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A cooperative user selection scheme based on energy efficiency and interference factor in cooperative communication systems①

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Abstract

With the rapid development of green communications, energy consumption issue plays more and more important role in cooperative communication strategies and communication systems. Based on cooperative transmission model, a cooperative user selection scheme is proposed in consideration of both energy efficiency and interference factor. With the proposed scheme, the selected cooperative user consumes less energy and receives less interference. Furthermore, the main factor is analyzed to affect system performance, including signal-to-noise ratio (SNR) of source user and cooperative user, distance between source user and cooperative user or base station (BS), and fading factor in the transmission model. Through the proposed scheme, energy consumption and influence of interference are jointly taken into account during the cooperative user selection process. Besides, bit error rate (BER) in proposed scheme is also superior to existing schemes. Simulation results are presented to show the performance improvement of the proposed scheme.

Key words: green communication, cooperative communication, energy efficiency, interference factor

0 Introduction

Research of cooperative communication needs date back to 50 years ago. The cooperative communication system is similar to the MIMO system, which can make a single antenna of mobile station to obtain energy gain. The basic idea is that the mobile station which has a single antenna can follow a certain way to share the antenna with each other in a multi-user communication environment. This method can create a virtual MIMO antenna system to obtain more energy gain[1].

Cooperative communication includes two main factors[1]: firstly, several idle mobile terminals (MTs) may exist in the network, but probably only a few mobile terminals have the communication requirements at the same time. Secondly, with cooperative communications, the service quality of the mobile terminals can be improved effectively[2]. Traditional cooperative communication schemes mainly aim to improve the capacity performance of a single source-destination pair with the help of single or multiple relays. Besides, much attention has been paid to wireless cooperative communication and relaying selection in previous work.

As concept of green communication has been introduced, more and more researchers notice that energy consumption and influence of interference in a cooperative communication system has always been ignored. Lots of references agree that the energy efficiency and the interference factor should be emphasized on communication network design[3-5]. Therefore, how to select a cooperative user with less energy consumption and less interference in cooperative communication systems becomes a hot topic.

There exist many methods on the energy efficiency issues of cooperative communications. A calculation method of energy efficiency is given in Ref. [3], the authors analyze the energy efficiency in different transmission models, such as direct transmission, two-hop transmission and decode-and-forward relay transmission. Ref. [4] proposes the total energy consumption for a general class of cooperative communication based on transmission schemes. The authors analyze the total energy consumption of data transmission for cooperative

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communication systems, and they optimize it over a more general class of relay selection criterion than those considered in the literature. Both Refs [3] and [4] emphasize the energy consumption in communication systems, however, the authors do not consider the influences of interference. Besides, the influence of the location between the source user and the cooperative user, and the fading factors are not adequately considered. Ref. [5] proposes a distributed cooperative topology control scheme with opportunistic IC (COIC) to improve network capacity in WANETs by jointly considering both upper layer network capacity and physical layer cooperative communications with interference cancellation. Ref. [6] considers energy-efficient transmit power control for uplink multiuser SIMO systems when the BS has imperfect CSI using a game-theoretic approach. The proposed energy-efficient uplink power control game is shown to have at least one Nash equilibrium. But neither of the authors have discussed the energy efficiency in cooperative communication systems. Based on the minimum total path loss selection method, Ref. [7] proposes a scheme for cooperative relay selection. But it also does not consider the energy efficiency and the influence of interference in the process of cooperative transmissions.

Aimed to improve the energy efficiency and decrease the influence of interference in cooperative communication systems, a cooperative user selection scheme is proposed, which utilizes the energy efficiency and the interference factor as a selection standard. In order to verify the proposed scheme, a cooperative communication model is considered which includes a special case and a common scenario. Refer to the concept of energy efficiency, a concept of interference factor is proposed, which describes the strength of the interference. Based on the cooperative communication model and the concept of energy efficiency and interference factor, an effective scheme to select the cooperative user is designed. This scheme includes two steps. In the first step, according to SNR, the distance between source user and cooperative user, and the fading factor, the scheme could determine the scope of the candidate cooperative users, the scope helps the cooperative user selection. In the second step, with the joint energy efficiency and interference factor, the optimal cooperative user from the set of candidate cooperative users is selected.

The rest of the paper is organized as follows. The cooperative transmission models of the proposed scheme are presented in Section 1. In Section 2, the concept of energy efficiency and interference factor are given, and a cooperative user selection scheme based on energy efficiency and interference factor is proposed. Simulation results are presented and discussed in Section 3. Finally, this study is concluded in Section 4.

