Feedback Delay Effect on Dual-hop MIMO AF Relaying with Antenna Selection

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Introduction

• The use of multiple antennas at the source, relay, and destination can significantly improve the performance of dual-hop relay networks [1].

• Transmit and receive (Tx/Rx) antenna subset selection has been widely researched as an efficient approach to achieve better trade-offs among the performance, hardware costs, and computational complexity of multiple-input multiple-output (MIMO) single-hop networks [2].

• Among these antenna-selection techniques, the best Tx/Rx antenna pair selection has already been employed as a suboptimal yet simple and efficient diversity transmission technique for dual-hop amplify-and-forward (AF) MIMO relay networks [3].

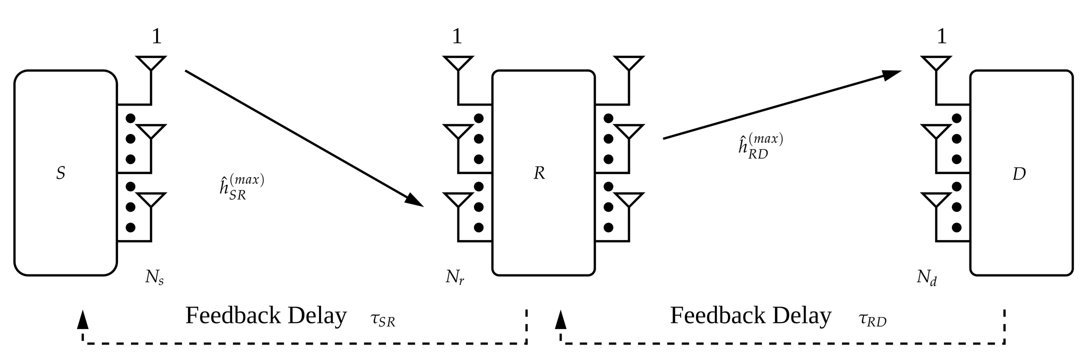
• **Motivation:** In practice, the outdated channel state information (CSI) could possibly be used for antenna pair selection at the source and relay when the CSI feedback rate is not sufficiently high compared to the Doppler fading rate.

• This feedback delay may cause severe performance degradation, however, this problem has not yet been investigated for MIMO relay networks.

• **Objective:** Develop a performance analysis framework for Tx/Rx antenna pair selection of MIMO AF relaying with outdated CSI.

System Model and Problem Formulation

• **System model:** We consider a dual-hop AF relay network with MIMO-enabled source (S), relay (R) and destination (D) having N_s, N_r and N_d antennas.



Channels are modeled as $\mathbf{H}_l(t) = \rho_l \mathbf{H}_l(t-\tau_l) + \mathbf{E}_{d,l}$, where ρ_l is the normalized correlation coefficients between $h_l^{i,j}(t)$ and $h_l^{i,j}(t-\tau_l)$. For Clarke's fading spectrum, $\rho_l = \mathcal{J}_0(2\pi f_l \tau_l)$, where f_l is the Doppler fading bandwidth. Further, $\mathbf{E}_{d,l}$ is the error matrix, incurred by feedback delay, having mean zero and variance $(1-\rho_l^2)$ Gaussian entries.

• **The end-to-end SNR is given by**

$$\gamma_{e2e}^{(i,j,k,l)} = \frac{\hat{\gamma}_{SR}^{(i,j)}\hat{\gamma}_{RD}^{(k,l)}}{\hat{\gamma}_{SR}^{(i,j)} + \hat{\gamma}_{RD}^{(k,l)} + 1}.$$

• **Tx/Rx Antenna pair selection strategy is given by**

$$\{(I,J),(K,L)\} = \underset{\substack{1\le i\le N_s, 1\le l\le N_d\\ 1\le j,k\le N_R}}{\operatorname{argmax}} \left(\gamma_{e2e}^{(i,j,k,l)}\right).$$

Performance Analysis

• **The following performance metrics are derived in closed-form:**

1. The exact CDF, MGF and generalized moments of the e2e SNR.
2. The exact outage probability and average symbol error rate (SER).
3. The asymptotic outage probability and the average SER at high SNRs, diversity order and array gain.

