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Research on Maximum SNR Relay Selection Algorithm Based on Channel Prediction

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Abstract: As one of the key candidate technologies for 5G, D2D communication technology can solve the problem of excessive data traffic caused by excessive number of mobile devices to a certain extent. Aiming at the problem of channel quality deterioration and communication interruption caused by the large distance between D2D communication parties, a relay selection algorithm based on maximum SNR channel prediction is proposed. Firstly, the relay set is established for the correctly decoded relay; Secondly, the channels in the relay set are predicted according to the existing MMSE algorithm, and a set of channel coefficients are obtained to calculate the SNR of each relay link; Finally, the one with the maximum SNR is selected as the optimal relay for forwarding. Simulation results show that the outage probability of the proposed algorithm is about 2 to 3 orders of magnitude lower than that of the random relay selection algorithm.

1. Introduction

The development of 5G technology has promoted the in-depth development of new information technology, resulting in the explosive growth of data traffic and the emergence of many high-bandwidth applications, which have brought a heavy burden to base stations [1,2] . D2D technology is one of the important candidate technologies for 5G, which can provide high-quality solutions to a certain extent and directly carry out terminal communication [3]. However, the communication distance of D2D is very short, and the signal transmission needs a lot of energy, so D2D relay technology is introduced to provide better service quality. D2D relay technology is to add another device as a relay node between two devices to assist their communication, which can reduce the interference to the cellular system and expand the network coverage [4]. Literature [5] proposes a random relay selection algorithm that does not need to consider the location of relay nodes. Based on the principle of probability, this algorithm can arbitrarily find a device as a relay to complete communication for any user who has a communication item. Literature [6] proposes an opportunistic relay algorithm, which determines whether to allow relay nodes to participate in cooperative transmission by introducing a new weight. Compared with existing algorithms, it improves system performance and reduces network overhead. In literature [7], a D2D single relay selection algorithm is proposed, and the algorithm is applied in different scenarios to determine the relay according to the relay set. Although the optimal trunk can be obtained, the use of the link is not specified. Literature [8] proposes a relay selection algorithm based on channel state Information

(CSI). In this algorithm, due to the difference of channel state in relay selection and forwarding, the performance of this algorithm has certain drawbacks. Based on location information and channel state information, literature [9] proposes a D2D relay bidirectional selection algorithm to reduce system complexity and improve network capacity on the premise of ensuring communication performance. In literature [10, 11], a relay algorithm based on AF forwarding is proposed, and the results show that this algorithm can improve the signal-to-noise ratio of the system. However, this algorithm aims at information amplification and will amplify all signals together, thus reducing the performance of the system when there are multiple users.

Based on this, in order to reduce the interruption probability of D2D relay communication and improve the reliability of communication, this paper decodes the relay and forms the relay set. Secondly, based on the MMSE algorithm, the channel coefficients in the relay set are predicted to calculate the signal-to-noise ratio of the relay link. Finally, the relay with the highest SNR is selected as the optimal relay for forwarding.

2. D2D Relay System Model and Performance Analysis

2.1. System Model

As shown in Figure 1, the system model of relay-assisted cellular communication is schematic diagram. The model includes S、N possible relay nodes $R_i(i=1,2,3,...,n)$ and a destination node T_i Assume that there is no interference between links and no interference between relay points. In the first slot, $R_i(i=1,2,3,...,n)$ receives the signal from S. In the second slot, $R_i(i=1,2,3,...,n)$ first decodes the signal, then re-encodes it and transmits it to the destination node T_i

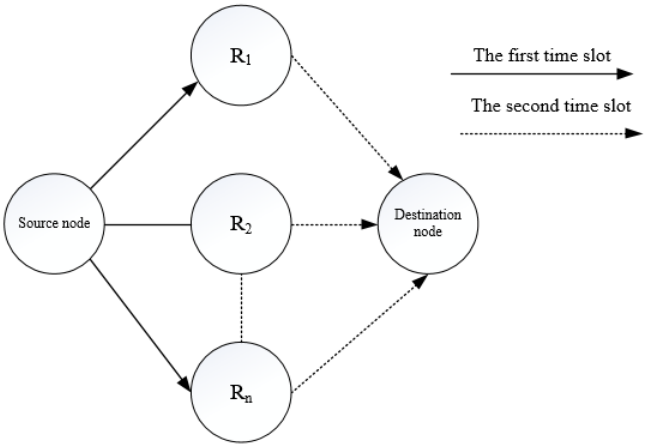

Figure 1: System model diagram of trunk - assisted cellular communication

2.2. D2D Relay Communication Performance Analysis

Since the amplification and forwarding mode does not decode and encode the received signal, the signal is directly transmitted to the destination node. During amplification, both noise and useful signals are enhanced, resulting in error propagation. If the decoding fails, the next encoding and forwarding will not be performed. Signals received by relay node R_i and destination node T_i are expressed as:

