An Extensive Review on Joint User-Relay Selection and Association for Multi-User Multi-Relay MIMO

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Abstract - Wireless communications has undergone rapid growth in the last two decades. Cellular telephony along with increasing demand of wireless connectivity has been the major driving force behind this surge. In this work, the focus is on a well-known concept, relaying, and on optimization and innovations in this concept to improve the performance of wireless communication systems. The major impairments of a wireless channel are fading and cochannel interference. Due to ground irregularities and typical wave propagation phenomena such as diffraction, scattering, and reflection, when a signal is radiated into the wireless environment, it arrives at the receiver along a number of distinct paths, and is referred to as a multi-path signal. Multiple users that access the same time-frequency-space resources may achieve signal separation in the spatial domain. In multi-user beamforming, each user's stream is precoded with beamforming weights at the transmitter using some form of user channel state information in order to optimize each user's signal-to-interference and noise ratio (SINR) and, in the process, reduce co-user interference. The use of MIMO concepts has the potential to significantly increase spectrum efficiency in close range portions of the communication system.

Keywords- Multi-User Multi-Relay MIMO, User-Relay Selection, Fading, Interference, SINR.

I. INTRODUCTION

Relays play an important role to establish wireless connections between sources with their respective destinations. If the sources, destinations, and relays are distributed in space, relaying offers multiplexing that allows for multiple source-destination pairs to efficiently share communication resources. A straightforward approach to establish such connections is to have sources transmit their data over orthogonal channels. The relays are then required to receive signals transmitted over each of these channels, and then amplify and forward on the same channel. Each destination then tunes in to its corresponding channel to retrieve data. There are, however, two disadvantages in these orthogonal schemes. The first disadvantage is inefficient use of communication resources: at any time instant, each orthogonal channel is needed to establish the connection between source and destination. Therefore, if any channel from that source to the relays or those from the relays to the corresponding destination go into deep fade, that specific connection cannot be established.

Considering the rapidly increasing demand for high data rate and reliable wireless communications, bandwidth efficient transmission schemes are of great importance. In recent years, user cooperation has attracted increased research interest and has been widely studied. By relaying messages for each other, mobile terminals can provide the final destination receiver with multiple replicas of a signal arriving via different paths. These techniques, known as cooperative diversity, are shown to significantly improve network performance through mitigating the detrimental effects of signal fading. Various schemes have been proposed to achieve spatial diversity through user cooperation. The most popular schemes are amplify-and-forward (AF), decode-and-forward (DF), and coded cooperation. A distributed beamforming system with a single transmitter and receiver and multiple relay nodes are studied in, and second order statistics of the channel are employed to design the optimal beamforming weights at the relays.

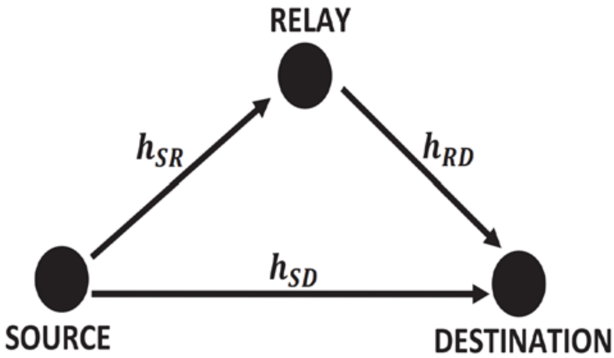

Figure 1.1 A three terminal relay channel with a single source-destination pair aided by a relay.

The classical relay channel model, shown in Fig. 1.1, was first proposed in the information theory literature in the late 1960's and early 70's. However, due to practical constraints little work was carried out on relays until recently. Advances in wireless communications technology have now rekindled interest in relays. Relaying exploits spatial diversity by employing antennas distributed over multiple terminals. Hence, each terminal can have less number of antennas and less number of RF chains. These terminals combined act as a distributed MIMO system. It has also been shown that relaying can enhance the coverage and capacity of wireless networks. In particular, relaying can evidently enhance the transmission capacity for users at the edge of a wireless cell. In addition to the other benefits, cooperative relaying reduces energy consumption. Thus, introducing relays can lead to significant improvements in wireless networks.

