Guest Editorial

Special Topic on Federated Learning over Wireless Networks

Guest Editors


CUI Shuguang


YIN Changchuan


ZHU Guangxu

Federated learning has revolutionized the way we approach machine learning by enabling multiple edge devices to collaboratively learn a shared machine learning model without the need for centralized data collection. Such a new machine learning paradigm has gained significant attention in recent years due to its ability to address privacy and security concerns associated with centralized learning, as well as its potential to reduce communication overhead and improve scalability. Deploying cross-device federated learning at the network edge over wireless networks has further extended its potential due to the close proximity to the gigantic number of mobile data and computing power provided by the surging number of Internet of Things (IoT) devices, and is expected to breed new intelligent applications that demand delay-sensitive and mission-critical services, such as smart industry, auto-driving, and metaverse. Despite its great promise, the successful deployment of federated learning over wireless networks has also presented its own unique set of challenges, including network heterogeneity, communication delays, and unreliable connections.

In this special issue, a series of articles are presented to address the aforementioned challenges and propose innovative solutions to enabling federated learning over wireless networks. These articles cover a wide range of topics, including wireless communication protocols, optimization algorithms, security and privacy concerns, network architecture designs, and the application of federated learning in IoT and 5G networks. The call-for-papers of this special issue have brought excellent submissions in both quality and quantity. After two-round reviews, five excellent papers have been selected for publication in this special issue which is organized as follows.

The first paper titled "Adaptive Retransmission Design for Wireless Federated Edge Learning" proposes a novel retransmission scheme for wireless federated edge learning (FEEL). The conventional retransmission schemes for wireless systems, which aim to maximize the system throughput or minimize the packet error rate, are not suitable for the FEEL system. The proposed scheme makes a tradeoff between model training accuracy and retransmission latency, with a retransmission device selection criterion designed based on the channel condition, the number of local data, and the importance of model update. Additionally, the air interface signaling is designed to facilitate the implementation of the proposed scheme in practical scenarios. Simulation experiments validate the effectiveness of the proposed retransmission scheme.

The second paper titled "Reliable and Privacy-Preserving Federated Learning with Anomalous Users" proposes a reliable and privacy-preserving federated learning scheme named RPPFL, based on a single-cloud model. The scheme addresses the issue of anomalous users holding low-quality data, which may reduce the accuracy of trained models. The proposed approach identifies the user's reliability and thereby decreases the impact of anomalous users, based on the truth discovery technique. The additively homomorphic cryptosystem is utilized to provide comprehensive privacy preservation (user's local gradient privacy and reliability privacy). Rigorous theoretical analysis shows the security of RPPFL, and extensive experiments based on open datasets demonstrate that RPPEL compares favorably with existing works in terms of efficiency and accuracy.

The third paper titled "RIS-Assisted Federated Learning in Multi-Cell Wireless Networks" proposes a reconfigurable intelligent surface (RIS) -assisted AirComp-based federated learning (FL) in multi-cell networks. The proposed system enhances the poor user signal caused by channel fading, especially for the device at the cell edge, and reduces inter-cell in-

DOI:10.12142/ZTECOM.202301001
Citation (IEEE Format): S. G. Cui, C. C. Yin, and G. X. Zhu, "Editorial: federated learning over wireless networks," *ZTE Communications*, vol. 21, no. 1, pp. 1–2, Mar. 2023. doi: 10.12142/ZTECOM.202301001.

terference. The convergence of FL in the proposed system is analyzed, and the optimality gap for FL is derived. To minimize the optimality gap, the paper formulates a joint uplink and downlink optimization problem, which is then divided into two separable nonconvex subproblems. Following the successive convex approximation (SCA) method, the paper first approximates the nonconvex term to a linear form, and then alternately optimizes the beamforming vector and phase-shift matrix for each cell. Simulation results demonstrate the advantages of deploying a RIS in multi-cell networks, and the proposed system significantly improves the performance of FL.

The fourth paper titled "Hierarchical Federated Learning: Architecture, Challenges, and Its Implementation in Vehicular Networks" discusses hierarchical federated learning (HFL) and its implementation in vehicular networks. HFL, with a cloud-edge-client hierarchy, can leverage the large coverage of cloud servers and the low transmission latency of the edge server. The limited number of participants in vehicular networks and vehicle mobility degrades the performance of FL training, and HFL is promising in vehicular networks due to its lower latency, wider coverage, and more participants. The paper clarifies new issues in HFL, reviews several existing solutions, introduces some typical use cases in vehicular networks, and discusses the initial efforts on implementing HFL in vehicular networks.

