Optimal Power Allocation and Best Relay Positioning in Opportunistic Incremental Amplify-and-Forward Cooperative System

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Abstract —In this paper, aiming to minimize the system outage probability in the condition of limited total power consumption, we study the optimal power allocation and relay positioning of the opportunistic incremental Amplify-and-Forward (OIAF) cooperative system over Rayleigh fading channels with the utilization of convex optimization theory. The analysis of the outage probability and bit error rate (BER) performance is provided. Moreover, we also provide the analysis about the impact of information rate R on the BER performance under certain conditions when the number of the relays, the relay position and also the total power vary. Simulation results show that the proposed joint power optimization and best relay positioning scheme has advantages over other schemes in outage performance.

Index Terms—Cooperative communication; amplify-and-forward; opportunistic incremental relay; optimal power allocation, relay positioning

I. INTRODUCTION

Cooperative technology [1], [2], with which each single antenna user can transmit its information with the help from the others and the transmit diversity can be obtained through a virtual antenna array, has been proposed to solve the problems in multiple-input multiple-output (MIMO) system where the wireless terminal may not be able to provide multiple antennas due to the cost of the hardware implementation and the limited size etc. Two typical cooperative protocols were presented by Laneman *et al.*, named amplify-and-forward (AF or non-regenerative) and decode-and-forward (DF or regenerative) in relay assisted cooperative systems [3]. Both of them contain two phases. In the first stage, the source broadcasts the information to the relay and the destination. Then, the relay amplifies the received signal in AF mode or decodes/encodes the signal in DF mode and retransmits it to the destination whereas the source becomes silent in the second stage. Here, more attentions have been paid to AF protocol for its simplicity.

In cooperative communications, power allocation is a key technique for the system optimization and performance improvement. Amount of power allocation strategies have been proposed for different transceiver structures and protocols in cooperative communications. [4] has investigated the optimal power allocation over multi-hop scenario for a given power budget considering both regenerative and non-regenerative protocols, where the outage probability is set as the optimization criterion. It proves that the optimization of the power allocation enhances the system performance. In order to optimize the signal-to-noise ratio (SNR) gain and the outage performance, the authors in [5] proposed the simple power allocation strategies for AF relaying that require only the statistic fading channel coefficients. Optimal power allocation scheme among the relays which can be obtained by an extended water-filling algorithm to maximize the system throughput with total and individual power constraints was firstly introduced in [6], and a relay selection scheme, called S-AF, was proposed. The selection AF scheme maintains full diversity order, and has better outage performance as well as average throughput compared with the conventional scheme. In addition, the distributed power allocation strategies in parallel relay networks with decode-and-forward protocol operating in orthogonal channels with limited channel state information (CSI) at the source and relays were studied in [7].

As another key technique for the performance improvement of cooperative system, relay selection has been widely studied. Incremental relaying as a typical relay selection scheme has been presented in [3] and its performance analysis with incremental-best-relay technique over Rayleigh fading channel and Nakagami-m fading channel has been given in [8] and [9], respectively. Owing to the inter-user interference and power

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consumption of the multiple relays, opportunistic relaying selection (ORS) was proposed to solve these problems by the selection of the best relay [10]. The asymptotic analysis of ORS has been presented in [11]. Based on the opportunistic AF cooperative scheme, a distributed relay selection framework was investigated in [12]. The analysis of the performance for an interference-aware ORS protocol for multi-hop networks and the throughput-optimal relay positioning were given in [13]. A strategy jointly combines relay selection with power minimization algorithm to minimize the total transmit power in a DF multi-user, multi-relay cooperative uplink implying the space-time coded cooperative diversity was presented in [14], which manifests significant power savings over a direct transmission link. The asymptotic symbol error rate and the outage probability analysis with equal and optimal power allocation in opportunistic AF cooperative networks for wireless sensor networks have been investigated in [15], where the system performance with optimal power allocation is superior to that of equal power allocation under the same environment and the same diversity order is derived for the two power allocation schemes.

