Combined Opportunistic Beamforming Methodology

Jaehak Chung, Younggun Ji, Yangsoo Kwon, and Seokhyun Kim

Abstract: **A combined opportunistic multiple beamforming method is presented that the first beam is designed with an aid of channel state information using uplink mid-amble and other beams are orthogonally generated to the first beam sequentially. The power allocation with SINR feedback increases overall throughput for the decentralized systems. The advantages of the proposed scheme is that the first beam is not interfered by other beams guaranteeing quality of service (QoS) and other orthogonal beams are operated opportunistically to obtain multi user diversity. The computer simulation demonstrates that the proposed scheme is effective at a small number of users, which is common in cellular systems, and outperforms conventional spatial division multiple access (SDMA) opportunistic beamforming methods.**

Index Terms: **Mobile WiMAX, opportunistic multiple beamforming, scheduling.**

I. INTRODUCTION

Future wireless mobile communication systems require high data rate with quality of service (QoS). Many multiple antenna technologies have developed to increase data rate, or guarantee QoS in a limited bandwidth. Array antenna systems were designed to obtain array gain, increasing capacity, extending coverage, and rejecting interferences [1], [2]. In mid-90's, Teletar and Foschini developed methodology, increasing capacity dramatically [3], [4]. After this triggering, many researches have been done based on multiple antenna theories.

Spatial diversity and spatial multiplexing techniques were developed for increasing capacity by diversity gain and multiplexing gain, respectively. On the other hand, other methods were developed, increasing capacities using multi-user rather than the number of antennas known as multi-user diversity [5]. This approach presents interesting fact that capacity can be obtained not by multiple antennas, but by scheduling schemes. In [5], the authors suggested that the single cell capacity of uplink where the multi-user communication to a single base station (BS) in time varying fading channel can be maximized by an opportunistic scheduling. In other words, if the user who experiences the strongest channel accesses the link to the BS at a given time, the maximum throughput can be achieved. Since the multiuser diversity arises from the fact that the channels of many users in a cell have independent fading statistics, a user whose channel is near the peak may exist at any time, frequency or space. For example, multiuser diversity is used for a multiple access channel in [5] and for frequency dimension in [6]. The multiuser diversity is implemented in commercial systems such as the IS-856 system [7]. As an extension of multi-user diversity of uplink, dumb antenna method in [8] was proposed with opportunistic beamforming scheme, which induces artificial channel fluctuations and power controls that increase downlink capacity significantly using scheduling algorithm. The advantage of this method is that beamforming without channel state information (CSI) can make beamforming the user as if the BS knows the channel to users with small amount of feedback when the number of user is large.

In [9], the authors extend the opportunistic beamforming idea to a single user in multiple-input multiple-output (MIMO) systems, and achieve additional multiplexing gain. Even though this method utilizes multiuser diversity, the multiple beams are not allocated to multiple users, which results in not achieving full multiplexing gain. Therefore, space division multi user diversity techniques with opportunistic multiple beamforming skills have been developed [10]–[12]. In this scenario, to achieve multiuser diversity fully, all users in a cell should report their beam index and channel quality information (CQIs) rather than CSI. Even though they feedback CQIs, the amount of feedback is also large. For this obstacle, authors in [13] developed limited feedback systems. In addition, however, when the number of users is small, which is practical in cellular systems, the multiuser diversity may not be achieved easily. Furthermore, IEEE 802.16d/e wireless metropolitan area network (WMAN) time division duplex (TDD) systems adopt uplink mid-amble to have CSI at the BS, and it enables cellular systems to generate multiple beamformings with adequate scheduling scenarios. However, the number of mid-amble transmitting users is small and limited. In this case, only a beamforming can be utilized, but spacial division multiple access (SDMA) scheme may not be applicable, which turns in loosing multiplexing gain and multiuser diversity gain.

Therefore, in this paper we propose a combined opportunistic multiple beamforming method that the first beam is obtained by uplink mid-ambles from small number of users and other orthogonal beams to the first beam are generated sequentially and utilize opportunistic multiple beamforming. The advantages of the proposed scheme is that the first beam is allocated optimally, and other orthogonal beams obtain multiuser diversity with scheduling. The first beam does not suffer from any interference from other beams since the other beams are generated orthogonally to the first beam, and allocate power optimally because the BS knows CSI for the beam. The other beams utilize multiuser diversity and obtain additional gain. In this paper, any conventional beamforming method is available for the first beam, and other beams are generated using Gram-Schmidt orthogonal method, and to reduce the amount of feedback, mobile stations (MSs) measure SINRs from multiple beams with a threshold and if the SINR is lower than the threshold, the users waive the feedback to the BS. However, since the channel is varying in time, the users have a chance that the CQI is higher than the threshold. In addition, to acquire additional gain, power

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control with using CQIs is applied to each beam. The computer simulations show that the proposed scheme presents higher sum rate at a small number of users and have multiplexing gain with multi-user diversity.