$$y_R = h_{sr} x \sqrt{P_s d_{sr}^{-\alpha}} + n_0 \tag{1}$$

$$y_T = h_{rt} x \sqrt{p_r d_{rt}^{-\alpha}} + n_0 \quad (2)$$

Where y_R represents the signal received by the relay node Ri from the source node, x is the transmitted signal of the source node, h_{sr} is the gain coefficient between the source node and the relay node, n_0 is the white Gaussian noise, N_0 is the power, P_s is the transmitted power of the source node, d_{sr} is the distance between the source node and the relay node, and α is the path index.

According to Formula (1), the maximum signal-to-interference-to-noise ratio (SINR) of relay user node in the first time slot is:

$$\gamma_{sR} = \frac{|h_{sr}|^2 P_s d_{sr}^{-\alpha}}{N_0} \quad (3)$$

According to Equation (2), the maximum signal-to-interference-to-noise ratio (SINR) of the end-user node in the second time slot is:

$$\gamma_{RT} = \frac{|h_{rt}|^2 P_r d_{rt}^{-\alpha}}{N_0} \quad (4)$$

The SNR of relay link depends on the part with poor communication link, so the total received SNR γ_{DF} in DF forwarding mode can be expressed as:

$$\gamma_{DF} = \min(\gamma_1, \gamma_2) \quad (5)$$

3. D2D Relay Selection Algorithm

3.1. Principle of Algorithm

Based on MMSE algorithm, this paper studies the relay selection algorithm of maximum SNR based on channel prediction.

Based on MMSE algorithm, channel prediction is carried out. Set samples for the current channel.

$h_{s,i}(n)$, based on the former sample k channel $h_{s,i}(n)$、$h_{s,i}(n\text{-}1)$、......、$h_{s,i}(n\text{-}k-1)$ makes MMSE prediction for channel $h_{s,i}(n+l)$, and obtains:

$$\tilde{h}_{s,i}(n+l) = \sum_{m=1}^{k} u_m h_{s,i}(n+1-m) \quad (6)$$

Which $h_{s,i}(n+l)$ to predict the channel coefficient, k as the forecast order, and have $J^{-1}r = [u_1, u_2, ..., u_k]^T$, Where J is the p×p autocorrelation matrix, r is the k by 1 autocorrelation vector, the coefficients are respectively:

$$J_{vm} = E[h_{sr}(n-v) h_{sr}^*(n-m)] \quad (7)$$

$$r_m = E[h_{sr}(n+l) h_{sr}^*(n+l)] \quad (8)$$

The channel coefficient is predicted by MMSE, which can be substituted into formulas (3) and (4) to obtain the predicted SNR from source node to relay point:

$$\tilde{\gamma}_{r,t} = \frac{P_s |\tilde{h}_{sr}(n+l)|^2}{N_0} \tag{9}$$

The predicted signal-to-noise ratio from the relay node to the destination node is:

$$\tilde{\gamma}_{r,t} = \frac{P_r |\tilde{h}_{rt}(n+l)|^2}{N_0} \tag{10}$$

By combining equations (5), (9) and (10), it can be deduced that the signal-to-noise ratio of the relay link is:

$$\tilde{\gamma}_{s,r,t} = \min(\tilde{\gamma}_{s,t}, \tilde{\gamma}_{r,t}) = \min(\frac{Ps |\tilde{h}_{sr}(n+l)|^2 d_{sr}^{-\alpha}}{N0}, \frac{\Pr |\tilde{h}_{rt}(n+l)|^2 d_{rt}^{-\alpha}}{N0}) \tag{11}$$

When the destination node and the source node communicate directly without D2D relay, the received signal-to-noise ratio of the destination node is:

$$\tilde{\gamma}_{s,t} = \frac{P_s |\tilde{h}_{st}(n+l)|^2|}{N_0} \tag{12}$$

According to formula (11), the SNR and predicted SNR of D2D relay communication links can be calculated, and the link with the maximum SNR in the calculation set is selected as the optimal trunk:

$$\begin{cases} r_{i,j}^* = \arg\max\{\tilde{\gamma}\} \\ \tilde{\gamma} = \min(\tilde{\gamma}_{s,r}, \tilde{\gamma}_{r,t}) \end{cases} \tag{13}$$

$r_{i,j}^*$ is the optimal relay node selected for forwarding.

