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Amplify-and-Forward Based Two-Way Relay ARQ System with Relay Combination

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Abstract—In this letter, we propose an automatic repeat request (ARQ) protocol for the amplify-and-forward (AF) based two-way relay system. In the proposed ARQ scheme, the ARQ process is carried out by the relay node (RN). We assume that the RN has one buffer and it can store the signals received. With the help of the buffer, the RN can combine the signals received from different slots and choose to transmit or receive adaptively. Two combining methods, namely the maximal sum signal-to-noise ratio combining (MSC) scheme and the maximal minimum signal-to-noise ratio combining (MMC) scheme, are proposed, which are shown to improve the reliability of the relaying systems.

Index Terms—Cooperative relaying, two-way relay ARQ, buffer-aided relaying.

I. INTRODUCTION

Recently, a lot of interest has been drawn by the two-way relaying scheme as it can effectively improve the efficiency of a relaying system by exploiting physical layer network coding [1]. To enhance its reliability, automatic repeat request (ARQ) protocol was adapted in [2]–[4]. In [2], the throughput of a two-way relay ARQ system with and without a direct link between the two users was compared. In [3] and [4], the throughput of different ARQ protocols for a two-way relay system was investigated. In all these two-way relay ARQ schemes, the decode-and-forward (DF) approach was used at the relay node (RN). In [5], the amplify-and-forward (AF) based two-way relay ARQ protocol was investigated. The diversity multiplexing tradeoff of the AF-based two-way relay ARQ scheme was obtained.

In this letter, we propose an ARQ protocol for the AF-based two-way relay system. Our scheme is different from the scheme of [5] from the following aspects: 1) The ARQ process of [5] is carried out by the users by feeding back positive or negative acknowledgement (ACK). In the proposed scheme, the ARQ process is carried out by the RN. 2) In our work, we assume that the RN has one buffer and it can combine the signal received in several slots, thus our scheme can benefit from some power gains. To the best of our knowledge, the combining strategies of the RN in a two-way relay ARQ system have not been investigated before. The buffer-aided two-way relaying was also investigated in [6]–[8]. In these works, the DF method was adopted and the RN switches between different working modes adaptively to maximize the system throughput. Inspired by these works, the RN in our proposed scheme chooses to receive or to transmit adaptively based on the channel quality at each

Fig. 1. A two-way relay channel.

time slot. Numerical results show that our proposed scheme can achieve higher diversity order than the scheme of [5]. In addition, two combining methods, the maximal sum signal-to-noise ratio (SNR) combining (MSC) scheme and the maximal minimum SNR combining (MMC) scheme are proposed, which are shown to improve the reliability of the system.

II. SYSTEM MODEL AND ASSUMPTIONS

A three-node system in which two single-antenna users S_1, S_2 exchange information with the help of a RN is considered. As there is no direct link between the users, S_1 and S_2 communicate only through R . We also assume that all nodes are half-duplex. Each time frame is divided into slots of equal length and block flat fading channel in which the channel coefficients are constant during one time slot and change independently from one slot to another is assumed. We denote h_{1k} and h_{2k} as the channel gains between S_1, S_2 and R in the k th time slot, respectively. The channels are assumed to be reciprocal as time-division-duplex method is used. Moreover, similar to [6]–[8], we assume that the RN has the knowledge of the channel coefficients. The received signals are corrupted by additive white Gaussian noise (AWGN) with a power spectral density (PSD) of N_0 . The transmitted power of the users and the RN is P . The target rates of S_1 and S_2 are denoted as R_1 and R_2 , respectively.

III. ARQ STRATEGY AND SIGNAL MODEL

The proposed ARQ strategy can be described as follows:

Slot 1: S_1 and S_2 transmit signal to R simultaneously, the RN quantizes the received signals and stores them in the buffer. Note that in the AF-based half-duplex relaying network, the RN receives and transmits in different time slots. Thus the received signals are actually always quantized and stored in a buffer. The received signal can be expressed as

$$y = \sqrt{P}h_{11}x_1 + \sqrt{P}h_{21}x_2 + n_r, \quad (1)$$

where x_1 and x_2 are the transmitted symbols by S_1 and S_2 , respectively, and n_r is the noise received at the RN. It is assumed that the RN has an infinite buffer size [8].

