 dB. Clearly, the proposed method exhibits a superior timing estimation performance compared to the NAC method. With the number of active RSSs increasing, the timing performance of the proposed slightly declines while that of the NAC method severely degrades. It also revealed that the timing performance of the two methods is improved with R_x increasing.

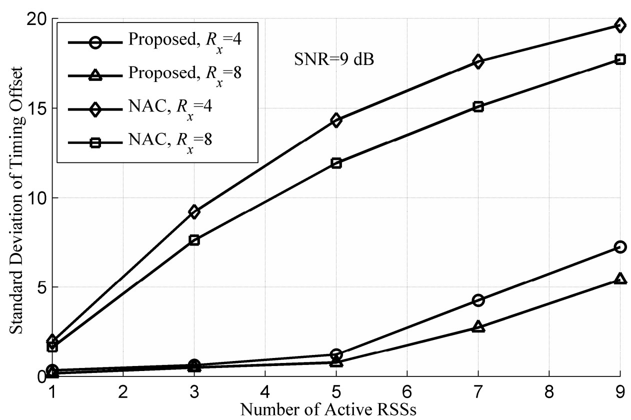

Fig. 3. Standard deviation of timing vs. number of active RSSs

Fig.4 shows the probability of successful detection of the two methods versus number of active RSSs in one IR time-slot at SNR equal to 9 dB. It can be seen that the successful detection performance of the proposed method is distinctly superior to that of the NAC method. Duo to the worse correct detection performance and timing accuracy of the NAC method, the successful detection performance of the NAC method severely degrades, even if R_x increases. It also revealed that the proposed method can dramatically improve the IR efficiency for each RSS to access into network with a small number of retransmissions compare with the NAC method.

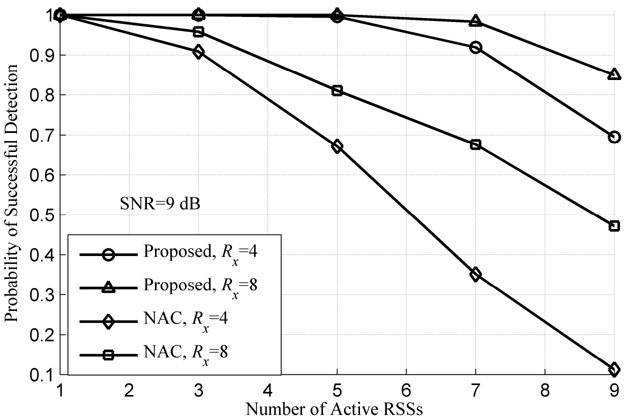

Fig. 4 Probability of successful detection vs. number of active RSSs

Fig.5 shows the probability of correct detection as a function of SNRs with different number of RSSs in one IR time-slot, where the receive antennas R_x at the BS is equal to 8. As the SNR increases, the correct detection performance of the two methods is improved, but the proposed method has a much better correct detection performance than that of the NAC method. When the number of RSSs K_R is 8 and the SNR is equal to 8dB, the probability of correct detection of the proposed method approaches the value of 0.95, and which is increased by 10% compared with the NAC method.

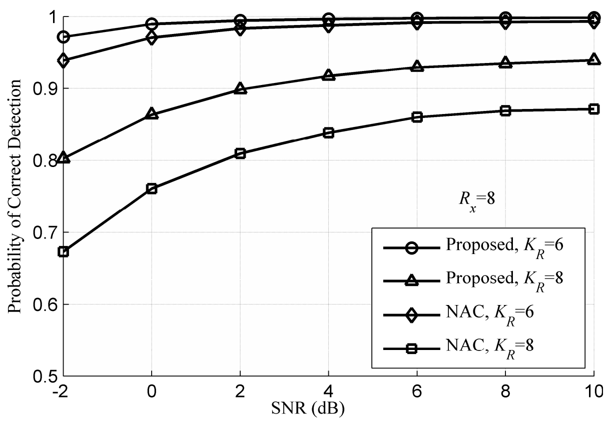

Fig. 5 Probability of correct detection vs. SNRs

Fig.6 shows the standard deviation of timing offset estimation versus SNRs with R_x equal to 8. It can be seen that the timing accuracy of the two methods is improved with the SNR increasing. As K_R increases, the timing performance of the two methods declined. However, the timing accuracy of the proposed method is much higher than that of the NAC method, even if the number of active RSSs in one IR time-slot is great.

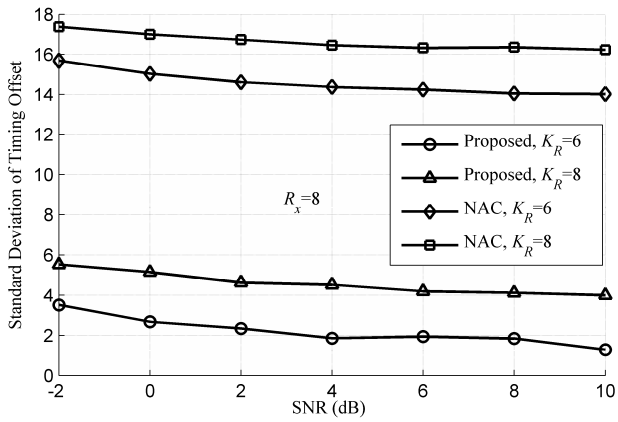

Fig. 6 Standard deviation of timing vs. SNRs

Fig.7 shows the probability of successful detection as a function of SNRs with R_x equal to 8. Obviously, the successful detection performance of the proposed scheme is much better than that of the NAC method with the SNR increasing. As K_R increases, the probability of successful detection of the proposed method slightly decreases while that of NAC method severely degrades. This indicated that the proposed scheme can accommodate more active RSSs simultaneously to access into networks than the NAC method.

