Guest Editorial Special Issue on Next Generation Multiple Access—Part II

Yuanwei Liu, *Senior Member, IEEE*, Shuowen Zhang, *Member, IEEE*, Zhiguo Ding, *Fellow, IEEE*, Robert Schober, *Fellow, IEEE*, Naofal Al-Dhahir, *Fellow, IEEE*, Ekram Hossain, *Fellow, IEEE*, and Xuemin Shen, *Fellow, IEEE*

I. Introduction

As the long-term evolution (LTE) system is reaching maturity and the fifth-generation (5G) systems are being commercially deployed, researchers have turned their attention to the development of next-generation wireless networks. Compared to current wireless networks, on the one hand, next-generation wireless networks are expected to achieve significantly higher capacity, extremely low latency, ultra-high reliability, as well as massive and ubiquitous connectivity for supporting diverse disruptive applications (e.g., virtual reality (VR), augmented reality (AR), and industry 4.0). On the other hand, the evolution toward next-generation wireless networks requires a paradigm shift from the communication-oriented design to a multi-functional design, including communication, sensing, imaging, computing, and localization. Looking back at the history of wireless communication systems, multiple access (MA) techniques have been key enablers. From the first generation (1G) to the fifth generation (5G), orthogonal multiple access (OMA) schemes are mainly employed, where multiple users are allotted in orthogonal frequency/time/code resources, and the uplink transmission of the code code-division multiple-access (CDMA) uses non-orthogonal code resources. However, given the enormous challenges and diverse services of next-generation wireless networks, which significantly differ from that in current and previous wireless networks, existing MA schemes may not be applicable. As a result, a fundamental issue is the design of next-generation multiple access (NGMA) techniques. The key concept of NGMA is to enable a very large number of users/devices to be efficiently, flexibly, and intelligently connected with the network over the given wireless radio resources to not only satisfy stringent communication requirements but also realize heterogeneous functions. The investigation of NGMA is still in the infancy stage, and extensive research efforts have to be devoted to areas, including but not limited to 1) the development of new MA schemes, such as non-orthogonal multiple access (NOMA) and space division multiple access (SDMA), which are capable of achieving higher bandwidth efficiency and higher connectivity compared with conventional MA schemes; 2) the development of innovative techniques, such as reconfigurable metasurfaces, random access, advanced modulation, and channel coding, which are beneficial to the overall design of NGMA; and 3) the exploitation of advanced machine learning (ML) tools and big data techniques for providing effective solutions to address newly emerging NGMA problems.

Yuanwei Liu is with the School of Electronic Engineering and Computer Science, Queen Mary University of London, London E1 4NS, U.K. (e-mail: yuanwei.liu@qmul.ac.uk).

Shuowen Zhang is with the Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, Hong Kong, SAR, China (e-mail: shuowen.zhang@polyu.edu.hk).

Zhiguo Ding is with the School of Electrical and Electronic Engineering, The University of Manchester, Manchester M13 9PL, U.K. (e-mail: zhiguo.ding@manchester.ac.uk).

Robert Schober is with the Institute for Digital Communications, Friedrich-Alexander-University Erlangen-Nürnberg (FAU), 91054 Erlangen, Germany (e-mail: robert.schober@fau.de).

Naofal Al-Dhahir is with the Department of Electrical and Computer Engineering, The University of Texas at Dallas, Richardson, TX 75080 USA (e-mail: aldhahir@utdallas.edu).

Ekram Hossain is with the Department of Electrical and Computer Engineering, University of Manitoba, Winnipeg, MB R2M 2J8, Canada (e-mail: ekram.hossain@umanitoba.ca).

Xuemin Shen is with the Department of Electrical and Computer Engineering, University of Waterloo, Waterloo, ON N2L3G1, Canada (e-mail: sshen@uwaterloo.ca).

