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Relay Selection for Bidirectional Wireless Networks With Outdated CSI Using Weight Factor

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Abstract: The Most researches on relay selection (RS) in bidirectional relay network typically assume perfect channel state information (CSI). However, outdated CSI, which is caused by the time-variation of channel, cannot be ignored in the practical system, and the performance of the conventional bidirectional RS scheme degrades greatly with outdated CSI. In this paper, to improve the performance of RS with outdated CSI, we propose a weighted bidirectional RS scheme, in which a deterministic weight factor decided by the correlation coefficient of outdated CSI, is introduced in the selection process. The outage probability bound of the weighted bidirectional RS is derived and verified, along with the asymptotic expression in high signal-to- noise ratio (SNR). Based on the analytical expressions, the optimal weight factor and the optimal power allocation scheme in minimizing the outage probability are obtained. Simulation results reveal that when the CSI is outdated, the diversity order reduces from full diversity to one. Furthermore, the weighted bidirectional RS scheme with the optimal weight factor yields a significant performance gain over the conventional bidirectional RS scheme, especially in high SNR.

Keywords: Relay selection, amplify-and-forward, outdated channel state information.

INTRODUCTION

In bidirectional relay communications two sources exchange information through the intermediate relays, and different transmission schemes of bidirectional relay have been proposed in [1], [2]. An amplify-and-forward (AF) based network coding scheme, named as analog network coding (ANC), was proposed in [2]. In that the exchange of information between two sources occupies two phases, and thus the spectral efficiency get improved [2]. Relay selection (RS) technique in bidirectional relay communications has been researched, due to its ability to achieve full diversity with only one relay [3]–[7]. Performing RS, the best relay is firstly selected before the subsequent data transmission, according to the predefined RS scheme. In [6], an optimal RS scheme in minimizing the average symbol error rate (SER) was proposed and analyzed, and the optimal power allocation scheme in minimizing the asymptotic SER was provided. The diversity order for various RS schemes of bidirectional RS was studied in [7], and it revealed that all the RS schemes can achieve full diversity when the channel state information (CSI) is perfect.

In this paper, to improve the performance of RS with outdated CSI, the weighted bidirectional RS scheme is proposed and analyzed in this paper. To compensate the performance loss caused by the outdated CSI, a novel weighted bidirectional RS scheme is proposed by introducing the weight factor in the selection process. The outage probability bound of the weighted bidirectional RS scheme with outdated CSI is derived and verified, along with the asymptotic expression in high signal-to-noise ratio (SNR). According to the analytical expressions, the optimal weight factor and the optimal power allocation scheme in minimizing the outage probability are also obtained. The expression of the optimal weight factor reveals that the factor is decided by the correlation coefficient of outdated CSI, the number of relays, and the channel variances. Simulation results reveal that once the CSI is outdated, the diversity order reduces from full diversity to one. Furthermore, the outage probability of the weighted bidirectional RS with the optimal weight factor can achieve the considerable performance gain over the conventional bidirectional RS, specifically in high SNR.

RELATED WORK

Most previous researches on RS in bidirectional relay network typically assume perfect CSI. In the conventional bidirectional RS scheme, the effect of correlation coefficients of outdated CSI has not been considered in the selection process. Outdated CSI, caused by the time-variation of channel, cannot be ignored in the practical system, and it makes the selected relay not the best for the data transmission. The impact of outdated CSI has been discussed in one-way relay and two-way relay. In [11], [12], the expressions of SER and outage probability for one-way AF RS were achieved, and the partial RS and opportunistic RS were both considered with

outdated CSI. The impact of outdated CSI on the one-way decode-and-forward (DF) RS was analyzed in [13]. In [14], the two-way network with one relay and multiple users was studied, and the effect of outdated CSI on user selection was researched. In [15], the performance of SER was analyzed in the bidirectional AF relay, when the CSI is outdated. Compared with the conventional RS scheme with outdated CSI, the proposed weighted RS scheme is revised by introducing the deterministic weight factor in the selection process. The outage probability bound of the weighted RS scheme with outdated CSI is derived and verified, along with the asymptotic expression in high signal-to-noise ratio (SNR).

