Compressed Channel Feedback for Correlated Massive MIMO Systems

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Abstract: **Massive multiple-input multiple-output (MIMO) is a promising approach for cellular communication due to its energy efficiency and high achievable data rate. These advantages, however, can be realized only when channel state information (CSI) is available at the transmitter. Since there are many antennas, CSI is too large to feed back without compression. To compress CSI, prior work has applied compressive sensing (CS) techniques and the fact that CSI can be sparsified. The adopted sparsifying bases fail, however, to reflect the spatial correlation and channel conditions or to be feasible in practice. In this paper, we propose a new sparsifying basis that reflects the long-term characteristics of the channel, and needs no change as long as the spatial correlation model does not change. We propose a new reconstruction algorithm for CS, and also suggest dimensionality reduction as a compression method. To feed back compressed CSI in practice, we propose a new codebook for the compressed channel quantization assuming no other-cell interference. Numerical results confirm that the proposed channel feedback mechanisms show better performance in point-to-point (single-user) and point-to-multi-point (multi-user) scenarios.**

Index Terms: **MIMO system, multi-user system, channel feedback, compressed feedback.**

I. INTRODUCTION

THE concept of multiple-input multiple-output (MIMO) wireless communication employing a number of antennas, a.k.a. massive MIMO, has been researched for several years. It was found that a base station (BS) with more antennas can recover information in lower signal-to-noise-ratio (SNR) when the number of antennas is sufficiently large [2]. With this motivation, the idea of using a very large number of antennas at the BS in a cellular system was proposed in [3]. Massive MIMO systems are known to provide large network capacity gain by supporting many users [4], and higher energy efficiency [5]. Practical issues, transmit precoding and receive post processing, and channel estimation issues for massive MIMO systems were discussed in [6] and [7].

A transmitter with multiple antennas has to exploit channel state information (CSI) to provide beamforming gains in single-user (SU) MIMO systems, and multiplexing gains in multi-user (MU) MIMO systems [8]. With inaccurate CSI, however, there is sum-rate saturation even in massive MIMO systems [9], [10]. It is, therefore, important to design efficient channel estimation and feedback strategies. In time division duplexing (TDD) systems, CSI can be implicitly obtained using reciprocity. In frequency division duplexing (FDD), which most of cellular systems employ nowadays, the receiver has to feed back information of channel state or precoding vectors. It is known that the feedback overhead must increase to maintain a certain level of CSI quantization loss [11]–[14]. From this point-of-view, it is essential to compress and quantize CSI efficiently due to the large number of antennas. To solve these issues, a feedback reduction technique that exploits spatial correlation of users was proposed in [15], and noncoherent trellis-coded quantization for FDD massive MIMO systems was proposed in [16]. In [15] and [16], however, it was assumed that the spatial correlation matrices are perfectly available at transmitters.

Compressive sensing (CS) based CSI compression was applied in [17]. It uses the fact that CSI in massive MIMO systems has high spatial correlation due to the limited physical distance between antennas. The theory of CS [18]–[20] has been applied in various areas including signal processing and communications, where the information is sparse. A sparse signal (or vector) is a signal that can be represented by few elements in a certain domain. Via random projections, CS is able to compress sparse information efficiently. With the insight that CSI can be represented in sparse form in a spatial-frequency domain, two sparsifying bases were adopted in [17]: The two-dimensional discrete cosine transform (2D-DCT) and the instantaneous Karhunen-Loeve transform (KLT). Unlike [15] and [16], there is no need to assume transmitters to know the correlation matrices in [17]. Without this assumption, however, the 2D-DCT basis fails to reflect the spatial correlation of the systems. The instantaneous KLT basis changes as the channel varies, making it, in practice, unfeasible. CS techniques simplify encoding, but require solving an optimization problem for decoding, thus demanding significant computing resources.

In this paper, we propose two new compression methods for channel feedback in massive MIMO systems using the fact that highly correlated CSI can be represented in a sparse form. For a sparsifying basis, we adopt the KLT, which considers the long-term correlation model of the channel. The first method compresses via random projection, while the second one uses the sparsifying basis directly. The former method is useful when the receiver does not know what basis to use (Scenario 1), while the latter method is prefered when the receiver and the transmitter select what sparsifying basis to use (Scenario 2). To quantize the compressed CSI, we adopt the widely used Linde, Buzo, and Gray (LBG) algorithm [21], and random vector quantiza-

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