3.2. Algorithm Description

The algorithm flowchart is shown in the figure 2.
The algorithm steps are as follows:
(1) Determine random relay set $R_i(i=1,2,...,n)$;
(2) The relay decodes the received signal;
(3) For the successfully decoded relay, establish a relay set $R_r(i=1,2,...,m), m<n$;
(4) Prediction of Channel Gain Coefficients Using MMSE Channels $h_{s,i}(n+l)$
(5) The SNR $r_{i,j}^*$ is calculated by the predicted channel gain coefficient
(6) Select the relay with high signal-to-noise ratio $r_{i,j}^*$ as the optimal relay.

3.3. Performance Description

From Formula (11), it can be known that the predicted signal-to-noise ratio of the relay link is:

$$\tilde{\gamma}_{s,r,t} = \min(\frac{Ps |\tilde{h}_{sr}(n+l)|^2 d_{sr}^{-\alpha}}{N0}, \frac{\Pr |\tilde{h}_{rt}(n+l)|^2 d_{rt}^{-\alpha}}{N0}) \tag{14}$$

The Shannon formula is:

$$C = B\log_2(1+\gamma) \tag{15}$$

Taking Formula (14) into Formula (15), we can get the channel capacity of the predicted link as follows:

$$\tilde{C} = B\log_2\{1+\min\frac{Ps\,|\,\tilde{h}_{sr}\,|^2\, d_{sr}^{-\alpha}}{N0}, \frac{\Pr|\,\tilde{h}_{rt})\,|^2\, d_{rt}^{-\alpha}}{N0}\} \tag{16}$$

The relation between transmission rate R and system capacity C is compared, when $R > C$, the interruption probability of D2D relay communication is:

$$\begin{aligned} P_{out} &= \Pr[\frac{1}{2}\min\{\log_2(1+\tilde{\gamma}_{s,r}),\log_2(1+\tilde{\gamma}_{r,t}) < R] \\ &= \Pr[\frac{1}{2}\log_2(1+\tilde{\gamma}_{s,r}) < R] + \Pr[\frac{1}{2}\log_2(1+\tilde{\gamma}_{s,r}) \ge R]\Pr[\frac{1}{2}\log_2(1+\tilde{\gamma}_{r,t}) < R] \end{aligned} \tag{17}$$

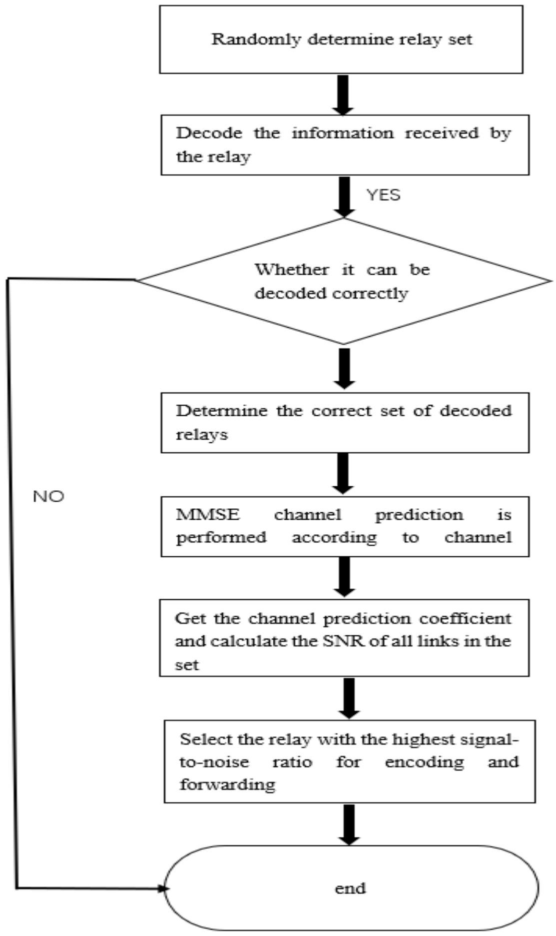

Figure 2: Flow chart of SNR relay selection based on channel prediction

4. Manuscript Preparation Simulated Analysis

4.1. First Section Parameter Configuration

This paper adopts MATLAB for simulation verification, and the specific simulation parameters are shown in Table 1:

Table 1: System simulation parameters selected by D2D relay

parameter	numerical
Radius of neighborhood R	50m
carrier frequency f_c	1GHz
Path loss factor α	6
white gaussian noise	-174dBm/Hz
D2D User distance	10 m
D2D bandwidth	180KHz
Channel impact facto H	0.63-3.6
Maximum transmit power (D2D user)	20 dBm

4.2. Parameter Configuration

In this paper, the random relay selection algorithm is used as a comparison algorithm to analyze the performance of the system. 100 Monte Carlo calculations were performed in the simulation, and the results are shown in Figure 3-6:

