Guest Editorial: Virtual MIMO

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MULTIPLE antenna (also known as MIMO: multiple input and multiple output) techniques have been widely accepted as a promising scheme to improve the spectral efficiency of mobile communication systems. MIMO becomes increasingly essential as the demand for broadband wireless data transmission increases. It has been supported by various international standards such as 3GPP LTE (3rd Generation Partnership Project Long Term Evolution), LTE-A (LTE-Advanced), and IEEE 802.16e/m. However, since the size of a mobile transmitter or receiver is very small, implementing conventional MIMO antenna technologies becomes challenging. Fortunately, spatial diversity can be obtained through cooperation among mobile terminals, and multiple single-antenna mobile terminals can cooperate to form a virtual MIMO (VMIMO) system through relaying. In the VMIMO system, antennas at the terminals are virtually joined together to form a so-called virtual antenna array.

The impetus for this special issue has been spurred by the strong desire to understand VMIMO, which is a rapidly growing research area. VMIMO is believed to be a key technology for beyond 4th generation mobile communications technologies (B4G). It enables one to make use of all the neighboring terminals and amortize the cost of multiple antennas; hence, a large MIMO channel can be created to increase capacity significantly as well as improve error rate performance. Nevertheless, fundamental roadblocks need to be addressed in order to take full advantage of VMIMO.

First of all, due to the limited processing capability of base stations, only a small number of mobile terminals can be supported to form a VMIMO system in a cellular network. So it becomes a huge challenge to optimally select mobile terminals to form a useful VMIMO system. Secondly, although mobile terminals can be grouped together to form a VMIMO system, information exchange among the mobile terminals is needed and should be minimized. Moreover, channel state information (CSI) of each mobile terminal is required at the BSs to carry out precoding, which results in a significant pilot and signaling overhead, especially in the FDD (Frequency Division Duplexing) mode. On one hand, it is necessary to study the impact of the overhead on the overall performance of the system. On the other hand, innovative schemes are required for mobile terminals to feed back sufficient information via limited signaling. Last but not least, in wireless ad-hoc networks and future cellular systems, collaboration among mobile terminals could be introduced. It is important to evaluate the trade-off of using mobile terminal collaboration in VMIMO.

Therefore, VMIMO is a pressing research topic that has a very wide range of applications in both cellular and wireless ad hoc networks. It is timely and important to develop enabling techniques for future VMIMO systems. The goal of this issue is to bring together the most updated research contributions that describe original and unpublished work addressing VMIMO.

The Call for Papers attracted 46 submissions worldwide. After the review process, 13 papers have been selected for publication. The 13 accepted papers are divided into four parts. The first part has two papers, addressing physical layer techniques critical to VMIMO, such as uplink multicell joint processing and direction of arrival (DOA) estimation.

The paper "Uplink Multicell Processing with Limited Backhaul via Per-Base-Station Successive Interference Cancellation" by Lei Zhou and Wei Yu studies the uplink multicell joint processing scenario where base stations (BSs) are connected to a central processor via limited backhaul. It is proposed that each BS should perform Wyner-Ziv compress-and-forward relaying and that successive interference cancellation (SIC) be carried out at the central processor. The scheme is shown to achieve the sum capacity of a special Wyner cellular model to within a constant gap as long as the capacities of the limited backhaul scale logarithmically with the signal-to-interference-and-noise ratio (SINRs) at the BSs.

The paper "A Novel AWSF Algorithm for DOA Estimation in Virtual MIMO Systems" by Haihua Chen, Zhengang Pan, Lin Tian, Jinglin Shi, Guanghua Yang and Masakiyo Suzuki addresses DOA estimation in VMIMO with smart antennas. An automatic weighted subspace fitting (AWSF) algorithm is proposed to detect the number of independent signals and provide accurate DOA estimation. Moreover, the optimal number of users in VMIMO is also investigated.

The second part comprises three papers, dealing with user grouping techniques and channel quantization.

The paper "Lightweight User Grouping with Flexible Degrees of Freedom in Virtual MIMO" by Ouldooz Baghban Karimi, Milad Amir Toutounchian, Jiangchuan Liu and Chonggang Wang proposes a two-step user grouping scheme

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for a large number of users. To achieve high throughput and fairness with reasonable computation, time slots are firstly assigned to groups of users ensuring proportional. Then the uplink grouping within each group is carried out using the instantaneous signal to noise ratio (SNR) to lighten the computation.

The paper "Joint User Grouping and Linear Virtual Beamforming: Complexity, Algorithms and Approximation Bounds" by Mingyi Hong, Zi Xu, Meisam Razaviyayn and Zhi-Quan Luo deals with the problem of optimally grouping users while designing the joint linear transmission scheme at the same time. Semi-definite relaxation (SDR) algorithms are proposed to obtain approximate solutions for the joint optimization problem. It is shown that the SDR algorithms have a guaranteed approximation performance in terms of the gap to global optimality, regardless of channel realizations.

The paper "Two-Stage Channel Quantization for Scheduling and Beamforming in Network MIMO Systems: Feedback Design and Scaling Laws" by Behrouz Khoshnevis, Wei Yu, and Yves Lostanlen proposes a two-stage channel quantization and feedback scheme for the downlink of limited feedback VMIMO systems. In the 1^{st} stage, the base stations schedule the best user for each antenna in each resource block according to the reports from users. In the 2^{nd} stage, the scheduled users are polled to feedback their quantized channel vectors. Given a total feedback budget of B bits, optimized bit allocations are studied, which provide a system sum rate that scales double-logarithmically with B.