Slot 2: As the RN knows the channel coefficients, it can calculate the end-to-end SNRs γ_1 and γ_2 of the two users. For

the AF-based two-way relaying system, the end-to-end SNRs can be expressed as [5]

$$\gamma_i = \rho |h_{\bar{i}1}|^2 |h_{i2}|^2 / (|h_{\bar{i}1}|^2 + |h_{i2}|^2 + |h_{i1}|^2 + 1/\rho), \quad (2)$$

where $\rho = P/N_0$, $i, \bar{i} \in \{1, 2\}$ are the user indices which satisfy that if $i = 1(2)$, then $\bar{i} = 2(1)$.

1) If it satisfies $\gamma_1 < \lambda_1, \gamma_2 < \lambda_2$, where $\lambda_1 = 2^{R_2} - 1$ and $\lambda_2 = 2^{R_1} - 1$, then the RN sends a negative ACK to both users. The two users retransmit their packets to R , and the RN receives and stores it in the buffer. The system works in a two-way mode.

2) If one of the users can successfully receive the packet, for instance $\gamma_1 > \lambda_1, \gamma_2 < \lambda_2$, the RN amplifies the received signal and retransmits it to both users. The received signal of user i can be expressed as

$$r_i = \beta \sqrt{P} h_{i1} h_{i2} x_i + \beta \sqrt{P} h_{\bar{i}1} h_{i2} x_{\bar{i}} + \beta h_{i2} n_r + n_i, \quad (3)$$

where $\beta = \sqrt{P/(P|h_{21}|^2 + P|h_{11}|^2 + N_0)}$ is the amplification factor. As $S_1(S_2)$ knows its transmitted signal $x_1(x_2)$, it can subtract it from $r_1(r_2)$, thus the self-interference is cancelled. As only S_1 can successfully detect the message, a negative ACK and a positive ACK are sent to S_1 and S_2 by the RN, respectively. In the following time slots, only S_1 retransmits its packet to R and the system transforms into a one-way mode.

3) If $\gamma_1 > \lambda_1, \gamma_2 > \lambda_2$, the RN amplifies the received signal and retransmits it to both users. As both users can successfully decode the messages, a positive ACK is transmitted to both users by the RN and the buffer is released to receive new packets.

Slot k ($k > 2$): As multiple copies of the signals are stored in the buffer, the RN firstly combines them. For the two-way mode, the signal received by the RN during the previous $k-1$ slots can be expressed as

$$\mathbf{y} = \sqrt{P} \mathbf{h}_{1k-1} x_1 + \sqrt{P} \mathbf{h}_{2k-1} x_2 + \mathbf{n}_r, \quad (4)$$

where $\mathbf{h}_{1k-1} = [h_{11}, \dots, h_{1k-1}]^T$, $\mathbf{h}_{2k-1} = [h_{21}, \dots, h_{2k-1}]^T$ are the channel vectors. The combined signal can be written as

$$\mathbf{r} = \mathbf{w}^H \mathbf{y} = \sqrt{P} h_{1k-1}^{eq} x_1 + \sqrt{P} h_{2k-1}^{eq} x_2 + \tilde{n}_r, \quad (5)$$

where $h_{ik-1}^{eq} = \mathbf{w}^H \mathbf{h}_{ik-1}$, $i = 1, 2$ are the combined equivalent channel gains, $\mathbf{w}$ stands for the combining vector, which has a Frobenius norm $\|\mathbf{w}\| = 1$. $\tilde{n}_r$ is the equivalent noise after combining. The RN calculates γ_1, γ_2 using h_{ik-1}^{eq} and h_{ik} , $i = 1, 2$ to decide whether to receive or to transmit in the k th slot. Then similar operations as those in slot 2 are performed.

If the system works in the one-way mode, for instance, we assume that S_2 has already successfully decoded x_1 in the n th ($n \leq k-1$) time slot, the RN only needs to forward x_2 to S_1 . Similar to the two-way mode, the RN combines the received signals and calculates the end-to-end SNR of S_2 to decide whether to transmit or to receive. However, in this case, $\mathbf{h}_{1k-1}$ in (4) should be rewritten as $\mathbf{h}_{1k-1} = [h_{11}, h_{12}, \dots, h_{1n}, 0, \dots, 0]$.

In this paper, we set a maximum delay of N time slots for the proposed ARQ scheme. If any one of the users fails to decode the message within N time slots, the system is in outage.

