Guest Editorial
Special Issue on Emerging Trends and Challenges in Fog Computing for IoT

WITH the emergence of the Internet of Things (IoT), billions of heterogeneous physical objects are connected through a network for collecting and sharing information, which can improve various aspects of daily lives, including smart living and transportation, and smart ambient environment, including smart city, smart home, smart agriculture, smart water, waste management, etc. The main objective of the IoT devices is to provide seamless services to the users without their intervention. The all-connected paradigm (i.e., connecting people, things, processes, and data in the network) is based on near Internet ubiquity and includes three types of communication: 1) machine-to-machine; 2) person-to-machine; and 3) person-to-person, and consists as the base for reliable services provision to the end devices at the edge. Fog paradigm implements effectively and efficiently the all-data requests to be shared in a reliable manner as fog implementations complement the cloud computing paradigm by extending computing and caching capabilities to the edges of the network, and it facilitates smart localization decisions and rapid responses. The wide range of IoT services calls for a disruptive, highly efficient, scalable, and flexible communication network able to cope with the increasing demands and the number of connected devices, as well as the diverse and stringent application requirements.

To this end, the current Special Issue on Emerging Trends and Challenges in Fog Computing for IoT aims at discovering: 1) novel management procedures for fog-computing-engaged approaches in the device-to-device and M2M communication facilitated to the use of Internet big data analysis; 2) new management approaches in the fog and cloud paradigm for the edge devices for improving the communication of the IoT and the cloud, including new APIs and web services; and 3) novel mechanisms for managing big data into IoT and fog environments using microservices and including all the contexts of confidentiality/privacy, integrity, authenticity, nonrepudiation, availability, and authorization for providing security related to IoT. Finally, a parallel aim of this special issue is to understand the potential technical limitations for a full integration of different applicability scenarios into IoT and fog-related paradigms.

To tackle all the above challenges, a careful consideration and assessment of all submissions were exercised, resulting in 15 accepted articles.

Abdel-Basset *et al.*, in “A novel intelligent medical decision support model based on soft computing and IoT,” suggest a novel IoT system-based decision-making model for detecting and monitoring patients with type-2 diabetes. The authors use the WBAN and mobile application interface for capturing the social exchanges and changes in symptoms of the user’s body. After gathering personal data and symptoms, the authors categorize users into diseased by type-2 diabetes or uninfected people by using a fog-oriented configuration. Yousafzai *et al.*, in “Process migration-based computational offloading framework for IoT-supported mobile edge/cloud computing,” propose a process migration-based computational offloading framework for IoT supported mobile-edge/cloud computing by implementing a lightweight process migration-based computational offloading framework. The proposed framework does not require application binaries at edge servers, and thus seamlessly migrates native applications. The VNF lifecycle management challenges that arise from heterogeneous architectures are discussed by Sarrigiannis *et al.*, in “Online VNF lifecycle management in an MEC-enabled 5G IoT architecture,” in terms of VNF onboarding and scheduling, providing one latency-based embedding and one online scheduling algorithm, respectively, enhancing the intelligence of the NFV orchestrator (NFVO). The authors provide a generic MEC-enabled 5G testbed composition and executed IoT-based experiments to further demonstrate our algorithms’ benefits that maximize the number of served users in the system by taking advantage of the online allocation of edge and core resources, without violating their SLAs.

Due to the continued rise of IoT and microservice-based architectures, the decision on which microservice to scale in order to increase performance becomes a challenging task. The article titled “Adaptive microservice scaling for elastic applications” by Cruz Coulson *et al.* propose a prototype autoscaling system for microservice-based web applications that demonstrate how a supervised model identifies which microservices should be scaled up more. The next article titled “*ICedge*: When edge computing meets information-centric networking” by Mastorakis *et al.* designs and prototypes information-centric edge (*ICedge*), a general-purpose networking framework that streamlines service invocation and improves reuse of redundant computation at the edge. The testbed deployment results demonstrate that *ICedge* can achieve better task completion times leveraging its network-based compute reuse mechanism compared to cases, where reuse is not available.

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Furthermore, a trustworthy data collection on the basis of edge computing in IoT is proposed in "Edge-computing-based trustworthy data collection model in the Internet of Things" by Wang *et al.* with mapping the trust value of a node onto a force for the mobile data collector.

