MULTICELL COOPERATION

EKRAM HOSSAIN ZANDER (ZHONGDING) LEI

It is well recognized that the conventional cellular networks can no longer meet the user performance requirements in terms of throughput and coverage, which is due to the significant increase in the number of mobile users along with their traffic demands and the limited spectrum resource. This has stimulated the search for new approaches to alleviate this problem. Recently, cooperative communications at both the base station (BS) and mobile station (MS) levels has been proposed as a key technology to address this problem. Multicell cooperation is a new and emerging communication paradigm promising significant improvement in system capacity by mitigating intercell interference. It has been shown that, with the aid of multicell cooperation, a significant improvement of cellular system performance can be achieved, and the increase in throughput can be as large as an order of magnitude. Although the advantages of multicell cooperation have been demonstrated, many problems related to the research and development of practical and effective schemes for multicell cooperation exist. They have attracted considerable research attention in both academia and industry. This special issue of *IEEE Wireless Communications* puts together some recent results in the area of multicell cooperation for the next generation cellular wireless networks. It includes 11 articles, a brief account for each of which is provided below.

In the first article, "Future Steps of LTE-A: Evolution toward Integration of Local Area and Wide Area" by Kishiyama *et al.*, the authors focus on the importance of integrating local area and wide area in the future of LTE-Advanced (LTE-A) networks. The concept of a macro-assisted small cell is introduced for this integration in a frequency-separated deployment scenario. The authors also identify some potential technologies such as 3D MIMO/beamforming, receiver interference cancelation, and dynamic TDD, to enhance the spectrum efficiency of higher frequency bands.

In the next article, "Multicell Cooperation: Evolution of Cooperation and Cooperation in Large-Scale Cellular Networks" by Burchardt and Hass, the authors emphasize the importance of multicell cooperation in large-scale cellular networks. They present different techniques to perform such cooperation including user-based cooperation, system-wide optimization, and large-scale multiple-antenna systems. A recently proposed Pareto-based optimal OFDMA transmission scheduling method is introduced as an example in which both the concept of user-based cooperation and multiple-antenna systems are combined.

In the third article, "Multicell Cooperation for LTE-Advanced Heterogeneous Networks Scenarios," Soret *et al.* present two scenarios in which simple multicell cooperation is used for LTE-A heterogeneous networks. In the co-channel deployment scenario, the cross-tier interference is mitigated by using enhanced intercell interference coordination, which also ensures that the number of offloaded users is sufficient. In the other scenario, different carriers are assigned to the deployed macro and small cells while using collaborative intersite carrier aggregation to fully utilize the fragmented spectrum. In addition, the authors point out the importance of explicit terminal support as well as distributed coordination among the base stations for both the scenarios to perform optimally.

Interference alignment is emerging as a key transmission strategy to facilitate interference cancellation for communication in interference channels. In the article "The Practical Challenges of Interference Alignment," El Ayach, Peters, and Heath, Jr. give an overview on interference alignment and its challenges. These challenges include the system performance in realistic propagation environments, how to obtain the channel state information at the transmitter, and the practicality of interference alignment in large-scale wireless networks.

Cooperation among multiple transmit antennas has been shown to be an effective interference management tool for communications over interference channels. In the fifth article, "CSI Sharing Strategies in Wireless Networks," de Karet and Gesbert emphasize the cost of exchanging the channel state information (CSI) among the collaborating transmitters. They present two scenarios, the interference alignment and network MIMO scenarios, in which the need for full CSI sharing could be compromised to get more practical and scalable cooperation while maintaining the same performance. To reduce the amount of CSI sharing in the interference alignment scenario, the authors use specific antenna configurations, whereas in the network MIMO scenario they exploit the decay property of signal power. Then they present the challenges of precoding design in the network MIMO channels.

The sixth article, "Multicell Cooperative Systems with Multiple Receive Antennas" by Hwang *et al.*, emphasizes the importance of using multiple receive antennas in a multicell cooperative system. The authors review recent developments in multicell advanced receiver-processing algorithms to mitigate the interference. Next, they outline the main limitations to achieve cooperation in multicell cooperative systems and provide an overview of recent research efforts to overcome such limitations using multiple receive antennas.

Coordinated multipoint transmission/reception (CoMP), in which base stations cooperate to mitigate or eliminate intercell interference, has been specified as one of the enabling techniques for LTE-Advanced networks (in Release 11). In the article "Interference Management through CoMP in 3GPP LTE-Advanced Networks," Sun *et al.* discuss the performance benefits of CoMP in both downlink and uplink scenarios defined in the 3GPP LTE-Advanced standard. In downlink CoMP, they focus on four different techniques: transmission scheme (which includes dynamic point selection, dynamic point blanking, joint transmission, and coordinated scheduling/beamforming), CSI report, interference management, and reference signal design. Next, the authors explain briefly why it is easier to support CoMP in the uplink than in the downlink. Then the efficiency of CoMP is evaluated for four different scenarios defined in the standard, and several unsolved problems as well as their possible solutions are also outlined.

