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# A link selection strategy for cooperative ad-hoc networks ☆

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ABSTRACT

Cooperative ad-hoc networks are popular because of their ability to provide reliable communication. In this paper, we consider a cooperative ad-hoc network consisting of a source, two decode-and-forward relays and a destination. The source intends to transmit its data to the destination directly as well as through relays. We employ a weighted selection combining at the destination which chooses either the weighted source-to-relay1-to-relay2-to-destination link or source-to-destination link depending upon the instantaneous signal-to-noise-ratio. We derive the end-to-end symbol error probability (SEP) of a triple-hop cooperative network with binary phase-shift keying for a flat, slow Rayleigh fading channel. Further, we develop an algorithm which investigates the performance of this cooperative ad-hoc network in terms of SEP. Results show that the cooperation among the nodes and weighted selection combining improves the performance of ad-hoc networks when compared to a point-to-point link and conventional selection combining.


## 1. Introduction

Next generation ad-hoc networks should serve more customers while supporting mobility and higher data rates which is planned to achieve through cooperative communications [1]. Cooperative diversity techniques improve the communication reliability by mitigating the effects of multipath fading with the help of spatially distributed relay nodes. Decode and forward (DF), amplify and forward (AF), etc are the most prominently used relaying schemes for forwarding the information signal from the relay nodes to the destination [2]. In AF, the relay amplifies the source's information and forward the same to the destination, and in DF, the relay detects the source information and forward it to the destination. Since the user cooperation concept proposed in [3], the performance analysis of cooperative diversity techniques have been the active research area for a decade or more.

Multi-hop cooperative diversity scenario along with spatial diversity benefit provides lower attenuation, which increases the cell coverage area. Till now cooperative diversity literature mainly dealt with the performance analysis of dual-hop relaying system with and without direct source-to-destination (S–D) link. In [4], outage and symbol error probability (SEP) performances of DF and AF relaying based dual-hop relaying system without direct S–D link is analyzed. In [5], the SEP performance of DF relaying based dual-hop single-relay cooperative selection diversity system with direct S–D link is analyzed considering *M*-ary phase-shift keying signaling (MPSK) using paired error approach. Similarly, the performance

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of a multi-relay cooperative diversity system considering dual-hop scenario with and without direct S–D link is analyzed in [6,7] respectively.

In [8], outage analysis of multi-hop AF based cooperative diversity system is carried out by employing maximal-ratio combining (MRC) at the destination. In [9], an analytical framework has been developed to evaluate the error rate performance of AF multihop transmission systems with both variable-gain and fixed-gain relays. A generalized system model in an independent-nonidentical Nakagami-m fading channel is assumed, and an analytical study on throughput, spectral efficiency, and latency distribution have been performed in [10].

The end-to-end system performance has been derived for a multi-relay network for various modulation techniques in the presence of Nakagami-*m* fading channels [11]. Further, the system performance has been studied for both analog and digital relays. A new analytical approach has been shown in [12] to solve the averaging of the $Q(\cdot)$ function. The expression $E[Q(\cdot)]$ has been expressed in terms of moment generating function of the inverse of the instantaneous signal-to-noise ratio (SNR).

In [13], a new scheme which combines the ideas of cooperative diversity and multiuser diversity has been proposed, in which the scheme first selects the best source based on the link quality of the direct links and then selects the best link from the selected source to the destination. In [14], the error performance of a cooperative parallel relay network with multiple hops for MPSK signaling in the presence of Rayleigh fading has been analyzed. A path-based cooperative multihop relaying has been proposed in [15] for vehicular ad hoc networks, in which the scheme is capable of reorganizing the delivery path if an outage happens in the transmission link. In [16], a new approximation for the instantaneous received SNR for AF multihop relaying has been presented and it provides accurate estimation on various system parameters. The error performance of the switch and examine combining with AF relaying has been investigated in [17] for a cooperative diversity system in the presence of Rayleigh fading. The packet delivery failure probability and packet delivery delay distribution parameters have been derived in [18] for a cross-layer automatic repeat request cooperative diversity system with multiple two-hop relays. The outage and ergodic capacity of a dual-hop wireless system with AF relay operating over independent and identically distributed $\alpha$–$\mu$ fading channels has been derived in [19].

The symbol error rate of a multiple hop cooperative network with two-antenna DF relays with space–time block code from coordinate interleaved orthogonal design has been investigated in [20]. In [21], the performance of an AF based multiple hop relay network for flat Nakagami-*m* fading where the signals from direct as well as relayed links are considered in the detection process. The outage performance of the combined serial (multi-hop) and parallel relaying has been analyzed in [22] for free-space optical mesh networks. In [23], a novel clustering algorithm is proposed based on the traffic demands and clustering concepts for deploying base stations.

To select the appropriate deployment locations for the base stations and relay stations from the candidate positions by accounting for the traffic demands and using the uniform cluster concepts.

As we observe from the literature that most of the investigations requires exact channel state information (CSI) of the link at the destination. In practice, obtaining the phase information is more cumbersome. The CSI has to be estimated for each symbol which increases the receiver complexity which in turn reduces battery life of the mobile units. To overcome this difficulty, the conventional selection combining (SC) has been employed for single hop cooperative system in [5]. However, the conventional SC fails to incorporate the effect of the interhop links (i.e. instantaneous SNR) in the link-selection rule of the destination. We overcome this problem, by proposing a weighted SC scheme in which the destination uses a weighting factor to bring the effect of the interuser link. Further, to the best our best knowledge, no work with weighted SC has been studied for three-hop ad-hoc network. This has motivated us to develop an analytical framework and simulation algorithm for a triple-hop cooperative ad-hoc network. Therefore, in this paper, we analyze the performance of a DF relaying based triple-hop cooperative diversity system considering direct S–D link over slow, flat, and independent Rayleigh fading channels for binary phase-shift keying (BPSK) signaling. Further, we employ weighted SC scheme at the destination node for combining the information signals from the source and last relay nodes. We derive the end-to-end SEP of this scheme in closed form. Further, we develop an algorithm for the proposed triple-hop cooperative selection ad-hoc network model and compare the analytical and simulation results for validation.

The paper is organized as follows. The present Chapter gives literature survey and problem definition. In Section 2, system model of the proposed triple-hop cooperative ad-hoc network is given. Further, performance analysis and detailed algorithm of the proposed system is given in Section 3. In Section 4, numerical results and discussions related to the results are given. Finally, concluding remarks are given in Section 5.

## 2. System model

In our triple-hop cooperative diversity system model, we consider a source (S), two intermediate DF relays (R1 and R2), and a destination (D) employed with weighted SC scheme as shown in Fig. 1. The information signal transmission is divided into three phases and symbol-by-symbol transmission methodology is assumed. In phase-I, the source broadcasts the information-bearing baseband symbol $s$ with energy $2E_s$ to R1 and D, where $s$ is one of the constellation points in the BPSK signal space $A'$ (i.e. $A' = \{\sqrt{2E_s}, -\sqrt{2E_s}\}, s \in A'$). Now the received complex baseband symbol at R1 and D can be written respectively as

$$r_{sr_1} = h_{sr_1}\, s + n_{sr_1}, \quad r_{sd} = h_{sd}\, s + n_{sd}, \tag{1}$$