Kaur *et al.*, in "KEIDS: Kubernetes-based energy and interference driven scheduler for Industrial IoT in edge-cloud ecosystem," present a competent controller, named KEIDS, for container management on edge-cloud nodes taking into account the emission of carbon footprints, interference, and energy consumption. An extensive evaluation of the proposed KEIDS scheduler in comparison to the existing state-of-the-art schemes is presented on the Google computer cluster data set. The Ocean-of-Things (OoT) framework is designed by Yang *et al.* for marine environment monitoring based on the IoT technology in "Fog-based marine environmental information monitoring toward Ocean of Things." The designed fog layer is evaluated based on marine multisensor information. The results demonstrate that fog-based multisensor data processing shows low time consumption and high reliability. The article "A reconfigurable method for intelligent manufacturing based on industrial cloud and edge intelligence" by Tang *et al.* introduces a cloud-assisted and edge-decision-making manufacturing architecture that contains a cloud and production edges. Basically, the authors model a multiagent system with the edge intelligence support, describing the agent-based reconfiguration mechanism from the three aspects, namely, agent interaction, agent behavior, and negotiation mechanism.

Liao *et al.* consider the optimization of channel selection that is critical for efficient and reliable task delivery in their article titled "Learning-based context-aware resource allocation for edge-computing-empowered Industrial IoT." The authors aim at maximizing the long-term throughput subject to long-term constraints of energy budget and service reliability. They propose a learning-based channel selection framework with service reliability awareness, energy awareness, backlog awareness, and conflict awareness, by leveraging the combined power of machine learning, Lyapunov optimization, and matching theory. The authors provide rigorous theoretical analysis and prove that the proposed framework can achieve guaranteed performance with a bounded deviation from the optimal performance with global state information (GSI) based on only local and causal information. Gao *et al.* analyze the combination of blockchain and SDN for the effective operation of VANET systems in 5G and fog-computing paradigms by presenting their work titled "A blockchain-SDN-enabled Internet of Vehicles environment for fog computing and 5G networks." With managerial responsibilities shared between the blockchain and the SDN, it helps to relieve the pressure off the controller due to the ubiquitous processing that occurs. A trust-based model that curbs malicious activities in the network is also presented. Simulation results substantially guarantee an efficient network performance, while also ensuring there is trust among the entities. Baek *et al.* consider three dynamic pricing mechanisms for resource allocation of edge computing for IoT environment with a comparative analysis: 1) the BID-proportional allocation mechanism (BID-PRAM); 2) the uniform pricing mechanism (UNI-PRIM); and 2) the fairness-seeking differentiated pricing mechanism (FAIDPRIM). Their work is titled "Three dynamic pricing schemes for resource allocation of edge computing for IoT environment." In this context, BID-PRAM is newly proposed to overcome the limitation of the auction-based pricing scheme; UNI-PRIM is a basic uniform pricing scheme; and FAID-PRIM is newly proposed to tackle the fairness issues of the differentiated pricing scheme. BIDPRAM is formulated as a noncooperative game. UNI-PIM and FAID-PRIM are formulated as a single-leader–multiple-followers Stackelberg game. In each mechanism, the Nash equilibrium (NE) or Stackelberg equilibrium (SE) solution is given with the proof of existence and uniqueness. Numerical results validate the proposed theorems and present a comparative analysis of three mechanisms.

Li *et al.* in their article titled "Fog-computing-based approximate spatial keyword queries with numeric attributes in IoV" present a novel methodology for a fog-based network structure FCV to improve query processing efficiency and reduce query feedback time. To deal with multiple and complex queries, a two-level hybrid index STAG-tree is proposed, whose first level is a G-tree which accelerates the calculation of the network distance between objects and the query, and whose second level is the textual and numeric component which efficiently organizes the information of objects in the edges and the subgraphs of the traffic network in IoV. The authors demonstrate through several lemmas an efficient Top-k A2SKIV query processing algorithm which is proved to be robust and highly scalable under heavy conditions.

In "Application offloading strategy for hierarchical fog environment through swarm optimization," Adhikari *et al.* design an optimal application offloading strategy in the hierarchical fog environment using the accelerated particle swarm optimization (APSO) technique. Toward this novel technique the APSO technique finds the best-fit computation device for each application using multiple objectives of IoT, i.e., the latency and cost, whereas the performance of the proposed algorithm is evaluated using four different real-time data sets with different performance metrics.

Liang *et al.* in their work "Toward edge-based deep learning in Industrial Internet of Things" tackle the problem of the enormous data volume collected by IoT devices that must be transmitted to the cloud affecting the IoT network performance as well as the supported applications. To address this aggravation, their work leverages the fog/edge-computing paradigm and proposes an edge computing-based deep learning model, which utilizes edge computing to migrate the deep learning process from cloud servers to edge nodes, reducing data transmission demands in the Industrial IoT network and mitigating network congestion. The authors thoroughly evaluate their proposed solution by designing a testbed implemented in the Google cloud and deploy the proposed convolutional neural network (CNN) model, utilizing a real-world I-IoT data set, conducting extensive experimental foundations that demonstrate the effectiveness of their approach.

