IEEE TRANSACTIONS ON GREEN COMMUNICATIONS AND COMPUTING: New Research Scope

THIS journal began in 2017, under the leadership of Founding Editor-in-Chief Prof. Ender Ayanoglou. On August 1^{st} 2020, Prof. Zhisheng Niu from Tsinghua University took over from Ender in this leadership role. The decision was taken to revise the structure of the journal and review the scope of the journal in detail. In his first editorial [item 1) in the Appendix], Prof. Niu has emphasised the fundamental research question around "how can Send More Information bits with Less Energy (SMILE)?" and recommended exploring "Energy Informatics for Smart Interaction of Energy and Information (EINSTEIN)." This article introduces the new editorial team and provides highlights of the journal's past, present and future.

The journal has been restructured to cover four major thematic areas, to match new developments in the research field. The editorial system has also been adapted, so that final decisions on each paper will be made by the Area Editor, in order to improve consistency in decision-making. The four thematic areas are:

- Green Internet and Service Provisioning
- Green Wireless Communications and Networking
- Green Internet of Things and Energy-harvesting Communications
- Green Computing and Artificial Intelligence

This article describes the scope of these areas in more detail and highlights some of the most significant research articles that have appeared in the journal since its inception.

1) *Green Internet and Service Provisioning (Area Editor: Daniel Kilper):* The Internet has been a focal point for achieving sustainability throughout society through what is often referred to as smart technologies. Communication networks in general have the potential to save more energy than they consume, and they are an essential piece of any global sustainability or climate neutral strategy. At the same time, the growth of information and communication technologies (ICT) and their inefficient use can have an adverse effect on sustainability. Core wireline networks are highly efficient in moving large amounts of data and therefore are looked at as a potential tool to reduce energy use in technologies such as data centers and access networks where ICT is far less efficient. In this topical area, papers examine the role that the Internet plays in enabling sustainability across the Internet as well as methods for achieving greater efficiency in wireline network services.

Improving the energy efficiency, use of renewable energy, reduction of brown energy sources has been examined from several different directions. At the start of Transactions on Green Communications and Computing, this area of study was already advanced and therefore papers have considered detailed and advanced aspects of the problem. In a highly cited paper, an EcoMultiCloud hierarchical data center workload management approach is studied, which is unique in that it considers a level of autonomy among the distributed data centers while preserving the overall efficiency [item 2) in the Appendix]. In other work considering VM migration in a cloud backbone scenario, data center placement and growth strategies are considered in terms of minimizing brown energy use [item 3) in the Appendix]. More recently fuel cells have gained interest from cloud providers as an efficient, potentially low carbon energy source, but with limited load following capability. In a recent paper, the use of networks to adapt the workload in order to better use fuel cells was studied [item 4) in the Appendix].

Software defined networking and network function virtualization have emerged as important tools for flexible and programmable control and management of networks. Service provisioning using these methods must also consider the impact that they might have on sustainability, and whether Software Defined Networking (SDN) or Network Function Virtualization (NFV) methods that might be used to achieve greater energy efficiency. This requires progress on measurement and evaluation methods as well as investigation of new architectures or implementations. One recent paper introduces a model-based analytics approach to profiling virtual network function workloads with the goal of achieving real-time monitoring of network key performance indicators such as power and delay [item 5) in the Appendix]. Another recent paper examines the energy efficiency of voice over internet protocol (IP) services managed over virtual network functions, including the evaluation of a testbed implementation [item 6) in the Appendix].

Energy use in wireline services remains focused on access networks. Similar to wireless access networks, wireline architectures are being transformed by the trend toward edge cloud networks. Increasingly optical access networks are considering more meshed approaches, breaking the tree structure of passive optical networks, in order to support peer communications at the edge. Cloudlet or micro data centers need to communicate directly to support emerging high speed, low latency applications. This new environment requires new approaches to green wireline access networks. In a very recent paper, energy efficiency is considered in a distributed bandwidth allocation strategy for

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passive optical networks incorporating different cloudlet access communication methods [item 7) in the Appendix].

2) *Green Wireless Communications and Networking (Area Editor: John Thompson):* The field of green wireless communications has had a long history. Since Shannon's seminal development of the channel capacity theorem in 1948, the basic trade-off between power efficiency and spectral efficiency in communications has been clear. From the inception of mobile wireless devices, the limited battery life has led to continual improvements in wireless communications standards to improve performance. More recently, there has also been an increased focus on the energy efficiency of wireless base stations and access points, as the importance of global warming and climate change have become apparent to humanity.

