Guest Editorial Wireless Transmission of Information and Power—Part I

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WIRELESS transmission of information and power has received growing attention in the research community in the past few years. In two consecutive special issues, a total of thirty papers present state-of-the-art results in the broad area of wireless transmission of information and power.

The first special issue starts with a guest editor-authored tutorial paper that summarizes the fundamentals of Wireless Information and Power Transfer (WIPT) ranging from RF energy harvester modeling to signal and system designs, and is followed by fifteen technical papers.

The tutorial paper provides an overview of WIPT challenges and technologies, namely Simultaneous Wireless Information and Power Transfer (SWIPT), Wirelessly Powered Communication Networks (WPCNs), and Wirelessly Powered Backscatter Communication (WPBC), highlights different linear and nonlinear energy harvester models, and shows how WIPT signal and system designs crucially revolve around the underlying energy harvester model in single-user and multi-user deployments. Topics discussed include rate-energy region characterization, transmitter and receiver architectures, waveform design, modulation, beamforming and input distribution optimizations, resource allocation, RF spectrum use, circuit simulations, prototyping and experimentation.

Next, fifteen technical papers are presented. A particular emphasis is put on papers dedicated to Wireless Power Transfer (WPT) and SWIPT in this first issue.

Kim *et al.* investigate the design of waveforms for multi-user WPT under a proportional fairness criterion. An optimization framework is developed for the fair design of the waveforms and numerical evaluations are conducted to confirm the performance benefits.

Rajashekar *et al.* depart from the conventional Gaussian input alphabet commonly assumed to characterize the rate energy tradeoff in SWIPT. The paper investigates this tradeoff under a finite input alphabet constraint for transmission over parallel Gaussian channels and highlights how power allocation strategies need to be optimized accordingly.

Wang studies the use of retrodirective frequency diverse array (FDA) focusing at base stations for long-range SWIPT applications. The proposed SWIPT scheme allows self-tracking of the direction-of-arrival of the pilot signals without the requirement of any a priori knowledge. The superiority of FDA over conventional phased arrays for SWIPT applications is verified from analysis and numerical simulations.

Hu *et al.* consider the design of SWIPT with power splitting (PS) and time switching (TS) protocols in a relay-assisted ultra-reliable low latency communication network operating with finite blocklength codes. A new protocol is also proposed and performance benefits over the PS and TS protocols are investigated.

Huang *et al.* focus on energy efficient resource allocation for SWIPT in a distributed antenna system. The transmission time and power are optimized subject to energy harvesting requirements at the users. The superiority of the proposed methods over various baselines is demonstrated through simulation results.

Liu *et al.* adopt a stochastic geometry framework to investigate the cell-load impact on the downlink and uplink transmissions of each BS in a heterogeneous cellular network with SWIPT. Particular attention is paid to the void cell event in which a BS does not have any users.

Wu *et al.* propose a novel fast and accurate angle-of-arrival estimation technique for lens antenna arrays for SWIPT. Simulations show that the proposed approach is more accurate than the state of the art and enhances the power transfer efficiency.

Dai *et al.* investigate SWIPT in millimeter massive multiple-input multiple-output (MIMO)-non-orthogonal multiple access (NOMA) systems in which users extract information and energy from the received RF signals by using

This work was supported in part by EPSRC of U.K. under Grant EP/P003885/1, in part by the National University of Singapore under Grant R-263-000-D12-114, in part by the Australian Research Council's Discovery Early Career Researcher Award funding scheme under Grant DE170100137, in part by the National Research Foundation of Korea (NRF) Grant through the Korean Government under Grant 2014R1A5A1011478, and the U.S. National Science Foundation under Grant CNS-1702808.

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Digital Object Identifier 10.1109/JSAC.2018.2872371

a power splitting receiver. Spectral and energy efficiencies are contrasted with those achieved by MIMO-orthogonal multiple access (OMA) with SWIPT.

