Guest Editorial Special Issue on Sustainable Solutions for the Internet of Things

AN ANALYSIS of many IoT deployments showed that most of them can address the sustainable development goals (SDGs) and the UN's 2030 agenda. Interestingly, most of these projects concentrate on five SDGs: 1) industry, innovation, infrastructure; 2) smart cities and communities; 3) affordable and clean energy; 4) good health and well-being; and 5) responsible production and consumption. Examples include a remote water-monitoring solution that ensures clean water in regions with an indigenous population and smart lighting initiatives in Chinese cities that halve total power output.

This special issue aimed to gather the recent advances and novel contributions from academic researchers and industry practitioners in the novel area of sustainable solutions for the IoT to fully leverage the potential capabilities and opportunities brought by this area.

We devised five main technical directions for research to contribute to the development of sustainable services: 1) user integration; 2) fog/cloud computing architectures; 3) low-power cooperative sensors; 4) shared and open infrastructures deployment; and 5) machine and deep learning.

The response to our call for this special issue was overwhelming, as we received 124 submissions from around the world. Each article was assigned to and reviewed by at least three experts in the field during the review process, with a rigorous multiround review process. Thanks to numerous reviewers' great support and dedicated work, we accepted 36 excellent articles covering various topics in the area of sustainable solutions for the Internet of Things. We will introduce these articles and highlight their main contributions in the following.

Ren *et al.* [A1] leveraged the idea of "divide and conquer" and proposed HT3O, a scalable scheduling approach for large-scale UAV-assisted MEC. Wang *et al.* [A2] proposed a reliable anomaly detection strategy for IIoT using federated learning.

Zeng *et al.* [A3] focused on strip-shaped networks and proposed a novel data transmission scheme, which employs a few supernodes near the sink to take traffic load.

Wang *et al.* [A4] proposed a novel human short-long cognitive memory mechanism for video surveillance in smart cities. In this mechanism, a memory with a high-reliability target is used as a "long-term memory," whereas a memory with a low-reliability target is used as a "short-term memory." During the monitoring process, the short-term memory and long-term memory alternation strategy is combined with the stored target appearance

Ali Naeem *et al.* [A5] identified the challenges of NDN-IoT caching with the aim to develop a new hybrid strategy for efficient data delivery. The proposed strategy is comparatively and extensively studied with NDN-IoT caching strategies through an extensive simulation in terms of average latency, cache hit ratio, and average stretch ratio. From the simulation findings, it is observed that the proposed hybrid strategy outperformed to achieve a higher caching performance of NDN-based IoT scenarios.

Abbas *et al.* [A6] proposed a novel multiparameter-based flexible scheme for idle channel prediction and channel ranking, which considers priorities as well as the heterogeneity of users. The scheme uses a probabilistic approach and employs multiple parameters simultaneously to evaluate the suitability of a channel before selecting it for transmission.

Kiziroglou *et al.* [A7] presented a power supply that collects, stores, and delivers regulated power from the stray magnetic field of current-carrying structures. In cm-scale structures, the skin effect concentrates current at edges at frequencies even below 1 kHz. A coil-core inductive transducer is designed, too.

Article [A8] by Sun *et al.* proposes a sustainable deep-learning-based heartbeat classification system, called BeatClass. It contains three main components: two stacked bidirectional long short-term memory networks (Bi-LSTMs), called Rist and Morst, and a generative adversarial network (GAN), called MorphGAN. Rist first classifies the heartbeats into five common Arrhythmia classes. Zhang *et al.* [A9] detailed UDARMF, an underwater distributed and adaptive resource management framework, which maximizes network capacity by supporting an increased number of communications in the network. It is a distributed deep multiagent reinforcement learning framework that uses an observation encoder and a local utility network to coordinate the collaboration among underwater nodes by adaptively tuning its transmit parameters. Tanyingyong *et al.* [A10] introduced the concept of dynamic sinks, a sensor device that can serve as an on-demand sink. They identify suitable metrics for decision mechanisms to activate/deactivate dynamic sinks and investigate three decision schemes, namely, autonomous, delegated, and centralized schemes; they also develop a protocol to disseminate the decisions. Lu *et al.* [A11] presented a dataspaces model utilizing distributed approaches to represent

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semantic information as a sustainable solution for IoT semantic interoperability. In this model, an attention-based entity embedding approach is designed to convert IoT entities into low-dimensional dense vectors, then calculations, including entities, relations, etc., can be further conducted.

Delnevo *et al.* [A12] envisioned the possibility to exploit Social Internet of Things for sensing of environmental conditions (solar radiation, humidity, air temperature, and soil moisture) and communications, deep learning for plant disease detection, and crowdsourcing for images collection and classification, engaging farmers and community garden owners and experts. Through data fusion and deep learning, the designed system can exploit the collected data and predict when a plant would (or not) get a disease, with a specific degree of precision, with the final purpose to render agriculture more sustainable. Chithaluru *et al.* [A13] proposed an ARFOR—Adaptive ranking fuzzy-based energy-efficient opportunistic routing protocol for sustainable IoT applications. The proposed protocol consists of parent node (PN) that acts as a head node in a cluster to aggregate the packets to DODAG root; and volunteer node (VN) acts as a forwarder to transfer the packets to PN with threshold energy limits to increase network lifetime during transmission cycle. The proposed VN selection is based on fuzzy parameters, such as Canberra distance, residual energy, and threshold.

Giuliano *et al.* [A14] presented the IMPERSONAL framework, with the twofold aim of both 1) tracking and monitoring social distancing and 2) alerting users in case of gatherings. The framework is based on a subnetwork of computer vision-based devices that is adopted to monitor and track users' movements to estimate their interdistance and compute the encounter time. Article [A15] by Na *et al.* presents a wearable low-power collaborative sensing system based on a time mask window canonical correlation analysis method (TMW-CCA). An 8-array spring dry electrode signal acquisition device based on a flexible circuit board is designed to address the shortcomings of traditional wet electrode acquisition devices, such as high-power consumption, discomfort, and being unsuitable for long-time use.