In this paper, to minimize the outage probability with limited total power consumption, we study the optimal power allocation and relay positioning of the opportunistic incremental Amplify-and-Forward (OIAF) cooperative system over Rayleigh fading channels. First, we optimize the power allocation with fixed best relay position, and then optimize the best relay position with fixed power allocation. Furthermore, we combine the power allocation with the best-relay position to minimize the outage probability. Moreover, an analysis about the bit error rate (BER) performance under a specific condition in order to get the impact of the information rate R on system performance has been presented when the number of the relays and the total power change.

The structure of this paper is organized as follows. Section 2 introduces the opportunistic incremental AF cooperative system model. The outage and BER performance are analyzed in Section 3. The optimal power allocation and best relay positioning schemes are investigated in Section 4 to minimize the outage probability with limited total power consumption. Section 5 provides the simulation results about the system performance of the proposed scheme. Finally, the conclusions are drawn in Section 6.

II. System Model of Opportunistic Incremental AF Cooperative System

We consider an AF cooperative communication system with one source node (S), one destination node (D), and M relay nodes (denoted as $\{R_i, i=1, 2,\ldots, M\}$). The system operates over Rayleigh fading channels and the fading is assumed to be block fading. The system diagram is shown in Fig. 1. Each node has single antenna and works in half-duplex mode, which means they can not transmit and receive the signal simultaneously. Here, we define h_{ij} as the channel fading coefficient between terminal i and j, which is modeled as a zero mean complex Gaussian random variable with variance $\sigma_{ij}^2 = d_{ij}^{-\alpha}$, where d_{ij} is the distance between node i and j, α is the path loss exponent whose value varies from 2.0 to 4.0. The additive white Gaussian noise (AWGN) at the destination and the relays are assumed to be independent with the distribution $N(0,1)$. The whole system power is set to be P_T.

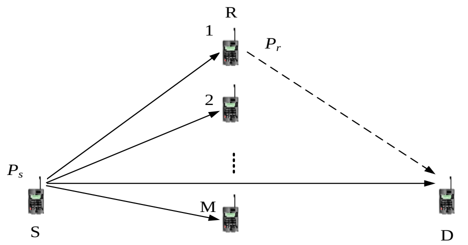

Fig. 1. Multi-relay amplify-and-forward cooperative system

The cooperative transmission is divided into two phases as introduced in Section 1. At first, the source broadcasts the information to the relays and the destination with transmit power P_s. The signal received at relay R_i and the destination D can be described respectively as,

$$y_{R_i} = \sqrt{P_s} h_{si} x_1 + n_{si}\ ,\ \ y_{d1} = \sqrt{P_s} h_{sd} x_1 + n_{sd}\ , \tag{1}$$

where x_1 is the signal transmitted from the source with an averaged unit power. h_{si} and h_{sd} are the channel coefficients of the S-R_i and S-D link, respectively. n_{si} is the AWGN at the relay i with variance σ_{si}^2 and n_{sd} is the AWGN of the destination with variance σ_{sd}^2 in the first phase.

If the destination can decode the signal from the source correctly, the destination will broadcast a simple signaling "success" to the source and the relays. The relays will stay silent and the source will transmit the new signal to the destination in the next slot. Otherwise, if the destination can not decode the signal from the source correctly, the source and the relays will receive the signaling message "failure" from the destination, and then the selected best relay will amplify and forward the information received from the source with power P_r to the destination in the second slot.

The best relay can be selected based on the ORS scheme presented by Bletsas [14], which is written as,

$$r = \arg\max_{i=1,2,\ldots,M} \min\left(\left|h_{si}\right|^2, \left|h_{id}\right|^2\right) \tag{2}$$

where h_{id} is the channel coefficient of the R_i-D link.

If the best relay r is selected, the destination will receive the signal in the second phase as,

$$y_{d2} = h_{rd} A y_r + n_{rd}\ , \tag{3}$$

where y_r is the signal received by the best relay r in the first phase, h_{rd} is the channel coefficient of the best relay to destination link, n_{rd} is the AWGN of the destination in the second phase with variance σ_{rd}^2, and A is the gain factor, which can be given as,

$$A = \sqrt{P_r / \left(P_s |h_{sr}|^2 + N_0\right)} \tag{4}$$

where h_{sr} is the channel coefficient of the source to the best relay link and N_0 is the power of AWGN at the best relay r.