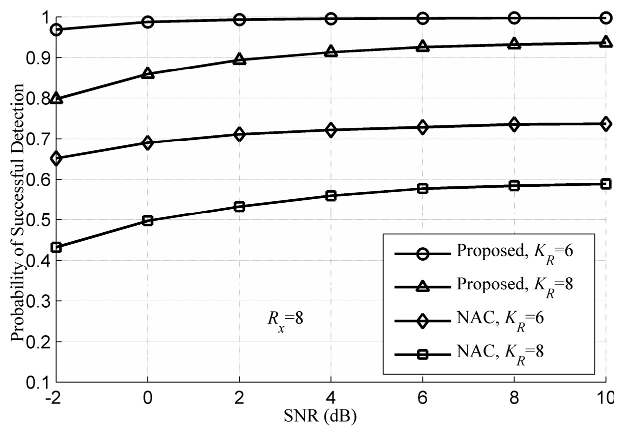

Fig. 7 Probability of successful detection vs. SNRs

6 Conclusion

A novel IR algorithm is proposed in MIMO-OFDMA uplink systems. By selecting the receive antenna with the largest received SINR, the proposed scheme achieves significant gains in IR signal detection with great number of RSSs. The simulation results show that the proposed method enhances the IR performance and increases the capacity of active RSSs compared with the NAC scheme. The proposed method not only can be used to enhance IR performance for MIMO-OFDMA systems based on the IEEE 802.16 standard, but also can be applied into the random access for the Long Term Evolution (LTE) systems.

Acknowledgement

This work was supported by the Key Scientific and Technological Project of He'nan Province of China (122102210389) and by the Applied Research Progra ms of Science and Technology of Luoyang Normal University of China (2014-YYJJ-002).

References:

[1] IEEE 802.16m, “IEEE standard for local and metropolitan area networks, part 16: air interface for broadband wireless access systems amendment 3: advanced air interface,” May 2011.

[2] X. Fu, H. Minn, “Initial uplink synchronization and power control (ranging process) for OFDMA systems,” IEEE Global Telecommunication Conference, Dallas Texas: IEEE, 2004, pp. 3999-4003.

[3] D. H. Lee, “OFDMA uplink ranging for IEEE 802.16e using modified generalized chirp-like polyphase sequences,” in Proc. International Con-ference in Central Asia on Internet (2005) , Bishkek, Kyrgyz Republic, Sept. 2005, pp. 1–5.

[4] Y. Zhou, Z. Zhang, and X. Zhou, “OFDMA initial ranging for IEEE 802.16e based on time-domain and frequency-domain approaches,” in Proc. 2006 Int. Conf. on Commun. Techn., pp. 1-5.

[5] H. A. Mahmoud, H. Arslan, and M. K. Ozdemir, “An efficient initial ranging algorithm for WiMAX (802.16e) OFDMA,” Computer Communications, vol. 32, no. 1, Jan. 2009, pp. 159-168.

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

[7] J. Zeng and H. Minn, “A novel OFDMA ranging method exploiting multiuser diversity,” IEEE Transactions on Communications, vol. 58, no. 3, Mar. 2010, pp. 945-955.

[8] M. Morelli, L. Sanguinetti and H. V. Poor, “A robust ranging scheme for OFDMA-based networks,” IEEE Trans. Commun., vol. 57, no.8, Aug. 2009, pp. 2441-2452.

[9] L. Sanguinetti, M. Morelli, and H. V. Poor, “An ESPRIT-based approach for initial ranging in OFDMA systems,” IEEE Trans. Commun., vol. 57, no.11, Nov. 2009, pp. 3225-3229.

[10] M. Ruan, M. C. Reed, and Z. Shi, “Successive multiuser detection and interference cancelation for contention based OFDMA ranging channel,” IEEE Trans. Wireless Commun., vol. 9, no. 2, Feb. 2010, pp. 481-487.

[11] C. Lin and S. Su, “A robust ranging detection with MAI cancellation for OFDMA systems,” in Proc. 2011 Int. Conf. on Adv. Commun. Technol., pp. 937-941.

[12] C. Lin and S. Su, “A differential successive multiuser ranging detection for OFDMA systems,” in Proc. Int. Conf. on Wireless Communications and Signal Processing, 2011, pp. 1-5.

[13] L. Sanguinetti and M. Morelli, “An initial ranging scheme for the IEEE 802.16 OFDMA uplink,” IEEE Trans. Wireless Commun., vol. 11, no. 9, Sep. 2012, pp. 3204-3215.

[14] J. Zeng, H. Minn and C. Chong, “Ranging signal designs for MIMO-OFDMA systems,” IEEE Global Telecommunication Conference, New Orleans: IEEE, 2008: 1-6.

[15] J. Zeng, and H. Minn, “Diversity exploiting MIMO-OFDMA ranging,” IEEE International Conference on Information, Communications & Signal Processing, Zhengzhou: IEEE, 2007: 1-5.

[16] Sanguinetti L, Morelli M and Marchetti L, “A random access algorithm for LTE systems,” Transactions on Emerging Telecommunications Technologies, vol. 24, no. 1 , Jan. 2013, pp. 49-58.