Guest Editorial
Special Issue on Empowering the Future Generation Systems: Opportunities by the Convergence of Cloud, Edge, AI, and IoT

THE FUTURE generation of the Internet of Things (IoT) systems is characterized by the fusion of technologies—from edge–fog–cloud computing to artificial intelligence (AI) and blockchain—closing the gap between the physical and digital worlds [A1]. Although these technologies have been developed separately over time, the synergy among them has taken a giant leap. We are witnessing a fast-paced convergence of these technologies resulting in a fundamental paradigm shift unlocking vast benefits and opportunities across vertical markets. However, there are still several barriers, such as a lack of consensus toward any reference models or best practices, hindering the full fusion of these technologies [A1]. To tackle these challenges and facilitate this promising transformation, this special issue was organized to provide a holistic multidisciplinary reference for solutions, architectures, protocols, services, and applications addressing all aspects of the future generation of IoT systems via the fusion of edge, cloud, AI, and blockchain, while considering the corresponding challenges. Thanks to the enormous support from the Editor-in-Chief, Prof. Honggang Wang, and the dedicated work of many reviewers, after a rigorous review process, 27 excellent articles out of 125 submissions were accepted for inclusion in this special issue of the IEEE INTERNET OF THINGS JOURNAL. We introduce these papers and highlight their key contributions below.

Zhu et al. [A2] proposed a holistic continuous glucose monitoring (CGM) based on the fusion of the Internet of Medical Things (IoMT) and deep learning (DL) technologies. The DL model, based on an attention-based evidential recurrent neural network, has been evaluated on three clinical data sets, including 47 subjects, achieving superior performance compared to a group of machine learning baseline methods.

Zhou et al. [A3] developed an IoMT-based smart toilet equipped with DL-based image processing techniques to automatically flag abnormal stools. The proposed toilet is a hierarchical solution distributed across edge and cloud with the help of an offloading technique to strike a balance between accuracy and delay.

Liu et al. [A4] proposed a visual monitoring solution by combining human inertial thinking theory and fuzzy inference mechanisms enabling the monitoring of targets in diverse IoT-assisted monitoring environments.

A personalized federated learning technique has been proposed in [A5] to tackle the problem of the non-independent and identically distributed data (non-IID) problem in distributed collaborative learning environments. The authors proposed to combine co-training and generative adversarial networks (GANs), enabling FL participants to develop and train their models independently.

Stephanie et al. [A6] designed a collaborative learning ensemble deep neural network (DNN) framework for the fusion of IoT and edge–cloud computing. While each participant can train a model individually at the corresponding private edge nodes using their privacy-sensitive data, the ensemble process is done in the cloud. The privacy of the proposed solution has also been enhanced by integrating differential privacy techniques.

Lin et al. [A7] proposed a blockchain-based decentralized Industrial IoT (IIoT)-oriented digital twin architecture by utilizing oracle as a communication tool to connect on-chain and off-chain states. The proposed hierarchical architecture facilitates rapid data flows and computing feedback between the physical and digital worlds.

Content caching has been utilized in edge IoT to tackle the high backhaul load as well as the long communication time caused by the immense mobile data traffic. Wang et al. [A8] combined federated learning and Wasserstein GAN (WGAN) techniques to precisely predict the content popularity with a high cache hit ratio.

Jarwan and Ibnkahla [A9] combined actor–critic deep reinforcement learning (DRL) and federated learning techniques to tackle the problem of backhaul selection at the edge for better managing the traffic of IoT.

IoT gateways play an essential role in the timely identification of malware in IoT systems by analyzing the corresponding network traffic. Hu et al. [A10] proposed a deep subdomain adaptation network by exploiting local maximum mean discrepancy (LMMD), transfer learning, as well as both channel and spatial attention mechanisms to detect malware variant traffic at the edge of IoT.

Gyamfi and Jurcut [A11] designed a lightweight online network intrusion detection system (NIDS) based on online incremental support vector data description (OISVDD) and

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adaptive sequential extreme learning machine (ASELM) while utilizing both edge and cloud computing resources to enable IIoT end devices to detect network intrusions and the types of corresponding attacks in real time.

Li et al. [A12] presented a graph-based differential privacy mechanism to collapse deep data silos in the Internet of Vehicles (IoV) by bridging the gap between users' privacy and vehicle data sharing (i.e., information availability) to improve the corresponding service and create innovative business models.

Gharib et al. [A13] developed a blockchain-based multipath key exchange solution for improving the resistance of multihop wireless networks against the node capture attack.

