Guest Editorial
The Nexus Between Edge Computing and AI for 6G Networks

WHILE 5G has gradually opened the curtain of internet of everything and brings vertical transform to change the society, 6G is believed to open a new era of "Internet of Intelligence" with connected people, connected things, and connected intelligence, solving human challenges in many aspects and helping perfect the world we all live in. To empower 6G networks with AI capabilities, large volumes of multi-modal data (e.g., user behavior records, audios, and videos) of physical surroundings will be continuously generated by the mobile and IoT devices which reside at the network edge. Driving by this trend, there is an urgent need to push the AI frontiers to the network edge so as to fully unleash the potential 6G networks. To meet this demand, edge computing, an emerging paradigm that pushes computing tasks and services from the network core to the network edge, has been widely recognized as an indispensable part for the upcoming 6G networks.

The special issue of "The Nexus Between Edge Computing and AI for 6G Networks" focused on the novel area of the interplay between edge computing and AI for 6G networks. Thanks to the extensive efforts of the reviewers and the great support from the Editor-in-Chief, Dr. Jianwei Huang, we were able to accept 21 contributed articles covering several important topics, ranging from (1) Edge computing and AI empowered emerging networks; (2) AI for edge computing; to (3) Edge computing for AI; and (4) emerging topics for 6G networks. A brief review follows:

The feature article of this special section, by Di et al., "In-Network Pooling: Contribution-Aware Allocation Optimization for Computing Power Network in B5G/6G Era," presents an in-network pooling framework to harvest idle computing and caching resources for the emerging new paradigm of computing power network (CPN). Specifically, the dynamic resource pool (RP) is first modeled to harvest the idle network resources, then the joint computing and caching problem is formulated as a long-term utility maximization problem and solved by an attention-based proximal policy optimization (APPO) scheme.

Except for the computing power network, in this special section, edge computing and AI have also witnessed successful applications in other emerging networks such as space-air-ground integrated networks, digital twin networks, vehicular networks, IoT networks, and UAV networks.

Liu et al. in "User Association, Subchannel and Power Allocation in Space-Air-Ground Integrated Vehicular Network with Delay Constraints" study the problem of resource allocation of small cells in space-air-ground integrated vehicular networks (SAGVN). Specifically, the user association is first considered to optimize connection between base stations and vehicles. On this basis, a subchannel and power allocation method is designed to ensure that users can obtain the maximum gain on its subchannel. Then, the Lagrangian duality theory is applied to solve the power allocation problem.

Sun et al. in "Lightweight Digital Twin and Federated Learning with Distributed Incentive in Air-Ground 6G Networks" design a lightweight digital twin architecture for air-ground 6G networks to realize low latency communication and intelligent network orchestration in air-ground networks. They combine federated learning with a distributed incentive mechanism to support digital twin empowered 6G networks. Simulation results show the effectiveness of the proposed lightweight scheme in terms of energy consumption and model accuracy.

Lv et al. in "Edge Computing Task Offloading for Environmental Perception of Autonomous Vehicles in 6G Networks" present a task offloading framework for collaborative environmental perception of autonomous vehicles in 6G networks. To improve the environmental perception quality through adaptive task offloading, the multi-vehicle and multi-server task offloading process is modeled as a Markov decision process. Based on the deep reinforcement learning method, an offloading decision scheme is devised to select edge nodes to maximize the long-term gains.

Prathiba et al. in "A Hybrid Deep Sensor Anomaly Detection for Autonomous Vehicles in 6G-V2X Environment" propose a Hybrid Deep Anomaly Detection (HDAD) approach for effective anomaly detection and cyber-attack mitigation in autonomous vehicles (AV). HDAD employs the multi-agent reinforcement learning algorithm over the 6G network to combat new-age cyber-attacks and provide a swift and accurate anomaly detection mechanism. HDAD further identifies and isolates malicious AVs by combining the maximum entropy inverse reinforcement learning method.

