Hybrid Relay Selection Scheme with Feedback Channel for Amplify-and-Forward Two-Hop Networks

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Outline

Motivation

- The interest in cooperative communications is growing, mainly by the distributed spatial diversity that can be exploited. Solving the problem of installing multiple antennas on small terminals;
- The Amplify-and-Forward (AF) is one of the most used protocols due to its simplicity and low complexity;
- Sometimes, relays provide a poor channel quality which can affect the end-to-end transmission. Therefore, the use of a relay selection scheme is an attractive and promising way to overcome this problem;
- In order to maximize the system end-to-end SNR, it is necessary use algorithms which optimizes the power allocation among the relays.

Objectives

- In this work we propose a hybrid relay selection scheme with feedback channel for two-hop diamond network;
- The hybrid scheme is based on relay selection, power allocation, antenna selection techniques and also on the pre-processing, and quantized channel state information (CSI) feedback designs;
- Show that the proposed scheme outperforms other good schemes in terms of SNR gain, has low complexity linear processing, and the receiver has low complexity. Those features make the proposed scheme an interesting solution for two-hop relay systems.

System Model

- The model considered is a specific two-hop AF network, known as diamond network.

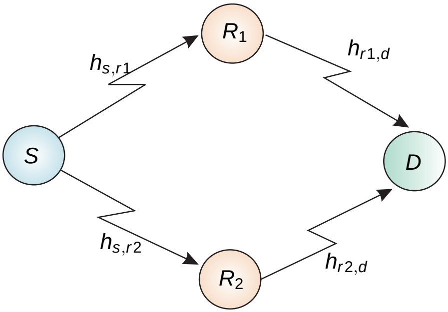


Figure: Diamond Network.

Some Considerations

- It is assumed a TDMA transmission mode;
- The cooperative node is operating in the half-duplex mode;
- There is no direct link between the source and the destination node;
- The channel is assumed to undergo quasi-static, flat Rayleigh fading;
- The channel coefficients are perfectly estimated by the destination node;
- Is assumed a feedback channel between destination-relay nodes;
- The total transmit power per time slot is P;
- The noise is considered as an additive white Gaussian noise (AWGN) with variance $N_0/2$ per complex dimension.

Mathematical Model

The received signal at the relays nodes, can be described as:

$$y_{r1} = \sqrt{P} s h_{s,r1} + \eta_{r1}, \quad (1)$$

and

$$y_{r2} = \sqrt{P} s h_{s,r2} + \eta_{r2}, \quad (2)$$

where,

- y_{ri} is the received signal at the i-th relay
- P is the total transmit power
- $h_{s,ri}$ is the channel coefficient from the source to the i-th relay
- η_{ri} is the noise on the receiver at the i-th relay

Mathematical Model

The received signal at the destination node, can be described as:

$$y_d = y_{r1,d} + y_{r2,d} + \eta_d\,, \tag{3}$$

where,

$$y_{r1,d} = \beta_1 h_{r1,d}\sqrt{P} s h_{s,r1} + \beta_1 \eta_{r1}, \tag{4}$$

and

$$y_{r2,d} = \beta_2 h_{r2,d}\sqrt{P} s h_{s,r2} + \beta_2 \eta_{r2}, \tag{5}$$

Mathematical Model

$$\beta_1 = \sqrt{\frac{P}{P|h_{s,r1}|^2 + N_0}} \cos(\theta) \tag{6}$$

and

$$\beta_2 = \sqrt{\frac{P}{P|h_{s,r2}|^2 + N_0}} \sin(\theta), \tag{7}$$

where, θ is the feedback phase informed.

Detection

The received signal can be given by:

$$y_d = s\sqrt{P}(\beta_1 h_1 + \beta_2 h_2) + \eta'_d, \quad (8)$$

where,

$$h_1 = h_{s,r1} h_{r1,d}, \quad (9)$$

and

$$h_2 = h_{s,r2} h_{r2,d}. \quad (10)$$

Detection

Hence, the variance of noise η'_d is given by:

$$N'_0 = \left(\beta_1^2 |h_{r1,d}|^2 + \beta_2^2 |h_{r2,d}|^2 + 1\right) N_0. \tag{11}$$

The detector is written as:

$$y'_d = \alpha y_d, \tag{12}$$

where α is determined such that the output SNR is maximized.

Detection

Therefore, α can be specified as:

$$\alpha = \frac{\beta_1\sqrt{P}h^*_{s,r1}h^*_{r1,d} + \beta_2\sqrt{P}h^*_{s,r2}h^*_{r2,d}}{N'_0}. \tag{13}$$

where '$*$' represents the complex conjugate operation.

SNR Analysis

The instantaneous SNR of the output detector is given by:

$$\gamma = \frac{P(\beta_1^2|h_1|^2 + \beta_2^2|h_2|^2 + 2\beta_1\beta_2\Re(h_1h_2^*))}{(\beta_1^2|h_{r1,d}|^2 + \beta_2^2|h_{r2,d}|^2 + 1)N_0}. \tag{14}$$

Best Relay Selection Scheme

- The relay which provides the best link (source-relay and relay-destination) is chosen;
- All the system resources are allocated in a unique relay, the best one;
- Note that for a two-hop network the system needs only one feedback bit.

So, θ can be described as:

$$\theta = \frac{i\pi}{2}, \tag{15}$$

where, $i \in [0, \ldots, 2^b - 1]$, and b is the number of feedback bits.

