Semantic Communications for the Metaverse

The concept of the Metaverse has grown in popularity as "the successor to the mobile Internet." While there exist light versions of the Metaverse today, they are still far from realizing the full vision of an immersive, embodied, and interoperable Metaverse. Without addressing the issues of implementation from the perspective of communication, computation, and networking, the Metaverse is difficult to succeed the Internet, especially in terms of its accessibility to billions of users today.

The possibility of real-time interaction and synchronization of the physical and virtual world has led to the concept of the Metaverse. The performance of Metaverse is dependent heavily on the collection and processing of data that reflects or describes human movements and changes of surroundings, which can guide Metaverse server operations, e.g., shifting rendered targets, displaying particular videos, and giving the corresponding tactile feedback. To guarantee the ideal immersive experience for users, the requirements for data rates, as well as timing of the data transfer and processing, need to be strictly met. In this regard, effective tracking and accurate prediction are key to reducing transmission and computation latency and ensuring a smooth user experience. In this context, the notion of Semantic Communications becomes essential, as there is a need to extract the semantics from the data collected and tracked by the end devices, such as head movement, arm swing, gestures, or speech. This allows the end device to transmit the information concerned by the Metaverse server for operation after understanding and filtering out the irrelevant information to save bandwidth and reduce computing latency at the Metaverse server. Meanwhile, the Metaverse server can also extract semantic information from video based on the user's preference, ignoring irrelevant details in the face of bandwidth constraints, thus reducing the pressure on the downlink.

Therefore, we propose this special issue to present and highlight the advances and the latest communication technologies, implementations, and applications of Semantic Communications for the Metaverse. We received 18 submissions, and selected five papers for this issue after a careful review process. Besides, we are glad to include two articles falling within the scope of our SI from the Open Call. Those papers provide visions of the different approaches toward Semantic Communications for the Metaverse.

The article, "Trustworthy Semantic Communications for the Metaverse Relying on Federated Learning," by Jianrui Chen, Jingjing Wang, Chunxiao Jiang, Yong Ren, and Lajos Hanzo conceives a trustworthy semantic communication system for the Metaverse based on a federated learning architecture by exploiting its distributed decision-making and privacy-preserving capability. A suite of promising research directions and open issues has been identified.

The article, "Quantum Semantic Communications for Metaverse: Principles and Challenges," by Uman Khalid, Muhammad Shohibul Ulum, Ahmad Farooq, Trung Q. Duong, Octavia A. Dobre, and Hyundong Shin investigates the potential benefits of incorporating quantum anonymous communication and variational quantum computing to develop quantum semantic communication (QSC) that enables Metaverse users to interact with virtual environments more efficiently and securely. This anonymous QSC framework fully capitalizes on unique quantum resources and properties for the Metaverse.

The article, "Semantic-Aware Digital Twin for Metaverse: A Comprehensive Review," by Senthil Kumar Jagatheesaperum-al, Zhaohui Yang, Qianqian Yang, Chongwen Huang, Wei Xu, Mohammad Shikh-Bahaei, and Zhaoyang Zhang introduces the digital twin framework, considering a smart industrial application, which enables semantic communication in conjunction with the Metaverse enabling technologies. The fundamentals of this framework are demonstrated on an industrial shopfloor management use case with a digital twin so as to improve its performance through semantic communication.

The article, "Adversarial Attacks and Defenses for Semantic Communication in Vehicular Metaverses," by Jiawen Kang, Jiayi He, Hongyang Du, Zehui Xiong, Zhaohui Yang, Xumin Huang, Shengli Xie designs a hierarchical framework for Semantic communication (SemCom) enabled vehicular metaverse. This framework consists of the global metaverse, local metaverses, SemCom module, and resource pool.

The article, "Secure Semantic Communication Model for Black-Box Attack Challenge under Metaverse," by Chang Li, Liang Zeng, Xin Huang, Xiaqing Miao, and Shuai Wang introduces the prospect of semantic communication under the background of metaverse, which has the advantages of large communication capacity and strong anti-noise ability. This article outlines three approaches to secure semantic communication.

The article, "Realizing the Metaverse with Edge Intelligence: A Match Made in Heaven," by Wei Yang Bryan Lim, Zehui Xiong, Dusit Niyato, Xianbin Cao, Chunyan Miao, Sumei Sun, and Qiang Yang discusses the architecture of the Metaverse, and mainly focus on motivating the convergence of edge intelligence and the infrastructure layer of the Metaverse. The authors present major edge-based technological developments and their integration to support the Metaverse engine.

The article, "The Roadmap of Communication and Networking in 6G for the Metaverse," by Fengxiao Tang, Xuehan Chen, Ming Zhao, and Nei Kato depicts the roadmap to the Metaverse in terms of communication and networking in 6G, including illustrating the framework of the Metaverse, revealing the strict requirements and challenges for 6G to realize the Metaverse, and discussing the fundamental technologies to be integrated in 6G to drive the implementation of the Metaverse.

We would like to convey our gratitude to all the authors, irrespective of whether their papers were accepted or rejected, for their efforts to submit manuscripts that made this Special Issue a success. We are also grateful to Professor Nirwan Ansari and Professor Dusit Niyato for understanding the importance of this timely topic and allowing us to organize this Special Issue. Finally, we would like to acknowledge the editorial team and the anonymous reviewers for their support and contributions.

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