In the next article, "How Do We Design CoMP to Achieve Its Promised Potential?," Yang *et al.* first discuss the features of CoMP systems that are different from those of single-cell MIMO systems. Then the challenges related to CSI acquisition are discussed for both time-division duplexing (TDD) and frequency-division duplexing (FDD) systems. Also, the challenges that arise due to the limited backhaul capacity for the cooperating base stations in a CoMP system are discussed, and possible approaches to tackle these challenges are outlined.

In the ninth article, "On the Impact of Network Geometric Models on Multicell Cooperative Communications Systems," Tukmanov *et al.* emphasize the trade-off between complexity and precision in modeling multicell cooperative networks. The authors describe the Wyner model as a well-known deterministic approach to model multicell cooperative networks, and then they present the stochastic geometry approach to model the random multicell cooperative wireless networks. The authors give examples of some common tools that can be used to model multicell cooperative networks considering fixed base stations and random user locations as well as random base stations and user locations.

An interesting overview on how to improve the energy efficiency in multicell cooperative cellular networks is given by Han and Ansari in their article "On Greening Cellular Networks via Multicell Cooperation." The authors discuss how the number of active base stations can be reduced and thus energy saved by using traffic-demand-aware multicell cooperation. Also, the authors introduce the concept of energy-aware multicell cooperation in which the power consumption of on-grid base stations is reduced by offloading traffic to off-grid base stations powered by renewable energy. To this end, the authors discuss how CoMP can be used to improve the energy efficiency of cellular networks as well as the challenges of energy-efficient multicell cooperation in next generation cellular networks.

In the last article, "Optimal Trade-off between Power Saving and QoS Provisioning for Multicell Cooperation networks," Zhang *et al.* develop a new scheme to achieve an optimal trade-off between the power saving and QoS provisioning in multicell cooperation. To obtain the optimal power scheduling policy that minimizes the power consumption at the base stations while guaranteeing QoS to the users, the authors formulate a stochastic optimization scheme based on a semi-Markov decision process.

The articles included in this Special Issue consider different aspects of multicell cooperative cellular wireless networks which will be very significant in the context of the evolving LTE-Advanced (and beyond) networks. We hope that you enjoy reading this issue and find the articles useful. We would like to thank all the authors for submitting their work and the reviewers for their time in reviewing the articles. Our special thanks to Dr. Hongyang Chen who first conceived the idea to organize this Special Issue and has helped us throughout the process. Also, we acknowledge the support from Professor Hsiao Hwa Chen who has guided us in this endeavor.

BIOGRAPHIES

EKRAM HOSSAIN [S'98, M'01, SM'06] (ekram@ee.umanitoba.ca) is a professor in the Department of Electrical and Computer Engineering at the University of Manitoba, Winnipeg, Canada. He received his Ph.D. in electrical engineering from the University of Victoria, Canada, in 2001. His current research interests include design, analysis, and optimization of wireless/mobile communications networks, cooperative and cognitive wireless networks, and green radio technology. He has authored/edited several books in these areas (http://www.ee.umanitoba.ca/~ekram). He serves as the Editor-in-Chief for *IEEE Communications Surveys and Tutorials* (for the term 2012–2013), and an Editor for *IEEE Journal on Selected Areas in Communications - Cognitive Radio Series* and *IEEE Wireless Communications*. Also, he serves on the IEEE Press Editorial Board (for the term 2013–2015). Previously, he served as Area Editor for *IEEE Transactions on Wireless Communications* in the area of Resource Management and Multiple Access from 2009 to 2011 and an Editor for *IEEE Transactions on Mobile Computing* from 2007 to 2012. He has won several research awards including the University of Manitoba Merit Award in 2010 (for Research and Scholarly Activities), the 2011 IEEE Communications Society Fred Ellersick Prize Paper Award, and the IEEE Wireless Communications and Networking Conference 2012 Best Paper Award. He is a Distinguished Lecturer of the IEEE Communications Society for the term 2012–2013. He is a registered Professional Engineer in the province of Manitoba, Canada.

ZANDER (ZHONGDING) LEI [M'01, SM'04] is a senior scientist and laboratory head, Institute for Infocomm Research, Singapore. He received his B.S. (Honor, 1st upper) and Ph.D. degrees from Beijing Jiaotong University in 1991 and 1997, and his M.Eng. degree from Tong Ji University (Shanghai Railway Institute) in 1994. From 1997 to 1999, he was a post-doctoral fellow at the National University of Singapore. Since 1999 he has been with the Institute for Infocomm Research Singapore, leading research teams working on next generation cellular and local area networks. He was a technical leader in the IEEE 802.22 standard working group that published the first IEEE standard for cognitive radio systems. His research interests include next generation/emerging wireless communication systems/technologies, cooperative communications, and cognitive radio, among others. He has 18 patents granted and over 90 technical papers published. He is a co-recipient of the Institution of Engineering of Singapore Prestigious Engineering Achievement Awards in 2005 and 2007. He has been the PHY Technical Editor for the IEEE 802.22 standard since 2006. He is an Editor for *IEEE Communications Letters* and *IEEE Communications Magazine*, a Lead Guest Editor for a *EURSIP WCN* Special Issue on Multicell Cooperation, and a Guest Editor for a *EURSIP WCN* Special Issue on Cognitive Radio.