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Review Article

Rate management in multiuser detection based MAC design for ad hoc networks

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ABSTRACT

We propose a framework that produces synergy between Medium Access Control (MAC) and physical layers in order to increase the users' individual throughput in a high-capacity CDMA ad hoc network. The MAC layer supports a multiuser detection based access protocol. Users send data packets at different rates, depending on the fading channel state. The framework is based on an LMS (Least Mean Square) prediction algorithm that estimates channel gain at the physical layer. The performance of the scheme is evaluated by simulations. Multiuser detection typically triples the throughput of ad hoc networks but our prediction-based scheme further doubles this metric. The main advantage of the proposed scheme is its flexibility and efficiency in a wide range of data rates and target bit error rates. It is also well fitted to support high-quality multi-media transmissions, and to improve the performance of applications that require high quality of service (QoS).

Contents

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1. Introduction

In recent years multiuser detection technology started to be considered in the research on ad hoc networks. The principal obstacles in the development of this field of research were the implementation issues related to the limitations in the processing power and the memory capacities of the network stations. Today, the systems became more powerful and novel concepts, such as the software-defined radio, removed several obstacles in the implementation. In particular, multiuser detection algorithms can be relatively easily implemented in military ad hoc networks, where the radios can be equipped with sufficiently powerful processors and large memories while energy limitations are less severe.

Adopting multiuser detection at physical layer involves finding solutions for several issues in the MAC protocol design. Multiuser detection based (MUD-based) protocol could be designed to detect one principal user signal and suppress the neighbour signals that constitute the interferences [1]. In this case, the detection algorithm is only used for interference cancellation. Although, the throughput gain of the protocol is confirmed, it is moderate in term of user capacity. Further increase of the users' capacity can be achieved by building protocols based on the simultaneous detection of several neighbour signals. These protocols have been investigated and recent field trial has demonstrated their efficiency [2,3]. Two views are developed in the design of protocols that detects several users simultaneously. The first view leads to the random access MUD-based protocol, described in [4], where users contend for the channels access. Those which win the contention send theirs packets to the receivers. This protocol works asynchronously. The second view leads to the scheduled access MUD-based protocol [5] that schedules the users access to the channel. Based on the selected criterion, the protocol selects the users for transmission and the packets are sent and detected synchronously. This type of protocol needs a relatively complex signalling mechanism and still requires further study to maximize the performance. In particular to work more efficiently the MUD-MAC protocols needs to use information from physical layer and this is the focus of this paper.

Exchanging information between layers has been demonstrated to be an important source of performance gains in ad hoc network [6–9]. Typically named ''cross-layer design'', this methodology is known to cope well with the effects of the wireless channel impairments that can degrade the whole network performance. The goal of our work is to develop a framework for MUD-MAC protocol that includes exchange of information between the physical and MAC layers. The focus is on the scheduled access MUD-based protocol detailed in [5] and objective is to propose a framework that vary the users' data transmission rates to maximise the spectrum usage efficiency while ensuring the users' target bit error rates. Variable bit rates are ensured by adapting the transmissions rates to the fading channel states and target bit error rates are ensured by choosing the detection filters adapted to this error rate. To achieve the objective, we integrate a fading channel predictor to compute the channel variations. We also adopted a software defined radio based physical layer. The architecture for the applied linear multiuser detection is described in [10]. It allows variation of the detection filter structure and ensures different error rates. Moreover, we introduced some modifications in the signalling mechanism of the protocol and its packets structure. Concerning the cross-layer design it is based on exchange, between the physical layer algorithms and the MAC protocol mechanisms; of several parameters including: the pilots for channel prediction, the channel prediction, the user's packet error rate requests, and their transmission rate requests.

The main novelty of this work consist of enhancing the MAC-MUD protocol by its integration with prediction algorithm that estimates channel gain at the physical layer and using it to achieve significant performance gains. The remainder of this paper is organized as follows: In Section 2 we provide the system description that consists of the MAC layer structure and the MUD-based protocol followed by the background of the physical layer. The proposed framework is described in Section 3. In Section 4 the