IEEE Access Special Section Editorial:
Ultra-Dense Cellular Networks

To satisfy the significant demand for wireless traffic growth in the near future, ultra-dense cellular networks have been extensively investigated recently in both academia and industry. Many techniques, such as massive MIMO (multiple-in multiple-out) antenna arrays, millimeter wave communications, small cells, and heterogeneous networks, have been proposed for the design of future ultra-dense cellular systems. For example, Massive MIMO technology enables the reduction of antenna transmission power, and millimeter wave channels are suitable for short distance communications in outdoor environments. Motivated by these new technologies, cell coverage has also been correspondingly reduced so as to improve the area spectrum usage. To realize seamless coverage, a large number of small cells will be deployed.

Currently, small cells, heterogeneous networks, massive MIMO antenna, and millimeter communications technologies have been investigated separately, whereas significant benefits may be derived by integrating the development of these technologies. Therefore, designing ultra-dense cellular networks using new transmission technologies is both promising and challenging. This Special Section in IEEE Access focuses on emerging technologies in the field of ultra-dense cellular networks. Eight high-quality papers have been accepted from leading groups around the world after rigorous peer-review processes.

In the first paper, millimeter wave (mmWave) communications greatly exploit the available transmission bandwidth, which is much wider than today’s microwave frequency bands. It has been recognized as an important component of future 5G wireless networks. However, the use of mmWave transmission in cellular channels needs further research in channel propagation measurements, especially in dense cellular networks. In the work by MacCartney et al. (http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7181638), “Millimeter-wave omnidirectional path loss data for small cell 5G channel modeling,” the authors present mmWave propagation measurement results are obtained in New York City during the summers of 2012 and 2013 and in downtown Austin during the summer of 2011. Large-scale path loss data measured at 28 GHz, 73 GHz, and 38 GHz are presented. Measurement layout maps with transmitter and receiver locations and GPS coordinates are also presented for the further use of other researchers.

It is important for future 5G systems to support highly mobile and dense users in ultra-dense networks with sufficient throughput and QoS requirements. In the article by Kela et al. (http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7214194), “Borderless mobility in 5G outdoor ultra-dense networks,” a novel scheduling algorithm is proposed to achieve a more uniform distribution of mobile user throughput in ultra-dense networks based on a new frame structure similar to IEEE 802.11ac and LTE-A. The results obtained for a high density of mobile users indicate that the proposed scheduling schemes achieve 77% higher median user-throughput than the maximum-throughput scheduler at the cost of 17% lower area-throughput. Furthermore, the proposed strategy performed better on a UDN deployment than on a micro-cell deployment using more massive planar antenna arrays.

In the third paper, link transmission scheduling plays an important role in millimeter wave communications and mmWave technologies networks based on small cells. In the paper by He et al. (http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7210127), “On link scheduling under blockage and interference in 60-GHz ad hoc networks,” the authors address the problem of link transmission scheduling in 60GH mmWave ad hoc networks while considering a generic link model. Both single-hop and multi-hop mmWave ad hoc networks are investigated and effective scheduling algorithms are proposed. The findings in this paper are instrumental to enabling future ultra-dense mmWave small cell networks.

The fourth paper describes how small-cell base stations can theoretically achieve the anticipated future data bandwidth demand of 10,000 fold growth in the next 20 years by using large-scale antenna systems and mmWave high-bandwidth spectra. In the article by Muirhead et al. (http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7226781), “Insights and approaches for low-complexity 5G small-cell base-station design for indoor dense networks,” small cell distances are leveraged to simplify SBS design, particularly considering dense indoor installations. Based on a link budget analysis, theoretical results are compared with the simulation results of a densely deployed indoor network using appropriate mmWave channel propagation conditions.
As discussed above, to enable the use of mmWave communication in mobile cellular networks, the mmWave propagation measurements conducted at 28 GHz and 73 GHz in New York City provided an abundance of valuable results.

In the fifth paper, an invited submission by MacCartney et al. (http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7289335), “Indoor office wideband millimeter-wave propagation measurements and channel models at 28 GHz and 73 GHz for ultra-dense 5G wireless networks,” details of this measurement are presented. The results show that novel large-scale path loss models provided in this paper are simpler and more physics-based compared to previous 3GPP and ITU indoor propagation models. Moreover, multipath time dispersion statistics for mmWave systems using directional antennas are presented.

