Tutorial T-6: Energy Harvesting and Energy Cooperation in Wireless Communications

Presenters: Sennur Ulukus (University of Maryland, USA), Aylin Yener (Penn State University, USA)

Tutorial Overview

The goal of this tutorial is to furnish the attendees with the mathematical foundations of energy harvesting wireless communication networks. As being green in our everyday lives is becoming more and more of a necessity, wireless communication devices and networks including wireless ad-hoc and sensor networks will turn into greener solutions, not only with respect to conserving energy in transmission and processing, but also through obtaining the energy needed for operation through external sources. Utilizing harvested ambient energy for operation of wireless networks is a crucial step in building next generation green and energy self-sufficient communication systems. This will improve the environmental impact of wireless devices in the global scale, while extending the network lifetime indefinitely and making the devices truly mobile in the network.
This tutorial will describe the new breed of "energy harvesting" wireless networks and their design fundamentals. Energy harvesting wireless networks present new challenges for communication system design: the harvested energy is variable and may be scarce, requiring tailored transmission policies to achieve the desired performance. For this reason, it is important to model and analyze energy harvesting wireless nodes starting from the physical layer performance limits to medium access and network layer solutions, all of which will be covered in this tutorial. In addition, energy cooperation, through wireless energy transfer, will be introduced and covered which enables controlled and optimized energy harvesting from man-made resources, and introduces both exciting new applications in practice, and challenging research problems.

The outline of the proposed tutorial is given below.
1. Brief review of energy efficient communications for conventional wireless systems
2. Energy harvesting communications: motivation, introduction and formulation
3. Transmission scheduling to minimize transmission completion time
4. Transmission scheduling to maximize throughput
5. Energy causality and no-energy-overflow constraints: energy feasibility tunnel
6. Directional water-filling for energy harvesting communications
7. Off-line and on-line algorithms
8. Energy harvesting communications in fading channels
9. Energy harvesting multiple access, broadcast, interference and relay channels
10. Energy storage imperfections and their impact on optimal transmission policies
11. Energy cooperation via wireless energy transfer
12. Joint energy and data routing policies for energy harvesting wireless communications
13. Capacity of energy harvesting communications
14. Emerging research directions and open problems

Presenter Biographies
Sennur Ulukus is a Professor of Electrical and Computer Engineering at the University of Maryland at College Park, where she also holds a joint appointment with the Institute for Systems Research (ISR). Prior to joining UMD, she was a Senior Technical Staff Member at AT&T Labs-Research. She received her Ph.D. degree in Electrical and Computer Engineering from Wireless Information Network

Laboratory (WINLAB), Rutgers University, and B.S. and M.S. degrees in Electrical and Electronics Engineering from Bilkent University. Her research interests are in wireless communication theory and networking, network information theory for wireless communications, signal processing for wireless communications, information theoretic physical layer security, and energy harvesting communications.

Dr. Ulukus received the 2003 IEEE Marconi Prize Paper Award in Wireless Communications, an 2005 NSF CAREER Award, the 2010-2011 ISR Outstanding Systems Engineering Faculty Award, and the 2012 George Corcoran Education Award. She served as an Associate Editor for the IEEE Transactions on Information Theory (2007-2010) and IEEE Transactions on Communications (2003-2007). She served as a Guest Editor for the IEEE Journal on Selected Areas in Communications for the special issue on wireless communications powered by energy harvesting and wireless energy transfer (2015), Journal of Communications and Networks for the special issue on energy harvesting in wireless networks (2012), IEEE Transactions on Information Theory for the special issue on interference networks (2011), IEEE Journal on Selected Areas in Communications for the special issue on multiuser detection for advanced communication systems and networks (2008). She served as the TPC co-chair of the 2014 IEEE PIMRC, Communication Theory Symposium at 2014 IEEE Globecom, Communication Theory Symposium at 2013 IEEE ICC, Physical-Layer Security Workshop at 2011 IEEE Globecom, Physical-Layer Security Workshop at 2011 IEEE ICC, 2011 Communication Theory Workshop (IEEE CTW), Wireless Communications Symposium at 2010 IEEE ICC, Medium Access Control Track at 2008 IEEE WCNC, and Communication Theory Symposium at 2007 IEEE Globecom. She was the Secretary of the IEEE Communication Theory Technical Committee (CTTC) in 2007-2009.

Aylin Yener received the B.Sc. degree in electrical and electronics engineering, and the B.Sc. degree in physics, from Bogazici University, Istanbul, Turkey; and the M.S. and Ph.D. degrees in electrical and computer engineering from Wireless Information Network Laboratory (WINLAB), Rutgers University, New Brunswick, NJ. She is a professor of Electrical Engineering at The Pennsylvania State University, University Park, PA since 2010, where she joined the faculty as an assistant professor in 2002. During the academic year 2008-2009, she was a Visiting Associate Professor with the Department of Electrical Engineering, Stanford University, CA. Her research interests are in information theory, communication theory and network science with recent emphasis on energy harvesting green wireless communications and information security. Dr. Yener received the NSF CAREER award in 2003, the best paper award in Communication Theory in the IEEE International Conference on Communications in 2010, the Penn State Engineering Alumni Society (PSEAS) Outstanding Research Award in 2010, the IEEE Marconi Prize paper award in 2014, the PSEAS Premier Research Award in 2014, and the Leonard A. Doggett Award for Outstanding Writing in Electrical Engineering at Penn State in 2014.

Dr. Yener has been the treasurer (2012-2014), and currently serves on the Board of Governors (2015-2017) of the IEEE Information Theory Society. She served as the student committee chair for the IEEE Information Theory Society 2007-2011, and was the co-founder of the Annual School of Information Theory in North America. She was a technical (co)-chair for various symposia/tracks at IEEE ICC , WCNC, PIMRC, VTC and Asilomar (2005-2014). She was as an editor for IEEE Transactions on Communications (2009-2012), an editor/editorial advisory board member for IEEE Transactions on Wireless Communications (2001-2012), a guest editor for IEEE Transactions on Information Forensics and Security (2011) and for IEEE Journal on Selected Areas in Communications (2015).