Chapter 8
Medium Access Control in Cooperative Networks

Most works in the literature on cooperative communications have focused mainly on the physical layer aspects such as coding, modulation, MIMO signal processing techniques etc., as described in the previous chapters. However, in practical systems, there may be multiple users that have the need to access the channel and therefore a proper design of medium access control (MAC) protocols is necessary to fully exploit the diversity advantages in cooperative networks. In this chapter, we discuss how MAC layer protocols can be modified to incorporate cooperation in the physical layer and what are the advantages of cooperation when viewed from a MAC layer perspective. These studies involve the consideration of stochastic packet arrivals, queuing dynamics, and user interactions. We first consider the cooperative slotted ALOHA protocol in Section 8.1 and its enhancements in collision resolution with cooperation in Section 8.2. Then, we discuss in Section 8.3 how simple modifications to IEEE 802.11 legacy systems can be made to support cooperation. In Section 8.4, cooperative transmission is exploited to enhance the efficiency of the distributed Automatic Retransmission reQuest (ARQ). Finally, throughput optimal scheduling policies based on the conventional maximum differential backlog algorithm is described in Section 8.5.

8.1 Cooperation with Slotted ALOHA

To investigate the advantages of cooperation in the MAC layer, let us first focus our studies on the fundamental slotted ALOHA random access protocol [1,3], where each user decides whether or not to transmit in each time slot based only on the outcome of a local coin toss. In such networks, no central controller exists to schedule the users’ transmissions and, thus, it is not immediately obvious that cooperation may be beneficial in these cases due to lack of coordination among users. However, it was shown in [9–11] that the
advantages may in fact be substantial in terms of increasing the achievable stable throughput. We summarize these results in the following.

Consider a wireless slotted ALOHA random access network with $N$ users communicating to a common access point (AP) through independent fading channels as shown in Fig. 8.1. The network consists of multiple cooperative pairs as well as non-cooperative users. We consider the case of pairwise cooperation, where cooperation occurs only between pairs of cooperative users. The system time is slotted with duration equal to the transmission time of a packet. Let $A_k^{\text{tot}}[m]$ be the total number of packets arriving at user $k$ in the $m$-th time slot, which may include an exogenous packet or a packet received from its partner. The packets arriving at user $k$ are stored in its local buffer, which we denote by $\text{buffer}_k$. If $\text{buffer}_k$ is non-empty at the beginning of the time slot, user $k$ will transmit a packet with probability $p_k$. Here, we consider the collision channel with transmission errors, where we define the probability $\psi_{k,D}$ to represent the probability that a transmission made by user $k$ is correctly received by the AP given that no other user is transmitting. If more than one user is transmitting in the same time slot, the users will collide and no packet will go through. The probability $\psi_{k,D}$ is used to model the effect of fading in a wireless system and is referred to as the correct reception probability. At the end of each time slot, the AP will send a $(0, 1, e)$ feedback to all users, where $0$ indicates that the slot was idle, $1$ indicates that the transmission was successful, and $e$ indicates that a transmission failed, due to either fading or collision. We assume that the feedback is always received correctly by the users.

Let us first consider a basic cooperation scheme based on simple decode-and-forward (DF) relaying. Specifically, we assume that if the transmission of cooperative user $k$ to the AP fails but is successfully overheard by its