Guest Editorial Special Issue on Smart IoT System: Opportunities by Linking Cloud, Edge, and AI

RECENTLY, the Internet of Things (IoT) technologies have made their entrances into many fields, such as smart city, healthcare, intelligent transportation, forest protection, and environmental monitoring.

However, the current IoT system is facing great difficulty to efficiently handle the huge data generated from IoT devices. It has become challenging to ensure low latency, energy efficiency, and so on. To cope with the huge data and reply promptly and accurately, a recent trend is to deploy well-trained artificial intelligence (AI) model on edge servers, whose capacities are somewhat bigger than those of IoT devices. However, since the training of AI demands huge computation and memory resources, the training process is preferred to be done in the cloud. This link among cloud, edge, and AI poses many challenges that call for novel approaches and rethinking of the entire architecture, communication, and processing to meet requirements in latency, reliability, and so on. This special issue aims to create a platform for researchers from both academia and industry to disseminate state-of-the-art results and to advance the use of cloud, edge, and AI to build intelligent IoT systems.

The response to our call for this special issue was overwhelming, as we received in total 164 submissions from around the world. During the review process, each article was assigned to and reviewed by at least three experts in the field, with a rigorous multiround review process. Thanks to the great support from the former Editor-in-Chief, Prof. Xuemin (Sherman) Shen, and the current Editor-in-Chief, Prof. Honggang Wang, and the dedicated work of numerous reviewers, we were able to accept 29 excellent articles covering various topics in IoT-enabled CAVs. In the following, we will introduce these articles and highlight their main contributions.

In the article "A provenance-aware distributed trust model for resilient unmanned aerial vehicle networks," Ge *et al.* study the security issues and trust assessment for unmanned aerial vehicle networks and propose a distributed trust model based on a provenance-aware approach. The proposed model collects the observational evidence for the distribute trust evaluation and leverages the source of the packet to identify the malicious nodes behaves, such as black hole, packet injection attack, and modification attack.

In the article "D2D-enabled mobile-edge computation offloading for multiuser IoT network," Yang *et al.* design computational offloading schemes in D2D networks. The designed scheme considers collaboration constraints among users and dynamic resource availability to fully utilize the available resources of idle devices at the edge.

In the article "FraudTrip: Taxi fraudulent trip detection from corresponding trajectories," Ding *et al.* propose a system, called FraudTrip, which detects "unmetered" taxi trips based on a novel fraud detection algorithm and a maximum fraudulent trajectory construction algorithm, without the help of taximeters.

In the article "A cluster-based multidimensional approach for detecting attacks on connected vehicles," D'Angelo *et al.* provide two algorithms that implement a data-driven anomaly detection system. The first algorithm (cluster-based learning algorithm) is used to learn the behavior of messages passing on the CAN bus, for baselining purposes, while the second one (data-driven anomaly detection algorithm) is used to perform real-time classification of such messages (licit or illicit) for early alerting in the presence of malicious usages.

In the article "Efficient and privacy-preserving decision tree classification for health monitoring systems," Liang *et al.* propose an efficient and privacy-preserving decision tree classification scheme (PPDT) for health monitoring systems. The privacy-preserving decision tree classification is achieved by searching the encrypted indexes with encrypted biomedical data.

In the article "A new subspace clustering strategy for AI-based data analysis in IoT system," Cui *et al.* propose a post-process strategy of subspace clustering for taking account of sparsity and connectivity. The proposed strategy defines close neighbors as having more common neighbors and higher coefficients neighbors, where the close neighbors are selected according to the nondominated sorting algorithm, and prunes the intersubspace connections by eliminating incorrect or useless connections.

In the article "Automatic detection of congestive heart failure based on a hybrid deep learning algorithm in the Internet of Medical Things," Ning *et al.* propose an automatic CHF detection model based on a hybrid deep learning algorithm which is composed of convolutional neural network (CNN) and recursive neural network (RNN). The proposed model classifies normal sinus heart rate signals and CHF signals based on electrocardiograph (ECG) and time–frequency spectra during the RR interval. The accuracy of this algorithm is 99.93%, sensitivity is 99.85%, and specificity is 100% when analyzing 5-min ECG signals.