The third part contains five papers addressing radio resource management techniques developed for VMIMO, such as resource allocation, scheduling and relay selection.

The paper "QoS-Aware Power Allocations for Maximizing Effective Capacity over Virtual-MIMO Wireless Networks" by Wenchi Cheng, Xi Zhang and Hailin Zhang addresses the power allocation problems of the existing and newly added users for collaborative and non-collaborative VMIMO systems where delay-aware QoS in the form of effective capacity is considered. In the optimization, the goal is to maximize the effective capacity of newly added users while guaranteeing the effective capacity of existing users. The optimization problems are formulated into strictly convex optimization problems.

The paper "Radio Resource Allocation in Multiuser Distributed Antenna Systems" by Huiling Zhu and Jiangzhou Wang investigates and presents an optimal resource allocation scheme for downlink multiuser distributed antenna systems (DASs). The effect of the number of remote antenna units (RAUs) used to communicate with each user is investigated extensively. Power, subcarrier and bit allocations are studied for DASs employing orthogonal frequency division multiple access (OFDMA) DAS. Moreover, a chunk-based allocation technique is adopted to reduce the complexity in the downlink resource allocation for multiple users.

The paper "Virtual MIMO in Multi-Cell Distributed Antenna Systems: Coordinated Transmissions with Large-Scale CSIT" by Wei Feng, Yanmin Wang, Ning Ge, Jianhua Lu and Junshan Zhang explores the performance gain achieved by coordinated transmissions for VMIMO with large-scale channel state information at the transmitter (CSIT), which is less demanding than that of full CSIT. Aiming at maximizing the ergodic sum rate, an iterative algorithm is proposed for the joint optimization of input covariances for all users in the coordinated transmission and its convergence is established.

The paper "Bidirectional Cellular Relay Network with Distributed Relaying" by Fanggang Wang, Xiaojun Yuan, Soung Chang Liew and Yonghui Li considers bidirectional communication between a base station and multiple independent users that is aided by distributed relays. A unified framework is proposed to design the transceivers in the system and low-complexity iterative algorithms are devised. Simulations indicate that the design outperforms conventional four-stage schemes in terms of throughput.

The paper "Optimal Relay Selection for Physical-Layer Security in Cooperative Wireless Networks" by Yulong Zou, Xianbin Wang and Weiming Shen explores physical-layer security in cooperative wireless networks with multiple relays. Both amplify-and-forward (AF) and decode-and-forward (DF) based optimal relay selection schemes are proposed to improve wireless security against eavesdropping attacks. For the proposed schemes, closed-form intercept probability expressions are derived in the presence of an eavesdropping attack and their diversity orders are shown to be equal to the number of relays.

The final part has three papers, dealing with system performance of VMIMO such as spectral efficiency, energy efficiency and degrees of freedom (DoF).

The paper "Spectral Efficiency of Distributed MIMO Systems" by Dongming Wang, Jiangzhou Wang, Xiaohu You, Yan Wang, Ming Chen and Xiaoyun Hou investigates the spectral efficiency of distributed MIMO systems and compares it with that of conventional co-located MIMO systems, when communication signals are assumed to experience propagation pathloss, shadowing and multipath fading. The authors present an analytical framework, based on which a range of closed-formulas for the spectral efficiency of distributed/co-located MIMO systems are derived.

The paper "Energy-Spectral Efficiency Trade-Off in Virtual MIMO Cellular Systems" by Xuemin Hong, Yu Jie, Cheng-Xiang Wang, Jianghong Shi and Xiaohu Ge investigates how two conflicting metrics, namely spectral efficiency (SE) and energy efficiency (EE), scale up in large cellular VMIMO networks. Using a system-level stochastic network model based on DF and broadcast-based protocols, and the new metric dubbed the EE-SE trade-off, a performance evaluation framework is presented. It is shown that the EE-SE trade-off of the VMIMO system is susceptible to many factors including protocol design and scenario characteristics. Closed-form approximations of the EE-SE trade-off are derived. A heuristic power and time allocation algorithm is also proposed to solve the EE-SE optimization problem.

The paper "Diophantine Approach to Blind Interference Alignment of Homogeneous K-User 2x1 MISO Broadcast Channels" by Qing F. Zhou, Q. T. Zhang, and Francis C. M. Lau casts the feasibility problem in the framework of finding solutions for a system of linear Diophantine equations and then derives a necessary and sufficient condition for the feasibility.

The Guest Editors would like to thank all the authors for their submissions, and the reviewers for their high-quality reviews and helpful suggestions to the authors on improving the content and presentation of the papers. We would also like to extend our sincere thanks to Professor Laurence Milstein, the Mentor, and Dr. Martha Steenstrup, the current Editor-in-Chief of IEEE JSAC, for their support and help in bringing forward this special issue.

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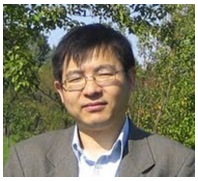

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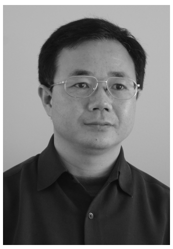

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