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Limited feedback SDMA schemes based on statistical CSI

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Abstract: This paper investigates the multi-beam selection algorithms for transmit correlation channels by using statistical channel state information (SCSI) and instantaneous channel state information. Unlike the conventional codebook-based transmission scheme, the proposed multi-beam selection with the single channel quality indicator (CQI) feedback (MBS-SCF) algorithm determines the preferred beam vector by exploiting the SCSI and only feeds back CQI at each timeslot. The performance of the MBS-SCF algorithm is nearly the same as that of the conventional scheme. In order to further improve the average sum rate, a novel multi-beam selection with the dual CQIs feedback (MBS-DCF) algorithm is proposed, which determines dual preferred statistical eigen-directions and feeds back dual CQIs at each timeslot. The theoretical analysis and simulation results demonstrate that the MBS-DCF algorithm can increase the multiuser diversity and multiplexing gain and exhibits a higher average sum rate.

Key words: spatial division multiple access; statistical channel state information; multiuser multiple-input multiple-output

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Multiuser multiple-input multiple-output (MU-MIMO) downlink systems exploit multiplexing gains and the multiuser diversity gains to significantly increase the throughput of the systems[1]. In practice, limited feedback spatial division multiple access (SDMA) schemes have attracted much attention due to the low computational complexity and little amount of overhead. A per-user unitary and rate control (PU2RC)[2] scheme, which is a practical implementation of the limited feedback SDMA scheme with predefined sets of orthogonal codebooks, has been proposed as a practical MU-MIMO solution in next-generation wireless communication standards. However, the major drawbacks of the PU2RC scheme are as follows: 1) The computational complexity and the feedback overhead of the users are higher when a larger codebook is used to reduce the interference, since the beamforming vector is generally determined by an exhaustive search in the sets of codebooks at the user side and it is sent back to the base station (BS) at each timeslot. 2) The schedulers become inefficient, especially when the user pool is small, because it is unlikely to find a few simultaneous users with semi-orthogonal channels in a small user pool.

In this paper, we consider a limited feedback SDMA scheme in a suburban scenario, where the channel fading of different antennas (e. g. uniform linear array) at the BS is highly correlated due to little scattering and small angular spread[3]. The statistical channel state information (SCSI) represents the statistical properties of the channel, generally including the distribution of channel fading, the average channel gain and the spatial correlation, etc. Its coherence period is generally much longer than that of the instantaneous channel realizations[4]. Therefore it can be easily obtained by the receiver and feed back to the transmitter[5]. An alternative is to exploit the uplink/downlink reciprocity of channel statistics[6]. Compared with the instantaneous CSI per timeslot, the overhead of the SCSI can be ignored.

Based on these observations, we propose simple and efficient SDMA schemes with limited feedback by exploiting the SCSI. First, assuming that the SCSIs (channel correlation matrices) are acquired by either of the above methods, the BS and each user can determine the preferred statistical eigen-direction (beamforming vector) during the period of updating the SCSI (or each user can determine the preferred statistical eigen-direction and send back the index of the preferred statistical eigen-direction to the BS). During the scheduling period, each user only feeds back the channel quality indicator (CQI) on its preferred statistical eigen-direction without the corresponding vector index at each timeslot. Secondly, in order to overcome the obstacle due to a small user pool, each active user can select dual preferred statistical eigen-directions according to the SCSI. At each timeslot, each user feeds back dual CQIs on its dual preferred statistical eigen-directions, which will increase the multiplexing gains and the multiuser diversity gains.

1 System Model

We consider the downlink MIMO system with K users.