Remark: In the proposed two-way relay ARQ scheme, the users can retransmit one packet for at most $N-1$ times. Thus by increasing N , the reliability of the system can be improved,

which on the other hand decreases the overall throughput of the system as more time slots are used to deliver a packet. In addition, a signal packet is dropped if it is not successfully delivered within N time slots, thus the end-to-end delay of the proposed ARQ scheme is controlled within N time slots. Furthermore, as the ACK is sent by the RN, the users can receive it directly, which is preferable for the two-way relay system without a direct link between the users.

IV. COMBINING APPROACH OF THE RELAY NODE

In this section, the MSC scheme and the MMC scheme are investigated for the two-way mode. The optimal combining method for the one-way mode is also obtained.

A. MSC Scheme

In the MSC scheme, the relay node attempts to maximize the sum SNR of the received signals and noise. As $\|\mathbf{w}\| = 1$, the PSD of the combined noise is N_0 . The sum power of the signals received in k time slots is $P_{sum} = P \mathbf{w}^H (\mathbf{h}_{1k} \mathbf{h}_{1k}^H + \mathbf{h}_{2k} \mathbf{h}_{2k}^H) \mathbf{w}$, thus the following optimization problem can be formed:

$$\begin{aligned} \max_{\mathbf{w}} \quad & \mathbf{w}^H \mathbf{H}_{sum} \mathbf{w} \\ \text{s.t.} \quad & \|\mathbf{w}\| = 1, \end{aligned} \quad (6)$$

where $\mathbf{H}_{sum} = \mathbf{h}_{1k} \mathbf{h}_{1k}^H + \mathbf{h}_{2k} \mathbf{h}_{2k}^H$ is a positive definite Hermitian matrix. It has been shown in [9] that the optimal combining vector $\mathbf{w}$ is the eigenvector corresponding to the maximum eigenvalue of $\mathbf{H}_{sum}$. Thus the optimal $\mathbf{w}$ can be obtained as $\mathbf{w} = \mathbf{u}_{max}$, where $\mathbf{u}_{max}$ is the eigenvector associated to the maximum eigenvalue of $\mathbf{H}_{sum}$.

B. MMC Scheme

In the MMC scheme, the RN attempts to maximize the minimum SNR of the two received signals. The power of the two combined signals can be written as $P_i = P \mathbf{w}^H \mathbf{H}_i \mathbf{w}$, $i = 1, 2$, where $\mathbf{H}_i = \mathbf{h}_{ik} \mathbf{h}_{ik}^H$. Thus the SNRs of the two signals at the relay node are $SNR_i = \rho \mathbf{w}^H \mathbf{H}_i \mathbf{w}$. The MMC scheme solves the following problem

$$\begin{aligned} \max_{\mathbf{w}} \quad & \min \{ \mathbf{w}^H \mathbf{H}_1 \mathbf{w}, \mathbf{w}^H \mathbf{H}_2 \mathbf{w} \} \\ \text{s.t.} \quad & \|\mathbf{w}\| = 1. \end{aligned} \quad (7)$$

As the objective function is a monotonously increasing function of $\|\mathbf{w}\|$, problem (7) is equivalent to the following problem

$$\begin{aligned} \max_{\mathbf{w}} \quad & \min \{ \mathbf{w}^H \mathbf{H}_1 \mathbf{w}, \mathbf{w}^H \mathbf{H}_2 \mathbf{w} \} \\ \text{s.t.} \quad & \|\mathbf{w}\| \leq 1. \end{aligned} \quad (8)$$

According to the results of [10], problem (8) is a non-convex problem which can be solved by adapting a semidefinite relaxation (SDR) approach. However, this approach has a high computational complexity. To reduce the complexity, we propose a suboptimal approach which has much lower complexity.

Lemma 1. *The optimal $\mathbf{w}$ lies in the set $\psi = \{\hat{\mathbf{h}}_{1k}, \hat{\mathbf{h}}_{2k}\}$, if it satisfies $|\mathbf{h}_{1k}^H \mathbf{h}_{2k}| > \min\{\|\mathbf{h}_{1k}\|^2, \|\mathbf{h}_{2k}\|^2\}$, where $\hat{\mathbf{h}}_{1k} = \mathbf{h}_{1k}/\|\mathbf{h}_{1k}\|$, $\hat{\mathbf{h}}_{2k} = \mathbf{h}_{2k}/\|\mathbf{h}_{2k}\|$.*