Power Allocation Scheme

- Available power is allocated among the available relays in order to maximize the numerator in (14);
- θ must be chosen to ensure that the product of the amplification factors β_1 and β_2 is positive;
- The higher the number of feedback bits is the closer to the maximum value the numerator in (14) is.

For this scheme, θ can be described as:

$$\theta = \frac{2j\pi}{2^{b+1}} - \frac{\pi}{2^{b+1}}, \tag{16}$$

where $j \in [1, \ldots, 2^b]$ is the set that maximizes the numerator in (14).

Hybrid Scheme

- Maximizes Equation (14);
- The proposed hybrid scheme consists in the combination of those schemes described previously;
- The higher the number of feedback bits is the closer to the of optimal case.

For the proposed scheme the phase θ is defined as:

$$\theta = \frac{k\pi}{2^b} - \frac{\pi}{2^b}. \tag{17}$$

where, $k \in [1, \ldots, 2^b]$ is the set that maximizes (14).

Simulation Results

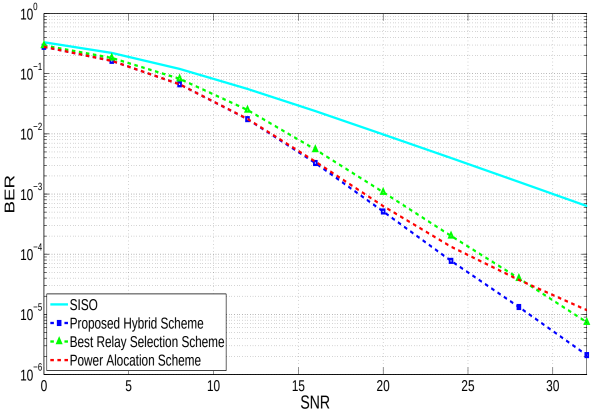
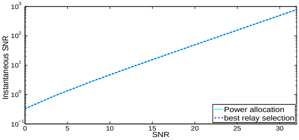
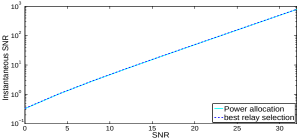


Figure: BER performance for the three relay selection schemes.

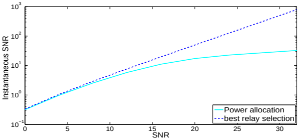
Simulation Results



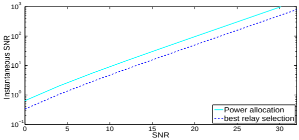
(a) $|h_{s,r1}| = 0.01$ and $|h_{r1,d}| = 0.01$.



(b) $|h_{s,r1}| = 1$ and $|h_{r1,d}| = 0.01$.



(c) $|h_{s,r1}| = 0.01$ and $|h_{r1,d}| = 1$.



(d) $|h_{s,r1}| = 1$ and $|h_{r1,d}| = 1$.

Figure: SNR comparison for schemes for specific channels coefficients. ($|h_{S,R2}| = 1$ and $|h_{R2,D}| = 1$)

Simulation Results

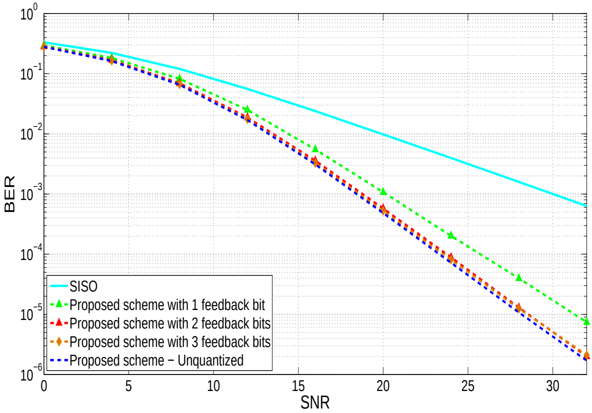


Figure: BER of the proposed scheme with different number of feedback bits.

Simulation Results

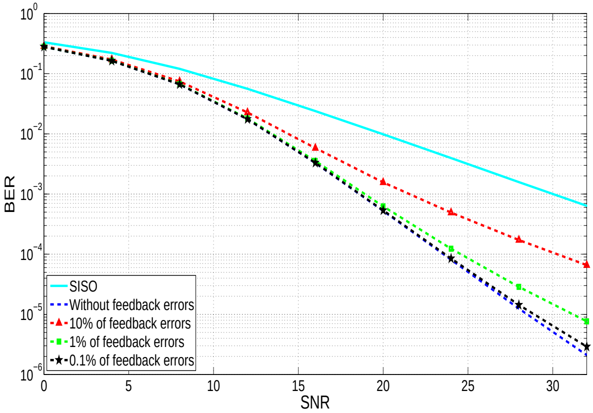


Figure: BER of the proposed scheme with no ideal feedback channel.

Concluding Remarks

- In this work it was proposed a hybrid AF relay selection scheme for a two-hop diamond network. Simulation results showed that the proposed scheme is an interesting solution for two-hop relay networks;
- It was demonstrated that the hybrid scheme achieves full diversity order and a performance gain over the other two good schemes considered in this work;
- It was also observed that the hybrid scheme does not need more than three feedback bits to achieve a very good BER performance and that it has a good robustness even when the feedback channel is not ideal;
- The receiver has low complexity since it is based on linear processing.

Thank you for your attention!