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Channels with Cooperation Links that May Be Absent

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***Abstract*—It is well known that cooperation between users in a communication network can lead to significant performance gains. A common assumption in past works is that all the users are aware of the resources available for cooperation, and know exactly to what extent these resources can be used. In this work a family of models is suggested where the cooperation links may or may not be present. Coding schemes are devised that exploit the cooperation links if they are present, and can still operate (although at reduced rates) if cooperation is not possible.**

***Index Terms*—Broadcast channel, conferencing decoders, cooperation, cribbing, multiple access channel.**

I. Introduction

Communication techniques that employ cooperation between users in a network have been an extensive area of research in recent years. The interest in such schemes stems from the potential increase in the network performance. The employment of cooperative schemes require the use of system resources - bandwidth, time slots, energy, etc - that should be allocated for the cooperation to take place. Due to the dynamic nature of modern, wireless ad-hoc communication systems, the availability of these resources is not guaranteed a priori, and the coding schemes are required to work also in the absence of the cooperation links, although possibly achieving lower communication rates.

In this work we study channels with cooperation links that may or may not be present. We focus on two cases - the physically degraded broadcast channel (BC) with conferencing decoders, and the multiple access channel (MAC) with cribbing encoders. The BC with conferencing decoders was first studied by Dabora and Servetto [2], [3], and independently by Liang and Veeravalli [6], [7], who studied also the more general setting of relay-broadcast channels (RBC). In the model of Dabora and Servetto, a two-users BC is considered, where the decoders can exchange information via noiseless communication links of limited capacities $C_{1,2}$ and $C_{2,1}$. When the broadcast channel is physically degraded, information sent from the weaker (degraded) user to the stronger is redundant, and only the capacity of the link from the stronger user to the weaker (say $C_{1,2}$) increases the communication rates. For this case, Dabora and Servetto characterized the capacity region. Their result coincides with the results of Liang and Veeravalli when the relay link of [6] is replaced with a constant rate bit pipe.

The MAC with cribbing encoders was introduced by Willems and Van Der Meulen in [9]. Here there is no dedicated communication link that can be used explicitly for cooperation. Instead, one of the encoders can crib, or listen, to the channel input of the other user. This model describes a situation in which users in a cellular system are located physically close to each other, enabling part of them to listen to the transmission of the others with high reliability - i.e., the channel between the transmitters that are located in close vicinity is almost noiseless. Willems and Van Der Meulen considered in [9] all consistent scenarios of cribbing (strictly causal, causal, non-causal, and symmetric or asymmetric), and characterized the capacity region of these models.

In the next sections, we propose and study extensions of the two models described above, when the cooperation links ($C_{1,2}$ of the physically degraded BC, and the cribbing link of the MAC) may or may not be present. For the MAC models, we first propose achievable rate regions which are based on the combination of superposition coding and block-Markov coding. Here, we consider the unreliable strictly causal, causal, and non-causal cribbing. Then, we propose a general outer bound, which is tight for some interesting special cases where some constraints on the rates of the users are added. For the physically degraded BC, the results are conclusive.

It should be noted that multi-user communication systems with uncertainty in part of the network links have been extensively studied in the literature - see, e.g., [8] and [5], and references therein. The models suggested here, of the BC and MAC with uncertainty in the cooperation links, have not been studied before.

The outline of the rest of the paper is as follows. In Section III, we consider the physically degraded BC with cooperating decoders. In Section IV, we consider the MAC with cribbing encoders,, and in Section V, we provide proofs for all our results.

II. Notation Conventions

We use $H(\cdot)$ to denote the entropy of a discrete random variable (RV), and $I(\cdot;\cdot)$ to denote the mutual information

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