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SPECIAL SECTION ON ADVANCES IN SIGNAL PROCESSING FOR NON-ORTHOGONAL MULTIPLE ACCESS

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EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: ADVANCES IN SIGNAL PROCESSING FOR NON-ORTHOGONAL MULTIPLE ACCESS

Orthogonal multiple access (OMA) technologies have prevailed from the first-generation (1G) to the fourth-generation (4G) of modern mobile communications, primarily because of their low complexity. The key idea of OMA is to ensure that the communication resources allocated to different users are orthogonal in at least one radio resource dimension. As a result, the number of active users allowed to access the OMA system is strictly limited by the number of available orthogonal resources, which becomes less effective for supporting massive connectivity and achieving user fairness. In contrast to OMA, non-orthogonal multiple access (NOMA) simultaneously accommodates a multitude of users using the same radio resource block via superposition signaling and employs various transmit or receive signal processing techniques to mitigate the resulting interference. However, the success of NOMA technologies relies heavily on the implementation of advanced signal processing techniques for transceivers, which may introduce large processing delays and increase computational complexity. Thanks to recent progress in hardware and theory in signal processing and machine learning, high signal processing complexity has become more affordable and processing latency can be significantly reduced, which enables the development of NOMA. Thus, sophisticated signal processing algorithms for multi-user detection, scheduling, and interference management are indispensable for the successful implementation of NOMA in the next-generation wireless systems.

As a novel multiple access technology, NOMA is a promising candidate to achieve high spectral efficiency and massive connectivity for future wireless communications. However, there are still many signal processing problems remaining to be solved to unlock the potential of NOMA technologies for beyond 5G (B5G) networks. This Special Section in IEEE Access aims to capture the state-of-the-art advances in NOMA, particularly from the perspective of signal processing, and foster new avenues for research in this area. The Call for Papers generated considerable interest in the research community, and in total, 24 high-quality articles, including one invited article, from leading research groups worldwide were accepted after a thorough review process. These 24 accepted articles can be broadly categorized into three groups: the first group of seven articles tackles the energy efficiency of NOMA systems, the second group of 11 articles addresses resource allocation issues including user pairing, power allocation, transmission power, and spectrum allocation in NOMA systems, and the third group of six articles focuses on the performance enhancement and analysis of NOMA systems.

In the first group, the article by Huang and Zhu, ''Energy efficiency maximization design for full-duplex cooperative NOMA systems with SWIPT,'' studies a cooperative NOMA system consisting of a near NOMA user, a far NOMA user, and a full-duplex (FD) wirelessly powered relay that assists the signal transmission from the base station to the far NOMA user. Aiming at maximizing the energy efficiency of the system, the authors obtain a near-optimal power-splitting ratio and transmit beamforming vectors.

The article by Luo *et al.*, ''A deep learning-based approach to power minimization in multi-carrier NOMA with SWIPT,'' investigates the joint downlink resource allocation problem for a simultaneous wireless information and power transfer (SWIPT)-enabled multi-carrier NOMA system employing time-switching-based receivers and the pattern division multiple access (PDMA) technique. A deep learning-based approach is proposed to minimize the total transmit power of the system while satisfying the quality-of-service requirements of each user in terms of data rate and harvested power.

The article by Wu *et al.*, ''Transceiver design for downlink SWIPT NOMA systems with cooperative full-duplex relaying,'' studies a downlink NOMA system, where a near user acts as an FD energy-harvesting relay to help transmission from the source node to the far user. The power allocation factor, power-splitting ratio, receiver filter, and transmit beamforming are jointly optimized to maximize the data rate of the near user while satisfying the quality-of-service (QoS) requirement of the far user and the energy causality condition of the near user.

The article by Zhou *et al.*, ''Green base station assignment for NOMA-enabled HCNs,'' focuses on the design of green base station assignment integrating with power allocation for heterogeneous cellular networks with NOMA to maximize the overall energy efficiency under users' signal-to-interference-plus-noise ratio constraints.

The article by Du *et al.*, ''Secure transmission for downlink NOMA visible light communication networks,'' considers the physical-layer security of NOMA visible light communication (VLC) networks. A closed-form achievable security rate is first derived, based on which the optimal secure beamforming design is then studied for minimizing the total LED power and for maximizing the minimum secrecy rate, respectively.

The article by Hu *et al.*, ''Application of non-orthogonal multiple access in wireless sensor networks for smart agriculture,'' studies an uplink transmission scheme for wireless sensor networks (WSNs) in agriculture with the aid of several relay nodes around the sink node to collect farm data for smart agriculture. It is shown that WSNs with relay-aided NOMA outperform those using the traditional OMA scheme and can achieve higher energy efficiency and sum data rate.

