Guest Editorial Special Section on Green Mobile Multimedia Communications

RECENT ubiquitous deployment of mobile broadband devices and services has led to the explosive demands for mobile multimedia communications, which have significantly increased not only spectrum requirements but energy consumption as well. Currently, the telecommunications industry is responsible for about 2% of global CO_2 emissions, and it could increase to 4% by 2020, given the projected growth in mobile multimedia communications. This demonstrates an urgent need for energy-aware and spectrum-efficient technologies to achieve green mobile multimedia communications.

The broadband nature of mobile multimedia communications, combined with radio channel variations due to user mobility, brings many technical challenges to the delivery of satisfactory quality of service (QoS) and quality of experience to mobile users. For a given performance requirement, there is a saturation point where energy consumption can no longer be reduced. For a fixed homogeneous network deployment, the performance saturation point is dictated by hardware performance, whereas for a flexible heterogeneous network deployment, the performance saturation point is dictated by the achievable capacity of the network architecture and transmission techniques. Moreover, traditional mobile communication networks are designed statically based on the "worst case" of all expected communication scenarios. Without considering the dynamic nature of channel conditions and user traffic demands, existing mobile communication networks often result in a very inefficient usage of the radio resources. For example, the conventional spectrum allocation approaches are not flexible enough to cope with the varying channel conditions and user demands. All these challenges have motivated comprehensive efforts from both industry and academia in designing new energy- and spectrum-efficient network architectures, protocols, algorithms, and transmission technologies for green mobile multimedia communications.

The objective of this Special Section is to cover the most recent research and development on the enabling technologies for green mobile multimedia communications and to stimulate discussions on state-of-the-art and innovative aspects in the field. The responses to our Call for Papers on this Special Section were overwhelming, with 41 papers submitted from around the globe. During the review process, each paper was assigned to and reviewed by at least three experts in the relevant area, with a rigorous two-round review process. Due to the lack of space, we can only accommodate 13 excellent papers covering various aspects of green mobile multimedia communications involving network architecture and algorithms, resource allocations, interference and power management, and multimedia and green services.

The first paper, "Toward Transcoding as a Service in Multimedia Cloud: Energy-Efficient Job Dispatching Algorithm," by Zhang *et al.*, investigated dispatching algorithms on how to route transcoding jobs in the multimedia cloud. To minimize the energy consumption by cloud service engines, they formulated the job dispatching policy as an optimization problem under the framework of Lyapunov optimization. The simulation results showed that the proposed algorithm is more energy-efficient than round-robin and random-rate algorithms.

The second paper, "Energy-Efficient Adaptive Video Transmission: Exploiting Rate Predictions in Wireless Networks," by Abou-zeid *et al.*, investigated how knowledge of future wireless data rates can improve spectral efficiency and provide downlink base station (BS) power savings. They used predicted rates to jointly optimize multiuser rate allocation, video segment quality, and BS on/off status. Simulations demonstrate that high network-wide energy efficiency gains are achieved by the proposed adaptive video transmission framework. The numerical results further indicate that the proposed algorithms achieve close to optimal performance, while exhibiting a higher degree of QoS robustness to prediction errors.

The third paper, "A Spectrum- and Energy-Efficient Scheme for Improving the Utilization of MDRU-based Disaster Resilient Networks," by Ngo *et al.*, proposed a scheme to improve the utilization of both spectrum and energy resources for better system performance. The considered movable and deployable resource unit (MDRU)-based network is composed of gateways deployed in the disaster area, which can replenish their energy by using solar panels. Unlike the previous work in spectrum efficiency, the proposed scheme can be used for multisender multireceiver topologies.

Liu *et al.* presented the fourth paper, "Energy-Efficient Power Allocation for Delay-Sensitive Multimedia Traffic over Wireless Systems." In this paper, the authors addressed resource allocation for maximizing the energy efficiency of a wireless link under statistical QoS constraints for mobile multimedia traffic. In the energy-efficiency analysis, both circuit energy and transmission energy of a mobile system are taken into account. The joint impact of statistical QoS constraints, underlying

Digital Object Identifier 10.1109/TVT.2014.2314522

circuit power consumption, transmission power, and spectral bandwidth are considered in this study.

The fifth paper, "Energy-Efficient Sleep Scheduling for Delay-Constrained Applications over WLANs" by Liu *et al.*, studied energy-efficient sleep scheduling for voice over Internet Protocol (VoIP) over a wireless local area network. By switching mobile nodes to low-power sleep mode, the energy consumption can be significantly reduced.