1 Cooperation transmission model of the system

This section describes the transmission model with cooperative communication systems. And both energy efficiency and interference factor are considered to select the cooperative user in these transmission models.

1.1 Cooperative transmission model

Fig. 1 shows a typical model of three-node cooperative communication network. Cooperative communication process is in two time slots: in the first slot, the source user sends information to both cooperative user and BS simultaneously; in the second slot, the cooperative user receives the signal and processes it. Then the cooperative user will transmits the signal to BS. Finally, BS merges the two signals[8].

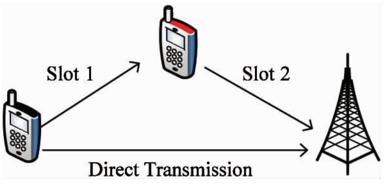

Fig. 1 Cooperative communication model of the three-node

The received signal y_{sd} at BS is specified as[9]

$$y_{sd} = \sqrt{P_1} h_{sd} x_s + n_{sd} \quad (1)$$

where x_s is the transmitted information symbol, P_1 is the transmission power of the source user, h_{sd} is the channel coefficient between the source user and BS and n_{sd} is the additive Gaussian noise, which obeys as zero-mean and unit variance.

The received signal y_{sr} at the cooperative user from the source user and the received signal y_{rd} at BS from the cooperative user are respectively specified as[10,11]

$$y_{sr} = \sqrt{P_1} h_{sr} x_s + n_{sr} \quad (2)$$

$$y_{rd} = \sqrt{P_2} h_{rd} x_r + n_{rd} \quad (3)$$

where P_2 is denoted as the transmission power of the cooperative user, h_{sr} is denoted as the channel coefficient between the source user and the cooperative user, h_{rd} is denoted as the channel coefficient between the cooperative user and the BS, x_s and x_r are denoted as the transmitted signals from the source user and the cooperative user, respectively. Besides, n_{sr} and n_{rd} are denoted as the additive white Gaussian noise for the cooperative user and BS, respectively. They follow the Gaussian distribution with zero-mean and unit variance.

1.2 Cell model

1.2.1 Special case

In order to decrease the computational complexity, simplify the environment of cooperative communication systems and verify the proposed algorithm clearly, a special case of cell models in a cooperative communication system is proposed, which includes $X(X=1,2,\cdots)$ source users, $Y(Y=1,2,\cdots)$ BSs and $Z(Z=1,2,\cdots)$ idle users. It is supposed that there has a straight line between the source user and BS, making a perpendicular bisector of this line. The Z idle users are equidistant distribution along with the perpendicular bisector in the cell. For the sake of simplicity, the cell model with $X=1$, $Y=1$ in the special case is presented. Besides, it is assumed each path in the cell with the conditions of same fading factor. An example of the special case is shown in Fig. 2. For the energy efficiency and the interference factor (the definitions will be listed in the following section) in cooperative communication systems, the special case has significant representation. However, this special case has particularity in daily life and it has limitation in communication systems. Therefore, without loss of generality, the common scenario will be discussed in Section 1.2.2.

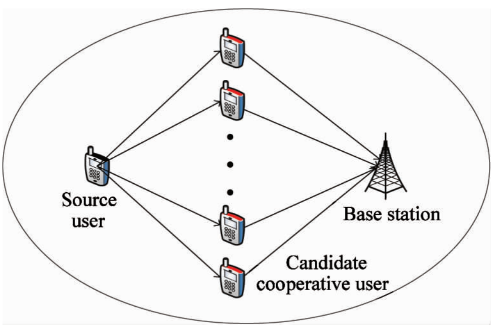

Fig. 2 The special case of cooperative communication model

Combining the cooperative transmission model in Fig. 1, it is assumed that the power of a source user is P_i, the candidate cooperative user receiving the power from source user P_{rn} can be expressed as

$$P_{rn} = P_i \cdot \left(\frac{l_n}{H_n}\right)^{-\alpha} \tag{4}$$

where l_n denotes the distance between the source user and the cooperative user, H_n is the antenna height, α is the path fading factor.

It is assumed that the environment of a cooperative user to BS is the same as the source user to the cooperative user. Therefore, the receiving power of BS P_{dn} can be expressed as

$$P_{dn} = P_{rn} \cdot \left(\frac{x_n}{H_n}\right)^{-\alpha} \tag{5}$$

where x_n is the distance from the cooperative user to BS.