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In the article "User-centric computation offloading for edge computing," Deng *et al.* design a user-centered joint optimization loading scheme and propose a branch-and-bound algorithm based on linear relaxation improvement to model the optimization problem as a mixed-integer nonlinear programming problem. A particle swarm optimization algorithm based on 0-1 and weight improvement is used to reduce the complexity of the proposed algorithm.

In the article "DaaS: Dew computing as a service for intelligent intrusion detection in Edge-of-Things ecosystem," Singh *et al.* present a dew computing as a service (DaaS) for intelligent intrusion detection in Edge-of-Things ecosystems. In DaaS, a deep-learning-based classifier is used to design an intelligent alarm filtration mechanism. In this mechanism, the filtration accuracy is improved (or sustained) by using deep belief networks.

In the article "Cloud–edge-based lightweight temporal convolutional networks for remaining useful life prediction in IIoT," Ren *et al.* combine cloud edge computing and AI techniques to propose a new data-driven approach, namely, cloud-edge-based lightweight temporal convolutional networks, for bearing remaining useful life (RUL) prediction.

In the article "Deep-learning-enhanced multitarget detection for end–edge–cloud surveillance in smart IoT," Zhou *et al.* present a new neural network model A-YONet by combining the advantages of YOLO and MTCNN and deployed it in an end-edge-cloud surveillance system. The proposed model can achieve lightweight training and feature learning with limited computational sources.

In the article "An efficient container management scheme for resource-constrained intelligent IoT devices," Chhikara *et al.* propose a new host overload/underload detection algorithm that first performs dimensionality reduction to improve visualization and then performs clustering analysis. The proposed algorithm is used to find the best container placement destination to solve the host overload/underload problem and thus improve the energy efficiency of the host server.

In the article "IoT microservice deployment in edge-cloud hybrid environment using reinforcement learning," Chen *et al.* propose a microservice-based deployment problem (MSDP) and use reinforcement learning and neural networks to learn deployment policies to minimize the average waiting time. By learning the policy, the service provider can fully utilize the limited resources to provide Quality of Service (QoS).

In the article "Toward anomaly behavior detection as an edge network service using a dual-task interactive guided neural network," Guo *et al.* propose an abnormal behavior detection algorithm as an edge network service by combining the advantages of cloud computing and the efficiency of edge networks. This method combines the double verification of global behavior detection and local fine-grained action cycle alignment to detect whether the behavior is abnormal. The proposed model uses an active label learning algorithm based on recurrent clustering to predict the test samples whose categories do not appear in the training phase.

In the article "Energy-aware metaheuristic algorithm for Industrial-Internet-of-Things task scheduling problems in fog computing applications," Abdel-Basset *et al.* present an energy-aware metaheuristic algorithm based on the Harris hawk search for task scheduling in fog computing (TSFC) to improve the QoSs in IoT applications. The proposed algorithm adopts a swap mutation operation and a local search strategy to balance the workload of tasks among all virtual machines and improve the quality of the best solution.

In the article "Efficient approaches to top-r influential community search," Luo *et al.* study the top-r influential communities problem in general networks where nodes have equal weight for the first time and develop an efficient algorithm to judge the connectivity of nodes with the same weight, which is shown to have a time complexity linear to the size of a subgraph accessed by the algorithm.

In the article "A Stackelberg game pricing through balancing trilateral profits in big data market," Xiao *et al.* propose a pricing mechanism and trilateral profit maximization model and develop a Stackelberg-game economic framework to model the interactions among three parties.

In the article "Large-scale high-utility sequential pattern analytics in Internet of Things," Srivastava *et al.* present a four-stage MapReduce framework that is solely based on the well-known Spark platform for use in HUSPM. This framework is shown to create more efficient and faster mining performance for dealing with the large data sets. It consists of four phases, such as initialization, mining, updating, and generation phases to handle the big data sets based on the MapReduce framework running on the Spark platform.