•**For example, the outage probability is given by**

$$P_{out} = 1 - \sum_{a=0}^{N_sN_r-1}\sum_{b=0}^{N_rN_d-1} \frac{(-1)^{a+b} N_s N_r^2 N_d \nu \binom{N_sN_r-1}{a}\binom{N_rN_d-1}{b}}{(a+1)(b+1)} \times \sqrt{\gamma_{th}(\gamma_{th}+c)}\, e^{-\mu\gamma_{th}} \mathcal{K}_1\left(\nu\sqrt{\gamma_{th}(\gamma_{th}+c)}\right),$$

where $\mu = \frac{a+1}{\bar{\gamma}_{SR}(1+a(1-\rho_{SR}))} + \frac{b+1}{\bar{\gamma}_{RD}(1+b(1-\rho_{RD}))}$, and $\nu = 2\sqrt{\frac{(a+1)(b+1)}{\bar{\gamma}_{SR}\bar{\gamma}_{RD}(1+a(1-\rho_{SR}))(1+b(1-\rho_{RD}))}}$.

•**Further, the asymptotic average SER is given by**

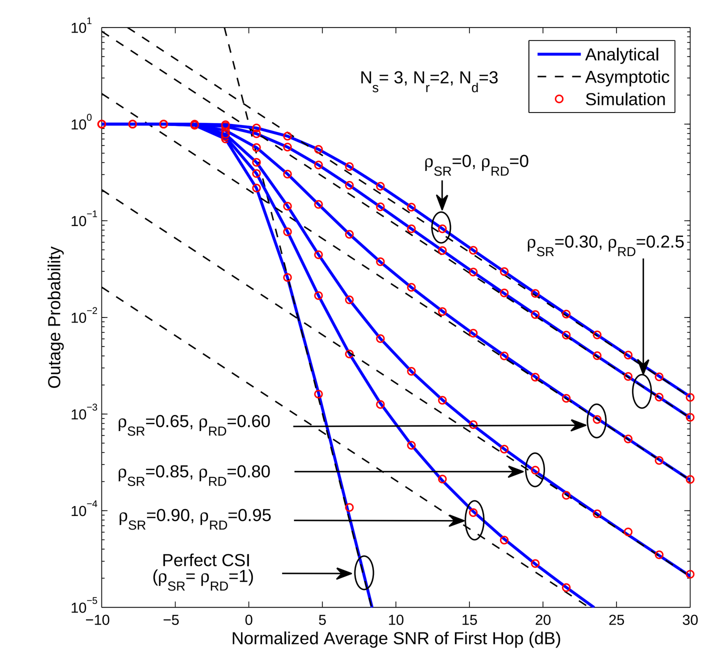
$$\bar{P}_e^{\infty} = \begin{cases} \frac{\eta\Omega_1\Gamma\left(G_d+\frac{1}{2}\right)}{2\sqrt{\pi}(\bar{\gamma}_{SR})^{G_d}}\left(\frac{2}{\zeta}\right)^{G_d-\frac{1}{2}} + o\left(\bar{\gamma}_{SR}^{-(G_d+1)}\right), & \rho_{SR}=\rho_{RD}=1 \\ \frac{\eta\Omega_2}{4\bar{\gamma}_{SR}}\sqrt{\frac{2}{\zeta}} + o\left(\bar{\gamma}_{SR}^{-2}\right), & 0\le\rho_{SR},\rho_{RD}<1. \end{cases}$$

