

Joint Source–Channel Coding via Statistical Mechanics: Thermal Equilibrium Between the Source and the Channel *

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Abstract

We examine the classical joint source–channel coding problem from the viewpoint of statistical physics and demonstrate that in the random coding regime, the posterior probability distribution of the source given the channel output is dominated by source sequences, which exhibit a behavior that is highly parallel to that of thermal equilibrium between two systems of particles that exchange energy, where one system corresponds to the source and the other corresponds to the channel. The thermodynamical entropies of the dual physical problem are analogous to conditional and unconditional Shannon entropies of the source, and so, their balance in thermal equilibrium yields a simple formula for the mutual information between the source and the channel output, that is induced by the typical code in an ensemble of joint source–channel codes under certain conditions. We also demonstrate how our results can be used in applications, like the wiretap channel, and how can it be extended to multiuser scenarios, like that of the multiple access channel.

Index Terms: joint source–channel coding, statistical physics, thermal equilibrium, mutual information, entropy.

1 Introduction

Consider the following two seemingly unrelated problems, which serve as simple special cases of a more general setting we study later in this paper:

The first is an elementary problem in statistical physics: We have two subsystems of particles which are brought into thermal equilibrium with each other as well as with the environment (a

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