This paper consists of five sections. Section II mentions background of beamforming and SDMA type opportunistic multiple beamformings. In Section III, we present the proposed algorithm that obtains multiplexing gain and multi-user diversity using combined multiple beamformings, i.e., fixed and opportunistic multiple beamforming. Section IV evaluates the cell throughput of the proposed method for various environments to show the advantages of the proposed method. Finally, Section V contains the conclusions.

II. BACKGROUNDS

A. Conventional Beamforming

The beamforming methods are utilized by multiple antennas at transmitter or receiver sides, and is designed to obtain *array gain* or *rejecting interferences* by nulling signals. To implement these methods, various techniques have been developed for many years [1], [2].

In general, only the BS are equipped with multiple antennas because of antenna space, power consumption, and system complexity. For down link, the multiple antenna systems are used for transmitter beamforming, and for uplink utilized for receiver beamforming. In this paper we are focusing on transmit beamforming. To generate transmit beamforming, transmitter should know the CSI between transmitter and receiver. The CSIs are available by estimating uplink stage for TDD systems, or feedback from receiver directly. The feedback strategy of full CSIs is not acceptable to the practical systems since the CSI overhead of the multiple antenna channels is so large.

Assume that channel information is available at the transmitter. The weighting vector, $\mathbf{w}_k = [w_{1k}, \cdots, w_{N_t,k}]$ for the kth user attaining from channel $h_k(t)$, is calculated by several ways [1], [2]. The received signal at the receiver is given by

$$y_k(t) = \sum_i w_{ik}^*(t) h_{ik}(t) x_k(t) + n_k(t), \qquad k = 1, \cdots, K \quad (1)$$

where $x_k(t)$ denotes transmitted data for the user k at time t, and $n_k(t)$ denotes noise at the kth receiver with zero mean and variance σ_n^2 per dimension and K denotes the total number of MSs in a cell. Then, the received signal $y_k(T)$ obtains an array gain.

Since beamforming has characteristics of space division, it deploys SDMA. The SDMA technique increases system throughput by increasing spectral utilization at the BS. From this advantage, the spatial multiplexing technology using multiple beams was developed. This idea is adopted to the standard of IEEE 802.16d/e wireless regional area networks (WRAN). However, exploiting SDMA is not practically simple since a BS should pay lots of cost to acquire CSI from all mobile stations (MSs). Thus, in practice, few of the users transmit uplink midambles to the BS to provide their CSIs to the BS. Then, the BS determines who is the best for their allocation rule. In OFDMA system, the available bandwidth is wide, where the allocation method should include frequency domain consideration.

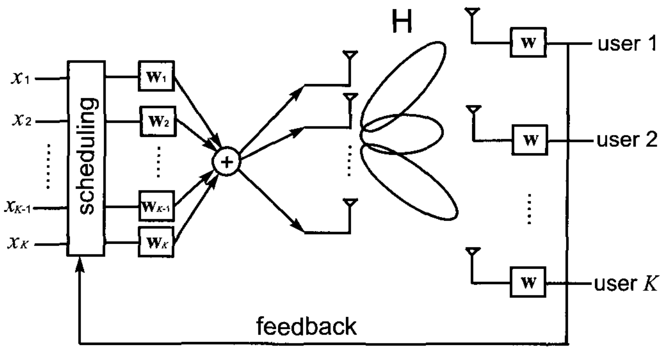

Fig. 1. Multiuser beamforming method.

B. Conventional Opportunistic Beamforming

From the previous section, we investigate the problems of obtaining CSI from the MSs, even though the BS collects CSIs of all users to maximize cell throughput. However, practically it may not be acceptable. In [8], the authors proposed the opportunistic beamforming method to obtain the array gain without knowledge of user's CSI at the BS. The idea is that firstly the BS generates an opportunistic beamforming with an arbitrary angle and power allocation, and secondly, the BS collects CQIs from the users rather than CSIs. Among the received CQI, the BS selects a user by scheduling rules such as proportional fair scheduling (PFS) or Max-SNR strategy.

Max-SNR method can maximize the throughput, while it cannot guarantee the QoS. Thus, the PFS algorithm is utilized widely in communication systems, e.g., IS-856.

The PFS allocates the channel resource to the user k who has the maximum ratio of the requested data rate $R_k(t)$ to the average throughput $T_k(t)$. The requested data rate is the feedback information of the channel quality of user k^* in time slot t, i.e., the maximum data rate that the channel of user can support the following equation as

$$\frac{R_k(t)}{T_k(t)} \quad (2)$$

where $T_k(t)$ denotes the average throughput of user k in a past window of length, which may be updated using an exponentially weighted low-pass filter

$$T_k(t+1) = \begin{cases} (1 - \frac{1}{t_c})T_k(t) + \frac{1}{t_c}R_k(t), & k = k^*, \\ (1 - \frac{1}{t_c})T_k(t), & k \neq k^*. \end{cases} \quad (3)$$

The backgrounds of this method are that the channel is varying fast, and the network is based on packet switching rather than circuit switching. The BS intentionally emphasizes channel fluctuations by randomly multiplying weighting and phase of beamforming. When the number of users is large, the possibility of hitting user from intentionally generated beam of BS increases. In other words, the BS makes a beamforming as if BS knows CSI of the user. This effects only when the number of user is large. If not, the method may not work well. Thus, this scheme utilizes multi-user diversity.

