Energy Efficient Relay Selection for Two-Way Relay System

Qi Sun*†, Lihua Li*†, Lei Song*†
*Key Laboratory of Universal Wireless Communications, Ministry of Education,
†Wireless Technology Innovation (WTI) Institute,
Beijing University of Posts and Telecommunications, Beijing 100876, P.R.China
Email: qisunsq@gmail.com

***Abstract*—In this paper, we investigate the energy efficient relay selection scheme for two-way relay network. Two optimal joint relay selection and power minimization schemes are studied. One approach is to minimize the total transmit power, including the relay power and the transceiver power, subject to the signal to noise ratio (SNR) requirements on the two transceiver. And the other focuses on relay power minimization. Closed-form solutions are obtained and only few parameters need to be broadcast to all relays. Based on the closed-form solution, a new relay selection criterion is proposed, which simply relies on the relay channel coefficients. Simulation results are presented to show the merits of the proposed scheme.**

***Index Terms*—Energy Efficient, Relay Selection, Two-Way Relay**

I. INTRODUCTION

Wireless relaying transmission attracts much attention in recent years since it offers significant performance benefits, including improvement of spectral efficiency and extending the coverage [1] [2]. Most relay systems are assumed to be operated in time division half-duplex (TDD) mode. For one way relay, one source transmits data to one destination in two separate time slots with the help of relay. Such relaying protocol suffers performance loss in terms of spectral efficiency due to double time slots being used for transmission. To overcome the spectral efficiency loss, a two-way relaying protocol, in which two transceivers exchange information through relays in two time slots, has been proposed [3] [4]. In the first time slot, two transceivers transmit their data to relay simultaneously, while in the second time slot, the relay forwards the processed signal to both transceivers. And at the transceivers, the self-interference is eliminated and the desired data can be obtained. Thus, two-way relaying scheme is much more spectral efficient compared to one-way relaying.

In two-way relaying networks, multiple relay cooperation is widely employed to improve spatial diversity and mitigate the fading of wireless channels. Opportunistic relaying, or relay selection, which is considered as a simple and effective manner of cooperation, has gained lots of attention. Relay selection schemes reduce the relay transmit power and synchronization complexity, while preserving the diversity benefits. And in practical relay system, an amplify and forward (AF) method is simpler for implementation compared with decode and forward (DF) system. Some preliminary research on opportunistic relaying scheme in two-way AF relay network can be found in [5]–[10]. In [5], the best relay is chosen to maximize the worse received signal to noise ratio (SNR) of the two transceivers. The error rate and diversity order are analyzed in the high SNR regime. Further, block error rate (BLER) of single relay and multiple relay selection with both non-coherent and coherent channel coefficients at the relays are derived in [6]. Also, based on the worse received signal-to-noise (SNR) criterion, the outage optimal opportunistic relaying is investigated in [7] with fixed power on the transceivers and relay nodes. And in [8], joint relay selection and power allocation scheme, which based on instantaneous local channel coefficients, is proposed under a total transmit power budget. Further, [9] provides a sub-optimal power allocation method with statistical channel knowledge by minimizing the outage probability of the system. While asymptotic symbol error rate (SER) is studied in [10] and full diversity order of the relay selection is proven. All the previous researches are operated to minimize SER/BLER/outage or maximize the worse SNR under the total transmit power or the relay power constraints.

However, from the system point of view, sometimes it is more desirable to consider a problem of minimizing the total transmit power or the relay power subject to a predefined quality of service requirement depending on the services. For the battery-limited wireless network, the network lifetime depends on the power consumed by the nodes. Thus there is strong motivation to find energy effective ways for the cooperative two-way AF relay networks. In this paper, we present energy efficient relay selection technique for bidirectional AF relay network. Two scenarios are investigated. The first scenario aims to minimize the total transmit power, including the power of two transceivers and the relay power, subject to SNR targets of the two transceivers. While the second focuses on the relay power minimization. Closed-form optimal amplification weight and simple relay selection criterions are obtained. The proposed method only requires the selected relay index to be broadcasted, which efficiently reduces the relay processing complexity. Compared with the existing relay selection scheme, the proposed method is energy efficient and more flexible to the practical power limited network.

