Computers and Electrical Engineering 39 (2013) 1399–1408

Contents lists available at SciVerse ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Performance analysis of ARQ cooperative diversity system with multiple two-hop relays over Rayleigh fading channels ☆

Haixia Cui [a,*], Gang Wei [b], Gaoyong Luo [c], Yongcong Yu [b], Wenlou Li [c]

[a] *School of Physics and Telecommunication Engineering, South China Normal University, 510006 Guangzhou, China*
[b] *School of Electronic and Information Engineering, South China University of Technology, 510640 Guangzhou, China*
[c] *School of Physics and Electronic Engineering, Guangzhou University, 510006 Guangzhou, China*

ARTICLE INFO

Article history:
Received 16 June 2011
Received in revised form 13 April 2013
Accepted 16 April 2013
Available online 21 May 2013

ABSTRACT

Cooperative communication systems can exploit spatial diversity by opportunistically choosing relays to forward information to the destination. In this paper, we investigate the statistical performance analysis of a general cross-layer automatic repeat request cooperative diversity (ACD) system by focusing on the scenario in which decode-and-forward relaying protocol and multiple two-hop relays are employed over Rayleigh fading channel environments. To obtain the theoretical closed-form formulas for end-to-end performance parameters, we develop a time division multiple access (TDMA)-based absorbing Markov model to help find all possible transition probabilities of each transmission process. Based on this proposed model and statistical analysis, we derive two tight closed-form expressions in terms of end-to-end packet delivery failure probability and end-to-end packet delivery delay distribution. In addition, an optimal power allocation scheme under a tight power constraint for the ACD system is proposed for further enhancing the symbol error rate (SER) performance, which outperforms the equal power allocation scheme obviously. Simulation results by Monte Carlo simulations demonstrate the correctness of our analysis eventually.

1. Introduction

Cooperative diversity has shown to play a major role in the next-generation mobile communication networks based on recent work on IEEE802.11s and IEEE802.16j [1]. With low complexity terminals, it is beneficial in enhancing data transmission performance by exploiting the broadcast nature and location dependent fading characteristics of wireless channels. Basically, a transmitting source node can be assisted by its surrounding nodes, if the direct transmission fails. By doing so, multiple copies of independent fading signal paths are provided at the destination, which brings spatial diversity [1,2].

Among the set of cooperative techniques, one most popular strategy for such cooperative diversity systems is the decode-and-forward (DF) relaying protocol [2,3] where each cooperative node decodes and re-encodes the received signal before forwarding it to the destination. The very early paper on DF cooperative diversity appeared in the single relay over physical layer [2–5]. Most of them have addressed the performance analysis in terms of symbol error rate, outage probability, and capacity. In [6], Lee et al. considered the true error probability for decode-and-forward cooperative communications with multiple relays over Nakagami-*m* fading channels. However, they dealt with one-layer symbol error rate analysis without considering upper layers. Recent research work [7–9] has shown that automatic repeat request (ARQ) can improve the multiplexing diversity tradeoff significantly by the retransmission round. In fact, a code division multiple access (CDMA)-based

☆ Reviews processed and approved for publication by Editor-in-Chief Dr. Manu Malek.

* Corresponding author.
E-mail address: cuicuihang0715@gmail.com (H. Cui).

0045-7906/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compeleceng.2013.04.004

analytical model for ARQ cooperative diversity was proposed in [7] which validated the desirable adaptive characteristics of cross-layer cooperative communication systems. But the authors focused on the system model where each source node transmitted a packet to its cluster head with its surrounding relays synchronously, if the direct transmission failed. It is not suitable for time division multiple access (TDMA) orthogonal channels, or a single channel for interference.

Motivated by all of the above, in this paper, we consider the ACD system in TDMA orthogonal channels with multiple two-hop relays and present statistical performance analysis of ACD system in terms of packet delivery failure probability and packet delivery delay distribution over Rayleigh fading channels in wireless networks. In order to take all possible transition probabilities of each transmission process into consideration, we develop an absorbing Markov model to help find their exact representations in the case of cooperative communications with retransmission round. In addition, we discuss the relationship of the power allocation scheme over different fading channels with the symbol error rate (SER) performance of the cross-layer ACD system. Based on the partial channel state information (CSI) and the analytical results developed, an optimal power allocation scheme is proposed to allocate the transmission power for further improving the performance of system. Afterward, the theoretical analysis is verified by computer Monte Carlo simulations. The numerical results show the correctness of our theoretical expressions for packet delivery failure probability and packet delivery delay distribution. It is also indicated that the performance with optimal power allocation scheme for the cross-layer ACD system is further improved compared with the equal power allocation scheme.

The rest of this paper is organized as follows. In Section 2, we describe the system model for the cross-layer ACD system. Then, based on this model, in Section 3, two tight closed-form expressions, i.e. packet delivery failure probability and packet delivery delay distribution, are derived. Section 4 presents an optimal power allocation scheme for enhancing the system SER performance. The numerical results are used in Section 5 and the conclusions are stated in Section 6.

2. System model

In this paper, we consider an ACD system that combines DF relaying at the physical layer and truncated stop-and-await ARQ at the link layer.

2.1. Physical layer system model

A distributed wireless cooperative relaying network with one source node "S", one destination node "D" and K relay nodes "R_k" with $k = 1, \ldots, K$ are employed over Rayleigh fading channels, as illustrated in Fig. 1. Each node is equipped with a single omni-directional antenna and operates in half-duplex mode. The source communicates with the destination through the help of the relay nodes which can fully decode the signal transmitted by node "S" in the first source-to-relay hop. Further, all the channel links are assumed to be mutually independent and the TDMA scheme is used for orthogonal channel access, i.e., only one node (the source node or relay nodes) is allowed to transmit a packet in each time slot. Therefore, the source-to-destination signal transmission via the relay nodes will occupy $K + 1$ time slots and the transmission procedure is fully described in Fig. 1.

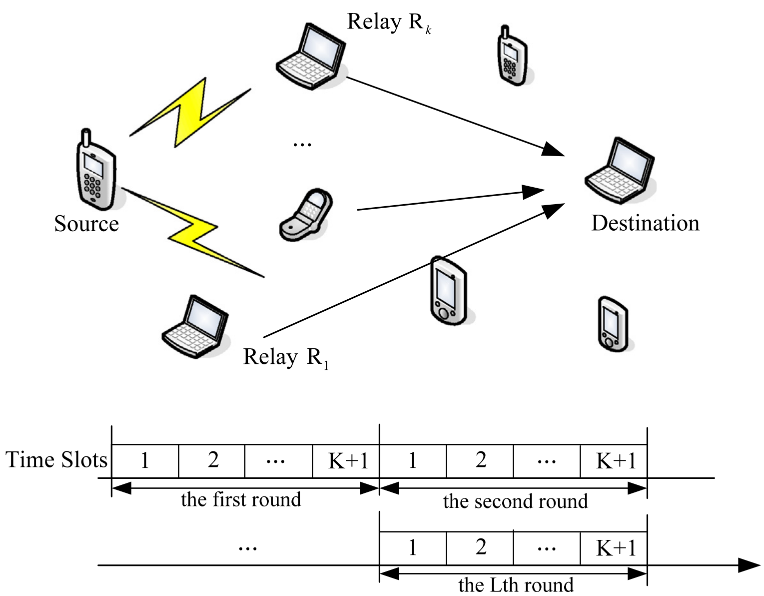

Fig. 1. Diagram of transmission system.