

A Review of Multi-User Semantic Communication

Tung Son Do, Thanh Phung Truong, 변재영*, 조성래
중앙대학교, *조선대학교

tsdo@uclab.re.kr, tptruong@uclab.re.kr, jypyun@chosun.ac.kr, srcho@cau.ac.kr

Abstract

Multi-user semantic communication has emerged as a promising paradigm in the context of next-generation communication systems, particularly in addressing challenges such as spectrum scarcity, data overload, and efficient information transmission. This survey paper explores various approaches and implementations of multi-user semantic communication, analyzing their design, implementation, and performance evaluation. We draw insights from recent studies to highlight the advancements and potential applications of this technology.

I. Introduction

The rapid evolution of communication technologies has paved the way for semantic communication, a paradigm that focuses on transmitting the meaning of information rather than its raw data. This approach is particularly beneficial in multi-user scenarios, where efficient and reliable communication is critical. Multi-user semantic communication systems leverage deep learning and artificial intelligence to enhance data transmission, reduce latency, and improve overall communication efficiency. This paper surveys the current state of multi-user semantic communication, examining its applications in various domains, including cooperative object identification, spectrum scarcity mitigation, and vehicular networks.

II. Literature Review

Zhang et al. [6] introduced a deep learning-driven system for multi-user semantic communication focused on cooperative object identification. Their model, named DeepSC-COI, employs convolutional neural networks (CNN) to combine individual semantic features into a unified feature set. This approach notably enhances identification accuracy without additional latency, achieving an 86.9% improvement in mean Average Precision (mAP) at -3 dB when compared to non-cooperative methods.

Fantacci and Picano [1] addressed the issue of spectrum scarcity in dense cellular networks through a semantic communication system. By employing artificial intelligence techniques, their system manages inter-user interference and enhances communication reliability in spectrum-constrained environments. The proposed solution is crucial for the efficient operation of future 6G networks, where

spectrum resources are limited (Fantacci & Picano, 2022).

Xu et al.[4] investigated the application of Non-Orthogonal Multiple Access (NOMA) in enhancing multi-user semantic communication. By integrating NOMA with semantic communication, the system improves spectrum efficiency and supports a higher number of simultaneous users. This approach is particularly beneficial in scenarios with limited bandwidth and high user density (Xu et al., 2022).

Hu et al. [2] proposed a one-to-many semantic communication system, MR_DeepSC, designed for broadcasting scenarios. Utilizing deep neural networks and transfer learning, their system achieves robust performance in various channel conditions, particularly in low signal-to-noise ratio (SNR) regimes. The use of pre-trained models like DistilBERT enhances the system's ability to distinguish between different users' information (Hu et al., 2022).

Xu et al. (2023) introduced a cooperative semantic-aware framework tailored for the Internet of Vehicles (IoV). This system alleviates data traffic by transmitting essential semantic information from collaborative users to servers, effectively tackling the issue of spectrum scarcity in vehicular networks. By doing so, it enhances transportation efficiency and security, ensuring reliable and effective communication among connected vehicles.

Xie et al. [6] extended their work on multi-user semantic communications by focusing on task-oriented applications. They developed systems for specific tasks such as image retrieval and machine translation, utilizing deep learning models to optimize communication processes and improve task outcomes. Their research highlights the potential of semantic

communication in various practical applications (Xie et al., 2022).

III. Discussion

The reviewed studies underscore substantial advancements in multi-user semantic communication. Despite these developments, several open issues and potential areas for future research remain. Key challenges include ensuring robust communication in highly dynamic and heterogeneous network environments, managing the complexity of deep learning models, and addressing security and privacy concerns associated with semantic data transmission.

Future research directions could explore the following areas:

- **Dynamic Network Adaptation:** Developing adaptive algorithms capable of adjusting to rapidly changing network conditions, such as varying user densities and mobility patterns, to maintain reliable semantic communication.
- **Model Complexity Management:** Investigating methods to reduce the complexity and computational requirements of deep learning models used in semantic communication systems, making them more efficient and scalable.
- **Security and Privacy:** Enhancing security measures to protect semantic data from interception and tampering, and ensuring privacy-preserving communication protocols.
- **Energy Efficiency:** Focusing on the energy efficiency of semantic communication systems, especially for battery-powered devices on the Internet of Things (IoT) and vehicular networks.
- **Interoperability:** Ensuring seamless integration and interoperability between different semantic communication systems and traditional communication networks.
- **Standardization:** Developing standards for semantic communication to facilitate widespread adoption and compatibility across different platforms and applications.

As communication technologies continue to evolve, addressing these challenges will be crucial for the widespread implementation and success of multi-user semantic communication in next-generation networks.

IV. Conclusion

Multi-user semantic communication represents a transformative approach in the field of communication technologies. By focusing on the meaning of information, these systems offer significant improvements in efficiency, reliability, and performance. The studies reviewed in this paper demonstrate the potential applications of multi-user semantic communication in various domains, paving the way for future research and development in this promising area.

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