IEEE ACCESS Special Section Editorial: Energy Harvesting and Scavenging: Technologies, Algorithms, and Communication Protocols
Mubashir Husain Rehmani, Ayaz Ahmad, Abderrezak Rachedi, Soumaya Cherkaoui, Kok-Lim Alvin Yau

To cite this version:
Mubashir Husain Rehmani, Ayaz Ahmad, Abderrezak Rachedi, Soumaya Cherkaoui, Kok-Lim Alvin Yau. IEEE ACCESS Special Section Editorial: Energy Harvesting and Scavenging: Technologies, Algorithms, and Communication Protocols. IEEE Access, IEEE, 2018, 6, pp.13461-13465. 10.1109/ACCESS.2018.2805538. hal-01857437

HAL Id: hal-01857437
https://hal.archives-ouvertes.fr/hal-01857437
Submitted on 16 Aug 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
IEEE ACCESS SPECIAL SECTION EDITORIAL:
Energy Harvesting and Scavenging: Technologies, Algorithms, and Communication Protocols

The operation of modern electronic communication devices relies on constant energy sources such as DC power, obtained from AC sources via AC to DC conversion, or small chargeable/replaceable batteries. However, in some cases, providing constant energy sources may not be feasible. Advanced energy harvesting technologies can be used to power up modern day electronic communication devices [item 1) in the Appendix]. These energy harvesting technologies rely on energy sources naturally present in the environment, such as solar energy, wind energy, and heat [item 2) in the Appendix]. Moreover, energy can also be acquired from the movement of different parts of the human body such as legs (walking), heart (beating) and arms (swinging), just to name a few. All these energy harvesting technologies and techniques may satisfy the need of energy for low power communication devices and may enable the charging of electronic mobile devices anywhere and at any time [item 3) in the Appendix].

In this Special Section in IEEE ACCESS, we focus on the most recent advances in several interdisciplinary research areas encompassing the energy harvesting domain. This Special Section has brought together researchers from diverse fields and specializations, such as communications engineering, computer science, electrical and electronics engineering, bio-medical engineering, education sector, mathematics and specialists in the areas related to energy harvesting technologies.

This Special Section includes 15 high-quality articles from leading researchers around the globe. Among those, one is the invited article entitled “Electric-field energy harvesting from lighting elements for battery-less Internet of Things” by Cetinkaya et al., which focuses on energy harvesting for Internet of Things (IoT).

The aim of IoT is to connect every device to the Internet. Many of the IoT devices will be battery operated, and so energy is a major concern for smooth operation [item 4) in the Appendix]. Monitoring and replacing the batteries of these thousands of IoT devices would be difficult; therefore, energy harvesting techniques have been proposed to meet their energy demands [item 5) in the Appendix]. Though there exist several energy harvesting techniques, in this article by Cetinkaya et al., authors propose a completely new energy harvesting paradigm i.e., to utilize the ambient electric field present in the vicinity of lighting elements. Authors designed the physical model and circuit diagram along with a prototype to demonstrate their approach. Authors also demonstrated that 1.5 J of energy can be gathered in a 30 minute period through a copper plate.

In the article entitled “Far-field RF wireless power transfer with blind adaptive beamforming for Internet of Things devices,” Yedavalli et al., propose a wireless power transfer method for IoT devices using the concept of radio frequency beamforming in the radiative far field. In fact, a blind adaptive beamforming algorithm has been proposed for wireless power transfer for the IoT devices. The proposed algorithm is computationally light as it does not rely on channel state information. Authors validated the proposed algorithm using a test bed composed of multiple antennas based on software defined radio. They showed that the harvested power is increased with beamforming and that the gain can be increased by increasing the number of antennas.

Wireless sensor networks (WSNs) are composed of tiny battery operated wireless sensor devices [item 9) in the Appendix]. When the sensor devices use solar energy, a question arises as to how much energy will be available in the future depending on weather conditions. In the article entitled “A new energy prediction algorithm for energy-harvesting wireless sensor networks with Q-learning” by Selahattin Kosunalp, the author proposed a Q-Learning based solar energy prediction algorithm for wireless sensor devices. One of the features of the proposed Q-Learning algorithm is that it does not only consider past weather conditions but it also accounts for current weather conditions in the solar energy prediction process.

