Two-way Writing on Dirty Paper in the Presence of Noise-dependent Interference

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Abstract—In this paper, we characterize the capacity regions of the Gaussian doubly dirty two-way channel (DD-TWC) in the presence of noise-dependent interference as well as input-dependent interference, and thereby we quantify the impact of such dependencies on the capacity region of the Gaussian DD-TWC. We also show that for the Gaussian DD-TWC with noise/input-dependent interference, adaptation (the use of formerly received signals in encoding process) is useless from a capacity point of view. The above-mentioned claims are proved by obtaining a capacity outer bound in the adaptive mode which is coincided with capacity inner bound derived in the non-adaptive mode.

Keywords—Adaptation; channel capacity; correlated random variables; dirty paper coding; Gaussian two-way channel

I. INTRODUCTION

Because of inherent bidirectional nature of the most channels in today’s wireless communication networks, the two-way channel (TWC), as an important research topic, has increasingly attracted the attention of research community in recent years, both theoretically and practically (e.g., see [1] and references therein). Characterizing the capacity region of TWC is the oldest open problem in multi-user information theory. It seems that as long as the role of adaptation (the use of previously received signals in encoding process) is not well-understood this problem remains open. However, some inner and outer bounds on the capacity region of TWC have been obtained. The first capacity results for the TWC were derived by Shannon [2], who obtained capacity inner and outer bounds for the discrete memoryless TWC which are not tight in general. Han presented a capacity inner bound [3] which surpasses the Shannon’s inner bound in the general case. Moreover, Han by obtaining the capacity region of the memoryless Gaussian TWC showed that (i) for the Gaussian TWC, the Shannon’s inner bound meets the Shannon’s outer bound and hence, gives the capacity region; (ii) adaptation is useless and cannot enlarge the capacity region of the Gaussian TWC.

The study of channels with side information (SI) known to the transmitters and/or receivers is of interest because of the positive effect of knowing such extra information on the interference mitigation and achieving more reliable communication with high information rates. One-way Gaussian channel in the presence of additive Gaussian interference as non-causal side information was studied by Costa in his famous paper named “writing on dirty paper” [4]. Costa, by extending the Gel’fand-Pinsker theorem [5] for the discrete-alphabet case to continuous-alphabet case and introducing dirty paper coding, characterized the capacity of the dirty paper channel equal to the capacity of the interference-free Gaussian channel provided that interference is non-causally known at transmitter. A two-way version of Costa’s problem named as two-way writing on dirty has been studied in [6] where the capacity region of a Gaussian two-way channel with non-causal side information has been determined.

In Costa’s dirty paper coding (and also its two-way version), it is assumed that there is no correlation between channel noise, side information and channel input and in fact they are mutually independent. In some communications scenarios, however, channel input, side information and channel noise may be correlated and therefore, they can be modeled as correlated random variables. A Gaussian channel with correlated random variables has been investigated in [7] where authors considered a Gaussian version of Cover-Chiang theorem [8] and derived the channel capacity in two special cases. In the first case, the channel capacity has been obtained when the side information, which is non-causally known at the receiver, is assumed to be correlated to the channel noise. In the second case, channel capacity has been obtained when the non-causal side information at transmitter is assumed to be correlated to the channel input.

In this paper, by considering a two-way version of [7], we determine the capacity regions of the Gaussian doubly dirty two-way channel (DD-TWC) in the presence of noise-dependent interference as well as in the presence of input-dependent interference, and thereby we quantify the impact of such dependencies on the capacity region of the Gaussian DD-TWC. Particularly, we show that (i) the correlation between channel noises and interference has a positive impact on the capacity region because of giving some information about channel noises to the receivers, (ii) the correlation between channel inputs and interference has a negative effect on the capacity region because of decreasing the input effective power, and (iii) for the Gaussian DD-TWC with noise/input-dependent interference, adaptation is useless from a capacity point of view. Our proof is based on deriving a non-adaptive inner bound and an adaptive outer bound on the capacity region.