According to Eqs (4) and (5), the receiving power of BS P_{dn} is deduced to

$$P_{dn} = P_i \cdot \left(\frac{l_n}{H_n}\right)^{-\alpha} \cdot \left(\frac{x_n}{H_n}\right)^{-\alpha} \tag{6}$$

In order to establish the relationship with transmission power and SNR, substituting Eq. (6) into the definition formula of SNR[12], the relationship between SNR, distance, power and fading factor can be expressed as

$$SNR = 10\log_{10}\left(\frac{P_i \cdot \left(\frac{l_n}{H_n}\right)^{-\alpha} \cdot \left(\frac{x_n}{H_n}\right)^{-\alpha}}{N}\right) \tag{7}$$

where N denotes the noise of the system. For the sake of simplicity, let $l_n = x_n = d$, the Eq. (7) can be simplified to

$$SNR = 10\log_{10}\left(\frac{P_i \cdot \left(\frac{d}{H_n}\right)^{-2\alpha}}{N}\right) \tag{8}$$

Based on Eqs (7) and (8), the scope of SNR, the distance between source user and cooperative user or BS, and the fading factors can be determined. In addition, if two parameters of SNR, distance and fading factor are determined, the scope of the third index can be calculated.

1.2.2 Common scenario

The special case has some limitations in cell models of a communication system, and it may not satisfy the realistic situation in the daily life. In order to analyze the universality and adaptability of the proposed algorithm, a common scenario is also considered which is similar to the realistic communication cell in daily life. Unlike the special case of cell models, in the common scenario, the Z idle users are randomly distributed in the cell. The distances between each candidate cooperative user are unequal. Meanwhile, the fading factor of each path may be different in this case. Besides, each candidate cooperative user has different channel environment. Therefore, the common scenario is similar to the actual environment. A common scenario of cooperative communication network is shown in Fig. 3.

In this case, the receiving power of the BS P_{dn} can be expressed as

$$P_{dn} = P_i \cdot \left(\frac{l_n}{H_n}\right)^{-\alpha_{n1}} \cdot \left(\frac{x_n}{H_n}\right)^{-\alpha_{n1}} \tag{9}$$

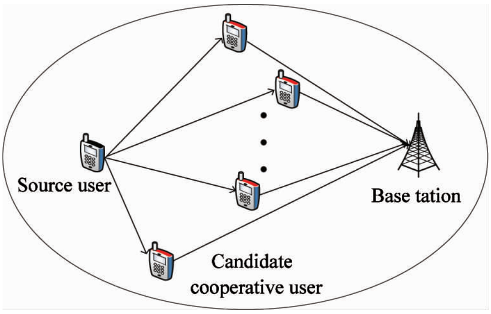

Fig. 3 The common scenario of cooperative communication model

where α_{n1} denote the path fading factor of source user to candidate cooperative users, α'_{n1} denote the path fading factor of candidate cooperative users to the BS.

According to Eq. (9), the relationship between SNR, the distance from the source user to the cooperative user, the power and the fading factor can be expressed as

$$SNR = 10\log_{10}\left(\frac{P_i \cdot \left(\frac{l_n}{H_n}\right)^{-\alpha_{n1}} \cdot \left(\frac{x_n}{H_n}\right)^{-\alpha'_{n1}}}{N}\right) \tag{10}$$

The conclusions about the relationship of SNR, distance between the source user and cooperative user and the fading factor in Section a) are similar to the condition in common scenario of the cell model. Besides, the conclusions in latter section are both suitable to the special case of the cell model and the common scenario of the cell model.

1.3 Analysis of bit error rate (BER)

In the proposed cell model of common scenario, the Gaussian interference model for fading channels provides the exact BER expression (as proven in Ref. [13]), the exact instantaneous BER expressions of source user to cooperative user and cooperative user to base station can be written respectively as

$$\begin{cases} P_S^R = Q\left(\sqrt{2\left|\left(\frac{l_n}{H_n}\right)^{-\alpha_{n1}}\right|^2 \cdot SNR}\right) \\ P_R^D = Q\left(\sqrt{2\left|\left(\frac{l_n}{H_n}\right)^{-\alpha_{n1}} \cdot \left(\frac{x_n}{H_n}\right)^{-\alpha'_{n1}}\right|^2 \cdot SNR}\right) \end{cases} \tag{11}$$

where P_S^R and P_R^D represent BER of source user to cooperative user and cooperative user to base station, respectively.

