Distributed Power and Admission Control for Time-Varying Wireless Networks

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Abstract — **This paper presents new distributed power and admission control algorithms for ad-hoc wireless networks in random channel environments. Previous work in this area has focused on distributed control for ad-hoc networks with fixed channels. We show that the algorithms resulting from such formulations do not accurately capture the dynamics of a time-varying channel. Hence, algorithms designed for fixed channels may perform quite poorly in random channels. In order to address these issues, this work proposes new algorithms, based on stochastic approximation, for optimal distributed power and admission control in random channels.**

I. Introduction

Adaptive control of transmission power in wireless networks allows devices to setup and maintain wireless links with minimum power while satisfying constraints on quality of service (QoS). The benefits of power minimization are not just increased battery life. Effective interference mitigation can also increase overall network capacity by allowing higher frequency reuse.

Typically, power control and interference mitigation techniques are designed for wireless networks with cellular architectures. The benefit of such an architecture is that one can assume a centralized controller has knowledge of the channel states for all users in the system. In this paper we consider a fundamentally different architecture where there is no centralized controller to distribute power control commands or channel information. Hence, the model we consider here is that of an ad-hoc wireless network with purely distributed control (we will clarify the details of this definition in the next section).

Some of the earliest work on decentralized power control for wireless networks was published by Foschini and Miljanic [2] in 1993. Their proposed control algorithm (now well known in the wireless community as simply the Foschini-Miljanic algorithm) provides for distributed on-line power control of ad-hoc networks with user-specific SIR requirements. Furthermore, their algorithm yields the minimum transmitter powers that satisfy the SIR requirements. This seminal work spawned a number of further publications [1, 5, 6] by various authors that extended the original algorithm to account for additional issues. Of particular interest for this paper is the work in [1] that provides a detailed analysis of active link protection and admission control for the underlying Foschini-Miljanic algorithm.

The original algorithm proposed by Foschini and Miljanic (and the extensions cited above) requires that the channel gains between nodes in the ad-hoc network are constants. In some settings this assumption is reasonable as the time scale for adaptation is much faster than the time scale of the channel variability (e.g. stationary users, slowly-varying channels, and so forth). This focus of the work presented in this paper is power adaptation and admission control in an environment where the adaptation and channel variability time scales are similar (e.g. when the network users are mobile).

We consider the same distributed power and admission control problems in [2] and [1], but we permit the links between network nodes to be time-varying stochastic processes. Within this setting we evaluate the performance of the original Foschini-Miljanic algorithm and show that it does not continue to satisfy the minimum power optimality conditions (optimality in this case is in terms of expected transmitter powers). Moreover, we also show that the Foschini-Miljanic algorithm always overshoots its SIR targets in a random channel environment. In order to address these shortcomings we propose a new criteria for power optimality in wireless ad-hoc networks. We then show that a power allocation that satisfies our new optimality criteria can be solved by stochastic approximation. In order to address the admission control problem we propose a modified version of the stochastic approximation algorithm for tracking non-stationary network equilibria (i.e. users entering and leaving the system). In both algorithms, the resulting stochastic approximation iterations yield fully distributed on-line power control algorithms that converge to the optimal power allocation for an ad-hoc network in a random channel environment. Simulation results published in [3] show that the proposed stochastic approximation algorithms provide superior performance over standard power control algorithms, both in terms of power consumption and response time to users entering and leaving the network.

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