Proof: As $|\mathbf{w}^H \mathbf{h}_{1k}|^2$ achieves the maximum value when $\mathbf{w} = \mathbf{h}_{1k}/\|\mathbf{h}_{1k}\|$, if it satisfies $|\mathbf{h}_{1k}^H \mathbf{h}_{2k}| > \|\mathbf{h}_{1k}\|^2$, problem (8) achieves the maximum value when $\mathbf{w} = \frac{\mathbf{h}_{1k}}{\|\mathbf{h}_{1k}\|}$. If $|\mathbf{h}_{1k}^H \mathbf{h}_{2k}| > \|\mathbf{h}_{2k}\|^2$, the optimal combining vector is $\mathbf{w} = \mathbf{h}_{2k}/\|\mathbf{h}_{2k}\|$. ■

Lemma 2. *There always exists $\mathbf{w} = \alpha \hat{\mathbf{h}}_{1k} + \beta \hat{\mathbf{h}}_{2k}$, $\alpha, \beta \in \mathbb{C}$ to make $\mathbf{w}^H \mathbf{H}_1 \mathbf{w} = \mathbf{w}^H \mathbf{H}_2 \mathbf{w}$, if it satisfies $|\mathbf{h}_{1k}^H \mathbf{h}_{2k}| < \min\{\|\mathbf{h}_{1k}\|^2, \|\mathbf{h}_{2k}\|^2\}$.*

Proof: Set $\mathbf{w} = \alpha \hat{\mathbf{h}}_{1k} + (1 - \alpha) \hat{\mathbf{h}}_{2k}$. As $|\mathbf{h}_{1k}^H \mathbf{h}_{2k}| < \min\{\|\mathbf{h}_{1k}\|^2, \|\mathbf{h}_{2k}\|^2\}$, we have $|\mathbf{w}^H \mathbf{h}_{1k}|^2 > |\mathbf{w}^H \mathbf{h}_{2k}|^2$, when $\alpha = 1$. When $\alpha = 0$, we have $|\mathbf{w}^H \mathbf{h}_{1k}|^2 < |\mathbf{w}^H \mathbf{h}_{2k}|^2$. As $|\mathbf{w}^H \mathbf{h}_{1k}|, |\mathbf{w}^H \mathbf{h}_{2k}|$ are continuous functions of α , there must be a $\alpha \in (0, 1)$ which makes $|\mathbf{w}^H \mathbf{h}_{1k}|^2 = |\mathbf{w}^H \mathbf{h}_{2k}|^2$. ■

In the scenario $|\mathbf{h}_{1k}^H \mathbf{h}_{2k}| < \min\{\|\mathbf{h}_{1k}\|^2, \|\mathbf{h}_{2k}\|^2\}$, we use $\mathbf{w} = a_1 \hat{\mathbf{h}}_{1k} + a_2 \hat{\mathbf{h}}_{2k}$, where a_1 and a_2 are complex scalars to approximate the optimal combining vector. Denote $\mathbf{a} = [a_1, a_2]^T$, $\hat{\mathbf{H}} = [\hat{\mathbf{h}}_{1k}, \hat{\mathbf{h}}_{2k}]$, and let $\mathbf{R}_1 = \hat{\mathbf{H}}^H \mathbf{H}_1 \hat{\mathbf{H}}$, $\mathbf{R}_2 = \hat{\mathbf{H}}^H \mathbf{H}_2 \hat{\mathbf{H}}$, then problem (8) can be transformed as

$$\begin{aligned} \max_{\mathbf{a}} \quad & \min\{\mathbf{a}^H \mathbf{R}_1 \mathbf{a}, \mathbf{a}^H \mathbf{R}_2 \mathbf{a}\} \\ \text{s.t.} \quad & \|\mathbf{a}\| = 1. \end{aligned} \quad (9)$$

Based on lemma 2, it can be concluded that the optimal $\mathbf{a}$ always satisfies $\mathbf{a}^H \mathbf{R}_1 \mathbf{a} = \mathbf{a}^H \mathbf{R}_2 \mathbf{a}$, thus we firstly find the $\mathbf{a}$ that satisfies $\mathbf{a}^H \mathbf{R} \mathbf{a} = 0$, where $\mathbf{R} = \mathbf{R}_1 - \mathbf{R}_2$ is a 2 by 2 Hermitian matrix. The eigenvalue decomposition of $\mathbf{R}$ can be expressed as $\mathbf{R} = \mathbf{V}^H \Sigma \mathbf{V}$, where $\mathbf{V}$ is a 2 by 2 unitary matrix that consists of the eigenvectors of $\mathbf{R}$, Σ is a diagonal matrix with diagonal elements λ_1 and λ_2 , which are the eigenvalues of $\mathbf{R}$. Denote $\mathbf{b}^H = \mathbf{a}^H \mathbf{V}^H$, then we let

