Chapter 7
Throughput Optimization of Cooperative Teleoperated UGV Network

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ABSTRACT

Cooperative communications among group of teleoperated unmanned ground vehicles (UGVs) allows to exploit spatial diversity in wireless fading channels by relaying signals between each other. Due to the high speed of the UGVs, the nature of the channel environments and the possible co-channel interference, the effect of multipath propagation and the Doppler spread are more pronounced. In this article, we proposed a low complexity dynamic channel assignment (DCA) technique with adaptive modulation and coding (AMC) strategy to allocate the available bandwidth over a number of communications links in a cooperative UGV network. In many processing algorithms and transmission protocols reported in the literature, performance improvement in terms of system throughput and reliability has been demonstrated. The proposed DCA with AMC in a cooperative UGV network has two objectives. First, to maximize the overall throughput of the cooperative UGV network and second, to significantly reduce the probability of outage in the system. In this article, the outage is defined as the percentage of time the links are incapable of supporting a minimum required transmission rate which is determined by the application. The DCA approach is formulated in terms of a binary optimization problem that is solved using the branch-and-bound method. The authors assume the links in the network to be Rayleigh faded and we used a finite state Markov chain (FSMC) for their modeling. Using Monte Carlo simulation, we showed that the proposed DCA approach in a cooperative UGVs provides significant gain in the overall throughput and reduction in the outage probability compared to the static channel assignment (SCA).

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INTRODUCTION

Nowadays, traffic transportation systems faces a lot of challenges, such as advanced traffic management, vehicle control, safety control, and networking and information services for users on the road. One suggested solution is developing cooperative unmanned ground vehicles (UGVs) to improve the safety, security and efficiency of the transportation systems, and to enable new mobile services and applications for the traveling public. The main challenge that a cooperative UGV network faces is the harsh nature of the communication links. The links in a network of UGVs suffer from many problems like power fluctuation of the received signal due to multipath propagation and Doppler spread that becomes more severe at high speeds and high carrier frequencies. Besides, the limited weight of the UGV imposes a restriction on its mission times. The relaying cooperation problem appeared in the information theory community (Cover, 1979), and were inspired by the concurrent development of the ALOHA system at the University of Hawaii. The relay channel model is comprised of three terminals: a source that transmits information, a destination that receives information, and a relay that both receives and transmits information in order to enhance the communication between the source and the destination. Recently multiple relays have been examined in (Kramer, 2005). Combination of relaying and cooperation are also possible, and are often referred to as cooperative communications and most of these models fall within the broader class of generalized feedback wireless channels (Cover, 1981). Unfortunately, the fundamental performance limits, in terms of Shannon capacity are not known in general till now. Although, some useful bound in capacity have been obtained. The application of cooperative diversity in communication system has been proved to have significant performance improvement in terms of various performance metrics, including, capacity as in (Kramer, 2005), improved reliability as in (Laneman, 2004), diversity multiplexing-tradeoff in (Azarian, 2005), and bit/symbol error probability in (Sendonaris, 2003).

In (Edrich, 2002), Edrich & Schmalenberger proposed the use of combined direct sequence spread spectrum (DSSS) and frequency hopping spread spectrum (FHSS) technique to reduce the effect of interference in the unmanned airbone vehicle (UAV) wireless links. This technique has the advantage of averaging the effect of interference but not avoiding it. Using dynamic channel assignment (DCA) with adaptive modulation and coding (AMC) (Ye, 2002), it is possible to significantly reduce the effect of interference by assigning sub-channels to the links with better conditions (since these sub-channels experience a better signal-to-interference plus noise ratio (*SINR*) over that link). Two recent contributions (Song, 2005; Song, 2005) showed that using the inherent frequency diversity of OFDM can optimize the network throughput by using AMC according to the channel state information (CSI) of each sub-channel. The quality of service (QoS) and the utility-oriented bandwidth allocation was studied in (Cao, 2002).

To the best of our knowledge no such performance analysis and optimization have been performed for teleoperated cooperative UGV network taking into consideration the complexity of the cooperative UGVs relay channel. In this article we propose a DCA with AMC approach in a cooperative UGV network to optimize the performance in terms of UGV network throughput and communication link reliability using relay transmission with optimal resource allocation. We adopted a finite state Markov chain (FSMC), previously introduced in (Wang, 1995) to model the Rayleigh fading in the wireless links. Each UGV is assumed to have a certain QoS requirement, which depends on the application the UGV is assigned for. Our objective is to maximize the network throughput and to reduce the system outage (i.e, increase reliability) through DCA of a group of sub-channels while satisfying the