Guest Editorial for ACM TECS: Special Issue on Autonomous Battery-Free Sensing and Communication

Recently, energy-harvesting technologies have emerged as a solution to the challenges posed by energy constraints in many mobile applications. Environmental energy, from sources such as light, movement, wind, radio frequency, and temperature gradient can be harvested and stored for sustainable operation, thereby enabling self-powered nodes. Such nodes can find applications in scenarios where small device form factor and perpetual operation are desirable. Moreover, they have the potential to enable autonomous sensing and communications tasks without human intervention following the deployment. However, challenges are posed by the need to coordinate the sensing and communications among the energy-harvesting nodes while guaranteeing the system performance. Since the harvesting of energy is typically hard to predict, some preliminary works designed efficient energy management schemes. Yet, designing new architectures that enable autonomous battery-free sensing and communications is an open problem.

The objective of this special issue is to highlight the state-of-the-art advances in this area, and foster new avenues for research. To this end, we selected 11 articles, which can be divided into three categories. Articles in the first category focus on optimizing the physical layer for energy-efficient communication in energy-harvesting networks. The article "Transmission Adaptation for Battery-Free Relaying" by Wang et al. designs a centralized and a distributed algorithm to address the transmission adaptation in the case of multiple relays, based on a full-duplex energy flow behavior model. The studies by Rajib et al. and Xu et al. both investigate transmission strategies in networks where connections between two nodes are intermittent due to node mobility or channel scarcity.

Articles in the second category attempt to address the energy efficiency in energy-harvesting networks by optimizing system design. The article "Near-Optimal Co-Deployment of Chargers and Sink Stations in Rechargeable Sensor Networks" by Li et al. designs near-optimal deployment chargers and sinks so that all sensors can obtain sufficient energy for data sensing and transmission. The article "Operating Energy-Neutral Real-Time Systems" by Wägemann et al. presents an operating system kernel that can switch to different working modes dynamically to increase energy efficiency. Lin et al. propose an optimal charging scheme where the objective is to complete the charging tasks with minimum traveling path. Finally, Hu et al. focus on joint optimization of sensing and power allocation in networks of energy-harvesting nodes.

The third category is concerned with energy-efficient computing in energy harvesting networks. The article "A See-through-Wall System for Device-Free Human Motion Sensing Based on Battery-Free RFID" by Wang et al. leverages passive RFIDs for efficient device-free human motion sensing. Gomez et al. adopt dynamic energy burst scaling to efficiently utilize small bursts of energy in networks with unpredictable energy arrival. Chen et al. design a self-sustained water quality sensing system that can harvest energy from water. The article "R3: Reliable Over-the-Air Reprogramming on Computational RFIDs" by Wu et al. presents an efficient and reliable over-the-air reprogramming scheme for passive RFIDs.

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Theses elected articles show case the recent advances in battery-free and energy-harvesting sensing and communication. They cover a broad spectrum ranging from theoretical contributions to system-oriented contributions.

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Guest Editors