Nano-scaled IoT devices working under harsh conditions typically experience hard failures due to various mechanisms, such as time-dependent dielectric breakdown (TDDB), bias temperature instability (BTI), and hot carrier injection (HCI). To address this critical reliability issue and tackle degradation and early hard failures, Ergun et al. [A14] proposed a reliability management system that can be utilized in multigateway IoT edge computing systems.

Chen and Huang [A15] presented a novel half quadratic supervised discrete hashing (HQSDH) algorithm to improve visual sensing robustness against partially observed data targeting Visual IoT (VIoT) applications, such as drones over flying ad-hoc networks (FANETs).

An in-network processing approach for efficient acoustic data separation enabling anomaly detection solutions in IIoT environments is proposed in [A16]. In contrast to the existing centralized methods, in the proposed technique, the data processing jobs are done in a distributed manner to unlock the full potential of the distributed environment of in-network processing.

Serverless computing is an emerging paradigm that has been extensively integrated into various IoT applications over the past few years. However, the existing solutions suffer from the cold start problem, which is rooted in the delay required to prepare the execution environment to run the corresponding function. Vahidinia et al. [A17] tackled this challenge by proposing a multilayer solution, integrating reinforcement learning and long short-term memory (LSTM) techniques to forecast the function invocation times and estimate the required prewarm containers.

Yan et al. [A18] formulated the unmanned aerial vehicles (UAVs)-enabled data offloading under limited communication conditions as a constrained multiobjective optimization problem to optimize the user data queue while increasing the operating time of UAVs. The extensive simulation and comparison against five state-of-the-art baseline algorithms show the time–energy efficiency as well as the adaptability of the system.

A heuristic-based transmission scheduling strategy, as well as a graph-based task offloading strategy, has been presented in [A19] to address the interplay of fog and cloud computing in the IIoT environment while capturing the energy–latency tradeoff.

AlQerm and Pan [A20] proposed an innovative and hierarchical resource facilitation framework for edge–IoT applications capturing both interzone schema and intrazone schema while addressing the dynamic situations, edge outlandish situations, as well as the mobility of the devices.

Herrera et al. [A21] studied the interplay of three critical dimensions of the next generation of IoT systems, namely, computing, networking, and application. In this context, a framework, Next-gen IoT Optimization (NIoTO), is also proposed to place microservices and networking resources over an infrastructure while co-optimizing the deployment cost and average response time.

The performance of offloading techniques, particularly in audio sensing applications, heavily relies on the quality of wireless links. To address this challenge, Cao et al. [A22] developed a distributed edge computing framework equipped with an accurate wireless link prediction by incorporating a cross-layer approach based on WiFi beacons, TCP-level statistics, as well as historical throughput observations.

Babar et al. [A23] designed a new edge–cloud IoT architecture to better support distributed big data analytics. The proposed architecture benefits from a hierarchical design by integrating MapReduce parallel algorithm and Yet Another Resource Negotiator (YARN) for efficient cluster management.

Generalized deduplication (GD) is a family of lossless compression schemes with impressive random access capabilities, perfect reconstruction of the original data, and high compression performance, making it well suited for edge–IoT applications. Hurst et al. [A24] proposed a deduplication-enabled approximate edge analytics (GLEAN) framework by utilizing a novel heuristic configuration technique in order to provide efficient edge analytics as well as data compression simultaneously.

UAVs have been widely utilized in object detection for different IoT applications, such as surveillance, search for missing persons, traffic, and disaster management. However, location awareness is challenging due to the presence of global positioning system (GPS) restricted areas and susceptibility to GPS sensor failure. Dilshad et al. [A25] proposed a DL-based solution to estimate the location of UAVs in real time by utilizing visual sensors and convolutional neural network (CNN).

Mobile crowdsensing (MCS) is an emerging paradigm in which intelligent mobile terminal devices carried by a community are utilized to extract insights and perform various sensing tasks collaboratively (e.g., environmental monitoring). Wei et al. [A26] proposed a mobility prediction model based on transfer learning as well as a heuristic two-stage search algorithm to strike a good balance between sensing quality and cost.

Finally, Khan and Ho [A27] proposed an edge-enabled IoT solution for crowd counting. In this work, CNNs and transfer learning techniques have been exploited to categorize the number of people in indoor environments by analyzing channel state information (CSI) data while capturing the temporal and environmental dynamics.

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APPENDIX: RELATED ARTICLES

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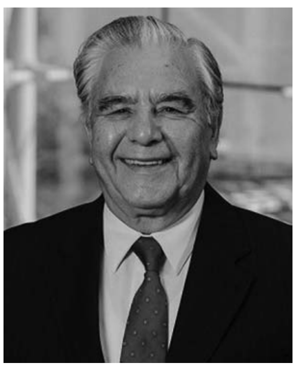

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