Guest Editors' Introduction: Special Issue on Efficient Management of SDN/NFV-Based Systems—Part II

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I. Introduction

RECENTLY, leading equipment providers in the network infrastructure market launched the first software-enabled appliances that support network virtualization capabilities. The main advantage of Software-Defined Networking (SDN) is the separation of network control and forwarding and the fact that it allows flexible management of the network resources. OpenFlow is currently the most prominent SDN-based communication protocol.

Future research should be devoted to design SDN-based systems and applications, which exploit the potential of SDN much more than the current OpenFlow-based systems. Solutions are required for managing large-scale software defined networks in a resource efficient way. There is also a need for software-defined networks able to provide automatic energy consolidation (i.e., activating only the hardware components that are required to fulfill a given network demand).

Furthermore, the architects and developers of SDN-based network infrastructure need agile and productive design environments (i.e., SDKs–Software Development Kits) comparable to existing ICT software technology development. These library-based SDKs will act as mediator to existing and future SDN control planes and will be used by orchestrator services, frameworks and tools for Virtualized Network Functions (VNFs). Built-in security and efficient resource management should be thoroughly taken into account when designing these Software Development Kits.

Finally, future SDN/NFV-based approaches will highly benefit from optimized virtualization techniques, which take into account the typical characteristics of the applications and services, deployed on top of the virtualized systems.

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II. Special Issue Overview

In Part I of the special issue [1], the main reported research contributions were: efficient resource allocation and management of softwarized network functions [2], [3], design of high-performance platforms to allow network function virtualization on commodity machines [4], and enabling efficient collaboration between providers in softwarized networks [5]. From the twenty six submitted papers, four papers had been selected for Part I of the special issue [1]. An additional set of four more papers have been accepted for this Part II, after a thorough revision by the authors to take into account the detailed comments from the reviewers.

The four selected papers in Part II of the special address three very important topics for the efficient management of SDN/NFV-based telecommunication systems: (i) optimizations to flow-based software-defined networks to address the scalability and energy consolidation requirements, (ii) programming abstractions in wireless software-defined networks, and (iii) improved network virtualization to more efficiently support latency sensitive applications.

III. Accepted Papers—Part II

Two papers in this special issue address optimizations to flow-based software-defined networks.

In "A Hybrid Hierarchical Control Plane for Flow-Based Large-Scale Software-Defined Networks," Fu *et al.* [6] address the scalability issues of flow-based Software-Defined Networks. Since a flat control plane for large-scale networks suffers from computational complexity and a hierarchical control plane very often results in inefficient routing, the authors propose a hybrid hierarchical control plane by using an abstracted hierarchical routing method. Their control plane is referred to as Orion. In addition, a hierarchical fast reroute method is proposed for large-scale software-defined networks.

By means of both theoretical and experimental results, the achieved gains in terms of reduced path stretch, computing time, flow setup rate and delay are characterized.

In "Fine-Grained Energy-Efficient Consolidation in SDN Networks and Devices," Bolla *et al.* [7] present an extension of OpenFlow to integrate energy-aware capabilities and power management primitives of the device hardware components, line cards, nodes and logical resources. Their approach is compliant with the Green Abstraction Layer (GAL), a recently

approved standard of the European Telecommunications Standards Institute (ETSI). An extensive optimization model is introduced for energy consolidation in SDN networks. By means of extensive simulations, the obtained energy reductions were reported upon. It was shown that for the considered scenarios, energy savings of up to 80% of the total network consumption could be achieved.

The following two papers focus on programming abstractions in wireless software-defined networks and improved network virtualization to more efficiently support latency sensitive applications (such as stream-based multimedia services), respectively.

In "Programming Abstractions for Software-Defined Wireless Networks," Riggio *et al.* [8] focus on specific radio data plane abstractions, controllers, and programming primitives for software-defined wireless networks. In this area, there are much less abstractions and programming primitives available than in wired packet-switched networks. The authors present a set of programming abstractions modeling the fundamental aspects of a wireless network, namely state management, resource provisioning, network monitoring, and network reconfiguration. A software-defined radio access network controller for enterprise WLANs is presented, together with a Python-based Software Development Kit implementing the proposed abstractions. Furthermore, the efficiency of the platform over a real 802.11-based WLAN is experimentally evaluated.

In "XCollOpts: A Novel Improvement of Network Virtualization in Xen for I/O-Latency Sensitive Applications on Multicores," Zeng *et al.* [9] present several improvements to the Xen scheduler to make it more suitable for I/O-latency sensitive applications in virtualized multi-core environments, such as multimedia streaming applications. The imbalanced multi-boosting problem among the cores and the premature preemption problem are addressed, together with two further optimizations for the network I/O virtualizations. By means of experimental results, the authors show that XCollOpts can significantly improve the performance of the considered applications at a cost of relatively small system overhead.

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