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“Performance Analyses for Large-Scale Antennas Equipped
Two-Way AF Relaying and Heterogeneous Networks”

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Abstract

In this dissertation, performance analyses for large-scale antennas equipped two-way amplify-and-forward (AF) relaying and heterogeneous network (HetNet) are carried out. Energy-efficiency oriented design becomes more important for the next generation of wireless systems, which motivates us to study the strong candidates, such as massive multiple-input multiple-output (MIMO) combined with cooperative relaying and HetNet. Based on the achievable rate analyses for both massive MIMO two-way AF relaying, effective power allocation schemes are presented to further improve system performance. Focusing on the MIMO downlinks in the HetNet, mean square error (MSE) based precoding schemes are designed and employed by the macro base station (BS) and the small cell (SC) nodes. Considering a HetNet where both macro BS and SC nodes are equipped with large-scale antenna arrays, the capacity lower bounds are derived, followed by the proposed user scheduling algorithms.

The work on multi-pair two-way AF relaying with linear processing considers a system where multiple sources exchange information via a relay equipped with massive antennas. Given that channel estimation is non-ideal, and that the relay employs either maximum-ratio combining/maximum-ratio transmission (MRC/MRT) or zero-forcing reception/zero-forcing transmission (ZFR/ZFT) beamforming, we derive two corresponding closed-form lower bound expressions for the ergodic achievable rate of each pair sources. The closed-form expressions enable us to design an optimal power allocation (OPA) scheme that maximizes the sum spectral efficiency under certain practical constraints. As the antenna array size tends to infinity and the signal to noise ratios become very large, asymptotically optimal power allocation schemes in simple closed-form are derived. The capacity lower bounds are verified to be accurate predictors of the system performance by simulations, and the proposed OPA outperforms equal power allocation (EPA). It is also found that in the asymptotic regime, when MRC/MRT is used at the relay and the link end-to-end large-scale fading factors among all pairs are equal, the optimal power allocated to a user is inverse to the large-scale fading factor of the channel from the user to the relay, while OPA approaches EPA when ZFR/ZFT is adopted.

The work on the MSE-based precoding design for MIMO downlinks investigates a HetNet system consisting of a macro tier overlaid with a second tier of SCs. First, a new sum-MSE of all users based minimization problem is proposed aiming to design a set of macro cell (MC)
and SC transmit precoding matrices or vectors. To solve it, two different algorithms are presented. One is via a relaxed-constraints based alternating optimization (RAO) realized by efficient alternating optimization and relaxing non-convex constraints to convex ones. The other is via an unconstrained alternating optimization with normalization (UAON) implemented by introducing the constraints into the iterations with the normalization operation. Second, a separate MSE minimization based two-level precoder is proposed by considering the signal and interference terms corresponding to the macro tier and the SCs separately. Furthermore, robust precoders are designed correspondingly with estimated imperfect channel. Simulation results show that the sum-MSE based RAO algorithm provides the best MSE performance among the proposed schemes under a number of system configurations. When the number of antennas at the macro-BS is sufficiently large relative to the number of MUEs, the MSE of the separate MSE-based precoding is found to approach those of RAO and UAON. Together, this thesis provides a suite of three new precoding techniques that is expected to meet the need in a broad range of HetNet environments with balance between performance and complexity.

The work on a large-scale HetNet studies the performance for MIMO downlink systems where both macro BS and SC nodes are equipped with large-scale antenna arrays. Suppose that the large-scale antenna arrays at both macro BS and SC nodes employ MRT or ZFT precoding, and transmit data streams to the served users simultaneously. A new pilot reuse pattern among small cells is proposed for channel estimation. Taking into account imperfect CSI, lower capacity bounds for MRT and ZFT are derived, respectively, in closed-form expressions involving only statistical CSI. Then asymptotic analyses for massive arrays are presented, from which we obtain the optimal antenna number ratio between BS and SCs under specific power scaling laws. Subsequently, two user scheduling algorithms, that is, greedy scheduling algorithm and asymptotical scheduling algorithm (ASA), are proposed based on the derived capacity lower bounds and asymptotic analyses, respectively. ASA is demonstrated to be a near optimal user scheduling scheme in the asymptotic regime and has low complexity. Finally, the derived closed-form achievable rate expressions are verified to be accurate predictors of the system performance by Monte-Carlo simulations. Numerical results demonstrate the effectiveness of the asymptotic analysis and the proposed user scheduling schemes.