Guest Editorial xURLLC in 6G: Next Generation Ultra-Reliable and Low-Latency Communications

Changyang She, *Senior Member, IEEE*, Cunhua Pan, *Senior Member, IEEE*, Trung Q. Duong, *Fellow, IEEE*, Tony Q. S. Quek, *Fellow, IEEE*, Robert Schober, *Fellow, IEEE*, Meryem Simsek, and Peiying Zhu, *Fellow, IEEE*

AS ONE of the new communication scenarios in 5th-generation (5G) mobile communication systems, ultra-reliable and low-latency communications (URLLC) have stringent requirements on latency (around 1 ms) and reliability (up to 99.99999%). Nevertheless, existing 5G URLLC alone cannot fulfill all the Key Performance Indicators (KPIs) in emerging mission-critical applications like industrial automation, intelligent transportation, telemedicine, Tactile Internet, and Virtual/Augmented Reality (VR/AR). The 6th generation (6G) communication systems need to meet additional requirements on some of the following KPIs in combination with URLLC: high spectrum efficiency (SE)/throughput/energy efficiency (EE)/network availability/security as well as low Age of Information (AoI)/jitter/round-trip delay. These new requirements pose unprecedented challenges in terms of design methodologies and enabling technologies in 6G. To fill the gap between 5G URLLC and the diverse KPI requirements of the neXt generation URLLC (xURLLC), novel methodologies and innovative technologies are much needed.

The Special Issue received 76 submissions, and 20 of them were selected after a careful review process. These papers cover a wide range of topics in xURLLC, including fundamental theories, network architecture, diverse KPIs, xURLLC for Metaverse, resource allocation, channel access, beam management, signal processing, and quantum telecomputation.

Manuscript received 31 May 2023; accepted 31 May 2023. Date of current version 6 July 2023. *(Corresponding author: Changyang She.)*

Changyang She is with the School of Electrical and Information Engineering, The University of Sydney, Sydney, NSW 2006, Australia (e-mail: changyang.she@sydney.edu.au).

Cunhua Pan is with the National Mobile Communications Research Laboratory, Southeast University, Nanjing 210096, China (e-mail: cpan@seu.edu.cn).

Trung Q. Duong is with the School of Electronics, Electrical Engineering and Computer Science, Queen's University Belfast, BT7 1NN Belfast, U.K. (e-mail: trung.q.duong@qub.ac.uk).

Tony Q. S. Quek is with the Information Systems Technology Design Pillar, Singapore University of Technology and Design, Singapore 487372 (e-mail: tonyquek@sutd.edu.sg).

Robert Schober is with the Department of Electrical, Electronics, and Communication Engineering (EEI), Friedrich-Alexander University of Erlangen–Nuremberg, 91058 Erlangen, Germany (e-mail: robert.schober@fau.de).

Meryem Simsek is with Nokia Bell Labs, Sunnyvale, CA 94085 USA (e-mail: meryem.simsek@nokia-bell-labs.com).

Peiying Zhu is with Huawei Technologies Canada Company Ltd., Ottawa, ON K2K 3J1, Canada (e-mail: peiying.zhu@huawei.com).

Digital Object Identifier 10.1109/JSAC.2023.3282543

A. Fundamental Theories

Oguz Kislal et al. [A1] evaluate the packet error probability of URLLC in massive multiple-input multiple-output (MIMO) systems, where a pilot-assisted transmission scheme is considered. The developed approach avoids a costly numerical averaging of the packet error probability over the realizations of stochastic channels. The numerical experiments show that their approach can estimate the packet error probability accurately, and the number of samples required for estimation is about two orders of magnitude fewer than the Monte-Carlo method.

Tuninetti et al. [A2] present the second-order achievable and converse rate regions over a single-antenna, static, scalar Gaussian broadcast channel with finite coding blocklength. Specifically, the reliability of the whole system and the reliability of each user are considered. The authors first analyze the rate regions in a two-user case and then generalize their results to the K-user case. The analytical results indicate that both superposition and rate splitting are required in the code construction to achieve the largest second-order achievable regions.

B. Network Architecture

Wang et al. [A3] propose cell-free massive MIMO-aided computing systems to improve computation performance in terms of computational latency and energy consumption. The authors formulate a total cost minimization problem and decouple it into bandwidth allocation and task allocation subproblems. The bandwidth allocation problem is solved using a convex optimization strategy, while the task allocation subproblem is addressed by formulating a dual problem and relaxing the binary constraint with Lagrange partial relaxation for heterogeneous task delay requirements. The simulation results demonstrate that the proposed task offloading scheme outperforms benchmark schemes.