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The BS is exposed to little scattering and is equipped with a uniform linear array (ULA) of M antennas, whereas each user is equipped with a single antenna. Since in a typical cellular system, the number of users is much greater than the number of transmit antennas ($K \gg M$). In each timeslot, the BS selects user sets $Q(B=|Q| \leqslant M)$ out of K users according to some scheduling algorithms. The data for scheduled users is transmitted by the BS through a multiuser precoding matrix $\boldsymbol{C}_B=\{\boldsymbol{w}_1, \ldots, \boldsymbol{w}_B\} \in \mathbf{C}^{M \times B}$, where $\boldsymbol{w}_k \in \mathbf{C}^{M \times 1}$, $k=1,2, \ldots, B$ are precoding vectors. The received signal at the i-th user is given by

$$y_i=\boldsymbol{h}_i \boldsymbol{C}_B \boldsymbol{s}_B+n_i \qquad i=1,2, \ldots, K \tag{1}$$

where n_i denotes the additive white Gaussian noise with a variance N_0. $\boldsymbol{s}_B$ is a $B \times 1$ transmit symbol vector. Without loss of generality, we assume that $E\{\boldsymbol{s}_B \boldsymbol{s}_B^{\mathrm{H}}\}=\boldsymbol{I}$. $\boldsymbol{h}_i \in \mathbf{C}^{1 \times M}$ denotes the channel vector between the BS and the i-th user. The channel correlation matrix of the i-th user is given by

$$\boldsymbol{R}_i=E\{\boldsymbol{h}_i^{\mathrm{H}} \boldsymbol{h}_i\} \tag{2}$$

The received signal-to-interference-plus-noise ratio (SINR) at user i can be given by

$$\mathrm{SINR}_i=\frac{\rho|\boldsymbol{h}_i \boldsymbol{w}_i|^2}{\rho \sum_{j \neq i}|\boldsymbol{h}_i \boldsymbol{w}_j|^2+\sigma^2} \tag{3}$$

where $\rho=P/B$ is the equally allocated power to the transmitted signals. Furthermore, the average sum rate of the system can be obtained as

$$C=E\left\{\sum_{i \in Q} \log_2(1+\mathrm{SINR}_i)\right\} \tag{4}$$

2 User Clustering and Statistical Eigen-Direction

In practice, the channels of different users in a cell generally show different transmit correlation matrices. We can design the user-dependent codebooks by exploiting the information in all correlation matrices[7]. However, it is not viable in reality due to high complexity. Alternatively, the DFT matrix is chosen to be the predefined matrix since the DFT-based matrix is effective for spatial correlation channels[8]. We observe that by multiplying a diagonal rotating matrix by the original DFT matrix, the corresponding space resource can be rotated in a virtual space domain. Based on this result, the codebooks can be defined as

$$\boldsymbol{W}_n=\boldsymbol{V}_n \boldsymbol{W}_{\mathrm{DFT}} \qquad n=0,1, \ldots, N-1 \tag{5}$$

where $\boldsymbol{W}_{\mathrm{DFT}}$ is the DFT matrix of order M and $\boldsymbol{V}_n=\operatorname{diag}(1, \ldots, \mathrm{e}^{\mathrm{j} 2 \pi n m / N M}, \ldots, \mathrm{e}^{\mathrm{j} 2 \pi n(M-1) / N M})$, $n=0,1, \ldots, N-1$ is the rotating matrix corresponding to the n-th basis.

According to Eq. (5), both the BS and the user side construct the same sets of bases. After acquiring the SCSI of user i, the BS and user i determine user clustering and the user's preferred statistical eigen-directions. The details of clustering the user and determining the statistical eigen-directions are described as follows.

2.1 User clustering

We define the degree of diagonalization as the criterion of determining the best basis, which can be defined as

$$d_{i, n_i}=\sum_{j \neq k}|(\boldsymbol{W}_{n_i}^{\mathrm{H}} \boldsymbol{R}_i \boldsymbol{W}_{n_i})_{k, j}|^2 \tag{6}$$

After obtaining all the values of d_{i, n_i}, $n_i \in \Psi_i=\{0,1, \ldots, N-1\}$, user i chooses its best basis index according to the following metric:

$$n_i^*=\arg \min_{n_i \in \Psi_i}(d_{i, n_i}) \tag{7}$$

This choice criterion can be explained as the choice of the basis index which most closely aligns with the user's statistical eigen-mode. All the users can be divided into at most N clusters according to Eq. (7).

