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Cooperative Opportunistic Beamforming for OCI Mitigation in Correlated Multi-User MISO Cellular System

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채널 상관도가 존재하는 다중 사용자 MISO 환경에서 인접 셀 간섭 제거를 위한 협력 기회적 빔포밍 기법

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Abstract

We consider cooperative opportunistic beamforming that can mitigate the other cell interference (OCI) in correlated multi-user multiple-input single-output (MISO) cellular environments. By only exploiting the spatial channel information of adjacent cells, the proposed scheme generates the cooperative random beam that statistically avoids the OCI from adjacent cells. Each cell selects a user in an opportunistic manner. Thus, the proposed scheme can simultaneously achieve the multi-user diversity (MUD) gain and the OCI avoidance gain..

I. Introduction

The deployment of multiple antenna techniques in [1] motivates the use of MUD to take advantages of independent user channel statistics. Allowing a user in the best channel condition, we can achieve a large improvement of the system capacity. However, the capacity of MIMO is nonetheless significantly limited by OCI in cellular environments

To solve this problem, previous works in [2] proposed BS cooperation that can work with full channel state information (CSI). However, the use of full CSI may not be practical due to large feedback overhead as well as so-called channel mismatch problem. In practice, the use of random beam is often considered for simplicity at an expense of performance loss. In this paper, we propose long-term based cooperative opportunistic beamforming for OCI mitigation.

II. System model

We consider a MISO cellular system comprising B BSs, where each BS has M transmit antennas and each user has a single receive antenna. Let $s_{Q(j)}$ be the signal, $Q(j)$ be a user index selected to beam $\mathrm{w_j}$, P be the average signal power, $\mathrm{h_{j,Q(j)}}$ be the $(M\times 1)$ channel vector between BS j and user $Q(j)$, and $n_{Q(j)}$ is AWGN noise with variance N_0.

When the channels are spatially correlated, the channel vector $\mathrm{h_{j,Q(j)}}$ can be generated using a complex white Gaussian random vector $\mathrm{h^w_{j,Q(j)}}$

$$\mathrm{h_{j,Q(j)}} = \mathrm{R^{1/2}_{j,Q(j)}}\,\mathrm{h^w_{j,Q(j)}} \tag{1}$$

where $\mathrm{R_{j,Q(j)}}$ is the channel correlation matrix.

$$\mathrm{R_{j,Q(j)}} = \mathrm{E}\{\mathrm{h_{j,Q(j)}}\mathrm{h^*_{j,Q(j)}}\} = \begin{bmatrix} 1 & \rho_{\mathrm{j,Q(j)}} \\ \rho^*_{\mathrm{j,Q(j)}} & 1 \end{bmatrix} \tag{2}$$

where the superscript $*$ denotes conjugate transpose and $\rho_{j,Q(j)} = \alpha_{j,Q(j)} e^{j\theta_{j,Q(j)}}$ is the transmit correlation coefficient. Here $0 \le \alpha_{j,Q(j)} \le 1$ and $0 \le \theta_{j,Q(j)} \le 2\pi$.

Without loss of generality, assume that user $Q(0)$ is the target user and scheduled by center BS 0.

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Then, the received signal can be presented as

$$y_{0,Q(0)} = \sqrt{P}\,\mathrm{h}^{*}_{0,\mathrm{Q}(0)}\mathrm{w}_0\mathrm{s}_{\mathrm{Q}(0)} + \sum_{j=1}^{\Omega_{Q(0)}} \sqrt{P}\,\mathrm{h}^{*}_{\mathrm{j},\mathrm{Q}(0)}\mathrm{w}_{\mathrm{j}}\mathrm{s}_{\mathrm{Q}(\mathrm{j})} + \sqrt{\mathrm{I}_{\mathrm{Q}(0)}} + \mathrm{n}_{\mathrm{Q}(0)} \tag{3}$$

where $\Omega_{Q(0)}$ denotes an active set strongly affecting the signal reception of user $Q(0)$, $\mathrm{I}_{\mathrm{Q}(0)}$ denotes the average interference power form neighbor cells not belonging to $\Omega_{Q(0)}$. Therefore, the instantaneous SINR $\gamma_{0,Q(0)}$

$$\gamma_{0,Q(0)} = \frac{|\mathrm{h}^{*}_{0,\mathrm{Q}(0)}\mathrm{w}_0|^2}{\sum_{j=1}^{\Omega_{Q(0)}} |\mathrm{h}^{*}_{\mathrm{j},\mathrm{Q}(0)}\mathrm{w}_{\mathrm{j}}|^2 + \mathrm{I}_{\mathrm{Q}(0)} + \mathrm{N}_0/(\gamma_0\mathrm{P})}. \tag{4}$$