The article by Nguyen and Shin, ''An efficient design for NOMA-assisted MISO-SWIPT systems with AC computing,'' considers a NOMA-assisted multiple-input single-output SWIPT system, where a power-splitting protocol is employed for users near the base station and an AC computing logic is incorporated into energy harvesting receivers to directly use the wirelessly harvested AC power. The beamformers and power-splitting ratios are jointly optimized to maximize the spectral efficiency subject to the constraints of QoS for the individual user, energy harvesting requirements, and the base station's maximum transmit power.

In the second group, the article by Liang *et al.*, ''Joint user-channel assignment and power allocation for non-orthogonal multiple access relaying networks,'' focuses on a NOMA-based decode-and-forward (DF) relaying downlink network and solves the joint user-channel assignment and power allocation problem by adopting a decoupled optimization method and a joint alternating optimization algorithm.

The article by Liang *et al.*, ''Distributed sequential coalition formation algorithm for spectrum allocation in underlay cognitive radio networks,'' leverages the so-called distributed sequential coalition formation algorithm to solve the user grouping problem in an underlay cognitive radio network employing NOMA, where multiple cognitive users within a group can access the primary user's spectrum band while satisfying a minimum rate requirement of the primary user.

The article by Duan *et al.*, ''Effective resource utilization schemes for decode-and-forward relay networks with NOMA,'' proposes an effective resource utilization scheme for the DF cooperative relaying network with NOMA. Unlike conventional systems, to improve the system performance and resource utilization, the unselected relays will continue receiving signals transmitted by the base station, while the selected relays forward the decoded signals to the user equipment.

The article by Liu *et al.*, ''Joint power allocation and user scheduling for device-to-device-enabled heterogeneous networks with non-orthogonal multiple access,'' proposes a framework for device-to-device (D2D)-enabled heterogeneous networks with NOMA, where small cells underlay the uplink spectrum of macrocells, NOMA is invoked to serve downlink users, and D2D-enabled multi-hop transmission is established to enhance signal reception of the far users on the cell edge. Joint power allocation and user scheduling are investigated to maximize the ergodic sum rate of the near users in the small cells while guaranteeing the QoS requirements of the far users and the macro-cell users.

The article by Xu *et al.*, ''Resource allocation in heterogeneous cognitive radio network with non-orthogonal multiple access,'' studies resource allocation problems for a two-tier cognitive heterogeneous network in interweave spectrum sharing mode, where NOMA is used to boost the number of accessible secondary users in small cells that opportunistically access the licensed spectrum resources. The aim is to maximize the sum throughput of a second-tier small cell network.

The article by Xiao *et al.*, ''Power control for clustering car-following V2X communication system with non-orthogonal multiple access,'' proposes a vehicle clustering method for dynamically classifying vehicles and adjusting cluster size in real time based on a car-following model in vehicle-to-everything (V2X) communications. A power control approach for NOMA is also proposed to balance the power allocation among the cluster-head vehicles.

The article by Wang *et al.*, ''Interference hypergraph-based 3D matching resource allocation protocol for NOMA-V2X networks,'' studies a D2D-enhanced NOMA-V2X system, where, except for the NOMA-based intra-group resource reuse, the D2D-enabled resource sharing based on spatial reuse among all the V2X communication groups is also permitted through centralized resource management. To manage the interference and allocate the resource, the authors propose a weighted tripartite interference hypergraph (IHG) to imitate the complex interference environment. They also propose an IHG-based 3-D matching resource allocation protocol with a greedy 3DM algorithm and an iterative 3DM algorithm.

The article by Lin *et al.*, ''Secure computation efficiency maximization in NOMA-Enabled mobile edge computing networks,'' studies a secure computation efficiency maximization problem in a multi-user NOMA-enabled mobile edge computing network, where physical layer security is used to prevent multi-user computing tasks from eavesdropping. The problem is formulated by optimizing the transmission power and central processing unit frequency jointly, and solved by low-complexity sequential fractional programming.

The article by Chen *et al.*, ''Optimal resource block assignment and power allocation for D2D-enabled NOMA communication,'' proposes a joint optimization framework for D2D-enabled NOMA networks. Considering the successive interference cancellation (SIC) decoding order of the NOMA-based cellular user equipment, the performance of the D2D communication is maximized by jointly optimizing resource block assignment and power allocation.

The article by Masaracchia *et al*., "A PSO-based approach for user-pairing schemes in NOMA systems: Theory and applications," analyzes a particle swarm optimization-based configuration applied in NOMA systems, which enables the transmitter to require the minimum downlink transmitting power while guaranteeing the QoS constraint of each user. The analysis is carried out for disaster relief network communications and unmanned aerial vehicle communications.

