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EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: FOG RADIO ACCESS NETWORKS (F-RANS) FOR 5G: RECENT ADVANCES AND FUTURE TRENDS

To satisfy the explosively increasing demands for high-speed data applications and massive access requirements of various Internet-of-thing (IoT) devices, a whole package of performance requirements has been proposed for the fifth-generation (5G) mobile communication system. Motivated by the necessity of network architecture enhancement, a paradigm of fog radio access networks (F-RANs) has emerged as a promising evolution path for 5G network architecture. In F-RANs, a fog-computing layer is formed at the edge of networks, and parts of service requirements can be responded to locally without interacting with the cloud computing center via the fronthaul links. Therefore, by taking full advantage of distributed caching and centralized processing, F-RANs provide great flexibility to satisfy quality-of-service (QoS) requirements of various 5G scenarios. F-RAN has become a research hotspot and draws a lot of attention from both academia and industry. As it integrates with artificial intelligence and other new emerging technologies, 5G is facing new challenges, and the study of F-RANs is entering a new era as well.

This Special Section focuses on the state-of-the-art protocols, techniques, and applications of F-RANs in the typical scenarios of 5G. The aim of this Special Section is to share and discuss recent advances and future trends of F-RANs, and to bring academic researchers and industry developers together.

This section received 44 submissions, which were all evaluated by at least two independent referees. After undergoing a rigorous peer review process, 18 articles were finally accepted. Based on their research topics, these articles can be divided into four categories. The articles in the first category analyze the information-theoretic performance of F-RANs. In the second category, the articles mainly focus on the enhancement of network architecture and management for F-RANs. The third category of articles studies resource allocation in F-RANs. In the last category, the articles discuss the potential applications of F-RANs.

The first category consists of four articles, which analyze the theoretical performance of F-RANs from transmission, edge caching and computing, and security perspectives.

In the article "Large system performance and distributed scheme of downlink beamforming in F-RANs with distributed antennas," by Zhu *et al.*, the authors analyze the performance of large-scale cooperation in F-RANs. The asymptotic performance is derived, which can provide some insights for the design of distributed beamforming in F-RANs.

The article by Jia *et al.*, "Fog-aided cognitive radio networks with guard zone and interference cancellation based opportunistic spectrum access," analyzes the performance of spectrum sharing in F-RANs. To guarantee the transmission reliability, the strategies of guard zone and interference cancellation are considered, and the coverage probability and throughput are studied to evaluate the performance of edge caching in F-RANs.

In the article "Fog radio access networks with hierarchical content delivery," by Zhong *et al.*, the authors analyze the performance of hierarchical fog-cloud content caching scheme in F-RANs. To fully explore the potential of edge caching, a cooperative content delivery scheme is studied, where both the downlink transmissions of F-APs and the D2D transmissions of users are considered. The theoretical performance results show the performance gains of caching in F-RANs.

In the article "Caching-aided physical layer security in wireless cache-enabled heterogeneous networks," by Zhao *et al.*, the authors analyze the theoretical performance of edge caching from a physical layer security perspective. The topology features of F-RANs are captured by a stochastic geometry-based model, and the impacts of content caching on security performance and network management are shown by the derived results.

Five articles were accepted in the second category. The research topics include enhancement of security frameworks, and networking and slicing in F-RANs.

In the article "A security authentication scheme of 5G ultra-dense network based on blockchain," by Chen *et al.*, the authors proposed a blockchain-based user authentication scheme. The efficiency of authentication can be improved with the help of trusted access points, which can provide a distributed authentication framework for F-RANs that operate in ultra-dense coverage areas.

In the article "Node state monitoring scheme in fog radio access networks for intrusion detection," by An *et al.*, the authors studied intrusion detection in F-RANs, which is a critical security issue. To reduce the communication

overhead and computational complexity, a fog-cloud collaborated detection mechanism is designed.

In the article "Non-interactive ID-based proxy re-signature scheme for the IoT based on mobile edge computing," by Zhang *et al.*, the authors proposed a network storage framework for the deployment of IoT in F-RANs. To improve the efficiency and security of cloud computing based architecture, a fog computing-based paradigm is designed, and a non-interactive pairing-free ID-based proxy re-signature scheme is introduced accordingly.