In order to decrease the carbon footprint of WSNs, energy harvesting techniques have been proposed. In the article entitled “Optimal power control in green wireless sensor networks with wireless energy harvesting, wake-up radio and transmission control” by Mahapatra et al., authors propose...
a wake-up radio scheme, an error control scheme, and an energy harvesting scheme to decrease the carbon footprint of WSNs. More precisely, authors formulated a utility lifetime maximization problem using a distributed dual sub-gradient algorithm based on Lagrange Multiplier method to decrease the carbon footprint of WSNs.

In the article entitled “Optimal recharging with practical considerations in wireless rechargeable sensor network” by Rao et al., authors considered a WSN in which a mobile charging vehicle is responsible for scheduled charging of the WSN. Authors considered both the charging distance and the angle while recharging the sensor nodes. Furthermore, authors proved that the charging vehicle would travel the shortest distance i.e., Hamiltonian distance. Additionally, through the proposed scheme, the charging efficiency has been improved by two times.

In the article entitled “Maximizing lifetime in wireless sensor network for structural health monitoring with and without energy harvesting” by Mansourkiaie et al., authors considered a WSN for structural health monitoring application. Authors proposed an optimization framework to improve the network lifetime of WSNs. They proposed two heuristic routing algorithms by using integer non-linear programming to formulate the problem and used Branch and Bound space algorithm to solve it. Authors considered both cases i.e., with and without energy harvesting, while evaluating the proposed heuristics.

In the article entitled “Outage analysis of wireless-powered relaying mimo systems with non-linear energy harvesters and imperfect CSI” by Zhang et al., authors considered a wireless powered relay network having multiple-input multiple-output system. Both energy harvesting and information decoding mechanisms are performed simultaneously at the relay node. Authors investigated the outage performance by considering that imperfect channel state information is available at both the source and destination nodes.

In the article entitled “Precoding design of mimo amplify-and-forward communication system with an energy harvesting relay and possibly imperfect CSI” by Benkhelifa et al., authors considered simultaneous wireless information and power transfer (SWIPT) in a MIMO system. Authors considered both the ideal and practical schemes and explored the rate-stored energy (R-E) tradeoff region.

In the article entitled “Energy-efficient power allocation in energy harvesting two-way AF relay systems” by Zhang et al., authors considered two-way amplify and forward relay systems and addressed the issue of energy efficiency optimization by using energy harvesting. Authors used non-linear fractional programming and Karush-Kuhn-Tucker conditions, and thus achieved a closed-form solution.

In the article entitled “Joint downlink/uplink design for wireless powered networks with interference” by Diamantoulakis et al., authors addressed the cascaded near-far problem. The cascaded near-far problem arises due to different path loss values and it degrades the users’ performance in a wireless network. Authors considered TDMA and NOMA for the uplink communication and rely on SWIPT.

Network coding is a technique wherein packets are encoded and decoded at intermediate nodes to achieve a gain in throughput and capacity. The technique has been widely used to improve the performance of different wireless networks such as cognitive radio networks [item 7) in the Appendix] and vehicular ad hoc networks [item 8) in the Appendix]. Network coding has also been applied to wireless networks in conjunction with energy harvesting. In the article entitled “Delay and energy tradeoff in energy harvesting multi-hop wireless networks with inter-session network coding and successive interference cancellation” by Liu et al., authors propose a cross layer framework that jointly considers scheduling, routing, and network coding for multi-hop wireless networks.

In the article entitled “Distributed user association in energy harvesting dense small cell networks: a mean-field multi-armed bandit approach” by Maghsudi et al., authors propose an energy harvesting scheme based on game theory. Authors considered a mean-field multi-armed bandit game to solve the uplink user association problem for the ultra-dense small cell network.

In the article entitled “SURE: A novel approach for self-healing battery starved users using energy harvesting” by Selim et al., authors propose a self-healing scheme for user equipment. In fact, authors propose an energy harvesting technique between the network operator and a battery starved user. The proposed scheme relies on radio frequency (RF) energy harvesting in which the network operator delivers energy to the users which require energy.

In the second to last article of this Special Section entitled “Performance limits of online energy harvesting communications with noisy channel state information at the transmitter” by Zenaidi et al., authors propose a Markov process that models the energy arrival process in a wireless network. Authors also studied the asymptotic behavior of the communication system while considering high and low recharge rate regimes.

The last article of this Special Section is entitled “Capacity region of Gaussian multiple-access channels with energy harvesting and energy cooperation” by Dong et al. In this article, authors considered K-user multiple access channels and derived the capacity region of this channel.