SYSTEM MODEL

As presented in Fig. 1, the system investigated in this paper is a bidirectional AF relay network, in which two sources S_j , j = 1, 2, exchange information through N relays R_i, i = 1, . . .,N, and each communication node is equipped with a single half-duplex antenna. The transmit powers of each source and each relay are denoted by P_s and P_r, respectively. The direct link between the two sources does not exist due to the shadowing effect, and the channel coefficients between S_j and R_i are reciprocal, denoted by h_{ij}. All the channel coefficients follow independent complex-Gaussian distribution with zero mean and variance of σ_j^2

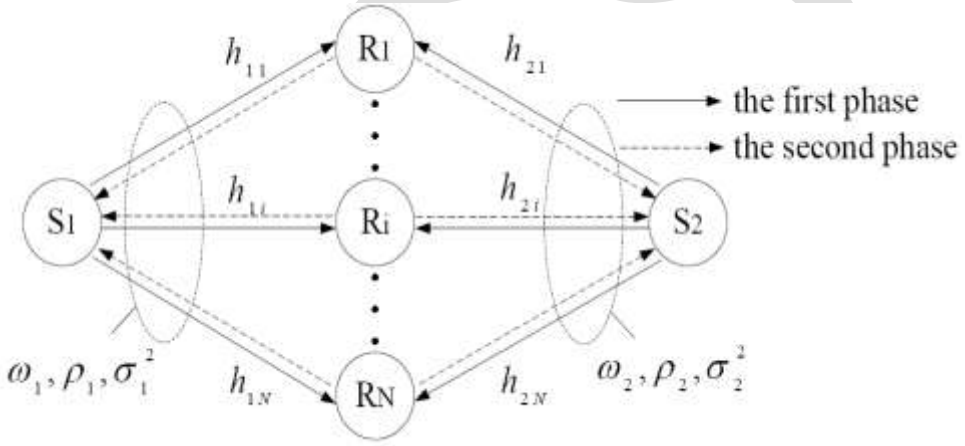

Fig 1: System model

A. Instantaneous Received SNR at the Sources

Considering the transmission via R_i, the data transmission process of bidirectional AF relay is divided into two phases when adopting the ANC. At the first phase, the sources simultaneously send their respective information to R_i. The received signal at R_i is expressed as $r_i = \sqrt{P_s}h_{1i}s_1 + \sqrt{P_s}h_{2i}s_2 + n_{ri}$, where s_j denotes the modulated symbols transmitted by S_j with the average power normalized, and n_{ri} is the additive white Gaussian noise (AWGN) at R_i, which has zero mean and variance of σ_n^2. At the second phase, R_i amplifies the received signal and forwards it back to the sources. The signal generated by R_i is $t_i = \sqrt{P_r}\beta_i r_i$, where β_i is the variable-gain factor [12]. The received signal at S_j is $y_j = h_{t,ji}t_i + n_{sj}$, where n_{sj} is the AWGN at S_j. The instantaneous received signal-to-noise ratio (SNR) at S_j via R_i is

$$\gamma_{ji} = \frac{\psi_s\psi_r|h_{ji}|^2|h_{\bar{j}i}|^2}{(\psi_s+\psi_r)|h_{ji}|^2 + \psi_s|h_{\bar{j}i}|^2 + 1}$$

where $\psi_s = P_s/\sigma_n^2$, $\psi_r = P_r/\sigma_n^2$

In high SNR, the expression can be further simplified, i.e.,

$$\gamma_{ji} \approx \frac{\psi_r|h_{ji}|^2\psi_h|h_{\bar{j}i}|^2}{\psi_r|h_{ji}|^2 + \psi_h|h_{\bar{j}i}|^2}$$

where $\psi_h = \frac{\psi_s \psi_r}{(\psi_s + \psi_r)}$.