2.2 Statistical eigen-direction

The best basis $\boldsymbol{W}_{n_i^*}$ of user i is determined by user clustering. At the BS and the user side, the matrix $\boldsymbol{R}_i$ is diagonalized by $\boldsymbol{W}_{n_i^*}^{\mathrm{H}}$, where the main diagonal elements are given as

$$a_{l_i}=(\boldsymbol{W}_{n_i^*}^{\mathrm{H}} \boldsymbol{R}_i \boldsymbol{W}_{n_i^*})_{l_i, l_i} \qquad l_i=1,2, \ldots, M \tag{8}$$

After obtaining all the values of a_{l_i}, $l_i=1,2, \ldots, M$, user i chooses its preferred statistical eigen-direction index in term of the criterion, that is

$$l_i^*=\arg \max_{1 \leqslant l_i \leqslant M}(a_{l_i}) \tag{9}$$

Therefore, we can obtain the preferred eigen-vector of user i as

$$\boldsymbol{w}_{n_i^*, l_i^*}=[\boldsymbol{W}_{n_i^*}]_{l_i^*} \tag{10}$$

The BS gathers the users with the same preferred statistical eigen-direction into a group. The users in each cluster can be divided into at most M groups according to Eq. (9).

3 Proposed Scheduling Algorithms

For a better understanding of the proposed SDMA scheme, a timing diagram is shown in Fig. 1. First, a scheduling period consists of multiple timeslots. Each user and the BS determine the preferred statistical eigen-direction according to the SCSI, which is only updated at the first timeslot of the scheduling period. Each user reports the instantaneous CQI to the BS at each timeslot. Secondly, based on the feedback information of all the users, the BS selects users according to some scheduling algorithms. Finally, the data for the scheduled users is trans

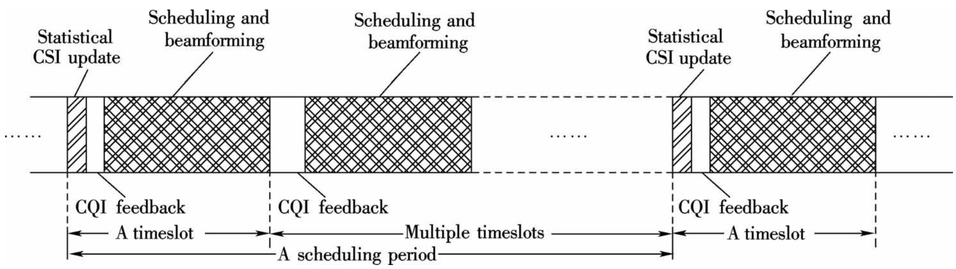

Fig. 1 Timing diagram of scheme

mitted through the beamforming vector. After a scheduling period, both the users and the BS will update the SCSI.

The goal of the SDMA scheduling algorithm is to fully exploit the multiuser diversity and the multiplexing gain. The baseline scheme (i. e. PU2RC) works as follows. At each timeslot, the active user selects a preferred vector from predefined codebooks adequate for downlink transmission based on some optimization criteria (e. g. maximum SINR) and sends back the corresponding precoding matrix index (PMI) and the resulting CQI. With the help of these feedbacks from all the users, the BS should then select several simultaneously active users using some optimal algorithms. For example, an exhaustive search can achieve the maximal sum capacity. However, it is unfeasible for a large number of users. The suboptimal scheduling algorithm is that the BS selects the first user with the maximal SINR, and then chooses other users with the maximal sum rate in the same orthonormal set. The above scheduling algorithm cannot always schedule M users, especially, when the number of users is small, and high computational complexity is required to select a preferred vector from a large codebook at the user side. To this end, we propose two scheduling algorithms by using the SCSI in this section.