In the third group, the article by Xia *et al*., "Optimal minimum Euclidean distance-based precoder for NOMA with finite-alphabet inputs," proposes a practical power allocation scheme for a downlink NOMA scenario. It is proved that optimal constellation-constrained capacity can be achieved under the criterion of maximizing the minimum Euclidean distance at high signal-to-noise ratio.

The article by Shah *et al*., "System capacity analysis for ultra-dense multi-tier future cellular networks," utilizes stochastic geometry for modeling and analyzing interference in ultra-dense multi-tier cellular networks. Different factors affecting the system capacity including network densification, cell load, and multi-tier interference are studied, and the role of ergodic channel capacity is discussed as well.

The article by Stoica *et al*., "Massively concurrent non-orthogonal multiple access for 5G networks and beyond," proposes a new signal-spreading-based NOMA scheme, which exploits frame-theoretic design principles to enable the efficient concurrence of multiple users in both downlink and uplink, and does not require built-in sparsity on the usage of resources by any individual users unlike other NOMA schemes. The proposed scheme can theoretically reach the capacity of the multi-user multi-input-multi-output channel and outmatches the state of the art in terms of maximum achievable rate over discrete constellations.

The article by Yang *et al*., "Design and performance analysis of cooperative NOMA with coordinated direct and relay transmission," studies the coordinated direct and relay transmission in the NOMA network, which consists of a base station, a cell-center user, a cell-edge user, and a group of half-duplex relays. A dynamic detection strategy is designed, based on which a relay selection scheme that maximizes the cell-center user's successful decoding probability while guaranteeing the reliable reception of the cell-edge user is proposed.

The article by Wang and Peng, "Secrecy performance analysis of relay selection in cooperative noma systems," investigates the security performance of two relay selection schemes for cooperative NOMA systems, where multiple randomly distributed relays are employed with either DF or amplify-and-forward (AF) protocols, and both two-stage relay selection and optimal relay selection schemes are considered. It is verified that the secrecy diversity orders for cooperative NOMA systems are determined by the number of the relays.

The article by Nomikos *et al*., "Flex-NOMA: Exploiting buffer-aided relay selection for massive connectivity in the 5G uplink," employs buffer-aided relay selection in the uplink of NOMA networks, which facilitates simultaneous transmissions from multiple sources to multiple relays, exploiting channel state information at the receiver, and dynamic decoding ordering by the relays that perform SIC.

Finally, the invited article, "User grouping for hybrid VLC/RF networks with NOMA: A coalitional game approach," by Papanikolaou *et al*., which should belong to the second group, studies a hybrid heterogeneous VLC/radio frequency (RF) network with NOMA. The authors use coalitional game theory for the optimal user grouping in NOMA, where the users served by the same access point form a single coalition, while the users can switch through coalitions based on their payoff. A coalition formation algorithm, as well as an efficient power allocation policy, is presented, and the effectiveness of the proposed user grouping scheme is revealed by computer simulations.

In conclusion, the Guest Editors of this Special Section would like to thank all the authors for their contributions, and the anonymous reviewers for their constructive comments and suggestions. We also would like to acknowledge the guidance from the Editor-in-Chief and staff members.

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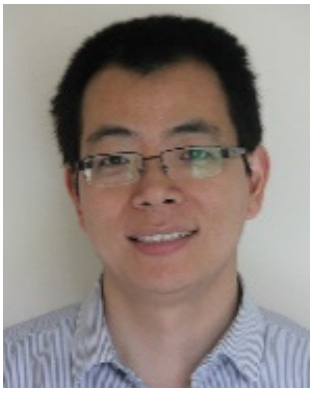

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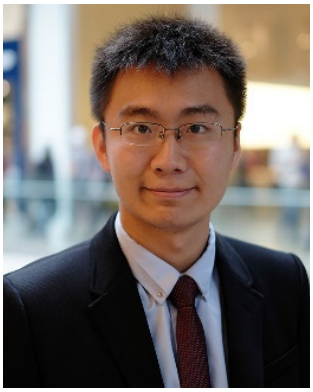

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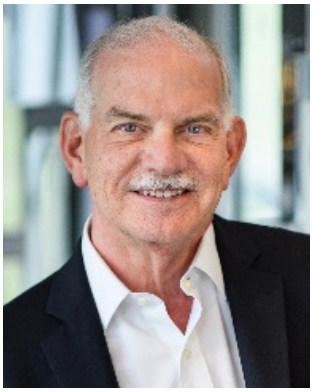

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