Special Issue on Energy Harvesting in Wireless Networks

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Energy consumption has emerged as a key issue for designing next generation wireless networks. Having to periodically recharge mobile devices using power cords hampers the mobile operation of the devices. On the other hand, energy-constrained wireless networks, such as sensor networks, have limited lifetime due to the difficulty in replacing or recharging batteries in the nodes. Energy harvesting is a promising approach that addresses these issues as it powers mobile devices and, in general, wireless networks by scavenging energy from the ambient environment. Specifically, the networks can be made self-sustaining by harvesting energy from rich sources including solar power, electromagnetic waves, thermal energy, wind energy, salinity gradients, and kinetic energy. The recent emphasis on green communications also provides a strong motivation for developing energy harvesting based communication techniques. This has become all the more urgent because the electricity consumption of the fast expanding networks that handle mobile devices has grown rapidly, and will soon contribute significantly to global warming.

However, considerable research needs to be done in order to make communication devices based on energy harvesting a universal reality. The challenges and constraints faced by energy harvesting devices differ from those faced by devices powered by conventional energy sources. This entails a redesign of the wireless communication algorithms, network protocols, and transceiver hardware. These need to handle the random and potentially sporadic nature of the harvested energy. Further, the amount of harvested energy itself might be very small. The goal of this special issue is to highlight the various challenges and constraints related to energy harvesting and bring forth promising solutions that address them and theoretical limits that characterize what energy harvesting networks are fundamentally capable of.

We received several papers that dealt with a wide variety of applications of energy harvesting communications such as relay networks, wireless sensor networks, interference and multiple access networks, etc. We also received several papers that dealt with the larger problem of energy-efficient communications on general topics such as adaptive power allocation in orthogonal frequency division multiple access (OFDMA) networks, and on specific topics related to the energy-efficient design of standards such as IEEE 802.16e WiMAX.

The papers in this issue are divided into the following three categories. These categories highlight some interesting and fruitful research on energy harvesting, and hopefully open the doors for further research in this promising area.

The first category deals with point-to-point energy harvesting systems, and contains the following two papers:

- In "Optimal packet scheduling for energy harvesting sources on time varying wireless channels," Kashef and Ephremides study the optimal transmission scheduling for a wireless energy harvesting transmitter to maximize the throughput over the time-varying channel. The problem is formulated as a Markovian decision programming for which a threshold type policy is proved to be optimal.
- In "A general framework for the optimization of energy harvesting communication systems with battery imperfections," Devillers and Gunduz consider a single-user energy harvesting link and develop a general framework for power allocation to maximize the throughput under various constraints, including energy leakage and time-varying battery size.

The second category deals with energy harvesting systems over shared channels and contains the following four papers:

- In "Optimal packet scheduling in a multiple access channel with energy harvesting transmitters," Yang and Ulukus study the optimal power and rate allocation for a two-user Gaussian multiple access channel with energy harvesting transmitters to minimize the transmission time of delivering a target number of data packets. Structural properties of the optimal solution are derived, based upon which an efficient algorithm is found to solve the problem optimally.
- In "Sum-rate optimal power policies for energy harvesting transmitters in an interference channel," Tutuncuoglu and Yener consider interference channels and develop a throughput maximizing power allocation algorithm based on a coordinate ascent approach. The authors also develop online and distributed near-optimal policies.
- In "Optimal utilization of a cognitive shared channel with a rechargeable primary source node," Pappas, Jeon, Ephremides, and Traganitis consider a cognitive radio setup where the primary nodes are powered by a rechargeable battery, while the secondary nodes have a power supply with no energy limitations. A random access scheme is proposed for secondary node access and the throughput is maximized through a proper selection of the access probability.
- In "Using range extension cooperative transmission in energy harvesting wireless sensor networks," Jung and Ingram study range extension cooperative transmission in multi-hop energy harvesting wireless sensor networks from a network layer perspective and show that more nodes and more frequent data collection can be supported.

The third category deals with energy-efficient techniques, and contains the following two papers:

- In "Dynamic-alternately power saving scheme for IEEE 802.16e mobile broadband wireless access systems," Chang and Lin present a dynamic sleep interval scheduling algorithm that takes into account different classes of traffic, and attempt to strike a balance between power saving and packet delay for a mobile subscriber station in IEEE 802.16e WiMAX systems.

- In "Energy efficient sequential sensing in multi-user cognitive ad hoc networks: A consideration of an ADC device," Gan considers energy consumption of A/D convertors (ADC) for spectrum sensing in cognitive radio networks and derives the optimal ADC sampling rate and sensing time for different network configurations.

Before we close, we would like to express our sincere thanks to JCN staff Yumin Hur for helping us throughout the entire process of preparing this special issue, for her constant reminders that kept us on our toes, and for her patience when we were late. We would also like to sincerely thank the reviewers for their expert reviews.