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II. System Model

Consider a two-way relay network which consists of two transceivers and N_r relays. We assume there is no direct link between the two transceivers. Two transceivers communicate with each other with the help of the relay node. Each relay is equipped with a single antenna for both transmission and reception. And the transceivers also has a single antenna. Among the N_r relays, only one relay is selected for transmission. The whole process of two-way transmission is shown in Fig.1. In the two-way relay system, data transmission takes place in two separate time slot.

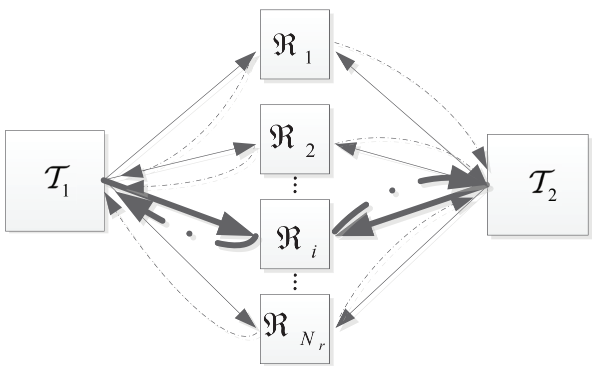

Fig. 1. A Two-Way Relay Network, solid line illustrates the 1th time slot transmission, dash line illustrates the 2th time slot transmission, and bold line denotes the selected relay transmission

Without loss of generality, we assume the i-th relay is selected. In the first time slot, two terminal nodes simultaneously transmit the data to the relay nodes. The signal received at the i-th relay nodes can be presented as

$$x_i = \sqrt{P_1} h_{i1} s_1 + \sqrt{P_2} h_{i2} s_2 + n_{Ri} \tag{1}$$

where $h_{i1} \sim \mathcal{CN}(0, \sigma_{h_1}^2)$ and $h_{i2} \sim \mathcal{CN}(0, \sigma_{h_2}^2)$ denotes the channel between the transceiver T1 and the i-th relay, and the channel between transceiver T2 and i-th relay ($i \in \{1, 2, \cdots, N_r\}$). x_i is the complex signal received at the i-th relay. P_1 and P_2 are the transmit power of transceivers T1 and T2. And n_{Ri} is complex relay noise. We assume that the transceivers have full channel state information of the source to relay and relay to destination link.

In the second time slot, the i-th relay multiplies its received signal by a complex weight w_i and transmit the processed signal. The signal transmitted by the i-th relay is

$$x_r = w_i x_i \tag{2}$$

The signals received at transceiver T1 and T2 can be written as

$$y_1 = \sqrt{P_1} h_{i1} w_i h_{i1} s_1 + \sqrt{P_2} h_{i1} w_i h_{i2} s_2 + h_{i1} w_i n_{Ri} + n_1 \tag{3}$$

$$y_2 = \sqrt{P_2} h_{i2} w_i h_{i2} s_2 + \sqrt{P_1} h_{i2} w_i h_{i1} s_1 + h_{i2} w_i n_{Ri} + n_2 \tag{4}$$

where n_1 and n_2 are the noise at the transceivers T1 and T2 respectively. All noises are assumed to be i.i.d Gaussian with zero-mean and variance $\mathbb{E}[|n_{Ri}|^2] = \sigma^2, \mathbb{E}[|n_1|^2] = \mathbb{E}[|n_2|^2] = \sigma^2$. The first term on the right-hand side of (3) and that of (4) are self-interferences of T1 and T2 respectively, which can be canceled by subtracting them from the received symbols [11]. Thus, the signals at T1 and T2 after self-interferences cancelation can be written as

$$\hat{s}_1 = \sqrt{P_2} w_i f_i s_2 + h_{i1} w_i n_{Ri} + n_1 \tag{5}$$

$$\hat{s}_2 = \sqrt{P_1} w_i f_i s_1 + h_{i2} w_i n_{Ri} + n_2 \tag{6}$$

where $f_i = h_{i1} h_{i2}$. The residual signals $\hat{s}_1$ and $\hat{s}_2$ can be processed at their corresponding transceivers to obtain the desired data.

