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Adaptive Transmission in MIMO Wireless Systems with Imperfect Channel State Information
不完備信道信息下 MIMO 無線系統中的自適應傳輸技術

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Abstract

Traditionally, adaptive transmission or link adaptation (LA) is a technique which dynamically adjusts the transmission parameters in time, such as modulation size and transmission power, according to the time-varying channel conditions to improve the system performance. Crucial to the LA is the requirement of the channel state information (CSI) at the transmitter (CSIT). However, it is unrealistic to assume perfect CSIT due to channel estimation errors, feedback delay, or quantization errors. The optimal design of LA algorithms with imperfect CSIT for multiple-input multiple-output (MIMO) channel links is challenging because the presence of the additional spatial domain makes either the optimization problems difficult to solve or the resulting algorithms end up with prohibitively large complexity. To bypass the difficulty, most of the existing designs have restricted the adaptation to one domain only, resulting in performance degradation.

The objective of this thesis is to study channel-adaptive techniques for multiple-antenna wireless communication systems with imperfect or partial CSIT to jointly exploit the temporal and spatial dimensions. We consider space-time coded MIMO systems over flat Rayleigh fading channels with beamforming to exploit the CSIT. First, we propose low-complexity spatial power allocation schemes to minimize the bit error rate (BER) for fixed data rate transmission. We take into account the uncertainty in the received signal-to-noise ratio (SNR) by defining a new compressed SNR criterion. Compared to the existing spatial power allocation algorithms, the proposed schemes are more computationally efficient, while not sacrificing the performance.

Next, we propose novel strategies to allocate the transmit power both in the space and time domains to further reduce the BER, based on the proposed low-complexity spatial-only power allocation schemes. The total transmit power is subject to the long term (time) average constraint and varied from symbol to symbol according to the CSIT. The spatial-temporal power adaptation provides exponential diversity gain at moderate SNR when the imperfection in CSIT is small, making it outperform the spatial-only power strategies and the existing methods. The diversity gain asymptotically reduces to polynomial at very high SNR, due to the imperfection of the CSIT. The effects of peak-to-average power ratio (PAPR) on the power adaptation schemes are evaluated. It is shown that the proposed joint power adaptation schemes maintain the superiority over the existing ones at moderate and high PAPR.

Another important function of adaptive transmission is its ability to increase the average spectral efficiency (ASE) while maintaining the BER requirement of the quality of service. For this objective, we propose variable-rate transmission schemes combined with joint spatial-temporal power allocation, where the modulation constellation, the total (temporal) power, the spatial power allocation and the transmit beam patterns are jointly adjusted. Although the variable-rate method integrated with temporal power allocation was well established in single-input single-output (SISO) systems, the design of variable-rate MIMO systems with spatial-temporal power adaptation remains unsolved due to the complication induced by the two-dimensional power adaptation. We solve the problem by introducing a new variable to decouple the original optimization problem into an inner and an outer one. Thanks to this transformation, a closed-form rate adaptation scheme, a closed-form temporal power control policy and a simple spatial power allocation algorithm are obtained. The complexity of the whole algorithm is reduced to one-dimensional root finding for a monotonic function. Compared to the existing methods, the proposed one greatly improves the ASE.

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