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Editorial

Distributed Space-Time Systems

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Space-time or multiple-input multiple-output (MIMO) wireless communication, which exploits multiple antennas at the transmitter and the receiver nodes, has been a rich and exciting research area. This technology has now matured and is now seeing widespread applications such as in WLANs (IEEE 802.11n) and WMANs/mobile internet (IEEE 802.16e, 3GPP LTE, and UMB). MIMO offers significantly higher throughputs and increased link reliability. Millions of MIMO-enabled wireless devices are now being shipped annually and this number can reach hundreds of millions in a few years.

For a variety of reasons including size and power limitations, wireless nodes (both user terminals and base stations) can only support a limited number of antennas. Therefore, the ability to use the antennas of other nodes in the vicinity can be very attractive. The large geographic antenna separation implied in using distributed nodes can often also significantly improve spatial multiplexing performance (due to better channel conditioning) and improve diversity performance (due to stronger fade decorrelation). Cooperative or distributed space-time techniques seek to realize the MIMO leverage by exploiting antennas spread across nodes. Cooperation may be used in transmission or in reception, or at both ends. Since such cooperating nodes need to communicate wirelessly (unlike in simple MIMO), the problem becomes significantly more complex and intellectually richer.

Cooperative or distributed space-time techniques can be used in relay networks where multiple relay nodes (and optionally, source or sink nodes) can form a virtual antenna array for MIMO operation. Similar opportunities can also arise in sensor networks. Another rich area is cellular systems where multiple user terminals can cooperate for up or down link MIMO operation. Likewise, multiple base stations can also cooperate. In many of these applications, the geographic separation of user terminals or base stations is the key advantage being exploited. In other applications, the increase in the number of effective antennas can boost the MIMO advantage. Cooperative MIMO is already supported in WIMAX 802.16e standard and has been field tested with marked success.

Distributed or cooperative space-time methods raise a number of important questions: what is the network capacity? How does this capacity scale with different numbers of nodes and antennas? What are good space-time codes for distributed antennas? What are the channel models for this problem? What are good strategies for channel estimation? How do we do precoding? Can we use cross-layer information for scheduling? Does distributed space-time coding (DSTC) work well with OFDMA as it does with standard MIMO systems? How can we develop cooperative communication schemes to suit the low power needs of sensor networks?

Cooperative space-time communications research has begun to attract significant attention. Many opportunities now exist to include this technology in the next generation broadband wireless systems. This special issue aims at capturing the state of the art in this emerging area. We received a total of fifteen submissions, and after a rigorous review process, a total of eleven papers have been selected. They cover topics ranging from systems design, DSTC, applications to sensor networks, and routing. We hope this collection will be a significant contribution to the growth of this important field.

The first four papers focus on system design and optimization. The paper "Distributed space-time block coded transmission with imperfect channel estimation: achievable rate and power allocation" by L. Musavian and S. Aissa investigates the effects of channel estimation error at the receiver on the achievable rate of distributed space-time block coding. The authors present efficient bounds on the mutual information of distributed space-time block codes (DSTBCs) when the channel gains and channel estimation error variances pertaining to different transmitter/receiver links are unequal. Furthermore, they propose an optimum power transmission strategy to achieve the outage capacity lower bound of DSTBCs under arbitrary number of transmit and receive antennas and provide closed-form expressions for this capacity metric. The next paper "Cooperative multibeamforming in ad hoc networks" by C. Li and X. Wang considers a scenario with multiple source nodes cooperatively forming multiple data-carrying beams toward multiple destination nodes. An iterative transmit power allocation algorithm is proposed under fixed beamformers subject to the maximal transmit power constraint as well as the minimal receive signal-to-interference-plus-noise ratio and receive power constraints. In addition, a joint optimization algorithm is developed to iteratively optimize the powers and the beamformers. Further, since channel state information (CSI) is required by the sources to perform this optimization, a cooperative scheme is proposed to implement a simple CSI estimation and feedback mechanism. The next paper "NAF, OAF, or noncooperation: which protocol to choose?" by A. Saadani and O. Traore addresses the problem of choosing between communicating without cooperation or by using one of the two well-known amplify and forward (AF) cooperative protocols, orthogonal or nonorthogonal. This problem is translated to a power sharing problem on the cooperation frame between source and relays, aiming to maximize the short-term channel capacity. The obtained solution shows that the cooperative protocol choice depends only on the available power at the relays. Furthermore, an efficient power allocation scheme is proposed, where relay selection improves the outage probability compared to the selective orthogonal and nonorthogonal protocols, with a significant capacity gain. The paper "How to solve the problem of bad performance of cooperative protocols at low SNR?" by C. Hucher et al. proposes some new adaptive AF and decode and forward (DF) protocols using a selection criterion which is a function of the instantaneous capacities of all possible transmission schemes (with or without cooperation). Results show that the adaptive cooperation protocols compensate for the performance degradation of cooperation protocols at low signal-to-noise ratio (SNR).