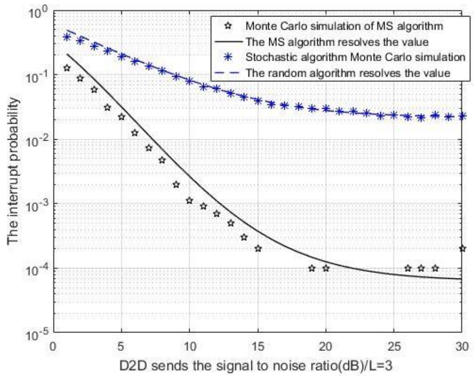

Figure 3: Outage probability of random relay selection algorithm

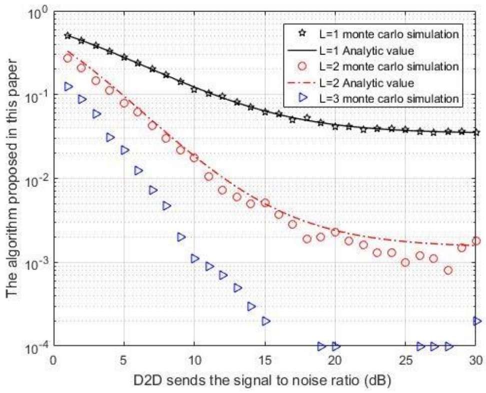

Figure 4: Outage probability of relay selection algorithm based on maximum SNR

Figure 3 and Figure 4 are interrupt probability graphs of random relay selection algorithm and maximum SNR relay selection algorithm respectively. As can be seen from the figure, the interrupt probability of relay selection algorithm gradually decreases with the increase of SNR. In addition, the interrupt probability decreases with the increase of the number of trunks, because the more trunks there are, the more trunks can be selected, and the probability of selecting a high-quality trunk also increases. However, when the number of relays is large enough, the interrupt probability does not change with the number of relays. This is because the interrupt probability is fixed. However, the interrupt probability tends to be stable when the number of successors reaches a set threshold, because the optimal relay can be extracted from the set once the number of successors is determined. Therefore, the probability of system interruption can be reduced effectively when the number of successors is high.

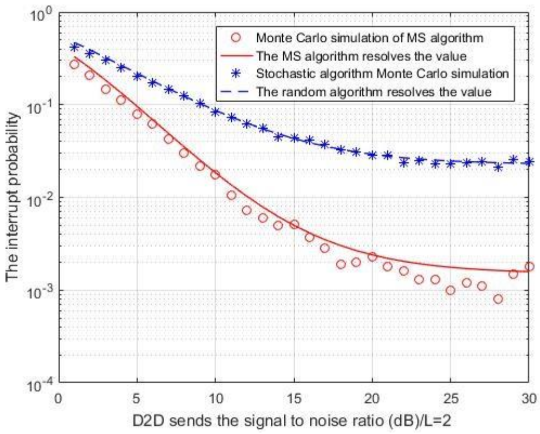

Figure 5: Outage probability of two different relay selection algorithms

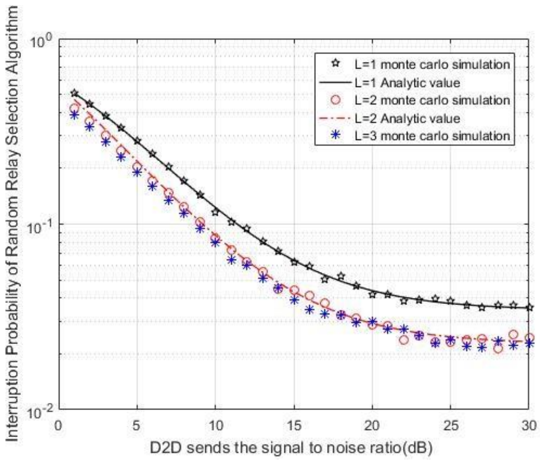

Figure 6: Outage probability for two different relay selection algorithms

Figure 5 and Figure 6 show the interrupt probabilities of the two algorithms when the number of relay nodes is 2 and 3 respectively. It can be seen that the interrupt probability of the MSRC algorithm proposed in this paper is far less than that of the random relay selection algorithm, and the interrupt probability is reduced by nearly two orders of magnitude. Simulation results show that MSRC can reduce the interrupt probability and improve the stability of the system.

5. Conclusions

This paper presents a relay selection algorithm based on channel prediction for maximum SNR. The simulation results show that compared with the random relay selection algorithm, the relay selection algorithm proposed in this paper can effectively reduce the interrupt probability of the system, effectively reduce the interrupt time of the system, and effectively solve the problem of channel quality deterioration and communication interruption.

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