$$|b_1|^2 \lambda_1 + |b_2|^2 \lambda_2 = 0. \quad (10)$$

It can be observed that any vector $\mathbf{b} = [b_1, b_2]^T$ that satisfies (10) will result in $\mathbf{a}^H \mathbf{R} \mathbf{a} = 0$. Without loss of generality, let $\mathbf{b} = e^{j\varphi} [\sqrt{\lambda_2}, \sqrt{-\lambda_1} e^{j\theta}]$, $\varphi, \theta \in [0, 2\pi]$. It can be observed that the value of φ has no influence on the value of $\mathbf{a}^H \mathbf{R}_1 \mathbf{a}$, so we only need to find the optimal θ that maximizes $\mathbf{a}^H \mathbf{R}_1 \mathbf{a}$. By using a one-dimensional search, the optimal θ can be found. After finding the optimal $\mathbf{a}$, we can obtain $\mathbf{w}$ and normalize its Frobenius norm to 1.

C. Combining in the one-way mode

If one of the transmitted signals is successfully detected, then the system works in the one-way mode. We assume that S_1 has correctly received x_2 , then the RN only aims to effectively deliver x_1 in this scenario. The optimal combining vector $\mathbf{w}$ of the RN should maximize the end-to-end SNR of S_2 , i.e.,

$$\begin{aligned} \max \quad & \text{SNR}_2 \\ \text{s.t.} \quad & \|\mathbf{w}\| = 1, \end{aligned} \quad (11)$$

in which $\text{SNR}_2 = \rho |\mathbf{w}^H \mathbf{h}_{1k}|^2 |g_{2k}|^2 / (|\mathbf{w}^H \mathbf{h}_{1k}|^2 + |\mathbf{w}^H \mathbf{h}_{2k}|^2 + |g_{2k}|^2 + \frac{1}{\rho})$. Denote $\mathbf{D} = \mathbf{H}_1 + \mathbf{H}_2 + [|g_{2k}|^2 + \rho] \mathbf{I}$, where $\mathbf{I}$ is the

TABLE I
COMPLEXITY COMPARISONS FOR DIFFERENT SCHEMES.

Scheme	Complexity
MSC	$72k^3 + 7k^2 + 7k$
MMC-proposed	$24k + 42 + 72 \times 2^3 + 72\pi/\varepsilon$
MMC-SDR	$\mathcal{O}(6k^{4.5} \log_{10}(1/e_1)) \lceil \log_2(t/e_2) \rceil$

identity matrix, then we get the following optimization problem

$$\begin{aligned} \max_{\mathbf{w}} \quad & \frac{\mathbf{w}^H \mathbf{H}_1 \mathbf{w}}{\mathbf{w}^H \mathbf{D} \mathbf{w}} \\ \text{s.t.} \quad & \|\mathbf{w}\| = 1. \end{aligned} \quad (12)$$

As $\mathbf{D}$ is a positive definite matrix, it has been proved that the optimal value of the objective function of (12) is the maximum eigenvalue of the matrix $\mathbf{D}^{-\frac{1}{2}} \mathbf{H}_1 \mathbf{D}^{-\frac{1}{2}}$ [10]. Denote the eigenvector of $\mathbf{D}^{-\frac{1}{2}} \mathbf{H}_1 \mathbf{D}^{-\frac{1}{2}}$ associated with the maximum eigenvalue to be $\mathbf{v}$, then let $\hat{\mathbf{w}} = \mathbf{D}^{-\frac{1}{2}} \mathbf{v}$. By Normalizing with $\hat{\mathbf{w}}$, we get the optimal solution of (12) to be $\mathbf{w} = \hat{\mathbf{w}}/\|\hat{\mathbf{w}}\|$.