III. Performance Analysis of OIAF Cooperative System

The approximate outage probability formulation is given in this section. Besides, we also provide the BER expression in a special case different from [8].

If the best relay r is selected, assuming the maximum ratio combing (MRC) at the destination, the instantaneous end-to-end SNR γ_{end} [3] is given as,

$$\gamma_{end} = \gamma_{sd} + \frac{\gamma_{sr}\gamma_{rd}}{\gamma_{sr} + \gamma_{rd} + 1}, \tag{5}$$

where $\gamma_{sd} = P_s|h_{sd}|^2$, $\gamma_{sr} = P_r|h_{sr}|^2$, and $\gamma_{rd} = P_r|h_{rd}|^2$ are the instantaneous SNRs of the *S-D*, *S-r*, and *r-D* link, respectively. Therefore, the above average link SNRs correspondingly equal to $\overline{\gamma_{sd}} = E(|h_{sd}|^2)P_s / N_0$, $\overline{\gamma_{sr}} = E(|h_{sr}|^2)P_s / N_0$, and $\overline{\gamma_{rd}} = E(|h_{rd}|^2)P_r / N_0$, where $E(.)$ means the statistical average.

In order to simplify the outage probability analysis, the end-to-end SNR can be upper-bounded as,

$$\gamma_{end} \le \gamma_{sd} + \max_{i=1,\dots,M} \min\left(\gamma_{si}, \gamma_{id}\right) = \gamma_{sd} + \gamma_b. \tag{6}$$

where $\gamma_b = \max_{i=1,\dots,M} \min\left(\gamma_{si}, \gamma_{id}\right)$ corresponds to the SNR of the best relay r.

A. Outage Performance Analysis

According to the above description, we derive the maximum mutual information for the OIAF cooperative protocol which is similar with [3] as,

$$I_{OIAF} = \begin{cases} I_{DT} = \log\left(1+\gamma_{sd}\right), & if \ \ |h_{sd}|^2 \ge \gamma_0 / P_s \\ I_{OAF} = \dfrac{1}{2}\log\left(1+\gamma_{sd}+\gamma_b\right), & \text{others} \end{cases} \tag{7}$$

where R is target spectral efficiency and $\gamma_0 = 2^R - 1$.

Therefore, the outage probability can be obtained at high SNR region as [11],

$$\begin{aligned} P_{out} &= \Pr\left(I_{OAF} < \frac{R}{2} \,|\, I_{DT} < R\right)\Pr\left(I_{DT} < R\right) \\ &= \Pr\left(I_{OAF} < \frac{R}{2}\right) = \Pr\left(\gamma_{sd} + \gamma_b < \gamma_0\right) \end{aligned} \tag{8}$$

B. BER Performance Analysis

As shown in [8], the average bit error probability can be written as,

$$P_e = \Pr\left(\gamma_{sd} \le \gamma_0\right) P_{div}\left(e\right) + \left(1 - \Pr\left(\gamma_{sd} \le \gamma_0\right)\right) P_{direct}\left(e\right) \tag{9}$$

where $\Pr\left(\gamma_{sd} \le \gamma_0\right) = 1 - e^{-\gamma_0/\overline{\gamma_{sd}}}$. $P_{div}(e)$ is the average bit error probability that an error happens to the combined signal at the destination from the source and the best relay. $P_{direct}(e)$ is the direct bit error probability that an error occurs at the destination for the transmission from the source, which is calculated for binary phase shift keying (BPSK) modulation as,