According to Refs [13] and [14], BER of proposed system model can be expressed as

$$Pe = P_S^R \cdot (1 - P_R^D) + P_R^D \cdot (1 - P_S^R) + P_S^R \cdot P_R^D \tag{12}$$

If the noise follow the Gaussian distribution with zero-mean and unit variance, Eq. (12) can be expressed as

$$\begin{aligned} Pe &= E[Q(\sqrt{2|h|^2 SNR})] \\ &= \frac{1}{2}\left(1 - \sqrt{\frac{SNR}{1+SNR}}\right) \approx \frac{1}{4SNR} \end{aligned} \tag{13}$$

2 Algorithm of energy efficiency and interference factor

The concept of "green communication" is more and more popular in the development of wireless communication, the energy consumption becomes a hot issue in cooperative communication systems. There is a trend that using less energy consumption in communication industry. Besides, the interference problems in communication system cannot be ignored, any wireless communication system exists interference problems. In exist green communication[15], more technologies concerning energy efficiency are considered by the researchers. However, the influence of interferences in communication system may be ignored. For example, in some cases, the cooperative user may consume less power, but the cooperative user receives more interference information. The scheme which ignores the interference may affect the reliability in cooperative transmission systems. Analogously, if the cooperative communication system may emphasize interference and ignore the energy consume, the energy may be wasted and the energy efficiency may be decreased. Therefore, a new effective scheme is proposed to select the cooperative user, the impact of energy efficiency and interference factor are considered in this scheme.

2.1 Energy efficiency

The study refers to the concept of energy efficiency which is given by Ref. [3], the energy efficiency is defined the achievable information transmission per Joule energy consumption with bit per Joule as the unit.

Given a transmission pair with transmission pattern $g(n)$, the total consumption of the transmission is $P_{g(n)}$, $C_{g(n)}$ is the achievable throughput in the transmission system. Energy efficiency $E_{g(n)}$ can be expressed as[3]

$$E_{g(n)} = \frac{C_{g(n)}}{P_{g(n)}} \tag{14}$$

For the transmission model in Section 1, let γ_{1n} and γ_{2n} denote the received SNR from the source user to the cooperative user and from the cooperative user to the BS, respectively. Therefore, the achievable link capacity can be expressed as[16]

$$\begin{cases} C_{g(n)} = \frac{1}{2}\min\{C_{SRn}, C_{RDn}\} \\ C_{SRn} = B\log_2(1 + \frac{1.5\gamma_{1n}\sigma^*}{0.2 - \sigma^*}) \\ C_{RDn} = B\log_2(1 + \frac{1.5\gamma_{2n}\sigma^*}{0.2 - \sigma^*}) \end{cases} \quad (15)$$

where σ^* is the target outage probability, which can be expressed as[17]

$$\sigma^*(P_{dn})^2 - (k_{1n} + k_{2n})P_{dn} + k_{1n}k_{2n} = 0 \quad (16)$$

In the special case, $k_{1n} = k_{2n} = \frac{N}{(d/H_n)^{-\alpha}}$; and in the common scenario, $k_{1n} = \frac{N}{(l_n/H_n)^{-\alpha_{n1}}}$, $k_{2n} = \frac{N}{(x_n/H_n)^{-\alpha'_{n1}}}$.

In the transmission model, three nodes are involved in the data transmission process. The process of communication has two transmission slots, there are two parts of power consumed. In the first time slot, the source user sends the information to both the cooperative user and the BS simultaneously.

In the second time slot, the cooperative user sends the information and the BS receives the information from the source user. The power can be expressed as[18,19]

$$\begin{cases} P_{slot1} = 2P_i + P_{rn} + P_{dn} \\ P_{slot2} = P_{rn} + P_{dn} \\ P_{g(n)} = P_{slot1} + P_{slot2} = 2P_i + 2P_{rn} + 2P_{dn} \end{cases} \quad (17)$$

Therefore, the energy efficiency in our proposed scheme can be expressed as

$$E_{g(n)} = \frac{\frac{1}{2}\min\{C_{SRn}, C_{RDn}\}}{2P_i + 2P_{rn} + 2P_{dn}} \quad (18)$$

2.2 Interference factor

In a communication system, there are many kinds of interference from other users and BSs. Especially, in a cooperative communication system, the cooperative user not only receives the signals from the source user, but also receives the interference signals from other users or other BSs. Therefore, the interference is not avoidant in a communication system.