Digital Object Identifier 10.1109/JSAC.2021.3139737

This Special Issue (SI) aims to pave the way for the development of novel NGMA schemes for future wireless networks. We were very encouraged by the fact that this SI received a strong response from the research community and attracted 105 submissions. Most of them were of high quality, which allowed us to select an excellent set of papers. However, given the tight publication schedule and the limited space unfortunately, we had to reject many high-quality papers. After a rigorous review process, 41 papers were accepted for publication in a double-issue. In addition, a survey paper authored by the Guest Editors was reviewed and accepted by the team of Senior Editors of IEEE Journal on Selected Areas in Communications. The first part of this double issue contains the survey paper and 20 technical papers, and the second part includes the remaining 21 technical papers. These papers cover a wide range of topics in the area of NGMA.

The 20 papers included in this issue are in the areas of 1) information-theoretic aspects of NGMA, 2) massive multiple access, 3) machine learning for NGMA, and 4) NGMA meets others. A brief account of each of these papers is given below.

II. Information-Theoretic Studies on NGMA

In [A1], Jiang and Yu explore the interference nulling capability of reconfigurable intelligent surface (RIS) in a K-user interference channel. When the channels between the RIS and the transceivers have line-of-sight and the direct channels are blocked, it is theoretically proved that the RIS phase shifts can be adjusted to completely null out the interference and achieve the maximum K degrees-of-freedom, when the number of RIS elements is larger than a finite value that only depends on K. On the other hand, for arbitrary channel realization, an alternating projection algorithm with local convergence guarantee is developed for nulling the interference, which is numerically shown to achieve interference nulling if the number of RIS elements is slightly larger than $2K(K-1)$. Moreover, low-complexity algorithms are proposed for the sum-rate maximization problem and the minimum rate maximization problem.

In [A2], Xu *et al.* study the secrecy achievable rate region of multiple-access wiretap (MAC-WT) channels, where users transmit both confidential messages and open messages to the legitimate user. First, an achievable rate region for the discrete memoryless (DM) MAC-WT channel is characterized based on random coding, which is then extended to the Gaussian vector (GV) MAC-WT channel. Based on these results, a sum secrecy rate maximization problem is studied, for which an iterative algorithm is proposed to find a suboptimal solution. Simulation results show that the proposed algorithm is able to achieve significantly enhanced performance compared to existing schemes while simultaneously increasing the spectral efficiency due to the transmission of open messages.

III. Massive Multiple Access

In [A3], Wang *et al.* investigate the activity detection and channel estimation in a cell-free Internet-of-Things (IoT) network with massive random access. A two-stage approach is proposed, where the activity of each device is jointly detected by its adjacent access points (APs) based on vector approximate message passing (AMP) in the first stage, while each AP re-estimates the channels using the linear minimum mean square error (LMMSE) method in the second stage. Closed-form expressions for the activity detection error probability and mean-squared channel estimation error for a typical device are derived, followed by a coverage probability analysis of the entire network. Simulation results validate the analytical results and effectiveness of the proposed approach.

In [A4], Fang *et al.* aim to reduce the energy consumption and age-of-information (AoI) in an energy harvesting aided massive multiple access network. Two sleep-scheduling policies based on multiple vacation or start-up threshold are considered, for which the peak AoI is derived in closed form. Moreover, an average peak AoI minimization problem is studied under the energy harvesting power constraint as well as the status update rate and stability conditions. The optimal solution is found via an exact linear search-based algorithm. Simulation results show that the proposed scheme achieves a lower peak AoI with low power consumption.

In [A5], Huang *et al.* aim to jointly detect the user activity and the desired data in a noncoherent massive random access system. First, a generalized approximate message passing (GAMP)-based algorithm is proposed, by exploiting the exact distribution information of the received signal. Then, a model-driven deep learning method is devised by utilizing deep neural networks (DNNs). Simulation results show that the GAMP-based algorithm is preferable for perfectly known channel distribution, while the deep learning method achieves better performance for imperfect channel distribution information.