B. Relay Selection Schemes

The outage probability of bidirectional RS is defined as

$$P_{out}(R) = \Pr\left\{\min\left[\frac{1}{2}\log_2(1+\gamma_{1k}), \frac{1}{2}\log_2(1+\gamma_{2k})\right] < R\right\}$$

where k is the index of the selected relay, R is the target rate, and γ_{jk} is the received SNR at S_j via the selected relay R_k. The pre-log factor is 1/2, because the transmission from one source to the other occupies two phases. Due to the monotony of the log function, the outage probability is re-expressed as

$$P_{out}(R) = \Pr\left[\min(\gamma_{1k}, \gamma_{2k}) < 2^{2R} - 1\right].$$

Therefore, the optimal RS scheme of bidirectional relay in minimizing the outage probability is

$$k = \arg \max_{i=1,\ldots,N} \min(\gamma_{1i}, \gamma_{2i})$$

where k is the index of the selected relay. The value of k is equivalent to

$$k = \arg \max_i \min\left\{|h_{1i}|^2, |h_{2i}|^2\right\}$$

Due to the time-variation of channel, h_{ji} gets outdated. Hence we replace value with $\hat{h}_{ji}$ thus the equation of k becomes

$$k = \arg \max_i \min\left\{|\hat{h}_{1i}|^2, |\hat{h}_{2i}|^2\right\}$$

Now we are introducing weights to the equation, ω_1 and ω_2. Then the above equation becomes

$$k = \arg \max_{i=1,\ldots,N} \min\left\{\omega_1|\hat{h}_{1i}|^2, \omega_2|\hat{h}_{2i}|^2\right\}$$

Due to the symmetry among different relay links, the RS scheme is equivalent to

$$k = \arg \max_{i=1,\ldots,N} \min\left\{|\hat{h}_{1i}|^2, \omega|\hat{h}_{2i}|^2\right\}$$

where $\omega \triangleq {\omega_2}/{\omega_1}$ i.e., only the ratio of ω_2 and ω_1 has impact on the system performance.

Therefore, the conventional bidirectional RS scheme can be treated as the special case of the proposed weighted bidirectional RS scheme , when $\omega = 1$. Accordingly, in the following, we analyze the outage probability of the weighted bidirectional RS scheme, as a function of the weight factor ω. Then, the optimal weight factor ω_{opt} in minimizing the outage probability is obtained. The following results will reveal that the weighted bidirectional RS with the optimal weight factor ω_{opt} will has lower outage probability than the conventional bidirectional RS, i.e., $\omega = 1$.

SIMULATION RESULTS

In this section, Monte-Carlo simulations are provided to validate the preceding analysis and to highlight the performance of the weighted bidirectional RS with outdated CSI. Without loss of generality, we assume the target rate R = 0.1 bps/Hz, the total average SNR is denoted by $\psi = 2\psi_s + \psi_r$. In Fig. 2, the outage probabilities of the conventional bidirectional RS , i.e., $\omega = 1$, and the weighted bidirectional RS, i.e., $\omega = \omega_{opt}$, versus the average SNR are studied. In Fig. 2, the impact of outdated CSI is studied when the number of relays N = 4 and the system structure is symmetric, i.e., the channel variances and the Doppler spreads fd1Td= fd2Td= fdTd. Due to the previous analysis, the optimal weight factor opt = 1, and thus the conventional bidirectional RS is equivalent to the optimal weighted bidirectional RS. Moreover, different lines are provided under different $f_d T_d$ means CSI is severely outdated,

whereas smaller $f_d T_d$ means CSI is slightly outdated, and especially $f_d T_d$ = 0 means CSI is perfect. In Fig. 3, it is shown when there is no relay used for transfer of packets between two nodes in a bidirectional wireless network. The direct bidirectional data transfer between the nodes. In this case due to noise and other impairments in the channel connecting two nodes, the data quality will degrade and will contain a lot of errors. Since the network is bidirectional the symbol from one node will be mixed with symbol from other node. But in case of using a number of relays we can select the best one that provides maximum efficiency to the bidirectional networks.

