Editorial

Fifth Edition of the IEEE JSAC Series on Network Softwarization & Enablers

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I. Introduction

On the verge of 5G devices commercialization, network softwarization is required to offer new capabilities for rapid service revenues, and better performance. This involves investing in enabling technologies, such as Network Function Virtualization (NFV) and Software Defined Networking (SDN). The research community is still investigating the enhancement of these key components with the sole purpose of reaching ultra-short latency, availability, and very high bandwidth.

Furthermore, to support the different 5G verticals, the combination of several techniques still needs to be optimized. For instance, Service Function Chaining (SFC) must ensure smoother steering communication between different components in both control and data planes, while multi-access edge computing (MEC) is envisioned to play an important role in enabling delay sensitive applications targeted by the 5G and beyond, thus many challenges arise.

In this vein, the fifth edition of the IEEE JSAC Series on Network Softwarization & Enablers received high quality contributions covering different aspects of network virtualization, and addressing issues related to network slicing, performance, interoperability, scalability, and security. In the following, the accepted papers are classified by topic:

A. Software Defined Networking

As opposed to TCP and its variants, which hurt application-level performance of streaming applications, the first paper introduces a novel bandwidth allocation model that performs well with awareness of the application layer performance requirements. To make the proposed model practical, the authors develop a cross-layer SDN-based framework which utilizes smartly the instantaneous information obtained from the application layer and provides on-the-fly and dynamic bandwidth allocation during the runtime of the streaming applications. By leveraging the cross-layer design, they introduce an exemplary mechanism for bandwidth sharing among multiple applications.

In SDN, a SDN controller can improve the network performance and services according to specific network features. The ability to effectively monitor the packet loss is vital to some critical network management functions such as anomaly detection. In the second paper, the authors proposed a two-way link-level packet loss monitoring solution for software-defined networks. The proposed solution uses a novel structure, called link-exclusive probe structure, to accurately probe the packet loss, and effectively localize the found packet losses based on flow statistic inquiries with a low and controllable controller overhead.

To support multimedia big data transmissions over 5G wireless networks, the third paper proposes information-centric virtualization architectures for software defined statistical delay-bounded QoS provisioning scheme. The proposed scheme integrates three 5G-promising candidate techniques: information-centric network (ICN), NFV, and SDN. To jointly optimize the implementations of these three techniques, the third paper develops three virtual-network selection and transmit-power allocation mechanisms: (1) to maximize single user's effective capacity, (2) to jointly optimize aggregate effective capacity and allocation fairness over all users, and (3) under non-cooperative gaming theory among all users.

To support seamless and efficient Intro/Inter domain handover in SDN, the fourth paper presents a novel mobility management scheme SDN-MM. The presented scheme separates mobility control from packet forwarding, and installs route optimizing and mobility control logics in an SDN controller. Simulation results demonstrate that the proposed SDN-MM not only greatly improves handover performance but also maintains high resource utilization efficiency.

The fifth paper investigates an algorithm of computing shortest recovery path and shortest guaranteed path for Fast Reroute in SDN. The proposed algorithm utilizes a two-hops algorithm whose time complexity is significantly lower than the state-of-the-art solution. Evaluation results also show that the proposed approach is scalable in a variety of real-world topology.

The aim in the sixth paper is to enhance the quality of service of autonomous driving applications. To this end, the authors design a framework that uses the 5G service slicing technologies. The framework is made of a distributed and scalable SDN architecture. A network slicing function is implemented to map autonomous driving functionalities into service slices. They present a theoretical analysis of the propagation delay and the handling latency based on GI/M/1 queuing system. Simulation results show that the framework meets the low-latency requirement of the autonomous driving application

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as it incurs low propagation delay and handling latency for autonomous driving.

The seventh paper introduces the problem of SDN-based IoT systems, in which the location of devices is not fixed. Therefore, it is important for the controller to maintain and update topology and network status information. A method named LS-SV is proposed to handle large-scale IoT network, and the authors apply SDN technology to manage virtual network in distributed systems. In specific, LS-SDV collects the mobility and network information by the controller and provides performance guaranteed management for each virtual network. Furthermore, experiment results show that LS-SDV outperforms current solutions.