Hernández *et al.* [A16] proposed an AI-based pipeline for processing natural disaster images taken from drones. The purpose of this pipeline is to reduce the number of images to be processed by the first responders of the natural disaster. Sharmeen *et al.* [A17] proposed a novel strategy, based on a semi-supervised approach. Two semi-supervised approaches, including unsupervised learning and deep-learning-based approaches, have been proposed. The proposed approaches can involve learning dynamic cyberattack patterns from unlabeled data in an SWTDN. We validate the proposed semi-supervised approach experimentally using an operational water treatment plant testbed. The proposed approach achieved almost 100% accuracy and substantially outperforms the existing baseline approaches used in this article. Shi *et al.* [A18] proposed a duration-aware cluster snapshot system, named Phalanx, which can take live snapshots of edge–cloud collaborative clusters with low-performance overhead. Jia *et al.* [A19] investigated how to coordinate the edge and the cloud resources to perform cost-efficient continuous learning, with the goal of simultaneously optimizing the model performance (in terms of accuracy and robustness) and resource cost.

Elayan *et al.* [A20] proposed a deep federated learning framework for healthcare data monitoring and analysis using IoT devices. The extensive results collected show that the deep federated learning models can preserve data privacy without sharing it, maintain the decentralized structure of the system made by IoT devices, improve the area under the curve (AUC) of the model to reach 97%, and reduce the operational costs for service providers.

Farhad *et al.* [A21] investigated various forms of adaptive data rate (ADR), and BADR in mobility environments, their limitations are highlighted, and a novel ADR retransmission-assisted resource management (R-ARM) system is proposed. Chen *et al.* [A22] introduced programming formulations of the mentioned issues using an improved ant colony optimization (IACO) algorithm. The method is combined with a new kind of local search algorithm to obtain higher quality responses. Also, for responding to privacy concerns, a privacy-preserving method has been suggested. The suggested approach has been tested widely, and the outcomes have been compared to the genetic and PSO algorithms. The results indicated the good ability of the proposed method in terms of network lifespan and energy consumption.

López *et al.* [A23] took another step forward by proposing a novel CSI-free rotary antenna beamforming (RAB) WET scheme that outperforms all state-of-the-art CSI-free schemes in a scenario where a power beacon (PB) equipped with a uniform linear array (ULA) powers a large set of surrounding EH IoT devices. RAB uses a properly designed CSI-free beamformer combined with a continuous or periodic rotation of the ULA at the PB to provide average EH gains that scale as 0.85M, where M is the number of PB's antenna elements. In [A24], the main contribution is to develop data management schemes to cope with inevitable data loss by identifying the data portion with a higher value to the overlaying applications. Gómez-Carmona *et al.* [A25] presented an approach that simplifies the complexity of supervised learning algorithms at the edge. Specifically, it separates complex models into multiple simpler classifiers forming a cascade of discriminative models.

Lan *et al.* [A26] presented a system framework, EDGEVISION, for computer vision applications partitioning and orchestration on heterogeneous edge computing platforms considering both CPUs and GPUs. Shamshiri *et al.* [A27] introduced a novel framework and a cost-efficient (power consumption and area) aging tag for remaining useful life estimation of IoT. Utilizing the proposed comprehensive system prevents failures in large IoT ecosystems. Huang *et al.* [A28], targeting optimization on a single-server MEC scenario, proposed NAFA, an adaptive processor frequency adjustment solution, to enable an effective plan of the server's energy usage.

Flueratoru *et al.* [A29] evaluated the power and energy consumption, distance measurements, and localization performance of two types of UWB physical interfaces (PHYs), which use either a low- or high-rate pulse repetition (LRP and HRP, respectively). The evaluation is done through measurements acquired in identical conditions, which is crucial in order to have a fair comparison between the devices.

Singh *et al.* [A30] proposed an optimized genetic algorithm (GA)-based sustainable and secure green data collection/transmission method for IoT-enabled WSN in healthcare by optimizing intracluster distance, systematic utilization of node's energy, and reducing hop count.

Baghezza *et al.* [A31] tackled the challenge of using machine learning to recognize the profile of pedestrians based on their gait and silhouette with the use of a thermal camera (FLIR Lepton) connected to a Raspberry Pi.

Silva *et al.* [A32] set out an optimization model and a distributed heuristic that is able to achieve and prolong ENO in IoT networks, by supporting periodic and event-based traffic data. Zhu *et al.* [A33] focused on the energy consumption of edge devices and cloud services in processing AIoT tasks and formulated the optimization problem in scheduling tasks in the edge and the cloud. Meanwhile, a novel online method is proposed to solve the optimization problem.

Wang *et al.* [A34] designed an ultra-low-power sensing framework for the Internet of Things and applied it to the smart gas meter. Based on a thorough analysis of the metering system, they propose an ultra-low-power system framework and a low-power peripheral management solution to reach ultra-low-power consumption. Manjarrés *et al.* [A35] presented a deep learning architecture that leverages the feature extraction capability of the convolutional neural networks and the construction of the temporal sequences of recurrent neural networks to improve existing classification results. Varri *et al.* [A36] proposed fog-enabled lightweight traceable attribute-based keyword search over encrypted data by using ciphertext-policy attribute-based keyword search to realize keyword search and fine-grained access control.

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We hope that this special issue will serve as a valuable reference for researchers, scientists, engineers, and academics in the field of IoT.

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APPENDIX: RELATED ARTICLES

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