III. Energy Efficient Relay Selection Scheme

In this section, we aim to find the relay weighting coefficient and the relay selection criterion such that the total transmit power P_T or the relay power P_R is minimized while maintaining the predefined SNR targets. Here the SNR target at transceiver T1 and transceiver T2 are denoted as γ_1 and γ_2 respectively. And the transmit power at i-th relay $P_{R,i}$ is obtained according to (2) as following

$$P_{R,i} = \mathbb{E}[|x_r|^2] = (P_1 |h_{i1}|^2 + P_2 |h_{i2}|^2 + \sigma^2) |w_i|^2 \tag{7}$$

Assuming the i-th relay is selected, the total transmit power $P_{T,i}$ can be written as

$$P_{T,i} = P_1(|h_{i1}|^2 |w_i|^2 + 1) + P_2(|h_{i2}|^2 |w_i|^2 + 1) + \sigma^2 |w_i|^2 \tag{8}$$

A. Total Power Minimization

The optimization of total power minimization under SNR Qos constraints can be formulated as the following problem

$$\begin{aligned} &\min_{P_1, P_2, w_i} P_{T,i} \\ &\quad s.t. SNR_1 \geq \gamma_1, SNR_2 \geq \gamma_2 \end{aligned} \tag{9}$$

where SNR_1 and SNR_2 denote the SNR at the transceiver T1 and T2 respectively. According to (5) and (6), SNR_1 and SNR_2 can be written as

$$SNR_1 = \frac{P_2 |f_i|^2 |w_i|^2}{\sigma^2 + \sigma^2 |h_{i1}|^2 |w_i|^2} \tag{10}$$

$$SNR_2 = \frac{P_1 |f_i|^2 |w_i|^2}{\sigma^2 + \sigma^2 |h_{i2}|^2 |w_i|^2} \tag{11}$$

Using (8) , (10) and (11), the optimization problem of (9) can be rewritten as

$$\begin{aligned} &\min_{P_1, P_2, w_i} P_1(|h_{i1}|^2 |w_i|^2 + 1) + P_2(|h_{i2}|^2 |w_i|^2 + 1) + \sigma^2) |w_i|^2 \\ &\quad s.t. \frac{P_2 |f_i|^2 |w_i|^2}{\sigma^2 + \sigma^2 |h_{i1}|^2 |w_i|^2} \geq \gamma_1, \quad \frac{P_1 |f_i|^2 |w_i|^2}{\sigma^2 + \sigma^2 |h_{i2}|^2 |w_i|^2} \geq \gamma_2 \end{aligned} \tag{12}$$

The optimal solution is obtained when the equalities are met in the inequality constraints (12). Thus, the transmit power at the transceivers can be written as the function of w_i as

$$P_1 = \frac{\sigma^2\gamma_2(1+|h_{i2}|^2|w_i|^2)}{|f_i|^2|w_i|^2} \tag{13}$$

$$P_2 = \frac{\sigma^2\gamma_1(1+|h_{i1}|^2|w_i|^2)}{|f_i|^2|w_i|^2} \tag{14}$$

Using (13) and (14), the optimization problem is turned into the following unconstrained problem

$$\min_{w_i}(\gamma_1+\gamma_2)\frac{(1+|h_{i2}|^2|w_i|^2)(1+|h_{i1}|^2|w_i|^2)}{|f_i|^2|w_i|^2}+|w_i|^2 \tag{15}$$

It can be seen that the objective function (15) is independent of the phase of w_i, so no phase compensation is needed at the relay. To solve the unconstraint optimization problem, we set the derivations of the objective function to zero and obtain

$$\frac{\gamma_1+\gamma_2}{|f_i|^2}(|f_i|^2-\frac{1}{|w_i|^4})=0 \tag{16}$$

The positive solution is given by

$$w_i^{opt}=\sqrt{\frac{\beta}{|f_i|}}=\sqrt{\frac{\beta}{|h_{i1}h_{i2}|}} \tag{17}$$

where $\beta=\sqrt{\frac{\gamma_1+\gamma_2}{1+\gamma_1+\gamma_2}}$.

