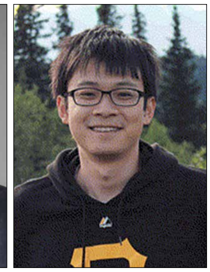
Network Digital Twin



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As we navigate the ever-evolving landscape of the internet, the intricate and dynamic nature of modern communication networks presents formidable challenges in their management, operation, and optimization. The emergence of the Digital Twin paradigm, a digital mirror of a physical entity or system, offers hope in addressing these challenges. This paradigm, which has already demonstrated its value in the manufacturing industry, is a conduit between the physical and digital realms, facilitating the accurate modeling of complex systems without direct interaction.

In this Special Issue, we explore the concept of the Network Digital Twin, a virtual counterpart of a physical network system. This groundbreaking approach empowers network operators to simulate various design scenarios, validate policies, and evaluate network behavior without risking the physical network. The Network Digital Twin unveils many possibilities for "what-if" scenarios, from network architecture design to troubleshooting, optimization, and upgrading. However, to fully harness its potential, we must tackle several challenges that span network simulation and modeling, network monitoring and measurements, network verification, and optimization.

We are delighted to share that our call for papers received an enthusiastic response, with 34 submissions. Out of these, we accepted 9 high-quality articles for publication. This overwhelming response from the community reinforces our belief that the Network Digital Twin is a compelling and crucial topic in communication networks. We are thrilled to present this Special Issue, highlighting the latest advances in the theories, methods, implementations, and applications of the Network Digital Twin.

In [A1], Guo et al. unveils ConfigReco, a tool designed to generate configuration templates automatically based on the network operator's intent. Leveraging graph neural networks, it models existing configurations and provides recommendations.

In [A2], Wang et al. introduces a method to model, evaluate, and optimize 6G network architecture using digital twin technology. It employs intra-domain and inter-domain hypergraphs for mathematical modeling and introduces network architecture entropy for evaluation.

In [A3], Nan et al. introduces a versatile data-driven framework for network traffic prediction in network digital twins, illustrated by a practical case study of cellular traffic prediction and discussions of future challenges.

In [A4], Lai et al. explores the unique aspects and vulnerabilities of integrated space and terrestrial networks (ISTNs), and introduces the space digital twin (SDT) as a security tool. It concludes by identifying challenges in fully utilizing SDT and suggesting future research directions.

In [A5], Song et al. explores the challenges of implementing digital twin technology in field-deployed optical networks. It offers operational guidance for accurate implementation and validates its effectiveness through a field-trial C+L-band optical transmission link.

In [A6], Wang et al. proposes a human-centric framework and a self-maintained mechanism for network digital twins. It emphasizes the necessity for fine-grained replication, high-fidelity screen rendering, and the integration of intelligent technologies.

In [A7], Mao et al. discusses the advantages of Low Earth Orbit (LEO) satellite networks and the challenges in their configuration and management. It introduces Digital Twin (DT) technology to mimic satellite operation and optimize network performance.

In [A8], Ma et al. proposes a resource aggregation and orchestration scheme based on network digital twinning. It introduces a system architecture that simulates and manages the network, enabling flexible scalability and elastic pooling of resources.

In [A9], Tan et al. proposes a Digital Twin-based Cloud-native Vehicular Networks (DT-CVN) architecture to enhance the efficiency of virtual-reality integration in real-world vehicle traffic scenarios. The DT-CVN uses digital twins to bridge the physical space and cyberspace gaps in real time, leveraging the distributed features of microservices based on cloud-native technology.

In conclusion, the collection of articles in this special issue illuminates both the challenges and opportunities inherent in the Network Digital Twin. We express our profound gratitude to the authors for their groundbreaking research contributions and to the reviewers for their meticulous and timely evaluations, which have significantly enhanced the quality of the articles. We also extend our appreciation to Dr. Chonggang Wang, the Editor-in-Chief, and the committed team at IEEE Network for providing us with this platform and for their invaluable support throughout the production process of this special issue. We sincerely believe that readers will find both interest and practical value in the articles featured in this special issue.

Appendix: Related Articles

[A1] Z. Guo et al., "ConfigReco: Network configuration recommendation with graph neural networks," *IEEE Netw.*, vol. 38, no. 1, pp. 7–14, Jan./Feb. 2024, doi: 10.1109/mnet.2023.3336239.

[A2] X. Wang et al., "6G network architecture based on digital twin: Modeling, evaluation, and optimization," *IEEE Netw.*, vol. 38, no. 1, pp. 15–21, Jan./Feb. 2024, doi: 10.1109/mnet.2023.3333822.

Digital Object Identifier:
10.1109/MNET.2024.3352356

[A3] H. Nan et al., "An efficient data-driven traffic prediction framework for network digital twin," *IEEE Netw.*, vol. 38, no. 1, pp. 22–29, Jan./Feb. 2024, doi: 10.1109/mnet.2023.3335952.
[A4] Z. Lai et al., "Space digital twin for secure satellite Internet: Vulnerabilities, methodologies and future directions," *IEEE Netw.*, vol. 38, no. 1, pp. 30–37, Jan./Feb. 2024, doi: 10.1109/mnet.2023.33371.
[A5] Y. Song et al., "Implementing digital twin in field-deployed optical networks: Uncertain factors, operational guidance, and field-trial demonstration," *IEEE Netw.*, vol. 38, no. 1, pp. 38–45, Jan./Feb. 2024, doi: 10.1109/mnet.2023.3332893.
[A6] J. Wang et al., "Self-maintained network digital twin for human-centric wireless metaverse," *IEEE Netw.*, vol. 38, no. 1, pp. 46–53, Jan./Feb. 2024, doi: 10.1109/mnet.2023.3337644.
[A7] B. Mao et al., "Digital twin satellite networks towards 6G: Motivations, challenges, and future perspectives," *IEEE Netw.*, vol. 38, no. 1, pp. 54–60, Jan./Feb. 2024, doi: 10.1109/mnet.2023.3332895.
[A8] Y. Ma et al., "Adaptive service provisioning for dynamic resource allocation in network digital twin," *IEEE Netw.*, vol. 38, no. 1, pp. 61–68, Jan./Feb. 2024, doi: 10.1109/mnet.2023.3337245.
[A9] X. Tan et al., "Digital twin-based cloud-native vehicular networks architecture for intelligent driving," *IEEE Netw.*, vol. 38, no. 1, pp. 69–76, Jan./Feb. 2024, doi: 10.1109/mnet.2023.3337271.

Biographies

Yong Cui (cuiyong@tsinghua.edu.cn) received the B.E. and Ph.D. degrees in computer science and engineering from Tsinghua University, China, in 1999 and 2004, respectively. He is currently a Full Professor with the Computer Science Department, Tsinghua University. His major research interests include mobile cloud computing and network architecture.

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