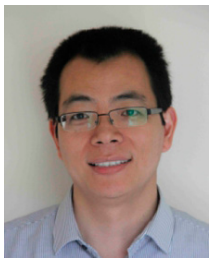
EDGE ARTIFICIAL INTELLIGENCE IN 6G SYSTEMS: THEORY, KEY TECHNIQUES, AND APPLICATIONS

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As the permeation of artificial intelligence (AI) in wireless applications, some data-driven and computing-intensive services are emerging, such as mobile high-definition AR/VR, and real-time fingertip interactions. Moreover, the application scenarios have been extended to penetrate the vertical industry, which have multi-dimension and diverse quality of service (QoS) requirements. Recently, the research and the development of 6G have been triggered, and much higher QoS requirements of data rate, latency, and connectivity will be raised.

To support the user experience of these services in 6G systems, the procedures of data transmissions and service implementations should be coupled tightly. It requires the fusion of AI and big data to enable the network intelligence, especially at the edge of wireless networks. Therefore, the concept of edge AI is raised to support AI-driven services, and to implement intelligent network management and signal processing. The key idea of edge AI is to support the applications of AI via the coordination of the edge nodes, such as the user devices and the access points, which can fully explore the potential of fog computing and edge caching capability of the future 6G systems.

Compared with the existing research fields that AI are successfully employed, the implementations edge AI in 6G systems faces some unique challenges: First, from the perspective of data, the data sets are sensed and collected by the edge nodes. The distributions of these data are neither independent nor identical, or unbalanced. Second, from the perspective of learning strategies and models, the existing centralized learning paradigms are not suitable, since the communication costs are extremely high, and there exist critical security issues to transmit the privacy-sensitive user data via wireless channels. Finally, from the perspective of implementations, the blue print of the application scenarios of edge AI is not clear enough, and its potential is still unknown.

Therefore, the target of this feature topic is to will focus on the state-of-art works with respect to the theory, key techniques and applications of edge AI in 6G systems, which can provide efficient solutions for the key challenges. We have received 16 submissions in total for this feature topic. After a rigorous review process, five papers have been accepted for publication. These works have investigated a wide spread of topics with respect to edge intelligence in 6G systems, which are summarized as follows in details.

The first article "The interplay between artificial intelligence and fog radio access networks," by Xia *et al.*, studies the deployment of AI in fog radio access networks (F-RANs), which can provide some insights for the evolution of the future 6G systems. In particular, the functions of AI have been integrated in F-RANs, and the corresponding cooperative learning paradigms have been proposed to enable network edge intelligence. Finally, the potential application cases have been presented.

The second article "Joint resource allocation and admission control in sliced fog radio access networks," by Ai *et al.*, investigates the joint optimization of different network slicing instances in F-RANs, and it provides a referenced framework of intelligent orchestration and management for future 6G wireless networks. In this article, both the resource allocation and admission control of the hotspot and Internet-of-things (IoT) slices are jointly designed to satisfy diverse QoS requirements with high efficiency of resource utilization.

The third article "Reinforcement learning-based joint task offloading and migration schemes optimization in mobility-aware MEC network," by Wang *et al.*, proposes an AI-based computation offloading scheme to fully explore the dispersive computation capability located at the edge of networks. To implement real-time adaption with high-speed mobile users, a reinforcement learning based

algorithm have been designed to maximize the system revenue of computation task offloading and migration.

The fourth article "Performance analysis of cooperative NOMA based intelligent mobile edge computing system," by Dong *et al.*, analyzes the theoretical performance of NOMA transmissions in intelligent mobile edge computing (MEC) systems. In this article, the cooperative learning scenario is considered in the MEC systems. To improve the efficiency of migrating the learning tasks from the user devices to the powerful MEC server, a NOMA-based scheme has been proposed, and both the offloading probability and throughput are analyzed to evaluate the reliability and efficiency of computation offloading, respectively.

The last article "PVF-DA: Privacy-preserving, verifiable and fault-tolerant data aggregation in MEC," by Zhang *et al.*, proposes a data aggregation scheme to guarantee the security and user privacy, which can provide a secure paradigm to collect training data for learning model generation and update. In this article, by employing zero-knowledge proof, aggregator oblivious encryption and ElGmal encryption, the proposed scheme is privacy-preserving, verifiable, and fault-tolerant.

