Expected Distortion for Gaussian Source with a Broadcast Transmission Strategy over a Fading Channel

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Abstract

We consider the problem of transmitting a Gaussian source on a slowly fading Gaussian channel, subject to the mean squared error distortion measure. The channel state information is known only at the receiver but not at the transmitter. The source is assumed to be encoded in a successive refinement manner, and then transmitted over the channel using the broadcast strategy. In order to minimize the expected distortion at the receiver, optimal power allocation is essential. We propose an efficient algorithm to compute the optimal solution in linear time $O(M)$, when the total number of possible discrete fading states is $M$. Moreover, we provide a derivation of the optimal power allocation when the fading state is a continuum, using the classical variational method. The proposed algorithm as well as the continuous solution is based on an alternative representation of the capacity region of the Gaussian broadcast channel.

I. INTRODUCTION

Fading channel occurs naturally as a model in wireless communications. For slow fading, the receiver can usually recover the channel state information (CSI) accurately, however the transmitter only knows the probability distribution of CSI, but not the realization. Such uncertainty can cause significant system performance degradation, and the broadcast strategy was used in [1], [2] as an approach to combat this detrimental effect. In this strategy, some information can only be decoded when the fading is less severe, which is superimposed on the information that can be decoded under more severe fading. Thus the receiver can decode the information adaptively according to the realization of the channel state. The similarity to the degraded broadcast channel [3] (see also [4]) is clear in this context, particularly for channels with a finite number of fading states. Generalizing this view, when the fading gain can take continuous values, the receiver can be taken as a continuum of users in a broadcast channel.

The broadcast strategy naturally matches the successive refinement (SR) source coding framework [5]–[7], as the information decodable under the most severe fading is protected the most, and should be used to convey the base layer information in the SR source coding. As more information can be decoded when the channel is subject to less fading, more SR encoded layers can be decoded, and the reconstruction quality improves. In this work, we consider this scheme for a quadratic Gaussian source on a single input single output (SISO) channel. In order to minimize the expected distortion at the receiver, it is essential to find the optimal power allocation in the broadcast strategy, and this is indeed our focus. It is worth noting here that though in [2] the objective function to be maximized is the expected rate, the cross layer design approach of combining SR source coding with broadcast strategy was in fact suggested (though not treated) in that work.

Initial effort on this problem was made by Sesia et al. in [8], where the broadcast strategy coupled with SR source coding was compared with several other schemes. The optimization problem was formulated by discretizing the continuous fading states, and an algorithm was devised when the source coding layers are assumed to have