Algorithms and Proofs of Concept for Massive MIMO Systems

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Abstract
This thesis focuses on algorithms and proofs of concepts in the area of wireless systems operating with a large number of antennas, especially at the base station side.
The first studied topic concerns the design and implementation of massive multiple-input multiple-output (MIMO) testbeds, primarily for communications. This is an entirely new engineering challenge on its own, due to the unprecedented use of a large number of base station antennas together with time division duplex (TDD)-based operation. We consider hardware and system-level aspects of extending current Long Term Evolution (LTE) systems in order to integrate a massive number of antennas at the base station side. We materialize our testbed design into the Lund University massive MIMO (LuMaMi) testbed, and finalize with (measured) proof-of-concept results to validate our design claims.
The second researched topic addresses transceiver calibration to re-establish the reciprocity assumption of a wireless link. This aspect is crucial to be dealt due to the preferred operation mode of massive MIMO, i.e. TDD. To overcome the practical hassles of hardware-based calibration schemes, we propose a convenient over-the-air sounding method between all pairs of base station antennas that allows gathering enough measurements in order to estimate robust calibration coefficients. We provide algorithmic contributions and experimental evidence that corroborate the use of this calibration methodology in practice. This calibration approach is also applied to the case of calibrating the transmitter and receiver chains individually, for classical array beamforming applications.
The topic of detection in block fading (massive) SIMO systems is also addressed. This system setup is very representative to those of many existing systems as of today, e.g., in low power sensor networks. Using an estimation framework learned from our work in transceiver calibration, namely the generalized method of moments (GMM), we study a closed-form estimator that balances complexity and performance nicely.
The last part of the thesis aims to bring together the emerging topic of Deep Learning with fingerprint-based terminal positioning using uplink massive MIMO channels. The key idea is that the intricate structure of raw massive MIMO channels can be learned by deep learning networks and therefore used for positioning purposes. We study the applicability of a particular case of deep learning methods, namely, convolutional neural networks, which are state-of-the-art learning machines in the context of image processing..

Key words: Massive MIMO, Algorithms, Parameter Estimation, Testbeds, Implementation, Generalized Method of Moments, Positioning, Deep Learning

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