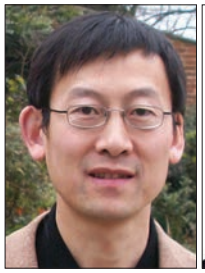
WIRELESS ENERGY TRANSFER IN FUTURE NETWORKS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With 5G starting to be commercially deployed, research on 6G mobile networks has started. One of the major key performance indicators for 6G is its extremely massive connectivity for small devices to enable the so-called Internet of Everything (IoE). Most of these IoE devices will be either battery-powered or battery-less. How to prolong the lifetime of these IoE devices becomes a key challenge. This calls for effort in two complementary areas:

1. Energy efficiency to reduce IoE device's energy consumption
2. Wireless energy transfer (WET) to open up new avenues to provide energy to IoE devices

The former area has been intensively researched under the banner of green communications. It is envisioned that 6G will utilize the latter to provide WET to massive IoE devices. Emerging 6G technologies such as THz and intelligent reflective surface (IRS) provide great potential to fulfill this vision of WET. For instance, higher THz frequencies will provide better directionality, which is more efficient for WET. Intelligent surfaces may be used actively or passively (using backscattering technique) to transmit or relay signals to IoE devices, enabling battery-less devices. IRS may also be manipulated to enable on-demand WET.

This Feature Topic (FT) is dedicated to presenting to the readership of *IEEE Communications Magazine* the latest advances in the area of WET in future networks. After impartial and rigorous reviews, five articles are selected to be contained in this FT. Both theoretical and experimental articles are included, covering new and emerging 6G communication technologies from different WET perspectives. This batch of articles serves to provide a holistic overview of some futuristic research directions of WET in collaboration with wireless information transfer (WIT). It is also our hope that this FT helps attract more attention from both academia and industry into this exciting field that has the potential to revolutionize our everyday life.

This FT commences with "Near-Field Wireless Power Transfer for 6G Internet of Everything Mobile Networks: Opportunities and Challenges" by H. Zhang *et al.* It studies WET in the Fresnel region of large-scale antennas in millimeter-wave (mmWave), which provides an efficient beam-focusing solution to recharging devices in near-field conditions. Moreover, the simultaneous operation with WIT, corresponding radiating waveforms, and typical antenna architectures are also discussed.

Orbital angular momentum (OAM) has been widely regarded as a new medium to substantially improve the WIT performance of future 6G. The second article, "OAM-SWIPT for IoE-Driven 6G" by R. Lyu *et al.*, innovatively discusses the potential of OAM in WET. This emerging paradigm can effectively provide sufficient degree of freedom in line-of-sight (LoS) radio frequency transmissions for the sake of achieving highly efficient WIT and WET. A dynamic power splitting scheme is also studied in an OAM-based WIT and WET system.

The third article, "Wireless Energy Transfer in RIS-Aided Cell-Free Massive MIMO Systems: Opportunities and Challenges" by E. Shi *et al.*, sees another widely regarded 6G technology, reconfigurable intelligent surfaces (RISs), being applied to WET. Both the operational modes and hardware design of RISs are discussed, while an optimal deployment of multiple RISs is exemplified.

The fourth article brings WET high into the sky by utilizing unmanned aerial vehicles (UAVs). Y. Wang *et al.* present a ground vehicular network based mobile recharging platform for UAVs in their article "Mobile Wireless Rechargeable UAV Networks: Challenges and Solutions." Both the security and privacy concerns are discussed, while an online double auction mechanism is developed for optimal recharging scheduling.

A ground-based mobile charging system is designed in "Robotic Wireless Energy Transfer in Dynamic Environments: System Design and Experimental Validation" by S. Wang *et al.* This mobile robot can be navigated through different regions in order to recharge energy harvesters deployed in a large area. By exploiting a hardware-in-the-loop joint optimization framework, this robotic WET system can avoid collisions with unknown obstacles in addition to satisfying WET requirements.

We would like to take this opportunity to thank all the anonymous reviewers for their effort and constructive comments, without which this FT would not have been possible. The same gratitude also goes to the former EiC (Prof. Tarek S. El-Bawab) and the current EiC (Dr. Antonio Sanchez-Esguevillas), for their integrity and patient guidance. Finally, we would like to thank all the authors for submitting their precious research work to this FT — we received more than 20 submissions, and the selection process was extremely competitive. We sincerely hope that the rejection of any submitted paper will not discourage its authors from carrying on researching in this exciting field and from submitting to this magazine.

BIOGRAPHIES

KUN YANG [SM'08] received his Ph.D. from University College London (UCL), UK. He is currently a Chair Professor at the University of Essex leading the Network Convergence Laboratory (NCL). Before joining the University of Essex in 2003, he worked at UCL on several European Union (EU) research projects for three years. His main research interests include wireless networks and communications, IoT networking, data and energy integrated networks, and mobile computing. He manages research projects funded by various sources such as UK EPSRC, EU FP7/H2020 and industries. He has published 300+ papers and filed 20 patents. He serves on the Editorial Boards of both IEEE and non-IEEE publications. He is a Member of Academia Europaea (MAE), a Fellow of IET, and a Fellow of BCS. He was an IEEE Communications Society Distinguished Lecturer (2020–2021).

JIE HU [S'11, M'16, SM'21] received his Ph.D. degree from University of Southampton, United Kingdom, in 2015. Since March 2016, he has been working with the University of Electronic Science and Technology of China (UESTC) as a research professor. He won UESTC's Academic Young Talent Award in 2019. He was also a recipient of the best paper award at IEEE SustainCom 2020. He is an Editor for both *IEEE Wireless Communications Letters* and *IET Smart Cities*. He was a Program Vice-Chair for IEEE TrustCom 2020 and a TPC Chair for IEEE UCET 2021. His current research focuses on wireless communications and resource management for B5G/6G, wireless information and power transfer, as well as integrated communication, computing, and sensing.

BURAK KANTARCI [SM'12] is an associate professor, and the founding director of the Smart Connected Vehicles Innovation Centre and the Next Generation Communications and Computing Networks Research Lab at the University of Ottawa. He holds a Ph.D. in computer engineering. He is an author/co-author of more than 200 publications, and has actively contributed to the field of mobile crowdsensing (MCS) for IoT systems, as well as AI-backed access control, authentication, and machine-learning-backed intrusion detection solutions in sensing environments. He served as the Chair of IEEE Communications Systems Integration and Modeling Technical Committee; an Editor of *IEEE Communications Surveys & Tutorials*, the *IEEE Internet of Things Journal*, and Elsevier's *Vehicular Communications*, and an Associate Editor for *IEEE Networking Letters* and the *Journal of Cybersecurity and Privacy*. He served as a Distinguished Speaker of the Association for Computing Machinery (ACM) in 2019–2021. He is a Senior Member of ACM.