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Channel Detection in Coded Communication

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Abstract

We consider the problem of block-coded communication, where in each block, the channel law belongs to one of two disjoint sets. The decoder is aimed to decode only messages that have undergone a channel from one of the sets, and thus has to detect the set which contains the prevailing channel. We begin with the simplified case where each of the sets is a singleton. For any given code, we derive the optimum detection/decoding rule in the sense of the best trade-off among the probabilities of decoding error, false alarm, and misdetection, and also introduce sub-optimal detection/decoding rules which are simpler to implement. Then, various achievable bounds on the error exponents are derived, including the exact single-letter characterization of the random coding exponents for the optimal detector/decoder. We then extend the random coding analysis to general sets of channels, and show that there exists a universal detector/decoder which performs asymptotically as well as the optimal detector/decoder, when tuned to detect a channel from a specific pair of channels. The case of sets of binary symmetric channels is discussed in detail.

Index Terms

Joint detection/decoding, error exponent, false alarm, misdetection, random coding, expurgation, mismatch detection, detection complexity, universal detection.

I. Introduction

Consider communicating over a channel, for which the prevailing channel law $P_{Y|X}$ (X and Y being the channel input and output, respectively) is supposed to belong to a family of channels $\mathcal{W}$. For example, $\mathcal{W}$ could be a singleton $\mathcal{W}=\{W\}$, or some ball centered at W with respect to (w.r.t.) a given metric (say, total variation). This ball represents some uncertainty regarding the channel, which may result, e.g., from estimation errors. The receiver would also like to examine an alternative hypothesis, in which the channel $P_{Y|X}$ is not in $\mathcal{W}$, and belongs to a different set $\mathcal{V}$, disjoint from $\mathcal{W}$. Such a detection procedure will be useful, for example, in the following cases:

1) *Time-varying channels*: In many protocols, communication begins with a channel estimation phase, and later on, at the data transmission phase, the channel characteristics are tracked using adaptive algorithms [1, Chapters