D. Complexity Comparison

The complexity of obtaining the combining vector is evaluated using the number of flops. A flop is defined to be a real floating point operation. A complex addition and multiplication have two and six flops, respectively. After k ($k \geq 2$) retransmissions, as $\mathbf{H}_{sum}$ is a Hermitian matrix, the MSC scheme needs $7k^2 + 7k$ flops to get $\mathbf{H}_{sum}$ and $72k^3$ flops to perform eigenvalue decomposition of $\mathbf{H}_{sum}$ [11]. Thus, the total complexity of the MSC scheme can be expressed as $72k^3 + 7k^2 + 7k$. For the proposed suboptimal MMC scheme, it takes $12k$ flops to get $\hat{\mathbf{H}}^H \mathbf{h}_{1k}$, thus the number of flops needed to get $\mathbf{R}$ is $24k + 42$. As $\mathbf{R}$ is a 2 by 2 matrix, its eigenvalue decomposition needs 72×2^3 flops. For the one-dimensional searching with step size ϵ , $2\pi/\varepsilon$ iterations are needed, and each iteration needs 36 flops to get the value of $\mathbf{a}^H \mathbf{R}_1 \mathbf{a}$. As a result, the total complexity of the proposed suboptimal MMC scheme can be written as $24k + 42 + 72 \times 2^3 + 72\pi/\varepsilon$. For the SDR-based MMC scheme, based on the result of [12], the complexity is provided in Table I where e_1 and e_2 denote the solution accuracies of the SDR process and bisection searching process, respectively. It can be observed that the proposed suboptimal MMC scheme has the lowest complexity when k is small. Both the proposed MSC scheme and the MMC scheme have lower complexity as compared to the SDR-based MMC scheme.

V. NUMERICAL RESULTS AND DISCUSSION

In Fig. 2, the outage probabilities of different schemes are provided. We define that the system is in outage if any one of the users fails to deliver the packet to the destination within a maximum number of N time slots. The target information rate of the two users is set to be $R = 1$ bit/s/Hz and all channel gains are independently Rayleigh distributed random variables with unit variance. The performance of the two-way relay ARQ scheme of [5] is also presented as a comparison. In [5], each ARQ round takes two time slots. In the first slot, both users

Fig. 2. Outage probabilities of the proposed ARQ scheme and the existing ARQ scheme in [5] with $N = 4$ and 6.

transmit signal to the RN and the RN broadcasts the received signal in the second slot. We present the achieved diversity order of different schemes by comparing the slopes of the outage curves with the reference outage curves plotted as $P_{out}^{ref} = A \cdot SNR^{-d}$, where A is a constant.

From Fig. 2, it can be observed that the proposed ARQ scheme achieves a diversity order of $N - 1$ while the diversity order of the scheme in [5] is $N/2$ when the maximum delay for both systems is set as N . This improvement results from the fact that in our scheme, the RN chooses to receive or transmit adaptively in each slot. The performance gains of the proposed combining schemes are illustrated by comparing with the scheme without combining at the RN. In the proposed ARQ scheme without relay combining, the RN releases the packets received in the previous slots and only stores the packet received in the current slot. As there is only one packet in the buffer, no combining is performed. It can be observed that the MSC scheme achieves more than 1dB SNR gain compared with the system without combination at the RN. The MMC scheme outperforms the MSC scheme by about 1dB if the SDR approach is used. Negligible performance loss is observed for the proposed suboptimal algorithm as compared with the SDR-based approach.

Fig. 3. Outage probabilities of the proposed schemes with different buffer sizes.

In Fig. 3, the effect of the buffer size on system performance is investigated. The outage probabilities of the MMC scheme with different RN buffer sizes are presented. For the one packet buffer case, the RN can only store one packet of information, thus the combining method at the RN becomes the selective combination. Specifically, the RN decides whether to keep the existing packet or to receive the new packet based on the channel response of different ARQ rounds. For the MMC scheme, the n th packet is stored if it satisfies $n = \arg \max_i \{\min[|h_{1i}|, |h_{2i}|]\}$. For the two packets buffer case, the RN can store two packets. From the third ARQ round, half of the buffer is used to store the combined packet of the previous ARQ rounds, the other half is used to receive the new packet; then these two packets are combined and forwarded to the destination. It can be observed from Fig. 3 that as the buffer size increases, the system can achieve lower outage probability.

VI. CONCLUSION

In this letter, we have proposed an ARQ scheme for the two-way relaying system. The combining technique was also applied at the RN as it has a buffer. Two combining schemes, i.e., the MSC scheme and the MMC scheme, have been proposed and the optimal combining vectors have been obtained. Numerical results have shown that the proposed ARQ method and the combining schemes can improve the system reliability.

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