The next three papers are on coding for distributed systems. The paper "Censored distributed space-time coding for wireless sensor networks" by S. Yiu and R. Schober deals with sensors using a common noncoherent DSTBC to forward their local decisions to a fusion center (FC) which makes the final decision. To overcome the problem of error propagation, censored DSTC, where only reliable decisions are forwarded to the FC, is proposed. Based on the performance analysis of a low complexity suboptimal decision rule, a gradient algorithm for optimization of the local decision/censoring threshold is derived. The next paper "Code design for multihop wireless relay networks" by F. Oggier and B. Hassibi considers an elaborate version of AF, where the relay nodes multiply their received signal with a unitary matrix, such that the receiver senses a space-time code. A full diversity condition is obtained for such codes using the rank criterion. A systematic way of constructing such codebooks with full diversity is also presented. The paper "Link-adaptive distributed coding for multisource cooperation" by A. Cano et al. presents a new protocol capable of achieving a diversity order up to the number of cooperating users and large coding gains. The diversity order is expressed as a function of the rank properties of the distributed coding strategy employed: a result analogous to the diversity properties of colocated multiantenna systems. The particular case of distributed complex field coding emerges as an attractive choice because of its high rate, full spatial diversity, and relaxed synchronization requirements.

The next two papers deal with performance analysis. The paper "Diversity analysis of distributed space-time codes in relay networks with multiple transmit/receive antennas" by Y. Jing and B. Hassibi extends the concept of DSTC to wireless relay networks with multiple-antenna nodes and analyzes the pairwise error probability at high SNR. The paper "On the duality between MIMO systems with distributed antennas and MIMO systems with colocated antennas" by J. Mietzner and P. A. Hoeher investigates the loss in the capacity and error performance in wireless systems with individual transmit or receive antennas spatially distributed on a large scale. It is shown that owing to a strong duality between MIMO systems with colocated antennas (and spatially correlated links) and MIMO systems with distributed antennas (and unequal average link SNRs), the two systems can be treated in a single, unifying framework.

The final two papers are on routing and transmission. The paper "Power-efficient relay-selection in cooperative networks using decentralized distributed space-time block coding" by L. Zhang and L. J. Cimini, Jr. presents a power-efficient relay selection strategy for decentralized distributed space-time block coding in a selective DF cooperative network, and by applying this idea to each relaying hop in a multihop network, a power-efficient hop-by-hop routing strategy is proposed. The paper "Low complexity distributed multibase transmission and scheduling" by H. Skjevling et al. addresses the problem of base station coordination and cooperation in multicell wireless networks. A distributed approach to downlink multibase beamforming, which allows for the multiplexing of multiple user terminals randomly located in a network with multiple base stations, is presented. It is shown that this scheme yields significant gains, when compared to schemes that do not allow cooperation between cells, without the extensive signaling overhead required in previously known multicell MIMO processing.

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