Guest Editorial
Massive Access for 5G and Beyond—Part I

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MASSIVE access, also known as massive connectivity or massive machine-type communication (mMTC), is one of the main use cases of the fifth-generation (5G) and beyond 5G (B5G) wireless networks. In the past few years, it has received considerable attention in academia and industry. This Special Issue (SI) of the IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS (JSAC) on Massive Access for 5G and Beyond contains the latest results of researchers, industry practitioners, and individuals working on related research problems. Due to the extremely high response to the Call for Papers, this SI is split into two parts. The first part includes a guest editor-authored survey paper and 17 technical papers focusing on access models and access protocols, while the second part contains 18 papers focusing on access techniques and coverage enhancement approaches. We sincerely thank the authors, reviewers, JSAC staffs, and the Senior Editor, Prof. Wayne Stark, for their effort and time in preparing this SI.

The first part starts with the survey paper "Massive access for 5G and beyond," by the Guest Editors, which provides a detailed overview of massive access from the perspectives of theory, protocols, techniques, coverage, energy, and security. The paper first introduces the typical application scenario of massive access for 5G and beyond, namely, cellular Internet-of-Things (IoT), and then reviews the results on the capacity of massive access channels. Subsequently, massive access protocols, massive access techniques, and massive coverage enhancement are discussed. Moreover, energy supply for massive access and massive access security are considered.

Next, 17 technical papers are presented. A particular emphasis is put on papers dedicated to access models and access protocols for massive access for 5G and beyond in this first part.

The paper "Spatio-temporal modeling for massive and sporadic access," by Zhong *et al.*, proposes a spatio-temporal model for massive and sporadic access to quantitatively describe the massive access of IoT devices. Based on the proposed model, it is found that the temporal correlation of interference is negligible, which simplifies the spatio-temporal analysis. The proposed model is promising to evaluate and design IoT networks with massive and sporadic access.

The paper "Statistical delay/error-rate bounded QoS provisioning over cell-free massive MIMO based 5G+ multimedia mobile networks in the finite blocklength regime," by Zhang *et al.*, develops analytical modeling schemes to precisely characterize the delay-bounded quality-of-services (QoS) performance of cell-free massive multiple-input multiple-output (MIMO)-based 5G+ multimedia mobile networks in the finite blocklength regime and derives closed-form expressions for the delay violation probability function. Using the developed modeling schemes, a closed-form solution for the optimal rate adaptation policy for each mobile user is obtained, which plays an important role in system design and performance analysis.

The paper "A decoupled learning strategy for massive access optimization in cellular IoT networks," by Jiang *et al.*, studies the Random Access CHannel (RACH) of massive IoT systems. In order to decrease access latency and energy consumption while guaranteeing a desired access success probability, deep reinforcement algorithms are proposed to optimize the RACH in real time by maximizing a long-term hybrid multiobjective function, which consists of the number of access success devices, the average energy consumption, and the average access delay.

The paper "A collision resolution protocol for random access in massive MIMO," by Bai *et al.*, investigates a grant-free random access protocol in massive MIMO systems with a large number of machines. A preamble collision resolution scheme is designed by applying successive interference cancellation techniques to the mixed preamble signals.

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Moreover, the access success probability of the proposed collision resolution scheme is analyzed.

The paper "Online control of preamble groups with priority in massive IoT networks," by Liu *et al.*, proposes to prioritize the random access procedure (RAP) to resolve congestions for massive activation of IoT devices. In particular, the number of active devices in each priority is recursively estimated based on a Bayesian rule, and then the preambles are accordingly allocated to each priority. Moreover, access class baring and access delay requirements are taken into account to enhance the performance of the proposed control algorithm.

The paper "Stabilizing frame slotted ALOHA based IoT systems: A geometric ergodicity perspective," by Yu *et al.*, focuses on the stability of frame slotted ALOHA in massive IoT systems. An additive active node population estimation scheme is first designed, and then the estimate is used to set the frame size and participation probability for throughput optimization. Theoretical analysis and simulation results confirm the stability of frame slotted ALOHA-based access in the sense of geometric ergodicity of Markov chains.

The paper, "Orthogonal AMP for massive access in channels with spatial and temporal correlations," by Cheng *et al.*, proposes a multiple measurement vector form of the orthogonal approximate message passing algorithm (OAMP-MMV) to address the joint device activity detection and channel estimation problem in a massive MIMO connectivity scenario where a small portion of the devices are active at any given time. A group Gram–Schmitt orthogonalization (GGSO) procedure is provided for the realization of OAMP-MMW.

The paper "Analyzing grant-free access for URLLC service," by Liu *et al.*, presents a spatio-temporal analytical framework for the contention-based grant-free access analysis in ultra-reliable low-latency communication (URLLC). Based on the framework, a tractable approach to derive and analyze the latent access failure probability of three typical grant-free hybrid automatic repeat request (HARQ) schemes is proposed.

The paper "Massive access in cell-free massive MIMO based Internet of Things: Cloud computing and edge computing paradigms," by Ke *et al.*, studies massive access in cell-free massive MIMO-based IoT and solves the challenging active user detection and channel estimation problem. Two processing paradigms, including cloud computing and edge computing, are considered to design cooperatively structured sparsity-based generalized approximated message-passing algorithms for reliable joint active user detection and channel estimation.

The paper "MIMO-based reliable grant-free massive access with QoS differentiation for 5G and beyond," by Abebe *et al.*, proposes a novel grant-free access scheme in which high QoS users superpose multiple preambles and transmit them to achieve collision and multiple access interference diversity and ultimately improve the access success rate. A low-complexity MIMO-based receiver is employed to correctly detect active preambles with an overwhelmingly high probability even under severe multiple access interference caused by nonorthogonal preamble transmission.