$$\begin{aligned} P_{direct}\left(e\right) &= \int_0^\infty P_{direct}\left(e \,|\, \gamma\right) f_{\gamma_{sd}|\gamma_{sd}|>\gamma_0}\left(\gamma\right) d\gamma \\ &= \frac{1}{2} erfc\left(\sqrt{\gamma_0}\right) - \frac{1}{2}\exp\left(\frac{\gamma_0}{\overline{\gamma_{sd}}}\right)\sqrt{\frac{\overline{\gamma_{sd}}}{1+\overline{\gamma_{sd}}}} erfc\left(\sqrt{\gamma_0\left(1+\frac{1}{\overline{\gamma_{sd}}}\right)}\right) \end{aligned} \tag{10}$$

where $erfc(x)$ is the complementing error function defined as $erfc\left(x\right) = \dfrac{2}{\sqrt{\pi}}\int_x^\infty \exp\left(-x^2\right)dx$.

The average bit error probability $P_{div}\left(e\right)$ can be given as,

$$P_{div}\left(e\right) = \int_0^\infty f_{\gamma_{end}}\left(\gamma \,|\, \gamma_{sd} \le \gamma_0\right) erfc\left(\sqrt{\gamma}\right) d\gamma \tag{11}$$

Assuming that the average SNRs of the links from the source to relay i and from relay i to the destination are the same and expressed as $\overline{\gamma_{si}} = \overline{\gamma_{sr}}$ and $\overline{\gamma_{id}} = \overline{\gamma_{rd}}$. We denote $\overline{\gamma_r} = \overline{\gamma_i} = \overline{\gamma_{si}}\,\overline{\gamma_{id}} / \left(\overline{\gamma_{si}} + \overline{\gamma_{id}}\right)$. The CDF of γ_b can be written as,

$$F_{\gamma_b}\left(\gamma\right) = \left(1 - \exp\left(-\frac{\gamma}{\overline{\gamma_r}}\right)\right)^M \tag{12}$$

Then, the probability density function (PDF) of γ_b is obtained as,

$$f_{\gamma_b}\left(\gamma\right) = \frac{M}{\overline{\gamma_r}}\exp\left(-\frac{\gamma}{\overline{\gamma_r}}\right)\left(1 - \exp\left(-\frac{\gamma}{\overline{\gamma_r}}\right)\right)^{M-1} \tag{13}$$

Based on the PDF of γ_{sd} and γ_b, we can calculate the PDF of γ_{end} in the condition of $\gamma_{sd} \le \gamma_0$, which can be expressed as,

$$f_{\gamma_{end}}\left(\gamma \,|\, \gamma_{sd} \le \gamma_0\right) = \begin{cases} \dfrac{1}{1-\exp\left(-\gamma_0/\overline{\gamma_{sd}}\right)}\displaystyle\int_0^\gamma f_{\gamma_b}\left(\gamma_b\right) f_{\gamma_{sd}}\left(\gamma - \gamma_b\right) d\gamma_b, & if\, \gamma \le \gamma_0 \\ \dfrac{1}{1-\exp\left(-\gamma_0/\overline{\gamma_{sd}}\right)}\displaystyle\int_{\gamma-\gamma_0}^\gamma f_{\gamma_b}\left(\gamma_b\right) f_{\gamma_{sd}}\left(\gamma - \gamma_b\right) d\gamma_b, & if\, \gamma > \gamma_0 \end{cases} \tag{14}$$

Furthermore, the average bit error probability $P_{div}(e)$ can be approximately expressed as,

$$P_{div}\left(e\right) = \frac{M}{2\left(1 - \exp\left(\dfrac{-\gamma_0}{\overline{\gamma_{sd}}}\right)\right)} \sum_{i=0}^{M-1} \binom{M-1}{i} \frac{(-1)^i}{i+1} \left(\frac{\overline{\gamma_r}}{i+1} - \overline{\gamma_{sd}}\right)^{-1} \times$$