Hao et al. [A4] propose to integrate sensing units into fabric fibers to perceive user data in the sixth-generation wireless networks (6G), and consider a joint sensing adaptation and model placement in fabric space. To minimize acquisition latency and to ensure accuracy, an intelligent-fiber-driven 6G fabric computing network is developed, where the fabric sampling rate, sampling density, and model placement are optimized. Their simulation results demonstrate the proposed scheme is optimal and outperforms several baseline algorithms.

Yang et al. [A5] exploit semantic information extracted from environment image data to make decisions for channel-related tasks in an environment semantics-aided wireless communication framework. In their case study, an environment semantics-aided network architecture for mmWave communication systems is developed, which is trained to predict the optimal beam index and the blockage state. The results show that their approach can achieve extremely efficient beam prediction and timely blockage prediction without pilot training or costly beam scans.

Shi et al. [A6] propose a parallel inference framework for deep learning applications in 6G mobile communication systems to improve inference efficiency while maintaining reliability. The latency refers to the time for completing a deep learning application, and the reliability refers to the percentage of devices that can continue operating when a device malfunction happens. The automatic pipeline parallelism framework schedules neural network inference processes according to the capability of the underlying physical devices. The experimental results demonstrate the priority of the proposed framework with other state-of-the-art parallel inference schedules.

C. Diverse KPIs

Tang et al. [A7] focus on the age of information (AoI) in a multiuser system, where a base station (BS) generates and transmits status updates to multiple users. The authors examine three packet management strategies for both broadcast and unicast transmission schemes, i.e., the non-preemption strategy, the preemption in buffer strategy, and the preemption in serving strategy. Through their analytical and simulation results, some useful insights are obtained. For example, it is better to use the unicast transmission scheme if the number of users is large. Otherwise, the broadcast transmission scheme is better.

Yue et al. [A8] propose a frame-slotted ALOHA (FSA)-based protocol for a random access network, and evaluate the AoI of the proposed protocol. They leverage stochastic geometry to model the interference of the system and derive the average and variance of the AoI in Poisson bipolar and cellular networks, respectively. The analytical results show that FSA-based protocol can reduce the average and variance of AoI significantly. In addition, if power control is adopted in the FSA-based protocol, the AoI performance can be further improved.

Zhang et al. [A9] investigate a downlink multidevice cell-free system with hard deadlines and analyze the delay and reliability in the finite block length regime. The authors first derive the analytic expression of transmission error probability for a single device, and then obtain the closed-form expressions of upper and lower bounds of the time overflow probability in a multidevice cell-free system. Furthermore, three methods are provided in this paper to balance the delay and reliability: transmission rate selection, device grouping, and space division multiplexing.

Li et al. [A10] aim to assure hard delay constraints by using frequency or spatial diversity techniques in harsh wireless environments. The authors consider both parallel and MIMO fading channels and exploit time domain power adaptation to meet the hard delay constraint with a finite average transmit power. The relationship between the required transmit power and delay-constrained throughput is analyzed by using the implicit function theorem. Their analytical results show that it is possible to meet the hard delay constraint when the sub-channels in the frequency and spatial domains are highly but not fully correlated.

Zhu et al. [A11] investigate the security of xURLLC in machine-type communications. They analyze the reliability-security tradeoff via a leakage-failure probability and find that the performance can be enhanced by allocating fewer resources for the transmission with finite block length codes, which is counter-intuitively. To solve the joint resource allocation problem, the authors leverage lower-bounded approximations for the decoding error probability in the finite block length regime. The reformulated problem is solved by an efficient iterative searching method. The accuracy of the proposed approach and the reliability-security tradeoff are verified by the numerical results.

D. xURLLC for Metaverse

Yu et al. [A12] investigate the reliability and latency of the Metaverse applications, where the asymmetric data sizes in uplink and downlink are considered. The authors design a multi-agent reinforcement learning algorithm to optimize computation offloading and channel assignment in the uplink stage and transmit power in the downlink stage. In the proposed reinforcement learning algorithm, there are two agents with separate local objectives and an overarching global objective. By developing a hybrid critic to guide the training and convergence of both agents, the proposed approach can improve the delay, retransmission percentage, and energy cost remarkably compared to an existing iterative reinforcement learning algorithm.

