Decentralized Power Adaptation in Ergodic Fading Multiple Access Channels

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***Abstract*—We consider decentralized power control in fading multiple-access channels (MAC). When compared to a centralized MAC, solving the optimal power control for a decentralized system is difficult even for moderate number of users. Good thumb-rules for decentralized power control are available in literature, which are also asymptotically tight in the number of users. In this paper, we first derive a structural property that any optimal decentralized power control scheme must follow, and use this property to suggest a modified power control scheme. Numerical results suggest that the scheme we propose outperforms the existing ones.**

I. Introduction

Multiple-access channels form an important class of communication models where many users try to send information over a common channel to a single receiver. In a mobile or wireless environment, the transmitted symbols are often subjected to time varying attenuations and phase shifts due to fading. Similar to a point-to-point channel, the capacity of a fading multiple-access channel depends on the availability of channel state information (CSI) at transmitters and/or receiver [1]. In this paper, we consider a *decentralized* MAC model [2], where the receiver has access to the CSI of all channels. However, the transmitters have only limited or distributed CSI availability. Such a model was first considered by Shamai and Telatar [3], where each transmitter has access only to its own current fading channel state. The users are allowed to adapt their respective transmit powers to maximize the overall throughput. The utility of interest is the ergodic sum-capacity, where coding over several channel realizations will attempt to compensate the lack of full CSI at the transmitters. More general models for CSI at transmitters (CSIT) were considered in [5], where the ergodic capacity region was formulated as a power control problem. Thus, users need to perform only power control, and the respective transmission-rates are fixed at the chosen operating point in the ergodic capacity-region, which is determined by the channel statistics and average powers.

The ergodic utilities can be contrasted against the delay-limited utilities typically used for slow-fading channels [4]. In particular, when the fading is sufficiently slow and the coding delay is of significance, an interesting utility is the so called adaptive capacity region [2, Chapter 23]. Notice that coding and decoding should be performed within each fading block for achieving the adaptive capacity region. The solution to the complete adaptive capacity region was recently found in [7]. On the other hand, the ergodic schemes considered in this paper can take advantage of the variability in fading, by using long term codes, and thus will achieve superior data-rates.

978-1-4799-6619-6/15/$31.00

Due to the computational difficulty of finding the optimal decentralized power control for even a moderate number of users, Shamai and Telatar [3] proposed a thumb-rule, of allocating a constant power whenever the fading magnitude is beyond a threshold. This scheme is shown to get close to full CSI rates, as the number of users get larger. While the proposed thumb-rule is tailored for Rayleigh fading, it is of significance to identify good power control schemes for general fading models. In particular, design guidelines which will make the optimal power control numerically tractable are highly desirable.

The main contribution of this paper is in proposing a new decentralized power-adaptation scheme for the distributed CSI MAC model of [3]. To this end, we first identify a structural property of any optimal power-allocation scheme for arbitrary fading distributions. Observing that this property is not a part of the existing schemes in literature, we propose a modification to account for this structure. In this process, we improve the ergodic rates of the existing schemes. The improvement is particularly noticeable in the low-power regime with a small number of users in the MAC. The sum-rate derivations and computations are demonstrated for Rayleigh fading, which is not only of practical relevance, but also gives useful insights.

The organization of the paper is as follows. Section II introduces the distributed fading MAC model, along with some definitions and notations. In Section III, we introduce the problem in finding optimal power allocation in distributed CSI MAC, and propose a general structural result on optimal power control. We will then propose a modified power control and evaluate the resulting sum-rates for Rayleigh fading channels. Numerical results are shown in Section IV. Conclusions and future work are presented in Section V.

II. System Model

Consider a discrete time $K-$user fading MAC given by,

$$Y = \sum_{i=1}^{K} H_i X_i + Z$$

where users transmit real-valued signals X_i, $1 \leq i \leq K$, and encounter real-valued multiplicative fades H_i. The noise