Achieving Fairness in Carrier Sense Multiple Access with Enhanced Collision Avoidance

Luis Sanabria-Russo, Jaume Barcelo, Boris Bellalta

Universitat Pompeu Fabra, Barcelona, Spain
{luis.sanabria, jaume.barcelo, boris.bellalta}@upf.edu

***Abstract*—It is possible to achieve a collision-free state implementing Carrier Sense Multiple Access with Enhanced Collision Avoidance (CSMA/ECA). It differs from CSMA/CA only in choosing a deterministic (instead of random) backoff after successful transmissions. On this work are exposed the fairness issues regarding CSMA/ECA and how they are leveraged by adjusting the number of packets transmitted on each opportunity. Results show a tottaly distributed, collision-free and fair protocol capable of achieving higher levels of throughput than those of the conventional CSMA/CA.**

***Index Terms*—Wireless, MAC, Collision-free, CSMA/ECA.**

I. Introduction

IEEE 802.11 networks use a shared and limited medium to establish communication among nodes. Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is the protocol in charge of coordinating access to the wireless medium in order to avoid simultaneous transmissions by different nodes. If two or more nodes (or *contenders* for the medium η) attempt transmission at the same time, a *collision* accurs and the resulting transmission is disregarded by receivers.

Time under CSMA/CA is slotted, that means that it is discrete and furthermore, it is divided in three slot types: *empty*, *successful* and *collision*; accounting for no transmission, successful transmission or collision respectively.

Each contender attempting to transmit a packet generates a random *backoff* counter $bo_r \in [0, \dots, CW_{min} - 1]$, where CW_{min} is referred to as the minimum *contention window* with a typical value of 32. Each passing empty slot decrements bo_r by one; when the backoff counter reaches zero the contender will attempt a transmission. The success of the transmission attempt is only confirmed by the reception of an *acknowledgement* (ack) from the receiver, otherwise a collision is assumed. If that were the case, each contender involved in the collision doubles its contention window $CW = 2^m CW_{min}, m \in [0, \dots, 5]$ incrementing the *backoff stage* (m) by one and generating another random backoff counter, bo_r.

Carrier Sense Multiple Access with Enhanced Collision Avoidance (CSMA/ECA) achieves less collisions and outperforms CSMA/CA in most typical scenarios. The only difference with CSMA/CA is that a deterministic backoff $bo_d = C$ is chosen after each successful transmission. C is defined in Eq. 1 as the *system capacity* and represents the maximum number of host (η) participating in the contend for transmission able to achieve a collision-free state. In Eq. 1, $\lceil \cdot \rceil$ is the ceiling operator, $E[\cdot]$ is the expectation operator, $\mathcal{U}$ is the uniform distribution and CW is the contention window.

$$C = \lceil E[\mathcal{U}[0, CW - 1]] \rceil \tag{1}$$

In a scenario where $\eta \le C$, eventually all contenders will be able to pick a different transmission slot, therefore achieving a collision-free state.

When the system is overcrowded, $\eta > C$, CSMA/ECA suffers a decrease in throughput as appreciated in Figure 1. This effect is caused by collisions originated by $\eta - C$ contenders forced to generate a random backoff counter and attempting transmission on slots previously picked by C nodes using a deterministic backoff.

