

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

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I. INTRODUCTION

CURRENTLY, there is a lot of interest in both industry and academia in the softwarization of telecommunication networks. This evolution is enabled by three paradigms, which are synergetic and reinforce each other. First, Software-Defined Networking (SDN) allows network control to be separated from the forwarding plane and allows for a flexible management of the network resources. Leading equipment providers in the network infrastructure market launched the first SDN-enabled appliances. Second, Network Virtualization (NV) brings virtualization concepts to the network, similar to cloud computing, which was enabled by virtualization of servers. The first products offering network virtualization capabilities are already available on the market. Third, Network Function Virtualization (NFV) focuses on virtualization of software-based network functions. Classical examples include virtualization of home gateways, firewalls, set top boxes, deep packet inspection components, IMS components, and monitoring probes. Instead of installing and managing dedicated hardware devices for these functions, they are instead implemented as software components and deployed on commodity hardware infrastructures, in most cases operated by a network operator and referred to as telco clouds. Service Function Chaining (SFC) consists of building services using virtual network functions (VNFs).

The main reasons for network operators to adopt the above principles of network softwarization are: (i) faster and easier deployment, configuration, and updating of network functions, (ii) maximization of resource utilization when using commodity hardware and software-based functions, and (iii) it enabling of a Network-as-a-Service business model. From the point-of-view of service providers, the main benefits include: (i) dynamic scaling of resources based on service requirements

and traffic patterns, (ii) facilitation of inter-domain Quality of Service and (iii) reduced time to market for services. Standardization activities already started, and are very likely to grow significantly in the near future.

II. SPECIAL ISSUE OVERVIEW

Based on these evolutions, efficient management of software-defined virtualized telecommunication systems and datacenters are of key importance in the future. This Special Issue presents recent research in the area of softwarized networks. Twenty six papers were submitted for this Special Issue. In order to allow a fast publication cycle, the Special Issue was split in two parts: Part I to appear in this issue (March 1st 2015) and Part II to appear in the next issue (June 1st 2015). After extensive review and discussion, it was decided to publish four accepted papers in Part I of the Special Issue. The authors of the four papers were given the time to update their paper and take the reviewers' comments and suggestions into account. The selected papers address three critical topics that play a central role in the management of SDN/NFV-based telecommunication systems: efficient resource allocation and management of softwarized network functions, design of high-performance platforms to allow network function virtualization on commodity machines, and enabling efficient collaboration between providers in softwarized networks.

III. ACCEPTED PAPERS—PART I

Two papers in this special issue address efficient resource allocation and management issues of virtualized network functions.

In "Heuristic Approaches to the Controller Placement Problem in Large Scale SDN Networks," Lange *et al.* [1] propose algorithms for function placement in virtualized infrastructures taking into account latency, fault tolerance and load balancing. They present POCO, a framework for Pareto-based Optimal Controller placement that provides operators with Pareto optimal placements with respect to different performance metrics. POCO performs an exhaustive evaluation of all possible placements and is also extended with a heuristic approach that is less accurate, but yields faster computation times. Extensive evaluations of the heuristic approach are presented in the paper, and the trade-off between time and accuracy is discussed.

Date of current version March 17, 2015.

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Digital Object Identifier 10.1109/TNSM.2015.2403775

In “Adaptive Resource Management and Control in Software Defined Networks,” Tuncer *et al.* [2] present a new SDN-based management and control framework for fixed backbone networks, which provides support for both static and dynamic resource management applications. The framework consists of three layers which interact with each other. Placement algorithms are designed and implemented by the authors to determine the allocation of managers and controllers in the proposed distributed management and control layer. The paper details how the requirements of two specific applications for adaptive load-balancing and energy management purposes can be met.

The following two papers focus on the design of a high-performance platform to allow network function virtualization on commodity machines and enabling efficient collaboration between providers in softwarized networks, respectively.

In “NetVM: High Performance and Flexible Networking using Virtualization on Commodity Platforms,” Hwang *et al.* [3] present the design of the NetVM platform. This platform allows high bandwidth network functions to operate at near line speed on commodity hardware and supports customizable data plane processing capabilities, such as firewalls, proxies, and routers to be embedded within virtual machines, complementing the control plane capabilities of Software Defined Networking. Furthermore, the platform allows complex policies and full packet inspection to determine subsequent processing. Evaluation results show the obtained line speeds and the improvements compared to existing techniques for virtualized networking.

In “An SDN based CDN/ISP Collaboration Architecture for Managing High-Volume Flows,” Wichtlhuber *et al.* [4] present a novel approach for enabling a beneficial collaboration between ISPs and CDN providers. The proposed approach is based on a minimal deployment of Software Defined Networking (SDN) switches in the ISP’s network. By influencing the CDN edge server selection, the ISP can manage the increasing amount of traffic originating from CDNs to reduce the Operational Expenditures (OPEX) of its infrastructure. Additionally, by including the ISP’s hidden network knowledge in the server selection process the offered Quality of Service (QoS) delivered by the CDN provider can be positively impacted. A proof-of-concept is presented, together with evaluation results that clearly show the benefits of the collaboration approach.

ACKNOWLEDGMENT

We express our thanks to the authors who submitted papers and to the reviewers for their thoughtful comments and useful suggestions. It has been a pleasure to put together an issue on such a timely topic. We are grateful to the Editor-in-Chief, Rolf Stadler, for giving us the opportunity to put together this Special Issue and for his support throughout the process.

REFERENCES

- [1] S. Lange *et al.*, “Heuristic approaches to the controller placement problem in large scale SDN networks,” *IEEE Trans. Netw. Serv. Manag.*, vol. 12, no. 1, pp. 4–17, Mar. 2015.
- [2] D. Tuncer, M. Charalambides, S. Clayman, and G. Pavlou, “Adaptive resource management and control in software defined networks,” *IEEE Trans. Netw. Serv. Manag.*, vol. 12, no. 1, pp. 18–33, Mar. 2015.

- [3] J. Hwang, K. K. Ramakrishnan, and T. Wood, “NetVM: High performance and flexible networking using virtualization on commodity platforms,” *IEEE Trans. Netw. Serv. Manag.*, vol. 12, no. 1, pp. 34–47, Mar. 2015.
- [4] M. Wichtlhuber, R. Reinecke, and D. Hausheer, “An SDN based CDN/ISP collaboration architecture for managing high-volume flows,” *IEEE Trans. Netw. Serv. Manag.*, vol. 12, no. 1, pp. 48–60, Mar. 2015.



Filip De Turck leads the network and service management research group at the Department of Information Technology of the Ghent University, Belgium and iMinds (Interdisciplinary Research Institute in Flanders). He (co-) authored over 450 peer reviewed papers and his research interests include telecommunication network and service management, and design of efficient virtualized network systems. In this research area, he is involved in several research projects with industry and academia, serves as the Technical Program Chair of the IEEE Technical Committee on Network Operations and Management (CNOM), chair of the Future Internet Cluster of the European Commission, and is on the TPC of many network and service management conferences and workshops and serves in the editorial board of several network and service management journals. He is a Senior Member of the IEEE.



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