$$\left(\begin{array}{l}\frac{\overline{\gamma_r}}{i+1}-\overline{\gamma_{sd}}-\frac{\overline{\gamma_r}}{i+1}\left(1+\frac{i+1}{\overline{\gamma_r}}\right)^{-\frac{1}{2}}+\left(\overline{\gamma_{sd}}-\frac{\overline{\gamma_r}}{i+1}\right)e^{\frac{-\gamma_0}{\overline{\gamma_{sd}}}}erfc\left(\sqrt{\gamma_0}\right)+\\ \overline{\gamma_{sd}}erf\left(\sqrt{\gamma_0\left(1+1/\overline{\gamma_{sd}}\right)}\right)\left(1+1/\overline{\gamma_{sd}}\right)^{-\frac{1}{2}}+\\ \frac{\overline{\gamma_r}}{i+1}e^{-\gamma_0\left(\frac{1}{\overline{\gamma_{sd}}}-\frac{i+1}{\overline{\gamma_r}}\right)}erfc\left(\sqrt{\gamma_0\left(1+\left(i+1\right)/\overline{\gamma_r}\right)}\right)\left(1+\left(i+1\right)/\overline{\gamma_r}\right)^{-\frac{1}{2}}\end{array}\right). \quad (15)$$

IV. Optimal Power Allocation and Best Relay Positioning

This section mainly focuses on the minimization of the system outage probability. The mathematic optimization algorithm, geometric programming (GP), is employed to allocate the power between the best relay and the source for opportunistic incremental non-regenerative cooperative system with fixed relay position and limited total power over Rayleigh fading channels. Then, considering the given power of the source and the best relay, we derive the optimal best relay positioning. Moreover, we further decrease the system outage probability by substituting the optimal distance to the outage probability formula and optimizing the problem once more.

A. Power Allocation Optimization with Fixed Best Relay Position

In this subsection, we will get the optimal power value for the source and the best relay in order to minimize the system outage probability under the limited total power P_T. We assume that the statistical channel information is acquirable for the communication nodes. Thus, the optimization problem can be formulated as,

$$\begin{array}{l}\min P_s^{-1}\prod_{i=1}^{M}\left(P_s^{-1}\sigma_{si}^{-2}+P_r^{-1}\sigma_{id}^{-2}\right)\\ \text{subject to } \; P_s+P_r\le P_T, \;\; 0\le P_s, P_r\le P_T\end{array} \quad (16)$$

By taking the second differential of the objective function (16) with respect to P_s or P_r, we know that the sign of the second differential is uncertain. Thus, the objective function is not convex or concave. However, we also realize that the target function as well as the constraints is posynomial function, and the majorization variables are positive. Hence, the formulation can be described as geometric programming problem in [16], which can be converted into convex optimization problem [17]. With this way, we can obtain the optimal power value based on the fixed distance via GP function through CVX function.

B. Best Relay Position Optimization with Fixed Power Allocation

The purpose of this subsection is to minimize the outage probability and get the optimal relay position with fixed power value. Firstly, without loss of generality, we assume that $d_{si}=d_{sr}$, $d_{id}=d_{rd}$ and $d_{sr}=\beta_1 d_{sd}$, $d_{rd}=\beta_2 d_{sd}$. Here, if the distance between the source and the destination is smaller than the distances between the source and the relays or the distances from the relays to the destination, direct transmission will be adopted and the relays will be silent. Therefore, the outage probability can be derived as,

$$P_{out}\approx\frac{\gamma_0^{M+1}}{M+1}P_s^{-1}d_{sd}^{(M+1)\alpha}\left(P_s^{-1}\beta_1^{\alpha}+P_r^{-1}\beta_2^{\alpha}\right)^M \quad (17)$$

Assume that the value of d_{sd} is fixed, the optimization problem of the best relay positioning can be formulated as,

$$\begin{array}{l}\min P_s^{-1}\beta_1^{\alpha}+P_r^{-1}\beta_2^{\alpha}\\ \text{subject to } \; 0\le\beta_1\le 1, 0\le\beta_2\le 1, \beta_1+\beta_2\ge 1\end{array} \quad (18)$$

Using optimization function, we can get that the distance factors which satisfies $\beta_1+\beta_2=1$. Therefore, in order to jointly combine the power allocation and the best relay positioning to optimize the system outage probability, we assume that the best relay lies in the line from the source to the destination and the distance between the source and the destination is normalized to be 1. The distance between the source and relay i is denoted as d_i, so the distance from relay i to the destination is $(1-d_i)$. Consequently, the channel fading coefficient variance of the link from the source to relay i and from relay i to the destination are $\sigma_{si}^2=d_i^{-\alpha}$ and $\sigma_{si}^2=\left(1-d_i\right)^{-\alpha}$, respectively.

