

ADVANCED NETWORKING AND APPLICATIONS FOR METAVERSE AND WEB 3.0



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Compared to the content-centric “read”-based Web 1.0 and the “read-write”-based Web 2.0, Web 3.0 is based on the “read-write-own” paradigm, which is user-centric. Web 3.0 applications are deployed decentralized and transparently, which prevents malicious programs from being set up. Metaverse shares the same ultimate vision as Web 3.0, which aims to provide inclusive, secure, trustworthy, and privacy-preserving interactions and transactions for humans, machines, and virtual economies. To create a fully immersive and self-sustaining virtual reality world, Metaverse involves the deep integration of physical, digital, and biological domains to eliminate the boundaries between reality and virtuality. Interactive technologies, such as virtual and augmented reality, provide users with a seamless and immersive experience. Furthermore, decentralized technologies, such as blockchain, play vital roles in the Metaverse ecosystem by guaranteeing fairness, transparency, and authentic rights for digital assets. Such advanced technologies facilitate the Metaverse to generate a digital replica of the physical world, produce unique virtual content, and lead to a surreal digital universe. Therefore, a full-fledged Metaverse also signifies the arrival of Web 3.0.

This special issue aims to attract contributions from academia and industry for deeper thinking about the Metaverse and Web 3.0. By providing a forum for the latest research, innovations, and applications, this issue is meant to expose the most recent advances in networking and applications for the Metaverse and Web 3.0, thereby thoroughly tapping their potential and promoting their development. This issue received 48 submissions, which were all evaluated by at least 3 independent referees.

The first article by Tang et al. [A1] aims to systematically explore the impact of edge computing on the development of Metaverse. This article provides an architectural overview of edge computing-enabled Metaverse and further explores the role of edge computing in the Metaverse by addressing questions such as why and how it can enhance the virtual world.

The second article by Chen et al. [A2] proposes a platform targeting the long-tail market comprising customized products, which is difficult for traditional companies to make profits due to small economies of scale and extremely high costs. Moreover, the micro-blockchain protocol is developed for scalability with more concurrent transactions, and a data-driven trust model is utilized to evaluate mutual trust between users in a decentralized manner.

In the third article by Wang et al. [A3], a digital twin architecture is introduced to achieve networking virtualization and

digitalization for Web 3.0. Based on the architecture, the digital twin-empowered low-latency communication scheme is proposed by disseminating tasks to the resource-sufficient infrastructure, while considering the communication cost of deploying digital twins.

The fourth article by Chi et al. [A4] provides an overview of the significance and current landscape of interoperability in parallel Metaverses. Then, this article analyzes the technical difficulties and business challenges associated with achieving interoperability for collaborations. Furthermore, decentralized knowledge inference is discussed to be used as a potential solution for facilitating knowledge sharing among parallel Metaverses.

The fifth article by Gong et al. [A5] presents a framework for secure data storage, where Ciphertext-Policy Attribute-Based Encryption (CP-ABE) is utilized to achieve fine-grained access control. Furthermore, blockchain is leveraged in the proposed ciphertext split storage model to guarantee openness and immutability. Moreover, efficient ciphertext retrieval is considered in this article and a keyword-based data search is proposed.

The sixth article by Zhang et al. [A6] explores Collusion-based Poisoning Attacks in the blockchain Federated Learning (FL) architecture, where malicious participants could manipulate the model training process and affects all participants due to the strong consistency of the blockchain. The proposed attack can obscure the state-of-the-art defense techniques to achieve the poisoned task.

In the seventh article by Xu et al. [A7], a temporal-dependent spherical-distortion model is proposed for efficient panoramic video coding. The independent mapping relationship between spherical-distortion and compression-distortion is modeled based on the geometric projection principle. Also, a temporal-dependent model for consecutive frames is deduced.

