A Survey on Semantic Communication in UAV Networks

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Abstract

Semantic communication, an emerging field in the world of 6G networks, focuses on delivering meaning rather than data. This technique has great promise for Unmanned Aerial Vehicle (UAV) networks, where efficient and reliable communication is critical. This study examines recent advances in applying semantic communication to UAV networks, focusing on major approaches, applications, and problems. The survey covers various aspects including image transmission, trajectory optimization, and environmental monitoring, providing a comprehensive overview of how semantic communication can enhance UAV network performance.

Ⅰ. Introduction

The introduction of 6G networks is set to transform wireless communication, with semantic communication as a cornerstone. Unlike traditional communication paradigms, which prioritize data integrity, semantic communication focuses on the delivery of important information, increasing efficiency and lowering bandwidth requirements. This notion is especially useful for UAV networks, which frequently face strict limits in terms of power, bandwidth, and latency [1]. UAVs are increasingly used for various applications, including surveillance, environmental monitoring, and disaster management. However, the efficiency of these operations is often hindered by the need to transmit large volumes of data over limited bandwidths. Semantic communication addresses this issue by focusing on the transmission of meaningful information, thereby optimizing the use of available resources . This paper surveys the current state of research in semantic communication for UAV networks, highlighting key advancements, challenges, and future directions.

Ⅱ. Key Concepts in Semantic Communication

Semantic communication involves encoding and transmitting only the essential information required for a specific task, significantly reducing the amount of data transmitted. This process often employs advanced techniques such as machine learning and natural language processing to interpret and convey meaning effectively [2]. In the context of UAV networks, semantic communication can optimize tasks such as image transmission, object detection, and environmental monitoring by focusing on critical features and discarding redundant data.

Ⅲ. Applications in UAV Networks

1. **Image Transmission and Object Detection:**
   Semantic communication can enhance the efficiency of image transmission in UAV networks. By utilizing multi-scale semantic encoders, UAVs can compress and transmit only the most relevant image features . Upon reception, these features are decoded to reconstruct the original image, focusing on essential details for object detection tasks. This method not only reduces the transmission load but also improves the accuracy of object detection through the integration of knowledge graphs, which provide contextual information and enhance semantic understanding [3].
2. **Trajectory Optimization and Data Collection:**
   In the scenario of multi-UAV, semantic communication facilitates efficient data collection and trajectory planning. UAVs equipped with semantic communication capabilities can prioritize and share critical information, optimizing their flight paths to cover more ground efficiently. This approach minimizes redundant data transmission and ensures timely updates, crucial for dynamic environments [4].
3. **Environmental Monitoring and Disaster Management:**
   UAV networks play an important role in environmental monitoring and disaster mitigation. Semantic communication allows UAVs to broadcast only relevant information, such as pollution or disaster indicators, speeding up response times and lowering the pressure on communication networks [5].

IV. Challenges and Future Directions

1. **Complexity in Semantic Encoding and Decoding:**
   The process of encoding and decoding semantic information is computationally intensive. Developing lightweight and efficient algorithms that can operate on UAVs with

limited processing power remains a significant challenge.

2. **Integration with Existing Communication Protocols:**
   In order to seamlessly integrating semantic communication scheme with the existing UAV communication protocols, it is required that we have to address about compatibility issues and ensuring smooth interoperability.
3. **Security and Privacy Concerns:**
   Transmitting semantically rich information may pose security and privacy risks. Ensuring the integrity and confidentiality of transmitted data is crucial, especially in sensitive applications like surveillance and defense.

IV. Conclusion

Semantic communication represents a transformative approach for UAV networks, promising enhanced efficiency and reduced bandwidth usage. While significant progress has been made, ongoing research is needed to address the challenges of complexity, integration, and security. Future advancements in semantic communication could further bolster the capabilities of UAV networks, making them more robust and versatile for a wide range of applications.

ACKNOWLEDGMENT

This research was supported by the MSIT (Ministry of Science and ICT), Korea, under the ITRC(Information Technology Research Center) support programs(IITP-2024-RS-2022-00156353 and IITP-2024-RS-2023-00258639) supervised by the IITP(Institute for Information & Communications Technology Planning & Evaluation).

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