**ACKNOWLEDGEMENT**

We would like to sincerely thank all the authors and reviewers for their tremendous efforts towards the success of this Special Section. We would also like to thank to the Editor-in-Chief, Prof. Michael Pecht, and the Editorial Office, including the Managing Editor, B. M. Onat, K. Shumard, and M. Meyer, for their help in the success of this Special Section.

MUBASHIR HUSAIN REHMANI, Post Doctoral Researcher
COMSATS Institute of Information Technology
Wah Cantt., Pakistan
AYAZ AHMAD, Assistant Professor
COMSATS Institute of Information Technology
Wah Cantt., Pakistan

ABDERREZAK RACHEDI, Associate Professor
University Paris Est, France

SOUMAYA CHERKAOUI, Professor
Université de Sherbrooke, Canada

KOK-LIM ALVIN YAU, Associate Professor
Sunway University, Malaysia

APPENDIX

RELATED WORKS


MUBASHIR HUSAIN REHMANI (M’14–SM’15) received the B.Eng. degree in computer systems engineering from the Mehran University of Engineering and Technology, Jamshoro, Pakistan, in 2004, the M.S. degree from the University of Paris XI, Paris, France, in 2008, and the Ph.D. degree from the University Pierre and Marie Curie, Paris, in 2011. He was an Assistant Professor for five years at the COMSATS Institute of Information Technology, Wah Cantt, Pakistan. He was a Post-Doctoral Fellow with the University of Paris Est, France, in 2012. His current research interests include cognitive radio ad hoc networks, smart grid, wireless sensor networks, and mobile ad hoc networks. He has authored/edited two books published by IGI Global, USA, one book published by CRC Press, USA, and one book is in progress with Wiley, U.K. Dr. Rehmani served on the TPC for IEEE ICC 2016, IEEE GLOBECOM 2016, CROWNCOM 2016, IEEE VTC Spring2016, IEEE ICC 2015, IEEE WoWMoM 2014, IEEE ICC 2014, ACM CoNEXT Student Workshop 2013, IEEE ICC 2013, and IEEE IWCMC 2013 conferences. He is currently an Editor of the IEEE COMMUNICATIONS SURVEYS AND TUTORIALS and an Associate Editor of the IEEE Communications Magazine, the IEEE Access journal, the Elsevier Computers and Electrical Engineering journal, the Elsevier Journal of Network and Computer Applications, the Ad Hoc Sensor Wireless Networks journal, the Springer Wireless Networks Journal, the KSII Transactions on Internet and Information Systems, and the Journal of Communications and Networks. He is also serving as a Guest Editor for the Elsevier Ad Hoc Networks journal, the Elsevier Future Generation Computer Systems journal, the IEEE Access journal, the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, the Elsevier Pervasive and Mobile Computing journal, and the Elsevier Computers and Electrical Engineering journal. He is the Founding Member of the IEEE Special Interest Group on Green and Sustainable Networking and Computing with Cognition and Cooperation. He received the Best Researcher of the Year 2015 of COMSATS Wah Award in 2015. He received the certificate of appreciation, Exemplary Editor of the IEEE Communications Surveys and Tutorials for the year 2015 from the IEEE Communications Society. He received the Best Paper Award from the IEEE ComSoc Technical Committee on Communications Systems Integration and Modeling in 2017.
AYAZ AHMAD (S’08–M’15–SM’16) received the B.Sc. degree in electrical engineering from the University of Engineering and Technology, Peshawar, Pakistan, in 2006, and the M.S. and Ph.D. degrees in telecommunication from Ecole Superieure d’Electricite (Supelec), Gif-sur-Yvette, France, in 2008 and 2011, respectively. From 2006 to 2007, he was a Faculty Member with the Department of Electrical Engineering, FAST-NUCES, Peshawar. He is currently an Assistant Professor with the Department of Electrical Engineering, COMSATS Institute of Information Technology, Wah Cantt, Pakistan. He has several years of research experience and has authored or co-authored several scientific publications in various refereed international journals and conferences. He has also authored or co-authored several book chapters, and is the Leading Co-Editor of the book *Smart Grid as a Solution for Renewable and Efficient Energy* published in 2016. He is Associate Editor with IEEE Access and Springer *Human-centric Computing and Information Sciences*. He received the best research paper award from Higher Education Commission of Pakistan for the years 2015–2016. His research interests include resource allocation in wireless communication systems, energy management in smart grid, and the application of optimization methods to engineering problems. He has also served as the Lead Guest Editor of a special issue on Optimization for Emerging Wireless Networks for the IEEE ACCESS. He is serving as a TPC member for several international conferences, including IEEE GLOBECOM and IEEE PIMRC, and as a reviewer for several renowned international journals. He is a member of the IEEE Communication Society.

