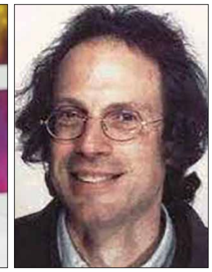
Special Issue Editorial: Quantum Communications and Networking: Series 3




Ruidong Li | Prineha Narang | Melchior Aelmans | Peter Mueller | Gui-Lu Long

Quantum communication researchers have achieved significant progress during the recent decades and quantum networking has shown promise in terms of improving the overall functional benefits of the Internet and enabling applications with no counterpart in the classical world. It is a breakthrough technology towards the unimaginable future. In a quantum network, the source and destination may be connected by quantum repeaters/routers for facilitating qubit transmissions. The quantum network of the future is envisaged to pervade the entire globe, relying on terrestrial components, satellites, airplanes, ships, and other vehicles. It is anticipated that it will support nearly unconditional security, super-computing power, large network capacity – even at high velocity - and privacy.

In the current era, quantum networks are similar to the early stage of the classical Internet in the 1970s. However, they exhibit fundamentally different features, obeying the uncertainty principle, the non-orthogonal indistinguishable theorem, the quantum non-cloning theorem, entanglement and superposition. These constraining features make the design of quantum networks a challenging task. Circumventing this task, we successfully organized IEEE Network special issue and series 1 on Quantum Communications and Networking (September Issue, 2022). Following those issues, we continue to organize series on this topic, and this is series 3 issue. Of the 34 submitted papers, 8 were accepted, and for this issue. The selected articles in this issue mainly cover the topics on quantum key distribution (QKD) network and entanglement-assisted quantum networks and computing.

QKD network will play the fundamental role to provide security for the near-future communications, and the long-distance QKD, function virtualization and softwarization, simulation and emulation, and the integration with classical network are discussed in this special issue. Targeting at achieving long-distance QKD, the first article, Bae et al. [A1] explore blockwise post-processing to address highly dynamic satellite channel conditions due to various environmental factors, which demonstrates that the blockwise strategy can significantly outperform the non-blockwise strategy. The second article, Lopez et al. [A2] quest the virtualization and softwarization of critical components in the quantum networks and introduces an operational model for QKD networks leveraging the virtualization of control and key management functionalities, which has been validated at the 5G Telefonica Open Network Innovation Centre. The third article, Mehic et al. [A3] emphasize the network emulators and describes the simulations and emulations of the national Czech QKD network including the processes of generating, processing, storing, and consuming cryptographic keys. The fourth article, Li et al. [A4] foresee QKD to be integrated into telecommunications networks as an add-on module with critical technologies, such as link multiplexing, miniaturized QKD, and transmission optimization, and envisions an evolution roadmap consisting of three stages for the future development of QKD networks.

For the entanglement-assisted quantum networks and computing, the key technologies for quantum data center network, space-air-ground integrated network (SAGIN), and quantum machine learning framework for wireless sensing applications are introduced here. The fifth article, Vista et al. [A5] focus on the quantum data center networks and uses the properties of quantum network hardware—specifically, the entanglement generation and quantum switch operation rates—to optimize quantum job execution schedules, where the system architecture and performance benchmark also have been introduced. The sixth article, Khan et al. [A6] demonstrate the integration of non-terrestrial networks (NTNs) and terrestrial networks (TNs) for quantum anonymous communication (QAC), highlighting possible architectures and key challenges in these integrated NTN-TN quantum anonymous networks (QANs). The seventh article, Liao et al. [A7] propose a general quantum machine learning framework for wireless sensing applications in the Artificial Internet of Things (AIoT), which provides a systematic approach for designing deeply interpreted wireless sensing models based on quantum machine learning. To solve the problem of blockages among the SAGIN nodes, the eighth article, Trinh et al. [A8] introduce the applications of optical reconfigurable intelligent surfaces (ORISs) in the SAGIN and outlines the road ahead towards the practical realization of ORIS-aided next-generation quantum SAGINs.

We would like to take this opportunity to thank all the reviewers for their great support in reviewing these manuscripts. We also thank the previous Editor-in-Chief, Dr. Chonggang Wang and the current Editor-in-Chief, Prof. Jiming Chen, for his supportive guidance during the entire process.

Ruidong Li
Institute of Science and Engineering
Kanazawa University
Kanazawa, Ishikawa 920-1192, Japan

Prineha Narang
Physical Sciences and Electrical and Computer Engineering
University of California at Los Angeles
Los Angeles, CA 90095 USA

Melchior Aelmans
Quantum Bridge Technologies
Toronto, ON M5G 0C6, Canada

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Peter Mueller
Department of Physics
University of Basel
4001 Basel, Switzerland

Gui-Lu Long
Department of Physics
Tsinghua University
Beijing 100084, China

Appendix: Related Articles

[A1] M. J. Bae et al., "Blockwise post-processing in satellite-based quantum key distribution," *IEEE Netw.*, vol. 39, no. 3, pp. 158–164, May/Jun. 2025.

[A2] B. Lopez et al., "An enhanced virtualized control and key management model for QKD networks," *IEEE Netw.*, vol. 39, no. 3, pp. 165–172, May/Jun. 2025.