This theme deals with research advances related to all types of wireless communications systems, including cellular networks, wireless local area networks and short range ad hoc networking technologies. In the last five years, there has been a major focus on so-called Massive Multiple Input Multiple Output (MIMO) as a major technology for energy efficient communications. Reference [item 8) in the Appendix] by Ngo *et al.* is one of the highest cited papers in the journal to date and analyses the energy efficiency of Massive MIMO systems when operated in a cell-free mode. This covers the case when the antenna arrays are distributed across multiple base station or access points. Reference [item 9) in the Appendix] by Buzzi and D'Andrea has also studied the performance of Massive MIMO systems when applied to the millimetre wave frequency bands above 30 GHz. The small wavelengths at this band permit very large antenna arrays to be deployed in compact apertures, enabling high capacity and energy efficient communication.

Energy efficient coding and modulation schemes are another important area to be considered in developing energy efficient wireless solutions. Reference [item 10) in the Appendix] by Shafique *et al.* studies the performance of automatic repeat request (ARQ) systems from the perspective of energy efficiency. They explore how selective re-transmissions can be used in the most efficient manner to achieve maximum data throughput while minimising energy consumption. [Item 11) in the Appendix] by Nguyen *et al.* studies a novel multiple antenna transceiver system making use of full duplex signal cancellation to enable signals to be transmitted and received simultaneously. Their paper addresses both the capacity improvement from such systems as well as devising a novel medium access control (MAC) protocol to control the operation of such radio devices.

In developing fifth generation wireless systems, there has been a significant focus on using small cell and ultra-dense cellular layouts to achieve high capacity performance. Reference [item 12) in the Appendix] by Yang *et al.* studies how propagation effects impact on the performance of ultra-dense networks. They develop a simple mathematical model for such systems and show through an optimization procedure important trade-offs between coverage, power consumption and energy efficiency. Reference [item 13) in the Appendix] by Mowla *et al.* considers a network perspective on the design of heterogeneous networks using different cell sizes. Their work uses a detailed energy model to study how many small cells are needed to maintain high service quality while also minimising overall energy consumption.

The journal looks forward to receiving more high quality research contributions in these topics as wireless technology continues to develop. We have also modified the scope of the journal to encourage contributions in two other important areas for cellular networks. Firstly, we are encouraging manuscripts in the field of "Environmental Impact Analysis of Wireless Communication". Papers on this topic will provide a holistic analysis of how wireless networks are impacting on the environment. Secondly, we are also looking for papers on "Experimental Testbeds for Green Wireless Systems" to showcase practical testbeds and deployments.

3) *Green Internet of Things and Energy-harvesting Communications (Area Editor: Yan Zhang):* This theme deals with research advances related to all types of Internet of Things (IoT), including Internet of Vehicles (i.e., transport), Internet of Electric Vehicles, Internet of Energy (i.e., smart grid), Internet of unmanned aerial vehicles (UAVs), agriculture, smart city, Blockchain, Internet of Medical Things (i.e., healthcare), and industry. An IoT system has its own unique features and challenges. Accordingly, different IoT systems require different considerations and solutions. The study in [item 14) in the Appendix] is a top-access paper in the journal and studied UAV as a flying Base Station for mobile edge computing where some tasks at mobile devices are computed locally and the remaining portion is transmitted to UAV for computing. The main goal is to minimize energy consumption in task processing. Demand response is a classic technique in Internet of Energy to balance energy demand and consumption. Pricing strategy is an efficient technique to significantly reduce end-users' energy consumption [item 15) in the Appendix]. The study in [item 16) in the Appendix] presented an optimal placement strategy of Road Side Units (RSUs) which are powered by conventional grid and solar power. The optimal placement of RSUs are performed by jointly optimizing the total number of RSUs deployed, the operational expenditure and the conventional grid energy consumed.

Another important direction of this theme is Energy harvesting communications. Energy harvesting communications has developed for several years and still a very hot topic in the field of wireless communications and networks. Further, we can observe that energy harvesting communications has increasingly important applications in IoT systems and services. For example, the study in [item 17) in the Appendix] is a top-access paper in the journal and studied the resource allocation problem for UAV-assisted networks, where a UAV acting as an energy source provides radio frequency energy for multiple energy harvesting-powered device-to-device (D2D) pairs.

The journal looks forward to receiving more high quality research contributions in the topics related to Green Internet of Things and Energy-Harvesting Communications. We also welcome special issue proposals on specific domain since Internet of Things covers many different types of systems, applications and services. In addition, we are looking forward to more submissions on emerging systems and applications including

Blockchain, Digital Twin, and Artificial Intelligence for the Internet of Things and 5G Beyond/6G networks.