Compared with the definition of energy efficiency, in this work, the concept of interference factor can be given as follows. The interference factor is defined to the interference information transmission per Joule energy consumption with bit per Joule as the unit. The concept of interference factor is aimed to accurately describe the situation of interference which is received by the source user and the cooperative users. With the interference factor, one can achieve the interference condition of each node in a communication system. Through the interference factor, the set of the candidate cooperative users which receive less interference signals can be determined, and the reliability of cooperative communication can be assured. The optimal cooperative user from the set of candidate cooperative users may be selected based on the interference factor, the interference factor plays an important role in a cooperative communication system.

Given a transmission pair with transmission pattern $h(n)$, compared with the energy efficiency, the definition of capacity and power can be defined as

$$I_{h(n)} = \frac{C_{h(n)}}{P_{h(n)}} \quad (19)$$

Let $C_{h(n)}$ denote the capacity of interference information, which includes the information from other transmitters. And the total power consumption of interference is $P_{h(n)}$[20,21].

For $C_{h(n)}$, it can be expressed as follows:

$$C_{h(n)} = B\log_2(1 + \frac{P_{rn}}{h^2_{m,n}P_{rn} + n_0}) \quad (20)$$

where P_{rn} denotes the power of cooperative user, n_0 denotes the channel noise power and $h_{m,n}$ denotes the path fading from the m*th* idle user to the cooperative user.

According to the path fading, $h_{m,n}$ can be expressed as[22]

$$h_{m,n} = \left(\frac{d_m}{H_n}\right)^{-\alpha} \quad (21)$$

where d_m denotes the distance from the m*th* idle user to the cooperative user.

For $P_{h(n)}$, it can be expressed as

$$P_{h(n)} = \sum_{m=1,\ m\neq n}^{N} h^2_{m,n}P_{rn} + n_0 \quad (22)$$

Therefore, the interference factor in this transmission model can be expressed as

$$I_{h(n)} = \frac{C_{h(n)}}{P_{h(n)}} = \frac{B\log_2(1 + \frac{P_{rn}}{h^2_{m,n}P_{rn} + n_0})}{\sum_{m=1,m\neq n,i}^{N} h^2_{m,n}P_{rn} + n_0} \quad (23)$$

Different from the concept of energy efficiency and Eq.(18), the interference factor is mainly considered by the candidate cooperative user which receives the interference signals from all the other users. Through calculating each interference factor of the candidate cooperative user, the interference condition of each candidate cooperative user can be obtained. Thereby the set of candidate cooperative users can be determined which satisfies certain constraints.

2.3 The proposed strategy

According to the energy efficiency and the interference factor, an effective scheme to select the cooperative user is proposed. Firstly, according to Eq. (8), the scope of the main parameters can be obtained, such as SNR, the distance between the source user and the cooperative user or BS and the fading factors. The number of users can be obtained which satisfies the scope of the main parameters. Secondly, the interference factor of the users will be calculated which is determined in the first step, and a set which includes the candidate cooperative users will be obtained and these candidate cooperative users are selected by the threshold of the interference factor. On this basis, the suitable cooperative user which has the maximum energy efficiency from the set can be selected.

The basic process of the proposed algorithm has two steps. In the first step, according to the interference factor, parameter β is set which denotes interference factor threshold of the candidate cooperative user. If $0 < I_m \leqslant \beta$, the users which match this condition can be selected as the candidate cooperative users, where I_m denotes the interference factor of the m*th* user. Set U of the candidate cooperative user can be expressed as $U = \{U_1, U_2, \cdots, U_m\}$.

In the second step, based on the energy efficiency, the candidate cooperative user is selected from set U which has maximum energy efficiency as cooperative user.

$$\eta = \underset{g(n) \in U}{\operatorname{argmax}}\left(\frac{C_{g(n)}}{P_{g(n)}}\right) \tag{24}$$

The flow diagram of the proposed strategy, with joint consideration energy efficiency and interference factor is shown in Fig. 4.

