Chapter 5
Interference Mitigation with Power Control and Allocation in the Heterogeneous Small Cell Networks

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ABSTRACT
With the introduction of Small Cell into current cellular structure, the ever-growing demand for mobile traffic gets the opportunity to be fulfilled. But the overlapped dense deployment caused by the Small Cell Heterogeneous Network (HetNet) also arouses the interference problems. In order to solve those problems, this chapter focuses on Game Theory based uplink power control and downlink power allocation strategies for the interference mitigation of the heterogeneous Small Cell Network (SCN). For the uplink scenario, this chapter proposes the non-cooperative game model based power control algorithm, which can optimize the initial transmission power of both Macro Cell and Small Cell users through the Nash Equilibrium solution. For the downlink scenario with multiple service types in the SCN, the non-cooperative game model based scheme is proposed to optimize the transmission power allocation with constraints of different Quality of Service (QoS) requirements. The simulation results show the merits of the proposed strategies over current works.

INTRODUCTION
Nowadays, the mobile Internet applications and corresponding versatile mobile services are influencing every aspects of our daily life, forcing the mobile network to face the challenges for revolutionary development to cope with the significant increase of the mobile traffic. Besides the spectrum expanding, the radio transmission efficiency improving, the mobile network architecture is also considered as
the most important potential for further empowering the capacity increase of the 5th Generation mobile systems (5G) (Andrews, 2013), (Hanzo et al., 2012). Fueled by the requirements of the capacity increase and improved coverage for home and office use, the Heterogeneous Network (HetNet) with Small Cell Network (SCN) deployments have attracted significant interests in the mobile communication industry and standard organizations (3GPP, 2012). The heterogeneous SCN will be a radically different network design that could provide a cost- and energy-efficient solution to cope with the forecast traffic growth. SCN is founded by the idea of dense deployments of self-organizing, low-cost, low-power base stations that are substantially smaller than the traditional Macro Cell equipment, which is also introduced into the standard framework of the 3rd Generation Partnership Project (3GPP) (3GPP, 2013) and so on. The small Cell evolved Node B (eNB) is a low power access node, working in an authorized or unauthorized spectrum. The Small Cell integrates Femto Cell, Pico Cell, Micro Cell and distributed Remote Radio Head (RRH) technologies. The covering ranges of Small Cell are much smaller than the Macro Cell, which can cover from 10 meters of indoor environment to the fields of 2km according to different transmission power settings (3GPP, 2013). The Small Cells could be deployed on the building walls or urban furniture, in the streets or inside the hotspot buildings, by which, the transmission range of Small Cells can offer better signal reception at indoor users. With the combination of the already deployed Coordinated Multi-Point Transmission/Reception (CoMP) and Relay techniques (3GPP, 2013), the heterogeneous SCN could bring more potential gain over current network architecture. Therefore, the heterogeneous SCN are expected to offload part of capacity from the Macro Cell, thereby reducing the Capital Expenses (CAPEXs) and Operational Expenses (OPEXs) for the network operators.

Although SCNs can provide significant benefits, they may also suffer severe interferences with the high density heterogeneous deployments, emanating from other nearby Small Cells and Macro Cells with the shared spectrum manner. The dynamic scheduling modes result in the random variation of inter-cell interferences, such as the Small Cell dynamically switching ON/OFF. The delayed exchange of load situations will further lead more complicated and unpredictable inter-cell interferences. Especially, cell edge users are far from the eNB and the relatively higher signal attenuation usually needs larger transmission power, which will produce a strong interference that could seriously deteriorate the adjacent cell performances. In these scenarios, the inter-cell interference will be one of the main obstacles to limit the performance in the heterogeneous SCN.

Furthermore, the heterogeneous SCN consists of both Macro Cells and a variety of Small Cells. In the heterogeneous SCN, the existing several eNB types, such as the Macro Cell eNBs, Micro Cell eNBs, Pico Cell eNBs and Femto Cell eNBs, have different transmission power limitations. For example, the Macro Cell eNBs are with high transmission power limitation and Small Cell eNBs are with low transmission power. According to the standards of 3GPP, the typical transmission power of Macro Cell eNBs and Small Cell eNBs are 46 dBm and 30 dBm respectively (3GPP, 2013).

The introduction of the Small Cell into the Macro Cell deployments could enhance the system capacity and user throughput, but this layout will also affect the user association. For the Long Term Evolution (LTE)/LTE-Advanced based systems, the Reference Signal Received Power-based (RSRP-based) user association is widely used (3GPP, 2013). In this scheme, users are associated with the cells of strongest downlink transmission power. As the Macro Cell eNBs have higher transmission power than the Small Cell eNBs, users may connect with the Macro Cell even though the path loss of the adjacent Small Cell is much lower than the Macro Cell. This will also cause more severe interferences. Moreover, because the coverage area of Small Cells is much smaller than the Macro Cells, the potential offloading gains from the Macro Cells to the Small Cells are also limited.