Du et al. [A13] study the interaction between the Metaverse service provider and the network infrastructure provider, and provide an optimal contract design framework for them. The goal is to maximize the utility, defined as a function of Metaverse users' quality of experience (QoE), while ensuring the incentives of the infrastructure provider. The authors incorporate the objective KPIs and subjective feelings of Metaverse users in a novel metric, named Meta-Immersion, to model the QoE mathematically. To improve QoE in xURLLC, an attention-aware rendering capacity allocation scheme is developed and validated using a user-object-attention level dataset.

E. Resource Allocation

Li et al. [A14] propose an energy-efficient packet delivery mechanism to fulfill the requirement of URLLC with finite transmit power. Frequency-hopping is applied to reduce uplink outage probability, and proactive packet dropping is exploited to control the downlink outage from queue clearing.

The authors jointly optimize bandwidth allocation and power control of uplink and downlink, antenna configuration, and subchannel assignment with a three-step method. The simulation results validate the analysis and evaluate the performance achieved by the proposed approach.

Peng et al. [A15] focus on resource allocation for cell-free massive MIMO-aided URLLC systems, where pilot reuse among multiple devices is considered. To maximize the number of devices that can be admitted, the authors formulate a joint pilot length and pilot allocation strategy and jointly optimize the power for pilot and payload. First, the authors derive the lower bounds of ergodic data rate under finite channel blocklength, and then propose a novel pilot assignment algorithm. The simulation results show that the proposed strategy can increase the number of admitted devices significantly and can achieve substantial gains in terms of weighted sum rate.

F. Channel Access

Liu et al. [A16] investigate URLLC in unlicensed spectrum, where the interference and collisions among multiple radio access technologies are considered. To achieve URLLC requirements, the authors develop novel centralized deep reinforcement learning and federated deep reinforcement learning frameworks to optimize the downlink URLLC transmission in New Radio and WiFi coexistence systems. Their results show that both the centralized and federated deep reinforcement learning approaches can improve the reliability of New Radio systems in unlicensed bands significantly, but the centralized one sacrifices the reliability of the WiFi system. To guarantee the reliability of the WiFi system, the authors further take fairness into account.

Ke et al. [A17] propose a unified semi-blind detection framework for sourced and unsourced random access that enables massive URLLC. The active devices transmit their uplink access signals in a grant-free manner, and the BS aims to achieve ultra-reliable data detection under severe inter-device interference without exploiting explicit channel state information. The authors put forth an efficient transmitter design that embeds a small amount of reference information in the access signal. In addition, they develop a successive interference cancellation-based semi-blind detection scheme at the receiver side. To reduce computational complexity and enhance reliability, a rank selection approach and a reference information-aided initialization strategy are incorporated. The numerical results show that the proposed framework can achieve a better scalability–latency–reliability tradeoff than compared with existing detection schemes.

G. Beam Management

Liu et al. [A18] investigate the orthogonal time frequency space (OTFS) transmission for URLLC, where accurate instantaneous channel state information is not available at the transmitter. To minimize the frame error rate, the authors adopt a deep learning approach to exploit implicit features from estimated historical delay-Doppler domain channels to predict the precoder in the next time frame. The closed-form expression of the frame error rate is derived and serves as the objective function to characterize the reliability. Specifically, a convolutional long short-term memory network is designed to extract the spatial–temporal feature from the estimated historical delay-Doppler domain channels. Their simulation results demonstrate that the proposed scheme can achieve a flexible reliability–latency tradeoff and an excellent frame error rate.

H. Signal Processing

Qiu et al. [A19] focus on the problem of designing downlink transmission schemes for supporting heterogeneous ultra-reliable low-latency communications and/or with other types of services. They consider a system, where the BS sends superimposed signals to multiple users over a broadcast channel. To cope with the heterogeneity in latency and reliability requirements, the authors propose a practical downlink transmission scheme with discrete signaling and single-user decoding, where successive interference cancellation is not needed. Furthermore, the second-order achievable rate under heterogenous blocklength and error probability constraints is derived and used to guide the design of channel coding and modulations.

I. Quantum Telecomputation

Zaman et al. [A20] investigate the user privacy and data security of URLLC in distributed networks. They devise a distributed quantum computation protocol that allows Bob to apply an arbitrary single-qubit unitary operator on Alice's qubit in a controlled and probabilistic fashion, without revealing the operator to her and without transmitting any physical particle over the quantum channel. This counterfactual concealed telecomputation protocol neither requires the preshared entanglement nor depends on the bipartite input state. The authors provide numerical examples of quantum anonymous broadcast networks using the counterfactual concealed telecomputation protocol and show their degrees of anonymity in the presence of malicious users.