As mentioned above, the condition of the proposed objective function R_m is denoted as

$$R_m : \begin{cases} U : 0 < \dfrac{B \log_2\left(1 + \dfrac{P_{rn}}{n_0 + h_{m,n}^2 P_{rn}}\right)}{\sum\limits_{m=1, m \neq n}^{N} h_{m,n}^2 P_{rn} + n_0} \leqslant \beta \\ f(g(n)) = \underset{g(n) \in U}{\operatorname{argmax}}\left(\dfrac{C_{g(n)}}{P_{g(n)}}\right) \\ C_{g(n)} > 0 \\ P_{g(n)} > 0 \end{cases} \tag{25}$$

According to Eq. (25), in order to improve the energy efficiency and reduce the influence of interference, the energy efficiency and interference factor are proposed, respectively. Meantime, the objective function R_m is defined as an important index to select the cooperative user. Refer to Eq. (25), a set of the candidate cooperative user is determined at first, and if more than two candidate cooperative users satisfy the scope of $0 < I_m \leqslant \beta$, Eq. (24) is utiliyed to select the optimal cooperative user. Using this approach and based on the objective function R_m, the cooperative user can be selected.

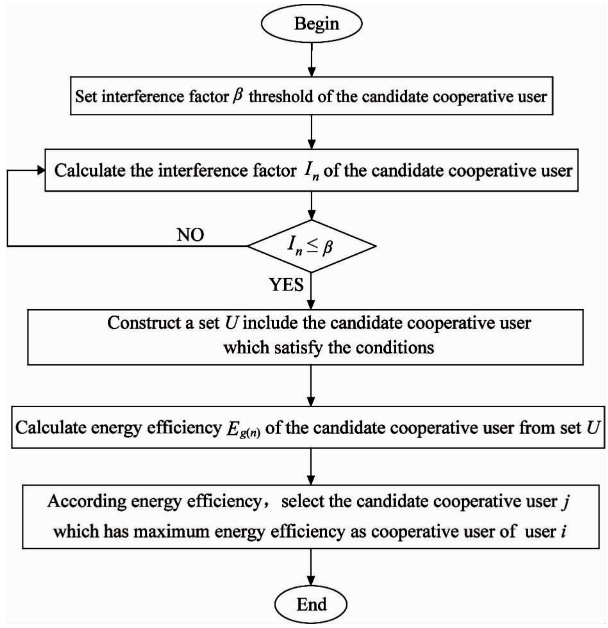

Fig. 4 The flow diagram of proposed strategy

3 Simulation results and discussions

This section simulates the proposed scheme of selecting cooperative user, uses the software which named MATLAB to simulate the results. Based on the special case of the cell model, the simulation results are divided into two parts, one is the relationship of the path loss factor, distance between the source user and the cooperative user, the number of cooperative users and SNR; the other is the influence of energy efficiency and interference factors. In order to discuss it easily, it selects the special case of the cell model as the simulation environment. Table 1 shows the main parameters of the system simulation environment[23].

Table 1 Parameters of the system simulation environment

Parameters	Description
Band width	10kHz
Distance of each idle user	50m
Distance between the source user and the cooperative user	2km ~ 7km
Path fading factor α	1:1:10
Threshold of SNR	5dB ~ 25dB
System noise	10dBm
Antenna height	1m
Transmission power	50W

In Fig. 5, the simulation results focus on different transmission style versus the energy efficiency. The results are simulated in three cases, the energy efficiency of cooperative user and base station in cooperative or direct transmission model, respectively. From Fig. 5, the energy efficiency with different transmission style still decreases with the increasing path fading factor in the cell. Meanwhile, the energy efficiency in cooperative transmission is better than in direct transmission. For example, if there have enough idle users in the cell, when the path fading factor reaches 3, the energy efficiency reaches about 0.085 in direct link, but the energy efficiency of cooperative user and base station in cooperative link can be reached to 0.11 and 0.097, respectively. The simulation results illustrate that the energy efficiency has the advantage in cooperative transmission than in direct transmission.

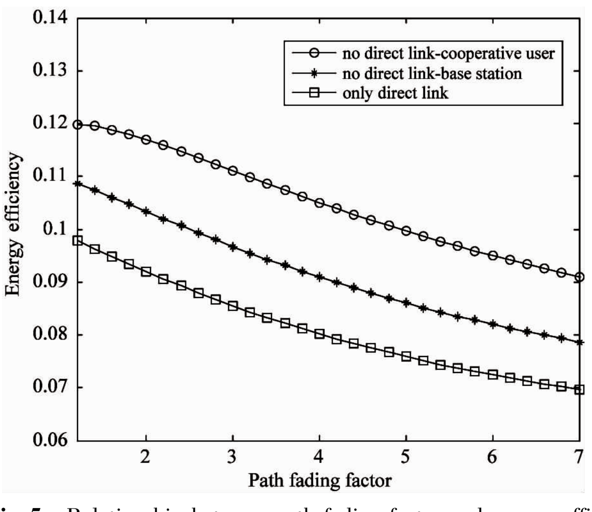

Fig. 5 Relationship between path fading factor and energy efficiency with different transmission model