As guest editors, we would like to express our gratitude to the authors for their excellent contributions to this special

issue. In addition, we would like to thank all the reviewers who dedicated their efforts in reviewing the articles, and for their valuable comments and constructive suggestions that significantly improved the quality of the articles. Finally, special thanks are due to the Editor-in-Chief of the IEEE INTERNET OF THINGS JOURNAL, for his help in the publication process. We hope that the carefully selected articles of this special issue can serve as a good reference for scientists, engineers, and academicians in the area of fog computing in the IoT era.

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CONSTANDINOS X. MAVROMOUSTAKIS, *Guest Editor*
University of Nicosia
CY-1700 Nicosia, Cyprus
(e-mail: mavromoustakis.c@unic.ac.cy)

MITHUN MUKHERJEE, *Guest Editor*
College of Artificial Intelligence
Nanjing University of Information Science and Technology
Nanjing 210044, China
(e-mail: m.mukherjee@ieee.org)

GEORGE MASTORAKIS, *Guest Editor*
Department of Management Science and Technology
Hellenic Mediterranean University
72100 Agios Nikolaos, Greece
(e-mail: gmastorakis@hmu.gr)

HOUBING SONG, *Guest Editor*
Department of Electrical Engineering and Computer Science
Security and Optimization for Networked Globe Laboratory
Embry–Riddle Aeronautical University
Daytona Beach, FL 32114 USA
(e-mail: h.song@ieee.org)

MARIA GORLATOVA, *Guest Editor*
Department of Electrical and Computer Engineering
Duke University
Durham, NC 27708 USA
(e-mail: maria.gorlatova@duke.edu)

MOHAMMAD AAZAM, *Guest Editor*
Department of Computer Science
Carnegie Mellon University
Doha, Qatar
(e-mail: aazam@ieee.org)

Constandinos X. Mavromoustakis (Senior Member, IEEE) received the five-year Dipl.Eng. degree (B.Sc., B.Eng., and M.Eng./KISATS approved/accredited) in electronic and computer engineering from the Technical University of Crete, Crete, Greece, the M.Sc. degree in telecommunications from the University College of London, London, U.K., and the Ph.D. degree from the Department of Informatics, Aristotle University of Thessaloniki, Thessaloniki, Greece.

He is currently a Professor with the Department of Computer Science, University of Nicosia, Nicosia, Cyprus. He is leading the Mobile Systems Lab, Department of Computer Science, University of Nicosia. He has a dense research work outcome in mobile and wearable computing systems and the Internet of Things, consisting of numerous refereed publications (>230), including several books (IDEA/IGI, Springer, and Elsevier). He has served as a consultant to many industrial bodies (including Intel Corporation LLC). He has participated in several FP7/H2020/Eureka and national projects. He has authored one patent and is the main author of one prototype Middleware for Assisted Living.

Dr. Mavromoustakis has been an Active Member (Vice Chair) of the IEEE/R8 Regional Cyprus Section since January 2016. Since May 2009, he has been serving as the Chair of the C16 Computer Society Chapter of the Cyprus IEEE Section. He is a Management Member of the IEEE Communications Society Radio Communications Committee and a Board Member of the IEEE-SA Standards IEEE SCC42 WG2040.

Mithun Mukherjee (Senior Member, IEEE) received the B.E. degree in electronics and communication engineering from the University Institute of Technology, Burdwan University, Bardhaman, India, in 2007, the M.E. degree in information and communication engineering from the Indian Institute of Science and Technology, Shibpur, India, in 2009, and the Ph.D. degree in electrical engineering from the Indian Institute of Technology Patna, Patna, India, in 2015.

He is currently a Professor with the College of Artificial Intelligence, Nanjing University of Information Science and Technology, Nanjing, China. He has (co)authored more than 80 publications in peer-reviewed international transactions/journals and conferences. His current research interests include wireless communications, fog computing, and ultrareliable low-latency communications.

Dr. Mukherjee was a recipient of the 2016 EAI International Wireless Internet Conference, the 2017 International Conference on Recent Advances on Signal Processing, Telecommunications and Computing, the 2018 IEEE SYSTEMS JOURNAL, and the 2018 IEEE International Conference on Advanced Networks and Telecommunications Systems Best Paper Award. He has been an Associate Editor of IEEE ACCESS and a Guest Editor of the IEEE INTERNET OF THINGS JOURNAL, the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, *ACM/Springer Mobile Networks and Applications*, and *Sensors*.

