

Chapter 4

A Weakly Synchronous and Distributed Coordination Function for QoS Management in CSMA/CA Wireless Access Networks

Andrea Vesco

Istituto Superiore Mario Boella, Italy

Riccardo Scopigno

Istituto Superiore Mario Boella, Italy

ABSTRACT

This chapter presents a novel weakly synchronous and distributed coordination function, called Time-Division Unbalanced Carrier Sense Multiple Access (TD-uCSMA). TD-uCSMA relies on synchronization among nodes and the contextual switching of channel access parameters to enable resource management and Quality of Service (QoS) provisioning over CSMA/CA wireless access networks. The TD-uCSMA operating principles and issue of synchronization are presented in detail.

Moreover a signalling architecture is here designed, for the first time, to enable dynamic and distributed resource reservation over the wireless network by means of two protocols: the Resource Reservation Protocols with Traffic Engineering (RSVP-TE), properly extended to work in TD-uCSMA networks and the new Resource State Management Protocol (RSMP). The TD-uCSMA operating principles and the signalling architecture are then validated by simulation over many scenarios comprising multi-hop wireless access networks. Finally the chapter addresses the issue of prototyping TD-uCSMA by open source IEEE 802.11 legacy drivers.

DOI: 10.4018/978-1-4666-1797-1.ch004

INTRODUCTION AND MOTIVATION

The use of wireless technologies for broadband access networks is relatively new and raises new challenges. The benefits of wireless solutions in the access tier are clear but leave several open issues, mainly concerning the capability of supporting a wide range of applications, in a flexible and scalable fashion. This indeed requires a solution that combines resource management capabilities and Quality of Service (QoS) provisioning.

Several solutions exist for the arbitration of channel access in wireless networks, spanning from OFDMA to CDMA, CSMA/CA or TDMA. Each of them brings its own benefits, such as QoS, scalability and distributed coordination.

The CSMA/CA-based solutions are becoming more and more popular thanks to their low cost and their ability to work without any central coordination. Basically this is the reason why CSMA/CA has been adopted also in Wireless Mesh Networks (IEEE 802.11s) (IEEE, 2011) and in Vehicular Ad-hoc Networks (IEEE 802.11p) (IEEE, 2010). The main point of strength in CSMA/CA is that the decision process is distributed among all the nodes consequently, each node determines individually when to access the channel, relying on the principle of random access. Thus the solution is indeed scalable, distributed and easy to implement, therefore it represents a likely candidate for a widespread and ubiquitous broadband wireless access. Unfortunately, CSMA/CA suffers from performance degradation to sub-optimal access decisions, hence to a higher number of collisions. As a result it performs poorly when strict QoS is required. Moreover, CSMA/CA performances get even worse in multi-hop scenarios because (i) node density increases access delay and reduces the overall throughput (ii) queuing and access delay at each hop additively contributes to the end-to-end delay and (iii) the number of possible hidden terminals and hidden collisions grows as well.

In order to support the increasing demand for QoS the IEEE 802.11e (now in IEEE 802.11

standard) was proposed. The standard introduces the *Hybrid Coordination Function* (HCF) and two channel access mechanisms are managed under the same HCF umbrella: the *HCF Controlled Channel Access* (HCCA) and the *Enhanced Distributed Channel Access* (EDCA).

The EDCA coordinates channel access in a distributed fashion and provides a flexible and scalable solution for differentiated QoS provisioning. It introduces the access class (AC) concept to classify and differentiate traffic whereas it differentiates service by prioritizing channel access using AC-specific EDCA parameters. Several works assess the EDCA performances (Mangold et al., 2003) and propose further optimizations (Zhu et al., 2004; Romdhani et al., 2003; Pries et al., 2008) to minimize contention delays and collision rates, hence improving throughput and delays. Other works study the issue of tuning the EDCA parameters (Casetti et al., 2004) to provide good service differentiation in specific traffic scenarios.

However this solution provides statistical service guarantees and it is not clear yet how to manage EDCA parameters to implement scalable resource management.

The HCCA offers a deterministic, TDMA-based channel access, which is centrally arbitrated by the hybrid controller (HC). The HC manages reservation requests and coherently splits time into a *contention-free period* (CFP) and a *contention period* (CP). Any node, willing to transmit in a CFP, has to negotiate with the HC channel access during a negotiation EDCA-based phase. The HC offers transmission opportunities (TXOPs) in response, if enough resources are available to meet QoS requirements. Thus HCCA avoids collisions that can lead to breaking established QoS and degradation of the overall performances and allows the HC to implement bandwidth reservation policies enabling parameterized QoS provisioning. However the need for a centralized HC potentially increases the complexity of the solution, it faces

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