C. Space Division Opportunistic Multiple Beamforming

The conventional opportunistic multiple beamforming provides one beam at a time to obtain array gain to the user. However, in the sense of sum rate at the BS, multiplexing techniques increase the sum rate, which is defined by

$$\mathcal{C}_{\text{sum}} \approx \mathbf{E}\{\sum_{m}^{N_t} \log_2(1 + \max_{k \in K} \text{SINR}_{k,m})\} \tag{4}$$

where SINR denotes signal interference and noise ratio of user k and the mth beam. This capacity is larger than that of $\mathcal{C}_{array} \approx \mathbf{E}\{\log_2(1+K\text{SINR}_{k,m})\}$, for which the multiplexing gain is larger than the array gain since the array gain simply increases the inside of log term compared with multiplexing gain that increases the sum of log terms [14].

From this advantage, many space division opportunistic multiplexing gain methods have been developed [12], [13]. The space division opportunistic multiplexing method is as follows: Firstly, the BS transmits multiple beams to support more than one users to access the channel within the a cell at time t. Thus, the opportunistic multiple beamforming can provide orthogonal beams, which result in increasing the hitting probability to the users. When the multiple beams are designed to satisfy orthogonality minimizing interference among beams, i.e., a beam of $\mathbf{w}_i$ and other beam of $\mathbf{w}_j$ are orthogonal, defined by

$$\mathbf{w}_i^*(t)\mathbf{w}_j(t) = \begin{cases} 1, & i = j, \\ 0, & i \neq j \end{cases} \tag{5}$$

where $(\cdot)^*$ denotes the conjugate transpose of a vector or matrix. Thus, the received signal at the user k for the opportunistic multiple beamforming is given by

$$y_k(t) = \sum_{i=1}^{K} \sum_{n=1}^{N_t} w_n^*(t) h_{n,k}(t) x_i(t) + n_k(t). \tag{6}$$

To make it simple, matrix notation may be applied to the (6), and then following equation is given as

$$y_k(t) = \sum_{i=1}^{K} \mathbf{w}^* \mathbf{h}_k(t) x_i(t) + n_k(t) \tag{7}$$

where $\mathbf{w}$ denotes the weighting matrix for the space division multiplexing.

Unlike one beam opportunistic beamforming, the space division opportunistic multiple beamforming suffers from interferences from other beams, even though the beams are designed orthogonally. If the number of user is not large, for which the probability that the opportunistic beam hits exact user k is low, and if assumed that the user k receives a beam of power P_k and other beam of power P_j, then the kth user experiences received signal as

$$y_k(t) = P_k^{1/2} h_{mk} x_k(t) + P_j^{1/2} h_{mj} x_j(t) + n_k(t). \tag{8}$$

Therefore, if the kth user selects the kth opportunistic beam for its beam, the jth beam is considered as an interference. From this assumption, we obtain SINR at a user k as

$$\text{SINR}_{k,m} = \frac{|\mathbf{h}_k \mathbf{w}_m|^2}{\sigma_N^2 + \sum_{k \neq m} |\mathbf{h}_k \mathbf{w}_m|^2}. \tag{9}$$

The users calculate all possible values of SINRs, which are defined by

$$\text{SINR}_k = \frac{P_k |h_{mk}|^2}{P_j |h_{mj}|^2 + \sigma_k^2}, \quad 1 \leq k \leq K \tag{10}$$

where the ith column denotes a vector from the ith user, and the jth row denotes a vector of SINRs by a beam j for all user K. A user calculates $K \times 1$ values, and reports them to the BS, and the BS collects all SINRs from all users. To simplify, the BS arranges them as

$$\text{SINR}_{\text{BS}} = \begin{bmatrix} \text{SINR}_{1,1} & \cdots & \text{SINR}_{K,1} \\ \vdots & \ddots & \vdots \\ \text{SINR}_{1,N_t} & \cdots & \text{SINR}_{K,N_t} \end{bmatrix}. \tag{11}$$

Then, a scheduling algorithm at the BS selects a set of beams and users to maximize sum rate capacity as

$$\mathcal{C}_{\text{sum}} \approx \max_{p \in N_t K} \sum_{p=1}^{N_t K} \log_2(1 + \text{SINR}_p), \quad 1 \leq p \leq N_t K. \tag{12}$$

To reduce the amount of feedback, some works have been developed [13].