To allocate available radio resources to maximize the aggregate throughput and multimedia quality performance in wireless networks, Wang *et al.* in the sixth paper, "Interference Allocation Scheduler for Green Multimedia Delivery," presented a new and effective scheduling policy that allocates resource blocks, such that interference power is shifted toward capacity-saturated users while improving the throughput of unsaturated users.

In the seventh paper, "Energy-Efficient Resource Allocation for Heterogeneous Services in OFDMA Downlink Networks: Systematic Perspective" by Xu *et al.*, a new energy-efficient resource-allocation scheme for orthogonal frequency-division multiple-access downlink networks, where both transmitter energy consumption for base station transmission and base station circuit energy consumption, and receiver energy consumption for user equipment receiver circuit energy consumption are considered in the problem formulation.

The eighth paper, "Quasi-Quadrature Modulation Method for Power-Efficient Video Transmission Over LTE Networks," by Maksymyuk *et al.*, addressed the problem of decreasing power consumption due to video transmission applications in Long-Term Evolution (LTE) networks. They proposed a new method of modulation for improving energy efficiency of wireless data transmission. Four different schemes of quasi-quadrature modulation using multiple-input–multiple-output (MIMO) techniques with different QoS performances are studied in this paper.

The ninth paper, "Energy-Efficient Resource Sharing for Mobile Device-to-Device Multimedia Communications" by Wu *et al.*, studied the problem of energy-efficient uplink resource sharing over mobile device-to-device (D2D) multimedia communications underlaying cellular networks with multiple potential D2D pairs and cellular users. They first constructed a novel analysis model of energy efficiency, which takes into account different sharing modes, as well as QoS requirement and spectrum utilization of each user. Then, they formulated the sharing problem as a nontransferable coalition formation game, with the characteristic function that accounts for the gains in terms of energy efficiency and the costs in terms of mutual interference.

Jin *et al.* presented the tenth paper, "Energy-Aware Cooperation Strategy with Uncoordinated Group Relays for Delay-Sensitive Services." In this paper, the authors developed an effective uncoordinated cooperative strategy for large-scale wireless networks, which is based on the backoff timer. In particular, they focused on a new framework, where multiple source–destination pairs share a group of relays with energy constraints. Based on the proposed algorithm, the theoretical bounds of the collision probability and transmission success probability can be derived.

The eleventh paper, "Green Cognitive Mobile Networks with Small Cells for Multimedia Communications in the Smart Grid Environment," by Bu and Yu, studied green cognitive mobile networks with small cells in the smart grid environment. Unlike most existing studies on cognitive networks, where only the radio spectrum is sensed, these cognitive networks sense not only the radio spectrum environment but the smart grid environment as well, and based on this, power allocation and interference management for multimedia communications are performed. They formulated and analyzed the problems of electricity price decision, energy-efficient power allocation, and interference management as a three-stage Stackelberg game.

Ge *et al.* in the twelfth paper "Energy Efficiency Optimization for MIMO-OFDM Mobile Multimedia Communication Systems with QoS Constraints," proposed an energy efficiency model for MIMO orthogonal-frequency-division-multiplexing mobile multimedia communication systems with statistical QoS constraints. Employing the channel matrix single-value-decomposition method, all subchannels are classified by their channel characteristics.

Finally, Ren *et al.* presented the last paper, "Energy-Efficient Resource Allocation in Downlink OFDM Wireless Systems with Proportional Rate Constraints." In this paper, the authors investigated energy-efficient and fair resource allocation in a downlink OFDM-based mobile multimedia communication system. Given a subcarrier assignment, they proposed a bisection-based optimal power-allocation scheme, which achieves the maximum energy efficiency and guarantees proportional data rates for users. Then, they designed a two-step subcarrier assignment to avoid unaffordable computational complexity of exhaustive search. The numerical results show that the proposed algorithm could approach the optimum and is more energy efficient than the traditional spectral-efficient method in the high channel-gain-to-noise-ratio regime.

In closing, we would like to thank all the authors for their excellent contributions. We also thank the reviewers for their dedication in reviewing the papers and providing valuable comments and suggestions for refining the quality of the articles. We appreciate the advice and support of former and current Editors-in-Chief of IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, Dr. Weihua Zhuang and Dr. Yuguang "Michael" Fang, and the senior publication editor Mr. Chris Perry, for their tremendous help in the publication process. Finally, we hope that the readership will find this feature topic interesting and informative. We also hope that the readership will stay tuned for new developments in this research area.

YI QIAN, *Guest Editor*
University of Nebraska-Lincoln
Lincoln, NE 68588 USA

XIAOLI CHU, *Guest Editor*
University of Sheffield
Sheffield S10 2TN, U.K.