3.1 Multi-beam selection with single CQI feedback (MBS-SCF)

We propose the MBS-SCF algorithm which has an essential difference when compared with the PU2RC scheme. In a scheduling period, we can determine the preferred beam vector by exploiting the SCSI instead of an exhaustive search per timeslot in the sets of codebooks. Each user only needs to send back the CQI to the BS without the corresponding PMI, since the corresponding PMI has already been obtained at the BS depending on the SCSI. The details of the MBS-SCF algorithm are described as follows.

Algorithm 1 MBS-SCF algorithm

Initialization: User sets $U = \{1, 2, \ldots, K\}$; user cluster sets $S = \{S_n\}$ where $S_n = \varnothing$ and $n \in \Psi_i = \{0, 1, \ldots, N-1\}$; user group sets $G = \{G_{n,l}\}$, where $G_{n,l} = \varnothing$, $n \in \Psi_i$ and $l \in \Phi = \{1, 2, \ldots, M\}$; user scheduling sets $Q = \{\varnothing\}$.

Step 1 Determining statistical eigen-direction

At the BS side

for $i = 1$ to K do

$n_i^* = \arg\min_{n_i \in \Psi_i}(d_{i,n_i})$, $l_i^* = \arg\max_{1 \leqslant l_i \leqslant M}(a_{l_i})$

$S_{n_i^*} = S_{n_i^*} \cup \{i\}$, $G_{n_i^*,l_i^*} = G_{n_i^*,l_i^*} \cup \{i\}$

end for

User $i \in U$ determines (n_i^*, l_i^*) according to Eqs. (6) to (10)

Step 2 CQI feedback

for $i = 1$ to K do

user i sends back CQI which is given by

$$\mathrm{SINR}_i^{(n_i^*, l_i^*)} = \frac{\| \boldsymbol{h}_i \boldsymbol{w}_{n_i^*, l_i^*} \|^2}{MN_0 + \sum_{k \neq l_i^*} \| \boldsymbol{h}_i \boldsymbol{w}_{n_i^*, k} \|^2} \tag{11}$$

end for

Step 3 Selecting the first user

The BS selects user j who has the maximal SINR criteria according to Eq. (12) and determines user cluster n_j^* and beam direction l_j^*.

$$j = \arg\max_{i \in U}(\mathrm{SINR}_i^{(n_i^*, l_i^*)}), \quad Q = Q \cup \{j\} \tag{12}$$

Step 4 Selecting other users

The BS selects other semi-orthogonal users from cluster n_j^* according to Eq. (13).

for $l = 1$ to M do

$$Q = Q \cup \{\pi_1 \mid \pi_l = \arg\max_{i \in G_{n_j^*, l}} \log_2(1 + \mathrm{SINR}_i^{(n_j^*, l)})\} \quad l \neq l_j^*, \; G_{n_j^*, l} \neq \varnothing \tag{13}$$

end for

Finally, the BS allocates the transmit power uniformly to $|Q|$ beams and performs communication.

3.2 Multi-beam selection with dual CQIs feedback (MBS-DCF)

The MBS-SCF algorithm can reduce the limited feedback without reporting the PMI and requires low computational complexity at the user side. However, it also has an obstacle. It is difficult to find a few simultaneous users with semi-orthogonal channels in a small user pool. To this end, we propose the MBS-DCF algorithm which selects dual preferred statistical eigen-directions in different clusters. At each timeslot, the user calculates the dual CQIs corresponding to the dual preferred statistical eigen-directions and feeds back the dual CQIs. This approach will enhance the opportunity to exploit multiuser diversity and multiplexing gain. We describe the details of the MBS-DCF algorithm as follows.