In the article "Distributed query processing in the edge-assisted IoT data monitoring system," Cai and Shi define a query processing problem in an EDMS which aims to derive a distributed query plan with the minimum query response latency and prove that this problem is NP-hard and propose a corresponding approximation algorithm.

In the article "Networking integrated cloud–edge–end in IoT: A blockchain-assisted collective Q-learning approach," Qiu *et al.* propose a blockchain-based collective Q-learning (CQL) approach, where lightweight IoT nodes are used to train parts of learning layers, then employ blockchain to share learning results in a verifiable and permanent manner.

In the article "METO: Matching-theory-based efficient task offloading in IoT-Fog interconnection networks," Swain *et al.* propose a matching-theory-based efficient task offloading strategy called METO that aims to reduce the total system energy and number of outages (number of tasks exceeding the deadline) in an IoT-Fog interconnection network.

In the article "Intelligent trust-based public-key management for IoT by linking edge devices in a fog architecture," Sayad Haghighi *et al.* propose a novel semidecentralized public-key management scheme for smart IoT systems in which devices intelligently decide whether to look for keying material locally at the edge or refer to the cloud for this purpose.

In the article "Security-aware deployment optimization of cloud–edge systems in Industrial IoT," Casola *et al.* present a novel formalization of the cloud–edge allocation problem for the Industrial IoT context. The proposed optimization process takes explicitly into account two critical aspects that are often

overlooked in similar approaches, namely, the new cloud-edge on-demand service offerings model for the allocation of resources and the impact on the deployed application.

In the article "EcRD: Edge-cloud computing framework for smart road damage detection and warning," Yuan *et al.* propose EcRD, an edge-cloud-based road damage detection and warning framework, that leverages the fast-responding advantage of edge and the large storage and computation resource advantages of cloud.

In the article "Multimodality sentiment analysis in Social Internet of Things based on Hierarchical Attentions and CSAT-TCN With MBM Network," Xiao *et al.* present a hierarchical self-attention fusion (H-SATF) model for capturing contextual information better among utterances, a contextual self-attention temporal convolutional network (CSAT-TCN) for the sentiment recognition in social IoT, and a multi-branches memory (MBM) network that stores self-speaker and interspeaker sentimental states into global memories.

In the article "KEEP: Secure and efficient communication for distributed IoT devices," Xi *et al.* presented the fast mobile key extraction protocol KEEP in order to improve the security of the system. The proposed protocol KEEP uses a verification and reorganization mechanism, with the help of the distributed computing method in the IoT environment, according to the measurement of the physical channel state information (CSI) of different subcarriers, so that the communication parties can generate the same encryption key without the public-key authentication, digital signature, or key distribution center (KDC) of the other party.

In the article "IoT application modules placement and dynamic task processing in edge-cloud computing," Fang and Ma propose the following solutions to resolve the different requests of the IoT device. In an edge-cloud heterogeneous network environment, create a mapping scheme between application modules and basic resource equipment, taking into account the two factors of tolerant task latency and system power consumption. In the application of the step-by-step execution process, the heuristic dynamic task processing algorithm is used to reduce the latency time of task processing.

In the article "Efficient parallel secure outsourcing of modular exponentiation to cloud for IoT applications," Hu *et al.* propose a parallel distribution scheme that uses parallel algorithms to safely and efficiently outsource modular power seeking to honest and curious servers, thereby significantly reducing the computational cost to the end user.

In the article "Cloud-edge orchestration for the Internet of Things: Architecture and AI-powered data processing," Wu investigates the state-of-the-art on AI-powered cloud-edge orchestration for IoT, in terms of architecture, offloading, security and privacy, and applications.

We would like to express our sincere thanks to all the authors for submitting their papers and to the reviewers for their valuable comments and suggestions that significantly enhanced the quality of these articles. We are also grateful to Prof. X. Shen, the former Editor-in-Chief, and Prof. H. Wang, the current Editor-in-Chief of IEEE INTERNET OF THINGS JOURNAL, for their great support throughout the whole review and publication process of this special issue, and, of course, all the editorial staff. We hope that this special issue will serve as a useful reference for researchers, scientists, engineers, and academics in the field of smart IoT system.

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