LOW COMPLEXITY DECODING IN DECODE-AND-FORWARD COOPERATIVE SYSTEMS

By

ANKUR BANSAL

Department of Electrical Engineering

Submitted

in fulfillment of the requirements of the degree of

Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

June, 2013

Certificate

This is to certify that the thesis entitled **"Low Complexity Decoding in Decode-And-Forward Cooperative Systems"** being submitted by **Mr. Ankur Bansal** to the Department of Electrical Engineering, Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** is the record of the bona-fide research work carried out by him under my supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted either in part or in full to any other university or institute for the award of any degree or diploma.

(Dr. Manav R. Bhatnagar)

Associate Professor

Department of Electrical Engineering

Indian Institute of Technology, Delhi

Hauz Khas, New Delhi 110016, India

Acknowledgements

I would like to express my profound gratitude to my advisor Dr. Manav R. Bhatnagar for his invaluable guidance, continuous encouragement, and support in every stage of this research work. His technical acumen, precise suggestions, and timely discussions are wholeheartedly appreciated. My sincere thanks also goes to Prof. Ranjan Mallik, Prof. Ranjan Bose, and Dr. Monika Aggarwal, for their insightful comments and valuable suggestions during this research. I also thank all of my PhD colleagues for their friendly support.

Most importantly, my heartfelt gratitude is for my grandfather and my parents who were the motivation behind me. Without their blessings this work could have not been accomplished. I am indebted to "Lord Krishna" and "Shri Radha Rani" for Their kind grace. I am also thankful to Prabhat Kumar Sharma and Satya Saurabh for their constant motivations towards "Lord Giriraj Ji". I am deeply grateful to my Didi and Jijaji (Deepa Maheshwari and Naresh Maheshwari) for their moral and emotional support in my life. My special gratitude is due to my brother, Ankit Bansal, for his loving and consistent support. Last, but not the least, I thank my sister Neelima, niece Akansha, and nephew Rohit, who had to miss lots of occasions of being with me, during the course of this work.

Ankur Bansal

Abstract

Cooperative communication is a promising technique for future wireless communication systems. It provides transmit diversity and improved capacity without implementing an actual antenna array. In this way, it creates a virtual multiple antenna environment and allows the users of a single-input single-output (SISO) system to exploit the advantages of a multiple-input multiple-output (MIMO) system. It has been shown in literature that cooperative communication system generally requires the destination receiver to have perfect knowledge of the channel gains of all links in the network, for decoding of the data of the source. It is not feasible in a large wireless network. In a cooperative communication system, it is very important to select a suitable forwarding strategy at the cooperating node. The commonly used relaying protocols, available in literature, are amplify-and-forward (AF) and decode-and-forward (DF). In AF protocol, the relay node scales the received signal from the source and forwards it to the destination; whereas in DF protocol, the relay decodes the data of the source before forwarding it to the destination. In a DF based cooperative communication system, erroneous relaying of data leads to degradation in the performance of destination receiver.

It is shown in the recent researches that a piece-wise linear (PL) decoder of the DF based

SISO cooperative communication system works well for arbitrary constellations and provides low decoding complexity. However, the *average* symbol error rate (SER) expression of the PL decoder is not available in literature so far. In this work, we carry out the performance analysis of the PL decoder for single-antenna based DF cooperative system and obtain a closed-form expression for average SER utilizing arbitrary M-QAM constellation. It is analytically shown by using the derived SER that the PL decoder in a DF based cooperative system with one source-destination pair and a single relay, achieves diversity of two.

In this dissertation, we derive a PL decoder for the DF based MIMO cooperative communication system utilizing an arbitrary complex-valued M-ary constellation, which performs close to the ML decoder. The PL decoder requires the destination node to possess the *average* information of the source-relay links. The proposed decoder outperforms an AF protocol based multi-antenna cooperative system. Further, we obtain a closed-form expression for the average probability of error of the PL decoder using M-PSK constellation and a single MIMO relay. It is analytically shown that the PL decoder achieves maximum possible diversity in multi-antenna cooperative system with a single MIMO relay.

In advance wireless communication systems, multiple antennas are employed on a node for achieving diversity gain and improved error performance. However, in some scenarios, the wireless terminals may not be able to support multi-antennas due to hardware limitation. In such cases, single antenna nodes can share their resources in a multi-user/multi-relay environment to achieve transmit diversity. Moreover, *distributed* space-time block codes (STBCs) can also be applied to multi-node cooperative systems where each cooperating node transmits a single row of the STBC designed for a co-located MIMO system. Therefore, the distributed STBC based

cooperative communication system realizes a virtual MIMO system with distributed antennas. In this dissertation, we analyze an ML decoder of the distributed Alamouti STBC for the DF based cooperative system with two imperfect relaying nodes. We also consider a DF cooperative system in which one out of two relays is in outage. A PL decoder for the DF cooperative system with the distributed Alamouti code and one relay in outage is proposed. The PL decoder provides approximately the same performance as that of the ML decoder with reduced decoding complexity. We derive the pairwise error probability (PEP) of the ML decoder with BPSK constellation. An optimized transmit power allocation for the relays is performed by minimizing an upper bound of the PEP. It is shown by simulations that the ML decoder enables the DF protocol based cooperative system to outperform the same rate AF protocol based cooperative system when both systems utilize the distributed Alamouti STBC.

Contents