Date of current version January 30, 2020.

Digital Object Identifier 10.1109/ACCESS.2019.2961102

EDITORIAL

IEEE ACCESS SPECIAL SECTION: DEPLOYMENT AND MANAGEMENT OF SMALL HETEROGENEOUS CELLS FOR 5G

The research of deployment and management of small heterogeneous cells toward the 5th generation of mobile cellular networks has been extensively investigated in both academia and industry. With the densification of small cells, the traffic requirements within each cell will fluctuate noticeably, so the traffic distribution and user behavior need to be studied based on different deployment and management scenarios. Furthermore, it is envisioned that 5G networks will be mostly for data-centric applications rather than voice-centric applications. Rethinking the systems architecture for ''5G'' in various deployment and management of small heterogeneous cells, supporting ultra-reliable and low latency communications, is needed to support a variety of new services, e.g., automotive, health, energy, and manufacturing. Therefore, designing ultra-dense cellular networks using new transmission technologies is a promising and challenging field.

This Special Section is intended to provide a platform for researchers and practitioners from both academia and industry in the area of ultra-dense deployment of ultra-dense small heterogeneous cells for 5G technologies. In this Special Section, we have included 14 high-quality articles from leading research groups around the world working on different research aspects of emerging wireless networks.

LTE usage is rapidly increasing with the increased demand for high data rate services. This may cause blocking for some users or degrade the quality for others. Aldabbagh *et al.*, in ''Hybrid clustering scheme for relaying in multi-cell LTE high user density networks,'' propose a new algorithm for relay selection in a multi-cell scenario based on K-means and selection strategy. Several techniques are adopted to increase the capacity of LTE cells. In the article by Eramo *et al.*, ''Trade-off between power and bandwidth consumption in a reconfigurable xhaul network architecture,'' a trade-off solution between power and bandwidth consumption is proposed and evaluated. The proposed solution consists of: 1) handling the traffic generated by the users through both RRU and traditional radio base stations (RBS) and 2) carrying the traffic generated by the RRU and RBS (CPRI and Ethernet flows) with a reconfigurable network.

Another emerging technology in big data analysis has also attracted attention, from academia to industry. In the article by Qiu *et al.*, ''A novel framework of data-driven networking,'' the authors propose a novel network paradigm to jointly consider CCN, SDN, and big data, and provide the architecture internal data flow, big data processing, and use cases which indicate their benefits and applicability. Simulation results are exhibited to show the potential benefits relating to the proposed network paradigm. Duong *et al.*, in ''Energy-efficient signaling in QoS constrained heterogeneous networks,'' consider a heterogeneous network, which consists of one macro base station and numerous small cell base stations cooperatively serving multiple user terminals.

Heterogeneous networks (HetNets), which consist of traditional macro-cells overlaid with newly envisioned small cells, are an appealing technology to satisfy the ever-increasing capacity requirements in future mobile networks. Yan *et al.*, in ''Modeling and analysis of two-tier HetNets with cognitive small cells,'' consider a two-tier cognitive HetNet, and utilize the statistic tool of stochastic geometry to model and analyze the coverage performance for macro-cell and small-cells over general Nakagami-m fading channels. The results can be used to help design the constraints on the configuration of small cells, considering the minimum requirements of coverage performance for macro-cell and small-cell.

The introduction of millimeter-wave (mm-wave) technologies in future 5G networks poses a rich set of network access challenges. Filippini *et al.*, in ''Facing the millimeter-wave cell discovery challenge in 5G networks with context-awareness,'' propose novel cell discovery algorithms enhanced by the context information available through a C-/U-plane-split heterogeneous network architecture. The results show that the proposed solutions have an outstanding performance with respect to basic discovery approaches and can fully enable millimeter wave cell discovery in 5G networks. Xu *et al.*, in ''Energy-aware power control in energy cooperation aided millimeter wave cellular networks with renewable energy resources,'' consider power control in energy cooperation enabled millimeter wave networks, to alleviate the harvested energy imbalance problem and reduce the energy waste. Power control is formulated as a stochastic optimization problem, aiming at maximizing the time average network utility while keeping the network stable. Zhou *et al.*, in ''Fair downlink traffic management for hybrid LAA-LTE/Wi-Fi networks,'' propose a fair

downlink traffic management (FDTM) scheme for hybrid LAA-LTE/Wi-Fi networks. Numerical results show a FDTM scheme can guarantee the throughput performance of Wi-Fi networks in a shared unlicensed spectrum while supporting proportional fairness for the LAA eNBs with different traffic loads.

Wang *et al.*, in "Safeguarding the ultra-dense networks with the aid of physical layer security: A review and a case study," give a review of the classical techniques in physical layer security from the perspective of resource allocation. Meanwhile, in a case study, it is shown that effective blockage of the eavesdropper in UDNs is achievable with the aid of physical layer security.

