MOBILE COMMUNICATIONS AND NETWORKS


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One of the most captivating aspects of last-generation mobile communication networks is their multitude of built-in features conceived to address use cases and applications in a variety of domains. As each feature brings about advantages to address applications demands, such a multi-faceted technology puts a number of new challenges in front of researchers and designers.

This issue of the Mobile Communications and Networks Series offers to our readers a selection of papers treating several relevant aspects of current and future network generations, covering local and cellular wireless networks operating in traditional microwave frequency bands and in mmWave frequencies, new use cases, architectures and design approaches.

With the increase of base station density, transmission bandwidths, size and complexity of basebands, RF and antenna systems, energy consumption has become an increasingly important design metric for wireless networks. The first article of our series, "Greener Physical Layer Technologies for 6G Mobile Communications", discusses the fundamental trade-offs between energy efficiency and spectral efficiency. The paper proposes a combination of non-orthogonal multiple access and energy efficient user scheduling/resource allocation that provides a simultaneous increase of energy efficiency and spectral efficiency.

Our second article, "ReLy: Machine Learning for Ultra-Reliable, Low Latency Messaging in Industrial Robots", highlights the need for ultra-high reliability and very low latency communication (URLLC) for robots on the factory floors, especially for the communication of unexpected events. In this work, the authors propose a machine learning based framework called ReLy that intelligently embeds the time-critical messages in the preamble of outgoing WiFi frames at the transmitter. For this, ReLy uses an encoding scheme that embeds information by distortions in the signal phases within the preamble of an outgoing WiFi frame. One advantage of ReLy is that it can work with all next-generation (IEEE 802.11ax/ac) as well as legacy (IEEE802.11a/n) WiFi devices, since it uses the legacy preamble fields. The receiver uses convolutional neural networks and can decode the emergency notifications from the changes in the channel state information. Since ReLy is implemented entirely at the physical layer, the information is delivered within 5 ms latency and an ultra-high reliability of 99 percent, getting us one step closer to the 5G URLLC requirements. Such performance has been experimentally demonstrated in a setup with moving robots in a busy workshop in a typical factory setting.

In our third article, "A 5G New Radio for Balanced and Mixed IoT Use Cases: Challenges and Key Enablers in FR1 Band", the authors analyze the NR-RedCap (NR for Reduced Capabilities devices) solution that is being studied within 3GPP, which targets high-end IoT use cases (such as video surveillance and industrial IoT), which neither fall in the enhanced mobile broadband (eMBB) nor in the URLLC categories, yet have different requirements than the low-end IoT use cases. The authors present the related design guidelines, the challenges faced and the open issues that need to be tackled.

The fourth article, "Integrated Access and Backhaul: A Key Enabler for 5G Millimeter Wave Deployments", studies the integrated access and backhaul (IAB) feature in 5G NR, considering a self-backhauling approach in millimeter wave (mmWave) deployments within the same spectrum. Such an approach is expected to provide a cost-effective and highly efficient solution, thanks to the specific features of mmWave communication. An interesting finding of the large-scale study of coverage and rate performance is that only a small number of fiber-connected (donor) base stations, e.g., less than 10 base stations per square km, would be needed using such an approach.

In Cloud-Radio Access Networks (C-RAN), central baseband units are connected to remote radio heads through high-capacity front-haul links. The delay introduced by the front-haul links is a serious limiting factor for some RAN functionalities, such as scheduling and resource allocation, as it may result in outdated channel quality information being delivered to the scheduler in the central unit. The fifth article of our series, "Hierarchical Scheduling for Suppression of Fronthaul Delay in C-RAN with Dynamic Functional Split", combines centralized and distributed scheduling methods in a hierarchical framework that enjoys benefits from both methods. Hierarchical scheduling mitigates the impact of fronthaul delay on the throughput of non-cell-edge users, whereas cell-edge users still benefit from interference mitigation obtained through a centralized control.