Sun *et al.* study the robust design of beamformers in multi-antenna NOMA cognitive radio networks with SWIPT under nonlinear harvester modeling. Simulation results show that the scheme outperforms its traditional OMA counterpart.

Khalfet *et al.* study information-theoretic limits of SWIPT in a two-user Gaussian interference channel with and without perfect channel-output feedback. It is shown that feedback can at most double the energy transmission rate at high signal to noise ratios.

Zhai *et al.* study a dual-band SWIPT network, in which a high-frequency band is used for short-distance information delivery, and a low-frequency band is used for short-distance energy transfer and long-distance information delivery. Performance benefits over conventional single-band networks are confirmed by simulation results.

Gautam *et al.* look at cache-assisted SWIPT cooperative systems, in which one source communicates with one destination via the aid of multiple relays equipped with cache memory and energy harvesting (EH) capability. The paper investigates the effect of caching on the system performance in terms of throughput and stored energy at the relay. Performance benefits of incorporating caching capabilities to SWIPT systems are confirmed by numerical results.

Dong *et al.* investigate a multi-antenna SWIPT system in the presence of multiple-eavesdroppers, where the base station delivers information signals to the legitimate users and broadcasts jamming signals to the eavesdroppers. The paper aims at designing the beamforming vector and artificial noise covariance matrix so as to minimize the ratio of total power consumption to sum secrecy rate. The performance of the proposed algorithms is confirmed by numerical evaluations.

Lu *et al.* consider a multi-antenna SWIPT system in which one transmitter serves multiple legitimate receivers in the presence of several eavesdroppers. Accounting for the nonlinearity of the energy harvester, the paper designs the transmit beamforming vectors and the artificial noise covariance matrix so as to maximize global energy efficiency. Numerical results demonstrate the overall performance of the system and further shed some light on the effect of nonlinearity of the energy harvester on SWIPT performance.

Alageli *et al.* consider the scenario of SWIPT and active eavesdropping. A two-antenna active energy harvester is capable of legitimately harvesting energy via one antenna, and illegitimately and actively eavesdropping upon the signal intended for certain information users via the other antenna for the purpose of information decoding or energy harvesting. The paper provides asymptotic analysis, which gives insights into how to tackle active attacks.

The tutorial paper and the fifteen papers in this first special issue provide an overview of the state-of-the-art as well as new results in the broad area of WIPT, with a particular emphasis on WPT and SWIPT. A second special issue will be offered with another set of fifteen papers on WIPT with an stronger emphasis on WPCNs and WPBC.

Bruno Clerckx (SM'17) received the M.S. and Ph.D. degrees in applied science from the Université Catholique de Louvain, Louvain-la-Neuve, Belgium, in 2000 and 2005, respectively. From 2006 to 2011, he was with Samsung Electronics, Suwon, South Korea, where he actively contributed to 3GPP LTE/LTE-A and IEEE 802.16m and acted as the Rapporteur for the 3GPP Coordinated Multi-Point (CoMP) Study Item. From 2014 to 2016, he was an Associate Professor with Korea University, Seoul, South Korea. He also held visiting research appointments at Stanford University, EURECOM, the National University of Singapore, and The University of Hong Kong. Since 2011, he has been with Imperial College London, first as a Lecturer from 2011 to 2015, then as a Senior Lecturer from 2015 to 2017, and now as a Reader. He is currently a Reader (Associate Professor) with the Electrical and Electronic Engineering Department, Imperial College London, London, U.K.

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Dr. Poor is a member of the National Academy of Engineering and the National Academy of Sciences, and is a Foreign Member of the Chinese Academy of Sciences, the Royal Society, and other national and international academies. He received the Marconi and Armstrong Awards of the IEEE Communications Society in 2007 and 2009, respectively. Recent recognition of his work includes the 2017 IEEE Alexander Graham Bell Medal, Honorary Professorships at Peking University and Tsinghua University, both conferred in 2017, and a D.Sc. *honoris causa* from Syracuse University also awarded in 2017.