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論　文　要　旨

With the rapid evolution of wireless communication technologies and the wide coverage of wireless hotspots, wireless systems are of paramount importance to provide ubiquitous wireless connectivity for lots of critical applications in daily life. However, security and privacy are critical in existing and future wireless systems since a large amount of confidential information (e.g., credit card information, physiological information for e-health) is transferred over the open wireless channels. How to guarantee information security has attracted increasing concerns from both academia and industry recently. Covert communication is a potential technique to prevent adversaries from detecting the existence of transmissions among both sides of the communication. Therefore, this thesis focuses on the protocol design and performance analysis for covert communications in the fundamental relay-assisted wireless systems.

We first investigate the covert communication in a two-hop wireless communication system with multiple relays, where a message is first transmitted from its source to a selected relay and then forwarded by the relay to its destination under the detection of a passive warden. We explore in detail the relay selection protocol design issue for this system. For evaluating the performance of covert communication, we develop a theoretical framework to analyze the transmission outage probability, the detection error probability of warden, and covert capacity based on a relay selection protocol proposed. We also explore covert capacity maximization through efficient numerical

searches under a given covertness requirement. Finally, extensive simulation and numerical results are provided to illustrate our theoretical findings and the performance of covert communication in two-hop wireless communication systems with multiple relays.

We then introduce cooperative jamming technology into relay-assisted wireless systems to interfere with the warden. In order to determine the forward relay and the jammer, we illustrate a new relay/jammer selection protocol in such systems. In order to explore the impact of cooperative jamming on the performance of covert communication, we introduce a jam-generating threshold into the theoretical framework and we further derive the expressions for three performance metrics, i.e., transmission outage probability, the detection error probability of warden, and covert capacity. We also explore covert capacity maximization through efficient numerical searches under given covertness and outage requirements. Finally, we present extensive simulation and numerical results to validate our theoretical results, as well as to demonstrate that cooperative jamming can confuse the warden well to improve the performance of covert communication.

We further extend our study to a scenario where the warden will actively attack the communication process as a jammer in relay-assisted wireless systems. We redefine the behavior of the warden that it will perform detection and jamming throughout the covert communication process. Notice that the transmitter has to increase the transmission power to ensure successful decoding due to the jamming of the warden, and thus increases the risk of being detected. To deeply understand such interactions, based on the related relay selection protocol designed previously, we develop a new theoretical framework to analyze the transmission outage probability, the detection error probability of warden, and covert capacity. Then, we optimize the covert capacity through power control under given covertness and outage requirements. Finally, extensive simulation and numerical results are provided to illustrate our theoretical findings and the performance of covert communication with an active warden in such systems.

審査結果の要旨

This dissertation first explores the relay selection protocol design for covert communication in two-hop multi-relay wireless communication systems with a passive warden, and conducts theoretical analysis to derive the corresponding achievable covert capacity performance. We then

introduce cooperative jamming technology into such systems to interfere with the warden, and design related relay/jammer selection protocols and provide theoretical analysis to demonstrate the impact of cooperative jamming on covert capacity. We further extend our study to the scenario where the warden will actively attack the communication process as a jammer in such systems. Finally, extensive simulations and numerical results are provided to demonstrate our theoretical findings and the performance of covert communication in such systems. The work in this thesis sheds new insights on the future researches of covert communications in relay-assisted wireless systems.

・論文の構成

Chapter 1 Introduction

Chapter 2 Related Works

Chapter 3 Covert Communication in Wireless Systems with Multiple Relays

Chapter 4 Cooperative Jamming based Covert Communication in Relay -Assisted Wireless Systems

Chapter 5 Cover Communications in Relay-Assisted Wireless Systems with an Active Warden

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

We first investigate the covert communication in two-hop wireless systems with multiple relays, where a message is first transmitted from its source to a selected relay and then forwarded by the relay to its destination under the detection of passive warden. We explore in detail the relay selection issue and propose two different relay selection protocols for this system. For evaluating the performance of covert communication, we develop a theoretical framework to analyze the transmission outage probability, detection error probability and covert capacity for a given relay selection protocol, and also explore the covert capacity maximization through efficient numerical searches under the condition of covertness requirement.

We then introduce cooperative jamming technology into relay-assisted wireless systems to interfere with the warden. In order to determine the forward relay and the jammer, we propose new relay/jammer selection protocols in the system. In order to explore the impact of cooperative jamming on the performance of covert communication, we introduce a jam-generating threshold into the theoretical analysis and further derive the expressions for the three performance metrics.

Finally, we extend our study to the scenario where the warden will actively attack the communication process as a jammer in relay-assisted wireless systems. We redefine the behavior of the warden that it will perform detection and jamming throughout the covert communication process.

To deeply understand such interactions, based on the two relay selection protocols designed previously, we develop a new theoretical framework to analyze the transmission outage probability, covert capacity and detection error probability of warden. We also explore the covert capacity optimization through power control under the covertness and outage requirements.

・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 insights.

1. It is expected that the proposed relay selection protocols and related theoretical models will provide an important guideline for the design of covert communication systems in practical applications.
2. The results obtained in this thesis can inspire subsequent theoretical researches on the study of the covert communication in two-hop wireless systems with multiple relays.