Xia et al. in "AI-Driven and MEC-Empowered Confident Information Coverage Hole Recovery in 6G-Enabled IoT" study the problem of coverage hole (CH) recovery in 6G IoT. Based on the fusion model of the disc model and the confident information model, a confident information CH recovery algorithm is first proposed to utilize the spatial correlation. Then, applying Q-learning, the algorithm is further improved to enhance recovery performance and reduce time complexity.

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Lu et al. in "Secure Transmission for Multi-UAV-Assisted Mobile Edge Computing Based on Reinforcement Learning" propose two secure transmission methods for multi-UAV-assisted mobile edge computing based on the single-agent and multi-agent reinforcement learning, respectively. In the proposed methods, the spiral placement algorithm is first applied to optimize the deployment of UAVs, Then, to reduce the information eavesdropping by a flying eavesdropper, DRL is adopted to optimize the secure offloading to maximize the system utility.

In this special section, AI methods such as deep reinforcement learning (DRL) have also shown their advantages in empowering edge computing and mobile edge networks.

He et al. in "Wireless Network Slice Assignment with Incremental Random Vector Functional Link Network" present an AI-assisted network slice prediction method, which adopts an incremental random vector functional link network to tackle the wireless network slice assignment problem in a data-driven way. The basic idea of the method is to use a data stream processing approach to gradually update output layer weights as new data arrives, rather than processing the data as a single large data set, and thus to improve the adaptability and expansibility.

Tang et al. in "Double Deep Q-Network based Dynamic Framing Offloading in Vehicular Edge Computing" study the problem of dynamical frame offloading in vehicular edge computing. This problem is formulated as a latency minimization program for multiple moving vehicles whose tasks can be divided into sequential subtasks. To address the challenge incurred by the mobility of vehicles, an online algorithm based on double deep Q-network (DDQN) is proposed to find the near-optimal offloading decision for sequential subtasks.

Huang et al. in "6G-Empowered Offloading for Realtime Applications in Multi-Access Edge Computing" propose a 6G-empowered learning-based offloading scheme real-time tasks. Specifically, the task offloading problem is first formulated as a Markov Decision Process. Thereafter, the problem is solved with a reinforcement learning algorithm, TD3. Furthermore, a lightweight learning architecture is developed to spatially decouple the training phase to the edge server, and the inference phase to the mobile devices.

Zhou et al. in "Cost Minimization-Oriented Computation Offloading and Service Caching in Mobile Cloud-Edge Computing: An A3C-based Approach" study the problem of computation offloading and service caching in a three-tier mobile cloud-edge structure. To meet the delay requirements of mobile users while reducing the cost of the cloud service provider, the authors jointly optimize the strategies of computation offloading, service caching, and resource allocation. This problem is formulated as a mixed integer nonlinear program and solved by an Asynchronous Advantage Actor-Critic (A3C)-based algorithm.

Yuan et al. in "A DQN-Based Frame Aggregation and Task Offloading Approach for Edge-Enabled IoMT" study the problem of energy-efficient frame aggregation in Wireless Body Area Network (WBAN). To address the performance, energy efficiency and flexibility deficiencies of traditional frame aggregation schemes, a Deep Q-learning Network (DQN) based frame aggregation and task offloading scheme is proposed to optimize the frame length and the aggregation node dynamically and adaptively.

In this special section, how to efficiently implement edge learning (e.g., federated learning) and edge inference serving in 6G networks is also a hot topic.

Zhao et al. in "Energy-Efficient and Fair IoT Data Distribution in Decentralised Federated Learning" address the challenges of device heterogeneity and network dynamics faced by federated learning, by proposing a data redistribution scheme that balances the data distribution on different participating devices. This problem is modeled as a bargaining game, and its equilibrium is formalized as an optimization problem. The problem is solved by a decentralized algorithm which enables each participant executes without centralized coordination.

