Guest Editors' Introduction

Network Function Virtualization and Software-Defined Networking:

Advancing Multimedia Distribution

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This new age of media entertainment offers viewers endless options: from binge watching our favorite TV shows to live streaming sporting events on the road to following camera feeds on social media in real time. On the other hand, network operators and service providers alike are under tremendous pressure to serve the rapidly growing Internet media traffic over existing infrastructure—while meeting the ever-raising bar of user expectations for media quality. Clearly, new technologies and solutions are needed to address the emerging challenges.

The last few years have also seen the widespread adoption of two related technologies by the telecommunications industry: network function virtualization (NFV) and software-defined networking (SDN). NFV focuses on the virtualization of software-based network node functions, such as firewalls and intrusion detection.[1] Complementary to this, SDN separates the control plane from the data plane in networking operations, thereby allowing for greater network visibility, dynamic resource provisioning, and flexible service deployments.[2] The fast expansion of both technologies has largely been fueled by active research and development, support from open source communities, and numerous field trials and test deployments by industry practitioners.

The greater visibility, agility, and flexibility promised by NFV and SDN enable innovative architectures for multimedia distribution, potentially transforming the entire delivery chain of multimedia contents. For example, recent research has explored how to use NFV for dynamic composition of service chains[3] and how to leverage SDN for fine-grained analytics collection,[4] as well as possible interactions between the cloud and NFV.[5] These investigations are mostly motivated by the requirements of multimedia applications, including high data rates, low latency, and the need for quality-of-experience optimization. In addition, as Yichao Jin and Yonggang Wen point out in one of this issue's feature articles, "When Cloud Media Meets Network Function Virtualization: Challenges and Applications," an NFV-enabled cloud media system brings about both interesting technical

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challenges and abundant opportunities for novel applications.

In This Issue

This special issue is dedicated to exploring how SDN/NFV-based systems can enhance multimedia distribution. The most effective way to explore this topic is to bring together researchers from both the networking and multimedia research communities, showcasing their research and striking up a discussion that reflects their diverse viewpoints.

In our first special issue article, "Dynamic Deployment and Optimization of Virtual Content Delivery Networks," Nicolas Herbaut, Daniel Négru, David Dietrich, and Panagiotis Papadimitriou investigate how the two main actors of the video delivery chain—the CDN operator and ISP—can benefit from network and server virtualization. They propose a scheme to negotiate dynamic service-level agreements that reduce both capital and operational expenses for CDNs while generating more revenue for the ISP. The authors present evaluations of the proposed solution based on simulations of dynamic, distributed traffic consumptions and discuss other possible optimizations. This article further enumerates and discusses various use cases for the proposed scheme. The authors indicate that the deployment and management of virtual CDNs (vCDNs) requires flexibility and careful design of several key business and network aspects, but upon appropriate configuration, added value can be achieved for a wide range of use cases. The most promising scenarios include footprint extension, quality improvement for niche markets, bandwidth burst, and vCDN operators.

The potential use case of vCDN operators is investigated in greater detail in the next article, "vCache: Supporting Cost-Efficient Adaptive Bitrate Streaming." Here, Guanyu Gao, Yonggang Wen, and Jianfei Cai present an NFV-based virtual caching (vCache) system. They propose leveraging NFVs to reduce the operational cost for adaptive bitrate (ABR) streaming, which normally consumes tremendous computation and storage resources due to the need to pre-transcode and cache video chunks at different bitrates and resolutions. With vCache, only a small percentage of frequently requested video chunks are kept in storage, while the majority of chunks are transcoded on the fly upon request. Using NFV, the caching state of each chunk is managed dynamically, and computing resources are provided accordingly to guarantee that transcoding delays are within an acceptable range.

Silvery Fu, Jiangchuan Liu, and Wenwu Zhu examine the effectiveness of NFV from an energy perspective. In "Multimedia Content Delivery with Network Function Virtualization: The Energy Perspective," they conduct a series of experiments to compare the energy consumption of a hardware network address translator (NAT) box against its virtual implementation counterpart. The results clearly indicate that the virtual implementation of NAT consumes significantly more energy—sometimes doubling the power cost with respect to hardware-based implementations—when supporting multimedia traffic. Motivated by these observations, the authors propose a CPU frequency scaling algorithm to control the power consumption of NFV hosts while meeting the QoS requirements of multimedia applications. The proposed solution can be extended to provide power management for other types of applications, thus opening up a new direction for future research.

An NFV-enabled cloud media system brings about both interesting technical challenges and abundant opportunities for novel applications.

Naturally, research on SDN/NFV-enabled multimedia distribution is a cross-disciplinary endeavor, drawing upon interests and efforts from both academic researchers and industry practitioners. The diverse viewpoints and perspectives on this topic are best

reflected by our interview with three experts with very different background and experiences: Baochun Li from the University of Toronto, Canada; Diego R. Lopez from Telefonica, Spain; and Christian Timmerer from Alpen-Adria-Universität Klagenfurt, Austria. In "The Future of Multimedia Distribution," we ask each of our interviewees about their current activities pertaining to this topic, their individual views on the potential benefits and issues that an SDN/NFV-enabled network might impose for multimedia distribution, and what they regard as the most prominent opportunities and daunting obstacles. We hope you will enjoy reading their informative and insightful answers.

Future Research Directions

Obviously, the collection of articles presented in this special issue is by no means comprehensive. Rather, these articles serve as a few representative samples of interesting research topics arising from this emerging area. Many more exciting questions and open problems lie ahead. For example, how can we best leverage the increased visibility of SDN to correlate application-level performance (such as audiovisual streaming quality) against network-level events? And how can we learn from empirically collected data and drive real-time reconfigurations of key parameters of the underlying network service?

It could also be beneficial to optimize the dynamic composition and deployment of service function chains for media services, especially across geographically dispersed mobile-edge-computing nodes. Furthermore, researchers have yet to explore the full potential of an SDN/NFV-enabled network in the presence of emerging rich media applications such as augmented reality streaming, which will require on-the-fly processing and guaranteed low-latency delivery. MM

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References

1. R. Mijumbi et al., "Network Function Virtualization: State-of-the-Art and Research Challenges," *IEEE Comm. Surveys & Tutorials*, vol. 18, no. 1, 2016, pp. 236–262; doi:10.1109/COMST.2015.2477041.
2. N. McKeown et al., "OpenFlow: Enabling Innovation in Campus Networks," *ACM SIGCOMM Computer Comm. Rev.*, vol. 38, no. 2, 2008, pp. 69–74.
3. S. Sahhaf et al., "Network Service Chaining with Efficient Network Function Mapping Based on Service Decompositions," *Proc. 1st IEEE Conf. Network Softwarization* (NetSoft), 2015; doi:10.1109/NETSOFT.2015.7116126.
4. W. John and C. Meirosu, "Low-Overhead Packet Loss and One-Way Delay Measurements in Service Provider SDN," *Proc. Open Networking Summit* (ONS), 2014; www.usenix.org/sites/default/files/ons2014-poster-john.pdf.
5. G. Carella et al., "Cloudified IP Multimedia Subsystem (IMS) for Network Function Virtualization (NFV)-Based Architectures," *Proc. IEEE Symp. Computers and Communication* (ISCC), 2014; doi:10.1109/ISCC.2014.6912647.

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