Algorithm 2 MBS-DCF algorithm

Step 1 Determining statistical eigen-direction

At the BS side

for $i=1$ to K do

for $m=1$ to 2 do

$n_i^* = \arg\min_{n_i \in \Psi_i}(d_{i,n_i})$, $l_i^* = \underset{1 \leqslant l_i \leqslant M}{\arg\max}(a_{l_i})$

$\Psi_i = \Psi_i \backslash \{n_i^*\}$

$S_{n_i^*} = S_{n_i^*} \cup \{i\}$, $G_{n_i^*, l_i^*} = G_{n_i^*, l_i^*} \cup \{i\}$

end for

end for

Similar to the BS side, each user determines dual (n_i^*, l_i^*).

Step 2 Dual CQIs feedback

for $i=1$ to K do

user i sends back dual CQIs according to Eq. (11).

end for

Step 3 Selecting the first user

The BS selects user j who has the maximal SINR criteria according to Eq. (12) and determines user cluster n_j^* and beam direction l_j^*.

Step 4 Selecting other users

The BS selects other semi-orthogonal users from cluster n_j^* according to Eq. (13).

Finally, the BS allocates the transmit power uniformly to $|Q|$ beams and performs communication.

3.3 Analysis of the number of scheduled beams

The proposed scheduling algorithms do not guarantee whether there are always M scheduled users or scheduled beams. As a result, the number of scheduled beams A becomes a random variable in $[1, M]$. In the following, we analyze the probability function of A.

Let the random variable N_u denote the number of users who belong to the same cluster. The probability of $N_u = k$ is given as

$$\Pr[N_u = k] = \binom{K}{k} P_u^k (1-P_u)^{K-k} \qquad k = 0, 1, \ldots, K \quad (14)$$

where P_u is the probability that a user feeds back one of the bases.

Given that k users are selected in the same cluster, the probability that there is only one scheduled beam can be calculated as

$$\Pr[A=1 \mid N_u = k] = \binom{M}{1}\left(\frac{1}{M}\right)^k \quad (15)$$

Given that k users are selected in the same base, the probability that there are only two scheduled beams can be calculated as

$$\Pr[A=2 \mid N_u = k] = \binom{M}{2}\left[\left(\frac{2}{M}\right)^k - \binom{2}{1}\left(\frac{1}{M}\right)^k\right] \quad (16)$$

where $\binom{M}{2}\left(\frac{2}{M}\right)^k$ denotes the probability that at most two beams are scheduled. The probability that only one of these two beams is scheduled can be expressed as $\binom{M}{2}\binom{2}{1}\left(\frac{1}{M}\right)^k$. Similarly, given that k users are selected in the same base, the probability that exactly m beams out of M available beams are scheduled can be calculated as

$$\Pr[A=m \mid N_u = k] = \frac{1}{M^k}\binom{M}{m}\sum_{p=1}^{m}(-1)^{m-p}\binom{m}{p}p^k \qquad m \leqslant \min(M, k) \quad (17)$$

Finally, combining Eq. (14) and Eq. (17), the probability that exactly m beams are scheduled can be obtained as

$$\Pr[A=m] = \sum_{k=1}^{K}\Pr[N_u = k]\Pr[A=m \mid N_u = k] = \sum_{k=1}^{K}\binom{K}{k}P_u^k(1-P_u)^{K-k}\frac{1}{M^k}\binom{M}{m}\sum_{p=1}^{m}(-1)^{m-p}\binom{m}{p}p^k \quad (18)$$

4 Simulation Results

In order to compare the performance of the proposed algorithms with the PU2RC scheme, the computer simulations are carried out. We use the spatial channel model (SCM)[9] to generate channels without considering path loss and shadowing fading. The BS is equipped with the ULA of four antennas and each user is equipped with a single antenna. The transmit correlation is high in this configuration in that the antenna spacing is set to $\lambda/\sqrt{3}$ at the BS, which makes the users' channel power concentrate on the eigen-direction. We consider a sector of 120° and the mean angles of departures (AoDs) for the users are generated independently in a range from 0° to 120°. The four DFT matrices with $N=4$ and $M=4$ are predefined according to Eq. (5) for both the BS and the users. Simulation results are averaged over 100 drops with 1 000 channel samples for every one of them, where one drop means that the AoDs of all the K users are generated randomly.