The diversity order is given by

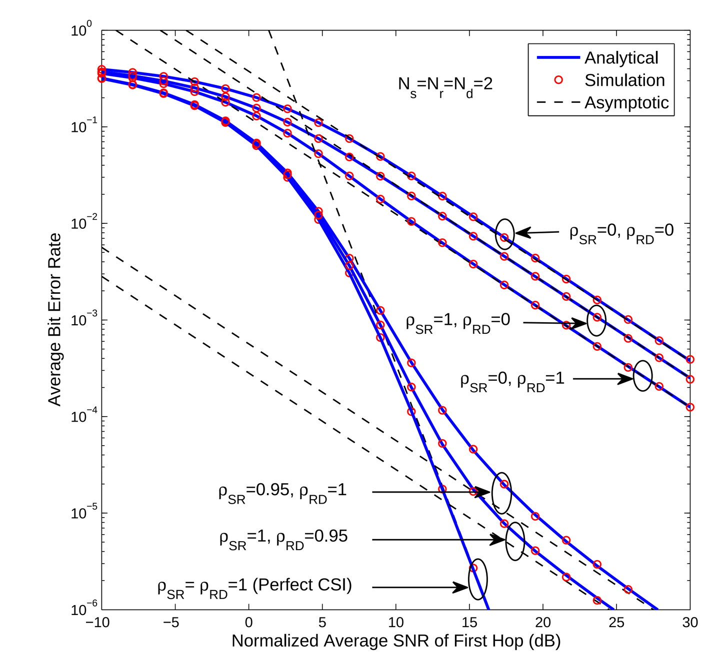
$$G_d = \begin{cases} N_r \min(N_s, N_d), & \rho_{SR}=\rho_{RD}=1 \\ 1, & 0\le\rho_{SR},\rho_{RD}<1. \end{cases}$$

Simulation Results

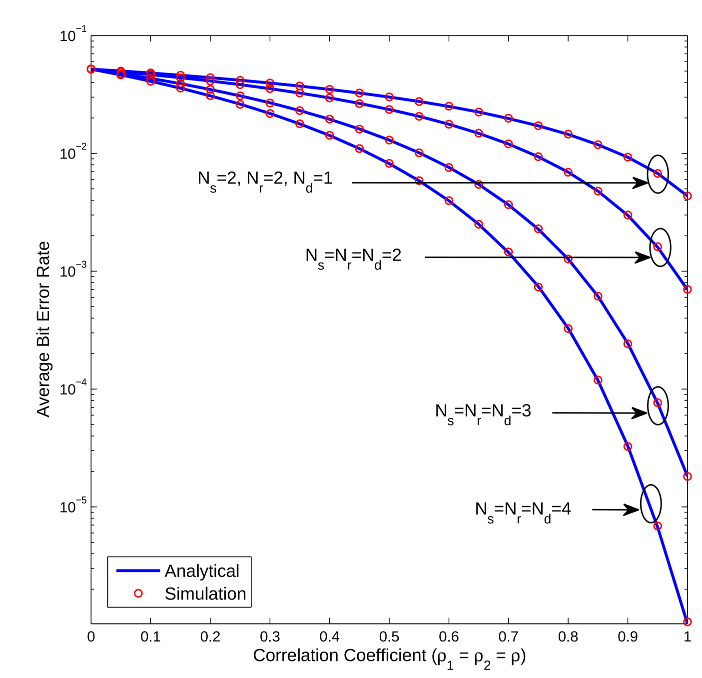
• **The outage probability:**



• **The average BER of BPSK:**



• **The average BER of BPSK versus feedback delay:**



Conclusion

1. The impact of outdated CSI on the performance of the best Tx/Rx antenna pair selection for dual-hop MIMO AF relay networks was studied.
2. As ρ_{SR} and ρ_{RD} decrease from 1 to 0 (i.e., as feedback delay increases), the performance of Tx/Rx antenna selection degrades significantly. Our asymptotic analysis shows that the Tx/Rx antenna selection based on the perfect CSI achieves the full diversity available in the MIMO relay channel; $G_d = N_r \min(N_s, N_d)$. However, when the antennas are selected based on the outdated CSI, this diversity gain decreases to one.
3. Our results reveal that delays in either the $R \to S$ or the $D \to R$ feedback channels have a significant detrimental impact on the performance of dual-hop MIMO relay networks with antenna selection. This result is clearly revealed by the curves corresponding to ($\rho_{SR}=1$, $\rho_{RD}=0.95$) and ($\rho_{SR}=0.95$, $\rho_{RD}=1$), respectively, where one hop has no feedback delays, and the other hop has a slight feedback delay.
4. As feedback delay increases (i.e., as ρ decreases), the moments of the SNR decrease significantly. Our numerical results also reveal that the impact of the feedback delays is less pronounced for the first moment than that for the second moment.
5. Our analysis may thus be useful for practical MIMO AF relay network designing, and the performance metrics can be used as benchmarks for such networks.

References

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