There are two main strategies of relay deployment: access-point relaying and cooperative relaying. In access-point relaying, fixed relays are deployed as access- points which aid users in communicating with source(s) such as base station. In cooperative relaying, users themselves act as relays for different users.

forming a cooperative network and exploiting what is termed as cooperative diversity. At this point in time, cooperative relaying is mostly limited to literature and still needs more work to make it feasible. On the other hand, fixed access-point relaying is already being incorporated into telecommunications standards. For instance, in Long Term Evolution (LTE)-Advanced systems, fixed access-point relays with only an in-band wireless connection to the backhaul network are to be deployed.

II. MULTI-ANTENNA SYSTEM MODEL

According to the number of the antennas used at the transmitter and the receiver, multi-antenna systems are divided into four schemes: single-input single-output (SISO), singleinput multiple-output (SIMO), multiple-input single-output (MISO), and MIMO. SISO, SIMO, and MISO can be treated as special cases of MIMO. Figure 2.1 shows a typical block diagram of the MIMO system with N_t transmit antennas and N_r receive antennas.

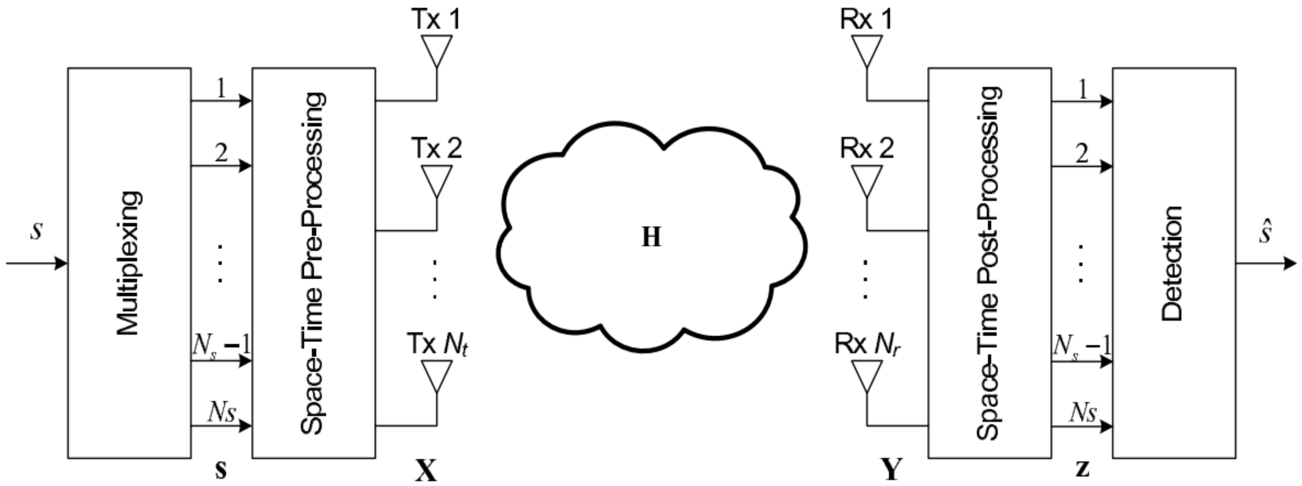

Figure 2.1 Block diagram of a MIMO system.

The input information stream s is assumed to be symbols that have been coded and mapped onto constellations. The input symbols are first divided into Ns data streams denoted by s, and then are pre-processed in space (and in time) domain into N_t x K blocks X, which are transmitted via the radio channel. Here K is the length of the space-time codewords. If no space-time coding is applied, K = 1.

The transmitted signal can be expressed as

$$X = f(s), \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .Eq.1$$

Where f denotes the operation of the space time pre processing.