In Fig. 6, the simulation results illustrate some changes by energy efficiency in the communication system. The results are obtained in different fading factors. The lower path fading factor, the better energy efficiency. When the distance between the source user and the cooperative user is set 2000 m, the energy efficiency reaches 0.09. When the path fading factor is 3, it is better than the energy efficiency when the path fading reaches 5 or 7. On the other hand, when the energy reaches 0.05, the maximum distance from the source user to the cooperative user is about 3500 m with high fading factor, while the maximum distance can reach about 4200 m with low fading factor[24].

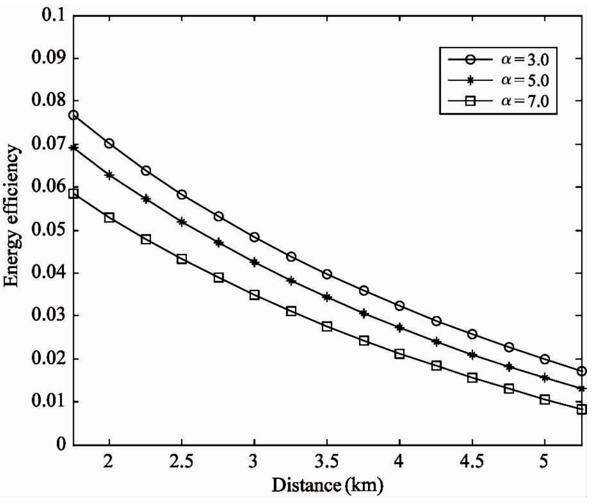

Fig. 6 Relationship between distance and energy efficiency with different fading factor

In Fig. 7, the simulation results show that the characteristic of the interference factor. From the results, at the high fading factor, the influence of the transmitter versus the cooperative user is obvious, and the trend is steady, it is still at nearly 1.8×10^{-3}. At the low fading factor, for example, when the fading factor reaches 5, the tendency reduces obviously. On the other aspect, the fading factor is set 3, the interference factor reaches about 1.2×10^{-3} when the distance reaches 2000m, while it decreases to 1.05×10^{-3} when the distance reaches 6500m. The reason is that the number of the candidate cooperative users in 2000m is more than the number of users in 6500m. Therefore, there has more interference from the other users in short distance.

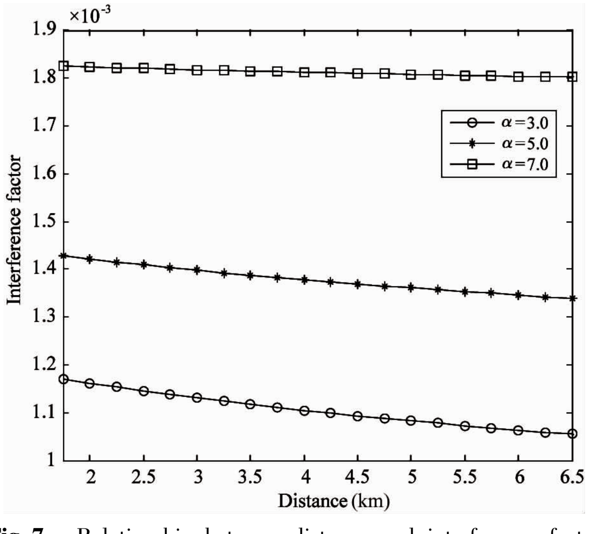

Fig. 7 Relationship between distance and interference factor with different fading factor

Fig. 8 characterizes the relationship between energy efficiency and interference factor in cooperative communication system. It can be seen that the energy efficiency increases with low interference factor and decreases with high interference factor. There will be a tradeoff between energy efficiency and interference factor in the proposed scheme, if interference factor is minimum, the energy efficiency cannot reach maximum. For examples when path fading factor is 3.0, the energy efficiency of cooperative user can reach the maximum value when interference factor is about 1.3×10^{-3}. It illustrates that the cooperative user can be selected with maximum energy efficiency but not minimum interference factor in the cooperative transmission. Compared with different path fading factor, it can be seen that the tendency of relationship between energy efficiency and interference factor is almost the same. Because of the existing tradeoff point, it cannot ignore the influence of energy efficiency and interference factor at the same time in cooperative process.