XIANBIN WANG, *Guest Editor*
University of Western Ontario
London, ON N64 3K7, Canada

FUMIYUKI ADACHI, *Guest Editor*
Tohoku University
Sendai 980-8577, Japan

HAI LIN, *Guest Editor*
Osaka Prefecture University
Osaka 599-8531, Japan

HUSSEIN T. MOUFTAH, *Guest Editor*
University of Ottawa
Ottawa, ON K1N 6N5, Canada

Yi Qian (M'95–SM'07) received the Ph.D. degree in electrical engineering from Clemson University, Clemson, SC, USA, in 1996.

He is currently an Associate Professor with the Department of Computer and Electronics Engineering, University of Nebraska–Lincoln (UNL), Lincoln, NE, USA. Prior to joining UNL, he worked in the telecommunications industry, academia, and the government. Some of his previous professional positions include serving as a senior member of scientific staff and a Technical Advisor with Nortel Networks, as a Senior Systems Engineer and a Technical Advisor at several start-up companies, as an Assistant Professor with the University of Puerto Rico at Mayaguez, Mayaguez, Puerto Rico, and as a Senior Researcher with the National Institute of Standards and Technology. He has a successful track record leading research teams and publishing research results in leading scientific journals and conferences. Several of his recent journal articles on wireless network design and wireless network security are among the most accessed papers on the IEEExplore Digital Library. His research interests include information assurance and network security, network design, network modeling, simulation and performance analysis for next-generation wireless networks, wireless ad hoc and sensor networks, vehicular networks, broadband satellite networks, optical networks, high-speed networks, and the Internet.

Dr. Qian is a member of the Association for Computing Machinery.

Xiaoli Chu (M'12) received the B.Eng. degree in electronic and information engineering from Xi'an Jiao Tong University, Xi'an, China, in 2001 and the Ph.D. degree in electrical and electronic engineering from the Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, in 2005.

From September 2005 to April 2012, she was with the Centre for Telecommunications Research, King's College London, London, U.K. She is currently a Lecturer with the Department of Electronic and Electrical Engineering, University of Sheffield, Sheffield, U.K. She is the leading Editor/Author of the book *Heterogeneous Cellular Networks—Theory, Simulation and Deployment* (Cambridge University Press, July 2013).

Dr. Chu was a Workshop Cochair for the IEEE International Conference on Green Computing and Communications in 2013 (GreenCom'13) and has been the Technical Program Committee Cochair of several workshops on heterogeneous networks for the IEEE Global Communications Conference, the IEEE Wireless Communications and Networking Conference, the IEEE International Symposium on Personal, Indoor, and Mobile Radio Communications, and some other international conferences. She served as a Guest Editor for the *ACM/Springer Journal of Mobile Networks & Applications Special Issue on Cooperative Femtocell Networks* in October 2012. She is an Editorial Board Member of the IEEE COMMUNICATIONS SOCIETY MULTIMEDIA COMMUNICATIONS TECHNICAL COMMITTEE R-LETTER. She received the U.K. Engineering and Physical Sciences Research Council (EPSRC) Cooperative Awards in Science and Engineering for New Academics in 2008, the U.K. EPSRC First Grant in 2009, and the U.K. Research Council U.K.–China Science Bridges Fellowship in 2011.

Xianbin Wang (S'98-M'99-SM'06) received the Ph.D. degree in electrical and computer engineering from National University of Singapore, Singapore, in 2001.

He is an Associate Professor with The University of Western Ontario and Canada Research Chair in Wireless Communications. Prior to joining Western, he was with Communications Research Centre Canada as Research Scientist/Senior Research Scientist between July 2002 and December 2007. From January 2001 to July 2002, he was a system designer at STMicroelectronics, where he was responsible for system design for DSL and Gigabit Ethernet chipsets. His current research interests include adaptive wireless systems and mobile applications, communications security, and distributed computing systems.

Dr. Wang has over 150 peer-reviewed journal and conference papers on various communication system design issues, in addition to 23 granted and pending patents and several standard contributions. He is an IEEE Distinguished Lecturer. He was involved in a number of IEEE conferences, including the IEEE Global Communication Conference, the IEEE International Conference on Communications, the IEEE Wireless Communications and Networking Conference, the IEEE Vehicular Technology Conference, and the IEEE International Conference on Multimedia and Expo, in different roles such as Symposium Chair, Track Chair, Technical Program Committee Chair, and Session Chair. He served as an Editor for the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS between 2007 and 2011. He currently serves as an Associate Editor for the IEEE WIRELESS COMMUNICATIONS LETTERS, the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, and the IEEE TRANSACTIONS ON BROADCASTING. He has received a number of prestigious domestic and international awards and recognitions, including Canada Research Chair, three IEEE Best Paper Awards, the President's Excellence Award and Technology Transfer Award from Communications Research Centre Canada, and the Public Service Award from the Canadian Federal Government.