Fig. 2 shows the normalized energy of the arbitrary eight users in different eigen-directions after user clustering in the MBS-SCF algorithm. We observe that more than 95% of the energy can be concentrated in one eigen-direction and little energy is leaked in other eigen-directions. Therefore, the users belonging to the same cluster and having different eigen-directions can be simultaneously scheduled to transmit data because the inter-user interference is ignored.

Fig. 3 shows the normalized energy of arbitrarily random selected eight users in the main eigen-direction of different clusters in the MBS-DCF algorithm. Compared

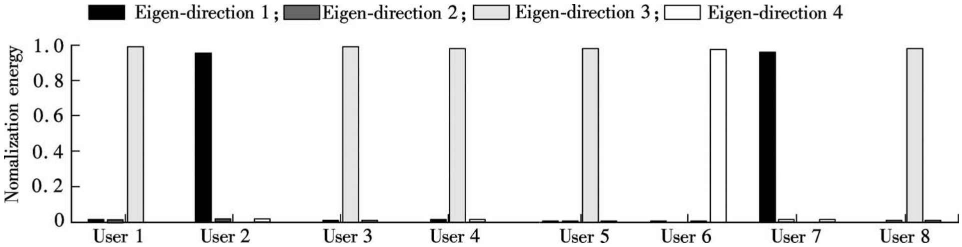

Fig. 2 Normalization of energy in the main eigen-directions after user clustering

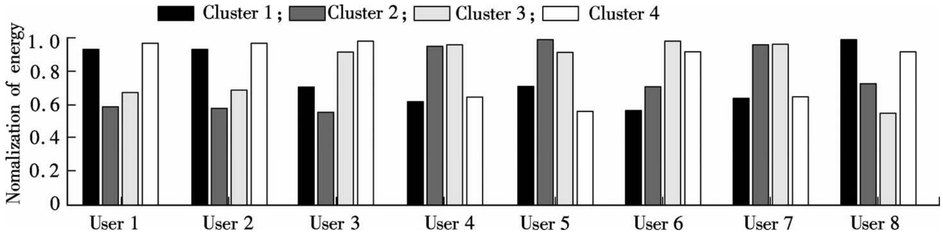

Fig. 3 Normalization of energy in different eigen-direction vs. different clusters

with the preferred cluster, only the second largest normalized energy in another cluster has the smallest gap, which sometimes is close to the best one. It can be explained that the user always has two adjacent spatial eigen-directions. Based on this observation, we select dual statistical eigen-directions to improve multiuser diversity and multiplexing gains.

Fig. 4 demonstrates the average sum rate variations, along with the number of users when the average SNR is equal to 10 dB. The performance of the MBS-SCF algorithm is nearly the same as that of the PU2RC scheme, because the MBS-SCF algorithm only sends back the CQI of the preferred statistical eigen-direction at each timeslot while the PU2RC scheme feeds back the best PMI and the corresponding CQI at each timeslot. The PU2RC scheme can further mitigate the inter-user interference due to more CSI feedbacks which can well track the instantaneous channel. In addition, Fig. 4 indicates that the MBS-DCF algorithm rapidly boosts the average sum rate as the number of users increases and outperforms the PU2RC scheme because the MBS-DCF algorithm can provide more opportunities to select well-matched users from more feedback information and can efficiently compensate for performance degradation in the small user pool.