APPENDIX: RELATED ARTICLES

[A1] A. Oguz Kislal, A. Lancho, G. Durisi, and E. G. Ström, "Efficient evaluation of the error probability for pilot-assisted URLLC with massive MIMO," *IEEE J. Sel. Areas Commun.*, early access, May 29, 2023, doi: 10.1109/JSAC.2023.3280972.

[A2] D. Tuninetti, P. Sheldon, B. Smida, and N. Devroye, "On second order rate regions for the static scalar Gaussian broadcast channel," *IEEE J. Sel. Areas Commun.*, early access, Jun. 5, 2023, doi: 10.1109/JSAC.2023.3280991.

[A3] K. Wang, D. Niyato, W. Chen, and A. Nallanathan, "Task-oriented delay-aware multi-tier computing in cell-free massive MIMO systems," *IEEE J. Sel. Areas Commun.*, early access, May 30, 2023, doi: 10.1109/JSAC.2023.3280965.

[A4] Y. Hao, L. Hu, and M. Chen, "Joint sensing adaptation and model placement in 6G fabric computing," *IEEE J. Sel. Areas Commun.*, early access, Jun. 5, 2023, doi: 10.1109/JSAC.2023.3280968.

[A5] Y. Yang, F. Gao, X. Tao, G. Liu, and C. Pan, "Environment semantics aided wireless communications: A case study of mmWave beam prediction and blockage prediction," *IEEE J. Sel. Areas Commun.*, early access, May 29, 2023, doi: 10.1109/JSAC.2023.3280966.

[A6] H. Shi, W. Zheng, Z. Liu, R. Ma, and H. Guan, "Automatic pipeline parallelism: A parallel inference framework for deep learning applications in 6G mobile communication systems," *IEEE J. Sel. Areas Commun.*, early access, May 29, 2023, doi: 10.1109/JSAC.2023.3280970.

[A7] Z. Tang, N. Yang, P. Sadeghi, and X. Zhou, "Age of information in downlink systems: Broadcast or unicast transmission?" *IEEE J. Sel. Areas Commun.*, early access, May 30, 2023, doi: 10.1109/JSAC.2023.3280986.

[A8] Z. Yue, H. H. Yang, M. Zhang, and N. Pappas, "Age of information under frame slotted ALOHA-based status updating protocol," *IEEE J. Sel. Areas Commun.*, early access, May 30, 2023, doi: 10.1109/JSAC.2023.3280990.

[A9] Z. Zhang et al., "Performance of multidevice downlink cell-free system under finite blocklength for uRLLC with hard deadlines," *IEEE J. Sel. Areas Commun.*, early access, Jun. 6, 2023, doi: 10.1109/JSAC.2023.3280962.

[A10] C. Li, W. Chen, and H. V. Poor, "Diversity enabled low-latency wireless communications with hard delay constraints," *IEEE J. Sel. Areas Commun.*, early access, May 29, 2023, doi: 10.1109/JSAC.2023.3280969.

[A11] Y. Zhu, X. Yuan, Y. Hu, R. F. Schaefer, and A. Schmeink, "Trade reliability for security: Leakage-failure probability minimization for machine-type communications in URLLC," *IEEE J. Sel. Areas Commun.*, early access, May 31, 2023, doi: 10.1109/JSAC.2023.3280960.

[A12] W. Yu, T. J. Chua, and J. Zhao, "Asynchronous hybrid reinforcement learning for latency and reliability optimization in the metaverse over wireless communications," *IEEE J. Sel. Areas Commun.*, early access, May 30, 2023, doi: 10.1109/JSAC.2023.3280988.

[A13] H. Du et al., "Attention-aware resource allocation and QoE analysis for metaverse xURLLC services," *IEEE J. Sel. Areas Commun.*, early access, Jun. 5, 2023, doi: 10.1109/JSAC.2023.3280978.

[A14] K. Li, P. Zhu, Y. Wang, F.-C. Zheng, and X. You, "Joint uplink and downlink resource allocation towards energy-efficient transmission for URLLC," *IEEE J. Sel. Areas Commun.*, early access, May 30, 2023, doi: 10.1109/JSAC.2023.3280967.

[A15] Q. Peng, H. Ren, M. Dong, M. Elkashlan, K.-K. Wong, and L. Hanzo, "Resource allocation for cell-free massive MIMO-aided URLLC systems relying on pilot sharing," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2023, doi: 10.1109/JSAC.2023.3280976.

