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Editorial

Theory and Applications in Multiuser/Multiterminal Communications

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Multiuser or multiterminal communication broadly covers many vibrant research areas in communications, signal processing, and networking. For some, it refers to the characterization of the fundamental limits of communication among multiple nodes, which, even for simple abstract models, has proved very challenging. Others may consider it more interesting to investigate efficient designs and resource management in practical systems and networks. Yet more and more researchers are turning to problems emerging from increasingly larger and more complex networks, where distributed processing and cross-layer approaches are favored. Whatever the circumstances, it is the rich nature of interactions among users/terminals that makes the study more intriguing from both the theoretical and practical point of view, and admittedly more demanding. This special issue is intended to provide a timely update of some recent progress in this exciting field.

The first four papers fall in the category of multiuser information theory. In the paper "Multiaccess channels with state known to some encoders and independent messages" by S. Kotagiri and J. N. Laneman, a state-dependent MAC channel with noiseless noncausal channel state knowledge at a strict subset of encoders is considered. Such models may find applications in information embedding and cognitive radios. Inner bounds are derived for the discrete memoryless and additive white Gaussian channels and compared to some outer bounds. In some special cases (binary channel with maximum entropy channel state, and Gaussian channel with large variance channel state subject to certain conditions on the signal powers), capacity regions are obtained. Some observations on the coding strategies are made that are different from the case of all encoders being informed. The second paper, "Slotted Gaussian multiple access channel: stable region and role of side information" by V. Aggarwal and A. Sabharwal, studies the relationship between the Shannon capacity and queuing stability of the multiple access channel. They explore the stable throughput regions in various scenarios regarding available knowledge about source arrival and queue state at the transmitters and receiver, for both large block length (in the conventional Shannon sense) and large SNR (but with finite block length) cases. It is revealed that the knowledge of mean arrival rates about all sources and one-bit side information about each queue state at all nodes is sufficient to guarantee that the stable throughput region coincides with the Shannon capacity region. Lack of such knowledge at the transmitters leads to a considerable decrease in the throughput region, which nonetheless can be recovered through feedback from the receiver. This work takes a nice step towards quantifying the importance of side information to the performance of real communication networks. The third paper by L. Ghabeli and M. R. Aref, "A new achievable rate and the capacity of some classes of multilevel relay network" switches the attention to another interesting topic in this area, capacity of relay channels. This work presents a new achievable rate for the multilevel relay network based on some partial decoding schemes, and shows that it is capacity-achieving for semi-deterministic and orthogonal relay networks. In the paper

"Cores of cooperative games in information theory," M. Madiman makes an interesting contribution to multiuser information theory by giving rate or capacity regions a game-theoretic interpretation. While most results presented, ranging from distributed source coding and multiple access channels to distributed inference and composite hypothesis testing, may already be known, the reader may find such an approach and the insights thus obtained inspiring.

Base station cooperation or multicell processing has drawn significant research interest recently due to its great potential to deal with cochannel interference, which is usually the limiting factor in modern cellular systems. The paper "Multi-cell downlink capacity with coordinated processing," coauthored by S. Jing et al., investigates a rich set of designs for cooperative downlink transmissions, considering Wyner-type network models with single-class and double-class users (cell-edge versus cell-interior), respectively. A singularity problem is identified for linear precoders, and some remedies are provided. This work contains a detailed discussion of tradeoffs between performance improvement, requirement of channel knowledge, and processing complexity. The following two papers study multicell processing on the uplink channel. The paper "Distributed iterative multiuser detection through base station cooperation" by S. Khattak et al. addresses cooperative detection in an uplink scenario through distributed and iterative processing among base stations. One interesting feature of this work is its emphasis on reducing backhaul traffic and thus cooperation cost. Two approaches are taken towards this objective: only information about strong signals is exchanged, and suitable quantization schemes are applied. In the same uplink framework with cooperative base stations, the paper "Throughput of cellular systems with conferencing mobiles and cooperative base stations," coauthored by O. Simeone et al., further considers cooperation among mobile stations through finite-capacity and localized channels orthogonal to the main traffic channel. Two scenarios are considered within the linear Wyner model: intercell conferencing with intracell TDMA, and intracell conferencing only. For both scenarios, a transmission scheme based on rate splitting and cooperative transmission is proposed, and proved to be optimal in the regime of high conferencing capacity. Some open problems in this exciting area are also presented.

Efficient transceiver design constitutes a perennial research topic in the communications and signal processing society, and recent years have seen increased interest on multiantenna and multiuser settings. The paper "Guaranteed performance region in fading orthogonal space-time coded broadcast channels," coauthored by E. Jorswieck et al., is concerned with a MIMO fading broadcast channel where the transmitter applies orthogonal space-time block coding, and mobiles only feed back the channel norm to the base station. This work studies the region of mean-square errors (MSE) achievable at each receiver, which directly maps to SINR in most cases and is also an appropriate performance metric in its own right in certain settings. Based on this system metric, the impact of various system and channel parameters is examined, and a range of designs with different levels of channel state information and precoding strategies are compared. The paper "Transmitter layering for multiuser MIMO systems," by C. Schlegel et al., proposes a transmitter structure for single- as well as multiuser MIMO systems, which admits a low-complexity iterative detection procedure and yet achieves outstanding performance over diverse operating scenarios. The work of M. Krause et al., "An unified approach to list-based multiuser detection in overloaded receivers," focuses on multiuser receiver design in the overloaded case, which is of special interest in practical wireless systems. The authors present an unified framework for list-based iterative multiuser detection, striking a good balance between performance and complexity as compared to the traditional linear and joint maximum likelihood detectors at the two extremes.

The last two papers of this special issue extend the study to the higher layers on the protocol stack. As one of the many attempts recently to improve the throughput scalability in wireless ad hoc networks, the paper "Scalable ad hoc networks for arbitrary-cast: practical broadcast-relay transmission strategy leveraging physical-layer network coding" by C. Chen et al. exploits recent advances in network coding to address the limiting factor in this scenario, mutual interference due to concurrent transmissions. The study ranges from the physical up to the network layer, and treats rather general network topologies and traffic patterns. Various issues concerning the implementation of physical-layer network coding in practice are coped with. Finally, the paper "An efficient scheduling scheme to enhance the capacity of VoIP services in evolved UTRA uplink" by Y.-S. Kim proposes an improved scheduling algorithm for 3GPP that allows adaptive resource sharing between users, and can improve the performance of real-time services such as voice over IP.

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