NETWORK AND SERVICE VIRTUALIZATION: PART 2


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The second installment of the Feature Topic on network and service virtualization takes off from where Part I concluded: network function virtualization (NFV) deployment and operation. We are currently observing a transition from software-defined networking (SDN) focusing solely on programming packet-switching network elements based on lower-layer flow-oriented primitives toward the wider concept of infrastructure programmability. Such programmability extends vertically within the network stack to encompass optical layer capabilities as well as features located at upper layers of the traditional network stack. In addition, infrastructure programmability extends horizontally well beyond SDN to other resource stacks to encompass virtualized compute and storage resources.

In this issue we point our attention to technologies that unify the management of software-defined networks, clouds and application services in carrier-oriented environments. In particular, we look into the complex problems related to the integration of resource controllers and orchestrators with virtual network functions. A healthy dose of optical layer components, open source code, and security considerations takes the debate out of the abstract world of standardized interfaces and provides insights about the novel aspects of practical implementations.

The first article in this issue is "Optical Service Chaining for Network Function Virtualization." Ming Xia *et al.* explore service chaining to the optical domain. Service function chaining (SFC) is well known in the context of packet-level technologies, and there are ongoing standardization efforts in the Internet Engineering Task Force (IETF) on this topic. This article presents an integrated packet-optical architecture for data centers that enables steering large aggregated flows solely in the optical domain. Based on a combination of wavelength-selective switches, tunable transceivers, and shipping containers that house compute, packet network, and storage resources as an independent unit, the proposed architecture aims to significantly improve operational flexibility and scalability. Furthermore, the authors point to power efficiency benefits as more resource-intensive virtual network functions (VNFs) are deployed, which makes the architecture relevant to service providers or large enterprises that need to handle tens or hundreds of gigabits of traffic every second.

In "A Service-Oriented Hybrid Access Network and Cloud Architecture," Velasco *et al.* present an architectural solution that integrates distributed micro data centers and active optical nodes located close to the end users under a dynamic orchestration platform. The Service-Oriented Hybrid Access Network and Cloud Architecture (SHINE) leverages the IETF work on the application-based network operations (ABNO) framework for interacting with the transport network that interconnects the micro data centers and the active remote nodes. Four use cases based on scenarios defined by the European Telecommunications Standards Institute (ETSI) NFV ISG illustrate the flexibility and performance of the proposed architecture. The direct interface between VNFs (generally referred to as "applications" in the article) and the joint cloud and network resource orchestrator facilitates optimized placement of the instances as well as scale-in and scale-out operations.

In the third article in this Feature Topic, "A Service-Aware Virtualized Software-Defined Infrastructure," Mamatas *et al.* present a proposal to unify the management and control of networks and clouds while providing uniform virtualization abstractions for networks and applications. Virtual routers supported by the very lightweight software-driven network and services platform (VLSP) that allows deploying new network control and service components in support of advanced programmability features. The flexibility of VLSP is validated by testbed deployment and experimentation.The VLSP code has been open sourced, enabling interested readers to experiment and verify the conclusions of the authors.

Montero *et al.* present their work on trusted virtual domains in the access network, which can provide homogeneous security for a user regardless on the type of the

device (laptop, tablet, mobile phone) employed for accessing the network. As their article, "Virtualized Security at the Network Edge: A User-centric Approach," explains, shifting from a device-centric to a user-centric security model has significant advantages from the user perspective. That said, implementation raises a range of challenges that the authors detail in the article. Three domain-specific policy abstraction layers as well as translation services between them are described and discussed in the article, along with requirements on network functions and virtual infrastructure to support trusted virtual domains. This article is representative for the complexity of the technological backend that is required to simplify the life of end users of a modern telecommunications infrastructure, and the challenges related to security and privacy-preserving services.

The final article in this Feature Topic is "Toward an SDN-Enabled NFV architecture." Matias *et al.* vividly document their experience designing and implementing a VNF based on 802.1x access control functionality. The authors propose the decomposition of the VNF in a stateful component that can be executed on virtual compute resources and a stateless component that can be executed on a physical SDN switch. The architectural options for building the Flow-Based Network Access Control VNF are discussed in detail, along with the challenges and open research issues in this area. Resource isolation is considered one of the major challenges that must be addressed in order for the infrastructure to support widespread adoption of SDN-enabled VNFs.

Achieving a programmable software-defined infrastructure by jointly orchestrating resources at both the network and cloud layers, as presented in the articles included in this Feature Topic, is a common item on several research agendas. A large-scale initiative along these lines is the UNIFY project, funded in the Seventh Framework Programme by the European Union, which creates a software-defined platform that combines network and cloud resources to enable the delivery of new services at high velocity (see www.fp7-unify.eu for more details).

Future research directions call for extending the programmability to higher-layer virtualized network functions and services that have the potential to support more sophisticated infrastructure services related to network optimization and security, to name just a couple of relevant areas. Lower-layer functions such as switching and routing, which have been considered in the original SDN proposals, were stateless and allowed an immediately transparent distribution of functionality within the infrastructure. In contrast, many higher-layer VNFs are stateful, which further complicates the definition of appropriate programming primitives. Higher-layer services are often composed of several VNFs. Such composition adds to the challenge by introducing dependencies at the flow processing level that can no longer be solved within one self-contained processing pipeline, be it stateful or stateless. Infrastructure programmability in such environments will need to take inspiration, for example, from parallel and distributed computing technologies that evolved in the computer science field. This opens up exciting new opportunities for new protocols and programming languages that are optimized for high-throughput and low-latency packet processing.

It is our hope as Guest Editors that both practitioners and academics will find this Feature Topic a handy reference in the emergent area of network infrastructure and service virtualization. We conclude this introduction by thanking the numerous dedicated reviewers for their thorough analysis and constructive comments. We commend the work of the authors who submitted their articles to our Call for Papers and show particular appreciation for those who worked diligently to improve their manuscripts throughout the peer-review process. We gratefully acknowledge the magazine's Editor-in-Chief at the time this Feature Topic was being prepared, Dr. Sean Moore, and the Editorial Board for their continuous help. Finally, we say a big thank you to the ComSoc final production editors and staff for their professionalism, and in particular to Charis Scoggins for her guidance throughout the entire process.

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KOSTAS PENTIKOUSIS (k.pentikousis@eict.de) dedicates this Feature Topic to his father, Michael Pentikousis (1931–2015), who passed away unexpectedly as this Editorial was being prepared. He was a devoted father, and he is deeply missed by his family and all who knew him.

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