In [A6], Li *et al.* aim to minimize the average queuing delay in a massive access system by applying cross-layer scheduling with joint channel and buffer awareness. An optimal cocktail filling policy and a suboptimal good-channel-first-serve (GCFS) policy are proposed, for which the performance in terms of the average delay and the queue-length-violation probability is evaluated by leveraging a mean-field approximation method. Moreover, it is shown that a complex massive user system can be decomposed into multiple single-user systems, for which the queue length distribution can be analyzed via a Markov chain model. Numerical results validate the accuracy of the mean-field approximation.

In [A7], Qiao *et al.* considered a massive IoT access system where an unmanned aerial vehicle (UAV) serves as an aerial base station (BS). A grant-free non-coherent index-modulation (NC-IM) scheme is studied, where information is modulated in the index of the transmitted signature sequence of the active devices. For the case where the UAV is equipped with a small-scale antenna array, a joint activity and blind information detection (JABID) algorithm is proposed, which is computationally efficient and achieves improved detection performance; while for the case where the UAV is equipped with a large-scale antenna array, an angular-domain based JABID algorithm is proposed. The proposed algorithms are numerically shown to outperform known state-of-the-art algorithms.

In [A8], Liu and Wang investigate the unsourced multiple access (UMA) scheme in multiple-input multiple-output (MIMO) channels. A transmission scheme based on the sparse Tanner graph is proposed, together with three iterative receiver algorithms each detecting and decoding a different number of codewords in each iteration. An asymptotic upper bound on the maximum achievable rate is derived via density evolution analysis for the Tanner graphs. Simulation results show that the proposed schemes outperform the existing compressed sensing-based UMA schemes, yet with lower receiver complexity.

In [A9], Fengler *et al.* study the unsourced random access problem over a Rayleigh block-fading additive white Gaussian noise (AWGN) channel with multiple receive antennas. An approach to split the user messages into two parts is proposed, one coded with a "pilot" codebook and the other encoded by a standard block code. The receiver applies the multiple measurement vector approximate message passing (MMV-AMP) algorithm for channel estimation from the "pilot" part, and then decodes the second part based on the estimated channels. The performance of the proposed scheme is analyzed, and the impact of power control is investigated.

In [A10], Li *et al.* studied joint device activity detection, channel estimation, and data decoding design in a MIMO massive unsourced random access (URA) system. The data is split into two parts: one coded by compressed sensing and the rest by a low-density-parity check (LDPC) code. A low-complexity iterative message-passing algorithm is proposed for decoding the data in the compressed sensing phase and the LDPC phase separately. Moreover, a collision resolution protocol is developed to handle the codeword collision. It is shown that the proposed algorithm exhibits substantial performance improvement over the state-of-the-art algorithms.

IV. Machine Learning for NGMA

In [A11], Yue *et al.* developed a federated meta-learning (FML) algorithm with a non-uniform device selection scheme (called NUFM) to accelerate the convergence of conventional FML algorithms in edge learning. Specifically, NUFM maximizes the theoretical lower bound of global loss reduction in each round. Then, a device selection and resource allocation strategy is proposed to optimize the tradeoff between energy consumption and wall-clock training time. Simulation results show that the proposed algorithms outperform the baseline algorithms.

In [A12], Cao *et al.* study an over-the-air federated averaging (Air-FedAvg) system with multiple edge devices and one edge server. First, the optimality gap of the loss function over different outer iterations is analyzed to characterize the impact of the over-the-air computing error on the Air-FedAvg performance. Then, the transmission power control is optimized to minimize the optimality gap. Moreover, the training latency minimization problem is studied via joint power control and hyper-parameter optimization. Numerical results validate the learning performance gain in Air-FedAvg achieved by power control optimization.

In [A13], Guo *et al.* propose an efficient medium access control (MAC) protocol for NGMA. Specifically, a QMIX-advanced listen-before-talk (QLBT) protocol is proposed based on the multi-agent reinforcement learning (MARL) algorithm, which employs centralized training with decentralized execution to improve network throughput, delay, and jitter. Simulation results show that QLBT outperforms several competing protocols in Poisson and VoIP traffic.