Taking (17) into (13) and (14), the optimal P_1 and P_2 is

$$P_1=\sigma^2(\frac{\gamma_2}{\beta|f_i|}+\frac{\gamma_2|h_{i2}|^2}{|f_i|^2}) \tag{18}$$

$$P_2=\sigma^2(\frac{\gamma_1}{\beta|f_i|}+\frac{\gamma_1|h_{i1}|^2}{|f_i|^2}) \tag{19}$$

So the total transmit power at the transceivers can be presented as

$$P_1+P_2=\sigma^2(\frac{\gamma_1+\gamma_2}{\beta|f_i|}+\frac{\gamma_1|h_{i1}|^2+\gamma_2|h_{i2}|^2}{|f_i|^2}) \tag{20}$$

Interestingly, we draw $P_1+P_2=P_{R,i}=\frac{1}{2}P_{T,i}$. This indicates that the optimal solution allocates half power to the relaying nodes and the remaining half will be divided by the two transceivers.

Substituting above equations into (8), the total transmitter power is given by

$$\begin{aligned}P_{T,i}&=2P_{R,i}\\&=2\sigma^2(\frac{\gamma_1}{|h_{i2}|^2}+\frac{\gamma_2}{|h_{i1}|^2}+\frac{\sqrt{(\gamma_1+\gamma_2)(\gamma_1+\gamma_2+1)}}{|h_{i1}||h_{i2}|})\end{aligned} \tag{21}$$

When $\gamma_1+\gamma_2\gg 1$, which is commonly met in practical systems, we get $\beta\approx 1$, Then the total transmit power can be simplified to the harmonic mean of the channel coefficient.

$$\begin{aligned}P_{T,i}&=2\sigma^2(\frac{\gamma_1}{|h_{i2}|^2}+\frac{\gamma_2}{|h_{i1}|^2}+\frac{\gamma_1+\gamma_2}{|h_{i1}||h_{i2}|})\\&=2\sigma^2(\frac{1}{|h_{i1}|}+\frac{1}{|h_{i2}|})(\frac{\gamma_1}{|h_{i1}|}+\frac{\gamma_2}{|h_{i2}|})\end{aligned} \tag{22}$$

Moreover, for the case of $\gamma_1=\gamma_2=\gamma$, the total transmit power leads to

$$P_{T,i}=2\sigma^2\gamma(\frac{1}{|h_{i1}|}+\frac{1}{|h_{i2}|})^2 \tag{23}$$

With the closed form solution for the minimal total power, the relay selection problem can be formulated as follows

$$i=\min_{i\in\{1,2,\cdots,N_r\}}(\frac{1}{|h_{i1}|}+\frac{1}{|h_{i2}|})(\frac{\gamma_1}{|h_{i1}|}+\frac{\gamma_2}{|h_{i2}|}) \tag{24}$$

which only relies on the local channel coefficient between the relay and the two transceivers.

Thus, the joint relay selection and power minimization processing for two-way relay system is summarized as follows

1) One of the transceivers, who knows the whole channels (channels between relay and the two transceivers), selected the optimal relay by minimizing the total transmit power according to criterion (24). The minimum total power is calculated for all relays, and the relay with the minimum total transmit power is selected.
2) Transceivers T1 or T2 broadcast the relay index to all the relays, and only the relay who gets its own index will participate in the transmission. And the selected relay calculates its own optimal amplification weighting coefficient as (17), and the coefficient only relies on the local relay channel coefficient.

It can be observed from the above discussion that the whole overhead required for the broadcasting is the selected relay index, which is determined by the total relay numbers N_r as $\log_2 N_r$.