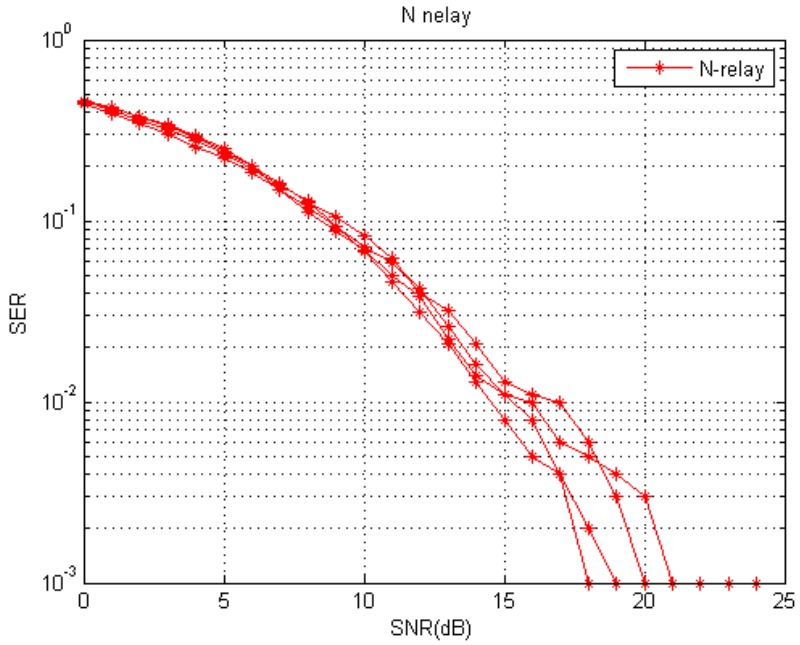

Fig 2: The outage probability with outdated CSI, when N = 4

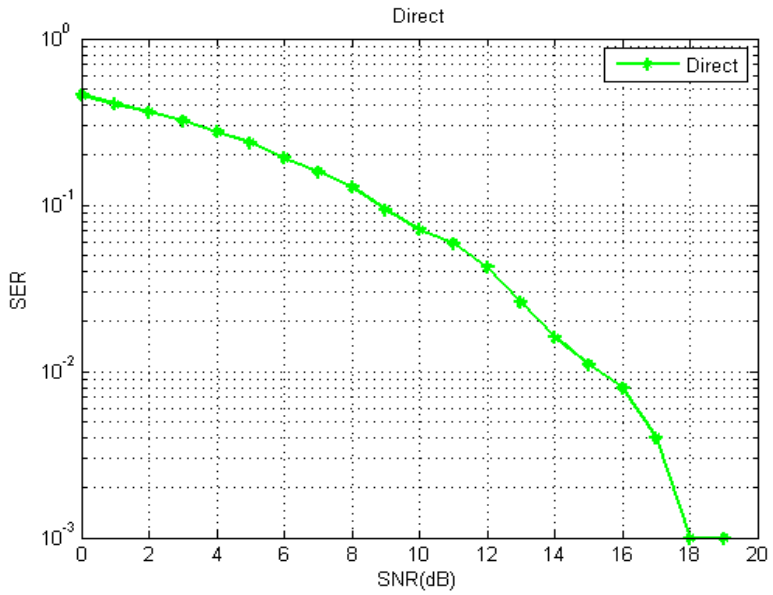

Fig 3: The outage probability with outdated CSI in direct data transfer

In Fig. 4.., the best relay for communication is selected based on the weight factors. According to the analytical expressions, the optimal weight factor and the optimal power allocation scheme in minimizing the outage probability are also obtained. The expression of the optimal weight factor reveals that the factor is decided by the correlation coefficient of outdated CSI, the number of relays, and

the channel variances. Therefore, the conventional bidirectional RS scheme can be treated as the special case of the proposed weighted bidirectional RS scheme, when $\omega = 1$. Accordingly, in the following, we analyze the outage probability of the weighted bidirectional RS scheme, as a function of the weight factor. Then, the optimal weight factor ω_{opt} in minimizing the outage probability is obtained. The following results will reveal that the weighted bidirectional RS with the optimal weight factor !opt will has lower outage probability than the conventional bidirectional RS, i.e., $\omega = 1$.