In practice, uplink mid-amble is utilized to estimate the CSI for down link. Thus, the BS can select a user to generate beamforming to maximize the capacity. However, the number of users who convey their mid-ambles to the BS is very limited by the orthogonal transmission from users. In this paper, the BS transmits the first beam using estimated CSI, e.g., exact beam, to a selected user and generates the orthogonal beams to transmit other users using the opportunistic multiple beamforming. The detailed method is described in the next section.

III. THE PROPOSED COMBINED SPACE DIVISION OPPORTUNISTIC MULTIPLE BEAMFORMING

As discussed above, in a practical system, the BS can generate a beamforming to a user easily. However, to deploy space division multiplexing it is difficult because the BS should have all users' CSIs. To achieve the multiplexing gain, the spatial division opportunistic multiplexing methodologies have been developed [12], [13]. However, the system requires many of the users in a cell to attain the multiuser diversity gain. If the number of user is not large, the multi user gain does not increase dramatically [8].

In this paper, we propose a combined opportunistic beamforming method where the first beam is generated based on the CSI estimated by uplink mid-amble and other beams are made orthogonally and operated opportunistically. Then, the proposed method guarantees a minimum QoS and attains multiuser diversity. In addition, the proposed method generates the first beam with no interference from other beams, while the conventional spatial division opportunistic multiple beamforming creates interference on each other when the beam is not exactly matched with the channel. Note that the proposed method also has interference from the second beam to the remaining beams.

In order to generate orthogonal beams from the first beam we adopt Gram-Schmidt orthogonalization, which is simple and generates all spatial division beams at a time. To apply this beam to the cellular systems, we obtain a following idea as

Lemma 1: Let $\mathbf{w}_\theta(t)$ beamforming with an angle of θ. If θ is a random variable with uniform distribution of $0 \leq \theta < 2\pi$, the angle of the orthogonal beam $\mathbf{w}_\theta^\perp(t)$ of $\mathbf{w}_\theta(t)$ has $0 \leq \theta < 2\pi$.

Proof: Let the angles of orthogonal beam be ϕ and the probability of the angle is defined by $P(\phi|\theta)$. If θ is distributed uniformly on $0 \leq \theta < 2\pi$, by marginal probability of $P(\phi|\theta)$ for θ, the probability of ϕ is given by $P(\phi)$. Thus, ϕ has any value, i.e., $0 \leq \phi < 2\pi$. □

From Lemma 1, the orthogonal beams generated from the first beam covers the all cellular ranges, which means the orthogonal beams can be transmitted to all users in a cell.

A. Generation of Orthogonal Multiple Beamforming Vectors

For the simple generation of the orthogonal beams we utilize Gram-Schmidt orthogonalization. The proposed method has one advantage that any beamforming method can be utilized for the first beam. This is an interesting property because the proposed system has more flexibility to be utilized to any kind of beamforming systems. In practice, adaptive antenna systems (AAS) deploys adaptive beamforming method. For example, to obtain the array gain a simple beamforming method may be utilized and to reduce inter-cell interference beamforming that rejects side beams to a certain direction [2].

The Gram-Schmidt method is given as: If the transmitter has N_t antennas, $N_t - 1$ orthogonal beams can be generated.

1) To generate $N_t - 1$ vectors, first, $N_t - 1$ arbitrary vector set needs to be obtained from the first beamforming vector $\mathbf{w}_1$ as

$$\mathbf{v}_1 = [w_{1,k}, w_{2,k}, \cdots, w_{n,k}+\alpha, \cdots, w_{N,k}]^T,\ n = 1, \cdots, N_t \tag{13}$$

where α denotes an arbitrary complex number to avoid linear dependency from the first vector. Then, $\mathbf{w}_1 \in \mathbb{C}^{N\times 1}$.

2) The second and the third vectors are obtained from calculating orthogonal weighting vectors $\mathbf{w}_i$ as

$$\mathbf{u}_k = \mathbf{v}_k - \sum_{j=1}^{k-1} \frac{\mathbf{u}_j^H \mathbf{v}_k}{\mathbf{u}_j^H \mathbf{u}_j} \mathbf{v}_j \tag{14}$$

$$\mathbf{w}_k = \mathbf{u}_k / \parallel \mathbf{u}_k \parallel . \tag{15}$$

3) Iterate procedure 2) until the $(N_t - 1)$th weighting vector is calculated.

If we do not consider a specific beamforming method for the first beam, other orthogonal multiple beamforming schemes are presented in [15]. Since the orthogonal vectors are orthogonal, they satisfy (5), too.

The proposed opportunistic multiple beamforming method generates a main beam based on CSI from a user and exploits opportunistic multiple beamforming for others.

B. The Procedure for the Proposed Combined Opportunistic Multiple Beamforming Method

The procedure of the proposed opportunistic multiple beamforming method structure is depicted in Fig. 1, and its frame structure is shown in Fig. 2. The detail procedure is described as follows.

