

TELECOM SOFTWARE, NETWORK VIRTUALIZATION, AND SOFTWARE DEFINED NETWORKS



Walter Cerroni



Alex Galis



Kohei Shiimoto



Mohamed Faten Zhani

The increasingly relevant and transformational role that software and virtualization are gaining in the telecommunications field today enables unprecedented levels of abstraction, disaggregation, distribution, extensibility, slicing, and programmability in network infrastructures and services. Software-based networking is radically changing the way communication infrastructures are designed, programmed, integrated, and operated, enabling rapid and innovative network functions and network services creation and deployment, and opening the door to a faster pace of innovation in the networking and ICT industry. Such transformation, referred to as “network softwarization,” is propelled by the emergence of several network technologies and paradigms, like network programmability (NP), intent-based networking (IBN), multi-access edge computing (MEC), network slicing (NS), software defined networking (SDN), and network function virtualization (NFV), which are gaining traction in production environments, and are bound to be core technologies of the maturing 5G and beyond networks. However, there are still several daunting challenges that need to be addressed before “telecom software” solutions fully leverage these technologies and become mature enough to be widespread and adopted by the industry.

The *IEEE Communications Magazine Series* on Telecom Software, Network Virtualization, and Software Defined Networks aims at bringing together high-quality articles written by leading experts from industry and academia to cover several aspects and challenges of software-based network technologies. The articles in this Series are selected after a thorough peer-review process and are written in the typical *IEEE Communications Magazine* tutorial style, with applications-driven content on the latest advances, technical innovations, open source projects, research, and development in telecom software, network virtualization, and software defined networks.

This second issue features five articles that deal with critical aspects ranging from the softwarization challenges at the edge to the control, design, and management of software-defined networks.

The first article, “A Multi-Protocol Software-Defined Networking Solution for the Internet of Things” by Tryfon Theodorou *et al.*, addresses the challenges posed by the Internet of Things (IoT) infrastructures in terms of elastic configuration

and deployment, hardware and software heterogeneity, and device mobility. The authors present a novel SDN platform named MINOS that aims at providing control elasticity for heterogeneous and mobile IoT deployments by enabling the operation and dynamic configuration of multiple topology control and routing protocols. The article describes the details of the MINOS platform architecture and presents an interesting experimental evaluation in a smart city scenario.

The second article, “Fusion of Software Defined Networking, Edge Computing, and Blockchain Technology for Wireless Network Virtualization” by Danda B. Rawat, applies blockchain technology to radio frequency (RF) slicing in edge computing infrastructures. As blockchain does not need a trusted third party, the proposed method increases the trust and transparency between the primary wireless resource owners (PWROs) and the virtual wireless network operators (VWNOs), and ensures a seamless subleasing process in future wireless communication networks.

The third article, “FUTEBOL Control Framework: Enabling Experimentation in Convergent Optical, Wireless, and Cloud Infrastructures” by Cristiano Both *et al.*, presents an overview of an existing research network and cloud infrastructure for networking experiments in the Brazilian Telecommunications Research Facility. The authors analyze the design and implementation of a control framework that bridges the gap between optical and wireless networks while linking them to the cloud and allowing experiments to be set up and carried out across all three domains.

The fourth article, “Secured Communication Channels in Software-Defined Networks” by Beytullah Yiğit *et al.*, focuses on the security and vulnerability issues of the data and control planes in software-defined networks. The authors propose a secure communication architecture for software-defined networks (called SECAS), which aims at securing the communications among SDN entities (i.e., controller, switch, and application) by providing a set of features including certificate generation and protection, access control list (ACL), security alarms, and an enhanced Transport Layer Security (TLS) protocol to strengthen confidentiality, integrity, authentication, and authorization between the communicating nodes.

The fifth article, “Toward Disaggregating the SDN Control Plane” by Douglas Comer *et al.*, argues that the existing

SDN controllers are monolithic, meaning that they aggregate all control plane functions into a single gigantic program, which restricts programmers to the interfaces and services provided by the controller itself. To address this limitation, the authors propose to redesign the controller software and advocate the use of a distributed and microservice-based architecture that divides the controller software into a small controller core and a set of cooperative microservices. Such a distributed controller allows programmers to choose the language that is more appropriate for each microservice and to easily incorporate new functions into the controller. The authors discuss two potential distributed architectures for the controller and evaluate them in terms of functionality and performance.