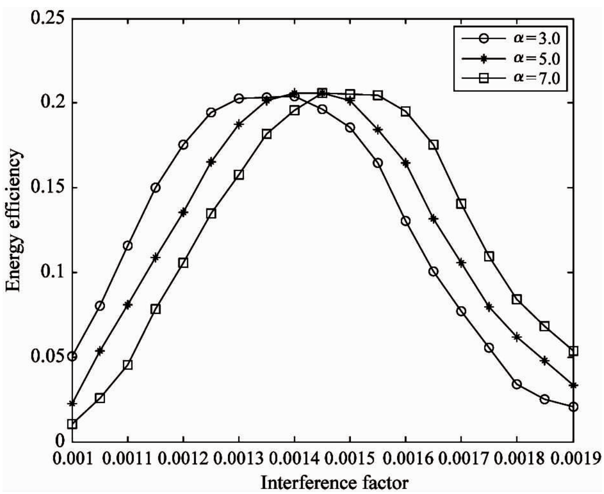

Fig. 8 Relationship between energy efficiency and interference factor with different fading factor

Except the energy efficiency and interference factor, BER in different transmission model is also compared. The simulation results are shown in Fig. 9. For the sake of fair comparisons, it can be seen from Fig. 9 that the reliability of transmission considering the interference factor in the proposed scheme is improved gradually. It illustrates that the BER versus SNR performance of the proposed algorithm in cooperative transmission outperforms the existing algorithm in direct transmission which was proposed in Ref. [7]. Superiority of the proposed scheme over the existing scheme is evident at lower SNRs. Comparing the direct transmission when SNR is 5 dB, the BER of data which is received by the base station in cooperative transmission can be reduced about 3×10^{-1}. Meanwhile, same to BER, the cooperative user or the base station in cooperative transmission can be achieved more SNR gain. For example, when BER reaches 10^{-1}, the base station in cooperative transmission is capable of achieving 4 dB SNR gain than the base station in direct transmission.

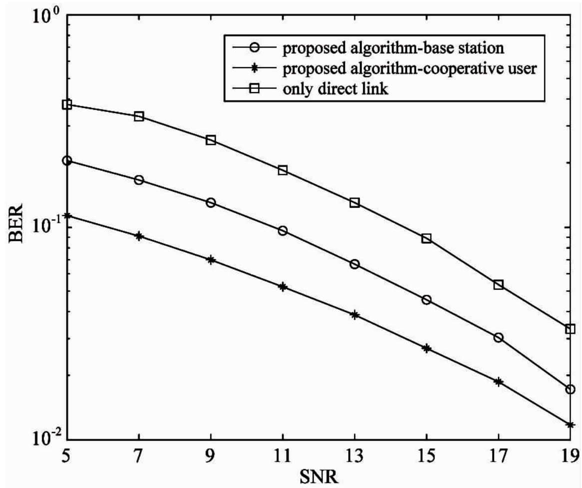

Fig. 9 Relationship between SNR and BER with different transmission model

Due to the limited space in this paper, all the simulation results cannot be listed in both the special case and the common scenario. However, the results in the common scenario have the same tendency as the results in the special case. Whether it is the common scenario or the special case, the BER decreases along with the increasing SNR. The simulation results have consistency in two cases.

4 Conclusions

In this study, transmission models are proposed, the concept of energy efficiency and interference factor are discussed. In the special case of transmission models, the relationship of path fading factor, the distance between source user and cooperative user or BS and the scope of SNR is studied. and the different environment to illustrate the influence by three factors is set. When the distance and SNR are determined, the maximum path fading factor could be selected. From the simulation results, the scope of candidate cooperative users in different environment has been presented. Besides, the energy efficiency and the interference factor based on cooperative transmission model is proposed. For energy efficiency, a calculation method is discussed in proposed models. And for interference factor, the influence of interference from other users to the cooperative user is introduced. According to the simulation results, the performance of energy efficiency and interference factor in proposed cooperative communication model are also verified. Furthermore, the effective strategy to select the cooperative including energy efficiency and interference factor in proposed scheme is discused. Based on these indices of efficiency, a cooperative user with high energy efficiency and less influence of interference could be selected. Both power consumption and BER performance are illustrated that the proposed scheme really outperforms the existing algorithm. Therefore, the proposed scheme had great advantages compared to the existing scheme in cooperative user selection.

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