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Performance analysis of cooperative diversity networks with imperfect channel estimation over Rician fading channels

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Abstract: In this study, the authors examine the effect of a channel-estimation error on the error and outage probabilities of a multi-relay system with amplify-and-forward relaying over a frequency-flat Rician fading channel. The authors consider orthogonal relaying and study both conventional cooperative systems (i.e. all relays participate in the relaying phase) and opportunistic cooperative systems (i.e. only the best relay participates in the relaying phase). Based on the derivation of an effective signal-to-noise ratio (SNR) at the destination node taking into account channel-estimation error, the authors obtain closed-form expressions for error and outage probabilities in a high SNR regime. Such closed-form solutions are highly desirable because they allow for rapid and efficient evaluation of system performance. Computer simulations are used to validate the authors' analytical results.

1 Introduction

Cooperative diversity is a promising solution for the high data-rate coverage required in future wireless communication systems [1, 2]. There are two main advantages of this technology; the low transmit RF power requirements and the spatial diversity gain [1]. The basic idea of cooperative diversity lies in the following: in addition to direct transmission from the transmitter to the receiver, there are other nodes, which can be used to enhance the diversity by relaying the source signal to the destination.

In the literature, different types of protocols such as 'receive diversity (RD)', 'transmit diversity (TD)' and 'simplified transmit diversity' protocols, among others, have been introduced [3, 4]. In an effort to address the spectral inefficiency of the conventional cooperation protocols that assume the participation of all relays, relay selection has been further proposed to improve the throughput [5]. Based on the pre-determined criteria, for example, signal-to-noise ratio (SNR), the 'best' relay is selected and only a single relay is allowed to participate in the relaying phase.

Several researchers have investigated channel estimation in the context of cooperative systems, for example, [6–8] and the references therein. However, these works mainly address estimator design and are mostly limited to simulation studies. A few exceptions are [9–11] which aim to analytically study the impact of channel estimation on the performance of amplify-and-forward (AF) relaying. In [9], Uysal and Mheidat have derived a pairwise error probability expression for the TD protocol. In [10], Patel and Stuber have obtained an approximate error rate performance expression for the RD protocol assuming binary phase shift keying (BPSK). In [11], Wu and Patzold have again considered the RD protocol and derived approximate symbol error rate expressions for M-ary phase shift keying and M-ary quadrature amplitude modulation. All the above works are devoted to study the system over Rayleigh fading channels.

In practice, a line-of-sight (LOS) component might be available; therefore the underlying channels can be modelled as Rician instead of commonly used Rayleigh distribution. The presence of LOS has been confirmed through physical measurement for a number of applications, such as micro-cellular mobile and indoor radio. In contrast to Rayleigh distribution, to the best of our knowledge, there are no reported performance results for wireless relay networks in Rician fading conditions. In our paper, similar to [12], we have modelled the source-to-destination, source-to-relay and relay-to-destination links as fixed LOS component and a randomly varying non-LOS component, which is often the case in cellular fixed relaying and wireless mesh networks.

In this paper, we analyse the error and outage performances at a high SNR for multi-node dual-hop relaying over Rician fading channels. First, the instantaneous output SNR of the dual-hop relaying system is studied. An approximate probability density function (PDF) for a high SNR regime is determined, which readily extends to multi-node dual-hop systems. Furthermore, simple asymptotic expressions of the end-to-end error and outage probabilities for both, conventional and opportunistic AF relaying, are presented. Simulation results are provided and verified for the tightness of the derived expressions at high SNRs.