1) Some MSs transmit uplink mid-amble to a BS at the end of uplink.
2) The BS receives uplink mid-ambles from some MSs.
3) The BS selects one of MSs by resource allocation method. In this paper, PFS algorithm is applied. Thus, the BS maximizes capacity in terms of guaranteeing QoS.
4) The BS generates a main beam to the MS, and calculates orthogonal multi-beams by orthogonalization methods, e.g., Graham-Schmidt method.
5) The BS transmits the main beam and multi-beams to users during a short time at the start of the frame in Fig. 2. The main beam conveys data to the selected user and other orthogonal beams contain preamble including its identification code.
6) All MSs except the main beam user measure SINRs and report to the BS.
7) The BS selects which user satisfies the resource allocation method. In general, the BS calculates sum rate as in (4).
8) The BS transmits data using the main beam and other multi-beams.
9) Iterate 1) through 8).

As seen above, the proposed algorithm selects the first user using uplink mid-amble and generates orthogonal beams to the users, the sum rate of the proposed scheme starts at a high throughput value compared with other opportunistic multiple beamforming methods. Then, other orthogonal beams are used for the conventional opportunistic multiple beamforming schemes attaining multi-user diversity. Therefore, even with a small number of user in a cell, the proposed scheme outperforms other opportunistic method and can be utilized in practice. The throughput performance comparison with the conventional opportunistic SDMA multiple beamforming method will be presented in the next section.

C. Capacity for the Combined Opportunistic Multiple Beamforming

From the second beam, orthogonal beams are allocated to the users who have max SINR among feedback users. Considering slow fading where the channel matrix of user k, $\mathbf{h}_k$, remains constant for all values of t. Without transmit processing, the channel capacity of user k is the same regardless and multiuser diversity cannot be attained. However, since the proposed method varies the effective channel of user k, by continuously changing the beamforming vectors, this method is able to obtain the multiuser diversity gain. In general, the maximum channel capacity is attained when the transmitter knows the channels of all users. However, the proportional fair algorithm will schedule transmission to users only when the channel capacity is near its peak if there are many users in a cell. Thus, we can presume that the channel capacity of the proposed algorithm approaches that of sum rate capacity with only the SINR feedback, which is justified by the following Lemma.

Lemma 2: Suppose that the slow fading states of users are independent and identically-distributed (i.i.d.) and are discrete and the joint stationary distribution of w_i, $i = 1, \cdots, N$, is the same as that of for any individual user k, which arises from the Gram-Schmidt orthogonalization. Let T_k^K denote the average throughput of user k in a cell with users when the proportional

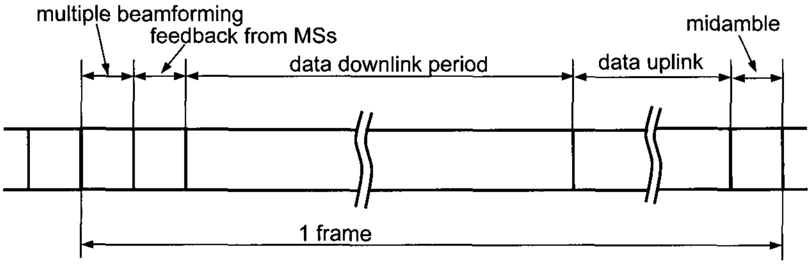

Fig. 2. Proposed data frame for combined opportunistic multiple beamforming method.

fair scheduling with infinite window ($t_c = \infty$) is used. Then, we have

$$\lim_{K\to\infty} KT_k^{(K)} = R_k^{bf} \tag{16}$$

for all k where R_k^{bf} is the instantaneous data rate that user k achieves when it is the beamforming configuration.

Proof: The proof follows [[8], Th .1]. □

Therefore, for many users in a cell, the PFS schedules the user the beamforming configuration with high probability and equal amount of time.

D. Feedback and Power Allocations

The feedback of SINRs from MSs to the BS induces problems of complexity and bandwidth of feedback channels. At the BS, when a number of feedbacks are received, the BS should calculate all of information to maximize the sum rate as shown in (11). For the feedback channel's point of view, if the number of user increases more than the limit of feedback channel, even though the users have high possibility to be selected by the BS, they may loose chances. It causes multiuser diversity gain decreasing for the system. To overcome this problem, the limited feedback has been researched by many authors [10], [13]. In this paper, we present some simulations of the effects of the amount of feedbacks.

One of the advantages of the proposed scheme is that the main beam is not affected by interference from other beams, which is one of problems of space division multiple beam methods. The other beams, however, suffer from interference from other beams. At the BS, to maximize the sum rate of the system, we utilize SINRs from MSs. In [12] and [16], the iterative waterfilling methods were presented. In this paper, we allocate power to increase the sum rate. The procedure is as follows

$$\begin{aligned} C &= \max_{p} \sum_{k} (\log_2(1+\kappa_k\lambda_k)) \\ \kappa_k &= (\mu - 1/\lambda_k)^{+} \\ &\text{subject to} \sum_{k} \kappa_k = P_{tot} \end{aligned} \tag{17}$$

where λ_k denotes SINR in (9), P_{tot} denotes the total transmit power and $(\cdot)^{+}$ takes a positive value or zero when the inside value is negative.