The sixth paper covers how to implement caching at small cells in an energy-efficient way in view of the explosive growth of mobile data traffic and rapidly rising energy prices. In a work by Zhou et al. (http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7268835), “Energy-efficient context-aware matching for resource allocation in ultra-dense small cells,” the authors study an energy-efficient context-aware resource allocation problem. To tackle this mixed integer nonlinear programming problem, an energy-efficient matching algorithm based on the Gale-Shapley algorithm is proposed. The simulation results demonstrate that the proposed algorithm achieves significant performance and satisfaction gains compared with the conventional algorithms.

As described in the seventh paper, for ultra-dense cellular networks, diverse proprietary network appliances increase both the capital and operational expenses of service providers while at the same time causing network ossification. Network Function Virtualization (NFV) is proposed to address these issues by implementing network functions as pure software on commodity and general hardware. In the work by Li et al., “Software-defined network function virtualization: A survey,” a thorough investigation of the development of NFV under the software-defined NFV architecture is presented. The software-defined NFV architecture as a state-of-the-art NFV technology, significant challenges and relevant solutions of NFV, and future research directions in this field are also provided and discussed.

In the last paper, for future 5G systems, different kinds of networks will work together to form ultra-dense cellular networks. Therefore, the network will be heterogeneous. In the work by Pervaiz et al. (http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7270991&tag=1), “Energy and spectrum efficient transmission techniques under QoS constraints toward green heterogeneous networks,” a joint energy efficiency and spectrum efficiency tradeoff analysis is proposed as a multi-objective optimization problem in two-tier heterogeneous networks subject to QoS constraints. The results show that the achievable energy efficiency and spectrum efficiency increase with an increase in network densification and user density.

The above papers exemplify the deep technical depth and wide span of this Special Section. However, we recognize that it cannot cover all of the aspects of ultra-dense cellular networks. Finally, we sincerely thank all the authors and reviewers for their efforts, and of course the Editor-in-Chief and Staff Members for their guidance.

XIAOHU GE
Huazhong University of Science and Technology
Wuhan, China

VICENTE CASARES-GINER
Universidad Politécnica de Valencia
Valencia, Spain

GUOQIANG MAO
University of Technology Sydney
Sydney, Australia

ADLEN KSENTINI
University of Rennes
Dionysos, France

ZHU HAN
University of Houston
Houston, TX, USA

XIAOHU GE (M’09–SM’11) received the Ph.D. degree in communication and information engineering from the Huazhong University of Science and Technology (HUST), China, in 2003. He has been with HUST since 2005. He is currently a Professor with the School of Electronic Information and Communications, HUST. He is an Adjunct Professor with the University of Technology Sydney, Australia. He has published about 100 papers in refereed journals and conference proceedings and holds 15 patents in China. His research interests are in the area of mobile communications, traffic modeling in wireless networks, green communications, and interference modeling in wireless communications. He is a Senior Member of the China Institute of Communications and a member of the National Natural Science Foundation of China and the Chinese Ministry of Science and Technology Peer Review College. He received the best paper awards from the IEEE Globecom 2010. He has been actively involved in organizing more than ten international conferences since 2005. He serves as the General Chair of the 2015 IEEE International Conference on Green Computing and Communications. He serves as an Associate Editor of IEEE Access, the Wireless Communications and Mobile Computing Journal (Wiley), and the International Journal of Communication Systems (Wiley).
VICENTE CASARES-GINER (M’75) received the Telecommunication Engineering degree from the Escuela Técnica Superior de Ingenieros de Telecomunicación (ETSIT), Universidad Politécnica de Madrid, in 1974, and the Ph.D. degree in telecommunication engineering from ETSIT, Universitat Politècnica Catalunya, Barcelona, in 1980. From 1974 to 1983, he worked on problems related to signal processing, image restoration, and propagation aspects of radio-link systems. In 1984, he was a Visiting Scholar with the Royal Institute of Technology, dealing with digital switching and concurrent programming for SPC switching systems. From 1994 to 1995, he was a Visiting Scholar with WINLAB, Rutgers University, USA, focusing on random access protocols for wireless environments, wireless resource management, and land mobile trunking systems. In the 1990s, he worked on traffic and mobility models in several EU projects. In the 2000s and 2010s, he was involved in several national and EU projects from several FP programs. Since 1996, he has been with ETSIT, Universitat Politècnica de Valencia, Spain. He has published numerous papers in international magazines and conferences, such as the IEEE, IEEE-Electronic Letters, Signal Processing, EURASIP-EUSIPCO, the International Teletraffic Conference, wireless conferences, the IEEE ICASSP, the IEEE ICC, the IEEE ICUPC, and the IEEE WCNC. His main interest is in the area of performance evaluation of wireless systems, in particular, mobility management, system capacity and dimensioning, cognitive radio and wireless sensor networks, and random access protocols. He has served as the General Co-Chair of the IEEE-ISCC 2005, the General Chair of NGI 2006, the Co-Chair of several workshops (Networking 2011, D2D Communication With and Without Infrastructure at the IEEE GLOBECOM 2013, D2D Communication for Cellular and Wireless Networks at the IEEE ICC 2015, and Track on LTE/LTE-A, 5G, and Wireless Heterogeneous Networks at the IEEE VTC Spring 2016), and a TPC Member in several IEEE conferences and workshops.