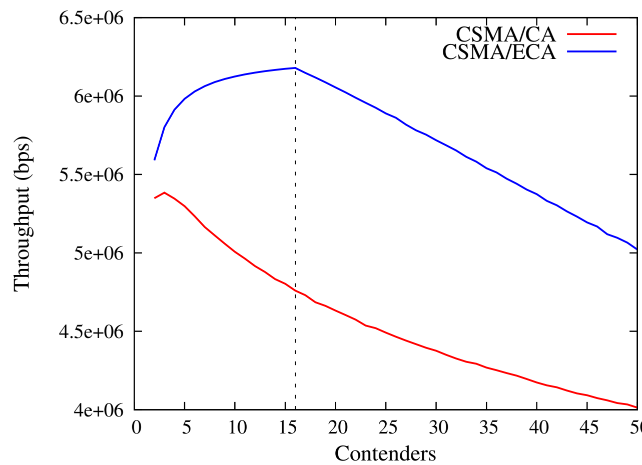

Fig. 1. Throughput and how it is affected when $\eta > C$

In Figure 1, when $\eta > C$ the CSMA/ECA system is overcrowded with contenders and the collision-free state is compromised. As more contenders are introduced, the system behavior tends to be more like CSMA/CA: nodes are forced to choose a random backoff.

In this work, a fully-distributed version of CSMA/ECA is presented and the throughput issue when $\eta > C$ is assessed.

II. A decentralized and fair CSMA/ECA

There are numerous reasons why CSMA/ECA is more useful when modeled as a decentralized protocol. One being the removal of the Access Point (AP) as a single point of failure. Also, AP Beacons are no longer used as a control measure to estimate the number of contenders in the network, which in turn reduces the overall convergence time.

If $\eta > C$ and under saturation (all contenders have something to transmit, all the time), $\eta - C$ contenders are forced to choose a random backoff, given that there are no unpicked slots available for transmission. This in turn provokes collisions on the C remaining nodes that picked a slot using a deterministic backoff [1].

CSMA/E2CA manages this issue forcing the nodes to *stick* to a deterministic backoff. That is, the contenders will choose a deterministic backoff two times after a successful transmission. If two consecutive collisions occur, then the contender will be forced to double its contention window (by incrementing the backoff stage, m in Eq. 2) and to pick a random backoff. This results in a faster convergence to a collision-free state, but at the same time reduces the fairness of the protocol given that some contenders may have to wait more than others to access the channel.

$$W = 2^m CW_{min}, \; m \in [0, ..., 5] \tag{2}$$

A. Ensuring fairness

Under CSMA/E2CA, nodes may have different contention windows (W in Eq. 2), this means that some arbitrary contenders have to wait more than others in order to access the channel; compromising the fairness of the protocol. To leverage this issue, nodes are set to transmit 2^m packets every time their backoff counter expires. That is, if a contender doubled its contention window, then it will also double the packets that are going to be transmitted on the next opportunity. This fairness mechanism for CSMA/E2CA is called Fair Share from here on.

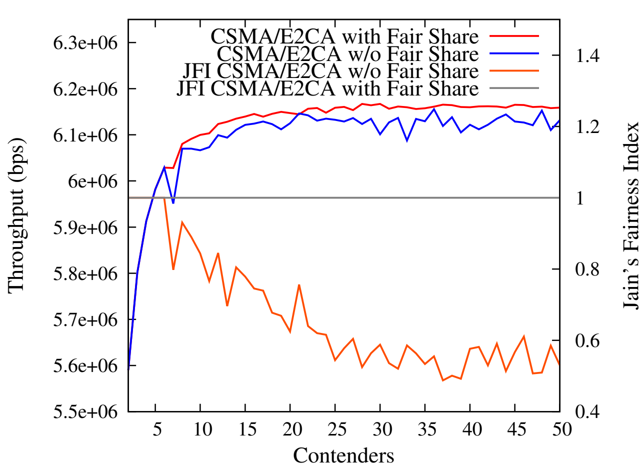

Fig. 2. Throughput and Jain's Fairness Index when implementing Fair Share in CSMA/E2CA

In Figure 2 it is appreciated through the estimation of the Jain's Fairness Index [2] that by implementing Fair Share every contender receives almost the same service time, therefore the system is considered fair.

III. Conclusions

Test

References

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[2] R. Jain, D. Chiu, and W. Hawe, *A Quantitative Measure of Fairness and Discrimination for Resource Allocation in Shared Computer System.* Eastern Research Laboratory, Digital Equipment Corporation, 1984.