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Outage Probability Evaluation for ADF Relay Systems with Burst Transmission over Quasi-Static INID Rayleigh Fading channels

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Abstract. In this paper, we propose the average outage probability expressions for adaptive decode-and-forward (ADF) relaying schemes based on burst transmission over quasi-static Rayleigh fading channels. The derived analytical approach is verified based on the number of relays and data symbols. Its accuracy is confirmed by comparison with simulation results.

Keywords: outage probability, ADF, burst transmission, Rayleigh fading channel

1 Introduction

The authors in [1] have shown the general approach applicable for both DF and ADF relaying and derived an exact bit error rate (BER) as well-known tractable forms. Note that even if it can give exact results [1], previous researches have been carried out under the assumption that relay nodes can detect symbol-by-symbol error. It is not practical and the performance based on this implies only an achievable lower bound. So far as we know, the practical approach covering burst transmission for ADF relay systems has not been addressed in the literature yet. Furthermore, no one has expressed the approximated outage probability expression as well-known tractable forms, which can explain how an erroneous detection at each relay affects both the received SNR and the average outage probability.

At first, we consider not symbol-by-symbol but burst-by-burst error detection for ADF relay systems. Based on this, we focus on the error-event at relay nodes for burst

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transmission and then, the probabilities of all possible error-events are derived as well-known forms. By considering burst transmission for ADF relay systems, we derive an outage probability expression over independent and non-identical distributed (INID) Rayleigh fading channels, so that it can show a practical performance. Furthermore, an exact outage probability is approximated to the simplified expression for an arbitrary link SNR. Numerical results obtained from analytical solutions and Monte-Carlo simulations are compared. Then, it is confirmed for ADF relay systems that the numerical result in [1] and the approximated performance in this paper can be the achievable lower bound and the upper bound, respectively.

2 ADF Relay Systems with Burst Transmission

ADF relay systems have a source(S), a destination(D), and *L* relay(R)s. In this paper, it is assumed that S and *L* relays transmit over orthogonal time slot [1][4][5]. For the ADF relay systems, the received signals for the S-D, the *r*th S-R, the *r*th R-D links can be presented, respectively, as

$$\begin{aligned} y_0[t] &= h_0\sqrt{E_0}\,s[t] + n_0[t] \\ y_{L+r}[t] &= h_{L+r}\sqrt{E_{L+r}}\,s[t] + n_{L+r}[t] \\ y_r[t] &= h_r\sqrt{E_r}\,\hat{s}_r[t] + n_r[t]. \end{aligned} \quad (1)$$

In DF relay systems, the *r*th relay participates in transmitting the regenerated symbol of $\hat{s}_r[t]$ only when burst messages are correctly decoded.

2.1 Error-Event of Relay Nodes with Burst Transmission

In order to derive the analytical method based on error-events at relays, let us define the *p*th error-event vector E^p as $E^p = \left[e_1^p \cdots e_r^p \cdots e_R^p\right]$ and the total number of error-events is 2^R. Generally, we can define that E^1 is all-zero vector, E^{2^R} is all-one vector, and so on. Note that for the *p*th error-event, $e_r^p = 0$ means the correct burst detection at the *r*th relay and $\hat{s}_r[t] = s[t]$ for $N_P < t \le N_F$ with the probability of $P_C^{N_D}(\overline{\gamma}_{L+r})$. Also, $e_r^p = 1$ leads to $\hat{s}_r[t] = 0$ with the probability of $1 - P_C^{N_D}(\overline{\gamma}_{L+r})$. Furthermore, the probability of the *p*th error-event at DF relay systems is presented as

$$Pr^p = \prod_{r=1}^{L}\left[P_C^{N_D}(\overline{\gamma}_{L+r})\right]^{\overline{e_r^p}}\left[1 - P_C^{N_D}(\overline{\gamma}_{L+r})\right]^{e_r^p}. \quad (2)$$

The burst correct probability can be written as [2][3]

$$P_C^{N_D}\left(\overline{\gamma}_{L+r}\right) = E\left[P_C^{N_D}\left(\gamma_{L+r}\right)\right] = \sum_{k=0}^{N_D}\binom{N_D}{k}(-1)^k E\left[P_b^k\left(\gamma_{L+r}\right)\right] \quad (3)$$

and the upper bound can be obtained as

$$E\left[P_b^k\left(\gamma_{L+r}\right)\right] < \int_0^\infty e^{-k\gamma_{L+r}} f_{\gamma_{L+r}}\left(\gamma\right) d\gamma = \frac{1}{1+k\overline{\gamma}_{L+r}} = E\left[P_b^k\left(\gamma_{L+r}\right)\right]_{UB}. \quad (4)$$