With the above analysis, the optimal best relay positioning problem can be formulated as,

$$\begin{array}{l}\min P_s^{-1}\left(P_s^{-1}d_i^{\alpha}+P_r^{-1}(1-d_i)^{\alpha}\right)^M\\ \text{subject to } \; 0\le d_i\le 1\end{array} \quad (19)$$

Taking the second derivative of the objective function with respect to d_i, we can obtain that it is positive, which means that the target function is convex. Therefore, the optimization problem is also convex. We can get the optimal value through the first derivative of the objective function with respect to d_i and set the first derivative function to be zero, that is,

$$d_i=\left(1+\left(P_r/P_s\right)^{\frac{1}{\alpha-1}}\right)^{-1} \quad (20)$$

C. Joint Optimization of Power Allocation and Best Relay Positioning

Based on the optimal relay position, we can substitute (20) into (19) to minimize the system outage probability further and obtain that,

$$\begin{array}{l}\min P_s^{-1}\left(P_s^{\frac{1}{\alpha-1}}+P_r^{\frac{1}{\alpha-1}}\right)^{M(1-\alpha)}\\ =\left(P_s^{\frac{M+1}{M(\alpha-1)}}+P_r^{\frac{1}{\alpha-1}}P_s^{\frac{1}{M(\alpha-1)}}\right)^{M(1-\alpha)}\\ \text{subject to } \; P_s+P_r\le P_T, \;\; 0\le P_s, P_r\le P_T\end{array} \quad (21)$$

Taking the second derivative of $\left(P_s^{\frac{M+1}{M(\alpha-1)}} + P_r^{\frac{1}{\alpha-1}} P_s^{\frac{1}{M(\alpha-1)}} \right)$ with respect of P_s, it is obvious to see that the value is negative. So it is concave and its reciprocal is convex. Therefore, the objective function is convex. To get the optimal power value, using the equal sign of the first limited condition, we can take the first derivative of the objective function with respect to P_s and set it to be zero,

$$\frac{d}{dP_s}\left(P_s^{\frac{M+1}{M(\alpha-1)}} + \left(P_T - P_s\right)^{\frac{1}{\alpha-1}} P_s^{\frac{1}{M(\alpha-1)}} \right)^{M(1-\alpha)} = 0 \quad (22)$$

To simplify the result, we set α=3. It is easy to get the following equation from (22) as,

$$2\left(M+1\right)^2 P_S^2 - \left(M+1\right)\left(M+3\right)P_S P_T + P_T^2 = 0 \quad (23)$$

With the solution of (23), the optimal power for the source and the relay, P_s and P_r, can be obtained as,

$$P_S = \frac{M+3 \pm \sqrt{M^2+6M+1}}{4\left(M+1\right)} P_T \quad (24)$$

V. SIMULATION RESULTS AND NUMERICAL ANALYSIS

In this section, we provide the simulation and numerical results about the system performance, the system outage probability and BER for BPSK modulation over Rayleigh fading channels are presented in OIAF cooperative systems.

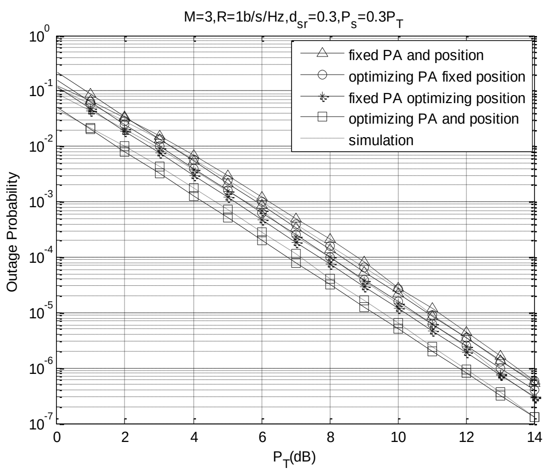

Fig. 2. System outage performance for different cooperative schemes.