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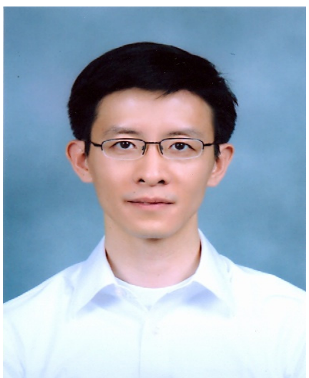
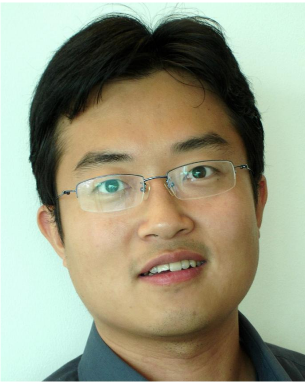


Kaibin Huang received the B.Eng. (first-class hons.) and the M.Eng. from the National University of Singapore in 1998 and 2000, respectively, and the Ph.D. degree from The University of Texas at Austin (UT Austin) in 2008, all in Electrical Engineering. Since Mar. 2009, he has been an assistant professor in the School of Electrical and Electronic Engineering at Yonsei University, Seoul, Korea. From Jun. 2008 to Feb. 2009, he was a Postdoctoral Research Fellow in the Department of Electrical and Computer Engineering at the Hong Kong University of Science and Technology. From Nov. 1999 to Jul. 2004, he was an Associate Scientist at the Institute for Infocomm Research in Singapore. He frequently serves on the technical program committees of major IEEE conferences in wireless communications. Recently, he is the technical co-chair for IEEE CTW 2013, the track chair for IEEE Asilomar 2011, and the track co-chair for IEE VTC Spring 2013 and IEEE WCNC 2011. He is an editor for the IEEE Wireless Communications Letters and also Journal of Communication and Networks. He received the Outstanding Teaching Award from Yonsei, Motorola Partnerships in Research Grant, the University Continuing Fellowship at UT Austin, and a Best Paper award at IEEE GLOBECOM 2006. His research interests focus on the analysis and design of wireless networks using stochastic geometry and multi-antenna limited feedback techniques.



Rui Zhang received the B.Eng. (First-Class Hons.) and M.Eng. degrees from the National University of Singapore in 2000 and 2001, respectively, and the Ph.D. degree from the Stanford University, Stanford, CA USA, in 2007, all in electrical engineering. Since 2007, he has worked with the Institute for Infocomm Research, A*STAR, Singapore, where he is now a Senior Research Scientist. Since 2010, he has also held an Assistant Professorship position with the Department of Electrical and Computer Engineering at the National University of Singapore. He has authored/coauthored over 100 internationally refereed journal and conference papers. His current research interests include wireless communications (e.g., multiuser MIMO, cognitive radio, cooperative communication, energy efficiency and energy harvesting), wireless power and information transfer, smart grid, and optimization theory for applications in communication and power networks. Dr. Zhang was the co-recipient of the Best Paper Award from the IEEE PIMRC (2005). He was Guest Editors of the EURASIP Journal on Applied Signal Processing Special Issue on Advanced Signal Processing for Cognitive Radio Networks (2010), the Journal of Communications and Networks (JCN) Special Issue on Energy Harvesting in Wireless Networks (2011), and the EURASIP Journal on Wireless Communications and Networking Special Issue on Recent Advances in Optimization Techniques in Wireless Communication Networks (2012). He has also served for various IEEE conferences as Technical Program Committee (TPC) members and Organizing Committee members. He was the recipient of the 6th IEEE ComSoc Asia-Pacific Best Young Researcher Award (2010), and the Young Investigator Award of the National University of Singapore (2011). He is an elected member for IEEE Signal Processing Society SPCOM Technical Committee.

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Leandros Tassiulas is Professor of Telecommunication Networks in the Department of Computer Engineering and Communications at the University of Thessaly Greece since 2002 and Associate Director of the Informatics and Telematics Institute of the Center for Research and Technology Hellas (CERTH). He holds a Diploma in Electrical Engineering from the Aristotelian Univ. of Thessaloniki, Greece, in 1987, and a Ph.D. degree in Electrical Engineering from the Univ. of Maryland, College Park in 1991. He has held positions as Assistant Professor at Polytechnic University New York (1991-95), Assistant and Associate Professor Univ. of Maryland College Park (1995-2001) and Professor Univ. of Ioannina Greece (1999-2001). He has been visiting researcher at IBM T. J. Watson research center in 1999 and in Flarion Technologies in 2003. His research interests are in the field of computer and communication networks with emphasis on fundamental mathematical models and algorithms, architectures and protocols of wireless systems, sensor networks, novel internet architectures and satellite communications. His contributions include foundational models and algorithms for network resource allocation as well as architectures and protocols for specific wireless technologies. His research has been recognized by several awards including the inaugural INFOCOM 2007 Achievement Award "For fundamental contributions to resource allocation in communication networks," the INFOCOM 1994 best paper award, a National Science Foundation (NSF) Research Initiation Award in 1992, an NSF CAREER Award in 1995, an Office of Naval Research Young Investigator Award in 1997 and a Bodosaki Foundation award in 1999.