

# Chapter 5

## Distributed Multicell Precoding for Network MIMO

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### ABSTRACT

*Interference is a performance limiting factor in dense cellular networks with aggressive frequency reuse. Cooperation among base stations (BSs) is a promising approach for improving data rates by eliminating or mitigating interference. For the downlink, the highest spectral efficiency gains are achieved through precoding with full coordination, which requires complete channel state information (CSI) and data sharing among BSs at the cost of significant utilization of the backhaul. In this chapter, the authors introduce distributed precoding techniques for the multicell MIMO downlink. Each BS designs its own precoder without requiring data or downlink CSI of links from other BSs. The authors also study the effect of imperfect CSI on these precoders and introduce a robust precoder in the presence of CSI uncertainty. Simulations show that these methods enjoy a rate increase with SNR similar to multicell joint dirty paper coding in the high SNR regime due to effective interference mitigation.*

### 5.1 INTRODUCTION

In next generation cellular networks, the increased density of base stations (BSs) and the aggressive reuse of frequencies are seen as the solution to the pressing problem of scarce frequency spectrum. As a result, cellular systems are going to be

interference limited. Multicell or network MIMO promises to reduce or eliminate the interference problem through cooperation or coordination between BSs (Viswanathan, Venkatesan, & Huang, 2003; Foschini, Karakayali, & Valenzuela, 2006; Andrews, Choi, & Heath Jr., 2007; Boudreau et al., 2009; H. Zhang & Dai, 2004; Tölli, Pennanen, & Komulainen, 2009; Cai, Quek, & Tan, 2011;

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Cai, Quek, Tan, & Low, n.d.). Multicell MIMO refers to a technique where BSs cooperate and use multiple antenna transmission to increase the performance of a cellular system. Multiple antennas may exist on the BSs, on the users, or both. As a result, the spatial dimension can be exploited to boost the users' rates or reduce the transmission power required, even with the same time and frequency resources.

Joint encoding with DPC among cooperating BSs has been shown to achieve the capacity or maximum sum rate of the multicell MIMO downlink. Joint encoding is hard to achieve in practical systems due to the requirement of precise time and phase synchronization of the transmitted signals from involved BSs (Andrews et al., 2007). Besides DPC, zero-forcing beamforming (Somekh, Simeone, Bar-Ness, Haimovich, & Shamai (Shitz), 2009) and game theoretic optimization for scheduling across frequency and time (Gesbert, Kiani, Gjendemsjø & Øien, 2007; Oteri & Paulraj, 2008) have also been proposed. Linear block diagonalization methods null out inter-cell interference using linear zero-forcing (ZF) techniques to create a block diagonal effective channel from the BSs to the users (Shim, Kwak, Heath Jr., & Andrews, 2008; Kaviani & Krzymien, 2008). Chae, Kim, and Heath Jr. (2009) proposed linear algorithms for full and clustered broadcast channel scenarios that approach the sum capacity of multicell DPC. Bhagavatula and Heath Jr. (2011) proposed a feedback-bit partitioning algorithm to ensure a manageable load on the finite-capacity backhaul. Ng, Evans, Hanly, & Aktas (2008) interpret the multicell downlink as a factor graph with local message passing between neighboring BSs. They proposed a downlink beamforming algorithm based on belief propagation. H. Huang et al. (2009) analyzed the effect of the coordination cluster size through cellular system simulations. Marsch and Fettweis (2008) proposed a framework for optimizing the downlink where multicell joint transmission is possible but constrained by a limited backhaul infrastructure between sites. Jing et

al. (2008) considered single-class and double-class networks and analyzed schemes involving cell-breathing, cophasing, superposition coding, as well as other hybrid strategies. Related work on the uplink can be found in the papers by Lee, Je, Shin, & Lee (2009); Simeone, Somekh, Poor, & Shamai (Shitz) (2009).

Most techniques assume a high level of cooperation among BSs in which (processed) data for an intended user needs to be available at multiple BSs. In such a scenario, multiple cooperating BSs act as a large virtual antenna array to beamform to a particular user. Clearly, system performance is improved at the cost of significant system overhead related to channel state information (CSI) feedback to the central processor and data exchange among the BSs. The concept of maximizing the signal-to-leakage-plus-noise ratio (SLNR) has been used to reduce the complexity of the transmitter processing (Sadek, Tarighat, & Sayed, 2007; H. Zhang, Mehta, Molisch, Zhang, & Dai, 2008; Lee, Je, Sohn, Shin, & Lee, 2008). Sadek et al. (2007) applied it in the single-cell multiuser MIMO downlink. H. Zhang et al. (2008) extended it to the multicell scenario using joint transmission. Lee et al. (2008) considered a single user per cell and applied the SLNR concept for decentralized precoding. SLNR-based precoding can be seen as a balance between the altruistic and egoistic beamforming strategies in the game theory of interference channels (Larsson, Jorswieck, Lindblom, & Mochaourab, 2009; Z. K. M. Ho, Kaynia, & Gesbert, 2010; Z. K. M. Ho & Gesbert, 2010; Björnson & Ottersten, 2009; Zakhour, Ho, & Gesbert, 2009; Zakhour & Gesbert, 2009; Björnson, Zakhour, Gesbert, & Ottersten, 2009).

In this chapter, we introduce two decentralized precoding methods for network MIMO downlink channels, where multi-antenna BSs serve multiple users equipped with one or more antennas. Each BS performs coordinated processing in a distributed fashion with only the CSI of links originating from itself and only the data intended for users in its own coverage region (intra-cell users). If

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