B. Network Slicing

In the eighth paper, the authors propose a two-level resource allocation framework in the wireless network slicing for 5G. The upper-level of the resource allocation framework is formulated as a generalized Kelly mechanism (GKM) framework where MVNOs compete with each other by submitting bidding value to get more proportion of wireless resource from the InP. At the lower-level, each MVNO efficiently allocates the resource it gained from the InP to its mobile users to provide specific services and guarantee the QoS requirement of its users.

C. Network Function Virtualization

The industrial adoption of the SDN/NFV paradigms in cloud networking calls for the efficient management of resources in the service providers networks. The ninth paper claims that novel simulator-based approaches are needed to realistically evaluate cloud provider network deployments. To that purpose, the paper proposes DCNs-2, a significant extension of ns-2 to simulate all the entities typically available in an IaaS network. The extensive experimental results reported in the paper show the flexibility of DCNs-2 for wide-scale network simulations, with limited overhead and execution time.

D. RAN Slicing

Iris is subject to the tenth paper. Iris is a shared spectrum radio access network architecture based on cloud-RAN and specifically designed for indoor neutral-host small-cell settings. At the core of Iris is a deep reinforcement learning based dynamic pricing mechanism that acts as a control mechanism for the distribution of the available shared spectrum, while providing participation incentives for the neutral-host and the tenants alike. A prototype implementation of Iris based on a design that follows network slicing principles demonstrates the feasibility of deploying the proposed system in practice. Extensive experimental evaluations of Iris verify its effectiveness in distributing the available spectrum across multiple network tenants with different traffic demands.

E. Service Function Chaining

The eleventh paper proposes a deep learning-based framework for geo-distributed VNF chain scaling. Observing the strong traffic pattern in Internet applications, the authors leverage a recurrent neural network as the traffic model to predict the incoming network traffic. On top of the traffic model, they design an online deep reinforcement learning algorithm based on the actor-critic framework to make VNF chain placement decisions in an online fashion. Trace-driven simulation demonstrates promising performances of the framework compared to existing representative approaches.

Modularized Service Function Chains (MSFCs) in NFV bring benefits on management and development but also introduce performance overhead and resource efficiency degradation. Deciding how to modularize elements is critical. The twelfth paper exploits the reusability, lightweightness and individual scalability features of elements and proposes MicroNF, an efficient framework for MSFC in NFV. MicroNF reuses the elements from different NFs, provides a performance-aware placement algorithm to optimize the global packet transfer cost, and introduces a push-aside scaling up strategy to avoid degrading performance and taking up new CPU cores.

The thirteenth paper presents an online orchestration framework for service function chaining across collaborative edge nodes. It jointly optimizes the resource provisioning and traffic routing to maximize the holistic cost-efficiency. Since the formulated long-term optimization problem is NP-hard and involves future uncertain information, a joint optimization framework is designed to carefully blends the advantages of an online optimization technique and an approximate optimization method. The resulting joint online algorithm achieves a good performance guarantee, as verified by both theoretical analysis and trace-driven simulations.

F. (Mobile/Multi-Access) Edge and Fog Computing

The fourteenth paper investigates the problem of provisioning mobile Virtual Reality (VR) group gaming services using the Mobile Edge Cloudlet (MEC) networks with a distributed content rendering architecture. The authors solve the underlying online rendering-module placement problem under the Model Predictive Control (MPC) framework and propose a polynomial-time algorithm by exploring the connection of the placement problem to the minimal graph cut problem. They formally prove the worst-case performance guarantee of the algorithm. They also conduct extensive trace-driven evaluations and demonstrate the superior performance of the approach.

G. Performance, Interoperability, and Scalability Issues

Network utility maximization (NUM) is a general framework for achieving fair, efficient, and cost-effective network sharing for a wide range of applications. However, the network sharing paradigm introduces the issue of information asymmetries and agents' selfish behaviors. The fifteenth paper studies the economic mechanisms and the distributed algorithms, considering strategic agents' private utility and constraint information. In particular, the authors propose economic mechanisms that yield the network utility maximizing equilibrium for a general class of NUM problems.

