LETTER

Sliding Window-Based Transmit Antenna Selection Technique for Large-Scale MU-MIMO Networks*

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SUMMARY In this letter, a novel *antenna selection* (AS) technique is proposed for the downlink of large-scale multi-user multiple input multiple output (MU-MIMO) networks, where a base station (BS) is equipped with large-scale antennas (N) and communicates simultaneously with $K(K \ll N)$ mobile stations (MSs). In the proposed scheme, the S antennas ($S \leq N$) are selected by utilizing the concept of a sliding window. It is shown that the sum-rate of our proposed scheme is comparable to that of the conventional scheme, while the proposed scheme can significantly reduce the complexity of the BS.
key words: large-scale MIMO, MU-MIMO, cellular network, antenna selection, pre-coding

1. Introduction

Recently, large-scale multi-user multiple input multiple output (MU-MIMO) has received much attention, as one of the techniques which can support the rapidly increasing mobile data traffic [1]. In the large-scale MU-MIMO networks, a base station (BS) is equipped with hundreds of antennas (or more) and can communicate simultaneously with multiple mobile stations (MSs). However, the large-scale antennas inevitably increase the hardware complexity of the BS in both digital and radio-frequency (RF)/analog domains. In order to reduce the hardware complexity, antenna selection (AS) techniques can be used, in which the number of baseband and RF chains is smaller than the number of available antenna elements. However, the solution to select the optimal subset of antennas for maximizing downlink sum-rate is not mathematically tractable, and thus several suboptimal AS techniques for the large-scale MU-MIMO networks have been proposed in [2], [3]. The beamforming vectors in these schemes are based on block-diagonalization (BD) or zero-forcing (ZF), to reduce the co-channel interference (CCI) among users. However, these schemes are also too complicated to be implemented in the BS operating on real-time basis, because the matrix inversion process required in the schemes generally causes the high computational complexity. Accordingly, we propose

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a practical AS scheme for the large-scale MU-MIMO networks.

2. System Model

Figure 1 depicts the block diagram and the channel model of a MU-MIMO system with large-scale antennas. A BS with N transmit antennas communicates simultaneously with K users with a single receive antenna. s_i indicates a scalar transmit signal for the user i. $\mathbf{v}_i$ is an $N \times 1$ BD-based beamforming vector [4]. $h_{ij}(1 \leq i \leq K, \ 1 \leq j \leq N)$ denotes the channel coefficient between the transmit antenna j in the BS and the user i. $\mathbf{H}_i^{\mathrm{u}}$ is an $1 \times N$ row vector denoting the channel coefficients between N transmit antennas and the user i, while $\mathbf{H}_j^{\mathrm{a}}$ is a $K \times 1$ column vector denoting the channel coefficients between the transmit antenna j and K users. All channel coefficients are assumed to be complex Gaussian random variables with zero-mean and unit-variance, and are also assumed to be independent and identically distributed (i.i.d.).

We consider a slow fading, where the channel coefficients are quasi-static during one transmission interval and are randomly variable for each transmission interval. Thus, none of channel coefficients include time indices in this paper. The signal-to-interference plus noise ratio (SINR) perceived at the user i is given by

$$\mathrm{SINR}_i = \frac{p_i \left\| \mathbf{H}_i^{\mathrm{u}} \mathbf{v}_i \right\|^2}{n_i + \sum_{k=1,k \neq i}^{K} p_k \left\| \mathbf{H}_i^{\mathrm{u}} \mathbf{v}_k \right\|^2} \tag{1}$$

where $p_k = \mathbb{E}\left[|s_k|^2\right]\left(\sum_{k=1}^{K} p_k = P\right)$, $\|\mathbf{v}_k\|^2 = 1$, and n_i denotes the additive white Gaussian noise (AWGN) with zero-mean and unit-variance.
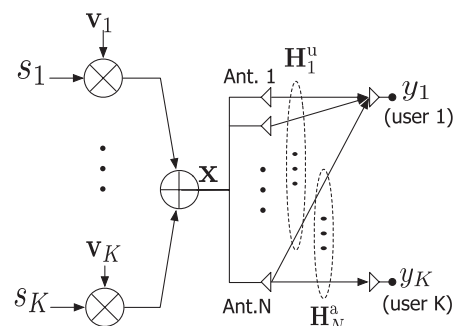

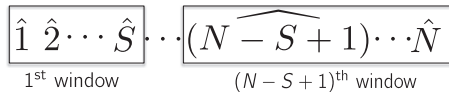**Fig. 1** Block diagram and channel model of MU-MIMO system with large-scale antennas.

Fig. 2 Proposed sliding window-based AS scheme.