III. Conventional beamforming

A. *Opportunistic Beamforming*

BS j assigns the resource to a user having the highest SNR, the SNR $\gamma_{j,Q(j)}$ is represented as

$$\gamma_{j,Q(j)} = \max \gamma_0 |\mathrm{h}^{*}_{\mathrm{j},\mathrm{k}}\mathrm{w}_{\mathrm{j}}|^2 \tag{5}$$

where $k=1,\ldots,K$. The capacity of the opportunistic beamforming is bounded as [1]

$$C_{j,Q(j)} \le \log_2\left(1+\gamma_0\left(1+\sum_{k=2}^{K}\frac{1}{k}\right)\right). \tag{6}$$

B. *Cooperative Beamforming*

With the knowledge of full CSI, the optimum cooperative beam w_{j} can be determined as [2]

$$\mathrm{w}_{\mathrm{j}} = \left(\mathrm{h}_{\mathrm{j},\mathrm{Q}(0)}\mathrm{h}^{*}_{\mathrm{j},\mathrm{Q}(0)} + \frac{\mathrm{N}_0}{\gamma_0\mathrm{P}}\mathrm{I}_{\mathrm{M}}\right)^{-1}\mathrm{h}_{\mathrm{j},\mathrm{Q}(\mathrm{j})},\ \mathrm{j} \neq 0 \tag{7}$$

where I_{M} is an identity matrix. Although the cooperative beam in [2] can provide optimum performance, it should exchange the full CSI between cooperative BSs.

IV. Proposed scheme

We introduce the concept of the opportunistic beamforming as in [1] and the cooperative beamforming as in [2]. BS j generates a beam as follows

$$\mathrm{w}_{\mathrm{j}} = \left(\mathrm{R}_{\mathrm{j},\mathrm{Q}(0)} + \frac{\mathrm{N}_0}{\gamma_0\mathrm{P}}\mathrm{I}_{\mathrm{M}}\right)^{-1}\mathrm{v}_{\mathrm{j}}/\|\mathrm{v}_{\mathrm{j}}\|,\ \mathrm{j} \neq 0 \tag{8}$$

where v_{j} is the random beam. Thus, the capacity of the proposed scheme is given by

$$C_{pro} = \int_0^{\infty}\log_2(1+z)f_{\gamma_{0,Q(0)}}(z)dz \tag{9}$$

where $f_{\gamma_{0,Q(0)}}(z)$ is the probability density function (pdf) of $\gamma_{0,Q(0)}$, represented as

$$f_{\gamma_{0,Q(0)}}(z) = K\left(1-e^{-\Omega_{Q(0)}z/\gamma_0}\right)^{K-1}\frac{e^{-\Omega_{Q(0)}z/\gamma_0}}{(1+z)^{\Omega_{Q(0)}}}\left(\frac{\Omega_{Q(0)}(1+z)}{\gamma_0}+\Omega_{Q(0)}-1\right) \tag{10}$$

V. Performance evaluation

Fig. 1 depicts the throughput according to K when $\gamma_0 = 0$ dB and $\alpha = 0.9$. It can be seen that the proposed scheme outperforms the original opportunistic beamforming in [1] without increasing the implementation complexity. This is mainly due to the facts that the proposed scheme statistically avoids the OCI. It can also be seen that the proposed scheme is somewhat inferior to [2], but, it can practically be applicable since it only utilizes the spatial correlation.

VI. Conclusion

We have proposed cooperative opportunistic beamforming based on the spatial correlation in downlink of multi-cell multi-user mobile environments. Based on the spatial correlation, the proposed scheme can improve the SINR of the users near the cell boundary by cooperatively generating the beam to minimize the OCI.

Reference

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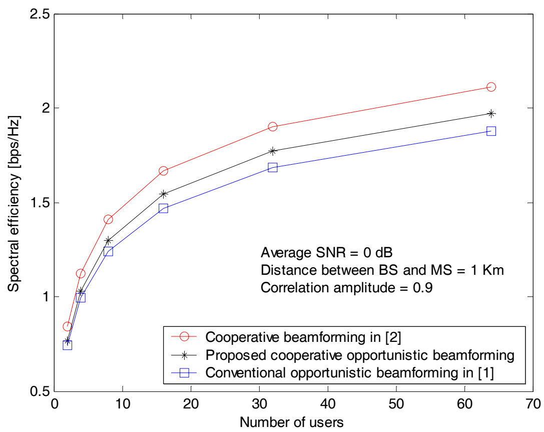

Fig. 1. Throughput when $\gamma_0 = 0$ dB