V. NGMA Meets Others

In [A14], Fu *et al.* study the average latency minimization problem in a cache-assisted NOMA network, where the content cache placement, personalized recommendation, NOMA user pairing, and power control strategies are jointly optimized. A divide-and-rule method is proposed to deal with this problem, where the user pairing and power allocation are optimized in the short term, while recommendation and caching are optimized in the long term. Monte-Carlo simulations show the superiority of the proposed algorithm in terms of latency and cache hit ratio compared to various benchmark schemes.

In [A15], Xiao *et al.* propose a novel transcoding-enabled VR video caching and delivery framework for edge-enhanced next-generation wireless networks. To alleviate the viewer motion sickness and improve the quality-of-experience (QoE), an edge cooperative caching strategy and a two-tier BS-multicast group matching algorithm are proposed. It is shown via experiments that the proposed solution achieves improved cache hit rate and latency compared to other state-of-the-art alternative solutions.

In [A16], Shahsavari *et al.* considered single-cell in-band full-duplex (FD) communications. Opportunistic user scheduling and mode selection for system utility (e.g., sum-rate) maximization are studied under short-term and long-term temporal fairness constraints for both single-carrier and multi-carrier systems. Optimal temporal fair schedulers called threshold-based strategies and practical low-complexity online algorithms are proposed, whose effectiveness is validated via simulation results.

In [A17], Huang *et al.* investigated the task management among a large number of workers with scattered computing power. Specifically, it proposes a two-stage multi-task allocation method based on discrete paper swarm optimization (TMA-DPSO), which increases the workers' income and potentially improves security and fault tolerance compared to previous methods. Extensive experiments are conducted based on synthetic and real-life data sets, where the results show that TMA-DPSO can achieve higher search efficiency and stable optimization performance.

In [A18], Hashida *et al.* considered an intelligent reflecting surface (IRS)-aided multibeam transmission scenario with user mobility and proposes a user-IRS association strategy aiming to optimize the long-term performance in terms of capacity and reliability. The proposed strategy reduces the channel estimation overhead by exploiting the beam tracking technique. Simulation results show that the proposed adaptive association strategy achieves improved performance compared to a static association strategy.

In [A19], Wang *et al.* provided a practical solution to multi-frequency access for magnetic induction (MI)-based transmissions. Specifically, a multi-frequency resonating compensation (MuReC) coil-based multi-band MIMO simultaneous wireless information and power transfer (SWIPT) system is developed, which can generate multiple resonant frequencies with only one coil. Based on this, the magnetic beamforming problem for transmit power minimization is studied. Numerical results demonstrate the effectiveness of the proposed scheme in supporting multi-frequency access.

In [A20], Li *et al.* propose a novel frequency-domain multiple access scheme, termed as rainbow-link, which serves a large number of narrowband users by exploiting wideband spectrum at the millimeter-wave band. Specifically, the frequency resources are mapped to specific spatial directions such that the users can be assigned with a subset of orthogonal frequency division multiple access (OFDMA) subcarriers and enjoy the beamforming gain of the entire array. Rainbow-link supports grant-free random access without the need of explicit beam-training, which is thus a promising candidate for latency-critical applications in future massive connectivity systems. Simulation results validate the analytical findings and demonstrate the great potential of the rainbow-link technique.

In [A21], Xing *et al.* investigate visible light communication (VLC) broadcast systems, where the rate-splitting multiple access (RSMA) technique is employed to compensate for the limited modulation bandwidth of the light-emitting diodes (LEDs). The precoding and power allocation optimization problem for energy efficiency maximization is studied for both single-cell and multi-cell networks, under the dynamic operation range constraints of LEDs, quality-of-service (QoS) constraints, and interference elimination constraints. To handle the considered non-convex problems, successive convex approximation (SCA) based algorithms are developed. Extensive simulation results show that the proposed schemes outperform various benchmark schemes in terms of energy efficiency.

