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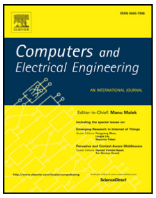

Performance of decode-and-forward over Nakagami-m fading channel in cooperative wireless networks[☆],[☆☆]

Qabas Ali Hikmat[a],[*], Bin Dai[a], Rokan Khaji[b], Benxiong Huang[a]

[a] Department of Electronics and Information Engineering, Huazhong University of Science and Technology, Wuhan 430074, PR China
[b] Department of Mathematics, College of Science, Diyala University, Diyala 32001, Iraq

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ABSTRACT

In this paper, we analyse the performance of a decode-and-forward (DF) multi-relay system over Nakagami-*m* fading channels. First, the closed form expression for the symbol error rate (SER) for both M phase shift keying (MPSK) and M quadrature amplitude modulation (MQAM) signals is derived using the concept of moment generating function (MGF) in the high signal to noise ratio (SNR) and determining a tight SER lower bound that converges to the same limit as the theoretical upper bound. Next, by optimising SER, we can identify the optimal amount of power that should be allocated at the source and relay nodes to develop an optimal power allocation (OPA) technique to reduce the SER. The validation of the theoretical analysis is corroborated by the simulation results of the proposed model over Nakagami-*m* fading compared to the various schemes regarding the performance in terms of the model's achievable SER and OPA.

1. Introduction

Recently, cooperative communication has attracted considerable attention because of its ability to mitigate fading in wireless networks and to ensure high network reliability, primarily in severe fading wireless communication channels. Studies have demonstrated that cooperative networks have advantages in terms of coverage range and energy efficiency [1]. Cooperative networks are considered to be among the most efficient techniques for achieving spatial diversity in wireless communication [2–4]. Cooperative communication can be achieved with spatial diversity by exploiting distributed virtual antennas of cooperative nodes. Many relaying techniques were introduced in [5], such as amplify-and-forward (AF) and DF. In the AF technique, the source signal is only scaled by a gain before being forwarded to the destination; in the DF technique, signal processing and coding must be performed by the relay before the source signal is forwarded [6,7]. The benefit of the DF relaying protocol is that DF relaying outweighs the noise amplification of the AF relaying and achieves a higher capacity than the AF protocol [8]. However, the diversity of cooperative communication systems is limited because of the use of only one relay; thus, the performance of the relay system can be improved using multiple relay networks [9].

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[*] Corresponding author. Tel.: 0086 13477083927.
E-mail address: qabasalbiaty@yahoo.com (Q.A. Hikmat).

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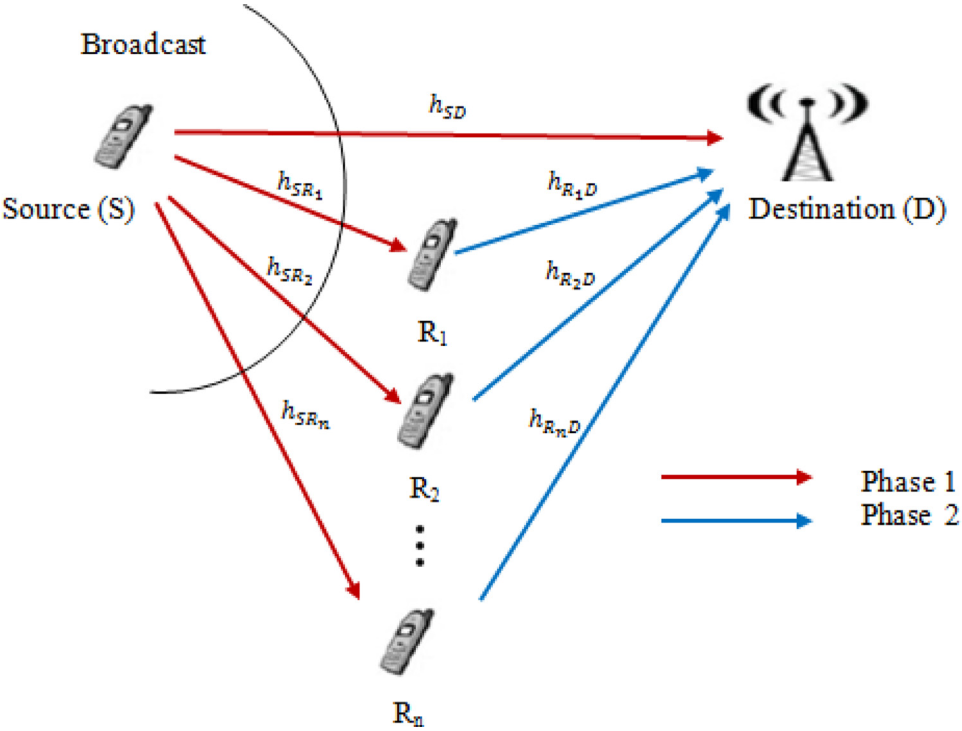

Fig. 1. Cooperative wireless network with a source (S), multiple relay ($R_1, R_2, \ldots, R_n$), and a destination (D).

In this study, we make use of the DF relaying protocol and analyse power allocation for a multi-relay system over Nakagami-*m* fading channels. Many papers in the recent literature could be found discussing the performance of a cooperative communication system with multi-relay in different fading environments. The authors in [10], calculated the bit error rate for a single DF relay system over multi-path fading channels. The expressions of SER of DF relaying over Rayleigh fading channels was reported in [11,12]. The authors in [13–15], focused on the outage probability for DF relaying over Nakagami-*m* fading channels.

In this work, we present SER and OPA techniques for DF multi-relay system over Nakagami-*m* fading channels and later compare it with the Rayleigh fading channels; to the best of our knowledge, such a study has not been reported in the literature. We first evaluated a closed-form SER formulation for MPSK and MQAM signals using the MGF to achieve a high SNR at the destination. As the SER formulation is too complex, we subsequently determined a tight lower bound, which converged to the same limit as the theoretical upper bound in the high SNR. Next, we exploited this result and formulated an OPA technique to minimise the SER and demonstrated by simulation results the performance development of our new model compared to the results obtained with EPA for different numbers of Nakagami fading figures.

The rest of the paper is organised as follows. In Section 2, we describe the system model and propose a class of cooperation protocols for multi-node wireless networks analysed over Nakagami-*m* fading channels. In Section 3, we analyse the SER performance using the concept of MGF to obtain the exact SER expression over Nakagami and Rayleigh fading channels and used the expression to examine two types of modulation signals: MPSK and MQAM modulation. In Section 4, we determine SER lower and upper bound and subsequently apply OPA for the tight SER lower bound. The simulation results are presented in Section 5. Finally, Section 6 presents the study's conclusions.

2. System model

Fig. 1 illustrates the DF wireless cooperative network of the suggested model with multi-relay system. We can apply this model to any wireless system, for example, ad hoc, LAN, or wireless sensor networks. In this instance, we supposed that the system will work over Nakagami-*m* flat fading channels, and the noise is assumed to be additive white Gaussian noise (AWGN). The main channel gains for the transmitters are known; assuming that the receiver has perfect channel state information (CSI). In addition, using the multiple access techniques, e.g., TDMA, FDMA, or CDMA schemes, users transmitted signals through orthogonal channels.

The DF cooperative wireless network considered in this study involves two phases. In the first phase, the source transmits the symbol and the symbol is subsequently received by the destination and all relays due to the broadcast

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