# IEEE TCCN Special Section Editorial: Intelligent Surfaces for Smart Wireless Communications

WE ARE delighted to introduce the readers to this special section of the IEEE TRANSACTIONS ON COGNITIVE COMMUNICATIONS AND NETWORKING (TCCN), which aims at reporting the latest most promising research advances in modeling, analysis, fabrication design, algorithms, and communication protocols of future wireless networks with reconfigurable intelligent surfaces (RISs), and at identifying new research directions in this emerging field of research. We have received a total number of 22 submissions, and after a rigorous review process, 12 articles have been selected for publication, which are briefly discussed in the sequel.

The first article, titled "On the Performance of RIS-Assisted Dual-Hop Mixed RF-UWOC Systems" by Li *et al.*, investigates the performance of an RIS-assisted dual-hop mixed radio-frequency underwater wireless optical communication (RF-UWOC) system, where a ground source does not have a reliable direct link to a given marine buoy. Analytical expressions of the outage probability, average bit error rate, and average channel capacity are derived assuming fixed-gain amplify-and-forward and decode-and-forward relaying protocols at the marine buoy. Numerical results demonstrate that RIS-assisted systems can effectively improve the performance of RF-UWOC systems.

The second article, titled "Joint Transmit Beamforming and Phase Shift Design for Reconfigurable Intelligent Surface Assisted MIMO Systems" by Wang *et al.*, aims to maximize the ergodic spectral efficiency (SE) of an RIS-assisted multiple-input multiple-output (MIMO) system under spatial fading correlations, with the statistical channel state information known at the transmitter and the RIS. A benchmark algorithm based on the semidefinite relaxation technique is proposed to jointly optimize the beamforming vector at the transmitter and phase shift matrix of the RIS. Then, the dominant eigen direction transmission scheme is applied for beamforming in order to reduce the complexity of the algorithm. Numerical results show the tightness of the upper bounds and the effectiveness of the proposed algorithm for improving the ergodic SE.

The third article, titled "Reconfigurable Intelligent Surface Assisted Mobile Edge Computing With Heterogeneous Learning Tasks" by Huang *et al.*, presents an RIS-assisted mobile edge computing system with learning-driven tasks. The design of a learning-efficient system is proposed by jointly optimizing the transmit power of the mobile users, the beamforming vectors of the base station (BS) and the phase-shift matrix of the RIS by using an alternating optimization framework. Simulation results demonstrate the validity of the learning error model and the superiority of the proposed scheme over various benchmarks. Also, a unified sensing-communication-learning platform is developed based on the CARLA platform and the SECOND network.

The fourth article, titled "Multi-Dimensional Polarized Modulation for Land Mobile Satellite Communications" by Qian *et al.*, proposes a novel multiple-input multiple-output transmission scheme for dual-polarized land mobile satellite communications, called generalized polarized enhanced spatial modulation (GPESM). A theoretical upper bound for the average bit error probability is derived. Two novel power allocation algorithms are introduced for improving the system reliability. To enhance the spatial diversity gain, an RIS-assisted GPSEM system is proposed and the corresponding power allocation algorithms are proposed. Simulation results show that the RIS-assisted GPESM system can significantly improve the system performance.

The fifth article, titled "RIS Configuration, Beamformer Design, and Power Control in Single-Cell and Multi-Cell Wireless Networks" by Buzzi *et al.*, tackles the problem of signal-to-interference plus noise ratio (SINR) maximization with respect to the RIS configuration and to the BS beamformer for a single-user setting. For a multi-user multi-cell scenario, the geometric mean of the SINRs is maximized with respect to the BS transmit power vectors and the RIS configuration, assuming that some of the users are jointly served by two BSs. Numerical results show that the beneficial impact on the system performance of the presence of an RIS and of the described optimization procedures.

The sixth article, titled "Beyond Cell-Free MIMO: Energy Efficient Reconfigurable Intelligent Surface Aided Cell-Free MIMO Communications" by Zhang *et al.*, introduces a hybrid beamforming scheme that consists of digital beamforming at the BSs and RIS-based analog beamforming to maximize the energy efficiency in an RIS-aided cell-free MIMO system. The energy efficiency maximization problem is formulated and an iterative algorithm is designed to solve it. The impact of the transmit power, the number of RISs, and the RIS size on the energy efficiency are investigated. Numerical evaluations show that the proposed system can achieve a higher energy efficiency than conventional schemes.