The paper "Jointly sparse signal recovery and support recovery via deep learning with applications in MIMO-based grant-free random access," by Cui *et al.*, investigates jointly sparse signal recovery and sparse support recovery in multiple measurement vector models of mMTC for IoT. Two model-driven approaches based on the standard autoencoder structure for real numbers are proposed to design common measurement matrices and to adjust model-driven decoders. Simulation results show that the proposed approaches have shorter computation time than the underlying advanced recovery methods.

The paper "Coexistence of human-type and machine-type communications in uplink massive MIMO," by Kuai *et al.*, studies the receiver design for uplink transmission in a massive MIMO system with coexisting human-type communications (HTC) and MTC. A probability model to characterize the crucial system features including channel sparsity of massive MIMO and signal sparsity of MTC packets is first established. Based on the probability model, two receiver schemes based on time-slotted and nontime-slotted grant-free random access are proposed to conduct joint device activity identification, channel estimation, and signal detection.

The paper "Massive unsourced random access based on uncoupled compressive sensing: Another blessing of massive MIMO," by Shyianov *et al.*, puts forward a new algorithmic solution to the massive unsourced random access (URA) problem by leveraging the rich spatial dimensionality offered by large-scale antenna arrays. The proposed scheme relies on a slotted transmission framework but eliminates the need for concatenated coding that was introduced in the context of the coupled compressive sensing paradigm.

The paper, "Remote state estimation with asynchronous mission-critical IoT sensors," by Tang *et al.*, considers a mission-critical remote state estimation system with asynchronous massive access of the IoT sensors. Exploiting the sparsity in the observation matrix induced by asynchronous massive access, a low-complexity 2-D message passing state estimation algorithm is proposed, where the cyclic loops in the 2-D factor graphs are removed based on the Gaussian-elimination-based quasi-diagonalization of the oversampled aggregated channel matrix of the IoT sensor.

The paper, "Joint access control and resource allocation for short-packet-based mMTC in status update systems," by Yu *et al.*, investigates the performance of mMTC in status update systems, where a massive number of devices send status packets to the BS for system monitoring. A closed-form expression of the average age of information for all devices is first derived, and then a joint access control, frame division, subchannel allocation scheme is proposed to improve the overall status update performance.

The paper "Spectrum sharing for massive access in ultra-narrowband IoT systems," by Hattab *et al.*, studies the coexistence capability of ultra-narrowband (UNB) networks and their scalability to enable massive access. A stochastic geometry framework is developed to analyze and model UNB networks on a large scale, and then closed-form expressions for the transmission success probability and network connection density are presented for several UNB protocols. Furthermore, a low-complexity multiband access protocol is proposed for UNB networks.

The paper, "Multi-operator spectrum sharing for massive IoT coexisting in 5G/B5G wireless networks," by Qian *et al.*, investigates the multioperator dynamic spectrum access problem to support the coexistence of rate-guaranteed cellular users and massive IoT devices. A wireless spectrum provider is introduced to facilitate spectrum trading with mobile network operators through the Stackelberg pricing game. Moreover, an iterative algorithm for the Stackelberg pricing game is provided, which can achieve the unique Stackelberg equilibrium solution.

The survey paper and the 17 technical papers in this first part of the two-part SI provide an overview of the state-of-the-art as well as new results in the broad area of massive access for 5G and beyond, with a particular emphasis on access models and access protocols. The 18 technical papers in the second part focus on access techniques and coverage enhancement approaches.

Xiaoming Chen (Senior Member, IEEE) received the B.Sc. degree from Hohai University in 2005, the M.Sc. degree from the Nanjing University of Science and Technology in 2007, and the Ph.D. degree from Zhejiang University, Hangzhou, China, in 2011, all in electronics engineering.

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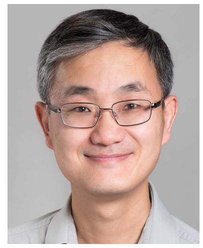
Dr. Ng received the Australian Research Council (ARC) Discovery Early Career Researcher Award 2017, the Best Paper awards at the IEEE TCGCC Best Journal Paper Award 2018, INISCOM 2018, the IEEE International Conference on Communications (ICC) 2018, the IEEE International Conference on Computing, Networking, and Communications (ICNC) 2016, the IEEE Wireless Communications and Networking Conference (WCNC) 2012, the IEEE Global Telecommunication Conference (GLOBECOM) 2011, and the IEEE Third International Conference on Communications and Networking in China 2008. He has been serving as an Editorial Assistant to the Editor-in-Chief of the IEEE TRANSACTIONS ON COMMUNICATIONS from January 2012 to December 2019. He is also serving as an Editor for the IEEE TRANSACTIONS ON COMMUNICATIONS and the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, and an Area Editor for the *IEEE Open Journal of the Communications Society*. Also, he was listed as a Highly Cited Researcher by Clarivate Analytics in 2018 and 2019.



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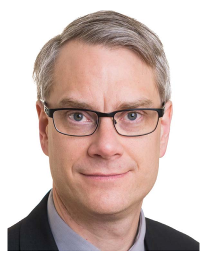

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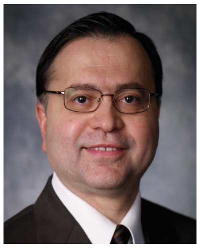

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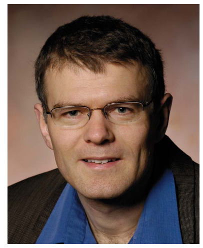

Robert Schober received the Diplom (Univ.) and the Ph.D. degrees in electrical engineering from the Friedrich-Alexander-University Erlangen-Nuremberg (FAU), Germany, in 1997 and 2000, respectively.

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