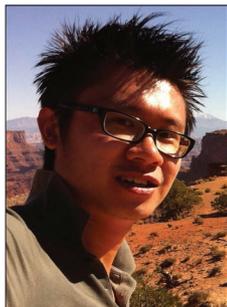


ENERGY HARVESTING COMMUNICATIONS: PART 2



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Over the last decade, energy harvesting has emerged as a promising approach to enable self-sufficient and self-sustaining operation for devices in energy-constrained networks by scavenging energy from the ambient environment to power up devices.

In particular for wireless sensor networks, if sensors, which spread throughout a home or factories, in buildings, or even outdoors, are powered by energy harvesting, there are no batteries to replace and no labor costs associated with replacing them. For a cellular network, energy harvesting can be used to provide power in many elements of a telecom network, saving considerable costs in electricity supply, and providing low maintenance monitoring. As another important focus, RF energy is currently broadcast from billions of radio transmitters around the world. The ability to harvest RF energy from ambient or dedicated sources enables wireless charging of low-power devices and has significant benefits for product design, usability, and reliability.

This Feature Topic focuses on energy harvesting related issues in communications, through presenting a holistic view of research challenges and opportunities in the emerging area of energy harvesting communications. We hope this Feature Topic is able to help readers obtain better understanding of some key issues in energy harvesting, and drive more research interests. The Feature Topic has three parts, with 10 accepted papers presented in Part 1, nine accepted papers included in Part 2, and four accepted papers to appear in Part 3.

The second part of this Feature Topic starts with an article “Toward Self-Sustainable Cooperative Relays: State-of-the-Art and the Future,” by Kuang-Hao Liu *et al.*, examines the current progress in energy harvesting relays with special emphasis on wireless power transfer through RF signals that carry both information and energy at the same time.

The article “RF-Powered Cellular Networks: Key Challenges and Solution Techniques,” by H. Tabassum *et al.*, surveys the related research advancements in RF-powered cellular networks and their limitations, as well as design considerations for RF-powered cellular networks that can

potentially tackle the major challenges and open up new research directions.

The article “Wireless Energy Harvesting in Interference Alignment Networks,” written by Nan Zhao *et al.*, presents an overview of wireless energy harvesting in interference alignment networks, and provides a unified framework to jointly study wireless energy harvesting and interference alignment.

The article “A Survey of Energy Harvesting Communications: Models and Offline Optimal Policies,” by Yejun He *et al.*, reviews the different ways of harvesting the ambient energy in energy harvesting communications and the models of energy harvesting communications.

The article “Cutting the Last Wires for Mobile Communication by Microwave Power Transfer,” by Kaibin Huang *et al.*, provides an introduction to wireless powered communications by describing the key features of wireless powered communications, shedding light on a set of frequently asked questions, and identifying the key design issues and discussing possible solutions.

The article “Energy Harvesting Small Cell Networks: Feasibility, Deployment and Operation,” by Yuyi Mao *et al.*, conducts a comprehensive study of energy harvesting small cell networks, and investigates important aspects, including the feasibility analysis, network deployment, and network operation issues.

The article “Wireless Energy Harvesting for Internet of Things,” written by Pouya Kamalinejad *et al.*, summarizes enabling technologies for efficient wireless energy harvesting units, analyzes the lifetime of wireless energy harvesting enabled Internet of Things devices, briefly studies future trends in the design of efficient wireless energy harvesting systems, and specifies research challenges that lie ahead.

The article “Joint Wireless Information and Energy Transfer in Massive Distributed Antenna Systems,” by Fangchao Yuan *et al.*, discusses the research opportunities in the joint wireless information and energy transfer in massive distributed antenna system.

The article “When Telecommunication Networks Meet Energy Grids: Cellular Networks with Energy Harvesting

and Trading Capabilities,” written by Davide Zordan *et al.*, presents recent developments in energy harvesting, the way future energy markets are expected to evolve, and the new fundamental trade-offs that arise when energy can be traded.

BIOGRAPHIES

CHAU YUEN (yuenchau@sutd.edu.sg) received his B. Eng and Ph.D. degrees from Nanyang Technological University, Singapore, in 2000 and 2004, respectively. He was a postdoctoral fellow at Lucent Technologies Bell Labs, Murray Hill, New Jersey, during 2005. He was a visiting assistant professor at Hong Kong Polytechnic University in 2008. During the period of 2006–2010, he worked at the Institute for Infocomm Research, Singapore, as a senior research engineer. He joined Singapore University of Technology and Design as an assistant professor in June 2010. He serves as an Associate Editor for *IEEE Transactions on Vehicular Technology* and was awarded Top Associate Editor for three consecutive years. In 2012, he received the IEEE Asia-Pacific Outstanding Young Researcher Award. He has held positions on several conference organizing committees, and is on Technical Program Committees of various international conferences.

MAGED ELKASHLAN received his Ph.D. degree in electrical engineering from the University of British Columbia, Canada, in 2006. From 2006 to 2007, he was with the Laboratory for Advanced Networking at the University of British Columbia. From 2007 to 2011, he was with the Wireless and Networking Technologies Laboratory at the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia. He also held an adjunct appointment at the University of Technology Sydney, Australia, between 2008 and 2011. In 2011, he joined the School of Electronic Engineering and Computer Science at Queen Mary, University of London, United Kingdom, as an assistant professor. His research interests include millimeter wave communications, energy harvesting, cognitive radio, and wireless security. He currently serves as an Editor for *IEEE Transactions on Wireless Communications*, *IEEE Transactions on Vehicular Technology*, and *IEEE Communications Letters*. He received Best Paper awards at IEEE ICC '14, International Conference on Communications and Networking in China in 2014, and IEEE VTC-Spring 2013. He received the Exemplary Reviewer Certificate of *IEEE Communications Letters* in 2012.