IV. SIMULATIONS

In this section, we evaluate the throughput performance of the proposed method for the slow fading channels. First, we exhibit that diversity gain can be obtained by the proposed scheme and compare it with the conventional opportunistic multiple beamforming method. Secondly, when the BS allocates the first beam with the best CSI user, i.e., centralized by the BS, and without the knowledge of whose channel is the best, i.e., contention based first user allocation, the proposed algorithm compares sum rates for two scenarios. Thirdly, we demonstrate the throughput variations when the amount of the feedback is limited. Fourthly, the throughput performance with the power control is compared with no power controlled combined opportunistic beamforming method.

A. Comparison of the Conventional SDMA Opportunistic Multiple Beamforming with the Proposed Method

The proposed scheme is that the CSI based first beam is generated by an arbitrary beamforming method and orthogonal beams are used opportunistically. As mentioned previously, this scenario is available in real systems, e.g., IEEE 802.16d/e, which has an uplink mid-amble. In Fig. 3, we demonstrate that the number of transmit antennas and receive antennas is three and one, respectively, i.e., 3 × 1 multiple input single output (MISO) system. Like other opportunistic multiple beamforming, the proposed scheme achieves diversity gain, even though there is slow fading. In Fig. 4, circle denotes the conventional SDMA opportunistic multiple beamforming and rectangle denotes the proposed method with contention based first beam selection and triangle denotes full SINR feedback of the proposed scheme. Note that the sum rate is larger than the conventional SDMA opportunistic multiple beamforming method specifically with a small number of users, e.g., 5~10. If the SINRs are fedback fully, the BS can schedule with full information of the MSs. Thus, using PFS, we can maximize the sum rate. In Fig. 5, as the number of transmit antennas increases by three, the gain becomes larger than that of two transmit antennas. Note that the proposed scheme exhibits the better sum rate performance at a small number of users, while the conventional SDMA opportunistic multiple beamforming method needs a number of users, which does not exist in practice.

B. Comparison of the Amount of Feedback

The feedback of the MSs is crucial because all users should report SINR of all beams to maximize the sum rate at the BS. In

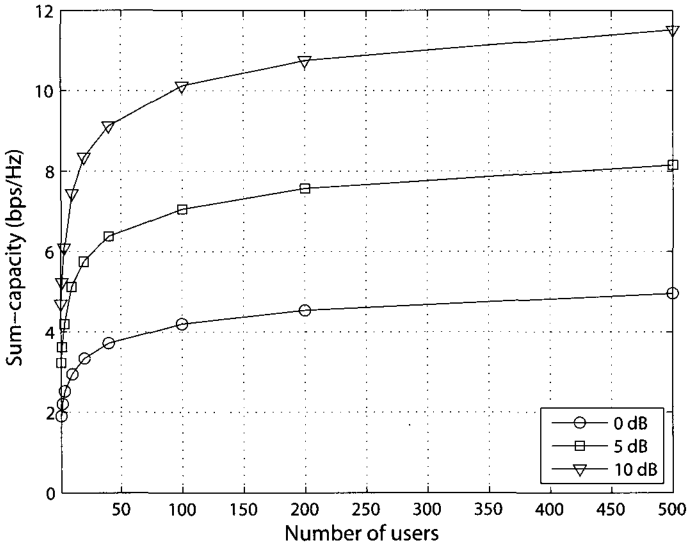

Fig. 3. The sum rate performance of the proposed combined opportunistic multiple beamforming with 3 × 1 MISO system.

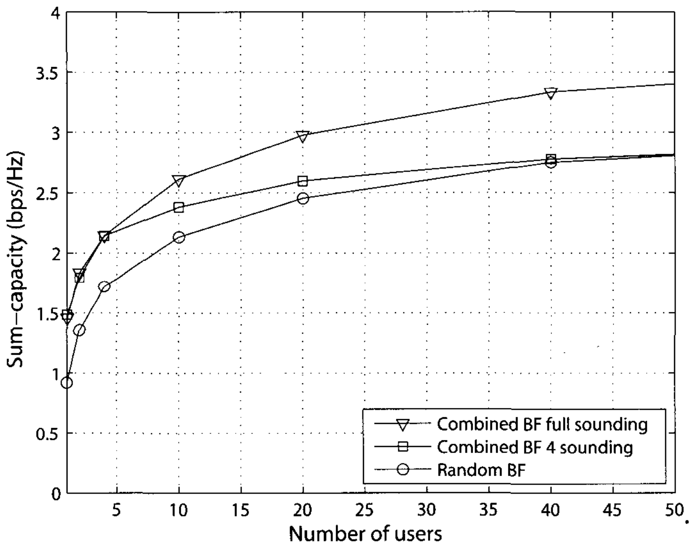

Fig. 4. Comparison of sum rate performance among opportunistic SDMA, combined method with full SINR feedback, combined method with un-centralized method for 2 × 1 case.

