Digital Object Identifier 10.1109/OJCOMS.2023.3320821

Guest Editorial: Special Section on Advancements for 6G

WHAT will the wireless networks of the next generation look like? The latest advances in industrial and academic research have shed some light into that direction. With the finalization of the framework recommendation for the 6th generation (6G) networks by the International Telecommunication Union (ITU), the pillar usage scenarios, supporting capabilities and technical enablers are becoming clearer. The overarching motivation for the development of 6G is to continue to build an inclusive information society in a sustainable way. In this context, a range of user and application trends are foreseen to become an integral part of 6G, including ubiquitous intelligence, immersive multimedia and multi-sensory interactions, digital twins, digital health, smart industries, ubiquitous connectivity, integration of sensing and communication, as well as sustainability. It is worth noting that many of the trending demands do not come from the traditional markets for private mobile users and instead, they are driven by strong needs from vertical industries including manufacturing, transportation, and health care.

To fully support these trends, there is a need for research on new architectures and technologies. To this end, the guest editorial team released a call for papers for this special section, striving to collect high-quality research and experimental results from the communications community. As a result, this special section attracted a good number of submissions from both the academia and the industry, touching upon many aspects of future 6G networks, from the physical layer to higher layers; from classical signal processing techniques to learning based approaches.

In the first article [A1], the hybrid analog and digital (HAD) structure with mixed analog-to-digital converters (ADC) is considered for directional of arrival (DOA) estimation of massive MIMO systems. Both the estimation performance loss and the energy efficiency of this architecture are evaluated theoretically and numerically, in order to demonstrate its superiority regarding practical implementations. Some design guidelines of the HAD structure with mixed ADCs are also provided.

The intelligent reflecting surface (IRS), also referred to as the reconfigurable intelligent surface (RIS), is seen as a promising technology for 6G. The second article by Wang et al. [A2] analyzes the theoretical boundaries and performance limitations of intelligent reflecting surface (IRS) aided networks. The article studies the active IRS, and factors limiting its performance. Performance under the assumption of infinite-resolution phase shifters on IRS side is studied first, then compared to the practical case of finite-resolution phase shifters. Analytical and numerical evaluation results provide guidelines that for active IRS, a 3-bit phase shifter is sufficient to achieve satisfactory performance.

A third article by Mirdita et al. [A3] focuses on fingerprint based positioning in the 6G era, where deep learning algorithms are expected to enhance the performance and precision. Deep learning based approaches typically demand large datasets, while the traditional centralization of data poses privacy and reliability risks, and here is where federated learning (FL) comes into play. In light of this, the article introduces FL to eliminate the need for servers to acquire labeled data directly from users. The proposed approach aims to minimize localization error in RSS fingerprints, preserve user privacy and reduce system latency.

In the fourth article [A4], based on multi-parameter CSS modulation, a slope-shift-keying and phase-shift-keying LoRa (SSK PSK-LoRa) modulation is proposed, which can achieve higher SE and better energy efficiency than the conventional LoRa modulation. The transceiver architecture of SSK PSK-LoRa is presented along with its detection methods. Moreover, the orthogonality of SSK PSK-LoRa symbols is analyzed and the closed-form approximations for bit error rate are derived.

The fifth article [A5] studies mission critical communications enabled by 5G and beyond networks. Specifically, the possible interplay of sidelink communications, directional unicast transmissions and multicasting is studied, enhanced by the deployment of integrated access backhaul (IAB) nodes. According to the numerical results obtained in this article, it is plausible that allocating more resources to multicasting can result in improved system performance.

The non-terrestrial network (NTN) is expected to become a lively component in 6G and serve as a complement to its terrestrial counterparts. The last two articles both address research problems emerged in NTN. The article by Xu et al. [A6] looks at the random access procedure for narrow band Internet-of-Things (NB-IoT) devices, and proposes a method to combat the large time of arrival and carrier frequency offset introduced by the nature of NTN. Different from existing literature which may rely on the global navigation satellite system (GNSS), the proposed method analyzes the phase series of the received signal and explores the linearity of phase series. A two-stage estimation method is adopted to detect the change points, and high detection rate is achieved under different noise models and signal to noise ratio (SNR).

In the last article [A7], a framework based on actor-critic reinforcement learning and generative models is developed for line-of-sight (LOS) estimation and traffic scheduling on multiple links connecting the user equipments to satellites in 6G-NTN integrated networks. Specifically, the generative adversal networks (GANs) and variational autoencoders are employed to construct a full observable Markov decision learning process, which can attain higher convergence speed.

Our guest editorial team members sincerely thank the authors and reviewers for their contributions to this special section. We also would like to thank Prof. Sinem Coleri, Editor-in-Chief of the IEEE OJ-COMS, Prof. Rui Dinis and Prof. Derrick Wing Kwan Ng, Associate Editors-in-Chiefs, and Chang Cai, the Managing Editor, for their valuable guidance and assistance.

APPENDIX: RELATED ARTICLES

[A1] B. Shi et al., "DOA estimation for hybrid massive MIMO systems using mixed-ADCs: Performance loss and energy efficiency," *IEEE Open J. Commun. Soc.*, vol. 4, pp. 1383–1395, 2023, doi: 10.1109/OJCOMS.2023.3290075.

[A2] Y. Wang et al., "Asymptotic performance analysis of large-scale active IRS-aided wireless network," *IEEE Open J. Commun. Soc.*, early access, Oct. 12, 2023, doi: 10.1109/OJCOMS.2023.3324064.

[A3] P. Mirdita, Y. Bello, A. Refaey, and A. Radwan, "6G-enabled mobile access point placement via dynamic federated learning strategies," *IEEE Open J. Commun. Soc.*, vol. 4, pp. 2093–2103, 2023, doi: 10.1109/OJCOMS.2023.3301679.

[A4] Q. Yu, D. He, Z. Lu, and H. Wang, "SSK-based PSK-LoRa modulation for IoT communications," *IEEE Open J. Commun. Soc.*, vol. 4, pp. 1487–1498, 2023, doi: 10.1109/OJCOMS.2023.3292521.

[A5] O. Chukhno et al., "Mission-critical connectivity enhanced by IAB in beyond 5G: Interplay of sidelink, directional unicasting, and multicasting," *IEEE Open J. Commun. Soc.*, vol. 4, pp. 1826–1838, 2023, doi: 10.1109/OJCOMS.2023.3304022.

[A6] Y. Xu, J. Jiang, D. He, and W. Zhang, "A NB-IoT random access scheme based on change point detection in NTNs," *IEEE Open J. Commun. Soc.*, vol. 4, pp. 2176–2185, 2023, doi: 10.1109/OJCOMS.2023.3304066

[A7] A. Machumilane, P. Cassara, and A. Gotta, "Toward a fully-observable Markov decision process with generative models for integrated 6G-non-terrestrial networks," *IEEE Open J. Commun. Soc.*, vol. 4, pp. 1913–1930, 2023, doi: 10.1109/OJCOMS.2023.3307209.

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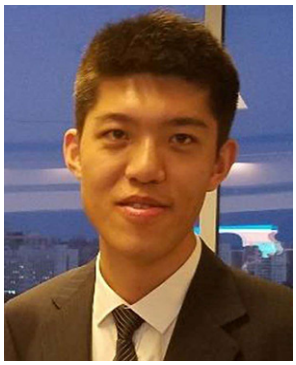

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