Chapter 4
Capacity Limits of Base Station Cooperation in Cellular Networks

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ABSTRACT

In the information-theoretic literature, it has been widely shown that multicell processing is able to provide high capacity gains in the context of cellular systems. What is more, it has been proved that the per-cell sum-rate capacity of multicell processing systems grows linearly with the number of base station (BS) receive antennas. However, the majority of results in this area have been produced assuming that the fading coefficients of the MIMO subchannels are completely uncorrelated. In this direction, this chapter investigates the ergodic per-cell sum-rate capacity of the Gaussian MIMO cellular channel under correlated fading and BS cooperation (multicell processing). More specifically, the current channel model considers Rayleigh fading, uniformly distributed user terminals (UTs) over a planar cellular system, and power-law path loss. Furthermore, both BSs and UTs are equipped with correlated multiple antennas, which are modelled according to the Kronecker product correlation model. The per-cell sum-rate capacity is evaluated while varying the cell density of the system, as well as the level of receive and transmit correlation. In this context, it is shown that the capacity performance is compromised by correlation at the BS-side, whereas correlation at the UT-side has a negligible effect on the system's capacity.

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INTRODUCTION

Since their conceivement, wireless communications have been greatly evolved while finding applications in every aspect of the contemporary life. The ubiquity of wireless systems has raised the demand for cost-efficient high-rate wireless services increases and thus the network operators have been in search for new transmission techniques which will allow them to reach the channel capacity limits. However, the improvement margin of the traditional cellular paradigm is getting more and more limited, as the increase in the system complexity becomes disproportional with respect to the provided capacity gain. In this direction, academia and industry have started investigating alternative cellular architectures which have the ability to provide high spectral efficiencies. In this direction, cooperative wireless cellular architectures are gaining momentum as a dominant candidate for an alternative approach in wireless cellular networks.

Cooperation in wireless networks can take many forms, such as User Terminal (UT) cooperation, Base Station (BS) cooperation and Relaying. UT cooperation is theoretically possible but practically it involves many complications, since the UTs have to communicate either on a separate wireless frequency band or through the BS in order to exchange cooperative information. This fact results in a waste of bandwidth and energy, which is very important in terms of battery life in mobile devices. Relaying can be beneficial but it either consumes the resources of relaying UTs or requires the installation of additional transponders by the network operator.

Based on the previous discussion, the approach of BS cooperation or Multicell Processing (Wyner, 1994; Somekh & Shamai, 2000; Letzepis, 2005; Shamai, Somekh, & Zaidel, 2004) is investigated, focusing on the *information-theoretic capacity limits*. In the literature, it has been widely shown that multicell processing is able to provide high capacity gains (Telatar, 1999; Foschini & Gans, 1998) in the context of cellular systems. What is more, it has been proved that the per-cell sum-rate capacity of multicell processing systems grows linearly with the number of Base Station (BS) antennas (Chatzinotas, Imran, & Tzaras, 2008e). However, the majority of results in this area has been produced based on the unrealistic assumption that the fading coefficients of the MIMO subchannels are completely uncorrelated. In general, MIMO point-to-point channels may appear correlated due to inadequate antenna separation and/or poor local scattering (Shiu, Foschini, & Kahn, 2000). More specifically, if the components of an antenna array are separated by a distance less than half of the communication wavelength, then the fading coefficients appear correlated. Furthermore, if the number of local scatterers is insufficient, then the regularities between the multiple paths can lead to correlated fading. In a typical macrocellular scenario, the inadequate antenna separation mainly affects the correlation at the UT side due to their size limitations, whereas poor local scattering affects the correlation at BS side due to their elevated position.

Taking into account the previous discussion, the purpose of this book chapter is to investigate the performance of the cooperative cellular systems which employ multi-cell joint processing under correlated fading conditions. In this direction, this chapter investigates the ergodic per-cell sum-rate capacity of the Gaussian MIMO Cellular Channel in both uplink and downlink. The employed channel model considers flat fading, uniformly distributed User Terminals (UTs) over a planar cellular system and power-law path loss. Furthermore, both BSs and UTs are equipped with multiple antennas, which are correlated according to the Kronecker product model.

More specifically, the main objectives of this book chapter are to: