Enhancing the IEEE 802.11e EDCA to Provide QoS Guarantees

Ali Hamidian and Ulf Körner
Department of Communication Systems, Lund University
E-mail: {*alex.hamidian, ulf.korner*}*@telecom.lth.se*

Extended Abstract

As a consequence of the increased popularity of *wireless local area networks* (WLANs) based on IEEE 802.11, the interest for ad hoc networks has also increased. An ad hoc network is an autonomous wireless network that can be formed without the need of any infrastructure or centralized administration. It is composed of stations that communicate with each other through single-hop or multi-hop paths in a peer-to-peer fashion.

One of the challenges that must be overcome to realize the practical benefits of ad hoc networks is *quality of service* (QoS). In order to support applications with QoS requirements, the upcoming IEEE 802.11e standard enhances the original IEEE 802.11 MAC sublayer by introducing the *hybrid coordination function* (HCF), which includes two medium access methods: *enhanced distributed channel access* (EDCA) and *HCF controlled channel access* (HCCA). The EDCA is distributed and can be used in ad hoc networks while the HCCA is centralized and manages access to the medium using a *QoS access point* (QAP), making it unsuitable for infrastructure-independent networks.

Two new features introduced in the HCF are the concepts of *access category* (AC) and *transmission opportunity* (TXOP). Each station using the EDCA, has four ACs and for each AC there is one transmit queue with an independent EDCA function that contends for access to the medium. The four ACs have different priorities and are used for different kind of traffic: background (AC_BK), best effort (AC_BE), video (AC_VI) and voice (AC_VO). A TXOP is a bounded time interval, defined by a starting time and a maximum duration, during which a station may transmit multiple frames.

Although the distributed EDCA is an important enhancement to the original 802.11, it is not enough to provide QoS guarantees due to its non-deterministic nature where stations must contend for access to the medium using a random backoff time. Moreover, the EDCA does not have any distributed admission control algorithm. Therefore, we are working on an enhancement to the EDCA, such that it can be used to provide, not only service differentiation, but also QoS guarantees. In our solution, a station (henceforth referred to as sender) with high-priority traffic can reserve TXOPs by requesting admission for its traffic stream. The request is not sent to any central station such as a QAP, but is handled internally within the sender. The sender either admits or rejects the traffic stream according to an admission control algorithm. If the traffic stream is rejected, the sender can try to lower its QoS demands and retry. Otherwise, if the traffic stream is admitted, the sender schedules its traffic by setting the *service start time* (SST) and the *scheduled service interval* (SI) parameters. The SST defines the start of the first reserved TXOP while the SI defines the interval between TXOPs

and is the same for all stations. Hence, during a service interval, traffic streams that have reserved TXOPs use the first part as a contention-free period and low-priority streams use the second part as a contention period. To increase the performance of the protocol and decrease the time it takes for the sender to reserve TXOPs, an AC (called AC_MA) has been added that is used only by management frames such as *add traffic stream* (ADDTS) requests and ADDTS responses. AC_MA has been given the same high priority as AC_VO (which has the highest priority) except that during a TXOP, no more than one single frame can be sent from AC_MA as opposed to AC_VO that can transmit several frames.

Once the traffic stream has been scheduled, the sender broadcasts an ADDTS request including a *traffic specification* (TSPEC) containing information such as mean data rate, nominal frame size, SST and SI. All stations that receive the ADDTS request store the information of the sender's SST and SI and schedule the new traffic stream exactly as the sender. This ensures that no station starts a transmission that cannot finish before a reserved TXOP starts and thus collision-free access to the medium is guaranteed for the streams with reserved TXOPs. All neighbors have to unicast an ADDTS response back to the sender. This is to make sure that the neighbors agree on the schedule and to keep the schedules synchronized. Every time the sender receives an ADDTS response from a neighbor, it stores the address of the neighbor. After receiving a response from all neighbors, the sender waits until the SST specified in the TSPEC and initiates a transmission. If the time instant when all responses are received occurs later than the advertised SST, the transmission is initiated at the subsequent TXOP instead. Once the TXOP is finished, the station waits until the next TXOP, which occurs after an SI. If a transmission failure occurs during a TXOP, the station does not start a backoff procedure as in the original 802.11 MAC. Instead, the transmission is resumed if there is enough time left in the TXOP to complete the transmission.

One advantage with our MAC scheme is that it regulates the medium access with a distributed admission control algorithm. Moreover, there is a resource reservation mechanism allowing the stations wishing to send traffic with strict QoS requirements to reserve TXOPs for collision-free access to the medium. These TXOPs are scheduled by a distributed scheduler, ensuring that no station starts a transmission that cannot finish before a reserved TXOP starts. Finally, our solution is based on existing commonly used protocols, and thus a credible candidate for providing QoS guarantees in WLANs operating in ad hoc mode.

Our scheme has been implemented in the popular and widely used simulation tool *network simulator 2* (ns-2) and compared to the EDCA by means of simulation. Since the default 802.11 implementation in ns-2 is rather simple, we used another more advanced and accurate 802.11 implementation, which also implements 802.11a/b/g and some features of 802.11e. This code was then modified and extended according to our solution described above. We have seen that our scheme performs much better than the EDCA in heavily loaded networks; i.e. our scheme is able to guarantee constant throughput, delay and jitter to multimedia applications with QoS requirements.

In the future, our aim is to further evaluate and improve the scheme. Thus, we plan to add support for e.g. dynamic resource reservation, retransmitting lost ADDTS requests, removing and rescheduling reserved TXOPs for traffic streams that have completed their transmission and handling stations that move in to and out from the network. Finally, it is our goal to develop the implementation further such that it can be used in a multi-hop ad hoc network and reserve resources along a multi-hop route, perhaps with the aid of a QoS-aware ad hoc routing protocol.