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Research on Secure Physical Layer Transmission Assisted by Intelligent Reflective Surfaces

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ABSTRACT: Intelligent Reflecting Surface (IRS) consists of large-scale low-cost passive reflective elements that can reflect and change the base station beam by changing the phase of the reflective units, thus enhancing the security of the physical layer of wireless communications. In the communication system, we will use the security rate to compare the confidentiality performance of a certain transmission signal. In this paper, we study the optimization problem of maximizing the security rate, and propose an alternating iteration method to decompose the problem which has more dimensions and the parameters are coupled with each other, and then design a suitable solution for each phase. Simulation results show a reduction in complexity and a greater advantage in the performance of the designed algorithm.

KEYWORDS: Smart Reflective Surface, Physical Layer Security, safe speed, alternating iteration

I. INTRODUCTION

In recent years, information technology has been developing rapidly, and the ownership of 5G (5th Generation Mobile Communication Systems, 5G) mobile devices has shown explosive growth. By the end of 2023, the number of 5G cell phone users reached 754 million, accounting for 43.7% of cell phone users. By the end of 2023, there will be 754 million 5G mobile phone subscribers, accounting for 43.7% of mobile phone subscribers. At the same time, there are higher requirements for the speed, diversity and security of information transmission.

With the large-scale commercialization of 5G technology, Intelligent Reflecting Surface (IRS) as a new type of communication hardware device has received extensive attention from academia, large technology enterprises, and so on. Intelligent Reflecting Surface (IRS) is a planar surface consisting of a large number of low-cost passive passive reflective elements placed between the base station and the user. Since each element can independently change the phase (or/and) amplitude of the incident signal, smart reflective surfaces can be utilized to enable the user to better receive signals sent from the base station, which can significantly improve the performance of wireless communication network technology, and have great application prospects in the field of secure communication and physical layer security in the future 5G.

The traditional wireless communication network in the information transmission security technology is usually based on cryptography application layer security transmission technology, the technology has long played an important role in the communication network technology, the main principle is to use encryption algorithms to encrypt the transmission signal, the signal receiver must be decrypted through the key to the signal to obtain the transmission information, due to the broadcasting characteristics of the technology, if the eavesdropper obtains the electromagnetic signal. Even if the key is not obtained, the electromagnetic signal cannot be decrypted directly, but due to the high-speed development of electronic computer hardware, the possibility of the key being deciphered is greatly increased under the calculation of some specific algorithms or compute r endless enumeration. Therefore, the traditional cryptography-based security technology for information transmission in wireless communication networks has been greatly challenged. In this case, a more excellent encryption method should be used to solve the security problems in the field of wireless communication at present and in the future, which has become the consensus of the community, in which the physical layer secure transmission technology based on the principle of wireless communication has received wide attention.

Based on the above analysis, this paper targets the IRS-assisted physical layer transmission system with the objective of optimizing the maximum security rate, and the results show that compared with the existing schemes, this paper's scheme achieves better results in terms of computational complexity and system security rate enhancement.

II. OPTIMIZATION PROBLEM FOR MAXIMIZING SAFE RATE AND ITS MATHEMATICAL REPRESENTATION

The optimization problem of maximizing the security rate is an important task in the design of secure transmission at the physical layer, which aims to optimize the system parameters in order to maximize the security of data transmission.

A. Optimize problem description:

In physical layer secure transmission, the optimization problem of maximizing the secure rate can be formulated as follows: given a sender, a receiver, and a potential hostile eavesdropper, the transmission parameters (e.g., transmit signal power, reflection coefficients, etc.) are reasonably designed to maximize the secure rate of the system under the premise of ensuring the reliability of the data transmission, i.e., even if an eavesdropper is unable to efficiently decode the transmitted information.

B. mathematical model

Suppose that in a multi-user communication system, the sender transmits information to the receiver with the presence of potential eavesdroppers. The maximization of the security rate can be expressed by the following optimization problem:

$$\max \quad \gamma_{secure} = W/B\log_2(1+P_r/(P_e+P_i))$$

W: channel bandwidth;

B: noise power spectral density;

Pr: received signal power;

Pe: channel estimation error of the legitimate user;

Pi: channel estimation error of eavesdropper.

Constraints include:Limits on the power of the transmitted signal Pt;Limitations on the amplitude range of the reflection coefficient h;Data transmission reliability requirements.

This design adopts the alternating iteration method to solve the above optimization problem. By adjusting the parameters such as transmit signal power and reflection coefficient, the system can reach the maximum safe rate under the premise of ensuring safe transmission, thus improving the safety and efficiency of the system.

III. SECURE PHYSICAL LAYER TRANSPORT DESIGN BASED ON ALTERNATING ITERATION

Alternating iteration based secure transmission design for the physical layer usually involves information transfer and interference injection between the sender, receiver and eavesdropper to achieve reliable communication and protect the content of the communication from being accessed by the eavesdropper. The following is a framework for alternate iteration based secure transmission design for physical layer:

A. system model

Consider a wireless communication system with a sender (Alice), a receiver (Bob), and an eavesdropper (Eve), where Alice wants to transmit information securely to Bob while preventing Eve from eavesdropping.

B. algorithmic step

Step 1: Communication between sender and receiver

Alice selects the message to be sent and encodes it into a sequence of symbols. Alice sends the sequence of symbols over the wireless channel to Bob, who receives the signal and tries to decode and recover the original message.

Step 2: Interference injection by eavesdroppers

Eve intercepts the signal transmitted over the wireless channel and tries to decode the message; Bob sends a jamming signal to interfere with Eve's decoding process so that it cannot accurately decode the original message.

Step 3: Alternate Iterative Optimization

Based on the feedback from Bob and Eve, Alice adjusts the signaling strategy of the transmitter to maximize Bob's reception quality and minimize Eve's reception quality; by alternately iterating the optimization algorithm, the signaling strategy of the transmitter is repeatedly adjusted until the balance between secure transmission and high quality reception is reached.

C. Optimization goals

Maximize the received SNR of Bob to ensure high quality reception; minimize the received SNR of Eve to make it difficult for eavesdroppers to decode the original message. Through the alternating iteration optimization algorithm, the signal strategy at the transmitter side is optimized to achieve secure transmission and efficient communication. The physical layer secure transmission design based on alternating iteration can be effectively optimized to maximize the security rate and improve the security and quality of communication, which has very broad applications.

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