Under the narrow-band flat fading assumption, the channel is represented by a N_r x N_t matrix H, where H_j denotes the channel coefficient between the i_{th} receive antenna and the j_{th} transmit antenna. Thus, the received signals are given as

$$Y = HX + n, \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots ..Eq.2$$

Where n is the complex while Gaussian noise vector. The received signal are then posts processed in space time domain to obtain the estimated signal.

The data rate of the system can be calculated as

$$R = \frac{N_s}{K}, \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots Eq.3$$

Which is a function of N_s and K.

I. RELATED WORK

G. O. Okeke, W. A. Krzymień, Y. Jing and J. Melzer,[1] In this work, study joint user-relay selection and association in multi-user multi-relay cooperative wireless relay uplinks with multi-antenna nodes. For non-regenerative and altruistic relays propose a low-complexity joint scheme, which simultaneously selects multiple relays and users for cooperation as well as assigns the selected users to different selected relays for service. The proposed scheme is sub-optimal and utilizes only the channel gains between the nodes, which leads to reduced feedback and overhead in comparison to schemes that require full channel knowledge. Furthermore, the complexity of the scheme scales linearly as the product of the total number of relays, the total number of users and the number of selected users. Simulation results demonstrate the superiority of the proposed joint scheme compared to a scheme with neither user-relay selection nor user-relay association and another scheme with user-relay association, but no user-relay selection. The favorable performance and low-complexity of the proposed scheme make it very attractive for possible implementation in emerging broadband wireless relay networks (e.g., LTE-Advanced).

SR. NO.	TITLE	AUTHOR	YEAR	APPROACH
1	A Novel Low-Complexity Joint User-Relay Selection and Association for Multi-User Multi-Relay MIMO Uplink	G. O. Okeke, W. A. Krzymień, Y. Jing and J. Melzer,	2015	Study a joint user-relay selection and association in multi-user multi-relay cooperative wireless relay uplinks with multi-antenna nodes
2	"A Gradient-Descent Weighted Sum MSE Transceiver Design for Multi-User Multi-Relay Downlink Systems,	C. E. Chen and S. K. Chou,	2015	A new transceiver design for multi-user multi-relay MIMO downlink channel
3	A joint precoding and beamforming algorithm for multi-relay multiuser MIMO-OFDM systems,	D. Zhou and B. Hu,	2014	Using matrix singular value decomposition, designs optimized precoding matrices beamforming vectors
4	Joint relay selection and power allocation for pairwise multi-way relay networks,	T. P. Do, Y. H. Kim, S. R. Lee and M. A. Jung,	2014	A multi-way relay network in which all source nodes share their data by the help of multiple single-antenna relay nodes
5	Beamforming and relay selection schemes for multi-antenna two-way relaying systems with physical network coding,	Y. Jeon, S. H. Moon, G. Noh and Y. O. Park,	2014	Design an efficient closed-form beamforming vector.
6	Joint Optimization in Bidirectional Multi-User Multi-Relay MIMO Systems: Non-Robust and Robust Cases,	M. Zhang, H. Yi, H. Yu, H. Luo and W. Chen,	2013	Design of bidirectional networks in which each node is equipped with multiple antennas.

C. E. Chen and S. K. Chou,[2] In this work, a new transceiver design for multi-user multi-relay MIMO downlink channel is proposed. Derive the closed-form expressions for the gradients of the weighted sum-MSE with respect to the precoders and present a new transceiver design based on the gradient descent

algorithm. The algorithm monotonically decreases the weighted sum-MSE and hence guarantees local convergence. Simulation results show that the proposed algorithm can generate good suboptimal solution with much faster convergence rate comparing to other algorithms.

