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論　文　要　旨

・論文の構成

Chapter 1 Introduction

Chapter 2 Related Works

Chapter 3 PLS Performance in One-Hop DMC Systems

Chapter 4 PLS Performance in Two-Hop DMC Systems

Chapter 5 PLS Performance in Cooperative Jamming-Assisted Two-Hop DMC Systems

Chapter 6 Conclusion

・研究目的の妥当性，　従来の手法との比較においての有意性，　および理論　・実験手法の新規性

Diffusive molecular communication (DMC) is a promising paradigm for information exchange in nanonetworks, with significant potential applications in areas such as health monitoring, targeted therapy, and biological population control. However, DMC systems face unique security challenges due to the stochastic nature of molecular diffusion, the limited computational resources of nanomachines, and their inherent vulnerability to eavesdropping attacks. Consequently, the design of efficient and robust security protocols to ensure reliable and secure communication in DMC systems has attracted great attention. Among the various approaches, physical layer security (PLS) techniques stand out due to their low resource consumption and computational simplicity, offering a highly promising solution to address the distinct security challenges in DMC systems.

This dissertation develops PLS transmission protocols tailored to various DMC scenarios to ensure secure communication in molecular networks. First, for one-hop DMC systems, this dissertation proposes a PLS protocol that uses multiple types of molecules (D-MoSK technique) to create parallel channels to significantly enhances secrecy capacity, and the related experimental results demonstrate that the higher-order D-MoSK can effectively improve the security of DMC systems. Second, for two-hop DMC systems, we consider the scenarios with single type of molecule (STM) or two types of molecules (TTM), and design corresponding PLS protocols and conduct secrecy performance modeling and optimization. This work offers valuable insights into the secrecy analysis and relay position optimization in two-hop DMC systems. Finally, we propose a cooperative jamming (CJ)-assisted PLS protocol for the two-hop DMC systems, where the nanomachines are equipped with nozzles and can introduce artificial no ise to degrade the eavesdropper's channel quality, so as to further enhance the secrecy performance of these systems.

It is expected that the proposed protocols and methodologies can significantly advance the secure molecular communication technologies and promote the applications of nanonetworks.

・得られた知見のシステム情報科学の分野における意義

The results of this thesis provide the following valuable insights.

1. This thesis develops PLS transmission protocols for one-hop, two-hop, and CJ-assisted two-hop DMC systems, establishing a solid foundation for secure molecular communication networks.
2. It is expected that the PLS performance analysis framework and optimization methods developed in this thesis help to enhance the security and applications of DMC in future nanonetworks.
3. The proposed PLS solutions, including D-MoSK-based parallel channels and cooperative jamming mechanisms, present innovative strategies to tackle the unique secrecy challenges inherent in DMC systems.

審 査 結 果 の 要 旨

This dissertation develops physical layer security (PLS) protocols for various diffusive molecular communication (DMC) scenarios to ensure secure communication in nanonetworks. First, for one-hop DMC systems, this dis se rt at ion designs a PL S pro to co I that I ever ages mu It i p I e types of molecules to create parallel channels, and demonstrates through performance modeling that higher-order D-MoSK can significantly enhance secrecy capacity. Second, for two-hop DMC systems, this dissertation develops PLS protocols and conducts secrecy performance modeling under scenarios with single type of molecule (STM) or two types of molecules (TTM), offering valuable insights for the design of secure two-hop nanonetworks. Finally, this dissertation proposes a cooperative jamming (CJ)-based PLS protocol to degrade the eavesdropper's ability and thus further improve the secrecy performanq: in two-hop DMC systems. These PLS solutions are expected to advance the development of secure molecular communication systems in future applications.