Chapter 5
DMT Optimal Cooperative MAC Protocols in Wireless Mesh Networks with Minimized Signaling Overhead

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ABSTRACT

In this paper, a cooperative protocol is proposed for wireless mesh networks. Two features are implemented: on-demand cooperation and selection of the best relay. First, cooperation is activated by a destination terminal when it fails in decoding the message from a source terminal. Second, a selection of the best relay is performed when cooperation is needed. The robustness of wireless links are increased while the resource consumption is minimized. The selection of the best relay is performed by a splitting algorithm, ensuring a fast selection process, the duration of which is now fully characterized. Only terminals that improve the direct link participate in the relay selection and inefficient cooperation is avoided. The proposed protocol is demonstrated to achieve an optimal diversity-multiplexing trade-off. This study focuses on Nakagami-\(m\) wireless channel models to encompass a variety of fading models in the context of wireless mesh networks.

INTRODUCTION

One of the major properties of wireless mesh networks (WMNs) consists in the possibility of breaking long distances into a series of shorter hops. Apart from increasing the signal quality of the links, the mesh architecture allows the cooperative forwarding of data packets through intermediate terminals in the network. Cooperative communications provide an interesting contribution in this context. More precisely, they enable data transmission between two terminals through an alternate path when the direct wireless link is experiencing a deep fade. Cooperative communications can be envisioned at several network layers. However, implementing the forwarding scheme at the lowest layers renders the protocol more reactive to network conditions and mini-
mizes the transmission delay since each layer adds its own processing time and hence includes its own latency. Cooperative protocols are mainly implemented in two layers: cooperative transmissions are managed at the physical (PHY) layer whereas the set up of the cooperation is done at the medium access control (MAC) layer. At the PHY layer, cooperative communications increase the wireless link reliability. In a cooperative scenario, a source terminal S sends data to a destination terminal D through a direct path. One or several relay terminals help the transmission by receiving the source message and forwarding it to D through a relaying path (Figure 1). Hence the direct path is rendered more robust (Laneman & Wornell, 2000, 2003; Sendorais, Erkip, & Aazhang, 2003; Hunter & Nosratinia, 2006). However, this comes at the price of bandwidth consumption so that the system operates at diminished capacity. One common way to compare cooperative transmission techniques is to compute the diversity-multiplexing tradeoff (DMT) (Zheng & Tse, 2002). The DMT analysis of a transmission scheme yields the diversity gain $d(r)$ achievable for a spatial multiplexing gain $r$. The diversity gain helps in quantifying the robustness of the S-D link and the multiplexing gain gives an hint on the capacity of the link. Both indicators should be maximized in order to get an optimal DMT curve. When $(N - 1)$ relay candidates are involved in a cooperative scenario, the optimal DMT curve $d(r)$ is achievable by protocols that implement both on-demand relaying and a selection of the best relay (Bletsas, Khisti, & Win, 2008; Escrig, 2010): $d(r) = N(1 - r)$ for $0 \leq r \leq 1$. In an on-demand relaying scenario (Laneman, Tse, & Wornell, 2004; Gomez, Alonso-Zarate, Verikoukis, Perez-Neira, & Alonso, 2007), the relay terminal transmits only when D fails in decoding the data transmitted by S. Thus, the bandwidth consumption due to cooperative transmissions is minimized. Moreover, when cooperation is needed, only the best relay terminal retransmits the source message (Bletsas, Khisti, Reed, & Lippman, 2006). This optimizes the robustness of the wireless link between the source terminal and the destination terminal through the property of spatial diversity while minimizing the resource consumption compared to the case of multiple relays. Hence, an optimal tradeoff between link robustness and bandwidth consumption is reached. This optimal tradeoff has been dem-

**Figure 1. Cooperation scenario with three relay candidates:** $(N - 1) = 3$