Dual-Hop Amplify-and-Forward Multi-Relay Maximum Ratio Transmission

Eylem Erdogan and Tansal Gucluoglu

Abstract: **In this paper, the performance of dual-hop multi-relay maximum ratio transmission (MRT) over Rayleigh flat fading channels is studied with both conventional (all relays participate the transmission) and opportunistic (best relay is selected to maximize the received signal-to-noise ratio (SNR)) relaying. Performance analysis starts with the derivation of the probability density function, cumulative distribution function and moment generating function of the SNR. Then, both approximate and asymptotic expressions of symbol error rate (SER) and outage probability are derived for arbitrary numbers of antennas and relays. With the help of asymptotic SER and outage probability, diversity and array gains are obtained. In addition, impact of imperfect channel estimations is investigated and optimum power allocation factors for source and relay are calculated. Our analytical findings are validated by numerical examples which indicate that multi-relay MRT can be a low complexity and reliable option in cooperative networks.**

Index Terms: **Channel estimation error, conventional and opportunistic relaying, maximum ratio transmission, multi-relay, power allocation.**

I. INTRODUCTION

WIRELESS channels can experience deep fading leading to unreliable communication, thus, increasing diversity order of the system is highly desirable to reduce symbol error rates and outage probabilities. Similar to well investigated multiple antenna techniques with proper coding such as famous space time block coding (STBC) [1], "cooperative/relay" transmissions [2]–[5] have become popular to obtain spatial diversity. In practice, neighbouring mobile units or fixed relays can help the transmitted signals to be delivered to destination over independent fading channels. For example, with amplify-and-forward (AF) approach, the source signal received at relays can be amplified with a variable gain depending on the channel coefficients and then forwarded to destination. Another relaying method is decode-and-forward (DF) where relays can detect the transmitted symbols and then retransmit to destination, however, this approach has more complexity and may result in significant error propagation due to detection errors at relays and thus reduce the cooperation advantages.

In the last decade, research works on the design and analysis of cooperative/relay communication schemes with multiple relays have been increasing tremendously. In [6]–[8], symbol error rate (SER) and outage probability over Rayleigh fading channels are derived whereas the same performance indicators are obtained in [9]–[10] for Nakagami-*m* fading channels. Like conventional relaying, opportunistic relaying in which the best relay is selected to maximize the received signal-to-noise ratio (SNR), proposed in [11]. In [12], outage probability and SER performance over Nakagami-*m* fading channels are studied whereas the performance of ergodic capacity and SEP are examined for Rayleigh fading channels in [13].

In an attempt to increase degrees of freedom, capacity and diversity gains further, using multiple-antenna techniques in relay/cooperative transmissions can be attractive, although the mathematical analysis can get quite complicated. Reference [14] explores SER and outage probability of a multi-antenna single-relay AF transmission with orthogonal space-time block coding (OSTBC) and maximal ratio combining (MRC). In [15], OSTBC based opportunistic relaying scenario is investigated where SER and outage probability expressions are derived. Recently, employing maximum ratio transmission (MRT), a transmit diversity method, has attracted several interest in the research of cooperative/relay structures since MRT can achieve full available diversity and perform better than the well-known STBCs while requiring low receiver complexity [16]. Although MRT requires feedback of channel state information (CSI) to the transmitter, this may cause negligible overhead when the channel is very slow fading or when the channel is almost reciprocal e.g. indoor wireless mesh networks. In [17], authors investigate a MIMO-MRT network and derives SER and outage probability for Nakagami-*m* fading channels. Besides, employing MRT has been investigated in single-relay dual-hop networks in [18]–[23]. Reference [18] considers a network in which multiple-antennas employ MRT at the source and derives outage probability for Rayleigh fading channels. In [19], DF MRT-based multi-antenna cooperative network is considered and outage probability is derived. Likewise, in [20], MRT both at the source and relay is investigated and SER is derived. Moreover, [21] and [22] consider a network where source and destination employing MRT/MRC and SER and outage probability are derived for Nakagami-*m* and Rayleigh-Rician fading channels. In [23], MRT/MRC scheme is applied at both hops where SER and outage probability in the presence of feedback delay, channel estimation errors and antenna correlation are derived. In addition, partial relay selection schemes employing MRT is investigated in [24]–[26]. In [24]–[25], outage probability and SER are derived over Nakagami-*m* and Rayleigh fading channels respec-

Manuscript received April 3, 2014; approved for publication by Jinho Choi, Division II Editor, August 29, 2015.

This work is supported by the Scientific and Technological Research Council of Turkey under research grant 113E229.

E. Erdogan is with the Department of Electrical and Electronics Engineering, Kadir Has University, Fatih, 34083, Istanbul, Turkey, email: erdoganeyl@gmail.com.

T. Gucluoglu is with the Department of Electronics and Communications Engineering, Yildiz Technical University, Esenler, 34220, Istanbul, Turkey, email: tansal@yildiz.edu.tr.

Digital object identifier 10.1109/JCN.2016.000005