MOBILE COMMUNICATIONS AND NETWORKS


Wanshi Chen


Ilker Demirkol


Miraj Mostafa


Stefano Ruffini

We are excited to have an unusually large number of articles in this issue of Mobile Communications and Networks series. These articles explore further evolutions of communications and some potentials for 6G, including delivery of high-precision clock sources, next generation connectivity for Railways, integration of terrestrial and non-terrestrial networks, integration of artificial intelligence (AI) into open Radio Access Network (O-RAN), investigation of MIMO channel quantization and channel error models towards 6G, the potential of near-field beam focusing for 6G, enabling rural connectivity by recycling TV towers with massive MIMO, integration of satellite communication systems into 5G networks, efficient decoders for short block length codes for ultra-reliability low-latency communications (URLLC), and the potential benefits of virtualized distributed unit (vDU) standardization in softwarized RAN.

Many network applications and services require high precision clock sources. The article "cnPRTC — Coherent Network Primary Reference Time Clock: A Geographically Distributed Resilient Timescale for Telecommunications" reviews the recent efforts of International Telecommunications Union (ITU) on the solution named "cnPRTC." cnPRTC exploits many independent sources of time and frequency, by combining them through high-accuracy links and by defining collaborative mechanisms for these clock sources to improve the timing performance delivered by the overall system and its resiliency. The article also defines the operational phases of a cnPRTC system, along with the impact of possible technical issues such as GNSS loss within these phases. Moreover, three cnPRTC deployment strategies have been defined and compared in terms of their resilience levels. We believe that an article on ITU's efforts towards a high-precision and resilient networked clock source solution will be of interest to our readership.

With the emergence of new use cases and advanced applications in railway communications, like automatic train control and radio-based signaling, the long-standing standard Global System for Mobile communication — Railway (GSM-R) is not able to support the evolving needs. The second article "Next-Generation Connectivity in a Heterogenous Railway World" describes an Adaptable Communication System (ACS) as the possible successor to provide a solution for all future mobile communication in all types of railways. The ACS complies with the new requirements and reference architecture defined by the standardization bodies like International Union of Railways (UIC), Rail Telecommunications Technical Committee of the European Telecommunications Standard Institute (ETSI TC-RT) and the 3rd Generation Partnership Project (3GPP). The article discusses several network models and enhancements including satellite communications (SatCom), Software-Defined Networking (SDN) integration, and antenna systems that support multiple bearers, saving limited mounting surface on a train.

Integration of terrestrial and non-terrestrial networks comes under focus in the third article, "Integrating Terrestrial and Non-terrestrial Networks: 3D Opportunities and Challenges," due to the potential opportunities it brings in long term, when ubiquitous connectivity would be unavoidable. Non-terrestrial networks can bring connectivity to the places where terrestrial networks fail due to their limitations. Besides, user experience can be improved with the non-terrestrial networks, compared to what is possible with the terrestrial networks. These advantages can be realized only with smooth integration, but it comes with different challenges. This article outlines opportunities in terms of use cases. A summary of relevant standards is also outlined. The article proposes re-engineering of terrestrial network by augmenting a ground deployment with uptilted cells, and also complementing it with a LEO constellation. The study finds some obstacles and suggests future direction for research to overcome those.

The integration of satellite communication systems into 5G networks will allow satellite operators to be an active part of the 5G value chain in providing enhanced services. This integration can enable 5G services in underserved or remote areas extending 5G applicability and use cases, although with some limitations for delay-sensitive or broadband applications. While some integration options are already viable and ready for market adoption, others still require refinements and developments, to be carried out in parallel with the progress of 3GPP specifications. The article "Modes and Models for Satellite Integration in 5G Networks" reconstructs the state-of-the-art of the satellite-related 3GPP standardization and uses outputs of some research projects to define the perimeter of the satellite adoption in the upcoming 5G-based communication services.

O-RAN is an emerging paradigm, where virtualized network infrastructure elements from different vendors communicate via open and standardized interfaces. A key element defined as part of the O-RAN architecture is the RAN Intelligent Controller (RIC), an AI-based controller. The article "Choose, Not Hoard: Information-to-Model Matching for Artificial Intelligence in O-RAN" presents and analyzes a new approach to the integration of AI in the O-RAN scenario, allowing to assign different model instances to each gNB of the network, and independently choose the data each instance is trained on. This approach deviates from the state-of-the-art that is typically based on training one model instance for the whole network and using all available data. Authors of this article shows how this approach yields an attractive trade-off between training time and learning effectiveness.

Future generations of mobile networks are expected to be using significantly larger numbers of antennas and higher carrier frequencies, which would create challenges on the correct channel state information (CSI) acquisition. For this, in the article titled "Multiple Antenna Systems in Mobile 6G: Directional

Channels and Robust Signal Processing," authors propose channel model enhancements based on geometry-based stochastic channel models. In addition, authors overview the recent developments of CSI quantization and feedback approaches, as well as robustness enhancements of MIMO transmissions with imperfect CSIT. Hence, this article is expected to provide a good reference for the topics of massive MIMO and extra-large (XL)-MIMO channel quantization and channel error models towards 6G mobile communications.

