# Guest Editorial Artificial Intelligence for 5G and Beyond 5G: Implementations, Algorithms, and Optimizations

THIS Special Issue of the IEEE JOURNAL ON EMERGING AND SELECTED TOPICS IN CIRCUITS AND SYSTEMS (JETCAS) is dedicated to demonstrating the latest research progress on artificial intelligence for 5G and beyond 5G (B5G) with respect to implementations, algorithms, and optimizations.

In order to fulfill the fast-growing economic and cultural needs of human society, wireless communication systems are required to sustain the extreme requirements of emerging networks and devices. Compared to 3G/4G wireless networks, 5G/B5G systems must provide tremendous increased throughput, substantially reduced latency, connecting with a large number of devices, and stringent quality-of-service (QoS) guarantees. In order to meet all of these requirements, 5G/B5G systems must address the problems which are much more complicated, even when *a priori* knowledge is varying, incomplete, or unavailable. Therefore, more advanced communication technologies beyond existing ones are dearly needed.

Considering the range of successful applications in other fields, researchers from both academia and industry are now combining artificial intelligence (AI) with 5G/B5G. Initial results have shown that AI can help to understand wireless communication scenarios which could not be easily modeled, to solve problems that are difficult to address, and to take care of other wireless uncertainties. Though AI has drawn a lot of research attention, research on this topic is still at its early stages. It is necessary to help researchers identify technical challenges, emerging techniques, and recent results related to the communications area.

To this end, this Special Issue aims at providing a comprehensive perspective on the state of research in the field of AI for 5G/B5G through a selection of recent contributions. In order to comply with the high-quality standards of JETCAS, all accepted papers went through a rigid review process. Unfortunately, not all very good papers could be selected due to limited space. This Special Issue contains a survey paper and eight technical papers on three themes: 1) learning for baseband processing; 2) hardware implementations for wireless learning; and 3) wireless sensing, localization, and environmental intelligence.

This Special Issue starts with a survey paper on "Artificial intelligence for 5G and beyond 5G: Implementations, algorithms, and optimizations" by the Guest Editors, which provides the readers with a review of the state-of-the-art on AI for 5G/B5G. Both advantages and limitations of AI are summarized. This paper surveys AI's applications in baseband processing, modeling wireless uncertainties, and device localization. Future research directions are pointed out in this survey paper. We hope that this survey will be useful for interested researchers and be timely to trigger future research in this area.

## I. LEARNING FOR BASEBAND PROCESSING

Following the survey paper, three papers focus on learning for baseband processing. For 5G/B5G systems, in order to increase the performance while mitigating increased complexity, AI has been applied to baseband processing related to precoding, equalization, channel coding, and so on. The three papers focus on different aspects of learning for baseband processing.

The first paper is titled "Deep learning-driven non-orthogonal precoding for millimeter wave communications," by Liu *et al.*, and proposes a nonorthogonal precoding-based hybrid beamforming scheme with the help of deep learning. Different from the existing methods, the neural network in the proposed method works as a general neural codebook, which reduces the training efforts when the channel changes.

The second paper is titled "Syndrome-enabled unsupervised learning for neural network-based polar decoder and jointly optimized blind equalizer," by Teng *et al.*, and focuses on a polar decoder and its joint optimization with a blind equalizer. The authors propose two modified syndrome losses to facilitate unsupervised learning and apply them to polar decoding. A jointly optimized syndrome-enabled blind equalizer is also proposed, which outperforms the nonblind minimum mean square error (MMSE) equalizer with $1.3$ dB gain.

The last paper in this group is titled "Deep learning-aided belief propagation decoder for polar codes," by Xu *et al.*, and employs deep learning (DL) methods to optimize polar belief propagation (BP) decoding. Concatenated LDPC-polar codes have been considered in this paper. Compared to the exact BP decoder, the proposed decoder can achieve similar performance but with lower complexity. The ASIC implementation for $1024$ length code is even superior to that of an existing list-2 CA-SCL decoder, which has a similar error-correction performance. The proposed method can also be applied to other baseband applications of Bayesian estimators.

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## II. Hardware Implementations for Wireless Learning

The next two papers demonstrate the hardware implementations for wireless learning. For 5G/B5G wireless systems, hardware implementations are of great significance since they can guarantee efficient and real-time deployment of learning approaches. Both application-specific hardware implementations and general hardware implementation frameworks are important. The two papers in this group present the most recent results for each aspect.

The first paper is titled "Hardware implementation of neural self-interference cancellation," by Kurzo *et al.*, and presents a hardware architecture for a neural network-based nonlinear self-interference (SI) canceller. Compared to the conventional polynomial-based SI canceller, the proposed canceller requires only $1/8.1$ area and $1/7.7$ power to achieve the same SI cancellation performance. Even with 7 dB more SI cancellation, the proposed canceller is still more area- and power-efficient than the conventional one.

The second paper is titled "SimuNN: A pre-RTL inference, simulation, and evaluation framework for neural networks," by Cao *et al.*, and proposes a pre-RTL neural network simulator (SimuNN) to enable early phase verification and fast prototyping of neural networks, and to efficiently bridge the gap between wireless algorithms and hardware designs. Two design flows for neural networks are also developed, for figuring the optimal hardware configurations under different performance and hardware constraints.

## III. Wireless Sensing, Localization, and Environmental Intelligence

The third group consists of three papers and focuses on wireless sensing, localization, and environmental intelligence. Not only in baseband processing, AI techniques are currently finding widespread applications in the above three areas. The research represented by the following three papers has shown that AI can successfully help with the identification of hidden features in wireless systems.

The first paper is titled "Transfer learning for semi-supervised automatic modulation classification in ZF-MIMO systems" by Wang *et al.*, and proposes a transfer learning (TL)-based semi-supervised AMC (TL-AMC) in a zero-forcing-aided multiple-input and multiple-output (ZF-MIMO) system. Equipped with a convolutional auto-encoder (CAE) and convolutional neural network (CNN), the TL-AMC has a new deep reconstruction and classification network (DRCN) structure. Compared with the CNN-based AMC trained on massive labeled samples, the TL-AMC achieves similar classification accuracy in the high-SNR regime.

The second paper is titled "Dethroning GPS: Low-power accurate 5G positioning with machine learning systems" by Gante *et al.*, and proposes a deep learning-based millimeter-wave positioning method. Its energy consumption is $47\times$ and $85\times$ more energy efficient than the most recent assisted-GPS implementations, for continuous and sporadic position fixes, respectively; also, the achieved estimation error is lower.

The last paper in this group is titled "Moving toward intelligence: Detecting symbols on 5G systems through deep echo state network," by Bai *et al.*, and proposes a deep echo state network (DESN) to detect symbols in 5G communication networks. By employing memristive synapses as the dynamic reservoir layer, this DESN can accelerate the learning algorithm and computation. For nonlinear system prediction, this DESN shows $10.31\times$ reduction on the prediction error compared to state-of-the-art neural network designs.

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