The fifth paper titled "Secure Federated Learning over Wireless Communication Networks with Model Compression" addresses the vulnerability of FL to gradient leakage attacks. A method is proposed to compress the model size to reduce the leakage risk and enhance the efficiency of FL. Specifically, this paper presents a new scheme that applies low-rank matrix approximation to compress the model and uses a secure matrix factorization technique to recover the original model. Experiments showed that the proposed method achieved better accuracy and security compared with the state-of-the-art methods.

To conclude, it is hoped that this special issue will serve as a valuable resource for researchers, practitioners, and students who are interested in federated learning over wireless networks. We also hope that it will inspire further research in this field, leading to new and innovative solutions that will drive the evolution of machine learning. Finally, we would like to express our sincere gratitude to all the authors, reviewers, and editorial staff who have contributed to the success of this special issue. Hopefully, the articles in this special issue are both insightful and informative for prospective readers in the field.

Biographies

CUI Shuguang received his PhD in electrical engineering from Stanford University, USA in 2005. Afterward, he has been working as an assistant, associate, full, Chair Professor in electrical and computer engineering at the University of Arizona (USA), Texas A&M University (USA), UC Davis (USA), and CUHK-Shenzhen (China), respectively. He has also served as the Executive Dean for the School of Science and Engineering at CUHK-Shenzhen and the Executive Vice Director at Shenzhen Research Institute of Big Data. His current research interests focus on data driven large-scale system control and resource management, large data set analysis, IoT system design, energy harvesting based communication system design, and cognitive network optimization. He was selected as the Thomson Reuters Highly Cited Researcher and listed in the World's Most Influential Scientific Minds by ScienceWatch in 2014. He was the recipient of the IEEE Signal Processing Society 2012 Best Paper Award. He has served as the general co-chair and TPC co-chair for many IEEE conferences. He has also been serving as the editor-in-chief for *IEEE Transactions on Mobile Computing*, area editor for *IEEE Signal Processing Magazine*, and associate editor for *IEEE Transactions on Big Data*, *IEEE Transactions on Signal Processing*, *IEEE JSAC Series on Green Communications and Networking*, and *IEEE Transactions on Wireless Communications*. He has been an elected member of the IEEE Signal Processing Society SPCOM Technical Committee (2009-2014) and the elected chair of IEEE ComSoc Wireless Technical Committee (2017-2018). He is a member of the Steering Committee for *IEEE Transactions on Big Data* and the Chair of the Steering Committee for *IEEE Transactions on Cognitive Communications and Networking*. He was also a member of the IEEE ComSoc Emerging Technology Committee. He was elected as an IEEE Fellow in 2013, an IEEE ComSoc Distinguished Lecturer in 2014, and an IEEE VT Society Distinguished Lecturer in 2019. He won the IEEE ICC best paper award, ICIP best paper finalist, and the IEEE Globecom best paper award all in 2020.

YIN Changchuan received his PhD degree in telecommunication engineering from Beijing University of Posts and Telecommunications, China in 1998. In 2004, he was a visiting scholar in the Faculty of Science, the University of Sydney, Australia. From 2007 to 2008, he held a visiting position with the Department of Electrical and Computer Engineering, Texas A&M University, USA. He is currently a professor with the School of Information and Communication Engineering, Beijing University of Posts and Telecommunications. His research interests include wireless networks and statistical signal processing. He was the co-recipient of the IEEE International Conference on Wireless Communications and Signal Processing Best Paper Award in 2009 and the IEEE Communications Society Young Author Best Paper Award in 2021. He has served as the symposium co-chair or TPC member for several IEEE flagship conferences (e.g., ICC, Globecom, ISIT, etc).

ZHU Guangxu received his BS and MS degrees from Zhejiang University, China and PhD degree from The University of Hong Kong, China, all in electronic and electrical engineering. He is now a research scientist with the Shenzhen Research Institute of Big Data. His research interests include edge intelligence, federated learning, and 5G/6G technologies. He is a recipient of the 2022 "AI 2000 Most Influential Scholar Award Honorable Mention", Hong Kong Postgraduate Fellowship (HKPF), Outstanding PhD Thesis Award from HKU, and the Best Paper Award from WCSP 2013. He served as a track/symposium/workshop co-chair of several IEEE conferences including IEEE PIMRC 2021, WCSP 2023, and IEEE Globecom 2023.