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Scattering in Non-Stationary Mobile-to-Mobile Communications Channels

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Abstract

The demand for mobile communication services has been permanently growing since the emergence of digital cellular systems in the early nineteen nineties. This trend is expected to continue well into the future. However, frequency resources are limited and must therefore be used more efficiently, such that capacity can be increased without adding spectrum. A promising technique for more efficient spectrum use is the application of smart antennas at the *Base Station* (BS). Adaptive antennas enable the BS to steer adaptive antenna beams to each individual user for directive transmission and reception. With this concept inter-cell as well as intra-cell interference can be reduced significantly. In this thesis we are concerned with the capacity gain, that can be obtained by transforming the reduced interference achievable with smart antennas into expanded capacity by applying advanced *Radio Resource Management* (RRM) methods. Thereby, we focus on F/TDMA based systems like, e.g., GSM.

We start by presenting a detailed review of RRM concepts and techniques in cellular communication systems, to serve as foundation for the development of new "smart antenna aware" RRM concepts. Then an overview of smart antenna beamforming is provided, followed by the discussion of three concepts to transform the reduced interference of directive antennas into capacity gain, namely, sectorization, *Spatial Filtering for Interference Reduction* (SFIR), and *Space Division Multiple Access* (SDMA). Among the three, SDMA has the highest potential to improve capacity, if appropriate RRM approaches are applied. We also provide a discussion of the feasibility of SDMA operation in GSM systems.

In order to assess the capacity of smart antenna systems, detailed simulations are required. For this purpose we present a simulation concept, which incorporates models for the mobile radio channel, smart antenna beam forming, as well as mobility, spatial distribution, and teletraffic of mobile users. Multicellular single-tier and multi-tier environments are considered with hexagonal and irregular cell cite scenarios. Novel channel allocation strategies for fresh calls and handovers are proposed and analyzed by means of extensive system simulations in homogeneous and inhomogeneous traffic and cell site scenarios. All strategies have in common that they utilize smart antennas in order to reuse channels within each cell by means of SDMA. We start with SDMA within each cell and fixed channel-to-cell assignment, which yields considerable capacity gains. We then move on, combining SDMA with *Dynamic Channel Allocation* (DCA), where SDMA and DCA are separated through the consideration of minimal reuse distances, obtaining improved capacity results. The next step is the introduction of complete dynamic channel allocation strategies, which allow for channel reuse even in neighboring cells. Different approaches for the determination of candidate channels and several channel selection strategies are investigated. The higher degree of free-dom, which these strategies bring about, further

increases the capacity. The complete dynamic strategies are then enhanced by introducing preferred channels for each cell, in order to attempt assigning channels according to a reuse pattern, before non-preferred channels are used. This approach yields the highest capacity in comparison to all afore mentioned strategies.

We extend the introduced channel allocation and handover strategies to the case of hierarchical cellular networks with a micro-cell layer and an overlay macro-cell layer. Fast moving users are assigned to the macro-cell layer to diminish the number of handovers while users with relatively low velocities are served by the micro-cell layer to make efficient use of the given resources. Adaptive control algorithms are developed and investigated for the threshold velocity, which determines which cell-layer a mobile user is assigned to, as well as for the channel splitting between both layers.

While the focus of this thesis is on F/TDMA based systems, we derive call blocking probabilities for multi-service smart antenna CDMA systems and present numerical results for the case of two service classes. We show that in case of a limited number of channelization codes, as for instance in the UMTS downlink, the application of smart antennas can shift the capacity from being interference limited to being channel limited. Thus, in order to fully exploit the potential capacity of such systems, code reuse should be applied, which can be done in a similar fashion as in F/TDMA systems. This implicates that the RRM methods investigated for F/TDMA systems have relevance to CDMA systems as well.

We conclude that smart antennas can boost the capacity of cellular systems in combination with advanced RRM approaches, which utilize SDMA and DCA techniques.

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