Network Coding Aware Cooperative MAC Protocol for Wireless Ad Hoc Networks

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Abstract—Cooperative communication, which utilizes neighboring nodes to relay the overhearing information, has been employed as an effective technique to deal with the channel fading and to improve the network performances. Network coding, which combines several packets together for transmission, is very helpful to reduce the redundancy at the network and to increase the overall throughput. Introducing network coding into the cooperative retransmission process, enables the relay node to assist other nodes while serving its own traffic simultaneously. To leverage the benefits brought by both of them, an efficient Medium Access Control (MAC) protocol is needed. In this paper, we propose a novel network coding aware cooperative MAC protocol, namely NCAC-MAC, for wireless ad hoc networks. The design objective of NCAC-MAC is to increase the throughput and reduce the delay. Simulation results reveal that NCAC-MAC can improve the network performance under general circumstances comparing with two benchmarks.

Index Terms—Cooperative communication, network coding, medium access control protocol, relay selection.

1 Introduction

Cooperative Communication (CC) has gained much interest recently as a new design paradigm to make terminals help each other in a distributed fashion so that the diversity gain is achieved via the user cooperation in wireless ad hoc networks. The broadcast nature of the wireless medium (the so-called wireless broadcast advantage) is exploited in cooperative fashion. The wireless transmission between a transmitter-receiver pair can be received and processed at neighboring nodes for performance gain, rather than be considered as the interference traditionally. Several replicas of the same data can be received at the destination node through different independent channels, which results in higher transmission rate, lower transmission delay, more efficient power consumption, or even increased coverage range.

Recently, extensive work on CC has been investigated in physical layer [1], [2], [3], and theoretic fields (including power allocation [18], [19], power saving [20], coverage expansion [21], topology control [22], relay selection and deployment [23], [24], [25], [26]), while less attention has been devoted to the Medium Access Control (MAC) layer. However, without considering the MAC layer interactions due to cooperation, the gain through physical layer cooperation may not improve the performance. Since the communication overhead and collision induced by relaying are generally overlooked in the physical layer protocol design. An efficient and holistic Cooperative MAC (CMAC) protocol is required.

CMAC can generally be categorized into two classes: the proactive CMAC [4], [5], [7], [16], [27] and the reactive C-MAC [6], [28], [29]. The proactive CMAC schemes trigger the relay selection process before the direct transmission. Thus, they introduce a constant overhead to all transmissions whatever the cooperative communication is needed or not. On the other hand, the reactive CMAC schemes select the relay node only when the direct transmission fails. A disadvantage is that all the potential relay nodes have to listen to the transmission of the source node, which consumes additional energy. In this paper, we focus on the reactive CMAC protocol which initializes the cooperative retransmission when the direct transmission fails. Most of the previous researches on reactive CMAC assume that the relay nodes are willing to help the source without pursuing their own interest (delivering their own data or getting rewarded). For majority of the wireless ad hoc network applications, however, the users are selfish and prefer to serve their own traffic prior to others.

In order to enable a relay node to retransmit the data for the source node, while delivering its own data simultaneously, Hybrid Cooperative Network Coding (HCNC) technique is becoming a growing concern in recent years. The key idea of HCNC is to employ the Network Coding (NC) technique [30], [31] into the cooperative transmission process and, gain the advantages of both NC and CC. Besides the related works on HCNC that focus on the information theoretic metrics or physical layer protocols [11], [12], [13], [14], Munari *et al.* proposed a reactive CMAC policy, namely Phoenix [9], based on HCNC. By Phoenix, relay nodes can assist other nodes and serve their own traffics simultaneously during the retransmission processes. In Phoenix [9], the relay node is selected randomly. When the direct transmission fails, the neighboring node sensing free medium at the end of a random backoff time, wins the contention and performs the retransmission on behalf of the source node. Phoenix has the following drawbacks. (i) The coding opportunity is not guaranteed. Whether the randomly selected relay node holds the packets that can be

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