Multi-Stream Opportunistic Network Decoupling With Virtual Full-Duplex Operation

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Abstract

For the $K \times N \times K$ channel with interfering relays and multiple-antenna configuration at sources and destinations, we introduce a new achievability scheme, termed multi-stream opportunistic network decoupling.

Ⅰ. Introduction

As a natural extension of the single-antenna configuration in [1], [2], we study the $K \times N \times K$ channel with interfering half-duplex relays, where the sources and destinations are equipped with M antennas and each source transmits $1 \leq S < M$ data streams. We propose a *multi-stream opportunistic network decoupling (MS-OND)* protocol such that the set of relays receives and forwards multiple data streams per source–destination (S–D) pair with virtual full-duplex operation. Our protocol intelligently integrates multi-source random beamforming (MS-RBF) for the first hop and opportunistic interference alignment (OIA) [3] for the second hop into the network decoupling network. As our main result, it is shown that in a high signal-to-noise ratio (SNR) regime, the MS-OND protocol achieves SK degrees of freedom (DoF) when the number of relays is higher than $\mathrm{SNR}^{3SK-S-1}$.

Ⅱ. System and Channel Models

The K sources and the corresponding destinations are equipped with $M > 1$ antennas and the relays are equipped with a single antenna. There is no direct communication path between each S–D pair, and thus each source transmits S data streams to its destination through multiple relays out of N relays. Each relay is assumed to fully decode, re-encode, and forward one data stream. Unlike the work in [1], the N relays are assumed to interfere with each other in our model. All the channels are assumed to be Rayleigh block-fading, having zero-mean and unit variance.

Ⅲ. Achievability Results

In our protocol, each source employs MS-RBF to confine the interference from other beams for the first hop, while each destination employs OIA to confine the interference leakage from other pairs' transmission for the second hop. In odd time slots, the K sources transmit to the relays in Π_1. Meanwhile, the relays in Π_2 forward the encoded data received from the sources in the previous even time slot to the destinations. In even time slots, the K sources transmit to the relays in Π_2. The relays in Π_1 forward the encoded data received from the sources in the previous odd time slot to the destinations. The destinations keep on receiving the symbols forwarded from either Π_1 or Π_2.

Opportunistic relay selection: 1) The first relay set selection: Based on the channel condition, relay $n \in \{1, \dots, N\}$ computes SK scheduling metrics, e.g., $L_{n,(k,s)}^{\Pi_1}$ for the stream s of the S–D pair k, consisting of other beam interference caused by MS-RBF for the first hop and interference leakage to destinations caused by OIA for the second hop. By using a distributed timer method, SK relays with small scheduling metrics are opportunistically selected as Π_1; 2) The second relay set selection: Relay $n \in \{1, \dots, N\}\backslash\Pi_1$ computes the sum of inter-relay interference from Π_1, denoted by $L_n^{(r)}$. The scheduling metric for Π_2 is computed as $L_{n,(k,s)}^{\Pi_2} = L_{n,(k,s)}^{\Pi_1} + L_n^{(r)}$, which captures the additional inter-relay interference. Then, SK relays are opportunistically selected as Π_2.

Theorem 1: Suppose that the MS-OND scheme with alternate relaying is used for the $K \times N \times K$ channel with interfering relays. Then, the total DoF is bounded by SK if N scales faster than $\mathrm{SNR}^{3SK-S-1}$.

ACKNOWLEDGMENT

References

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