

NETWORK SOFTWARIZATION AND MANAGEMENT



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The IEEE Communications Magazine Series on Network Softwarization and Management represents a timely source of in-depth, cutting-edge articles on state-of-the-art technologies and solutions related to two fields that are highly relevant for today's Communication Networks and their evolution. On one hand, Network Softwarization advocates for architectures where software and programmability aspects in the implementation of network functions, protocols, and services are decoupled from the underlying infrastructure, fostering unprecedented levels of flexibility, abstraction, automation, and intelligence. On the other hand, Network Management aims at integrating fault, configuration, accounting, performance, and security (FCAPS) capabilities in the network, and supporting advanced autonomic and self-management features, often taking advantage of the potential offered by Network Softwarization.

This ninth installment of the series includes five papers which provide new and timely material about techniques and processes for Network Softwarization and Management. They address the challenges that are apparent in today's networks from different perspectives, with a view on the complexity and scalability that arise when addressing both new and well-known problems. In particular, the areas covered by the articles include accessibility to smart public networks and services, resilience engineering for networked systems, and a view point on ethics in networks. More focused topics related to virtualized programmable metasurfaces and scalable management of network slices are also addressed.

The first article, "Toward Smart Public Interconnected Networks and Services — Approaching the Stumbling Blocks," by Lønsethagen *et al.*, delves into the issue of providing open and equal access to public and Internet-scale connectivity services that go beyond traditional best-effort provisioning, with support for multiple quality of service requirements. The authors identify the difficulties, both technical and non-technical, to solve such a multifaceted and complex problem, and propose to address it by leveraging a Multi-Level Best-Effort approach, defining three best-effort traffic modes with different levels of loose performance guarantees and an assured quality traffic mode with strict performance requirements. After discussing the main challenges of the proposed approach, the authors provide a simulation-based assessment to prove the potentials of their solution to support emerging highly demanding applications.

In the second article, "Toward the EthicNet: Challenges and Enablers for Ethics-aware Networks," by Atzori *et al.*, the authors introduce the framework of ethics-aware networking (EthicNet). This framework is centered on the sustainability of future networks and the need for these networks to provide the interfaces and tools to specify, support, and verify the value of the delivered service (VoS). The VoS concept is introduced as a measure of the satisfaction of the ethical service requirements in terms of key value indicators (KVIs), capturing trustworthiness, inclusive-

ness and sustainability. The article presents a high-level architecture of EthicNet as well as the underlying technological enablers. The challenges pertaining to the application of EthicNet and related concepts to next generation services and applications are highlighted through the use case of immersive multimedia communications.

The third article, "On the Importance of Resilience Engineering for Networked Systems in a Changing World," by Hutchison *et al.*, focuses on the concept of applying resilience engineering to communication networks. After summarizing recent and current research initiatives on resilient engineering, the authors discuss the challenges that a rapidly changing environment poses on resilient networked systems, and the consequent sustainability issues and costs, as well as non-technical barriers that must be overcome. A set of potential technical enablers for improving resilience in networked systems are then presented, such as programmability and virtualization, Artificial Intelligence and Machine Learning, monitoring data management, automation, as well as emerging application areas and new challenges. The article finally suggests a multidisciplinary research agenda to achieve resilience engineering in networks.

In the fourth article, "Resource Management for Programmable Metasurfaces: Concept, Prospects and Challenges," by Liaskos *et al.*, the authors present their view on the problem of including programmable metasurfaces within a unified computing and communication resource management system. In particular, they introduce the concept of virtualized programmable metasurfaces (VPMs) as multi-tenancy, cloud-like resources managed by a hypervisor system, which provides a northbound application programming interface and slicing capabilities. The authors analyze how VPMs enable the dynamic deployment of end-to-end services across heterogeneous networks, guaranteeing performance isolation among different tenants. The article then presents relevant use cases and extensions of cloud operations, such as migration and scaling, and concludes with a discussion on open challenges and research questions.

The fifth article, "AI-Driven Framework for Scalable Management of Network Slices," by Blanco *et al.*, addresses the scalability problem of the centralized network slices management & orchestration (M&O) by introducing an approach that decomposes the M&O plane using separation of concerns and declarative policies (intents). The objective is to reduce the information exchanged between M&O subsystems and further control loops based on artificial intelligence to automate such M&O plane operations. The authors also illustrate a case study centered on building a scalable M&O platform that can accommodate the requirements of massive network slices while avoiding or limiting violations of service level agreements. The article ends by briefly describing some challenges and future directions for realizing scalable M&O on the road to 6G networks.

SERIES EDITORIAL

We hope that the reader will find the published papers as inspiring and impactful as we do. While we are in the process of selecting the contributions for the next issue, we invite scientists, researchers, practitioners, and professionals to submit new papers on advancements in the state of the art of Network Softwarization and Management. Last, but not least, we wish to thank all the authors and reviewers who contributed to the success of this Series, and the IEEE Communications Magazine editorial board and staff members for their invaluable and continuous support.

BIOGRAPHIES

OSCAR CAICEDO [GS'11, M'15, SM'20] (omcaicedo@unicauca.edu.co) is a full professor at the Universidad del Cauca, Colombia, where he is a member of the Telematics Engineering Group. He received his Ph.D. degree in computer science (2015) from the Federal University of Rio Grande do Sul, Brazil, and his M.Sc. in telematics engineering (2006) and his degree in electronics and telecommunications engineering (2001) from the Universidad del Cauca. His recent research interests include network and service management, network functions virtualization, software-defined networking, machine learning for networking, and network softwarization. He serves as Series Editor for the IEEE Communications Magazine Series on Network Softwarization and Management and Associate Editor of the IEEE Networking Letters. He served and keeps serving as Technical Program Co-Chair for IEEE-sponsored international workshops and conferences.

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