Let us consider the case of combining signals from S-D and R-D links. Then, the combined instantaneous SNR can be written as

$$\gamma_C^p = \gamma_0 + \sum_{r=1}^{L}\overline{e_r^p}\,\gamma_r = \sum_{r=0}^{L}\overline{e_r^p}\,\gamma_r. \quad (5)$$

2.2 Average Outage Probability

When the outage probability of P_{out}^p for the *p*th error-event is defined as the probability that the channel mutual information (I) falls below the required transmitting rate T_R, it is expressed as $I = \left(L+1\right)^{-1}\log_2\left(1+\gamma_C^p\right) \le T_R$. The ratio of $\left(L+1\right)^{-1}$ is caused by the fact that we need $L+1$ orthogonal channels for ADF relay systems. Therefore, for the *p*th error-event, P_{out}^p can be written as

$$P_{out}^p = Pr\left(\frac{1}{2}\log_2\left(1+\gamma_C^p\right) \le T_R\right) = F_{\gamma_C^p}\left(2^{(L+1)T_R} - 1\right) \quad (6)$$

where $F_{\gamma_C^p}\left(x\right)$ is the CDF of random variable of γ_C^p. Consequently, when we consider all the possible error-events, the average outage probability can be shown as

$$P_{out} = \sum_{p=1}^{2^L} Pr^p\left(\left\{\overline{\gamma}_{L+r}\right\}_{r=1}^{L}\right) P_{out}^p \quad (6)$$

3 Numerical and Simulation Results

Fig. 1 shows the average outage probability versus SNR for ADF relay systems. From this figure, we can find that the average outage probability performance decreases in proportion to N_D (number of data symbols within a burst) and the diversity order linearly increases as the number of relays. The derived numerical results are well matched with simulation results. Consequently, it is confirmed that the derived analytical approach can be used as a general tool to verify effects of burst transmission on the average outage probability and cooperative diversity gain over quasi-static Rayleigh fading channels.

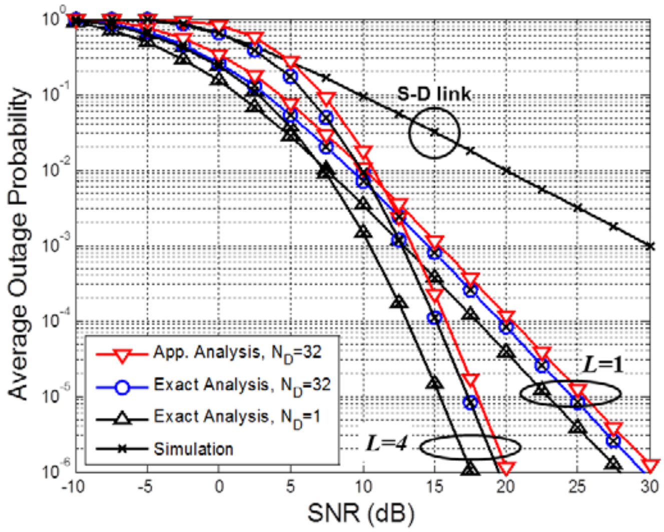

Fig. 1. Average outage probability versus SNR (dB) with respect to different L ($L=1,2$, $N_D=1,32$).

References

1. Jang, J. Y. and Ko, K. B.: Exact Closed-form BER Analysis using PDF approach for Fixed-DF and Selective-DF Relay Systems over Rayleigh Fading channels. IEICE Trans. on Commun. E94-B, no. 08:2419--2422, (2011)
2. Proakis, J.: Digital Communication. McGraw Hill, 3rd edition, (1995)
3. Simon, M. and Alouini, M. S.: Digital Communication over Fading Channels. New York, (2000)
4. Ikki, S. S. and Ahmed, M. H.: Performance Analysis of Adaptive Decode-and-Forward Cooperative Diversity Networks with Best-Relay Selection. IEEE Trans. Commun., 58(1):68--72, Jan. (2010)
5. Ko, K.B. and Woo, C.W.: More Tractable Average Error Rate Expression for the Nth Best Relay Selection scheme of DF Relaying over Rayleigh fading Channels. International Journal of Communication Systems, 25(10):1356--1364, Oct. (2013)