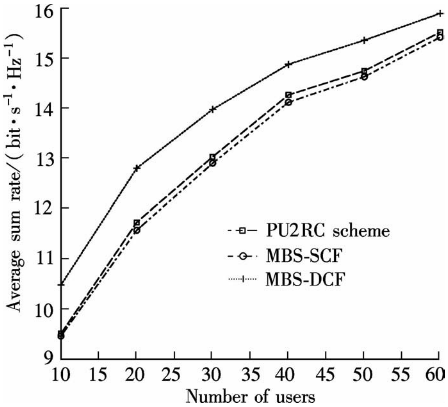

Fig. 4 Average sum rate vs. the number of users

In Fig. 5, the average sum rate performance is evaluated. When the average SNR is small and the number of users is 20, the MBS-DCF algorithm outperforms the PU2RC scheme while the MBS-SCF algorithm and the PU2RC scheme have nearly equal average sum rates. As the average SNR increases, the scenario is interference-limited. Hence, the MBS-DCF algorithm has a higher average sum rate than the PU2RC scheme by selecting more beams with little inter-user interference. The MBS-SCF algorithm has a slightly lower average sum rate than the PU2RC scheme since the PU2RC scheme can acquire more CSI to select well-matched users than the MBS-SCF algorithm.

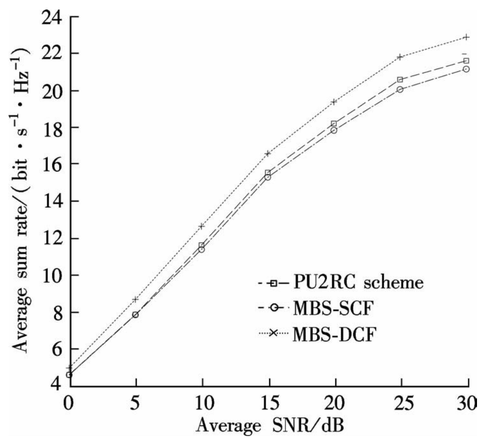

Fig. 5 Average sum rate vs. average SNR

Tab. 1 demonstrates the probability comparison of m selected beams for K users by the numerical results using Eq. (18) and simulation results in the MBS-SCF algorithm. Since the users exist in a cell uniformly, the spatial direction distribution of the users is uniform. The space domain is uniformly divided by the bases. Hence P_u is equal to 1/4. From the results, we can verify that the numerical results using Eq. (18) well approximate the simulation results. The probability of four scheduled beams is very low in the small user pool, which implies that this algorithm cannot make the best use of the spatial multiplexing gains.

Tab. 2 demonstrates the probability comparison of m selected beams for K users by the numerical results using Eq. (18) and the simulation results in the MBS-DCF algorithm. Since each user feeds back dual CQIs, P_u is equal to 1/2. From the results, we can verify that the numerical results using Eq. (18) well approximate the simulation results. Compared to Tab. 1, we observe that the probability of four selected beams in the MBS-DCF algorithm is much higher than that in the MBS-SCF algorithm, especially in the small user pool.

Tab. 1 The probability of m selected beams for K users in MBS-SCF algorithm

Number of users	1 beam		2 beams		3 beams		4 beams	
	Numerical results	Simulation results	Numerical results	Simulation results	Numerical results	Simulation results	Numerical results	Simulation results
10	0. 276 3	0. 209	0. 411 8	0. 425	0. 220 3	0. 300	0. 035 4	0. 066
20	0. 050 2	0. 034	0. 245 6	0. 212	0. 445 7	0. 444	0. 255 3	0. 310
30	0. 007 2	0. 005	0. 086 7	0. 081	0. 381 5	0. 380	0. 524 5	0. 534
40	0. 000 9	0. 001	0. 025 8	0. 032	0. 248 1	0. 244	0. 725 1	0. 723
50	0. 000 1	0. 000	0. 007 2	0. 006	0. 144 0	0. 145	0. 848 7	0. 849
60	0. 000 0	0. 000	0. 001 9	0. 002	0. 079 3	0. 084	0. 918 7	0. 914