Arshad *et al.*, in "Handover management in 5G and beyond: A topology aware skipping approach," shed light on the HO problem that appears in dense 5G networks and proposes an effective solution via topology aware HO skipping. The article by Gerasimenko *et al.*, "Adaptive resource management strategy in practical multi-radio heterogeneous networks," is based on network flow optimization techniques, and adapts the concept of weighted α-fairness for efficient resource management in future HetNets. Qiao *et al.*, in "Joint deployment and mobility management of energy harvesting small cells in heterogeneous networks," develop a tractable framework of the location deployment and mobility management of EH-SCBSs with various traffic load distributions and environmental energy models.

In the article by Shojaeifard *et al.*, "Stochastic geometric analysis of energy-efficient dense cellular networks," the authors develop an analytical framework using tools from stochastic geometry theory for the performance analysis of DenseNets, where load-awareness is explicitly embedded in the design. Müller *et al.*, in "Analyzing wireless indoor communications by blockage models," apply a regular transmitter grid, show the influence of the relative orientation between walls and transmitter–receiver path, and also elaborate on the influence of interferers in different tiers around the desired transmitter.

We would like to thank all the authors and the reviewers for their efforts to make this Special Section successful. We would also like to thank the former and current Editors-in-Chief, Prof. Michael Pecht, and Prof. Derek Abbott, the Managing Editor, Bora M. Onat, and the Publication Editors, Kimberly Rybczynski and Margery Meyer, for their help throughout the course of this Special Section.

MUHAMMAD ALI IMRAN, *Guest Editor*
School of Engineering
University of Glasgow
Glasgow G12 8QQ, U.K.

YAN ZHANG, *Guest Editor*
University of Oslo
0315 Oslo, Norway

INKYU LEE, *Guest Editor*
School of Electrical Engineering
Korea University
Seoul 02841, South Korea

XING ZHANG, *Guest Editor*
Beijing University of Posts and Telecommunications
Beijing 100876, China

DANIEL BENEVIDES DA COSTA, *Guest Editor*
Department of Computer Engineering
Federal University of Ceará (UFC)
Sobral 62010-560, Brazil

ALI IMRAN, *Guest Editor*
The University of Oklahoma
Norman, OK 73019, USA

MUHAMMAD ALI IMRAN (M'03–SM'12) is currently a Professor of wireless communication systems with research interests in self-organized networks, wireless networked control systems, and the wireless sensor systems. He heads the Communications, Sensing and Imaging CSI Research Group, University of Glasgow. He is also an Affiliate Professor with The University of Oklahoma, USA, and a Visiting Professor with the 5G Innovation Centre, University of Surrey, U.K. He has over 20 years of combined academic and industry experience with several leading roles in multimillion pounds funded projects. He has filed 15 patents. He has authored or coauthored over 400 journal and conference publications. He was an Editor for three books and author of more than 20 book chapters. He has successfully supervised over 40 postgraduate students at Ph.D. level. He is a Fellow of IET and a Senior Fellow of HEA. He has been a consultant to international projects and local companies in the area of self-organized networks. He is an Associate Editor of IEEE ACCESS and the IEEE TRANSACTIONS ON COMMUNICATIONS.

YAN ZHANG received the Ph.D. degree from the School of Electrical and Electronics Engineering, Nanyang Technological University, Singapore. He is currently a Full Professor with the University of Oslo, Norway. He is also with the Simula Research Laboratory, Norway. He serves as organizing committee chairs and technical program committee for many international conferences. He is also serving the Book Series Editor-in-Chief of the book series on *Wireless Networks and Mobile Communications* (CRC Press). He is an Associate Editor or on the Editorial Board of a number of well-established scientific international journals.

INKYU LEE (S'92–M'95–SM'01–F'16) received the B.S. degree (Hons.) in control and instrumentation engineering from Seoul National University, Seoul, South Korea, in 1990, and the M.S. and Ph.D. degrees in electrical engineering from Stanford University, Stanford, CA, USA, in 1992 and 1995, respectively. From 1995 to 2001, he was a member of the Technical Staff with Bell Laboratories, Lucent Technologies, where he studied high-speed wireless system designs. From 2001 to 2002, he was a Distinguished Member of the Technical Staff with Agere Systems (formerly the Microelectronics Group, Lucent Technologies), Murray Hill, NJ, USA. Since 2002, he has been with Korea University, Seoul, where he is currently a Professor with the School of Electrical Engineering. In 2009, he was a Visiting Professor with the University of Southern California at Los Angeles, Los Angeles, CA, USA. He has authored or coauthored more than 180 journal articles in the IEEE publications and has 30 U.S. patents granted or pending. His research interests include digital communications, signal processing, and coding techniques applied for next-generation wireless systems. He was elected as a member of the National Academy of Engineering in Korea, in 2015. He was a recipient of the IT Young Engineer Award from the IEEE/IEEK Joint Award, in 2006, and the Best Paper Award at the Asia–Pacific Conference on Communications, in 2006, the IEEE Vehicular Technology Conference, in 2009, and the IEEE International Symposium on Intelligent Signal Processing and Communication Systems, in 2013. He was also a recipient of the Best Research Award from the Korean Institute of Communications and Information Sciences (KICS), in 2011, the Best Young Engineer Award from the National Academy of Engineering in Korea (NAEK), in 2013, and the Korea Engineering Award from the National Research Foundation of Korea (NRF), in 2017. He served as an Associate Editor for the IEEE TRANSACTIONS ON COMMUNICATIONS, from 2001 to 2011, and the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, from 2007 to 2011. In addition, he was a Chief Guest Editor for the IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS (Special Issue on 4G Wireless Systems), in 2006. He is an IEEE Distinguished Lecturer.