B. Relay Power Minimization

In the scenario with mobile relays, where the relay power is limited while the transceivers' power can be fully supported. To maximize the network lifetime, the relay power minimization should be paid great attention.

In this part, we consider the relay power minimization problem when the transceiver power P_1 and P_2 are given. The minimization problem subject to SNR requirements can be formulated as

$$\begin{aligned}&\min_{w_i}(P_1|h_{i1}|^2+P_2|h_{i2}|^2+\sigma^2)|w_i|^2\\&s.t.\frac{P_2|f_i|^2|w_i|^2}{\sigma^2+\sigma^2|h_{i1}|^2|w_i|^2}\geq\gamma_1,\quad\frac{P_1|f_i|^2|w_i|^2}{\sigma^2+\sigma^2|h_{i2}|^2|w_i|^2}\geq\gamma_2\end{aligned} \tag{25}$$

For the selected i-th relay, the objective function $P_{R,i}$ is monotonic and grows linearly with $|w_i|^2$. So the minimization problem is equivalent to the minimization of $|w_i|^2$.

The optimal solution is developed as following

$$\begin{aligned}|w_i^{opt}|^2&=\max\{\frac{\gamma_1\sigma^2}{P_2|f_i|^2-\gamma_1\sigma^2|h_{i1}|^2},\frac{\gamma_2\sigma^2}{P_1|f_i|^2-\gamma_2\sigma^2|h_{i2}|^2}\}\\&=\begin{cases}\frac{\gamma_1\sigma^2}{P_2|f_i|^2-\gamma_1\sigma^2|h_{i1}|^2} & \frac{P_1}{\gamma_2}-\frac{P_2}{\gamma_1}\geq\sigma^2(\frac{1}{|h_{i2}|^2}-\frac{1}{|h_{i1}|^2})\\ \frac{\gamma_2\sigma^2}{P_1|f_i|^2-\gamma_1\sigma^2|h_{i2}|^2} & \frac{P_1}{\gamma_2}-\frac{P_2}{\gamma_1}\leq\sigma^2(\frac{1}{|h_{i2}|^2}-\frac{1}{|h_{i1}|^2})\end{cases}\end{aligned} \tag{26}$$

Note that at the optimal, at least one of the inequality constraints is satisfied and with the other SNR higher than the required Qos. This means some given transceiver's power is wasted. And it can be seen from (25), relay power grows linearly with the transceivers' power P_1 and P_2. So we can reduce the transceiver power to further minimize the relay power. Take the following instance. If $\frac{P_1}{\gamma_2} - \frac{P_2}{\gamma_1} \geq \sigma^2(\frac{1}{|h_{i2}|^2} - \frac{1}{|h_{i1}|^2})$, it's easily to obtain that

$$\frac{P_2|f_i|^2|w_i|^2}{\sigma^2 + \sigma^2|h_{i1}|^2|w_i|^2} = \gamma_1 \tag{27}$$

$$\frac{P_1|f_i|^2|w_i|^2}{\sigma^2 + \sigma^2|h_{i2}|^2|w_i|^2} \geq \gamma_2 \tag{28}$$

It is obviously that we can further reduce P_1, which just need to be big enough to meet the equality of (28). So at the optimal solution, the two inequalities should both satisfy the equality. Then we have

$$\frac{P_2|f_i|^2 - \gamma_1\sigma^2|h_{i1}|^2}{P_1^o|f_i|^2 - \gamma_2\sigma^2|h_{i2}|^2} = \frac{\gamma_1}{\gamma_2} \tag{29}$$

where P_1^o is the power of transceiver 1 after the adjustment. Then the minimum P_1^o is given by

$$P_1^o = \frac{\gamma_1}{\gamma_2}P_2 + \sigma^2\gamma_2(\frac{1}{|h_{i2}|^2} - \frac{1}{|h_{i1}|^2}) \tag{30}$$