The seventh article, titled "Energy Efficient Reconfigurable Intelligent Surface Enabled Mobile Edge Computing Networks With NOMA" by Li *et al.*, investigates an RIS-aided single-cell multi-user mobile edge computing system where the users communicate with a BS based on a non-orthogonal multiple access (NOMA) protocol. The sum energy consumption minimization problem is formulated by jointly optimizing

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the phase shifters, the size of the transmission data, the transmission rate, the power control, the transmission time, and the decoding order. Since the resulting problem is nonconvex, the block coordinate descent method is used to alternately optimize two separated subproblems, which are tackled with the dual and penalty methods. Numerical results demonstrate that the proposed scheme can increase the energy efficiency and can achieve significant performance gains over the three benchmark schemes.

The eighth article, titled "Channel Estimation Method and Phase Shift Design for Reconfigurable Intelligent Surface Assisted MIMO Networks" by Mirza *et al.*, proposes a two-stage channel estimation method for RIS-aided MIMO time-division duplexing systems, where a bilinear adaptive vector approximate message passing (BAdVAMP) algorithm is used to estimate the RIS channels accurately and robustly. A phase shift design (passive beamforming) is also proposed for the RIS by formulating an optimization problem that maximizes the total channel gain at the receiver. Numerical results show that the proposed BAdVAMP-based RIS channel estimation performs better than its counterpart bilinear generalized AMP (BiGAMP) scheme.

The ninth article, titled "Channel Estimation Approach for RIS Assisted MIMO Systems" by Shtaiwi *et al.*, investigates the channel estimation problem for RIS-aided multi-user MIMO uplink systems. An algorithm is proposed to estimate the composite channel, the separate RIS-based channels, and the direct channel for the RIS-assisted system by exploiting the properties of symmetric positive definite matrices. A simple passive pilot sequence scheduling scheme is further proposed to jointly adjust the phase shift coefficients of the RIS elements. Simulation results justify the efficiency and effectiveness of the proposed approach algorithm.

The tenth article, titled "Weighted Sum-Rate Maximization for Multi-IRS-Assisted Full-Duplex Systems With Hardware Impairments" by Saeidi *et al.*, investigates how multiple intelligent reflecting surfaces (IRSs) affect the performance of multi-user full-duplex communication systems under hardware impairments at each node, wherein the BS and the uplink users are subject to maximum transmission power constraints. The authors formulate the resource allocation design problem, to maximize the system weighted sum-rate as an optimization problem, which jointly optimizes the beamforming and the combining vectors at the BS, the transmit powers of the uplink users, and the phase shifts of multiple IRSs. An efficient iterative alternating approach is further proposed to obtain a suboptimal solution for the considered problem. Numerical results are presented to identify how multiple IRSs enhance the performance metric under hardware impairments.

The eleventh article, titled "Delay-Constrained Joint Power Control, User Detection and Passive Beamforming in Intelligent Reflecting Surface-Assisted Uplink mmWave System," authored by Cao *et al.*, proposes a novel IRS-assisted mmWave system to minimize the user power, by jointly optimizing the transmit powers of the devices, the multi-user detector at the BS, and the passive beamforming at the IRS, thereby overcoming the impact of blockages. To solve this problem, an alternating optimization framework is developed to decompose the joint optimization problem into three subproblems that are iteratively optimized till convergence. Numerical results corroborate the effectiveness of the proposed scheme in terms of power saving, as compared with a semidefinite relaxation-based alternative.

Finally, the last article, "A 3D Non-Stationary Channel Model for 6G Wireless Systems Employing Intelligent Reflecting Surfaces With Practical Phase Shifts" by Sun *et al.*, proposes a three-dimensional (3D) geometry based stochastic model for a massive MIMO communication system employing practical discrete IRSs. The proposed channel model supports the scenario where both transceivers and environments move. The evolution of clusters in the space domain and the impact of discrete phase shifts are considered in the channel model. Through statistical analysis, the non-stationary properties of the channel are investigated. The time auto-correlation function of continuous-type and discrete-type phase shifts are compared against each other.

Our Guest Editorial team is pleased with the technical depth and span of this Special Section in IEEE TCCN. We also recognize that it cannot cover all open research issues that pertain to the application of RISs in future wireless communications and networks. We sincerely thank all the authors and reviewers for their efforts, and the Editor-in-Chief and Staff Members for their gracious support. We hope that the readers will enjoy this special section.

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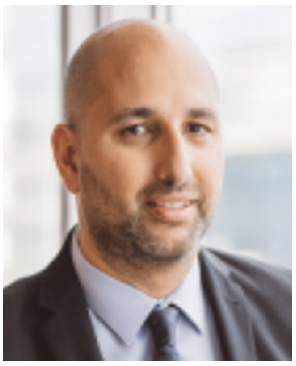

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