Smart, Optimal, and Explainable Orchestration of Network Slices in 5G and Beyond Networks

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Network slicing is a much discussed topic in Fifth Generation (5G) and beyond networks. The network slice feature differentiates the 5G and beyond (B5G) networks from the earlier generations since it replaces the conventional concept of Quality of Service (QoS) with end-to-end multi-service provisioning and multi-tenancy. A diverse set of resources for computing, networking, storage, and power need to be smartly assigned in network slices. Traditional optimization/resource scheduling techniques are typically one-dimensional and may not scale well in large-scale 5G/B5G networks. Therefore, there is a pressing need to smartly address the orchestration and management of network slices. Since beyond 5G networks will heavily use embedded intelligence, how to leverage AI-based techniques, such as machine learning, deep learning, and reinforcement learning, to address and solve the various, complex network slicing problems is emerging as a challenging problem. The guest editors strived hard to reach out to researchers from academia and industry to address these points in this special issue in quest of a genuinely intelligent beyond 5G network rollout that could be both smart and practical.

We had phenomenal support from the Editor-in-Chief of the IEEE WCM, and the IEEE staff to be able to organize the special issue with the tight scheduling and reshuffling of priorities from everyone involved, particularly during the ongoing pandemic. We had 23 submissions, out of which five articles were selected through a rigorous review process with an acceptance ratio of 21.7%. The Guest Editors are thankful to the authors for submitting their articles which addressed how to best leverage IoT and computing resources at the edge with robust security and privacy requirements of COVID-19 data collection, delivery, and processing. As such, we have selected a variety of articles which cover the relevant topics and main research challenges in the direction of

smart, optimal, and explainable orchestration and management of network slices in 5G and beyond networks using AI-based techniques.

The first paper by Wen et al. conceptualized an AI-native network slicing technique for 6G networks. They proposed AI-native network slicing involves the information exchange among various network elements, such as end users, access points, and the software-defined network (SDN) controllers in integrated space-air-ground networks. A case study was provided on AI-assisted resource reservation, aiming at reducing long-term overall system cost. Joint design of 6G network planning and operation was highlighted to be a key challenge for network slice provisioning in such complex and large network scenarios.

Next, the second article by Rodrigues et al. considered the combined resource slicing in satellite-ground networks through reinforcement learning in both centralized and decentralized manner. The proposed reinforcement learning technique was compared with conventional methods and demonstrated to provide a significantly high user acceptance ratio for both growing number of users and servers.

In the third article by Babbar et al., three use-cases of network slicing in 5G were discussed. These use-cases demonstrated enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (uRLLC), and massive Machine Type Communications (mMTC), respectively. Slice Service Type (SST) values were smartly assigned to the slices reflecting different applications, such as automotive, electric utility, and other consumer uses. The key finding of the article was the improvement of eMBB slices with the increasing number of compact cells. The uRLLC slices were found to have ten times smaller performance than the eMBB slice in a compact cell environment. On the other hand, due to increased interference, the total capacity of the mMTC slice was shown to diminish with the growing number of compact cells.

The fourth article by Jianhang et al. proposed a new and interesting architecture called the slicing-based software-defined Unmanned Aerial Vehicle (UAV)-enabled mobile edge computing. In this work, the authors exploited resource slices to offer customized multi-dimensional resources. With the flexibility and mobility of UAVs or drones, the work identified various resource slicing schemes and key research challenges. Then, a Lyapunov optimization-based offloading algorithm was designed to select the relevant resource slice, performance of which was shown to be encouraging through simulation results. Also, the authors hinted on using emerging tools such as Kubernetes and OpenDaylight to facilitate practical roll-out of this system in the emerging networks in the future.

The fifth and final article by Wang et al. considered the security of network slicing in vehicular networks in 5G and beyond settings. Efforts were given towards presenting the potential of network slicing for security protection and also analyzing its security threats from various

perspectives. In addition, a case study of using deep reinforcement learning (DRL) for resilient recovery after attacks was provided to improve the service success rate of slices in 5G/B5G vehicular networks. The comparison of the proposed DRL method with the theoretical optimization reveals a small gap at the advantage of near real-time performance which is required in vehicular networks due to the critical need for accurate road perception and real-time collaborative control.

This special issue has successfully addressed important topics in the area of optimal and smart network slicing in emerging 5G/B5G networks. Besides these studies in the accepted articles, there are still many open challenges in this area. For instance, there are integrated aerial-satellite-terrestrial-underwater networks which have different radio access technologies with inherent requirements and challenges, and slice provisioning in such combined networks may require a robust dataset for investigating application of AI models. While end-to-end communication systems in B5G networks could be assisted by deep learning frameworks, it is important to interpret the results from a communication systems perspective (e.g., over individual blocks of the communication system) without falling into the danger of using these AI models as mere blackboxes. The incorporation of intelligent surfaces, cell-free networks, and other paradigm shifts in the B5G networks can also pose further challenges to obtaining closed-form optimization of network slice provisioning.

To conclude, we would like to thank the authors, numerous reviewers, and the EiC for helping the Guest Editors to organize this timely Special Issue. We anticipate that the breadth and diversity of the articles will encourage researchers and practitioners from academia and industry to come up with intelligent network slicing solutions and applications for emerging networks in the future.

Biographies

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