ABDERREZAK RACHEDI (S’05–M’08–SM’15) received the engineering degree in computer science from the University of Science and Technology Houari Boumedienne, Algiers, Algeria, in 2002, the M.S. degree in computer science from the University of Savoie, Chambéry, France, in 2003, the Ph.D. degree in computer science from the University of Avignon, Avignon, France, in 2008, and the Habilitation to Direct Research (H.D.R.) degree in computer science from Paris- Est University, Champs-sur-Marne, France, in 2015. He has been a member of the Gaspard Monge Computer Science Laboratory since 2008. He is currently an Associate Professor (maitre de conferences) with the University Paris-Est Marne-la-Valleeé, Champs-sur-Marne, France. His research interests include wireless networking, wireless multihop networks, wireless sensor networks, vehicular ad hoc networks, machine-type communication, Internet of Things, distributed algorithms, the quality of services with security, trust models design, and network performance analysis and evaluation. He supervised multiple Ph.D. and master’s students in Paris-Est University. His research efforts have culminated in over 90 refereed journal, conference, and book publications in a wide variety of prestigious international conferences and journals, including the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, the Elsevier *Ad Hoc Networks*, the IEEE ICC, and the IEEE GLOBECOM. He serves as an Associate Editor for the IEEE ACCESS, and on the Editorial Board for *Wireless Communications and Mobile Computing* (John Wiley) journal, and the *International Journal of Communication Systems* (John Wiley). He has served as a technical program committee member and a reviewer of many international conferences and journals.

SOUMAYA CHERKAOUI is currently a Full Professor with the Department of Electrical and Computer Engineering, Université de Sherbrooke, Canada, which she joined in 1999. She is also the Director with the INTERLAB, a Research Laboratory which conducts research funded by government and industry. In 2005, she was appointed as an Adjunct Full Professor with Lulea University, Sweden. Before joining as a Faculty Member, she was a Project Leader on projects targeted at the Aerospace Industry. She was a Visiting Professor with the Department of Electrical Engineering, University of Toronto. In 2006, she was a Visiting Professor with the Centre of Distributed Systems and Software, Monash University, Australia, and with the Bell Laboratories, Toronto. In 2012, she was an Invited Visiting Scholar with the University of California at Berkeley. She has over 200 publications in reputable journals, conferences, and workshops in the area of communication networks. Her research and teaching interests include wireless networks. She particularly works on vehicular communications, cyber physical systems, machine-to-machine communications, and IoT. She has participated as a General Chair, an Editor, a Member of Technical Committee, the Session Chair, or a Program Committee Member of numerous conferences or referenced journals. In 2010, she was appointed as a member of the Board of Directors of the Canadian Network of Centers of Excellence Auto21, Canada, and a member of the Expert Advisory Panel of Precarn, Canada.
KOK-LIM ALVIN YAU received the B.Eng. degree (Hons.) in electrical and electronics engineering from Universiti Teknologi Petronas, Malaysia, in 2005, the M.Sc. degree in electrical engineering from the National University of Singapore in 2007, and the Ph.D. degree in network engineering from the Victoria University of Wellington, New Zealand, in 2010. He is currently an Associate Professor with the Department of Computing and Information Systems, Sunway University. He has authored or co-authored over 50 publications in international journals, book chapters, and conferences. He researches, lectures, and consults in cognitive radio, wireless networking, and applied artificial intelligence. He received the 2007 Professional Engineer Board of Singapore Gold Medal for being the best graduate of the M.Sc. degree in 2006/07. He serves as the Editor of the KSII Transactions on Internet and Information Systems, the Guest Editor of the IEEE ACCESS and IET Networks, and a regular reviewer for over 20 journals. He serves as a TPC and a reviewer for various major international conferences including ICC, VTC, LCN, GLOBECOM, and AINA. He also served as the General Co-Chair for IET ICFCNA’14 and Co-Chair Organizing Committee for IET ICWCA’12.