Fig. 2 shows the system outage performance for different schemes, such as optimization of the power allocation (PA) with fixed relays position d_1=d_2=d_3=0.3, optimization of the best relay position with fixed PA (P_s=0.3P_T) and relay position, optimization of PA and relay position under the condition of different total power P_T with R=1.0 b/s/Hz and M=3. It is shown from Fig. 2 that the scheme optimizing PA and relay position achieves better performance than the other schemes. For the same outage probability of 10^{-4}, it obtains about 2.0dB gain compared to fixed PA and relay position scheme. Moreover, optimizing the best relay position with fixed PA also has better performance than optimizing PA with fixed relays position, which implies that the relay position has significant influence to the system outage performance. Fig. 3 shows the system outage performance compared with the traditional schemes, such as the equal power allocation scheme. From Fig. 3, it can be seen obviously that the proposed schemes in this paper achieve better outage performance than the equal power allocation scheme. For example, when the outage probability is 10^{-4}, the joint optimization scheme of power allocation and best relay positioning in this paper has about 0.3dB gain compared to the equal power allocation scheme.

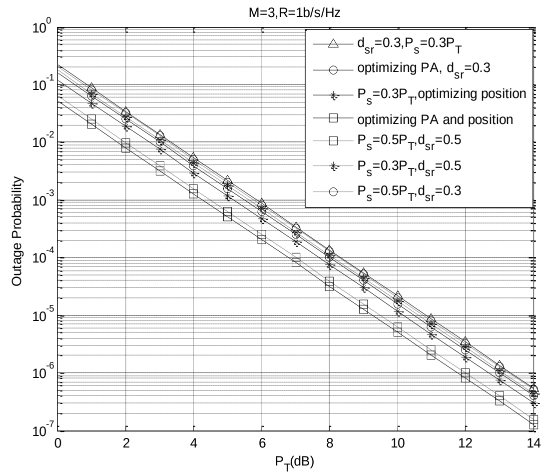

Fig. 3. System outage performance compared with traditional schemes.

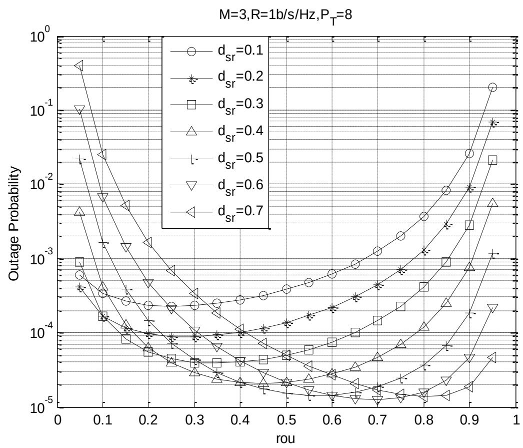

Fig. 4. System outage probability with different PA and fixed relay position.

Fig. 4 illustrates the outage probability with different PA and fixed relay position, assuming d_{si}=d_{sr} and d_{id}=d_{rd} and P_S=rou*P_T, *rou* is the power allocation factor between the source power and total system power. We can see that when d_{sr}=0.5 the optimal value of *rou* is 0.5~0.6. When we use GP algorithm, we can get the optimal value of *rou* is 0.5714, which matches well with the simulated result. Fig. 5 describes the outage probability with different relay position and fixed PA.For example, when P_S=0.7P_T we can get the optimal value of d_{sr} is 0.6044 from equation (18), which matches well with the value from Fig. 5. From (8), we can see that with the increase of information rate *R*, the outage performance becomes worse.