[A3] M. Mehic et al., "Virtual quantum key distribution network ecosystem: The national Czech QKD network," *IEEE Netw.*, vol. 39, no. 3, pp. 173–179, May/Jun. 2025.

[A4] J. Li et al., "Integration of quantum key distribution networks and classical networks: An evolution perspective," *IEEE Netw.*, vol. 39, no. 3, pp. 180–187, May/Jun. 2025.

[A5] F. Vista et al., "Entanglement request scheduling in quantum datacenter networks," *IEEE Netw.*, vol. 39, no. 3, pp. 188–195, May/Jun. 2025.

[A6] A. Khan et al., "Integrated non-terrestrial and terrestrial quantum anonymous networks," *IEEE Netw.*, vol. 39, no. 3, pp. 196–206, May/Jun. 2025.

[A7] P. Liao et al., "Wireless sensing in artificial intelligence of things: A general quantum machine learning framework," *IEEE Netw.*, vol. 39, no. 3, pp. 207–214, May/Jun. 2025.

[A8] P. V. Trinh et al., "Towards quantum SAGINs harnessing optical RISs: Applications, advances, and the road ahead," *IEEE Netw.*, vol. 39, no. 3, pp. 215–222, May/Jun. 2025.

Biographies

Ruidong Li (liruidong@ieee.org) received the Ph.D. degree in computer science from the University of Tsukuba in 2008. He is currently an Associate Professor with Kanazawa University, Japan. His research interests include quantum networks, metaverse, and future networks. He was a recipient of the Best Paper Awards for IEEE ICC 2022 and IWCMC 2022 and an IEEE Distinguished Lecturer. He serves as the Chair for IEEE Internet Technical Committee (ITC) and served as the Chair for several conferences, such as the General Chair for ICNC 2025, IEEE HealthCom 2024, MSN 2021, CPSCom 2021, the Area TPC Chair for INFOCOM 2023, and the TPC Chair for QCNC 2024, ICNC 2024, IEEE MetaCom 2023, HotICN 2022, IWQoS 2021, and IEEE MSN 2020.

Prineha Narang received the M.S. and Ph.D. degrees in applied physics from the California Institute of Technology. She was an Assistant Professor of computational materials science at Harvard University. Before starting on the Harvard faculty in 2017, she was an Environmental Fellow at HUCE, and a Research Scholar in condensed matter theory at the Department of Physics, Massachusetts Institute of Technology. She is currently a Professor and the Howard Reiss Chair in physical sciences with the University of California at Los Angeles. Her research interests span areas of quantum information science including quantum algorithms for quantum computation, simulation and emulation directions in quantum network science, and quantum repeaters. Her work has been recognized by many awards and special designations, including the 2023 Maria Goeppert Mayer Award from the American Physical Society, the 2022 Outstanding Early Career Investigator Award from the Materials Research Society, the Mildred Dresselhaus Prize in 2021, the Bessel Research Award from the Alexander von Humboldt Foundation in 2021, the Max Planck Award from the Max Planck Society in 2021, the IUPAP Young Scientist Prize in Computational Physics in 2021, the NSF CAREER Award in 2020, being named a Moore Inventor Fellow by the Gordon and Betty Moore Foundation, the CIFAR Azrieli Global Scholar by the Canadian Institute for Advanced Research, and the Top Innovator by MIT Tech Review (MIT TR35).

Melchior Aelmans is currently the Chief Growth Officer with Quantum Bridge, where he leads global strategy and ecosystem development for quantum-safe networking. With over two decades of experience in network architecture and security, he focuses on advancing scalable key distribution technologies, such as Distributed Symmetric Key Establishment (DSKE). He works closely with partners, standards bodies, and research communities to drive the adoption of practical quantum-safe solutions. He is a frequent speaker at industry events and a passionate advocate for building secure communications infrastructure ready for the post-quantum era.

Peter Mueller (Senior Member, IEEE) is currently a Research Associate with the University of Basel, Switzerland, and a Research Staff Member at IBM Research, for more than 35 years. He has authored or co-authored over 100 articles and two books, granted 30 patents, and served as guest editor for many special issues. His research interests include computing systems architecture, noise and reliability, and quantum technologies. He is a Founding Member and was the Chair of the IEEE ComSoc Communications and Information Systems Security Technical Committee (CIS-TC) and the Technical Committee on Quantum Communications and Information Technologies (QCIT). He is a member of the Society of Industrial and Applied Mathematics (SIAM), the Electrochemical Society (ECS), the Swiss Physical Society (SPS), and the European Physical Society (EPS).

Gui-Lu Long received the B.S. and Ph.D. degrees in 1982 and 1987, respectively. He is currently a Professor with Tsinghua University, China, and a Vice-President of the Beijing Academy of Quantum Information Sciences. He has published more than 400 refereed articles and received many awards. His research interest includes quantum communications and computing, and optical microcavity. He is a fellow of IoP and APS. He served as the President for AAPPS from 2017 to 2019 and the Vice-Chair for C13 for IUPAP from 2015 to 2017.