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Research on Performance of Multi-hop Cooperative Transmission Scheme for Internet of Things

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Abstract: This paper presents a new cooperative transmission scheme for relay enhancement between source node and destination node for the scenario of multi-hop transmission in Internet of Things (IoT) system. Simulate and analyze the performance of the three transmission schemes to compare and obtain the optimal solution for multi-hop collaborative transmission over the Internet of Things. The transmission scheme from the source node to the destination node considers a total of three transmission methods, including line-of-sight (LOS) transmission, multi-hop cooperative transmission and optimal relay selection transmission. All communication channels use the Nakagami-m channel. All schemes communicate through multiple diversity paths. The destination node obtains the received signal by maximal ratio combining. Finally, the simulation compares the error rate and outage probability of the three system transmission schemes. It is concluded that the optimal transmission scheme of the Internet of Things coordinated communication system is the maximum ratio combining scheme of line-of-sight and optimal relay selection.
Keywords: Multi-hop relay, Internet-of-things (IoT), outage probability, bit error rate (BER).

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1. INTRODUCTION

At present, the Internet of Things has become an integral part of the fifth generation of mobile communications (5G) system. For example, the Internet of Things can provide a large number of access nodes for wireless services in a 5G Ultra-dense Network(UDN) scenario[1][2].According to reports, the number of IEEE papers on the Internet of Things has exceeded 3,000, and the number of journal papers has exceeded 600.For example, radio frequency identification (RFID) as an IoT reader has been studied both in the physical layer and the MAC layer[3],in which a soft defined radio (SDR) platform is used to ensure tag identification. The time delay ,the cost and performance trade-offs of selecting platforms in the Internet of Things have been proven[4].In the literature, intelligent manufacturing with real-time traceability was studied through the Internet of Things[5], in which the author proposed a production performance analysis and abnormality diagnosis model. In the literature, the author reviewed the channel access protocol of the IoT system and discussed the ALOHA protocol in detail[6].All these findings show that the Internet of Things has good performance in wireless communication. However, there is currently no research on the probability of outages and bit error rate analysis of the Internet of Things subject to Nakagami distribution for wireless channels from the source node to the destination node.

In the existing wireless communication systems, there are many studies on the performance analysis of Multi-hop relay systems, but there are fewer analysis on the interruption probability and error rate performance of the Internet of Things. Compared with traditional networks, Multi-hop Cooperation Relaying System (MCRS) has many advantages, such as improving system connectivity and increasing system capacity. In a Multi-hop wireless communication system, the source can communicate with the terminal through a large number of relay nodes, especially for long-distance communication, the transmission power can be significantly reduced and the reliability of the wireless link can be improved in [4]-[7].There is literature studied multi-hop and multi-branch relay cooperation systems that use amplify-and-forward protocol and have non-regenerative fixed gain[7].The performance of multi-hop relay systems in Nakagami-m fading channels, such as end-to-end SNR, outage probability, and average bit error rate are studied in[8].In [9],the average mis-symbol rate and outage probability of Multi-hop cooperative relay networks under Generalized-K fading channels are studied. In [10], the performance expression of Amplify-and-Forward (AF) relay system is obtained by using Generalized Transformed Characteristic Function (GTCF). The literature [11] uses statistical theory to analyze the performance of multi-hop relay systems. There are also some literatures on the relay forwarding method. The literature [12] discusses the ergodic capacity of a wireless relay system using Decode-and-Forward (DF). From the literature [13], we obtain that compared with the corresponding systems with fixed DF, selective DF and selective AF, the multi-hop diversity transmission system with fixed AF relay has better performance. All of the above studies have applied only one relaying protocol. In [14], two relaying protocols were tested by deriving the expression of outage probability. Nath et al. conducted a theoretical analysis of two-hop wireless communication systems from [15]-[17], in which performance analysis was based on different assumptions. However, these research results only analyze a certain transmission scheme of a multi-hop relay system and do not compare and analyze various transmission schemes. Therefore, it is impossible to know which transmission scheme will have the best transmission performance. The contribution of this paper is to provide a variety of multi-hop relay cooperative transmission schemes under the Nakagami-m channel and through the performance simulation (outage probability and bit error rate) to obtain a relatively optimal relay cooperative transmission scheme.

The structure of this paper is as follows: The second part introduces three system transmission schemes for multi-hop relay wireless communication of the Internet of Things. In the third part, the proposed three system transmission schemes are simulated and analyzed. Finally, the fourth part summarizes the full text.

2. SYSTEM TRANSMISSION SCHEME

This section presents three system transmission schemes for multi-hop cooperative relay networks.