Hai Lin received the B.E. degree from Shanghai JiaoTong University, Shanghai, China, in 1993, the M.E. degree from University of the Ryukyus, Okinawa, Japan, in 2000, and the Dr. Eng. degree from Osaka Prefecture University, Sakai, Japan, in 2005.

Since 2000, he was a research associate with the Graduate School of Engineering, Osaka Prefecture University, where now he is an associate professor.

Dr. Lin has acted many times as technical program committee member for IEEE ICC, GLOBECOM, WCNC, VTC, etc. He also served as Technical Program Co-Chair for the Wireless Communications Symposium of IEEE ICC 2011, the Signal Processing for Communications Symposium of IEEE ICC 2013, and the Wireless Communications Symposium of IEEE GLOBECOM 2013. He received the IEEE SPCE TC Outstanding Service Award 2013. Currently, he is an Editor of the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, and an Editor of the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY. His research interests are in signal processing for communications, wireless communications, and statistical signal processing.

Fumiyuki Adachi (M'79–SM'90–F'00) received the B.S. and Dr. Eng. degrees in electrical engineering from Tohoku University, Sendai, Japan, in 1973 and 1984, respectively.

In April 1973, he joined NTT Laboratories and conducted various types of research related to digital cellular mobile communications. From July 1992 to December 1999, he was with NTT DoCoMo, Inc., where he led a research group on W-CDMA for 3G systems. Since January 2000, he has been with Tohoku University, Sendai, Japan, where he is currently a Professor of electrical and communication engineering with the Graduate School of Engineering. He is the author of over 500 papers in journals and conference proceedings. His research interests include gigabit wireless signal processing and networking, particularly wireless access, equalization, transmit/receive antenna diversity, equalization, channel coding, and distributed multiple-input–multiple-output signal processing.

Dr. Adachia is a Fellow of the Institute of Electronics, Information, and Communication Engineers (IEICE). He received the IEEE Vehicular Technology Society Avant Garde Award in 2000, the IEICE Achievement Award in 2002, the Thomson Scientific Research Front Award in 2004, the Ericsson Telecommunications Award in 2008, the Telecom System Technology Award in 2010, and the Prime Minister Invention Prize in 2010.

Hussein T. Mouftah (S'74–M'76–SM'80–F'90) received the B.Sc. degree in electrical engineering and the M.Sc. degree in computer science from the University of Alexandria, Egypt, in 1969 and 1972, respectively, and the Ph.D. in electrical engineering from Laval University, Canada, in 1975.

From 1979 to 2002, he was with the Department of Electrical and Computer Engineering, Queen's University, Kingston, ON, Canada, where he took the position of Full Professor and Department Associate Head. He has six years of industrial experience, mainly with Bell Northern Research of Ottawa (now Nortel Networks). In 2002, he joined the School of Information Technology and Engineering, University of Ottawa, Ottawa, ON, Canada, as a Tier 1 Canada Research Chair Professor and then became a University Distinguished Professor in 2006. He is the author or coauthor of nine books, 48 book chapters, more than 1300 technical papers, 12 patents, and 142 industrial reports.

Mr. Mouftah is a Fellow of the Canadian Academy of Engineering, the Engineering Institute of Canada, and the Royal Society of Canada Academy of Science. He has been a Distinguished Speaker of the IEEE Communications Society (ComSoc) (2000–2007). He served as the Editor-in-Chief for the IEEE COMMUNICATIONS MAGAZINE (1995–1997) and as the IEEE ComSoc Director of Magazines (1998–1999), as the Chair of the Awards Committee (2002–2003), as the Director of Education (2006–2007), and as a Member of the Board of Governors (1997–1999 and 2006–2007). He has received numerous prestigious awards, such as the 2007 Royal Society of Canada Thomas W. Eadie Medal, the 2007–2008 University of Ottawa Award for Excellence in Research, the 2008 ORION Leadership Award of Merit, the 2006 IEEE Canada McNaughton Gold Medal, the 2006 EIC Julian Smith Medal, the 2004 IEEE ComSoc Edwin Howard Armstrong Achievement Award, the 2004 George S. Glinski Award for Excellence in Research of the University of Ontario Faculty of Engineering, the 1989 Engineering Medal for Research and Development of the Association of Professional Engineers of Ontario, and the Ontario Distinguished Researcher Award of the Ontario Innovation Trust. He has coreceived 18 Best Paper and/or Outstanding Paper Awards.