3. Proposed Antenna Selection Scheme

In the proposed scheme, the BS ranks N transmit antennas in descending order according to the sum of the channel gains for all users, $\left\|\mathbf{H}_j^a\right\|^2$ ($j = 1 \cdots N$). The channel vectors ranked in descending order are indexed by $\hat{j}$ so that $\left\|\mathbf{H}_{\hat{1}}^a\right\|^2 \geq \cdots \geq \left\|\mathbf{H}_{\hat{N}}^a\right\|^2$. Then, we introduce a *window* which includes S consecutive antenna elements in the ranked set, as shown in Fig. 2. We can have $(N - S + 1)$ windows. The SINR of the user i for the w-th window can be obtained as

$$\text{SINR}_{i,w} = \frac{p_i \left\|\mathbf{H}_{i,w}^u \mathbf{v}_{i,w}\right\|^2}{n_i + \sum_{k=1,k\neq i}^{K} p_k \left\|\mathbf{H}_{i,w}^u \mathbf{v}_{k,w}\right\|^2} \quad (2)$$

where $\mathbf{H}_{i,w}^u$ denotes the channel coefficient vector between the user i and S antenna elements included the w-th window and $\mathbf{v}_{k,w}$ is the BD-based beamforming vector of the user k for the w-th window. The sum-rate for the w-th window, c_w, can be calculated as $c_w = \sum_{i=1}^{K} \log_2 (1 + \text{SINR}_{i,w})$. Finally, we can select the window with the highest sum-rate out of $(N - S + 1)$ windows.

4. Performance Evaluation

In this section, we evaluate the sum-rate of our proposed scheme and compare it with that of the conventional scheme in [2]. In addition, the computational complexities of the proposed and conventional schemes are analyzed in terms of the number of singular value decomposition (SVD) operations, which are required to calculate the BD-based beamforming vectors. Note that the SVD significantly increases the computation load of the BS. The conventional scheme requires $(N - S)$ stages to select S antennas because it removes one antenna minimizing the sum-rate in each stage. In the i-th stage, $K(N-i+1)$ operations are required. Finally, the computational complexity of the conventional scheme can be obtained by

$$M_{\text{conv}} = \sum_{i=1}^{N-S} K(N-i+1) = \frac{K(N-S)(N+S+1)}{2} \quad (3)$$
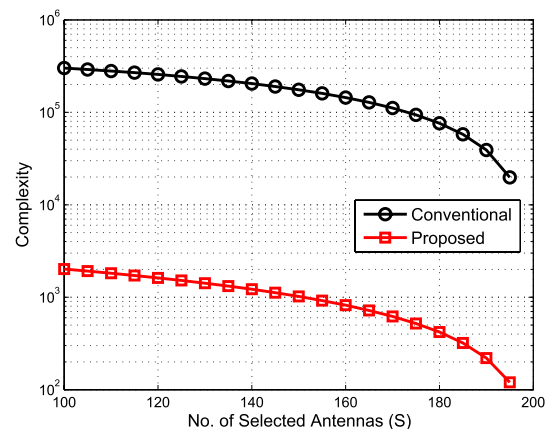
On the other hand, the proposed scheme can select a window with S antennas out of $(N - S + 1)$ windows. Thus, the complexity of the proposed scheme is given by

$$M_{\text{prop}} = \begin{cases} K(N - S + 1) & \text{if } S \neq N \\ 0 & \text{if } S = N \end{cases} \quad (4)$$

Figure 3 shows the average sum-rate and the computational complexity when $N = 200$ and $K = 20$. The total
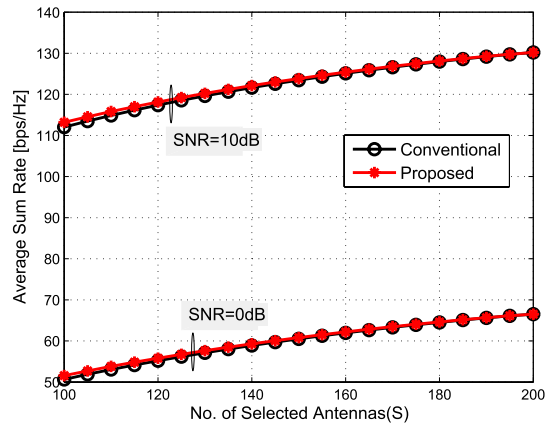
(a) Average sum-rate when SNR=0 and 10 dB

(b) Computational complexity

Fig. 3 Average sum-rate and computational complexity when $N = 200$ and $K = 20$.

transmit power available at the BS, P, can be interpreted as SNR because AWGN is assumed to have unit-variance. The sum-rates of both schemes increase as S increases due to the increasing array gain of the BS. Note that the sum-rate of the proposed scheme almost agrees with that of the conventional scheme and the performance gap is negligible as S increases. On the other hand, the computational complexity of the proposed scheme is significantly reduced compared with that of the conventional scheme regardless of S values.

References

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