The first scheme consists of an optimal relay-selection path and a multi-hop relay path. The multi-hop relay path consists of $\bar{N}-1$relays, a source S, and a terminal D. Studies have shown that Max-Min's relay selection scheme, which maximizes the signal-to-noise ratio (SNR) of the smaller link, is a near-optimal selection strategy [18].So, we choose the relay path to maximize the smaller link SNR strategy selects the relay for communication, as shown in fig.1.In the first time slot, the source S sends a signal to the cooperative relay node. The first relay node of the multi-hop path and the relay of the selected path receive the source signal at the same time. In the second time slot, the relay node of the relay-selection path amplifies and forwards the received signal to the destination node D.At the same time, the first relay node of the multi-hop path amplifies and forwards the signal received from the source end to the second relay, and so on. In the $\bar{n}$ ($\bar{n}=2,3,...\bar{N}-1$)th time slot, the $\bar{n}-1$th relay amplifies the received signal and then forwards it to the $\bar{n}$ th relay node. Finally, in the $\bar{N}$ th time slot, the $\bar{N}-1$th relay node amplifies the received buffer signal and then forwards it to the destination.

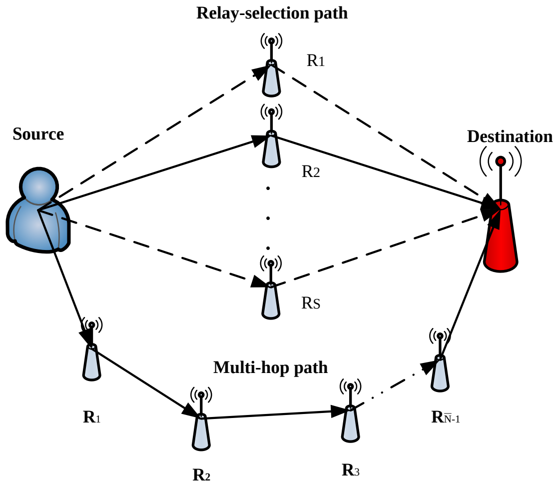

Figure 1. The first type of relay cooperative system transmission

The second scheme consists of a line-of-sight path and a multi-hop relay path. The multi-hop relay path consists of $\bar{N}-1$ relays, a source(S), and a destination node(D), as shown in Fig.2.In the first time slot, the source sends a signal to the first relay node and the destination receives the signal sent by the source through the wireless channel. This is usually ignored by most existing methods in the literature. In the $\bar{n}$ ($\bar{n}=2,3,...\bar{N}-1$)th slot, the $\bar{n}-1$th relay node amplifies the received buffer signal and then forwards the signal to the $\bar{n}$ th relay node. Finally, in the $\bar{N}$ th time slot, the $\bar{N}-1$th relay node amplifies the received signal and forwards to the destination. The destination receives signals from two branches of the LOS and multi-hop relay paths, respectively. The relay node adopts the amplifying and forwarding protocol and all nodes are configured with a single antenna. At the destination, we adopt the maximum ratio combining technique to combine the signals of these two branches to maximize the SNR at the receiving end.

The third scheme consists of an optimal relay-selection path and a LOS path. As in scenario 1, selecting the relay path uses a SNR (signal to noise ratio) strategy to maximize the smaller link. The relay path for communication is shown in Fig.3.In the first time slot, the source S sends a signal. The selected relay and destination node D receive the source signal at the same time. In the second time slot,the relay node of the selected path amplifies and forwards the signal received from the source to the destination node.The final destination receives two signals from the direct path and the selected path. At the destination, the signals of the two branches are combined by the maximum ratio combining technique.

