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Sphere detection and LDPC decoding algorithms and architectures for wireless systems

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ABSTRACT

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Ever increasing demand for high data rate wireless transmissions with high spectral efficiency leads to utilization of communication systems with multiple transmit and receive antennas. In addition, excellent error-rate performance can be achieved with iterative receiver structure composed of inner detection and outer decoding. In this work we design algorithms and architectures for iterative wireless receivers with multiple antennas that are applied in both downlink and uplink scenarios. It is our goal to develop wireless receivers with implementable hardware cost, excellent error-rate performance while achieving high data rates in the order of 1 Gbps.

Soft sphere detection algorithm with reduced computational complexity based on probabilistically bounded candidate-search process is proposed. The error-rate performance are improved compare to other bounded soft sphere detection schemes for the same hardware cost. Partial candidate-search process called QRD-QLD detection is also developed for fast mobile downlink receivers. It has significantly smaller detection latency than the well-known QRD-M algorithm proposed for several emerging wireless systems. The error-rate performance are equivalent for identical hardware complexity. We apply bounded soft sphere detection in the single-carrier uplink receiver specified for the 3GPP-LTE wireless standard. By applying sphere post-

detection after MMSE-based channel pre-equalization, the interference from multiple users is successfully suppressed with limited increase of computational complexity. Cost-efficient high-speed architecture design of soft sphere detector based on bounded candidate-search has been also implemented.

Outer LDPC decoding is used at the receiver back-end. Different levels of processing parallelism for outer structured semi-parallel LDPC decoders are investigated. We propose estimation methodology that quickly and accurately determines decoder architecture with the best tradeoff between area cost, decoding throughput and error-rate performance. Two decoder architectures with different levels of processing parallelism are implemented. Block-structured LDPC codes are designed for particular inner soft sphere detector and channel environment supporting modular high-speed decoder architectures. Finally, we propose methodology to estimate level of processing parallelism for the physical layer portion of iterative receiver necessary to achieve real-time data-rates of future wireless systems, such as the 1 Gbps downlink transmission.

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Chapter 1

Introduction

Ever increasing demand for high data rate wireless transmissions with high spectral efficiency leads to utilization of communication systems with multiple transmit and receive antennas. Excellent quality of service represented with near-channel capacity error-rate performance can be achieved with iterative receiver structure composed of inner soft detection and outer soft-input soft-output decoding. Emerging wireless standards such as: Wireless Local Area Network (W-LAN), Worldwide Interoperability for Microwave Access (WiMAX), 3^{rd} Generation Partnership Project Long Term Evolution (3GPP-LTE), etc are being constantly revised to provide higher data rates and better error-rate performance. Iterative receivers based on inner soft detection and outer decoding are promising solutions.

In this thesis, we propose to address issues of designing efficient physical layer receiver structure targeting its use in emerging wireless systems, including both downlink and uplink scenarios. It is our goal to develop performance-efficient wireless receiver with implementable hardware cost while achieving data throughputs in the order of hundreds MBits/sec.

1.1 Motivation

Excellent error-rate performance in MIMO environment are made possible by employing sophisticated algorithms such as maximum *a posteriori* (MAP) detection techniques and outer channel decoding that provides error-correction in the presence of multiple access interference, burst channel fading, channel multi-paths, additive receiver noise, etc. An approximation of impractically complex optimal joint detection/decoding is achieved by iteratively improving the *a posteriori* probabilities (APPs) of transmitted coded bits between inner soft detection and outer decoding [1]. Inner detection is typically based on the simplification of exponentially complex maximum-likelihood (ML) approach such as the sphere detection [2].

Bibliography

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