The proliferation of data-hungry applications is causing a surge in data rate demands that is challenging the current local access networks' capabilities. The next Wi-Fi generation, based on the new IEEE 802.11be specification, is designed to address those demands by delivering multi-gigabit per sec-

ond data rates with higher reliability and lower latency compared to earlier generations. The sixth article of our Series, "IEEE 802.11be: Wi-Fi 7 Strikes Back", overviews the latest news about Wi-Fi evolution and provides an updated digest of the new 802.11be essential features. The article discusses multi-access point coordinated beamforming, one of the most appealing enablers to complement improved peak throughput with boosted network efficiency, lower latency and higher reliability. Gains are evaluated in realistic set-ups.

The challenge of serving indoor environments through cellular networks has been targeted in our seventh article, "Adding Indoor Capacity without Fiber Backhaul: A mmWave Bridge Prototype". As a cost-effective solution to this, the authors propose an out-of-band repeater that converts a sub-6 GHz cell signal from a cell tower to a mmWave frequency for the fronthaul to buildings or distributed antenna sites, where the signal is down-converted to the original frequency and emitted for example inside a building. The several advantages of this approach are summarized as: less fiber attachment points, backward compatibility to equipment already in use, offloading of the indoor network traffic, and spatial multiplexing thanks to directive mmWave beamforming. An important contribution of this paper is the validation of this concept through the evaluations of a prototype, the implementation of which has also been provided in the paper.

Increasing the spectral efficiency of mmWave communication is the focus of the last article: "Higher Spectral Efficiency for mmWave MIMO: Enabling Techniques and Precoder Designs". The article discusses and compares several types of hybrid precoding methods for mmWave communications. Index modulation-aided hybrid precoding methods are advocated as promising solutions for achieving higher spectral efficiency in next-generation mmWave systems. The authors compare and evaluate several IM-based methods, showing that they can achieve attractive performance while having contained complexity.

The Series' broad charter has brought us papers on a number of different subjects which we hope will be of interest to our readers.

We would like to thank our contributors for their excellent articles and express our gratitude to the reviewers for helping us maintain the quality of the Series. As always, we are glad to have the help and encouragement of our Editor in Chief, Associate Editor in Chief and the publications staff. Lastly, this is the first issue where we have Dr. Wanshi Chen and Dr. Miraj Mostafa as Series Editors on our team. We welcome Wanshi and Miraj and look forward to a fruitful cooperation.

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 the 3GPP TSG RAN1 Chair, reappointed in August 2019 after being first appointed in August 2017. Previously, he was a 3GPP RAN1 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, CA, USA.

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 currently is focused on network algorithmics, Internet of Things and mobile networks. He received the B.Sc., M.Sc., and Ph.D. degrees in computer engineering from the Bogazici University, Istanbul, Turkey. Over the years, he has worked in a number of research laboratories and industrial corporations in Europe and the USA. He has coauthored more than 75 ACM/IEEE journal and conference papers. He is the recipient of the Best Paper Award at IEEE ICC'13 and the Best Demo Award at IEEE MASS 2019. He is currently a member of the *IEEE Communications Magazine* Editorial Board and has been actively participating in IEEE conferences, e.g., 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 represented his companies to the standardizations and industry collaboration activities in 3GPP, IEEE 802.11, Wi-Fi Alliance, GSM Association, and so on. He received his Ph.D. in communications engineering, master of engineering in telecommunications, and bachelor of science in electrical and electronics engineering from Tampere University of Technology, Asian Institute of Technology, and Bangladesh University of Engineering and Technology, respectively.

Alberto Perotti [S'01, M'03, SM'14] (alberto.perotti@ieee.org) received his M.Sc. and Ph.D. degrees in telecommunications from Politecnico di Torino, Italy, in 1999 and 2003, respectively. He is a senior research engineer at Huawei Technologies, where he is involved in wireless networks' PHY layer research and 5G standardization. Previously, he carried out research on mobile wireless and satellite communications at Politecnico di Torino. His interests cover coding and modulation, multiple access, and software-defined radios. He is the lead editor for the Mobile Communications and Networks Series in *IEEE Communications Magazine*.