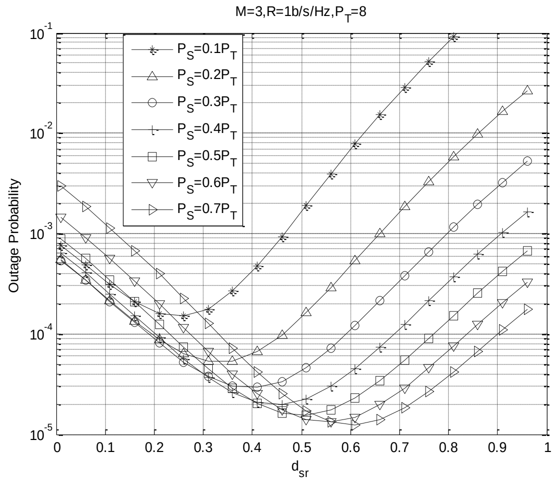

Fig. 5. System outage probability with different relay position and fixed PA.

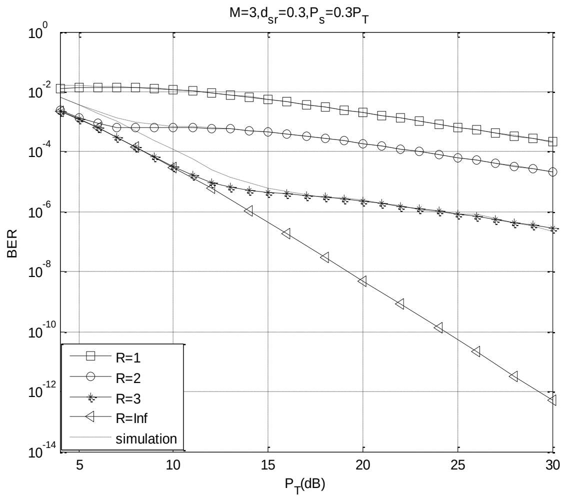

Fig. 6. BER performance with fixed relay position and PA with different *R*.

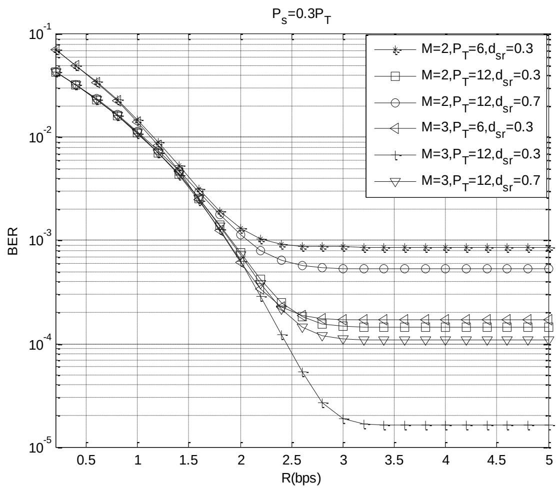

Fig. 7. BER performance with fixed relay position and PA with different *R*, *M*, d_{sr} and P_T.

In order to know the impact of the information rate *R* on the system performance, we also provide the BER performance with different *R* in Fig. 6 and Fig. 7. Fig. 6 gives BER performance with fixed best relay position d=0.3 and fixed power P_S=0.3P_T considering different *R*. It shows that with the increase of *R*, the BER performance becomes better. In high SNR, the simulation matches with the theory analysis well. Fig. 7 presents the BER performance versus the information rate *R* with various values of relay number *M* and the total power P_T. As information rate *R* increases, the BER tends to be a stable value. In order to make comparison between the outage probability and BER, we can get the best value of *R*. For example, when M=2, P_T=12 and d_{sr}=0.3, we can utilize the successive approximation method and get the optimal value of *R*, which is 3.1458bps.

VI. Conclusions

In this paper, we first investigate the power allocation and best relay positioning scheme for opportunistic incremental Amplify-and-Forward cooperative system, respectively. The joint optimization scheme of the power allocation and best relay positioning has been proposed to minimize the system outage probability. Simulation results prove that the joint optimization scheme has better system outage performance compared with other schemes. Moreover, we also provide the impact of the information rate *R* on the system performance as the relay number *M*, the best relay position and the total system power.

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