D. Zhou and B. Hu,[3] Based on amplify-and-forward cooperative relay multi-relay multi-user system, in order to reduce the bit error rate of OFDM-based wireless systems, a practical limited bits feedback precoding algorithm is proposed. Using matrix singular value decomposition, designs optimized precoding matrices beamforming vectors. Source precoding and relay beamforming matrices are jointly optimized. The precoding and beamforming matrices index can be fed back using offline codebooks. Achievable sum-rate formula is derived. Simulations indicate the effectiveness of the proposed joint precoding and beamforming design. The proposed method can improve bit-error-rate performance and can obtain good sum-rate performance contrast to existing algorithm. It is a practical scheme of multi-user networks for linear algorithm.

T. P. Do, Y. H. Kim, S. R. Lee and M. A. Jung, [4] consider a multi-way relay network in which all source nodes share their data by the help of multiple single-antenna relay nodes. To mitigate a loss in the spectral efficiency, the network employs a pairwise digital network coding (DNC) which pairs the source nodes for simultaneous transmission so that the relay forwards the DNC bits of the pairs. For the network, devise a joint relay selection and power allocation (RS-PA) scheme based on an approximation on the instantaneous symbol error probability incorporating error propagations. Simulation results show that the network with the proposed RS-PA outperforms the conventional network with the RS only with a larger gain with a larger number of relays.

Y. Jeon, S. H. Moon, G. Noh and Y. O. Park,[5] In this work, consider a beamforming technique and relay selection method in two-way relaying systems employing physical network coding where the relays are equipped with multiple antennas. In order to exploit the benefits of multiple antennas, design an efficient closed-form beamforming vector. Furthermore, to achieve diversity gain from multiple relays, suggest the minimum distance based relay selection criterion. Since the minimum distance based approach generally requires a huge search size, also propose a method to calculate the minimum distance with the reduced search size. Simulation results confirm that the proposed schemes are able to attain the full diversity order which results from both beamforming and relay selection.

M. Zhang, H. Yi, H. Yu, H. Luo and W. Chen,[6] This work studies the precoder design of bidirectional networks in which each node is equipped with multiple antennas. In contrast to the conventional model of bidirectional relay networks, this work considers a more general scenario, i.e., a multi-user multi-relay network. First, by assuming that perfect channel state information (CSI) is available, investigate the precoding design for the relays and users to minimize the sum mean squared error (MSE) and the maximum of single user's MSE, respectively. Then, consider a more practical scenario where CSI estimation error is taken into account. By means of alternating optimization approach, decompose the main problem into several decoupled subproblems with tractable solutions. It is shown that, in both the perfect and imperfect CSI cases, the proposed precoding algorithms outperform the existing solutions in terms of MSE and bit-error-rate (BER) performance.

II. PROBLEM STATEMENT

Each of multi-path signal paths has a distinct and time-varying amplitude, phase and angle of arrival. These multi-paths may add up constructively or destructively at the receiver. Hence, the received signal parameters may vary over frequency, time, and space. These variations are collectively referred to as fading and deteriorate link quality. Moreover, in cellular systems, to maximize the spectral efficiency and accommodate more users while maintaining minimum quality of service, frequencies have to be reused in different cells that are sufficiently separated. Therefore, a desired user's signal may be corrupted by the interference generated by other users operating at the same frequency.

This work studies the problem of minimizing the total consumed power under peak power constraints on the individual nodes and a maximum threshold constraint on the end-to-end SNR. Specifically the works in and minimized outage probability under a total power constraint, while this work minimizes the total consumed power under an end-to-end SNR constraint. Similarly, considers SNR maximization under power constraints.

III. CONCLUSION

This work present a survey with a study of an uplink cooperative system equipped with multi-antenna relays under a capacity maximization criterion. The specific scheme that users access the base station through a single multi-antenna relay is studied. To meet the very high data rate requirements for wireless Internet and multimedia services, co-operative systems with multiple antennas have been utilized for future generation wireless systems. In this work, focus on multiple antennas at the source, relay and destination. Studied both downlink and uplink cooperative systems with single antenna relays and multiple antenna relays. Also study the optimization of relay weights.

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