George Mastorakis (Member, IEEE) received the M.Sc. degree in telecommunications from University College London, London, U.K., in September 2001, and the Ph.D. degree in communication networks from the University of the Aegean, Mytilene, Greece, in July 2008.

He currently serves as an Associate Professor with the Department of Management Science and Technology, Hellenic Mediterranean University, Irákleion, Greece, where he is the Director of the e-Business Intelligence Laboratory. He has actively participated in a large number of EU-funded research projects (FP6, FP7, and Horizon2020) and national research ones. He has also acted as a Technical Manager in many research projects funded by the General Secretariat for Research and Technology, Ministry of Development, Greece. He has more than 300 publications at various international conferences proceedings, workshops, scientific journals, and book chapters. He has also authored/edited more than ten books. His research interests include cognitive radio networks, IoT applications, IoE architectures, radio resource management, artificial intelligence applications, Internet-of-Vehicles technologies, and 5G mobile networks.

Dr. Mastorakis has acted as a reviewer for several scientific journals and a member of conferences technical program committees.

Houbing Song (Senior Member, IEEE) received the M.S. degree in civil engineering from the University of Texas, El Paso, TX, USA, in December 2006, and the Ph.D. degree in electrical engineering from the University of Virginia, Charlottesville, VA, USA, in August 2012.

In August 2017, he joined the Department of Electrical, Computer, Software, and Systems Engineering, Embry–Riddle Aeronautical University, Daytona Beach, FL, USA, where he is currently an Assistant Professor and the Director of the Security and Optimization for Networked Globe Laboratory. He served on the faculty of West Virginia University, Charlottesville, VA, USA, from August 2012 to August 2017. In 2007, he was an Engineering Research Associate with Texas A&M Transportation Institute, Dallas, TX, USA. His research has been featured by popular news media outlets, including IEEE GlobalSpec's *Engineering360*, *USA Today*, *U.S. News & World Report, Fox News*, the Association for Unmanned Vehicle Systems International, *Forbes*, WFTV, and *New Atlas*. His research interests include cyber–physical systems, cyber security and privacy, Internet of Things, edge computing, AI/machine learning, big data analytics, unmanned aircraft systems, connected vehicle, smart and connected health, and wireless communications and networking.

Dr. Song has been serving as an Associate Technical Editor for the *IEEE Communications Magazine* since 2017; an Associate Editor for the IEEE INTERNET OF THINGS JOURNAL since 2020; and a Guest Editor for the IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, the IEEE INTERNET OF THINGS JOURNAL, the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, IEEE SENSORS JOURNAL, the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, and IEEE NETWORK.

Maria Gorlatova received the Ph.D. degree (with the Highest Departmental Distinction) in electrical engineering from Columbia University, New York, NY, USA.

She is an Associate Research Scholar and an Associate Lab Director with the Department of Electrical Engineering, Princeton University, Princeton, NJ, USA. Her research focuses on the challenges and opportunities associated with adding connectivity and intelligence to every device big and small—the multidisciplinary area currently, known as the Internet of Things. She worked in industry in research, development, and business strategy roles at several companies, including Telcordia Technologies, Bridgewater, NJ, USA; IBM, Armonk, NY, USA; and D. E. Shaw Research, New York. She is heavily involved in the activities of the industry-wide OpenFog Consortium that accelerates the development and deployment of fog computing architectures.

Dr. Gorlatova received several recognitions, including the Google Anita Borg USA Fellowship, the 2016 IEEE Communications Society Young Author Best Paper Award, the 2011 ACM SenSys Best Student Demonstration Award, the 2011 IEEE Communications Society Award for Advances in Communications, and the Jury Award for Advances in Communications. She serves on the Technical Program Committees of IEEE INFOCOM, IEEE VTC, and ACM/SIGBED EWSN, co-chairs the Internet of Things and Wearable Tech track of the Grace Hopper Celebration of Women in Computing that is attended by 18 000 people, and judges prestigious Innovation Awards of the Consumer Electronics Show.

Mohammad Aazam (Senior Member, IEEE) received the Ph.D. degree in computer engineering from Kyung Hee University, Seoul, South Korea, in 2015.

He is currently a Senior Research Scientist with Carnegie Mellon University in Qatar, Doha, Qatar. He has previously worked as a Postdoctoral Fellow with Carleton University, Ottawa, ON, Canada, and Ryerson University, Toronto, ON, Canada. In addition to that, he has completed a course on Data Science with R from Harvard University, Cambridge, MA, USA, in 2017, and a course on Internet of Things from King's College London, London, U.K., in 2016. He has more than 100 publications, including three patents.

Dr. Aazam is a Founding Member of the IEEE SIG Intelligent Internet Edge. For more details, visit: www.aazamcs.com.