Note that the reduction of P_1 will further reduce the relay power. Define $\mathcal{Q}_i = \frac{P_1}{\gamma_2} - \frac{P_2}{\gamma_1} - \sigma^2(\frac{1}{|h_{i2}|^2} - \frac{1}{|h_{i1}|^2})$. Then the closed-form optimal solution for relay power minimization can be summarized as follows

if $\mathcal{Q}_i \geq 0$

$$\begin{aligned} w_i^{opt} &= \sqrt{\frac{\gamma_1\sigma^2}{P_2|f_i|^2 - \gamma_1\sigma^2|h_{i1}|^2}} \\ P_1^o &= \frac{\gamma_2}{\gamma_1}P_2 + \sigma^2\gamma_2(\frac{1}{|h_{i2}|^2} - \frac{1}{|h_{i1}|^2}) \end{aligned} \tag{31}$$

elsif $\mathcal{Q}_i < 0$

$$\begin{aligned} w_i^{opt} &= \sqrt{\frac{\gamma_2\sigma^2}{P_1|f_i|^2 - \gamma_1\sigma^2|h_{i2}|^2}} \\ P_2^o &= \frac{\gamma_1}{\gamma_2}P_1 - \sigma^2\gamma_1(\frac{1}{|h_{i2}|^2} - \frac{1}{|h_{i1}|^2}) \end{aligned} \tag{32}$$

It should be noted that the objective function is independent of the phase of w_i. So here we just give the positive solution of w_i^{opt}. Substituting (26) into $P_{R,i}$, the optimal relay power is given by

$$P_{R,i}^o = \sigma^2(\frac{\gamma_1}{|h_{i1}|^2} + \frac{\gamma_2}{|h_{i2}|^2} + (\gamma_1 + \gamma_2 + 1)|w_i^{opt}|^2) \tag{33}$$

With the optimal solution, the relay power efficient relay selection problem can be presented as follows

$$i = \min_{i \in \{1,2,\cdots,N_r\}} P_{R,i}^o \tag{34}$$

where $P_{R,i}^o$ is given by (33) and $|w_i^{opt}|^2$ is given by (26).

The whole procedure of the relay power minimization and relay selection scheme is conducted as follows.

1) Transceivers calculate $\mathcal{Q}_i$ and compare $\mathcal{Q}_i$ with zero. Then $P_{R,i}^o (i = 1, 2, \cdots, N_r)$ is obtained as (33). The minimum $P_{R,i}^o$ among the N_r relays is selected for transmission.
2) Transceiver T1 or T2 broadcasts the relay index and the sign of $\mathcal{Q}_i$ (i-th relay is the selected relay for transmission). The relay who hears its own index, calculates the optimal amplification coefficient w_i^{opt} given by (26) according to the sign bit. The overhead bits required is the relay index and the sign bit. The optimal selected relay index takes $\log_2 N_r$ bits and the sign needs 1 bit.

IV. Simulation Results

In this section, we demonstrate the proposed scheme by simulation results. We consider a network consisting of 10 relays. The channel coefficients h_{i1} and h_{i2} are generated as zero-mean complex Gaussian random variables with variance $\sigma_{h_1}^2$ and $\sigma_{h_2}^2$. The noise variance is assumed to be 0.

A. Total Transmit Power Minimization

Fig.2 shows the average total transmit power P_T, relay transmit power P_R and the transceiver power P_1 and P_2 versus $\gamma = \gamma_1 = \gamma_2$ in dB in the case of $\sigma_{h_1}^2 = \sigma_{h_2}^2 = 0dB$. For comparison, we also consider the random relay selection with optimal power allocation. The caption of 'appro pro' shows the approximate total transmit power of the proposed scheme given by (22) and 'RRS' demonstrates the random relay selection. Compared with the random relay selection scheme, the energy efficient relay selection scheme achieves approximately 12dBW gain in terms of total transmit power.

