Cooperative Resource Allocation in Cellular Networks with Multiple Antennas

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Abstract

Multi-antenna transmission and reception technique, also known as MIMO, has evolved as one of the key enabling techniques to meet the ever-increasing demand for high-speed wireless data access in current and emerging wireless cellular networks. This dissertation addresses some critical issues on the resource allocation for MIMO-enhanced cellular networks with centralized or distributed antenna architecture.

With the dramatic growth of mobile services provided by cellular networks, the first problem that we should confront is to support and differentiate diverse services, particularly the quality of services (QoS) guarantee for real-time services. However, traditional algorithms for resource allocation fail to provide a better solution that dynamically guarantees the QoS requirements while obtaining the throughput efficiency, since they have neglected competing and sharing characteristics between services from a systems perspective. In contrast, I consider this problem based on a cooperative game model, which gives great insights into the nature of competing and cooperative relations. Consequently, I successfully formulated this problem on resource allocation as a cooperative game and obtained the notion of QoS guaranteed fairness based on the well known Nash bargaining solution. The algorithm based on QoS guaranteed fairness, can satisfy the QoS requirements of all services and achieve the Pareto optimal system throughput, which is validated through

simulations and discussed at the end of Chapter 3. Moreover, this work also provides a theoretical framework that paves the way to solving resource allocation problems in other similar scenarios.

At the same time, the huge amount of traffic have highly saturated the bandwidth available by current cellular networks, which pushes us to utilize bandwidth more efficiently than ever so that universal frequency reuse is usually considered by future cellular networks. However, this raised the second problem, severe inter-cell interference(ICI), which has become the bottleneck of further enhancement of spectral efficiency. The spatial multiplexing transmissions in MIMO-enhanced cellular networks, whose main advantage is a dramatic improvement in spectral efficiency, lose much of their effectiveness due to this high levels of interference. Fortunately, the advances in MIMO technique such as cooperative transmission, especially that between base stations (BS) within a cellular context, have emerged as one of the most promising techniques to mitigate ICI and thus improves total system throughput. I proposed an algorithm in Chapter 4 for allocating wireless resources cooperatively, which is aimed at mitigating ICI and efficiently utilizing wireless resources. Based on game theoretic analysis, the proposed algorithm achieves Pareto optimal efficiency and considers proportional fairness. Due to the prohibitive complexity of computation, I also developed a heuristic algorithm and compared it with a benchmark that is regarded as a Nash equilibrium outcome in a non-cooperative scenario. The simulation and analysis results are also given at the end of Chapter 4.

I also investigated the distributed antenna scenarios in both Chapter 5 and 6 that have a topology of distributed antennas for the BS at each cell. The intuitive advantages of this architecture are better signal coverage and lower power consumption. However, We expect to further exploit other advantages since resource allocation with distributed antennas is more flexible in cooperation and optimization than that in traditional architectures. In Chapter 5, I proposed two energy-efficient resource allocation algorithms, based on beamforming transmission and selection transmission, respectively. the simulation results shows that both algorithms have a higher energy efficiency that conventional algorithms, and the selection transmission outperforms the beamforming transmission algorithm in terms of energy efficiency and complexity. The ICI problem in distributed antenna architecture is also investigated in Chaper 6. I proposed a cooperative beamforming algorithm that mitigates ICI and achieves a higher system capacity. A comparison and analysis of performance between a scenario with co-located antennas and that with distributed antennas are given, which clearly demonstrate the advantages of the architecture with distributed antennas.

In summary, the cooperative resource allocation problems is investigated in the MIMO-enhanced cellular networks. The game theoretic framework is proposed to provide QoS guarantee for diverse services, mitigate interference, and conserve transmission energy. All these algorithms can achieve the Pareto optimal in terms of system throughput. my investigations with both architectures of distributed antenna and traditional co-located antenna is also discussed in this dissertation.