Title: Evaluation of precoding and feedback quantization schemes for multiuser communications systems

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Abstract

Multiple-input multiple-output (MIMO) communication systems have emerged as one of the most promising technologies in the field of wireless communications, allowing to exploit the spatial dimension as well as the time and frequency dimensions. Thus, higher rates can be obtained by using the same bandwidth, which is a scarce resource, and keeping a low transmit power, which is crucial in battery-operated devices. For these reasons, MIMO technologies have been adopted by many standards such as Long-Term Evolution (LTE), LTE advanced (LTE-A) and Worldwide Interoperability for Microwave Access (WiMAX).

MIMO techniques can also be used in a multiuser scenario, where several users share the spatial dimension causing multiuser interference. By means of precoding and the use of multiple antennas at the transmitter, the signal of the different users can be spatially multiplexed so that multiuser interference is mitigated even for single-antenna users. These systems, known as multiuser multiple-input singular-output (MU-MISO) systems, have attracted much attention in recent years since they allow the development of small and inexpensive terminals, keeping the most expensive hardware at the transmitter.

However, these benefits come at the cost of having a more complex system. On the one hand, spatial multiplexing requires a considerable processing load that depends on the size of the system: number of transmit antennas, number of receivers and bandwidth. On the other hand, MIMO techniques require accurate channel state information at the transmitter (CSIT). In frequency-division duplex (FDD) systems, channel state information (CSI) has to be estimated at the receiver and provided to the transmitter through the feedback link, hence reducing the efficiency of the system. Therefore, this thesis is primarily focused on improving the efficiency of precoding implementations and the performance of feedback schemes in MU-MISO systems.

First, the problem of precoding is addressed. An analysis of some of the most utilized precoding techniques is conducted, paying special attention to their performance and computational complexity. The analysis reveals that those techniques that make use of lattice reduction (LR) achieve the best performance. However, the computational complexity of LR makes its implementation difficult for practical systems. The analysis reveals that zero-forcing (ZF), Tomlinson-Harashima precoding (THP) and lattice reduction Tomlinson-Harashima precoding (LR-THP) are the most suitable techniques for covering the entire range of performance and computational complexity. An analysis of these techniques with imperfect CSIT has also been performed. In this analysis, LR has proven to be a key technique also when imperfect CSIT is available.

Next, parallel implementations of the precoding techniques on a graphic processing unit (GPU) are presented and compared to implementations that use a central processing unit (CPU). Since the implementations of THP and LR-THP have shown to best fit the GPU architecture and since they also share many operations, a GPU implementation of a reconfigurable THP scheme combined with LR has been proposed. The reconfigurable nature of GPUs allows gating the LR stage off when the user requirements are sufficiently guaranteed by the THP scheme, trading computational cost and performance. Although this implementation achieves a significant speed-up compared to its CPU implementation, its parallelism is limited by the sequential nature of LR. Therefore, several strategies for the parallelization of the LR problem are proposed and evaluated on different platforms: multicore CPU, GPU and a heterogeneous platform consisting of CPU+GPU. Results reveal that a GPU architecture allows a considerable reduction of the computational time of the LR problem, especially in the heterogeneous platform.

The second part of this thesis addresses the problem of feedback in FDD systems. In these systems, a quantized version of the channel is usually provided by the receivers through the feedback link. In order to keep a high efficiency, the channel must be quantized using as few bits as possible. First, the use of the frequency correlation to reduce the feedback information is explored. Two different schemes based on vector quantization (VQ) and the Karhunen-Loève (KL) transform, respectively, are presented and compared with existing schemes in terms of performance and complexity. Results show that both techniques are able to significantly reduce the feedback overhead by taking advantage of the frequency correlation.

Finally, the spatial correlation is leveraged to reduce the feedback information. A spatial statistical characterization of the spatial channel model (SCM) from the 3rd Generation Partnership Project (3GPP) for a highly correlated environment is presented. Based on this characterization, a channel quantization scheme for highly correlated environments is proposed. In order to obtain a statistical characterization for both high and low correlations, a simpler model such as the Kronecker correlation model is considered. Based on this characterization, two quantization schemes have been presented and evaluated using a realistic channel model such as the SCM. Results show that both schemes are able to reduce the feedback overhead in highly and moderately correlated scenarios.

Keywords: wireless communications, mobile communications, MIMO, precoding, GPU, limited feedback, channel quantization