In the article "Multiple protocols interworking with open connectivity foundation in fog networks," by Li *et al.*, the authors design a scheme to enable interworking among multiple protocols. The authors provide a framework to guarantee the compatibility of heterogeneous edge access points in F-RANs.

The article "IVCN: Information-centric network slicing optimization based on NFV in fog-enabled RAN," by Jin *et al.*, studies the network orchestration based on NFV technique in F-RANs. Both the network slicing scheme and resource optimization algorithm are studied to improve the QoS with integrating edge caching into conventional network management.

Five articles are included in the third category, which study the optimization of computation, caching, and communication resources in F-RANs.

The article by Wang *et al.*, "Mobility-aware task offloading and migration schemes in fog computing networks," studies computation offloading in F-RANs. It provides a paradigm of task offloading and migration, which can enable fog computing-based offloading when users are in mobile status, and performance can be improved by the proposed resource optimization algorithm.

The article by Wu *et al.*, "User satisfaction-aware resource allocation for D2D enhanced communication," studies the optimization design of D2D transmissions in F-RANs. The features of mobility and social relationships are employed to improve the user satisfaction, which help the optimization of resource allocation.

In the article "Joint access mode selection and spectrum allocation for fog computing-based vehicular networks," by Yan *et al.*, the authors optimized the performance of vehicular networks which are based on the paradigm of F-RANs. A reinforcement learning-based algorithm is proposed to optimize the access mode selection and spectrum allocation, which aims to balance the costs and performance gains.

The article by Bai *et al.*, "Research on channel power allocation of fog wireless access network based on NOMA," proposes a power optimization algorithm for NOMA transmissions in F-RANs, which can improve the detection performance of successive interference cancellation. It shows that sophisticated interference management is necessary to achieve the performance gains of NOMA in F-RANs.

In the article "Delay-optimal joint processing in computation-constrained fog radio access networks," by Han *et al.*, the authors study the joint optimization of edge devices clustering and the association of fog computing servers. It can be employed for dynamic network orchestrations in F-RANs.

Four articles are included in the last category, which study the potential application scenarios in F-RANs, such as IoT and mobile edge computing.

In the article "Mobility-aware fog computing in dynamic environments: Understandings and implementation," by Waqas *et al.*, the authors provide a comprehensive literature review with respect to the deployment of fog computing in mobile circumstances, where the frameworks of mobility management, application scenarios, and experiment evaluations are introduced.

In the article "Non-orthogonal multiplexing of ultra-reliable and broadband services in fog-radio architectures," by Kassab *et al.*, the authors study the multiplexing of ultra-reliable and broadband services, which are two key application scenarios of 5G, based on the architecture of F-RANs. To satisfy the diverse QoS requirements, a non-orthogonal based coexistence scheme is proposed.

The article "Optimizing resources allocation for fog computing-based Internet of Things networks," by Li *et al.*, studies resource optimization for the IoT application scenarios in F-RANs. It considers employing NOMA techniques to support the association requirements of IoT devices.

In the article "Cooperative content caching for mobile edge computing with network coding," by He *et al.*, the authors employ network coding to improve the utility of edge content caching in F-RANs. A content recommendation scheme is designed accordingly, and its performance is evaluated by an established platform.

Finally, we would like to thank all the authors who contributed to this Special Section. We also appreciate the great efforts of the reviewers, and the guidance from the Editor-in-Chief and staff members.

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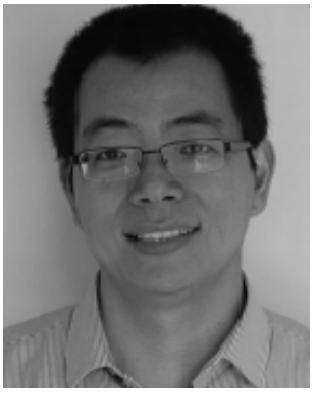
GUOQIANG MAO, photograph and biography not available at the time of publication.



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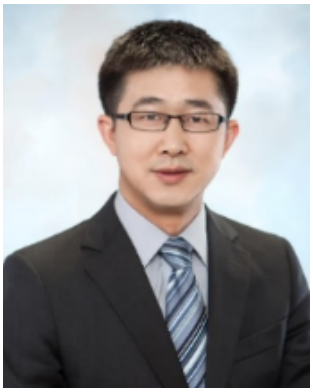

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