The sixteenth paper proposes two new solutions (RAPID and RAPID-ED) to solve the TCP in cast throughput collapse problem in a data center by intelligently discarding

so-called robust packets before the buffer of a bottleneck switch becomes completely full. The key idea is to ensure that the loss of robust packets can trigger Fast Retransmission/Fast Recovery rather than the expensive Retransmission Timeout (RTO) at the sender(s) when the network starts to get congested. Theoretical analysis and simulation results demonstrate that RAPID and RAPID-ED perform very well to prevent RTO of TCP incast flows and hence the throughput collapse. Compared with other incast solutions, RAPID and RAPID-ED do not modify TCP protocols and therefore are more suitable in public clouds where tenants can use a variety of TCP versions.

H. Security, Trust, and Privacy Issues in Virtualized Environments

Due to networks' concern of revealing sensitive information, multi-domain resource reservation systems often result in substantial inefficiencies. Toward addressing this fundamental limitation, the seventeenth paper presents Mercator, a novel multi-domain network resource discovery system to provide fine-grained, global network resource information, for collaborative sciences. Mercator develops an algebraic-expression-based abstraction as a compact representation of multiple properties of network resources in multi-domain networks, and an obfuscating protocol to protect networks' privacy. Experiments on a small network and trace-driven simulations on a large operational federation network demonstrate the efficiency and efficacy of Mercator.

Tarik Taleb received the B.E. degree (Hons.) in information engineering and the M.Sc. and Ph.D. degrees in information sciences from Tohoku University in 2001, 2003, and 2005, respectively.

From 2005 to 2006, he was a Research Fellow with the Intelligent Cosmos Research Institute, Sendai, Japan. Until 2009, he was an Assistant Professor with the Graduate School of Information Sciences, Tohoku University, Japan, in a laboratory fully funded by KDDI. He was a Senior Researcher and a 3GPP Standards Expert at NEC Europe Ltd., Heidelberg, Germany. He is currently a Professor with the School of Electrical Engineering, Aalto University, Finland, where he is the Founder and the Director of the MOSA!C Lab. He has also been directly involved in the development and standardization of the Evolved Packet System as a member of 3GPP's System Architecture Working Group. His research interests lie in the field of architectural enhancements to mobile core networks, network softwarization and slicing, mobile cloud networking, network function virtualization, software-defined networking, mobile multimedia streaming, inter-vehicular communications, and social media networking.

Dr. Taleb is a member of the IEEE Communications Society Standardization Program Development Board. He was a recipient of the IEEE ComSoc Communications Software Technical Achievement Award in 2017 for his outstanding contributions to network softwarization. He was also a (co)recipient of the IEEE Communications Society Fred W. Ellersick Prize in 2017, the IEEE ComSoc Asia–Pacific Best Young Researcher Award in 2009, the TELECOM System Technology Award from the Telecommunications Advancement Foundation in 2008, the Funai Foundation Science Promotion Award in 2007, the IEEE Computer Society Japan Chapter Young Author Award in 2006, the Niwa Yasujirou Memorial Award in 2005, and the Young Researcher's Encouragement Award from the Japan Chapter of the IEEE Vehicular Technology Society (VTS) in 2003. Some of his research works have also received the best paper awards at prestigious IEEE-flagged conferences. As an attempt to bridge the gap between academia and industry, he founded the IEEE Workshop on Telecommunications Standards: From Research to Standards, a successful event that was awarded the Best Workshop Award by the IEEE Communication Society (ComSoC). Based on the success of this workshop, he also founded and has been the Steering Committee Chair of the IEEE Conference on Standards for Communications and Networking. Until 2016, he served as the Chair for the Wireless Communications Technical Committee, the largest committee in the IEEE ComSoC. He also served as the Vice Chair for the Satellite and Space Communications Technical Committee of the IEEE ComSoc from 2006 to 2010. He has been on the Technical Program Committee of different IEEE conferences, including Globecom, ICC, and WCNC, and chaired some of their symposia. He is the General Chair of the 2019 Edition of the IEEE Wireless Communications and Networking Conference (WCNC'19) to be held in Marrakech, Morocco. He is the Guest Editor-in-Chief of the IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS Series on Network Softwarization & Enablers. He is/was on the Editorial Board of the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, the *IEEE Wireless Communications Magazine*, the IEEE JOURNAL ON INTERNET OF THINGS, the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, the IEEE COMMUNICATIONS SURVEYS & TUTORIALS, and a number of Wiley journals.