GUOQIANG MAO (S’98–M’02–SM’08) received the Ph.D. degree in telecommunications engineering from Edith Cowan University, in 2002. He was with the School of Electrical and Information Engineering, University of Sydney, from 2002 to 2014. He joined the University of Technology Sydney as a Professor of Wireless Networking and the Director of the Center for Real-time Information Networks in 2014. The Center is among the largest university research centers in Australia in the field of wireless communications and networking. He has published more than 150 papers in international conferences and journals, which have been cited more than 3500 times. His research interests include intelligent transport systems, applied graph theory, and its applications in telecommunications, wireless sensor networks, wireless localization techniques, and network performance analysis. He is an Editor of the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS (since 2014) and the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY (since 2010). He received the Top Editor Award for outstanding contributions to the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY in 2011 and 2014. He is a Co-Chair of the IEEE Intelligent Transport Systems Society Technical Committee on Communication Networks. He has served as a Chair, Co-Chair, and TPC Member in a large number of international conferences.

ADLEN KSENTINI (SM’14) received the M.Sc. degree in telecommunication and multimedia networking from the University of Versailles Saint-Quentin-en-Yvelines, and the Ph.D. degree in computer science from the University of Cergy-Pontoise, in 2005, with a dissertation on QoS provisioning in the IEEE 802.11-based networks. He is currently an Associate Professor with the University of Rennes 1, France. He is a member of the Dionysos Team with INRIA, Rennes. He is involved in several national and European projects on QoS and QoE support in future wireless and mobile networks. He has co-authored over 80 technical journal and international conference papers. His other interests include future Internet networks, mobile networks, QoS, QoE, performance evaluation, and multimedia transmission. He received the best paper award from the IEEE ICC 2012 and ACM MSWiM 2005. He is the TPC Chair of the Wireless and Mobile Symposium of the IEEE ICC 2016. He was a Guest Editor of the IEEE Wireless Communication Magazine, and two ComSoc MMTC letters. He has been on the Technical Program Committee of major IEEE ComSoc, ICC/Globecom, ICME, WCNC, and PIMRC conferences.
ZHÚ HĀN (S’01–M’04–SM’09–F’14) received the B.S. degree in electronics engineering from Tsinghua University, in 1997, and the M.S. and Ph.D. degrees in electrical engineering from the University of Maryland, College Park, in 1999 and 2003, respectively. From 2000 to 2002, he was an R&D Engineer with JDSU, Germantown, MD. From 2003 to 2006, he was a Research Associate with the University of Maryland. From 2006 to 2008, he was an Assistant Professor with Boise State University, Idaho. He is currently a Professor with the Electrical and Computer Engineering Department and the Computer Science Department, University of Houston, TX. His research interests include wireless resource allocation and management, wireless communications and networking, game theory, wireless multimedia, security, and smart grid communication. He received an NSF Career Award in 2010, the Fred W. Ellersick Prize of the IEEE Communication Society in 2011, the EURASIP Best Paper Award from the Journal on Advances in Signal Processing in 2015, and several best paper awards in IEEE conferences, and is currently an IEEE Communications Society Distinguished Lecturer.

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