The article, "6G Wireless Communications: From Far-Field Beam Steering to Near-field Beam Focusing," discusses the need of extremely large-scale antenna arrays, motivated by the requirements expected in 6G networks in terms of data rates, energy efficiency, latency, and user diversity. It focuses on the possibility of 6G wireless communications in the radiating near-field (Fresnel) region assuming the spherical wavefronts, in contrast to the conventional far-field operation assuming the plane-wave propagation. After describing the challenges and characterizing the key physical properties of near-field communications, the authors provide several appealing application scenarios by exploiting spherical wavefronts via beam focusing. These applications include interference mitigation in multiuser communications, accurate localization and focused sensing, and wireless power transfer with minimal energy pollution.

There is another effort of connecting unconnected and under-connected population in the eighth article, "Enhancement of Rural Connectivity by Recycling TV Towers with Massive MIMO Techniques," but this time by using TV towers with multi-user massive multiple input multiple output (mMIMO) technique. It uses the concept of super cells with high power signal emission from a high tower, resulting in large coverage area. The article shows that the obtained result is promising, based on applying the solution to a realistic case study in an Ethiopian rural area. Different advantages of the solution are also outlined. At the end, the article describes the challenges in deploying the solution and direction for possible enhancements to overcome those.

URLLC is one of the key pillars of 5G and beyond. The need for making the communication ultra-reliable with low end-to-end latency and packet-size flexibility makes the channel coding very challenging. Besides, the evolution to 6G demands even stringer requirements for all these aspects. The ninth article "Efficient Decoders for Short Block Length Codes in 6G URLLC" reviews and compares different decoding techniques for URLLC. The article also suggests decoder selections and potential research directions. Short block-length allows better error correction capabilities, but at the expense of degrading transmission reliability, making it a difficult trade-off between block length and reliability. Keeping this challenge in mind, the article investigates advanced Ordered-Statistics Decoding (OSD), Guessing Random Additive Noise Decoding (GRAND), Successive Cancellation List (SCL), with short block-length for high error-correction capability. They are evaluated and compared in terms of their complexity and block error rate (BLER) performance.

The 5G mobile communications are promoted as an enabler for the Enhanced Mobile Broadband (eMBB) services with high-bandwidth requirements e.g., Virtual Reality (VR), URLLC services demanding low-latency and high-reliability. Initial deployments of these services indicate that the 5G system supports their fundamental functionalities; nevertheless, support for complex use cases of such services remains challenging. The article "On the Benefits of vDU Standardization in Softwarized NGRAN: Enabling Technologies, Challenges, and Opportunities" presents the gains of NG-RAN softwarization along with vDU standardization benefits for MNOs (Mobile Network Operators) to adopt cutting-edge technologies and operate their network more flexibly and efficiently resulting in a reduced Total Cost of Ownership (TCO), particularly when it comes to addressing different needs of new services.

We are very grateful to receive a large number of submissions recently, resulting in ten accepted articles in this issue. The review process for the submissions involved many researchers around the world, and we are very thankful for their dedication and great efforts, especially considering the tight deadlines and the many iterations of reviews and revisions for a manuscript to be accepted. We would also like to acknowledge the continuous support from the editors and staff members.

We hope that the readers will enjoy reading the rich set of papers in this issue.

Biographies

Wanshi Chen (wanshic@qti.qualcomm.com), IEEE Senior Member, is a Sr. 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 and successfully led the group to deliver both the first and the second 5G releases 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, USA.

Ilker Demirkol (ilker.demirkol@upc.edu), IEEE Senior Member, 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 has the focus on network algorithmics, Internet of Things and mobile networks. 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, including the recipients of the Best Paper Award in IEEE ICC'13 and the Best Demo Award in IEEE MASS 2019.

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 contributed to the standardizations and industry collaboration activities in 3GPP, IEEE 802.11, Wi-Fi Alliance, and GSM Association. He received his Ph.D. in Communications Engineering, Master of Engineering in Telecommunications, and Bachelor of Science in EEE from Tampere University of Technology, Asian Institute of Technology, and Bangladesh University of Engineering and Technology respectively.

Stefano Ruffini (stefano.ruffini@calnexsol.com) graduated in telecommunication engineering from the University of Rome La Sapienza. After a long experience at Ericsson, he is currently working as Strategic Technology Manager at Calnex Solution. Stefano is currently contributing to ITU-T SG15 Q13 (serving as Rapporteur), IEEE1588, and other relevant synchronization standardization bodies and forums. He has published several international journal papers and delivered talks at various conferences. He is member of the steering group of the International Timing and Sync Forum and a member of the Steering Committee of the Workshop on Synchronization in Telecommunication Systems.