The main results reported by the five articles can be summarized in the following three key findings:

1. Softwarization at the edges: (first article) the demonstration of the potential benefits that an SDN control plane can bring in diverse and challenging network environments such as IoT by enabling real-time measurements and dynamic protocol reconfiguration; (second article) the application of blockchain technology to RF slicing in edge computing to bring the trust and transparency between PWROs and VVNOs
2. Control frameworks for softwarized networks: (third article) the design and implementation of a control framework that unifies experimentation across optical, wireless, and cloud domains, through the slicing of physical resources; (fourth article) the design of a distributed architecture for the controller software to disaggregate it into a small core controller and a set of microservices to make it easy to incorporate new functions into the controller
3. Communication security in software defined networks: (fifth article) the design of a secure communication architecture to ensure the confidentiality, integrity, authentication, and authorization between the SDN entities by leveraging an enhanced TLS protocol in combination with ACLs, certificate verification, and real-time notifications and alarms.

In our role as Series Editors, we strive to achieve a fast, quality, and selective review process for all submissions in order to quickly publish high-quality and cutting edge papers on relevant topics in this area, since the research

and development efforts in telecom software are fast-paced. For the five articles appearing in this second issue, the average review period was 41 days per review round, with one to three review rounds. As of August 28, 2019, we had received 48 independent submissions from the Series Call for Papers.

We would like to thank all the authors and reviewers who contributed to the series, as well as the *IEEE Communications Magazine* editors and staff for their continuous support.

We hope that you will enjoy this second issue and find these articles as inspiring and impactful as we do. While we are currently selecting the articles for the next issue, we invite interested authors to submit their work as per the Call for Papers available at <http://bit.ly/commag-telcosw>.

BIOGRAPHIES

WALTER CERRONI [M'01, SM'16] (walter.cerroni@unibo.it) is an assistant professor of communication networks at the University of Bologna, Italy. His recent research interests include software-defined networking, network function virtualization, service function chaining in cloud computing platforms, intent-based northbound interfaces for multi-domain/multi-technology virtualized infrastructure management, modeling and design of inter-data and intra-data center networks. He has co-authored more than 120 articles published in well renowned international journals, magazines, and conference proceedings. He serves/served as Associate Editor for *IEEE Communications Letters* and Technical Program Co-Chair for IEEE-sponsored international workshops and conferences.

ALEX GALIS is a professor in Networked and Service Systems at University College London (www.ee.ucl.ac.uk/~agalys/). His current interests are in 5G and beyond 5G networking, AI and networking, virtualization and softwarization, and network and cloud programmability. He has co-authored more than 250 publications in the future Internet areas and standards including 10 research books. He is a Co-Editor of the *IEEE Communications Magazine* Series on Telecom Software, Network Virtualization, and Software Defined Networks, the *IEEE JSAC* Series on Network Softwarization and Enablers, and the *ETRI Journal* published by Wiley.

KOHEI SHIOMOTO [M'90, SM'15] is a professor at Tokyo City University, Japan. He was engaged in R&D in the data communication industry for over 25 years since he joined NTT Laboratories in 1989. He has been active in the areas of network virtualization, data mining for network management, and traffic and QoE management since he joined Tokyo City University in 2017. He served as Guest Co-Editor for a series of Special Issues established in *IEEE TNSM* on Management of Softwareized Networks. He has served in various roles organizing IEEE ComSoc high profile conferences such as IEEE NOMS, IEEE IM, and IEEE NetSoft.

MOHAMED FATEN ZHANI is an associate professor at ÉTS Montreal, University of Quebec, Canada. His research interests include network function virtualization, software-defined networking, and resource management in large-scale infrastructures. He has co-authored several research papers published in renowned conferences and journals. He has served as the General/Technical Program Chair of several international conferences and workshops. He is a co-editor of *IEEE Transactions on Networks and Service Management* and the IEEE softwarization newsletter. He received the IEEE/IFIP IM 2017 Young Researchers and Professionals Award for outstanding research contributions and leadership in the field of network and service management.