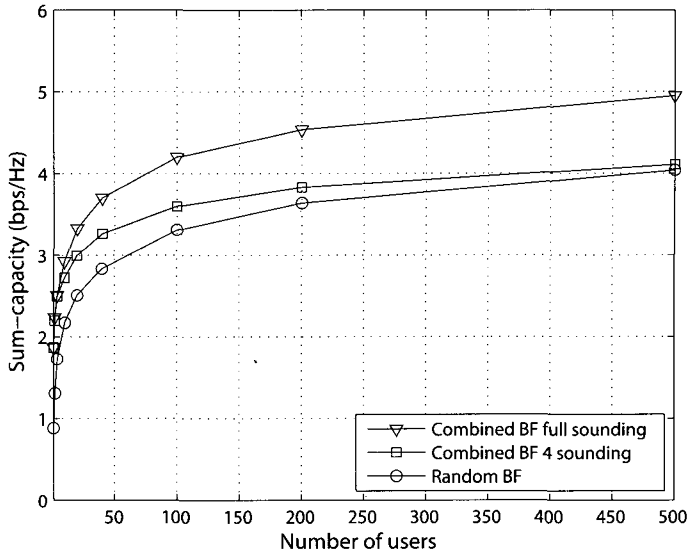

Fig. 5. Comparison of sum rate performance among opportunistic SDMA, combined method with full SINR feedback, combined method with un-centralized method for 3 × 1 case.

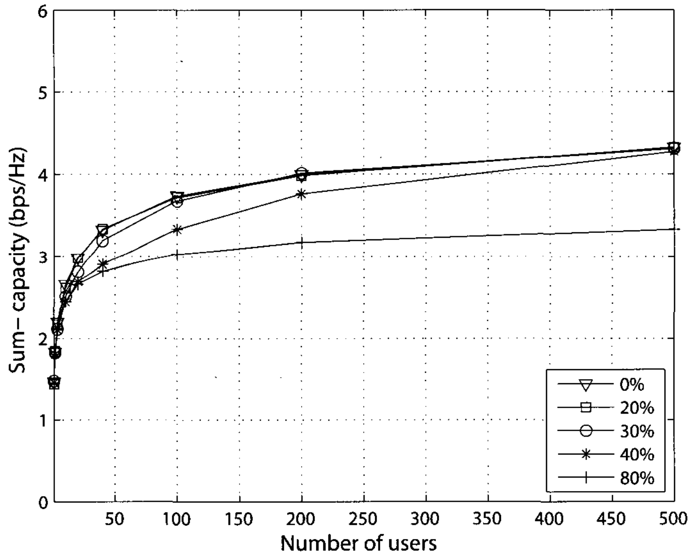

Fig. 6. The sum rate performance with the outage users whose SINR is below the threshold for 2 × 1 MISO systems.

other words, the total number of feedback information is KN_t, where K is the number of users and N_t is the number of beams or transmit antennas. Not only the calculation complexity for the scheduling is a problem at the BS, but also the feedback channel is limited practically. In this paper, to show the effects of reducing the amount of feedback information, firstly MSs decide whether they transmit the SINRs to the BS using some threshold methods [13]. In Fig. 6, the triangle denotes full feedback from all users, and rectangle, circle, asterisk and cross denote the 20%, 30%, 40%, and 80% outage users who do not send the SINRs back to the BS, respectively. As the the number of outage users increases, the sum rate of the proposed scheme decreases. However, when the number of user is large, even though the percentage of the outage user is the same, the sum rate is close to the full rate feedback case because the number of user is large. Fig. 7 demonstrates the same contents as in Fig. 6 except the number of transmit antennas is three. In this case, even a small percentage of outage users causes lower sum rate compared with a two transmit antenna scenario.

C. Comparison of the Power Control

Fig. 8 exhibits that the effects of the power control is applied to the proposed scheme of 2 × 1 MISO using (17). In this case, we observe that the power control effect depends on the centralized system or the contention based system. In the centralized system, the BS has *a priori* information of whose channel is the best. The power control of this scheme is already applied to the user. Thus, the power control by SINR feedback method does not attain an additional gain. This is because the capacity of the first beam is the largest since the BS already chooses the best quality channel. By water-filling method, the more power