XING ZHANG is currently a Professor with the School of Information and Communications Engineering, Beijing University of Posts and Telecommunications, China. His research interests are mainly in satellite networks, mobile edge computing, big data, and the Internet of Things.

DANIEL BENEVIDES DA COSTA (S'04–M'08–SM'14) was born in Fortaleza, Ceará, Brazil, in 1981. He received the B.Sc. degree in telecommunications from the Military Institute of Engineering (IME), Rio de Janeiro, Brazil, in 2003, and the M.Sc. and Ph.D. degrees in electrical engineering, area: telecommunications, from the University of Campinas, Brazil, in 2006 and 2008, respectively. From 2008 to 2009, he was a Postdoctoral Research Fellow with INRSEMT, University of Quebec, Montreal, QC, Canada. Since 2010, he has been with the Federal University of Ceará, where he is currently an Associate Professor. He is a member of the IEEE Communications Society and the IEEE Vehicular Technology Society. His Ph.D. thesis was awarded the Best Ph.D. Thesis in electrical engineering by the Brazilian Ministry of Education (CAPES) at the 2009 CAPES Thesis Contest. He was a recipient of four conference paper awards. He received the Exemplary Reviewer Certificate of the IEEE WIRELESS COMMUNICATIONS LETTERS, in 2013, the Exemplary Reviewer Certificate of the IEEE COMMUNICATIONS LETTERS, in 2016 and 2017, the Certificate of Appreciation of Top Associate Editor for outstanding contributions to the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, in 2013, 2015, and 2016, the Exemplary Editor Award of the IEEE COMMUNICATIONS LETTERS, in 2016, and the Outstanding Editor Award of IEEE ACCESS, in 2017. He is the Vice-Chair of Americas of the IEEE Cognitive Networks Technical Committee (TCCN), the Director of the TCCN Newsletter, and the Chair of the Special Interest Group on Energy-Harvesting Cognitive Radio Networks in IEEE TCCN. He has been involved on the Organizing Committee of several conferences. He is also the Latin American Chapters Coordinator of the IEEE Vehicular Technology Society. He also acts as a Scientific Consultant of the National Council for Scientific and Technological Development (CNPq), Brazil, where he is a Productivity Research Fellow. He is also an Editor of the IEEE COMMUNICATIONS SURVEYS AND TUTORIALS, IEEE ACCESS, the IEEE TRANSACTIONS ON COMMUNICATIONS, the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, and the *EURASIP Journal on Wireless Communications and Networking*. He has also served as Associate Technical Editor for the *IEEE Communications Magazine*. From 2012 to 2017, he was an Editor of the IEEE COMMUNICATIONS LETTERS. He has served as an Area Editor for the *KSII Transactions on Internet and Information Systems* and as a guest editor for several journal special issues. He is a Distinguished Lecturer of the IEEE Vehicular Technology Society.

ALI IMRAN (M'15) received the B.Sc. degree in electrical engineering from the University of Engineering and Technology, Lahore, Pakistan, in 2005, the M.Sc. degree (Hons.) in mobile and satellite communications, and the Ph.D. degree from the University of Surrey, Guildford, U.K., in 2007 and 2011, respectively. He is currently an Assistant Professor of telecommunications with The University of Oklahoma, USA, where he is also the Founding Director of the Big Data and Artificial Intelligence Enabled Self Organizing Research Center. He has been leading several multinational projects on Self-Organizing Cellular Networks, such as QSON, for which he has secured research grants of over $2 million in last four years, as the Lead Principal Investigator. He is also leading two NSF funded projects on 5G SON amounting to over $750K. He has authored over 60 peer-reviewed articles and presented a number of tutorials at international forums, such as the IEEE International Conference on Communications, the IEEE Wireless Communications and Networking Conference, the European Wireless Conference, and the International Conference on Cognitive Radio Oriented Wireless Networks, on his topics of interest. His research interests include self-organizing networks, radio resource management, and big data analytics. He is an Associate Fellow of the Higher Education Academy, U.K., and a member of the Advisory Board to the Special Technical Community on Big Data of the IEEE Computer Society.