OPTIMAL POWER ALLOCATION WITH AF AND SDF STRATEGIES IN DUAL-HOP COOPERATIVE MIMO NETWORKS

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Abstract Dual-hop cooperative Multiple-Input Multiple-Output (MIMO) network with multi-relay cooperative communication is introduced. Power allocation problem with Amplify-and-Forward (AF) and Selective Decode-and-Forward (SDF) strategies in multi-node scenario are formulated and solved respectively. Optimal power allocation schemes that maximize system capacity with AF strategy are presented. In addition, optimal power allocation methods that minimize asymptotic Symbol Error Rate (SER) with SDF cooperative protocol in multi-node scenario are also proposed. Furthermore, performance comparisons are provided in terms of system capacity and approximate SER. Numerical and simulation results confirm our theoretical analysis. It is revealed that, maximum system capacity could be obtained when powers are allocated optimally with AF protocol, while minimization of system’s SER could also be achieved with optimum power allocation in SDF strategy. In multi-node scenario, those optimal power allocation algorithms are superior to conventional equal power allocation schemes.

Key words Dual-hop cooperative Multiple-Input Multiple-Output (MIMO) network; Optimal power allocation; Amplify-and-Forward (AF); Selective Decode-and-Forward (SDF); System capacity; Asymptotic Symbol Error Rate (SER)

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I. Introduction

Cooperative communication based on relaying nodes have emerged as a promising approach to increase spectral and power efficiency, network coverage, and to reduce outage probability in the next generation wireless networks. User cooperation diversity was introduced by Sendonaris, et al. in Ref. [1]. Similar to multi-antenna transceivers, relays provide diversity by creating multiple replicas of signals. By properly coordinating different spatial distributed nodes, one can effectively synthesize a virtual antenna array that emulates the operation of a multi-antenna transceiver. Therefore, cooperative Multiple-Input Multiple-Output (MIMO) network that consists of multiple relay nodes equipped with single antenna could be established. Through work with other nodes cooperatively, the cooperative nodes can obtain spatial diversity gain, multiplexing gain, and coded gain simultaneously in the virtual MIMO system.

Since energy is constrained in many distributed networks such as Wireless Sensor Network (WSN), Dual/multiple hop networks, etc. Those could be modeled in cooperative MIMO network with some specific cooperative protocols between nodes. In cooperative MIMO networks, outage performance and power allocation are the basic index for system’s robustness, which are also unique characteristics that differ from the conventional single node multi-antenna MIMO system. Power allocation scheme should be carefully laid out in order to achieve energy efficiency in the system. Cui et al. analyzed energy-efficient of cooperative MIMO techniques in WSN, and took both energy savings
and delay reduction into account, which could be achieved simultaneously in cooperative MIMO network\cite{2}. Yang and Host-Madsen proposed two heuristic algorithms for routing and power allocation under Decode-and-Forward (DF) relay protocol, in order to obtain cooperation efficiency in asynchronous Gaussian multiple relay channels\cite{3}. Sadek, et al. investigated power-allocation problem in multiple nodes cooperation scenario with Selective Decode-and-Forward (SDF) strategy between cooperative nodes, and provided optimal power allocation solutions for some typical network topologies\cite{4}. Seddik, et al. studied optimal power allocation problem based on the derived outage probability analysis of the multi-node Amplify-and-Forward (AF) relay network\cite{5}. Zhao, et al. considered power allocation problem in the improved AF relay networks, they proposed optimal power allocation methods aiming at minimizing system outage probability as well as Symbol Error Rate (SER), they also provided optimal relay selection scheme with AF strategy, which could maintain full diversity order and have significantly better outage behavior and average throughput than the conventional all-participate scheme\cite{6}. Hong, et al. gave out a tutorial survey on various power allocation strategies for cooperative networks based on different cooperation strategies, optimization criteria, and Channel State Information (CSI) assumptions\cite{7}.

In this paper, we mainly focus on distributed resource-constrained wireless networks such as dual-hop multi-relay cooperative network\cite{8}, and propose our research on optimal power allocation schemes based on AF strategy and the minimum asymptotic SER criteria with SDF protocol, both of which are restricted to a fixed total power condition. System model is built in Section II, power allocation problems for two and multiple cooperative nodes with AF protocol are formulated and solved in Section III, while optimal power allocation for two and multiple cooperative node scenarios with SDF protocol are derived in Section IV. In Section V, numerical and simulation results are presented to demonstrate our proposed theoretical analysis. Furthermore, performance comparison of those two relay strategies in terms of system capacity and approximate SER performance are also provided in detail. Conclusions and future research prospects are drawn in Section VI.

II. Cooperative MIMO Network Model

Sketch diagram of dual-hop cooperative MIMO network model can be described in Fig. 1.

Consider $N$ cooperative node scenario including source $(S)$ and $(N-1)$ relays $(R)$ share their antennas to create a virtual open loop transmit diversity, and destination $(D)$ use Maximum Ratio Combination (MRC) criterion and Maximum Likelihood (ML) detection algorithm.

We make the following assumptions: the receiver could measure the realized fading coefficients in their received signals accurately. However, the transmitter does not obtain any knowledge about fading coefficients\cite{9}. That is, the receiver could obtain complete CSI and channel statistics.

(1) Channel coefficients $\{h_{ij}\}(i = s, r_1, \ldots, r_{N-1}; j = r_1, \ldots, r_{N-1}, d)$ are circularly symmetric complex Gaussian random variables with zero-mean, variance $\sigma^2_{ij}$, which also conform to the central chi-square distribution with 2 degrees of freedom\cite{10}, and $\{n_{ij}\}(i = s, r_1, \ldots, r_{N-1}; j = r_1, \ldots, r_{N-1}, d)$ denote complex Additive White Gaussian Noise (AWGN) in the corresponding channels, with variance $N_0$, i.e. $n_{ij} \sim \mathcal{CN}(0, N_0)$. For simplicity, we assume that all $N_{ij}$ equals to $N_0$;

(2) Assuming that all the time slots have unit duration, because the transmission scheme for all terminals is a block strategy, and each information block $s(k)$ is composed of $M$ symbols and it is linearly encoded;

(3) Information symbols are independent identical distribution (i.i.d) with BPSK/QPSK/