Two-Path Relay Systems with Inter-Relay Interference Suppression

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Abstract. This paper considers two-path multiple-input multiple-output (MIMO) relay systems in which the inter-relay interference (IRI) between two relay nodes leads to a degradation of the system performance. In this paper, we study the use of beamforming techniques to resolve the problem of IRI. To suppress the IRI, the transmit and receive beamforming schemes based on singular value decomposition (SVD) of the inter-relay channel were proposed. Simulation results show that the proposed scheme has better performance than existing approaches.

Introduction

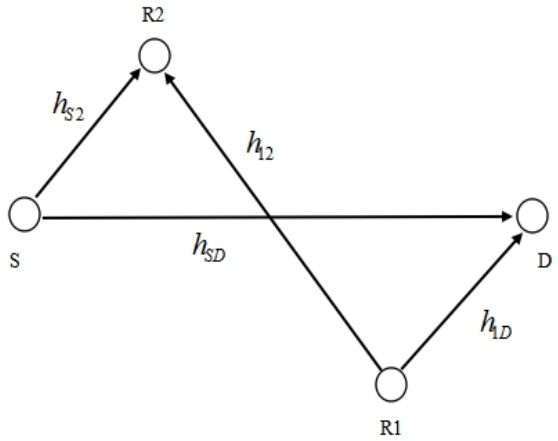
MIMO relay systems have been extensively considered due to the potential benefits of MIMO techniques such as spectral efficiency and link reliability [1,2]. Even though a half-duplex relay, which cannot transmit and receive a signal simultaneously, is in general preferable to full-duplex relay from an implementation aspect, the former leads to 50% or more loss in spectral efficiency. To recover the spectral efficiency loss, two-path relaying peotocol has been proposed in [3,4].

Despite the time efficiency of two-path relay systems, the IRI resulting from the two-path relaying protocol itself decreases the signal at the destination node. To solve this issue, several IRI cancellation schemes have been proposed in [5,6]. In [5], each relay node decodes the IRI and then subtracts it from the received signal before decoding the desired signal when the IRI is stronger than the desired signal. In [6], the achievable rates of two-path relaying were studied by exploiting dirty-paper coding for IRI cancellation. However, the previous works in [5,6] consider only a deployment of single antenna at all the nodes. Our goal is therefore to remove the IRI using multiple antennas while not sacrificing the performance significantly.

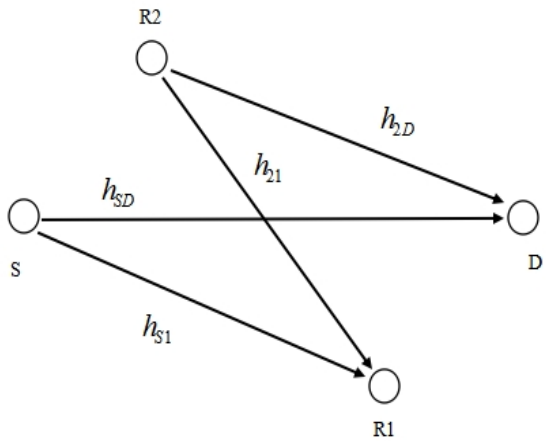
In this paper, an alternative technique for suppressing the IRI is proposed. To suppress the IRI, we employ transmit and receive beamforming vectors at the relay nodes. Our simulation results show that the proposed scheme improves the full- duplex MIMO relay system throughput.

System Model

The two-path relay scheme is illustrated in Fig.1, there is one source node *S*, one destination node *D*, and two relay nodes R_1 and R_2, the relay nodes are equipped with multiple antennas. We assume at odd numbered time slots, the source *S* transmits date to relay R_1, and at the same time the relay R_2 relays the data received from *S* at the previous time slot to *D*. Similarly at even numbered time slots, *S* transmits data to R_2, and R_1 relays previously received data to *D*, h_{S1} and h_{S2} represent the channel matrices between $S-R_1$ and $S-R_2$, respectively. h_{1D} and h_{2D} represent the channel matrices between R_1-D and R_2-D, respectively. h_{12} is the inter-relay channel matric between R_1 and R_2. Unlike the single relay scheme, the source continuously transmits data to the two relay nodes alternatively.