ACKNOWLEDGMENT

The Guest Editors would like to express their deepest appreciation for the invaluable support and guidance from Prof. Raouf Boutaba, Prof. Larry Milstein, and Janine Bruttin. In addition, the Guest Editors would like to express their gratitude to all the authors and reviewers for their contributions in ensuring the high quality and relevance of this Special Issue.

APPENDIX: RELATED ARTICLES

[A1] T. Jiang and W. Yu, "Interference nulling using reconfigurable intelligent surface," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1392–1406, May 2022.

[A2] H. Xu, T. Yang, K.-K. Wong, and G. Caire, "Achievable regions and precoder designs for the multiple access wiretap channels with confidential and open messages," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1407–1427, May 2022.

[A3] X. Wang, A. Ashikhmin, Z. Dong, and C. Zhai, "Two-stage channel estimation approach for cell-free IoT with massive random access," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1428–1440, May 2022.

[A4] Z. Fang, J. Wang, Y. Ren, Z. Han, H. V. Poor, and L. Hanzo, "Age of information in energy harvesting aided massive multiple access networks," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1441–1456, May 2022.

[A5] J. Huang, H. Zhang, C. Huang, L. Yang, and W. Zhang, "Noncoherent massive random access for inhomogeneous networks: From message passing to deep learning," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1457–1472, May 2022.

[A6] C. Li, W. Chen, and K. B. Letaief, "Achieving low latency in massive access: A mean-field approach," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1473–1488, May 2022.

[A7] L. Qiao *et al.*, "Joint activity and blind information detection for UAV-assisted massive IoT access," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1489–1508, May 2022.

[A8] J. Liu and X. Wang, "Unsourced multiple access based on sparse tanner graph-efficient decoding, analysis, and optimization," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1509–1521, May 2022.

[A9] A. Fengler, O. Musa, P. Jung, and G. Caire, "Pilot-based unsourced random access with a massive MIMO receiver, interference cancellation, and power control," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1522–1534, May 2022.

[A10] T. Li *et al.*, "Joint device detection, channel estimation, and data decoding with collision resolution for MIMO massive unsourced random access," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1535–1555, May 2022.

[A11] S. Yue, J. Ren, J. Xin, D. Zhang, Y. Zhang, and W. Zhuang, "Efficient federated meta-learning over multi-access wireless networks," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1556–1570, May 2022.

[A12] X. Cao, G. Zhu, J. Xu, and S. Cui, "Transmission power control for over-the-air federated averaging at network edge," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1571–1586, May 2022.

[A13] Z. Guo, Z. Chen, P. Liu, J. Luo, and X. Yang, "Multi-agent reinforcement learning based distributed channel access for next generation wireless networks," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1587–1599, May 2022.

[A14] Y. Fu, Y. Zhang, Q. Zhu, M. Chen, and T. Q. S. Quek, "Joint content caching, recommendation, and transmission optimization for next generation multiple access network," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1600–1614, May 2022.

[A15] H. Xiao *et al.*, "A transcoding-enabled 360° VR video caching and delivery framework for edge-enhanced next-generation wireless networks," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1615–1631, May 2022.

[A16] S. Shahsavari, F. Shirani, M. A. Khojastepour and E. Erkip, "Opportunistic temporal fair mode selection and user scheduling in full-duplex systems," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1632–1651, May 2022.

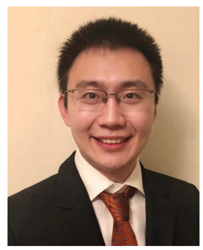
[A17] M. Huang, V. C. M. Leung, A. Liu, and N. N. Xiong, "TMA-DPSO: Towards efficient multi-task allocation with time constraints for next generation multiple access," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1652–1666, May 2022.

[A18] H. Hashida, Y. Kawamoto, N. Kato, M. Iwabuchi, and T. Murakami, "Mobility-aware user association strategy for IRS-aided mm-wave multibeam transmission towards 6G," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1667–1678, May 2022.

