School of Electrical, Computer and Energy Engineering

PhD Final Oral Defense
Performance Characterization of Communication Channels through Asymptotic and Partial Ordering Analysis

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Abstract

Asymptotic comparisons of ergodic channel capacity at high and low signal-to-noise ratios (SNRs) are provided for several adaptive transmission schemes over fading channels with general distributions, including optimal power and rate adaptation, rate adaptation only, channel inversion and its variants. Analysis of the high-SNR pre-log constants of the ergodic capacity reveals the existence of constant capacity difference gaps among the schemes with a pre-log constant of 1. Closed-form expressions for these high-SNR capacity difference gaps are derived, which are proportional to the SNR loss between these schemes in dB scale. The largest one of these gaps is found to be between the optimal power and rate adaptation scheme and the channel inversion scheme. Based on these expressions it is shown that the presence of space diversity or multi-user diversity makes channel inversion arbitrarily close to achieving optimal capacity at high SNR with sufficiently large number of antennas or users. A low-SNR analysis also reveals that the presence of fading provably always improves capacity at sufficiently low
SNR, compared to the additive white Gaussian noise (AWGN) case. Numerical results are shown to corroborate our analytical results.

This dissertation derives high-SNR asymptotic average error rates over fading channels by relating them to the outage probability, under mild assumptions. The analysis is based on the Tauberian theorem for Laplace-Stieltjes transforms which is grounded on the notion of regular variation, and applies to a wider range of channel distributions than existing approaches. The theory of regular variation is argued to be the proper mathematical framework for finding sufficient and necessary conditions for outage events to dominate high-SNR error rate performance. It is proved that the diversity order being \( d \) and the cumulative distribution function (CDF) of the channel power gain having variation exponent \( d \) at 0 imply each other, provided that the instantaneous error rate is upper-bounded by an exponential function of the instantaneous SNR. High-SNR asymptotic average error rates are derived for specific instantaneous error rates. Compared to existing approaches in the literature, the asymptotic expressions are related to the channel distribution in a much simpler manner herein, and related with outage more intuitively. The high-SNR asymptotic error rate is also characterized under diversity combining schemes with the channel power gain of each branch having a regularly varying CDF. Numerical results are shown to corroborate our theoretical analysis.

This dissertation studies several problems concerning channel inclusion, which is a partial ordering between discrete memoryless channels (DMCs) proposed by Shannon. Specifically, majorization-based conditions are derived for channel inclusion between certain DMCs. Furthermore, under general conditions, channel equivalence defined through Shannon ordering is shown to be the same as permutation of input and output
symbols. The determination of channel inclusion is considered as a convex optimization problem, and the sparsity of the weights related to the representation of the worse DMC in terms of the better one is revealed when channel inclusion holds between two DMCs. For the exploitation of this sparsity, an effective iterative algorithm is established based on modifying the orthogonal matching pursuit algorithm. The extension of channel inclusion to continuous channels and its application in ordering phase noises are briefly addressed.