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EDITORIAL

High-Precision, Predictable and Low-Latency Networking

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New waves of networked applications continue to push the limits of what is possible with networks today. For example, Industrial Control, Augmented Reality, Tactile Internet all require ultra-low latency in the single-digit millisecond range and do not tolerate jitter at all. Economic pressures mandate increasingly cloudification of real-time applications with precision service level needs, yet many of those applications are mission-critical and cannot afford any loss in connectivity or even of single packets. Collectively, these applications require networking services that support high-precision and predictable service levels with associated guarantees that border on determinism. This requires a rethinking of many of the principles underlying existing "Best Effort" internetworking technology.

Various approaches are emerging that try to tackle those challenges. Data centers with fixed topologies and a constant number of hops rapidly replace conventional routing and more general Internet topologies. Networks are becoming more programmable to allow to custom-tailor and optimize treatment of packets and flows. Related technologies range from Service Function Chaining to Network Slicing to SDN. While 5G is making ultra-reliable and low latency communications (URLLC) at the network edge a reality, momentum for Beyond 5G (B5G) and 6G is building to push the boundaries of precision services beyond the edge and across the core. One overarching question concerns how these technologies can be harnessed and what additional approaches are needed to be able to actually deliver on high-precision networking with service levels that are predictable and that can be guaranteed.

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This will involve advances across all networking planes, including but not limited to approaches for the programming and processing of packets in the data plane, evolved control interfaces and ultra-low latency control loops to optimize service levels in the control-plane, methods for high-precision measurements and telemetry with nanosecond accuracy at scale, as well as advances in the related platforms and algorithms in the management plane.

To address these issues, we have invited researchers to share their visions and solution approaches for high-precision, predictable and low-latency networking in this Special Issue.

The paper by M. Letourneau et al. proposes a characterization of threats targeting low-latency services. The authors are taking a close look at L4S, a proposal that is currently under standardization at the IETF to allow classic and low-latency services to be concurrently supported. Specifically, the authors analyze potential vulnerabilities that might be exploited by L4S attacks, the conclusions of which may help mitigate such attacks.

The paper by M. Máté et al. focuses on a time-aware shaper for time-sensitive networking. It proposes a new traffic shaper that prevents interference from low-priority streams with high-precision traffic. The proposal builds on the concept of assigning packets of flows to gate-controlled queues to avoid collisions, but does not require clock synchronization or central control in contrast to other proposals.

Time-Sensitive Networking (TSN) also features prominently in the paper by F. Rezabek et al. This paper presents a sophisticated platform that allows researchers to conduct experiments with TSN for different high-precision networking application domains and deployment scenarios such as industrial automation.

A scalable architecture for precision networking is also proposed in the paper by V. Angilella et al. This architecture leverages the concept of gate-controlled queues and complements it with a novel algorithm to quickly take admission control decisions.

The paper by T. Eckert et al. investigates high-precision latency forwarding for wide area networks through intelligent in-packet header processing. The authors present a solution that ensures latency guarantees by preventing the possibility of burst accumulation. This is accomplished using metadata that ensures spacing between packets is properly preserved.

The paper by S. Gallenmüller et al. takes a close look at various operating system parameters that impact packet processing latency on a networking device and complements this with a detailed case study of an intrusion prevention system.

The paper by A. Syed et al. considers fault-tolerant dynamic scheduling and routing for in-vehicle networks. It introduces a clever new approach to achieve this. The approach utilizes network coding instead of alternatives such as Frame Replication and Elimination for Redundancy (FRER) and promises advantages such as more efficient network utilization.

Finally, the paper by X. Marchal et al. presents a comprehensive measurement study on the four main commercial cloud gaming platforms (Google Stadia, Nvidia GeForce Now, Microsoft xCloud, Sony PlayStation Now) in order to infer their adaptive behavior to differing and degraded network conditions. The authors show that the four platforms exhibit different behaviors that in many cases result in degraded QoS, leaving room for improvement at both application and/or network levels.

We believe that collectively these papers provide an excellent sample of current work in this important area that, when successful, will pave the way for a whole new generation of networked applications. Enjoy the Special Issue!

Raouf Boutaba, Alexander Clemm, Guillaume Doyen, Bertrand Mathieu, Mohamed Faten Zhani.

Guest Editors

Alexander Clemm is a Distinguished Engineer at Futurewei in Santa Clara, California. He has been involved in networking software and management technology throughout his career, most recently in the areas of green networking, high-precision networks and future networking services, as well as network analytics, intent-based networking, service assurance, and telemetry. Alex is the recipient of the 2020 Salah Aidarous Award given by IEEE CNOM and IFIP TC6.6 to "an individual who has provided unremitting service and dedication to the IT and Telecommunications Network Operations and Management community". Alex has an extensive publication record including around 70 papers, 70 patents, and 15 RFCs. He holds an M.S. degree in computer science from Stanford University and a Ph.D. from the University of Munich, Germany.

Raouf Boutaba received the M.Sc. and Ph.D. degrees in computer science from Sorbonne University in 1990 and 1994, respectively. He is currently a University Chair Professor and the Director of the David R. Cheriton School of Computer Science at the University of Waterloo (Canada). His research interests fall in the areas of computer networking and distributed systems. Dr. Boutaba served as the founding Editor-in-Chief of the IEEE Transactions on Network and Service Management (2007–2010) and the Editor-in-Chief of the IEEE Journal on Selected Areas in Communications (2018–2021). He is a Fellow of the IEEE, the Engineering Institute of Canada, the Canadian Academy of Engineering, and the Royal Society of Canada.

Guillaume Doyen has been a Professor at IMT Atlantique since 2021. Formerly, he was an associate professor at Troyes University of Technology where he was head of the Network and Telecommunication engineering program from 2019 to 2021 and co-chair of the Cyber-Security transversal research project from 2014 to 2020. His current research interest focuses on the design of autonomous management and control solutions applied to the performance and security of the Future Internet. He is an active member in the network and service management community where he has published more than 50 papers and is a regular TPC member of high-venue conferences (e.g. IEEE/IFIP CNSM, IEEE/IFIP IM and NOMS, IFIP AIMS), having also co-chaired several events (e.g. ManSDN/NFV, IFIP AIMS). He holds a Habilitation from University of Technology of Compiegne, France, a PhD from University of Nancy I, France and an MSc from INSA Toulouse, France.

Bertrand Mathieu received the M.Sc. degree from the University of Marseille, the Ph.D. degree from the Sorbonne University, Paris, and the Habilitation à Diriger des Recherches degree from the University of Rennes. He is a Senior Researcher with Orange Innovation. He contributed to 14 national/European projects and published more than 80 papers in international conferences, journals or books. He is working on

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Mohamed Faten Zhani is currently an Assistant Professor with the department of Networks and Multimedia at the Institut Supérieur d'Informatique et des Techniques de Communication (ISITCom, University of Sousse) in Tunisia. Before that, he was Associate Professor with the department of software and IT engineering at l'École de Technologie Supérieure (ÉTS Montreal) in Canada (2015–2023). His research interests include future Internet architectures, cloud computing, network function virtualization, software-defined networking and resource management in large-scale distributed systems. He is co-founder and vice-chair of the IEEE Network Intelligence Emerging Technology Initiative. Faten received the IEEE/IFIP IM 2017 Young Researchers and Professionals Award as a recognition for outstanding research contribution and leadership in the field of network and service management. He is a senior IEEE member and ACM member.

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