[A19] J. Wang, W. Cheng, W. Zhang, W. Zhang, and H. Zhang, "Multi-frequency access for magnetic induction based SWIPT," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1679–1691, May 2022.

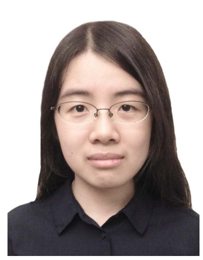
[A20] R. Li, H. Yan, and D. Cabric, "Rainbow-link: Beam-alignment-free and grant-free mmW multiple access using true-time-delay array," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1692–1705, May 2022.

[A21] F. Xing, S. He, V. C. M. Leung, and H. Yin, "Energy efficiency optimization for rate-splitting multiple access based indoor visible light communication networks," *IEEE J. Sel. Areas Commun.*, vol. 40, no. 5, pp. 1706–1720, May 2022.



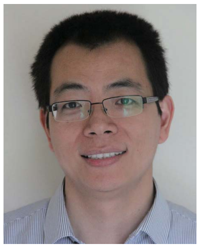
Yuanwei Liu (Senior Member, IEEE) received the B.S. and M.S. degrees from the Beijing University of Posts and Telecommunications in 2011 and 2014, respectively, and the Ph.D. degree in electrical engineering from the Queen Mary University of London, U.K., in 2016.

He was with the Department of Informatics, Kings College London, from 2016 to 2017, where he was a Post-Doctoral Research Fellow. He has been a Senior Lecturer (Associate Professor) with the School of Electronic Engineering and Computer Science, Queen Mary University of London, since August 2021, where he was a Lecturer (Assistant Professor) from 2017 to 2021. His research interests include nonorthogonal multiple access, 5G/6G networks, RIS, integrated sensing and communications, and machine learning. He received the IEEE ComSoc Outstanding Young Researcher Award for EMEA in 2020. He received the 2020 IEEE Signal Processing and Computing for Communications (SPCC) Technical Early Achievement Award and the IEEE Communication Theory Technical Committee (CTTC) 2021 Early Achievement Award. He received the IEEE ComSoc Young Professional Outstanding Nominee Award in 2021. He has served as the Publicity Co-Chair for VTC 2019 (fall). He is the leading contributor for "Best Readings for Non-Orthogonal Multiple Access (NOMA)" and the primary contributor for "Best Readings for Reconfigurable Intelligent Surfaces (RIS)." He serves as the Chair of the Special Interest Group (SIG) in the SPCC Technical Committee on the topic of signal processing techniques for next-generation multiple access (NGMA), the Vice-Chair of SIG Wireless Communications Technical Committee (WTC) on the topic of reconfigurable intelligent surfaces for smart radio environments (RISE), and the Tutorials and Invited Presentations Officer for reconfigurable intelligent surfaces emerging technology initiative. He was a Web of Science Highly Cited Researcher in 2021. He is currently a Senior Editor of IEEE COMMUNICATIONS LETTERS and an Editor of the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS and the IEEE TRANSACTIONS ON COMMUNICATIONS. He serves as the leading Guest Editor for IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS's Special Issue on Next Generation Multiple Access, a Guest Editor for IEEE JOURNAL OF SELECTED TOPICS IN SIGNAL PROCESSING's Special Issue on Signal Processing Advances for Non-Orthogonal Multiple Access in Next Generation Wireless Networks (http://www.eecs.qmul.ac.uk/yuanwei).



Shuowen Zhang (Member, IEEE) received the B.Eng. degree in information engineering from the Chien-Shiung Wu Honors College, Southeast University, Nanjing, China, in June 2013, and the Ph.D. degree from the Graduate School for Integrative Sciences and Engineering (NGS), National University of Singapore, in January 2018, under the NGS Scholarship. From 2017 to 2020, she was a Research Fellow with the Department of Electrical and Computer Engineering, National University of Singapore. Since 2020, she has been with the Department of

Electronic and Information Engineering, The Hong Kong Polytechnic University, where she is currently an Assistant Professor. Her current research interests include intelligent reflecting surface-aided communications, UAV communications, multiuser multiple-input multiple-output (MIMO) communications, communication theory, and optimization methods. She was the sole recipient of the Marconi Society Paul Baran Young Scholar Award in 2021.