To our knowledge, no preliminary work mentioned the energy efficient relay selection scheme for two-way non-regenerative relay network. So here we only considere the random relay selection scheme for comparison. The network model of this paper is similar to that in [8]. However, our work is quite different from [8]. The scheme proposed in [8] aims to maximize the minimum end to end SNR, and always leads to $\gamma_1 = \gamma_2$ for SNR balancing processing, which is not suitable for the circumstance that the two transceivers are of different SNR constraints. For an example, lower SNR target is sufficient for transceiver 1 and transceiver 2 need much higher SNR quality to support the transmission. In this case, our proposed energy efficient relay selection scheme will work efficiently and the scenario can not be supported by [8].

B. Relay Transmit Power Minimization

In this experiment, we assume that the transceiver power are initially set as $P_1 = 20dBW$ and $P_2 = 16dBW$. And the total relay number is 20. Fig.3 shows the average minimum relay power P_R and total transmit power P_T with original transceiver powers as $P_1 = 20dBW$ and $P_2 = 16dBW$ for $\sigma_{h_1}^2 = 7dB, \sigma_{h_2}^2 = 3dB$ and $\sigma_{h_1}^2 = 0dB, \sigma_{h_2}^2 = 0dB$. Random relay selection with optimal relay power minimization scheme is also considered for comparison. Similarly, the caption 'RRS' indicates the random relay selection schemes. The relay power and the total transmit power of the proposed

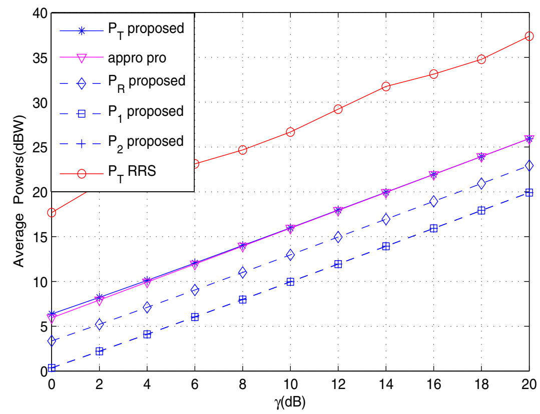

Fig. 2. The average minimum total transmit power P_T, the corresponding average relay transmit power P_R, average transceiver power, P_1, P_2,versus $\gamma_1 = \gamma_2 = \gamma$, with $\sigma_1^2 = \sigma_2^2 = 0dB$.

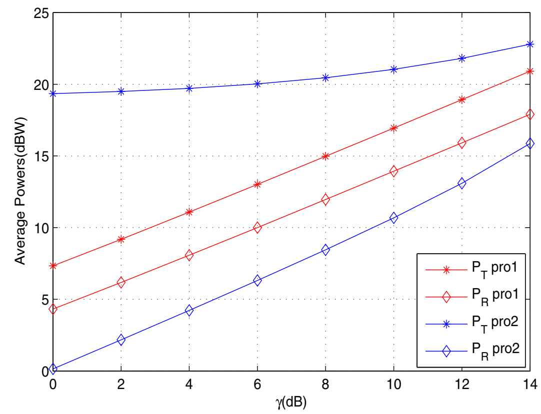

Fig. 4. The average relay transmit power P_R and P_T, in the total transmit power minimization and relay power minimization versus $\gamma_1 = \gamma_2 = \gamma$ with $\sigma_{h_1}^2 = \sigma_{h_2}^2 = 0dB$

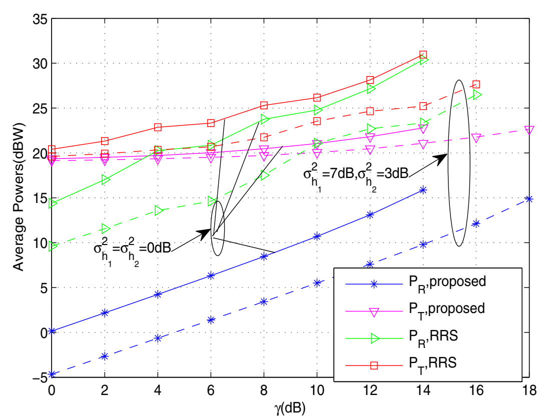

Fig. 3. The average minimum relay transmit power P_R and the corresponding average total transmit power P_T versus $\gamma_1 = \gamma_2 = \gamma$, with initial transceiver power $P_1 = 20dBW$, $P_2 = 16dBW$, solid line for $\sigma_{h_1}^2 = \sigma_{h_2}^2 = 0dB$ and dash line for $\sigma_{h_1}^2 = 7dB, \sigma_{h_2}^2 = 3dB$.

