Chapter 12

Single and Double-Differential Coding in Cooperative Communications

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ABSTRACT

In this chapter, we discuss single and double-differential coding for a two-user cooperative communication system. The single-differential coding is important for the cooperative systems as the data at the destination/relaying node can be decoded without knowing the channel gains. The double-differential modulation is useful as it avoids the need of estimating the channel and carrier offsets for the decoding of the data. We explain single-differential coding for a cooperative system with one relay utilizing orthogonal transmissions with respect to the source. Next, we explain two single-differential relaying strategies: active user strategy (AUS) and passive users relaying strategy (PURS), which could be used by the base-station to transmit data of two users over downlink channels in the two-user cooperative communication network with decode-and-forward protocol. The AUS and PURS follow an improved time schedule in order to increase the data rate. A probability of error based approach is also discussed, which can be used to reduce the erroneous relaying of data by the regenerative relay. In addition, we also discuss how to implement double-differential (DD) modulation for decode-and-forward and amplify-and-forward based cooperative communication system with single source-destination pair and a single relay. The DD based systems work very well in the presence of random carrier offsets without any channel and carrier offset knowledge at the receivers, where the single differential cooperative scheme breaks down. It is further shown that optimized power distributions can be used to improve the performance of the DD system.

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INTRODUCTION

Cooperative communication has several promising features to become a main technology in future wireless communication systems. It has been shown in literature (Sendonaris et al., 2003a, Nosratinia et al., 2004) that the cooperative communication can avoid the difficulties of implementing actual antenna array and convert the single-input single-output (SISO) systems into a virtual multiple-input multiple-output (MIMO) system. In this way, cooperation between the users allows them to exploit the diversity gain and other advantages of MIMO system at a SISO wireless network. Many cooperative protocols have been proposed in last seven years. There exist three key protocols (1) Decode-and-Forward (DAF) (2) Amplify-and-Forward (AAF) (3) Coded Cooperation. We concentrated over the cooperative systems with DAF and AAF protocols in this chapter.

In the DAF protocol with a single relay, a user (source) needs to select another user which agrees to relay its data to the destination (Sendonaris et al., 2003a, Sendonaris et al., 2003b). The source sends information to the destination and the relay as well. The relay decodes the data sent by the source and retransmits the decoded data to the destination. Hence, the destination has two received replicas (in the case of perfect relaying) of the same data and the quality of reception is expected to improve. To avoid the wrong relaying of data, some intelligence could be included into the relay terminal to make a decision about the quality of reception and for this the source may apply *ideal* cyclic redundancy code (CRC) (Merkey & Posner, 1984) over the transmitted data. Using the CRC, the relay can judge whether it has received the signal correct or not, hence, it can stop relaying wrong data and the performance of the cooperative system is improved. In (Su et al., 2005), the symbol error rate (SER) performance analysis for the coherent DAF relaying protocol for M-PSK and M-QAM modulation is performed.

To avoid the problem of error propagation in DAF scheme, a selection relaying protocol is proposed in (Laneman et al., 2001, Laneman et al., 2004), where depending upon the channel between the source and the relay, the relay decides whether it should relay the data or not. Another method to avoid the error propagation called incremental relaying is proposed in (Laneman et al., 2004), where the destination decides whether it needs relaying or not based on the channel between the source and the destination.

In AAF protocol, the relaying terminal acts *non-regeneratively* over the received data. It amplifies the received data such that an instantaneous or average power constraint is satisfied and forwards toward the destination. This protocol was proposed and analyzed in (Laneman et al., 2004). It has been shown in (Laneman et al., 2004) that for the two-user case, this method achieves diversity order of two, which is the best possible outcome at high SNR.

A cooperative network can be implemented coherently, but it requires that the destination node must possess the information about the channel coefficients of all links (involved in cooperation) in the network in case of AAF protocol. For DAF protocol based cooperative system the destination needs the information about the channel between the source and the destination and the channels between the relays and the destination. In order to satisfy this requirement, lots of training data and feed forward transmissions from the relays are required. One attractive solution to avoid this requirement is differential modulation. In a differential cooperative system it is not required for a node to possess information about the channels of the other links. Hence, differential modulation can save a significant amount of the training data and avoid the difficulty of practical implementation of the cooperative systems with a small loss in the performance. It is worth mentioning here that DAF protocol in particular is more suitable for realization of a differential modulation based cooperative network as it completely avoids the need of any information about the channel (even of the channel statistics which is required by AAF based

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