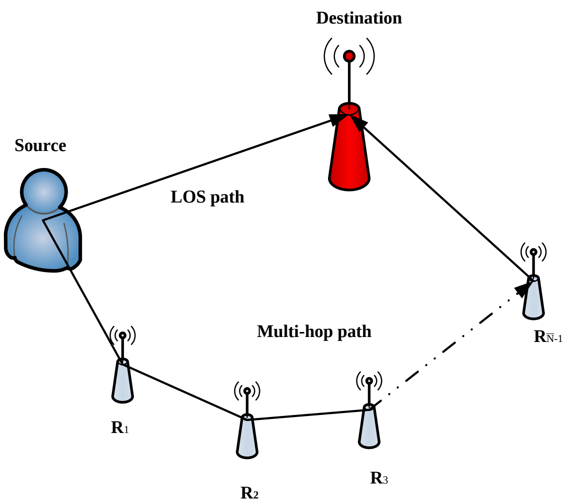

Figure 2. The second relay cooperative system transmission

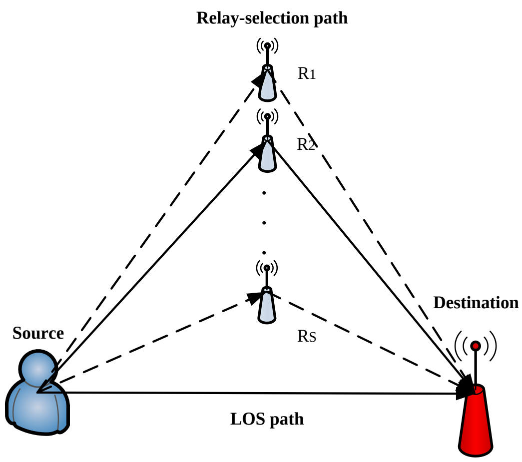

Figure 3. The third relay cooperative system transmission

3. SIMULATION ANALYSIS

This section simulates and contrasts the three kinds of Internet of Things Multi-hop cooperative relay network system transmission scheme, in which the coding modulation method uses BPSK. Assuming that the transmission power of the source node and the relay node are the same, all channels obey the Nakagami-m distribution. In the three transmission schemes, the number of hops of the multi-hop cooperative link from the source node to the destination node is set to three hops. Selecting the relay path obtains the communication link by maximizing the SNR strategy of the smaller link. All relay nodes adopt the amplifying and forwarding protocol and are equipped with a single antenna. The destination nodes of the three schemes use the maximum ratio combining to obtain the received signal.

As shown in Figure 4, we simulated the outage probability of the three schemes when m=1.The results show that scheme 3 with direct path and optimal relay-selection path has the lowest probability of outage. Scheme 1 with path selection and multi-hop path performance is lower than scheme 3, scheme 2 with direct path and multi-hop path performance is the worst.

As shown in Figure 5, we have obtained the error rates of the three proposed transmission schemes. As can be seen from the figure, scheme 3 (direct path and optimal relay-selection path) has the smallest bit error rate under the same m value. Scheme 1 (optimal relay-selection path and multi-hop path) has the highest bit error rate. Under the same transmission scheme, comparing different m values, it is found that the larger the m value, the lower the system error rate. This is because the larger the value of m, the more obvious the effect of direct path and the better the performance of the system.

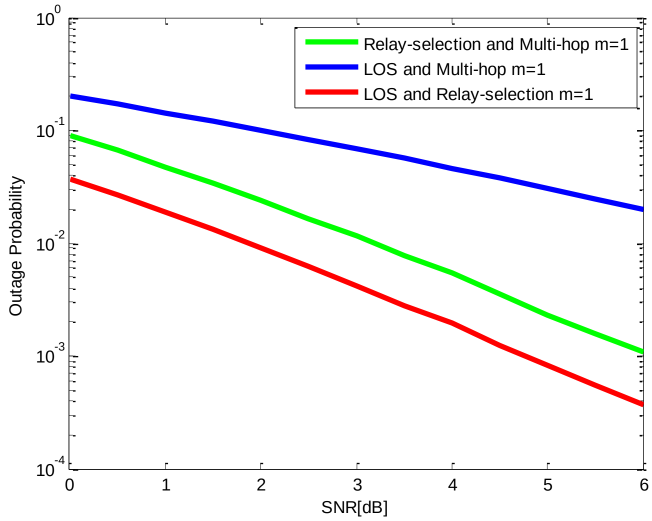

Figure 4. Outage probability of three transmission schemes with m=1

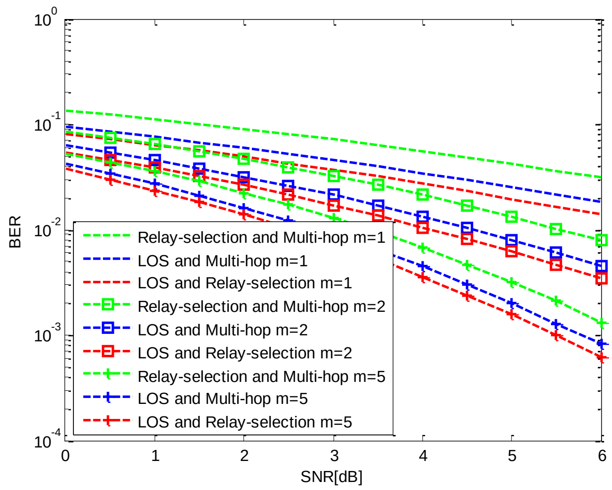

Figure 5. Bit error rates of three transmission schemes with different m values

4. CONCLUSION

In this paper, three kinds of IOT multi-hop relay cooperative network transmission schemes are presented. The three transmission schemes are introduced in detail and their performance is simulated and analyzed. The results show that under the same conditions, the scheme 3 with direct path and optimal relay-selection path has the best transmission performance. It can also be seen that as the value of m increases, the system's bit error rate is lower. It is worth noting that the research on configuring multiple antennas for different nodes and considering relay node error propagation will serve as the next step in this paper.

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