YI QIAN [M'95, SM'07] is an associate professor in the Department of Electrical and Computer Engineering, University of Nebraska-Lincoln (UNL). 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 technical advisor at Nortel Networks, a senior systems engineer and technical advisor at several startup companies, an assistant professor at the University of Puerto Rico at Mayaguez, and a senior researcher at the National Institute of Standards and Technology. 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, smart grid communication networks, broadband satellite networks, optical networks, high-speed networks, and the Internet. He has a successful track record in 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 in the IEEE Digital Library. He is the current Chair of the Communications and Information Security Technical Committee in the IEEE Communications Society. He is an IEEE Distinguished Lecturer.

TRUNG Q. DUONG received his Ph.D. degree in telecommunications systems from Blekinge Institute of Technology (BTH), Sweden, in 2012, and then continued working at BTH as a project manager. Since 2013, he has joined Queen's University Belfast, United Kingdom, as a lecturer (assistant professor). He held visiting positions at Polytechnic Institute of New York University and Singapore University of Technology and Design in 2009 and 2011, respectively. His current research interests include cooperative communications, cognitive radio networks, green communications, physical layer securi-

ty, massive MIMO, cross-layer design, mmWave communications, and localization for radios and networks. He has been a TPC chair for several IEEE international conferences and workshops, including most recently the IEEE GLOBECOM '13 Workshop on Trusted Communications with Physical Layer Security. He currently serves as an Editor for *IEEE Communications Letters* and *Wiley Transactions on Emerging Telecommunications Technologies*. He served as Lead Guest Editor of the Special Issue on Location Awareness for Radios and Networks of the *IEEE Journal on Selected Areas in Communications*, Lead Guest Editor of the Special Issue on Secure Physical Layer Communications of *IEEE Communications*, Guest Editor of the Special Issue on Green Media: Toward Bringing the Gap between Wireless and Visual Networks of *IEEE Wireless Communications*, Guest Editor of the Special Issue on Millimeter Wave Communications for 5G of *IEEE Communications Magazine*, Guest Editor of the Special Issue on Cooperative Cognitive Networks of the *EURASIP Journal on Wireless Communications and Networking*, and Guest Editor of the Special Issue on Security Challenges and Issues in Cognitive Radio Networks of the *EURASIP Journal on Advances Signal Processing*. He was awarded the Best Paper Award at IEEE VTC-Spring '13 and the Exemplary Reviewer Certificate of *IEEE Communications Letters* in 2012.

LEI SHU [M] received his B.Sc. degree in computer science from South Central University for Nationalities, China, in 2002, his M.Sc. degree in computer engineering from Kyung Hee University, Korea, in 2005, and his Ph.D. degree from the Digital Enterprise Research Institute, National University of Ireland, Galway, Ireland, in 2010. Until March 2012, he was a specially assigned researcher in the Department of Multimedia Engineering, Graduate School of Information Science and Technology, Osaka University, Japan. He is a member of IEEE IES, IEEE ComSoc, EAI, and ACM. In October 2012, he joined Guangdong University of Petrochemical Technology, China, as a full professor. In 2013, he started to serve Dalian University of Technology as a Ph.D. supervisor in the College of Software, Beijing University of Posts and Telecommunications as a Master's supervisor in information and communication engineering, Wuhan University as a Master's supervisor in the College of Computer Science, guest professor at Tianjin University of Science and Technology, and a guest researcher at Guangzhou Institute of Advanced Technology, Chinese Academy of Sciences. Meanwhile, he is also working as vice-director of the Guangdong Provincial Key Laboratory of Petrochemical Equipment Fault Diagnosis, China. He is the founder of the Industrial Security and Wireless Sensor Networks Lab. His research interests include wireless sensor networks, multimedia communication, middleware, fault diagnosis, and security. He has published over 230 papers in related conferences, journals, and books in the area of sensor networks. Currently, his H-index is 21 in Google Citation. Total citations of his papers by other people are more than 1600. He developed an open source wireless sensor networks simulator, NetTopo, to evaluate and demonstrate algorithms. NetTopo has been downloaded more than 3420 times over the past three years, and is widely used by international researchers and students. He was awarded the MASS 2009 IEEE TCs Travel Grant and the Outstanding Leadership Award of EUC 2009 as Publicity Chair, GLOBECOM 2010, and ICC 2013, the ComManTel 2014 Best Paper Award, and the Outstanding Service Award of IUCC 2012 and ComcomAP 2014. He also received a few more awards from the Chinese government: Top Level Talents in “Sailing Plan” of Guangdong Province, China, and Outstanding Young Professor of Guangdong Province, China. He has been serving as Editor-in-Chief for *EAI Endorsed Transactions on Industrial Networks and Intelligent Systems*, and Associate Editor for *IEEE Access*, *ACM/Springer Wireless Networks*, *Journal of Network and Computer Applications*, *Transactions on Emerging Telecommunications Technology*, and several other publications. He has served as Co-Chair for many international conferences. He has obtained more than 4 million RMB in research grants since October 2012.

FRANK SCHMIDT is a pioneer in energy harvesting and the visionary in the management team of EnOcean. As chief technology officer he is responsible for the overall technical orientation, patent related activities, as well as the relationship management with educational, research and scientific organizations. Before joining EnOcean he was at the Central Research Department of Siemens AG, where he created self-powered wireless sensor technology as early as 1995. He has been granted more than 40 patents for his energy harvesting inventions and is the author of numerous technical publications in this field. He is a physicist and studied at the Technical University of Chemnitz, Germany.