Tab. 2 The probability of m selected beams for K users in MBS-DCF algorithm

Number of users	1 beam		2 beams		3 beams		4 beams	
	Numerical results	Simulation results	Numerical results	Simulation results	Numerical results	Simulation results	Numerical results	Simulation results
10	0. 032 5	0. 02	0. 234 6	0. 200	0. 481 8	0. 490	0. 250 2	0. 272
20	0. 000 3	0	0. 018 0	0. 016	0. 239 8	0. 238	0. 741 9	0. 746
30	0	0	0. 001 1	0	0. 070 7	0. 098	0. 928 2	0. 902
40	0	0	0. 000 1	0	0. 019 0	0. 026	0. 980 9	0. 974
50	0	0	0	0	0. 005 0	0. 006	0. 995 0	0. 994
60	0	0	0	0	0. 001 3	0. 003	0. 998 7	0. 997

5 Conclusion

In this paper, we propose the MBS-SCF algorithm to reduce feedback overhead and computational complexity by exploiting the SCSI while maintaining nearly the same sum rate performance as the conventional algorithm. However, it is unlikely to find a few of the simultaneous users with semi-orthogonal channels, especially, in a small user pool. To this end, we propose the MBS-DCF algorithm which sends back dual CQIs and increases the opportunity to exploit multiuser diversity and multiplexing gain. The simulation results show that the MBS-DCF algorithm obviously outperforms the conventional PU2RC scheme.

References

[1] Gesbert D, Kountouris M, Heath R, et al. Shifting the MIMO paradigm[J]. *IEEE Signal Process Mag*, 2007, **24**(5): 36 − 46.

[2] Huang K, Andrews J, Heath R. Performance of orthogonal beamforming for SDMA with limited feedback[J]. *IEEE Trans Veh Technol*, 2009, **58**(1): 152 − 164.

[3] Ertel R, Cardieri P, Sowerby K, et al. Overview of spatial channel models for antenna array communication systems[J]. *IEEE Pers Commun*, 1998, **5**(1): 10 − 22.

[4] Gesbert D, Pittman L, Kountouris M. Transmit correlation-aided scheduling in multiuser MIMO networks[C]// *Proc IEEE Int Conf Acoust, Speech, Signal Process*. Toulouse, France, 2006: 14 − 19.

[5] Kountouris M, Gesbert D, Pittman L. Transmit correlation-aided opportunistic beamforming and scheduling [C]//*Proc EUSIPCO*. Florence, Italy, 2006: 1 − 4.

[6] Gao X, Jiang B, Li X, et al. Statistical eigenmode transmission over jointly correlated MIMO channels[J]. *IEEE Trans Info Theory*, 2009, **55**(8): 3735 − 3750.

[7] Huang Y, Yang L, Bengtsson M, et al. Exploiting long-term channel correlation in limited feedback SDMA through channel phase codebook[J]. *IEEE Trans Signal Process*, 2011, **59**(3): 1217 − 1228.

[8] Sayeed A. Deconstructing multiantenna fading channels [J]. *IEEE Trans Signal Process*, 2002, **50**(10): 2563 − 2579.

[9] Salo J, Del Galdo G, Salmi J, et al. Matlab implementation of the 3GPP spatial channel model (3GPP TR 25. 996) [EB/OL]. (2005-01) [2006-07-05]. http://www. tkk. fi/Units/Radio/scm.

基于统计信道状态信息的有限反馈空分多址方法

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摘要:研究了在发送相关信道场景下,综合利用统计信道状态信息和瞬时信道状态信息的多波束选择算法. 与传统的基于码本的传输方案不同,基于单信道质量标识反馈的多波束选择算法利用统计信道状态信息决定其最佳的波束矢量,每一时隙只反馈信道质量标识,而且该算法的性能与传统方案基本相近. 为了进一步提高平均和速率,提出了基于双信道质量标识反馈的多波束选择算法,该算法决定 2 个最佳统计特征方向,并且每时隙反馈双信道质量标识. 理论分析和仿真结果表明:基于双信道质量标识反馈的多波束选择算法可以增加多用户分集和复用增益,具有更高的平均和速率.

关键词:空分多址;统计信道状态信息;多用户多输入多输出

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