MOBILE COMMUNICATIONS AND NETWORKS


Wanshi Chen


Ilker Demirkol


Miraj Mostafa


Stefano Ruffini

Networks are continuously evolving with the provisions of new communication capabilities and services; while 5G is being deployed, several research activities are starting to define the next big step in mobile technology, 6G, with the expectation for commercial developments in the 2030s.

Technological advances are paving the way for unlimited possibilities, such as those offered by haptic and Tactile Internet or holograms, for an immersive experience. A number of challenges remain to be addressed while evolving the networks to support these applications. Some of these challenges are analyzed in the articles that, after a scrupulous review process, have been selected for this issue of the Mobile Communications and Networks Series. These articles present proposals for solutions in the areas of edge computing, device-to-device communication, digital-twin-based architecture, and massively parallel nonlinear processing.

The first article, "Design of Edge Computing for 5G-Enabled Tactile Internet-Based Industrial Applications," presents the design of edge computing for Tactile Internet (TI) industrial applications in response to the stringent requirements such as high data reliability and sub-millisecond latency. After a brief description of the increasingly important role that 5G-based communication networks play in industrial applications, the authors summarize numerous TI industrial use cases. Detailed analysis of the missing building blocks in the edge computing design is also provided. These blocks include the aspects of computation, communication, and storage resource management. Several open challenges toward TI industrial applications are listed as part of the conclusion.

One direction of 5G and 6G research and standardization is the use of millimeter-wave and terahertz frequency bands. However, there may be a gap in terms of the enthusiasm of researchers and practical concerns from operators. This is the focus of the second article, "The Proximity Radio Access Network for 5G and 6G." After discussing some potential 6G use cases and some commercial deployment restrictions (e.g., deployment limitations at high frequencies, operation cost, and electric cost), the author presents a possible solution called operator-controlled proximity radio access network (P-RAN), where a user without connection or with a weak connection can be helped by operator-controlled relays, forming device-to-device communication. The corresponding challenges and potential solutions are summarized, along with evaluations in terms of improved user data rates. Several applicable business use cases of P-RAN are also identified.

Digital twins is a relatively recent concept, where objects or systems are represented virtually. The third article, "Digital-Twin-Enabled 6G: Vision, Architectural Trends, and Future Directions," studies the digital twin of a 6G physical system by first presenting its key design requirements such as the decoupling (generalization) of twins from the underlying physical system. The architectural components are presented, along with trends based on the deployment fashion of twins, such as edge-based twins, cloud-based-twins, and edge-cloud-based twins, which might be needed for scalability purposes. We believe that the future research directions provided in this article, such as the mobility management for edge-based twins, also provide good pointers for community members interested in working within this domain.

Our fourth article addresses a critical need of finding the suitable processing approach in 6G. It proposes massively parallel nonlinear (MPNL) processing as the potential approach, considering the anticipated 6G scenarios of extremely dense networks and devices, ultra-massive device connectivity, combination of human-type and machine-type traffic, and higher frequency bands. The linear approach has been broadly deployed in 5G systems. However, it has limitations as far as achieving the required capacity and capability of 6G. A nonlinear approach has the potential to overcome the limitations, but it is highly computation-intensive and sequential in nature, hindering its deployment in practical communication systems so far. A massively parallel processing framework is proposed to make nonlinear processing useful by supporting optimized use of available spatial, frequency, and time resources. The article also provides a direction for additional research to extract more out of MPNL to enable its deployment in 6G.

This issue of the Series presents a collection of articles addressing some of the key aspects related to the evolution of mobile networks as moving toward 6G, which we hope will be of interest to our readers.

We would like to thank our contributors for their excellent articles and the reviewers for their effort in reviewing the manuscripts, helping us to maintain the quality of the Series. We also thank the Editorial Board and staff members for their invaluable continuous support during the entire process.

We would also like to welcome Stefano Ruffini, who recently joined the Series as an Editor. In addition, our deep appreciation goes to Alberto Perotti for his contributions and leadership during his role as Lead Editor for the Series. We congratulate Alberto and wish him best luck in his new endeavor.

BIOGRAPHIES

WANSHI CHEN [SM] (wanshic@qti.qualcomm.com) is a senior director, Technology at Qualcomm Inc., where he is involved in 5G research and standardization. He is currently 3GPP TSG RAN plenary Chair appointed in April 2021. Previously, he was 3GPP TSG RAN WG1 Chair from August 2017 to May 2021, and a Vice-Chair from August 2013 to August 2017. As RAN WG1 Chair, he successfully led the group to deliver both the first 5G release (Release 15) and the second 5G release (Release 16) on time and with high quality. The highest degree that he received is a Ph.D. degree in electrical engineering from the University of Southern California, Los Angeles.

ILKER DEMIRKOL [SM] (ilker.demirkol@upc.edu) is an associate professor in the Department of Mining, Industrial and ICT Systems Engineering at the Universitat Politècnica de Catalunya, Barcelona, Spain, where his research is currently focused on network algorithmics, the Internet of Things, and mobile networks. He received his B.Sc., M.Sc., and Ph.D. degrees in computer engineering from Bogazici University, Istanbul, Turkey. Over the years, he has worked in a number of research laboratories and industrial corporations in Europe and the United States. He has coauthored more than 75 ACM/IEEE journal and conference papers, including the recipients of the Best Paper Award in IEEE ICC '13 and the Best Demo Award in IEEE MASS 2019. He is currently a member of the *IEEE Cmmunications Magazine* Editorial Board and has been actively participating in IEEE conferences, for example, as IEEE INFOCOM 2019 FlexNets Workshop TPC Chair, IEEE WCNC 2018 FlexNets Workshop Chair, IEEE CCNC '17-GCCN TPC Chair, and IEEE CCNC '15 Demo Chair.

MIRAJ MOSTAFA (miraj.mostafa@americantower.com), is a senior manager for Network Engineering at American Tower Corporation. Previously, he worked for Nokia and Microsoft. He also directly contributed to the standardizations and industry collaboration works in 3GPP, IEEE 802.11, Wi-Fi Alliance, GSM Association, and so on. He has many granted patents, and has been acknowledged with multiple top industry awards for his impacting contributions to technology and business. He received his Ph.D. in communications engineering, Master of Engineering degree in telecommunications, and Bachelor of Science degree in electrical and electronics engineering from Tampere University of Technology, Asian Institute of Technology, and Bangladesh University of Engineering and Technology, respectively.

STEFANO RUFFINI (stefano.ruffini@ericsson.com) graduated in telecommunication engineering from the University of Rome La Sapienza; he joined Ericsson in 1993. He is currently working in the Optical Systems research area in the Ericsson Research organization. He is one of the Ericsson experts working on the evolution of the mobile backhaul/fronthaul networks and on the related network synchronization solutions. He is currently actively contributing to ITU-T SG15 Q13 (serving as Rapporteur) and IEEE1588 (serving as Vice-Chair of the New Feature subcommittee) and to other relevant synchronization standardization bodies and forums. He has published several international journal papers and delivered presentations at various conferences. He is the Chairman of the International Timing and Sync Forum and also a member of the Workshop on Synchronization in Telecommunication Systems Executive Committee.