Chapter 4

Interference Management for Full-Duplex Massive MIMO Relaying System with Hardware Impairments

ABSTRACT

Massive MIMO full-duplex relaying (MM-FDR), where multiple source-destination pairs communicate simultaneously with the help of a common full-duplex relay equipped with very large antenna arrays, is studied in this chapter. Different from the traditional MM-FDR protocol, a general model where sources/destinations are allowed to equip with multiple antennas is considered. The effect of hardware impairments is taken into consideration, and is modeled using transmit/receive distortion noises. We propose a low complexity hardware impairments aware transceiver scheme (named as HIA scheme) to mitigate the distortion noises by exploiting the statistical knowledge of channels and antenna arrays at sources and destinations. A joint degree of freedom and power optimization algorithm is presented to further optimize the spectral efficiency of HIA based MM-FDR. The results show that the HIA scheme can mitigate the "ceiling effect" appears in traditional MM-FDR protocol, if the numbers of antennas at sources and destinations can scale with that at the relay.

INTRODUCTION

In multi-user MIMO systems, one main challenge is the increased complexity and energy consumption of the signal processing to mitigate the interferences between multiple co-channel users. To achieve energy efficient transmission, the multi-user MIMO system with very large antenna arrays at each base
station (known as “massive MIMO” system) has been advocated by the authors of T. L. Marzetta. (2010) recently. The key result shown by T. L. Marzetta. (2010) and H. Q. Ngo, E. G. Larsson. (2013) is that, with very large antenna arrays at each base station, both the intracell and intercell interferences can be substantially reduced with simple linear beamforming (BF) processing.

On the other hand, full-duplex relaying (FDR) is a promising approach to improve the spectral efficiency (SE) of relaying network while retains the merits of half-duplex relaying (HDR). In FDR, it is shown in D. Bharadia, E. McMilin. (2013) that the relay transmits and receives simultaneously at the same frequency and time, but at the cost of a strong echo interference (EI) due to signal leakage between the relay output and input. To mitigate EI, three approaches have been investigated, i.e.:

1. Passive cancellation,
2. Time-domain cancellation by D. Bharadia, E. McMilin. (2013), and

The passive cancellation relies on a combination of path loss, cross-polarization and antenna directionality. The time-domain cancellation is based on the fact that EI signal is known at full-duplex node. Thus, the authors in D. Bharadia, E. McMilin. (2013) shown that it can be regenerated and removed in time-domain. In spatial suppression, H. A. Suraweera, I. Krikidis. (2014) showed in their previous work that EI is mitigated with the multiple transmit/receive antennas by approaches such as null-space projection. Inspired by these works, a number of works have dedicated to the study of FDR protocol on both theory and testbed (See the works of D. Nguyen, L.-N. Tran. (2014) and A. Sabharwal, et al. (2014) and the references therein). To achieve spectral and energy efficient transmissions of multiple source-destination pairs, recent works of H. Cui, L. Song. (2014), H. A. Suraweera, N. Hien Quoc. (2013), H. Q. Ngo, H. A. Suraweerat. (2013), H. Q. Ngo, H. A. Suraweera. (2014) and X. Xia, W. Xie. (2015) sought to incorporate both HDR and FDR with massive MIMO.

However, the aforementioned works on massive MIMO are actually based on the assumption that the base stations or relays are equipped with a large number of high-quality transmit/receive radio frequency (RF) chains (which are expensive and power-hungry). In contrast to conventional MIMO system (e.g., at most 8 antennas in LTE system), the authors in E. G. Larsson, O. Edfors. (2014) showed in their work that massive MIMO must be built with low-cost components since the deploy cost and energy consumption of circuits will increase dramatically as the number of antennas grows very large. Such low-cost components are prone to hardware imperfections (e.g., phase noise, nonlinear power amplifier, I/Q imbalance, nonlinear low-noise amplifier and ADC impairments), which must be considered in the design of practical massive MIMO system.

This chapter focuses on the transceiver design for massive MIMO full-duplex relaying (MM-FDR) with hardware impairments. The effect of hardware impairments is modeled using transmit/receive distortion noises by the authors in B. P. Day, A. R. Margetts. (2012) and G. Zheng, I. Krikidis. (2013). There are several challenges in the design of practical transceiver scheme in the considered system. The first is: \textit{How to deal with the EI cancellation without instantaneous EI channel?} EI cancellation is a critical problem in MM-FDR transceiver design which is not only important to reduce EI power, but also useful to reduce distortion noises caused by hardware impairments at the relay (as will be shown in section IV). Different from FDR with small-scale relay antenna arrays, that is discussed in D. Bharadia, E. McMilin. (2013), E. Everett, A. Sahai. (2014), H. A. Suraweera, I. Krikidis. (2014), C. Y. A. Shang, P. J. Smith. (2014), D. Nguyen, L.-N. Tran. (2014) and A. Sabharwal, et al. (2014), the instantaneous EI channel