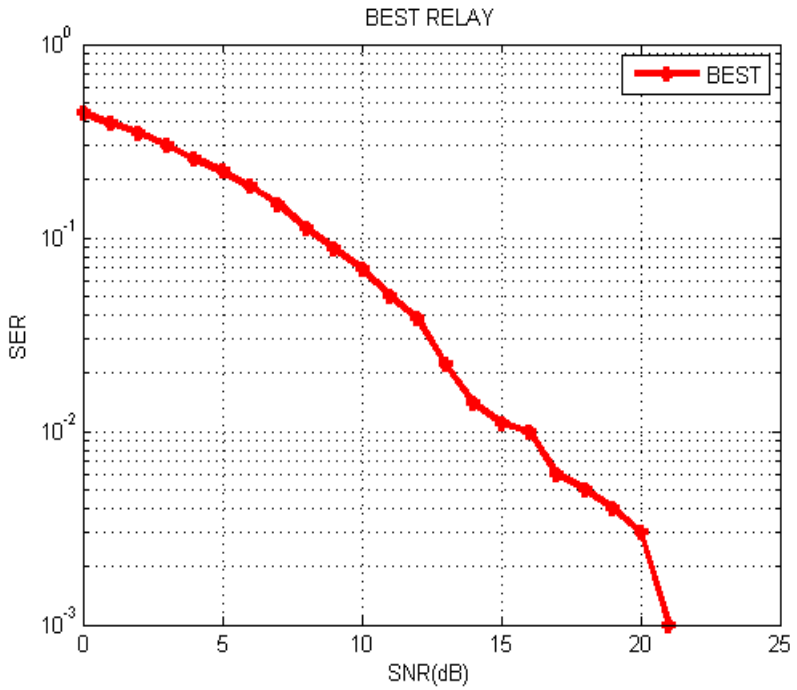

Fig 4: The outage probability with outdated CSI for the best relay among the 4.

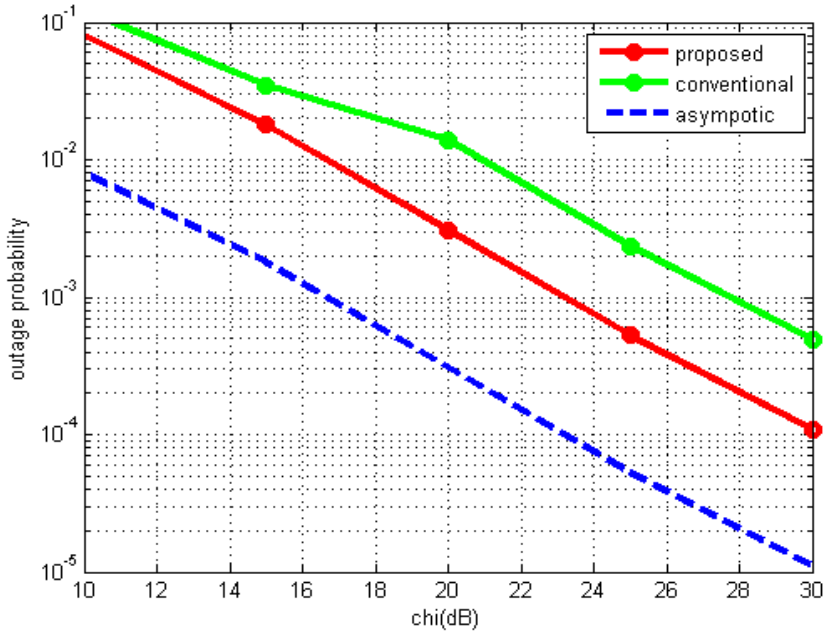

Fig 5: Outage probability with outdated CSI, when the doppler spread are different