[A16] Y. Liu, H. Zhou, Y. Deng, and A. Nallanathan, "Channel access optimization in unlicensed spectrum for downlink URLLC: Centralized and federated DRL approaches," *IEEE J. Sel. Areas Commun.*, early access, May 29, 2023, doi: 10.1109/JSAC.2023.3280982.

[A17] M. Ke, Z. Gao, M. Zhou, D. Zheng, D. W. K. Ng, and H. V. Poor, "Next-generation URLLC with massive devices: A unified semi-blind detection framework for sourced and unsourced random access," *IEEE J. Sel. Areas Commun.*, early access, May 29, 2023, doi: 10.1109/JSAC.2023.3280981.

[A18] C. Liu, S. Li, W. Yuan, X. Liu, and D. W. K. Ng, "Predictive precoder design for OTFS-enabled URLLC: A deep learning approach," *IEEE J. Sel. Areas Commun.*, early access, May 30, 2023, doi: 10.1109/JSAC.2023.3280984.

[A19] M. Qiu, Y.-C. Huang, and J. Yuan, "Downlink transmission with heterogeneous URLLC services: Discrete signaling with single-user decoding," *IEEE J. Sel. Areas Commun.*, early access, May 29, 2023, doi: 10.1109/JSAC.2023.3280994.

[A20] F. Zaman, S. N. Paing, A. Farooq, H. Shin, and M. Z. Win, "Concealed quantum telecomputation for anonymous 6G URLLC networks," *IEEE J. Sel. Areas Commun.*, early access, May 29, 2023, doi: 10.1109/JSAC.2023.3280989.

Changyang She (Senior Member, IEEE) received the B.Eng. degree from the Honors College (formerly School of Advanced Engineering), Beihang University (BUAA), Beijing, China, in 2012, and the Ph.D. degree from the School of Electronics and Information Engineering, BUAA, in 2017. From 2017 to 2018, he was a Post-Doctoral Research Fellow with the Singapore University of Technology and Design. From 2018 to 2021, he was a Post-Doctoral Research Associate with The University of Sydney. He is currently the Australian Research Council Discovery Early Career Research Award (ARC DECRA) Fellow with The University of Sydney. His research interests include ultra-reliable and low-latency communications, deep learning in wireless networks, mobile edge computing, and the Internet of Things. He served as the Guest Editor for IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS's Special Issue on xURLLC in 6G and the Guest Editor for IEEE WIRELESS COMMUNICATIONS's Special Issue on Intelligent URLLC in 6G.

Cunhua Pan (Senior Member, IEEE) received the B.S. and Ph.D. degrees from the School of Information Science and Engineering, Southeast University, Nanjing, China, in 2010 and 2015, respectively.

From 2015 to 2016, he was a Research Associate with the University of Kent, U.K. He held a post-doctoral position with the Queen Mary University of London, U.K., from 2016 and 2019. From 2019 to 2021, he was a Lecturer with the Queen Mary University of London. Since 2021, he has been a Full Professor with Southeast University. He received the IEEE ComSoc Leonard G. Abraham Prize in 2022 and the IEEE ComSoc Asia–Pacific Outstanding Young Researcher Award in 2022. He is currently an Editor of IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, IEEE WIRELESS COMMUNICATION LETTERS, and IEEE COMMUNICATIONS LETTERS. He serves as a Guest Editor for IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE JOURNAL OF SELECTED TOPICS IN SIGNAL PROCESSING, and *IEEE Vehicular Technology Magazine*.

Trung Q. Duong (Fellow, IEEE) received the Ph.D. degree in telecommunications systems from the Blekinge Institute of Technology, Sweden, in 2012.

Since 2012, he has been an Adjunct Professor and the Director of the Institute for AI and Big Data, Duy Tan University, Vietnam. In 2013, he joined Queen's University Belfast, U.K., as an Academic Staff, where he is currently a Chair Professor of telecommunications. He was a Distinguished Advisory Professor with Inje University, South Korea, from 2017 to 2019. He is also a Research Chair of the Royal Academy of Engineering. He is also a Distinguished Professor with Thuyloi University, Vietnam, during 2023–2028, and a Visiting Professor (under Eminent Scholar Program) with Kyung Hee University, South Korea, during 2023–2024. His current research interests include quantum communications, wireless communications, signal processing, machine learning, and real-time optimization. He is a fellow of the Asia-Pacific Artificial Intelligence Association (AAIA). He was a recipient of the prestigious Royal Academy of Engineering Research Fellowship (2015–2020). He received the Best Paper Award from IEEE VTC-Spring 2013, IEEE ICC 2014, IEEE GLOBECOM 2016, 2019, and 2022, IEEE DSP 2017, and IWCMC 2019. He received the prestigious Newton Prize in 2017. He has served as an Editor/Guest Editor for IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, IEEE TRANSACTIONS ON COMMUNICATIONS, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, IEEE COMMUNICATIONS LETTERS, IEEE WIRELESS COMMUNICATIONS LETTERS, IEEE WIRELESS COMMUNICATIONS, *IEEE Communications Magazine*, and IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS. He is also serving as an Executive Editor for IEEE COMMUNICATIONS LETTERS.