Finally, we would like to thank all the authors who contribute to this feature topic. We also appreciate the great efforts of the reviewers, and the guidance from the Editor-in-Chief, managing editors and staff members.

Biographies

Zhongyuan Zhao, received the B.S. degree in applied mathematics and the Ph.D. degree in communication and information systems from Beijing University of Posts and Telecommunications (BUPT), Beijing, China, in 2009 and 2014, respectively. He is currently an associate professor with BUPT. His research interests include fog/edge computing, content caching, and edge intelligence in wireless networks. Dr. Zhao serves as an editor of IEEE COMMUNICATIONS LETTERS (since 2016), and received Exemplary Editors Award twice (2017 and 2018). He was the recipient of the Best Paper Awards at the IEEE CIT 2014 and WASA 2015, and the Exemplary Reviewer Awards of IEEE Transaction on Communications 2017 and IEEE Wireless Communication Letters 2019.

Zhiguo Ding, received the B.Eng. degree in electrical engineering from the Beijing University of Posts and Telecommunications, Beijing, China, in 2000, and the Ph.D. degree in electrical engineering from Imperial College London, London, U.K., in 2005. From July 2005 to April 2018, he was working with Queen's University Belfast, Imperial College, Newcastle University, and Lancaster University, England, U.K. Since April 2018, he has been with The University of Manchester, Manchester, U.K., as a Professor in communications. From October 2012 to September 2020, he has also been an Academic Visitor with Princeton University, NJ, U.S. His research interests are 5G networks, game theory, cooperative and energy harvesting networks and statistical signal processing. He is serving as an Area Editorfor the IEEE OPEN JOURNAL OF THE COMMUNICATIONS SOCIETY, an Editor for the IEEE TRANSACTIONS ON COMMUNICATIONS, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, and Journal of Wireless Communications and Mobile Computing. From 2013 to 2016, he served as an Editor for the IEEE WIRELESS COMMUNICATION LETTERS and IEEE COMMUNICATION LETTERS. He was the recipient of the Best Paper Award in the IET ICWMC in 2009 and the IEEE WCSP in 2014, the EU Marie Curie Fellowship from 2012 to 2014, the Top IEEE TVT Editor in 2017, the IEEE Heinrich Hertz Award in 2018, the IEEE Jack Neubauer Memorial Award in 2018, and the IEEE Best Signal Processing Letter Award in 2018.

Tony Q. S. Quek, received the B.E. and M.E. degrees in electrical and electronics engineering from the Tokyo Institute of Technology, Tokyo, Japan, in 1998 and 2000, respectively, and the Ph.D. degree in electrical engineering and computer science from the Massachusetts Institute of Technology, Cambridge, MA, USA, in 2008. Currently, he is the Cheng Tsang Man Chair Professor with Singapore University of Technology and Design (SUTD). He also serves as the Acting Head of ISTD Pillar, Sector Lead of the SUTD AI Program, and the Deputy Director of the SUTD-ZJU IDEA. His currentresearch topics include wireless communications and networking, network intelligence, internet-of-things, URLLC, and big data processing. Dr. Quek has been actively involved in organizing and chairing sessions, and has served as a member of the Technical Program Committee as well as symposium chairs in a number of international conferences. He is currently serving as an Editor for the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, the Chair of IEEE VTS Technical Committee on Deep Learning for Wireless Communications as well as an elected member of the IEEE Signal Processing Society SPCOM Technical Committee. He was an Executive Editorial Committee Member for the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, an Editor for the IEEE TRANSACTIONS ON COMMUNICATIONS, and an Editor for the IEEE WIRELESS COMMUNICATIONS LETTERS. Dr. Quek was honored with the 2008 Philip Yeo Prize for Outstanding Achievement in Research, the 2012 IEEE William R. Bennett Prize, the 2015 SUTD Outstanding Education Awards-Excellence in Research, the 2016 IEEE Signal Processing Society Young Author Best Paper Award, the 2017 CTTC Early Achievement Award, the 2017 IEEE ComSoc AP Outstanding Paper Award, and the 2016-2019 Clarivate Analytics Highly Cited Researcher. He is a Distinguished Lecturer of the IEEE Communications Society and a Fellow of IEEE.

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