In Fig. 5, the graph shows the outage probability with doppler spread for proposed scheme and conventional scheme. As doppler spread increases the outage probability decreases. This is because the CSI value depends on the value of doppler spread. When doppler spread is high that means the CSI is severely outdated, whereas smaller doppler spread means CSI is slightly outdated, and especially doppler spread is zero means CSI is perfect. However, increasing the number of relays N can still lower the outage probability, because the coding gain, i.e., the shift of the curve in SNR gets improved. From the figure we can see that the weighted bidirectional RS yields the significant performance gain over the conventional bidirectional RS. Specifically, the bidirectional RS are further compared when the number of relays N=4. The situation of different channel variances when the Doppler spreads are same The figure verifies the analytical expressions when the system structure is asymmetric. The figure shows that even if doppler spreads are equal, $\omega = 1$ is still not the optimal due to the difference of channel variances. The figure also reveals that although the weighted bidirectional RS cannot improve the diversity order, it can improve the coding gain, and the gain grows larger when increasing the number of relays N or increasing the average SNR.

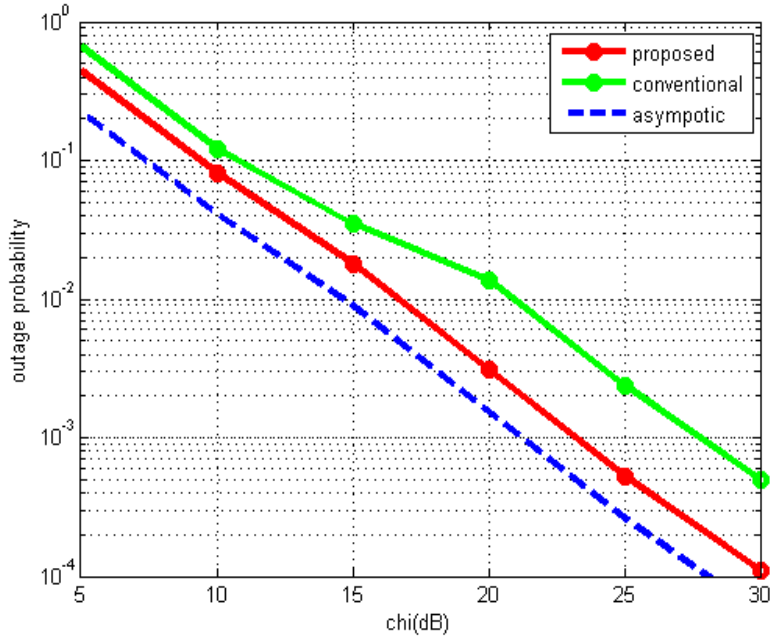

Fig 6: Outage probability with outdated CSI, when the channel variances are different

