RESEARCH ARTICLE

Achievable rate regions for a three-user multiple access channel with partial side information

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ABSTRACT

A generalisation of the Gaussian doubly dirty multiple access channel to a Gaussian triply dirty multiple access channel (GTD-MAC) is considered, where there are three additive interference signals, each one non-causally known to only associated transmitter. Same as in the Gaussian doubly dirty multiple access channel, Costa’s strategy (i.e. random binning scheme) cannot achieve positive rates in the limit of strong interferences. In contrast, it is shown that positive rates independent of the interferences can be achieved by lattice strategies. In fact in some cases—which depend on the noise variance and power constraints—lattice strategies are optimal, in particular, in the high signal-to-noise ratio (SNR) regime. For the GTD-MAC, two models are considered, full side information and partial side information at the transmitters. The results show that partiality in side information reduces the achievable rates as numerical illustrations confirm. Also, the results for the GTD-MAC can be extended to the \( K \)-user case. Copyright © 2013 John Wiley & Sons, Ltd.

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1. INTRODUCTION

Side information channels theory has been an attractive research area since the initiation by Shannon [1] from both information-theoretic and communication aspects. Transmitter and/or receiver might have a side information (SI) named side information at transmitter (SIT) and/or side information at receiver (SIR), respectively. Encoding for a single-user with causal SIT was first studied by Shannon [1]. The capacity of a general discrete memoryless channel with noncausal SIT was characterised by Gel’fand and Pinsker [2]. Costa [3] extended Gel’fand–Pinsker theorem to the special model of Gaussian channel with additive Gaussian interference, and showed that the channel capacity in the presence of interference known at the transmitter is the same as the case without interference. In Costa’s dirty-paper channel (DPC), Gaussian random binning is able to remove the effect of interference known at the transmitter, and thus achieves capacity. Cover and Chiang [4] unified the results for discrete alphabet and memoryless channels and generalised the Gel’fand–Pinsker theorem to two-sided state information channels.

Gueguen-Sayrac [5] derived the capacity of the DPC with partial side information knowledge. The partial side information knowledge models the sensing process approximating the original information. It was shown that the capacity of the DPC with partial SI is reduced compared with the DPC with exact or complete side information.

In the multi-user setting, Das and Narayan [6] determined the capacity region of time-varying multiple access channels (MACs) with various degrees of SIT and SIR. Discrete-time channels with finite input, output, and state alphabets were considered. In [7], a general framework for the capacity region of MACs with causal and noncausal SIs was presented where focused on the MAC with independent side informations at two transmitters. Philosof–Zamir [8, 9], extended Jafar’s work [7] and provided achievable rate regions for the discrete memoryless MAC with correlated side informations known noncausally at the encoders by using a random binning technique. The Gaussian doubly dirty MAC in the high SNR and strong interference regime is considered in [8–15]. By using the Costa Gaussian binning, positive rates are not achieved for Gaussian doubly dirty MAC (GDD-MAC) in the limit of strong interferences and high SNR. In contrast, it is shown that lattice-strategies can achieve positive rates, independent of the interference power. Philosof-Zamir [13, 14] extended their results to the \( K \)-user MAC in the symmetric case.