He et al. in "AceFL: Federated Learning Accelerating in 6G-enabled Mobile Edge Computing Networks" study the problem of training acceleration of FL with heterogeneous mobile edge networks. In particular, the authors first formulate a training efficiency maximization problem to derive the analytical relation among the training loss, resource consumption and heterogeneity via convergence analysis. Then, to mitigate the straggler effect caused by the heterogeneity of edge devices, a control algorithm is developed to optimize the inexactness of local models and frequency band allocation for edge devices.

Fan et al. in "Mobile Devices Strategies in Blockchain-based Federated Learning: A Dynamic Game Perspective" implement a blockchain-based FL system and propose an incentive mechanism to establish a decentralized and transparent trading platform. To better understand the mobile devices' behaviors, an economic analysis is provided for this market. Also, the interaction among the non-cooperative mobile devices is formulated as a dynamic game, and the existence of the Nash equilibrium (NE) is verified via both theoretical analysis and numerical simulations.

He et al. in "Improving Accuracy and Convergence in Group-based Federated Learning on Non-IID Data" improve the convergence of FL on Non-IID Data via a group-based method Auto-Group, which groups users and allows localized aggregations within the group before a global aggregation. To further reduce the communication delay, Auto-Group adopts an optimized genetic algorithm to ensure that the data distribution of each group is similar to the global distribution.

Li et al. in "AI Service Placement for Multi-Access Edge Intelligence Systems in 6G" study the problem of energy-efficient AI service placement in 6G edge AI systems. To balance the three-way tradeoff among the performance, energy consumption and inference accuracy, the joint optimization of resource allocation and computing offloading is formulated as a mixed-integer non-linear programming (MINLP) problem. To efficiently solve this non-convex problem, an alternating direction multiplier method (ADMM) based distributed algorithm is proposed.

Finally, other emerging issues faced by 6G networks and applications, such as AoI (age-of-information), memory management, economic incentive, and privacy protection, have also received attention in this special section.

Feng et al. in "Joint Detection and Computation Offloading with Age of Information in Mobile Edge Networks" study

the problem of Age-of-Information (AoI)-aware computation offloading in mobile edge networks. To minimize the AoI of status and optimize offloading decisions, a node sorting algorithm is proposed based on status and AoI to generate the optimal detection sequence. To reduce the detection overhead, a threshold-based nodes' status detection scheme is further proposed to adaptively control the number of detections.

Chen et al. in "A Novel Non-Volatile Memory Update Mechanism for 6G Edge Computing" present PostMerge, a new data-update mechanism for Non-Volatile Memory (NVM) without any consistency loss. It stores data increments directly into a new NVM space and then merges them into the target blocks. To maintain the read performance, a low-overhead metadata-management policy is further developed. PostMerge has been implemented on a well-known NVM file system PMFS, experimental results show that it improves the write bandwidth by 1.7X compared to baselines.

Jiang et al. in "A Game-Theoretic Analysis of Joint Mobile Edge Caching and Peer Content Sharing" established a joint framework for mobile edge caching and peer content sharing, to study the strategic behaviors and interactions of edge devices. Specifically, their interaction is modeled as a non-cooperative game, where each edge device (player) can choose to be an agent who caches and shares contents with others, or a requester who doesn't cache but requests contents from other devices. The game equilibrium under a generic usage-based pricing scheme is characterized via both theoretical analysis and empirical simulations.

Li et al. in "Privacy Protection Method Based on Multidimensional Feature Fusion Under 6G Networks" present an information hiding framework based on multidimensional feature fusion for privacy protection in 6G networks. This framework first performs private information preprocessing to encrypt private information. Then, it conducts multidimensional feature extraction on the carrier and fuses these features to obtain the final feature region. Finally, information hiding or extracting private information is performed.

In summary, the collected articles offer innovative application scenarios and shed light on the nexus between edge computing and AI for 6G networks. We hope that this timely special section will trigger more future work in the emerging area.

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