GUEST EDITORIAL

HETEROGENEOUS CLOUD RADIO ACCESS NETWORKS


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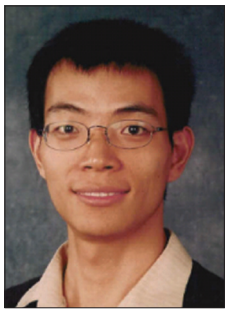
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With the rapid development of mobile Internet and the Internet of Things, the demand for high-speed high-quality data applications, such as wireless video streaming, mobile interactive gaming, social networking, and machine-to-machine communications, has been growing dramatically. To meet this rapidly growing demand, there is an urgent need for revolutionary approaches involving new wireless network architectures as well as advanced networking technologies. Heterogeneous networks (HetNets) have attracted significant interest from both academia and industry as a means to potentially improve spatial reuse and coverage, thus allowing cellular systems to achieve higher data rates, while retaining the seamless connectivity and mobility of cellular networks. However, considering the severe inter-tier interference and limited cooperative gains, new techniques for improving both the spectral efficiency and energy efficiency through suppressing inter-tier interference and enhancing cooperative processing capabilities are needed. On the other hand, cloud computing technologies have emerged as a promising solution for providing high energy efficiency together with flexibility through software defined virtualization of communication networks and protocols. Consequently, heterogeneous cloud radio access networks (H-CRANs) that combine HetNets with cloud computing have been recognized as a potential cost-effective solution for alleviating inter-tier interference and improving cooperative processing gains in HetNets.

In H-CRANs, the control and user planes are decoupled, and the delivery of control and broadcast signalling is shifted from remote radio heads (RRHs) to macro base stations (MBSs), which improves system throughput and alleviates time delay in the fronthaul. By bringing together academic and industrial researchers to identify and discuss technical challenges and recent results related to H-CRANs, this Special Issue aims to attract greater attention from the academic and industrial communities for developing advanced and innovative methodologies and techniques for H-CRANs. We received a considerable number of original submissions to this issue, of which 11 papers were accepted for publication after peer reviews. We regret that we were not able to accept many other high-quality papers due to space constraints.

In this Special Issue, several articles discuss applications and advanced system architectures for H-CRANs. The first article, "Video Delivery in Heterogeneous-CRAN: Architectures and Strategies," proposes integration of an enhanced baseband unit (eBBU) pool with basic gateway functions for controlling and scheduling video packets across multiple radio access technologies. Furthermore, the authors compare and evaluate three possible video delivery architectures: without a centralized eBBU pool, without eBBU pool caching, and with eBBU pool caching, respectively. The second article, "Ultra-Low-Latency Ubiquitous Connections in Heterogeneous Cloud Radio Access Networks," presents several methodologies enabling ultra-low-latency connections in H-CRANs to reduce latency in the air interface, latency of radio resource optimization, and latency in backhaul packet forwarding. The third article, "Large-Scale Antenna Operation in Heterogeneous Cloud Radio Access Networks: A Partial Centralization Approach," provides a partially centralized approach that offers a flexible and scalable solution for reducing fronthaul overhead in H-CRANs with large-scale antenna arrays. The fourth article, "Balancing Backhaul Load in Heterogeneous Cloud Radio Access Networks," proposes a workload balancing scheme for alleviating data transmission pressure in fronthauls of H-CRANs.

Device-to-device (D2D) technology can be employed in H-CRANs to decrease burdens on the fronthaul. The fifth article, "D2D Based Heterogeneous Radio Access Network Architecture for Mobile Cloud Computing," presents a hierarchical cloud computing architecture for H-CRANs by adding a mobile dynamic cloud, which offers advantages of quick computing and latency reduction for tasks generated by end-user devices. The sixth article, "User-Centric Local Mobile Cloud Assisted D2D Communications in Heterogeneous Cloud-RAN," proposes user-centric local mobile cloud assisted D2D communications in H-CRANs, which includes an energy-aware subtask allocation strategy with limited fronthaul data transfer.

Radio resource allocation in H-CRANs is another important area of research. The seventh article, "Resource Allocation in Heterogeneous Cloud Radio Access Networks: Advances and Challenges," addresses challenges and advances such as user association, quantization design, and joint resource allocation and flow control in H-CRANs. The eighth article, "Resource Sharing in Heterogeneous Cloud Radio Access Networks," discusses the benefits and challenges of

employing different resource sharing protocols in H-CRANs. "Large-Scale Convex Optimization for Ultra-Dense Cloud-RAN" presents new convex optimization methods for dense C-RANs, including a convex relaxation approach, a convex regularized optimization approach, and a large-scale convex optimization algorithm.

In order to further enhance the performance of H-CRANs, it is essential to develop techniques to mitigate interference. The article "Cooperative Interference Mitigation and Handover Management for Heterogeneous Cloud Small Cell Networks" investigates the issue of cooperative interference mitigation and handover management in heterogeneous cloud small cell networks (HCSNets). The last article, "Acquisition of Channel State Information in Heterogeneous Cloud Radio Access Networks: Challenges and Research Directions," presents a comprehensive survey of various approaches for channel state information acquisition in H-CRANs striking different trade-offs between system complexity and performance.

