Joint Antenna and User Selection in Downlink Massive MIMO Systems

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Abstract

In massive multiple-input multiple-output (MIMO) systems, a large number of radio frequency (RF) chains is a big problem, and antenna selection technology has been attracted as one of promising solutions. In this paper, we develop a joint antenna and user selection algorithm to maximize the weighted sum rate. Then, we show that our proposed algorithm provides near-optimal performance through the simulation.

I. Introduction

To resolve the increased number of radio frequency (RF) chains in massive multiple-input multiple-output (MIMO) systems, antenna selection technology has been attracted as the one of solutions [1], [2]. Unlike many existing studies that maximize the sum rate, in this paper, we study the joint antenna and user selection problem in the downlink massive MIMO system to maximize the weighted sum rate. We develop a greedy-based heuristic joint antenna and user selection (JAUS) algorithm and show its effectiveness through the simulation.

II. System model and problem formulation

We consider the downlink massive MIMO system, where one BS equipped with $M$ antennas and $N$ RF chains is serving $K$ single-antenna users. The index sets of the antennas at the BS and the users are defined by $\mathcal{M} = \{1, \ldots, M\}$ and $\mathcal{K} = \{1, \ldots, K\}$, respectively. The received signal, $y_k$, at user $k$ is given by

$$y_k = (h_k)^H \sqrt{p_k} w_k q_k + n_k.$$

(2)

Now, we define the antenna selection vector, $\mathbf{\beta} = (\beta_m)_{m \in \mathcal{M}}$, where

$$\beta_m = \begin{cases} 1, & \text{if antenna } m \text{ is selected,} \\ 0, & \text{otherswise.} \end{cases}$$

(3)

Similarly, we define the user selection vector, $\mathbf{\alpha} = (\alpha_k)_{k \in \mathcal{K}}$, where

$$\alpha_k = \begin{cases} 1, & \text{if user } k \text{ is selected,} \\ 0, & \text{otherswise.} \end{cases}$$

(4)

Then, for given $\mathbf{\beta}$ and $\mathbf{\alpha}$, the received signal-to-noise ratio at user $k$ can be given by

$$\rho_k = \alpha_k p_k |\text{diag}(\mathbf{\beta}) h_k|^2.$$

(5)

where $\text{diag}(\mathbf{\beta})$ is a diagonal matrix for $\mathbf{\beta}$. Thus, the data rate of user $k$ is achieved by

$$R_k = \alpha_k \log_2 (1 + \rho_k).$$

(6)

Based on (3), (4), and (6), the joint antenna and user selection problem can be formulated as

$$\text{maximize } \sum_{k \in \mathcal{K}} w_k R_k$$

subject to

$$\sum_{k \in \mathcal{K}} \alpha_k \leq U,$$

$$\sum_{m \in \mathcal{M}} \beta_m \leq N,$$

$$\sum_{k \in \mathcal{K}} p_k \leq P_{TX},$$

$$\alpha_k \in \{0, 1\}, \forall k \in \mathcal{K},$$

$$\beta_m \in \{0, 1\}, \forall m \in \mathcal{M},$$

(7)
where \( w_k \) is the weight factor for user \( k \), \( P_{TX} \) is the total transmit power, \( U \) and \( N \) are the maximum numbers of users and antennas that can be selected, respectively. We assume that antennas are selected at most as many as the number of RF chains, and the power is allocated according to the water-filling scheme [3], under the limited total transmission power, \( P_{TX} \), of the BS.

### III. Joint antenna and user selection algorithm

We first denote the index sets of the selected users and antennas by \( \mathcal{K}_s \) and \( \mathcal{M}_s \), respectively. Now, we develop the JAUS algorithm to solve Problem (7) using the greedy algorithm. In detail, we first initialize \( \mathcal{K}_s = \mathcal{K} \) and \( \mathcal{M}_s = \mathcal{M} \). Accordingly, we set \( \alpha_k = 1, \forall k \) and \( \beta_m = 1, \forall m \). Then, as a first step, under the assumption that the antenna selection is fixed, we update the user selection. We first find user \( k^* \) who contributes the least in the weighted sum rate as

\[
k^* = \arg\min_{k \in \mathcal{K}} w_k R_k.
\]

Then, we delete \( k^* \) from \( \mathcal{K}_s \). Next, as a second step, under the assumption that the user selection is fixed, we update the antenna selection. To this end, we first find antenna \( m^* \) which provides the greatest weighted sum rate when it is excluded as

\[
m^* = \arg\max_{m \in \mathcal{M}_s} \tilde{R}(\tilde{m}),
\]

where

\[
\tilde{R}(\tilde{m}) = \sum_{k \in \mathcal{K}_s} w_k \log_2 \left( 1 + p_k \left| \text{diag}(\tilde{\beta}) \mathbf{h}_k \right|^2 \right),
\]

where \( \tilde{\beta} = (\tilde{\beta}_m)_{m \in \mathcal{M}} \) is given by \( \tilde{\beta}_m = \beta_m \) for all \( m \in \mathcal{M} \setminus \{\tilde{m}\} \) and \( \tilde{\beta}_{\tilde{m}} = 0 \). Then, we delete \( m^* \) from \( \mathcal{M}_s \). Until both \( |\mathcal{K}_s| = U \) and \( |\mathcal{M}_s| = N \), we iterate the first and second steps. Note that if either antenna selection or user selection has reached the desired number first, the deletion procedure is repeated only for the other one that has not reached.

### IV. Simulation results and conclusions

We consider a scenario where one BS equipped with 10 transmit antennas is serving 10 users, and 5 antennas and 5 users are selected. Each user’s weight is randomly given between 0 and 1. To show the effectiveness of JAUS, we consider an exhaustive-search-based algorithm, called ES, as a benchmark. Through Fig. 1, we show that the weighted sum rate performance of JAUS is very close to that of ES. The performance difference is only 0.2511 bps/Hz (1.28%) on average. This demonstrates that JAUS is a very effective algorithm to provide good performance.

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### REFERENCES