The eighth article by Hui et al. [A8] proposes three new evaluation considerations, CAN—Continuous, Active, and Non-intrusive authentication, for the Metaverse environment. The three considerations are leveraged for the evaluation of the existing smartphone-employed and Metaverse-oriented biometric methods.

The ninth article by Yu et al. [A9] provides a solution that tackles the problem of socially-aware traffic scheduling in the Metaverse from a novel perspective. A hybrid network architecture is introduced to enhance network flexibility and scalability.

The tenth article by Luo et al. [A10] investigates privacy issues in Vehicular Twin (VT) migrations within vehicular Metaverses. It introduces the VT migration process and discusses four privacy attacks affecting the identity and location privacy of Vehicular Metaverse Users (VMUs) and VTs. To counter these attacks, a VMU-VT dual pseudonym scheme with four modules is proposed.

The eleventh article by Xu et al. [A11] focuses on combining Edge Computing (EC) and Artificial Intelligence (AI) to advance Metaverse development, creating an edge intelligence-empowered Metaverse. Outlining the Metaverse architecture and key technologies, the paper emphasizes EC's role in Metaverse infrastructure. Additionally, it explores two primary categories of edge intelligence in Metaverse settings, encompassing AI for edge and AI on edge.

The twelfth article by Wang et al. [A12] presents the Account Service Network (ASN), a layer 2 blockchain solution concerning credible anonymity and user control when accessing Web 3.0 services. Users' biometric data are bound to realize the one-person-one-account framework. Meanwhile, the design and prototype implementation of ASN are presented.

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APPENDIX: RELATED ARTICLES

- [A1] C. Tang et al., "A systematic exploration of edge computing-enabled Metaverse," *IEEE Netw.*, vol. 37, no. 6, pp. 10–17, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3321541.
- [A2] J. Chen et al., "A decentralized Web 3.0 platform for manufacturing customized products," *IEEE Netw.*, vol. 37, no. 6, pp. 18–25, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3318609.
- [A3] Q. Wang et al., "Low-latency communications for digital twin empowered Web 3.0," *IEEE Netw.*, vol. 37, no. 6, pp. 26–33, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3319380.
- [A4] Y. Chi et al., "Networking parallel Web3 Metaverses for interoperability," *IEEE Netw.*, vol. 37, no. 6, pp. 34–41, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3320660.
- [A5] B. Gong et al., "Toward secure data storage in Web 3.0: Ciphertext-policy attribute-based encryption," *IEEE Netw.*, vol. 37, no. 6, pp. 42–49, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3317109.

- [A6] X. Zhang et al., "Collusion-based poisoning attacks against blockchained federated learning," *IEEE Netw.*, vol. 37, no. 6, pp. 50–57, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3318179.
- [A7] X. Yang et al., "Efficient panoramic video coding for immersive Metaverse experience," *IEEE Netw.*, vol. 37, no. 6, pp. 58–66, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3319958.
- [A8] H. Zhong et al., "Metaverse CAN: Embracing continuous, active, and non-intrusive biometric authentication," *IEEE Netw.*, vol. 37, no. 6, pp. 67–73, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3318890.
- [A9] A. Yu et al., "Socially-aware traffic scheduling for edge-assisted metaverse by deep reinforcement learning," *IEEE Netw.*, vol. 37, no. 6, pp. 74–81, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3317108.
- [A10] X. Luo et al., "Privacy attacks and defenses for digital twin migrations in vehicular Metaverses," *IEEE Netw.*, vol. 37, no. 6, pp. 82–91, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3317320.
- [A11] Y. Xu et al., "Edge intelligence empowered Metaverse: Architecture, technologies, and open issues," *IEEE Netw.*, vol. 37, no. 6, pp. 92–100, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3317477.
- [A12] T. Wang et al., "Account service network: A unified decentralized Web 3.0 portal with credible anonymity," *IEEE Netw.*, vol. 37, no. 6, pp. 101–108, Nov./Dec. 2023, doi: 10.1109/MNET.2023.3321090.

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