(a) First phase



(b) Second phase

Fig.1 System model for IRI suppression

The received signals of the relayand the destination at the *n*th time slot are given by

$$y_2(n) = h_{S2}x_s(n) + h_{12}x_1(n) + n_2(n) \tag{1}$$

$$y_d(n) = h_{SD}x_s(n) + h_{1D}f_1x_1(n) + n_d(n) \tag{2}$$

In the following time solt, the received singals of the relay R_1 and the destination D at n+1th are given by

$$y_1(n+1) = h_{S1}x_s(n+1) + h_{21}f_2x_2(n) + n_1(n+1) \tag{3}$$

$$y_d(n+1) = h_{SD}x_s(n+1) + h_{2D}^H f_2x_2(n+1) + n_d(n+1) \tag{4}$$

where x_s is the data symbol from the source, x_1 is the signal from R_1, n_2, n_d and n_1 are complex Gaussian noises. f_1 and f_2 denote the transmit beamforing vectors at relay R_1 and R_2, respectively. Hence, the transmit signals of the relay R_1 and R_2 are generated as

$$x_1(n) = f(g_1^H y_1(n-1)) = f(g_1^H h_{S1} x_s(n-1) + g_1^H h_{21} f_2 x_2(n-1) + g_1^H n_1(n-1)) \quad (5)$$

$$x_2(n+1) = f(g_2^H y_2(n)) = f(g_2^H h_{S2} x_s(n) + g_2^H h_{12} f_1 x_1(n) + g_2^H n_2(n)) \quad (6)$$

where $f(\cdot)$ presents the demodulation and re-modulation operation, g_1 and g_2 denote the receive beamforing vectors at relay R_1 and R_2, respectively.

IRI Suppression

First, the relay bamforming vectors are chosen to ignore the inter-relay links and focus on the incoming and outgoing links. The receive bamforming vectors are optimized such that the received power from the source node is maximized and the transmit beamforming vectors are formed such that the power is directed towards the destination node.

The solution in such a case is well known, and the beamformers are chosen as

$$g_2 = \frac{h_{S2}^*}{\|h_{S2}\|}, \quad \text{and,} \quad \mathrm{f}_2 = \frac{h_{2D}^*}{\|h_{2D}\|} \quad (7)$$

This solution is optimal when no IRI exist. Therefore, in cases where inter-relay strength is low, the scheme is expected to perform well.

Alternatively, rather than focusing on the incoming and outgoing links, we can focus on the inter-relay links to reduce the IRI. We can choose the transmit and receive beamforming vectors such that the receive power is minimized from the direction of the other relay and the transmit power is nulled in the direction of the other relay.

We can formulate the criterion for such scenarios as

$$\min_{f_1, g_2} \left\| g_2^H h_{12} f_1 \right\|^2 \quad \text{and} \quad \min_{f_2, g_1} \left\| g_1^H h_{21} f_2 \right\|^2 \quad (8)$$

By decomposing h_{12} and h_{21} using Singular Value Decomposition (SVD), we get

$$h_{12} = U_2 \Sigma V_1^H \quad (9)$$

$$h_{21} = U_1 \Sigma V_2^H \quad (10)$$

By choosing g_2, f_1 as the left and right singular vectors corresponding to the smallest singular value of h_{12}, and choosing g_1, f_2 as the left and right singular vectors corresponding to the smallest singular value of h_{21}, we can ensure that the cost function in (8) is minimized.

Simulation Results

In this section, the theories presented in the previous sections are verified through computer simulations. We assume the Rayleigh fading channel and the average received SNRs at the source node, the destination node, and the relay node are all identical. The simulation conditions are as follows: $P_S = P_R = 1/2$, $s_R^2 = s_B^2 = 1$ and $M_R = N_R = 2$. Fig. 2 illustrates the capacity of the two-path relay system, in which the relay nodes are equipped with two antennas. We can observe that the the interference suppression scheme improve the capacity, and thus fulfills its task of suppress IRI.

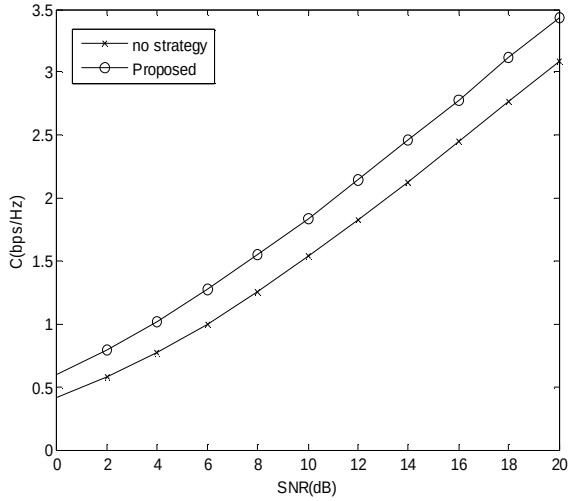


Fig.2 Comparison of capacities for different schemes

Summary

In this paper, we investigated the scenario where two relays were present and an alternating algorithm was applied to increase the relaying capacity of the system. We identified the problem associated with this setup, which mainly lies the interference caused by one relay to the other relay node. From here, we employed transmit and receive beamforming vectors for suppressing the IRI. The proposed approach has significant better performance than the no strategy scheme.

Acknowledgements

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