In summary, this Special Issue provides a set of papers that inform researchers on new architectures, perspectives, and methodologies about H-CRANs, which have important applications not only in telecommunications, but also in general wireless communications. We hope that this provides readers an opportunity for forward thinking about H-CRANs and serves as a milestone for stimulating future advances in this emerging research area.

ACKNOWLEDGMENTS

The Guest Editors would like to thank all authors for their submissions, the anonymous reviewers for their efforts in reviewing the submitted manuscripts, and the editorial staff of *IEEE Wireless Communications* for their contributions to this Special Issue.

BIOGRAPHIES

MUGEN PENG [M'05, SM'11] (pmg@bupt.edu.cn) received his B.E. degree in electronics engineering from Nanjing University of Posts & Telecommunications, China, in 2000 and a Ph.D. degree in communication and information systems from Beijing University of Posts & Telecommunications (BUPT), China in 2005. After receiving his Ph.D., he joined BUPT and has become a full professor with the School of Information and Communication Engineering at BUPT since October 2012. During 2014, he was also an academic visiting fellow at Princeton University, New Jersey. He is leading a research group focused on wireless transmission and networking technologies in the Key Laboratory of Universal Wireless Communications (Ministry of Education) at BUPT. His main research areas include wireless communication theory, radio signal processing, and convex optimization, with particular interest in cooperative communication, radio network coding, self-organizing networking, heterogeneous networks, and cloud communication. He has authored/coauthored over 60 refereed IEEE journal papers and over 200 conference proceeding papers. He is currently on the Editorial/Associate Editorial Boards of *IEEE Communications Magazine*, *IEEE Access*, *IET Communications*, the *International Journal of Antennas and Propagation*, *China Communications*, and the *International Journal of Communications System*. He has the leading Guest Editor for a Special Issue of *IEEE Wireless Communications*. He was a recipient of the 2014 IEEE ComSoc AP Outstanding Young Researcher Award, and the best paper award at IEEE WCNC 2015, GameNets 2014, IEEE CIT 2014, ICCTA 2011, IC-BNMT 2010, and IET CCWMC 2009. He received the First Grade Award of Technological Invention Award in Ministry of Education of China for his excellent research work on hierarchical cooperative communication theory and technologies, and the Second Grade Award of Scientific and Technical Advancement from China Institute of Communications for his excellent research work on the coexistence of multi-radio access networks and the 3G spectrum management.

TONY Q. S. QUEK [S'98, M'08-SM'12] (tonyquek@sutd.edu.sg) received his B.E. and M.E. degrees in electrical and electronics engineering from Tokyo Institute of Technology, Japan. At the Massachusetts Institute of Technology, he earned his Ph.D. in electrical engineering and computer science. Currently, he is an assistant professor with the Information Systems Technology and Design Pillar at Singapore University of Technology and Design (SUTD). He is also a scientist with the Institute for Infocomm Research. His main research interests are the application of mathematical, optimization, and statistical theories to communication, networking, signal processing, and resource allocation problems. Specific current research topics include sensor networks, heterogeneous networks, green communications, smart grid, wireless security, compressed sensing, big data processing, and cognitive radio. He has been actively involved in organizing and chairing sessions, and has served as a member of the Technical Program Committee as well as Symposium Chair for a number of international conferences. He served as TPC Co-Chair for IEEE ICCS in 2014 and the Wireless Networks and Security Track for IEEE VTC-Fall in 2014, and is serving in the same position for the PHY & Fundamentals Track for IEEE WCNC in 2015 and the Communication Theory Symposium for IEEE ICC in 2015. He is currently an Editor for *IEEE Transactions on Communications*, *IEEE Wireless Communications Letters*, and an Executive Editorial Committee Member for *IEEE Transactions on Wireless Communications*. He was a Guest Editor for the *IEEE Communications Magazine* Feature Topic on Heterogeneous and Small Cell Networks in 2013 and the *IEEE Signal Processing Magazine* Special Issue on Signal Processing for the 5G Revolution in 2014. He was honored with the 2008 Philip Yeo Prize for Outstanding Achievement in Research, the IEEE GLOBECOM 2010 Best Paper Award, the 2011 JSPS Invited Fellow for Research in Japan, the CAS Fellowship for Young International Scientists in 2011, the 2012 IEEE William R. Bennett Prize, the IEEE SPAWC 2013 Best Student Paper Award, and the IEEE WCSP 2014 Best Paper Award.

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VINCENT LAU [F'12] (eeknlau@ee.ust.hk) obtained his B.Eng. (Distinction 1st Hons) from the University of Hong Kong (1989–1992) and Ph.D. from Cambridge University (1995–1997). He was at Bell Labs from 1997 to 2004, and joined the Department of ECE, Hong Kong University of Science and Technology (HKUST) in 2004. He is currently a Chair Professor at HKUST, the founding director of Huawei-HKUST Joint Innovation Lab, Senior Croucher Research Fellow, and Changjiang Chair Professor. His current research focus includes robust cross layer optimization for MIMO/OFDM wireless systems, interference mitigation techniques for wireless networks, device-to-device communications, as well as networked control systems.

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