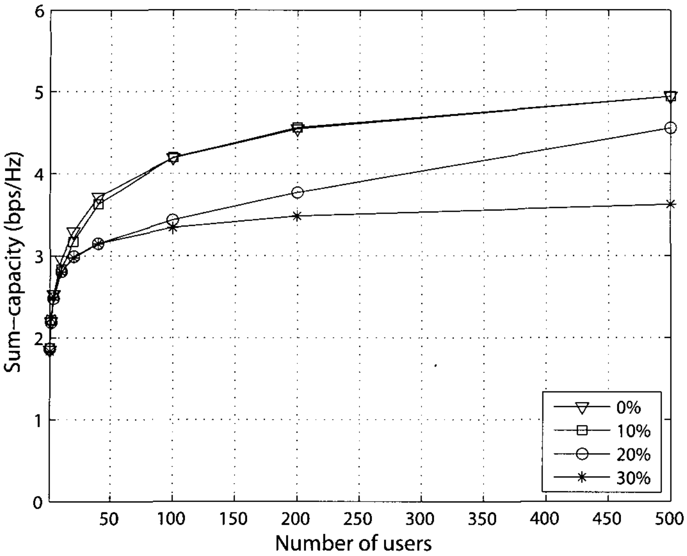

Fig. 7. The sum rate performance with the outage users whose SINR is below the threshold for 3 × 1 MISO systems.

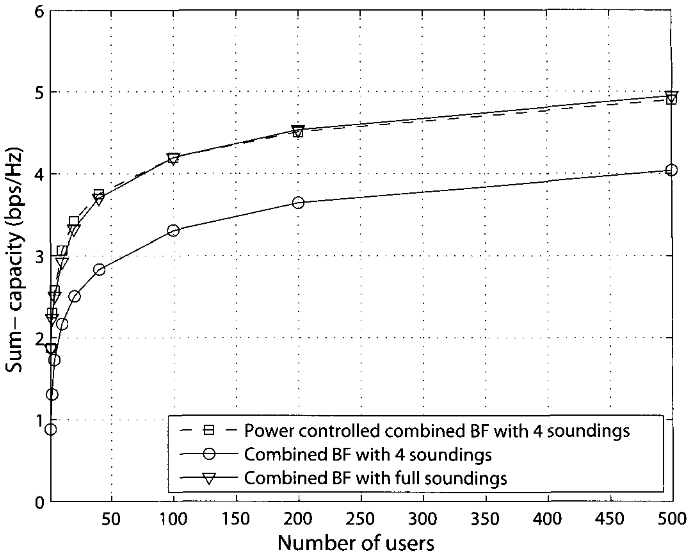

Fig. 9. The sum rate performance of the power control with contention based first beam allocation for 3 × 1 MISO systems.

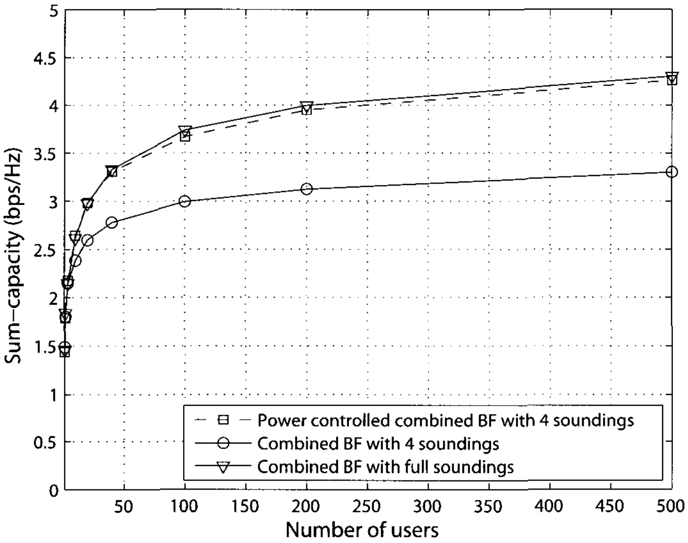

Fig. 8. The sum rate performance of the power control with contention based first beam allocation for 2 × 1 MISO systems.

should be allocated to the best user, i.e., the first user. However, when the BS does not select the best user, i.e., the first user is selected by contention based allocation, which is a more practical system scenario, the power control method outperforms the non-power allocation scheme. The sum rate gets closer to the case that the first user is selected optimally. Therefore, the proposed algorithm achieves the additional gain without additional feedback from the MSs when the first user is selected by contention based system.

V. CONCLUSIONS

This paper proposes the combined opportunistic multiple beamforming method that presents higher sum rate in a small number of user environments. For the first user, the proposed method utilizes uplink mid-amble, and selects the first user using the conventional multiple beamforming method. From the second beams, the proposed method utilizes opportunistic multiple beamforming attaining multiuser diversity. The simulation exhibits that the sum rate of the proposed method outperforms when the number of user in a cell is small, and achieves an additional power control gains for two and three transmit antenna cases.

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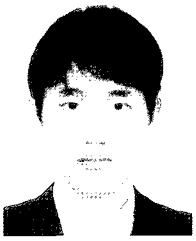

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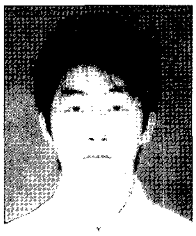

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