5 Cross-Layer Architecture

5.1 Introduction

In the previous chapters, spectrum management methods were discussed which enhance the performance of wireless LANs based on the dynamic selection of transmit frequencies, transmit power and physical bit rate. These methods are applicable to optimise the coexistence between neighbouring networks. However, also in case of a single network with an access point which serves a number of stations, optimisations are possible.

A prerequisite which is assumed for the further investigations in this chapter is that the access point has full control of the channel access. It allocates airtime to the different mobile stations inside its range. In case of the uplink, this is done by sending polling packets which request a mobile station to transmit any data which might be available. As long as no poll packets are sent, the mobile stations are not allowed to transmit as it was described in chapter 2; during this time, the access point can send packets in the downlink direction.

Another feature of the resource allocation method discussed in this chapter is the cross-layer architecture: Legacy protocol stacks strictly separate the different layers inside the protocol stack, as proposed by the OSI reference model. There is no communication between the layers to exchange control information; only the user payload is transferred between the layers through the Service Access Points (SAPs), cf. section 2.1. The transmission of packets can be optimised by lifting this separation; a cooperation between the layers can increase the performance. The cross-layer approach allows requirements of the application layer to be considered in the MAC scheduling. Moreover, information about PHY layer capabilities for a certain user and the transmission channel are provided which can be used in the application layer to adapt accordingly. The exchange of MAC and PHY layer information can significantly increase system and user performance. If, for example, information is exchanged about the importance of packets belonging to different flows and about the channel conditions, the order of transmission can be determined as a compromise between the packet priority and the channel capacity. The physical access can be enhanced in several steps, starting with the legacy single-antenna transmission which is extended to a MIMO transmission combined with SDMA and OFDMA. The PHY scheduler considers both the Quality-of-Service (QoS) requirements of the MAC layer and the availability of resources on the PHY.
layer (space, time, frequency), assigning the PHY resources to the users on a per-packet basis.

The separation of the layers is in particular problematic for the design of the two lowest layers, which is the MAC and the PHY layer, because there are close mutual dependencies between these two layers. QoS requirements do not only have to be considered when selecting a certain data flow on the MAC layer, but also on the physical layer when ordering the packets according to their transmission priority. The PHY layer has to combine this ordering policy with information about the current channel state when taking the decision in which order a number of packets should be transmitted. A cross-layer approach between these two layers is also relatively easy to implement because the MAC and the PHY layer are usually implemented inside the same hardware device, so that the effort for signalling between the two layers is low. If signalling is needed between different hardware devices to transfer cross-layer related control information, suitable protocols have to be designed which allow to exchange this cross-layer information between the devices.

In this chapter, first the concept of the cross-layer scheduler is introduced which has been developed in the framework of this work. After that, different scheduling strategies for the MAC layer are discussed, including the introduction of a novel quality-of-service aware scheduling mechanism. The operation of the cross-layer scheduler is considered first with a sequential transmission of packets by TDMA which is then extended to parallelised transmission based on OFDMA and SDMA.

5.2 Two-Stage Cross-Layer Scheduler

In legacy WLAN protocol stacks, the packets for different data flows are scheduled only on the MAC layer. An example for this method is the IEEE 802.11e standard which defines eight traffic classes. The service of these data streams can be controlled in a decentralised manner using the Enhanced Distributed Coordination Function (EDCF) or in a centralised manner using the Hybrid Coordination Function (HCF). Due to the centralised approach of the HCF, it is possible to start transmissions exactly at specified times and serve different flows with specified service rates. However, the HCF does not consider the state of the physical transmission channel when sending a packet. If the channel is bad for a certain user at the time when a packet is transmitted, that packet may be lost.

These problems can be tackled if the physical channel capacity is considered for the packet transmission. The channel capacity is included into the scheduling by adding a second scheduling stage to the existing MAC scheduler. While the MAC scheduler is located in the MAC layer and does not have knowledge about