Tony Q. S. Quek (Fellow, IEEE) received the B.E. and M.E. degrees in electrical and electronics engineering from the Tokyo Institute of Technology in 1998 and 2000, respectively, and the Ph.D. degree in electrical engineering and computer science from the Massachusetts Institute of Technology in 2008. He is currently a Cheng Tsang Man Chair Professor, an ST Engineering Distinguished Professor, and the Head of the ISTD Pillar, Singapore University of Technology and Design, as well as the Director of the Future Communications Research and Development Program. He is a fellow of the Academy of Engineering Singapore. He was honored with the 2008 Philip Yeo Prize for Outstanding Achievement in Research, the 2012 IEEE William R. Bennett Prize, the 2017 CTTC Early Achievement Award, the 2017 IEEE ComSoc AP Outstanding Paper Award, the 2020 IEEE Communications Society Young Author Best Paper Award, the 2020 IEEE Stephen O. Rice Prize, the 2020 Nokia Visiting Professor, and the 2022 IEEE Signal Processing Society Best Paper Award.

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

From 2002 to 2011, he was a Professor and a Canada Research Chair with 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 with FAU. His research interests include communication theory, wireless and molecular communications, and statistical signal processing. He is a fellow of the Canadian Academy of Engineering, a fellow of 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, the 2017 Wireless Communications Recognition Award by the IEEE Wireless Communications Technical Committee, and the 2022 IEEE Vehicular Technology Society Stuart F. Meyer Memorial Award. Furthermore, he received numerous best paper awards for his work, including the 2022 ComSoc Stephen O. Rice Prize. He served as the Editor-in-Chief for IEEE TRANSACTIONS ON COMMUNICATIONS, the VP Publications of the IEEE Communication Society (ComSoc), the ComSoc Member-at-Large, and the ComSoc Treasurer. He also serves as a Senior Editor for PROCEEDINGS OF THE IEEE and as the ComSoc President-Elect. Since 2017, he has been listed as a Highly Cited Researcher by Web of Science.

Meryem Simsek has held various scientific leadership roles with VMware, Intel Labs, UC Berkeley, ICSI, and the Technical University of Dresden. She is currently the Head of the Network Architecture Research (NAR) Laboratory, Nokia Bell Labs, and is leading an interdisciplinary team of experts to drive network architecture innovations across multiple network layers and all network segments. Her research interests include distributed systems, ambient networks, AI/ML and multi-agent systems, E2E system modeling and optimization, game theory, and control theory. She was a recipient of the IEEE Communications Society 2602 Fred W. Ellersick Prize in 2015 and the Rising Star in Computer Networking and Communications by N2Women in 2019. She has initiated and is the Chair of the IEEE Tactile Internet Technical Committee and serves as the Vice Chair for the IEEE P1918.1 Standardization Working Group, which she has co-initiated.

Peiying Zhu (Fellow, IEEE) is currently a Senior Vice President of Wireless Research. She is a Huawei Fellow. She is also leading 6G wireless research and standardization with Huawei. Before joining Huawei in 2009, she was a Nortel Fellow and the Director of Advanced Wireless Access Technology, Nortel Wireless Technology Laboratory. She is actively involved in 3GPP and IEEE 802 standards development. She has been regularly giving talks and panel discussions on 5G/6G vision and enabling technologies. She led the team to contribute significantly to 5G technologies and standardization. Many technologies developed by the team have been adopted into 5G standards and implemented in 5G products. She led the team and pioneered research and prototyping on MIMO-OFDM and multi-hop relay, which were adopted into LTE standards and 4G products. She has more than 200 granted patents. Her research interests include advanced radio access technologies.

She is a fellow of the Canadian Academy of Engineering. She served as a Guest Editor for *IEEE Signal Processing Magazine*'s Special Issue on the 5G Revolution and IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS's Special Issue on Deployment Issues and Performance Challenges for 5G.