scheme are both lower than the random relay selection method. Fig.4 illustrates the relay power of two proposed energy efficient method. The caption 'pro1' means the proposed total transmit power minimization scheme and 'pro2' denotes the proposed relay power minimization scheme. Under the same SNR targets, compared with total transmit power minimization problem, the relay power minimization leads to much lower relay power at the price of higher total transmit power. Therefore, the relay power minimization is quit suitable for the network where the relay power is limited while with sufficient power provided to the transceivers. The relay power minimization is efficient for mobile relays to maximize the network lifetime with predefined SNRs.

V. Conclusions

We develop two energy efficient relay selection scheme for bidirectional relay networks consisting of two transceivers and multiple relay nodes. By minimizing the total transmit power or the relay power under predefined SNR constraints of two transceivers, we obtain closed-form solution of the relay amplify weight. And the relay selection criterion is found to be a simple function of the relay's local channel coefficients. The proposed approaches are feasible solutions for the practical battery limited system. The energy efficient characteristic will be quite useful for maximizing the network lifetime. Simulation results indicate that the proposed method enjoys great gain in terms of total transmit power and relay transmit power compared to the random relay selection scheme.

References

[1] B. Wang, J. Zhang, and A. Host-Madsen, "On the capacity of mimo relay channels," *IEEE Trans. Inf. Theory*, vol. 51, no. 1, pp. 29–43, 2005.

[2] H. Bolcskei, R. U. Nabar, O. Oyman, and A. J. Paulraj, "Capacity scaling laws in mimo relay networks," *IEEE Trans. Wireless Commun.*, vol. 5, no. 6, pp. 1433–1444, 2006.

[3] C.E.Shannon, "Two-way communication channels," in *Proc. 4th Berkeley Symp. Math. Stat. Prob*, 1961, pp. 611–644.

[4] S. J. Kim, P. Mitran, and V. Tarokh, "Performance bounds for bidirectional coded cooperation protocols," *IEEE Trans. Inf. Theory*, vol. 54, no. 11, pp. 5235–5241, 2008.

[5] Y. Jing, "A relay selection scheme for two-way amplify-and-forward relay networks," in *Proc. Int. Conf. Wireless Communications & Signal Processing WCSP 2009*, 2009, pp. 1–5.

[6] S. Atapattu, Y. Jing, H. Jiang, and C. Tellambura, "Opportunistic relaying in two-way networks," in *Proc. 5th Int Communications and Networking in China (CHINACOM) ICST Conf*, 2010, pp. 1–8.

[7] J. Zheng, B. Bai, and Y. Li, "Outage-optimal opportunistic relaying for two-way amplify and forward relay channel," *Electronics Letters*, vol. 46, no. 8, pp. 595–597, 2010.

[8] S. Talwar, Y. Jing, and S. Shahbazpanahi, "Joint relay selection and power allocation for two-way relay networks," *IEEE Signal Process. Lett.*, vol. 18, no. 2, pp. 91–94, 2011.

[9] Y. Yang, J. Ge, and Y. Gao, "Power allocation for two-way opportunistic amplify-and-forward relaying over nakagami-m channels," *IEEE Trans. Wireless Commun.*, no. 99, pp. 1–6, 2011, early Access.

[10] L. Song, "Relay selection for two-way relaying with amplify-and-forward protocols," *IEEE Trans. Veh. Technol.*, vol. 60, no. 4, pp. 1954–1959, 2011.

[11] R. Zhang, Y.-C. Liang, C. C. Chai, and S. Cui, "Optimal beamforming for two-way multi-antenna relay channel with analogue network coding," *IEEE J. Sel. Areas Commun.*, vol. 27, no. 5, pp. 699–712, 2009.