Zhiguo Ding (Fellow, IEEE) received the B.Eng. degree from the Beijing University of Posts and Telecommunications in 2000 and the Ph.D. degree from Imperial College London in 2005. From July 2005 to April 2018, he was working at Queen's University Belfast, Imperial College, Newcastle University, and Lancaster University. Since April 2018, he has been with The University of Manchester as a Professor in communications. From October 2012 to September 2022, he has also been an Academic Visitor at Princeton University. His research interests are 5G networks, game theory, cooperative and energy harvesting networks, and statistical signal processing. He is a Distinguished Lecturer of the IEEE ComSoc and a Web of Science Highly Cited Researcher in two categories in 2021. He recently received the EU Marie Curie Fellowship 2012–2014, the Top IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY Editor in 2017, the IEEE Heinrich Hertz Award in 2018, the IEEE Jack Neubauer Memorial Award in 2018, the IEEE Best Signal Processing Letter Award in 2018, the Friedrich Wilhelm Bessel Research Award in 2020, and the IEEE SPCC Technical Recognition Award in 2021. He was an Editor of IEEE WIRELESS COMMUNICATION LETTERS, IEEE TRANSACTIONS ON COMMUNICATIONS, and IEEE COMMUNICATION LETTERS, from 2013 to 2016. He is serving as an Area Editor for IEEE OPEN JOURNAL OF THE COMMUNICATIONS SOCIETY and an Editor for IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY.

Robert Schober (Fellow, IEEE) received the Diploma (University) and Ph.D. degrees in electrical engineering from the Friedrich-Alexander University of Erlangen-Nüremberg (FAU), Germany, in 1997 and 2000, respectively.

From 2002 to 2011, he was a Professor and the Canada Research Chair at the University of British Columbia (UBC), Vancouver, Canada. Since January 2012, he has been an Alexander von Humboldt Professor and the Chair for digital communication at FAU. His research interests fall into the broad areas of communication theory, wireless communications, and statistical signal processing.

Dr. Schober is a fellow of the Canadian Academy of Engineering and the Engineering Institute of Canada and a member of the German National Academy of Science and Engineering. He received several awards for his work including the 2002 Heinz Maier Leibnitz Award of the German Science Foundation (DFG), the 2004 Innovations Award of the Vodafone Foundation for Research in Mobile Communications, the 2006 UBC Killam Research Prize, the 2007 Wilhelm Friedrich Bessel Research Award of the Alexander von Humboldt Foundation, the 2008 Charles McDowell Award for Excellence in Research from UBC, the 2011 Alexander von Humboldt Professorship, the 2012 NSERC E.W.R. Stacie Fellowship, and the 2017 Wireless Communications Recognition Award by the IEEE Wireless Communications Technical Committee. Since 2017, he has been listed as a Highly Cited Researcher by the Web of Science. He served as the Editor-in-Chief for the IEEE TRANSACTIONS ON COMMUNICATIONS from 2012 to 2015 and as the VP Publications for the IEEE Communication Society (ComSoc) in 2020 and 2021. Currently, he serves as a member of the Editorial Board of the PROCEEDINGS OF THE IEEE, the Member-at-Large of the ComSoc Board of Governors, and a ComSoc Treasurer.

Naofal Al-Dhahir (Fellow, IEEE) received the Ph.D. degree from Stanford University. He was a Principal Member of Technical Staff at the GE Research Center and AT&T Shannon Laboratory from 1994 to 2003. He is currently an Erik Jonsson Distinguished Professor and the ECE Department Associate Head at UT-Dallas. He is a co-inventor of 43 issued patents, the coauthor of about 480 papers, and a co-recipient of four IEEE Best Paper Awards. He is a fellow of the National Academy of Inventors. He received the 2019 IEEE SPCC Technical Recognition Award and the 2021 Qualcomm Faculty Award. He served as the Editor-in-Chief of IEEE TRANSACTIONS ON COMMUNICATIONS from January 2016 to December 2019.