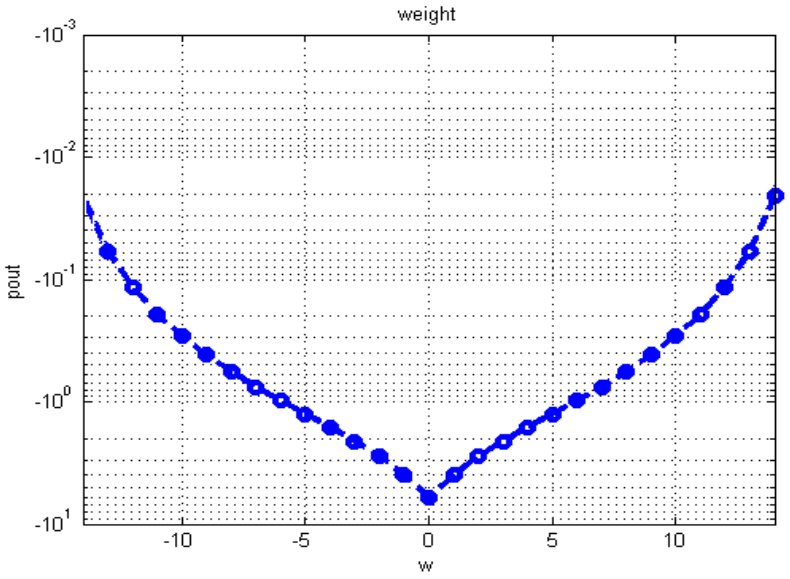

Fig 7: The impact of weight factor on outage probability

In Fig. 7, the effect of the weight factor on the simulated outage probabilities are investigated. This figure reveals that there exists the optimal weight factor in minimizing the outage probability; when the number of relays N increases, the curve around !opt becomes steeper, and thus the performance gain of the weighted bidirectional RS scheme gets improved, which explains the phenomenon that increasing N results in larger performance gain. From Fig. 7, we can also verify that the optimal weight factor obtained by the simulated outage probability matches with that obtained by the analytical lower bound.

CONCLUSION

In this paper, we analyzed the impact of outdated CSI on the performance of bidirectional AF RS. The weighted bidirectional RS was proposed to improve the performance of RS with outdated CSI. The outage probability bound of the proposed RS scheme was obtained and verified, along with the asymptotic outage probability. Based on the analytical expressions, the optimal weight factor and the optimal power allocation scheme in minimizing the outage probability were achieved. The optimal weight factor is mainly decided by the number of relays, the correlation coefficients of outdated CSI, and the channel variances. Nevertheless, the optimal power allocation scheme has no relationship with these parameters. Furthermore, the analytical and simulation results reveal that when the CSI is outdated, the diversity order reduces from full diversity to one. However, the weighted bidirectional RS with the optimal weight factor outperforms the conventional bidirectional RS, when the system structure is asymmetric. In the future work we will be proposing SNR based relay selection for Fading Channels. In this based on the SNR of the received signal at the destination, the destination decides whether relaying is needed or not by comparing received SNR with a threshold SNR.

REFERENCES:

[1] S. Zhang and S.-C. Liew, Channel coding and decoding in a relay system operated with physical-layer network coding, IEEE J. Sel. Areas Commun., vol. 27, no. 5, pp.788796, Jun. 2009.

[2] P. Popovski and H. Yomo, Wireless network coding by amplify-and forward for bi-directional traffic flows, IEEE Commun. Lett., vol. 11, no. 1, pp. 1618, Jan. 2007.

[3] Z. Ding and K. K. Leung, Impact of imperfect channel state information on bi-directional communications with relay selection, IEEE Trans. Signal Process., vol. 59, no. 11, pp. 56575662, Nov. 2011.

[4] L. Fan, X. Lei, P. Fan, and R. Q. Hu, Outage Probability Analysis and Power Allocation for Two-Way Relay Networks with User Selection and Outdated Channel State Information, IEEE Commun. Lett., vol. 16, no. 9, pp. 14421445, Sep. 2012.

[5] Y. Li, R. H. Y. Louie, and B. Vucetic, Relay selection with network coding in two-way relay channels, IEEE Trans. Veh. Technol., vol. 59, no. 9, pp. 44894499, Nov. 2010.

[6] L. Song, Relay selection for two-way relaying with amplify-and-forward protocols, IEEE Trans. Veh. Technol., vol. 60, no. 4, pp. 19541959, May 2011.

[7] P. K. Upadhyay and S. Prakriya, Performance of two-way opportunistic relaying with analog network coding over Nakagami-m fading, IEEE Trans. Veh. Technol., vol. 60, no. 4, pp. 19651971, May 2011.

[8] D. S. Michalopoulos, H. A. Suraweera, G. K. Karagiannidis, and R. Schober, Amplify-and- forward relay selection with outdated channel estimates, IEEE Trans. Commun., vol. 60, no. 5, pp. 12781290, May 2012.

[9] H. Cui, R. Zhang, L. Song, and B. Jiao, Relay selection for bidirectional AF relay network with outdated CSI, IEEE Trans. Veh. Technol., vol. 62, no. 9, pp. 43574365, Nov. 2013.

[10] H. Cui, L. Song, and B. Jiao, Weighted amplify-and-forward relay selection with outdated channel state information, IEEE Wireless Commun. Lett., vol. 2, no. 6, pp. 651654, Dec.