4) *Green Computing and Artificial Intelligence (Area Editor: Kaibin Huang):* Recent years have witnessed growing cross-disciplinary research merging wireless communication, *mobile edge computing* (MEC), and *artificial intelligence* (AI) (i.e., machine learning and inference). One vein of research focuses on applying AI to improve the efficiency, robustness, and adaptivity of a communication system, known as the area of *AI for communication*. We are also observing the emergence of another vein of research on leveraging rich mobile data and computation resources distributed at the network edge to help the training of large-scale AI models. Subsequently, the trained models can be then deployed to endow on devices the needed intelligence for supporting new applications ranging from augmented reality to auto-driving. The communication-efficient techniques for deploying learning and inference at the edge are collectively called *communication for AI*. On the other hand, one mission of 5G and 6G is to provide an efficient MEC architecture for implementing complex learning algorithms as well as delivering to users low-latency cloud computing services. In these new paradigms, edge servers with finite capacities and resource constrained devices are required to execute highly complex tasks (e.g., AI model training) and transmit high-dimensional data, which are all power hungry and call for green designs. For this reason, green computing and communications are becoming an increasingly important issue in designing an AI enabled intelligent edge in 5G-and-Beyond. The fast growing interests and research activities on relevant topics have motivated the creation of the journal's new thematic area of Green Computing and Artificial Intelligence as a venue for reporting latest advancements in the area.

A key topic in green MEC is energy efficient computation offloading that offloads computation intensive tasks from mobile devices to edge servers to reduce mobile energy consumption as well as speed up the computation by overcoming the limitation of devices' computation capacities. Several popular articles on relevant topics have been published in the journal. Reference [item 18) in the Appendix] by Yao and Ansari studies intelligent schemes based on online reinforcement learning for offloading from IoT devices to fog nodes (mini-servers) deployed at the network edge based on the criterion of minimum average task completion time under the constraints of device's energy and completion deadline. In [item 19) in the Appendix], targeting a similar system, Chen *et al.* have develop an energy-optimal dynamic computation offloading scheme supporting partial offloading. The design involves the joint optimization of the offloading ratio, transmission power, local processor computation speed and transmission time aiming at minimizing mobile energy consumption under constraints on overhead and latency. The deployment of MEC in multi-cell networks gives rise to the issue of optimal association between base stations and devices, which was addressed in [item 20) in the Appendix] by Chen *et al.* In this work, offloading decisions and association are jointly optimized with transmission power and channel assignments so as to minimize the total mobile energy consumption under tasks' latency constraints. In addition, researchers have studied energy efficient computation offloading for new types of wireless systems such as one with unmanned aerial vehicles as flying base stations to process the application tasks offloaded from the terminal devices in [item 14) in the Appendix] by Hua *et al.*

The two areas, AI for communication and communication for AI, are still in their nascent stage. There are already some publications in the journal while we are witnessing growing submissions recently. For example, [item 21) in the Appendix] by Ortiz *et al.* applies reinforcement learning to design a power allocation policy for maximizing the throughput at two-hop communication system with energy harvesting. Besides the topics we discuss above, the scope of the area has been broadened to include latest trends with potential impact on green communications and computing including cloud-edge cooperative computing, quantum computing and green communications, data storage and chip design for green communications, data analytics for green communication networks, blockchain and green networking. We welcome high quality research contributions to all of the above new exciting topics.

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APPENDIX
RELATED WORK

1) Z. Niu, "Green communication and networking: A new horizon," *IEEE Trans. Green Commun. Netw.*, vol. 4, no. 3, pp. 629–630, Sep. 2020.
2) A. Forestiero, C. Mastroianni, M. Meo, G. Papuzzo, and M. Sheikhalishahi, "Hierarchical approach for efficient workload management in geo-distributed data centers," *IEEE Trans. Green Commun. Netw.*, vol. 1, no. 1, pp. 97–111, Mar. 2017.
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4) X. Hu *et al.*, "Joint workload scheduling and energy management for green data centers powered by fuel cells," *IEEE Trans. Green Commun. Netw.*, vol. 3, no. 2, pp. 397–406, Jun. 2019.
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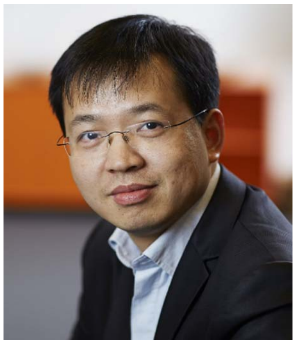
John Thompson (Fellow, IEEE) is currently a Professor with the School of Engineering, University of Edinburgh. He specializes in antenna array processing, cooperative communications systems, and energy-efficient wireless communications. He has published in excess of 350 papers on these topics. He was the Coordinator for the recently completed EU Marie Curie Training Network ADVANTAGE, which studies how communications and power engineering can provide future smart grid systems. In 2018, he was a Technical Co-Chair of the IEEE SmartGridComm conference held in Aalborg, Denmark. He currently participates in several projects which study new concepts for future generation wireless communications. In January 2016, he was elevated to Fellow of the IEEE for research contributions to antenna arrays and multihop communications.



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