Ekram Hossain (Fellow, IEEE) is currently a Professor and the Associate Head (graduate studies) with the Department of Electrical and Computer Engineering, University of Manitoba, Canada. He is a member (class of 2016) of the College of the Royal Society of Canada. He is also a fellow of the Canadian Academy of Engineering and the Engineering Institute of Canada. His current research interests include the design, analysis, and optimization beyond 5G cellular wireless networks. He was elevated to an IEEE Fellow "for contributions to spectrum management and resource allocation in cognitive and cellular radio networks." He received the 2017 IEEE ComSoc Technical Committee on Green Communications and Computing (TCGCC) Distinguished Technical Achievement Recognition Award for outstanding technical leadership and achievement in green wireless communications and networking. He has won several research awards, including the 2017 IEEE Communications Society Best Survey Paper Award and the 2011 IEEE Communications Society Fred Ellersick Prize Paper Award. He was listed as a Clarivate Analytics Highly Cited Researcher in computer science in 2017, 2018, 2019, 2020, and 2021. Currently, he serves as an Editor for IEEE TRANSACTIONS ON MOBILE COMPUTING. Previously, he served as the Editor-in-Chief (EiC) of the IEEE Press (2018–2021) and the EiC of the IEEE COMMUNICATIONS SURVEYS AND TUTORIALS (2012–2016). He was a Distinguished Lecturer of the IEEE Communications Society and the IEEE Vehicular Technology Society. He served as the Director of Magazines for the IEEE Communications Society (2020–2021). He was also an Elected Member of the Board of Governors of the IEEE Communications Society for the term 2018–2020.

Xuemin (Sherman) Shen (Fellow, IEEE) received the Ph.D. degree in electrical engineering from Rutgers University, New Brunswick, NJ, USA, in 1990.

He is currently a University Professor with the Department of Electrical and Computer Engineering, University of Waterloo, Canada. His research focuses on network resource management, wireless network security, the Internet of Things, 5G and beyond, and vehicular networks.

Dr. Shen is a registered Professional Engineer of Ontario, Canada, an Engineering Institute of Canada Fellow, a Canadian Academy of Engineering Fellow, a Royal Society of Canada Fellow, a Chinese Academy of Engineering Foreign Member, and a Distinguished Lecturer of the IEEE Vehicular Technology Society and Communications Society. He received the Canadian Award for Telecommunications Research from the Canadian Society of Information Theory (CSIT) in 2021, the R. A. Fessenden Award in 2019 from IEEE, Canada, the Award of Merit from the Federation of Chinese Canadian Professionals (Ontario) in 2019, the James Evans Avant Garde Award in 2018 from the IEEE Vehicular Technology Society, the Joseph LoCicero Award in 2015 and Education Award in 2017 from the IEEE Communications Society (ComSoc), and the Technical Recognition Award from the Wireless Communications Technical Committee (2019) and the AHSN Technical Committee (2013). He has also received the Excellent Graduate Supervision Award in 2006 from the University of Waterloo and the Premiers Research Excellence Award (PREA) in 2003 from the Province of Ontario, Canada. He served as the Technical Program Committee Chair/Co-Chair for IEEE GLOBECOM'16, IEEE INFOCOM'14, IEEE VTC'10 Fall, and IEEE GLOBECOM'07, and the Chair for the IEEE ComSoc Technical Committee on Wireless Communications. He was the Vice President for Technical and Educational Activities, the Vice President for Publications, the Member-at-Large on the Board of Governors, the Chair of the Distinguished Lecturer Selection Committee, and a member of IEEE Fellow Selection Committee of the ComSoc. He is the President of the IEEE ComSoc. He served as the Editor-in-Chief for the IEEE INTERNET OF THINGS JOURNAL, *IEEE Network*, and *IET Communications*.