# Fairness in Collision-free WLANs

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***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 in choosing a deterministic (instead of random) backoff after successful transmissions. Also in CSMA/ECA, contenders keep the increased length of the contention window even after a successful transmission, what results in an uneven distribution of the channel access time. This fairness issue is assessed in this work by adjusting the number of packets each contender is allowed to transmit on each opportunity. Results show a totally 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 $\eta$) 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 chooses a uniformly 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 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 choosing another uniformly random backoff counter, $bo_r$. If the transmission was successful, the sender resets its contention window to the minimum value ($CW = CW_{min}$) and chooses another $bo_r$.

Carrier Sense Multiple Access with Enhanced Collision Avoidance (CSMA/ECA) achieves less collisions and outperforms CSMA/CA in most typical scenarios [1]. 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 ($\eta$) 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 $\eta \leq C$, eventually all contenders will be able to pick different transmission slots, 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.

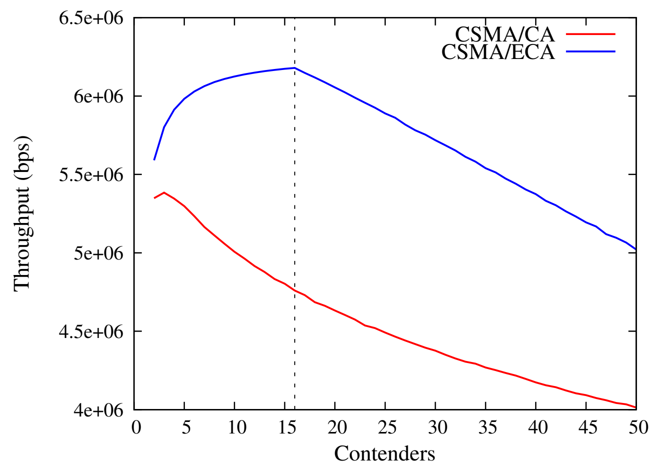


Fig. 1. Throughput and how it is affected when $\eta > C$

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

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 of the protocol.

In an overcrowded CSMA/ECA ($\eta > C$), colliding nodes will double $CW$ each time and reset it ($CW = CW_{min}$) upon each transmission success, augmenting the collision probability. This behavior accounts for the throughput reduction in Figure 1.

In order to leverage this issue, CSMA/ECA forces nodes to *stick* to its backoff stage (or *stage stickiness* from here on), $m$. That is, $CW$ is no longer reset after a successful transmission; resulting in a greater system capacity because of the larger $CW$. This leads to a collision-free state while $\eta \leq C_m$, where $C_m$ accounts for $C$ in Eq. 1 computed with a $CW$ in a backoff stage $m$.

Having a greater system capacity ($C_m > C$) means that more nodes are able to achieve a collision-free state. Nevertheless, in a $\eta \leq C_m$ scenario, contenders may have different deterministic backoff counters ($bo_d$) which provoke some nodes to access the channel more often than others. This fairness issue is averted with *fair share*.

This mechanism consist on allowing each contender to send $2^m$ packets every time its backoff expires ($bo_d = 0$), making sure that contenders with longer backoff are compensated proportionally.

Figure 2, depicts how CSMA/ECA with stage stickiness and fair share achieves greater throughput than CSMA/CA, maintaining a collision-free state and being fair (Jain's Fairness Index [2] (JFI) equals 1) for any number of contenders.

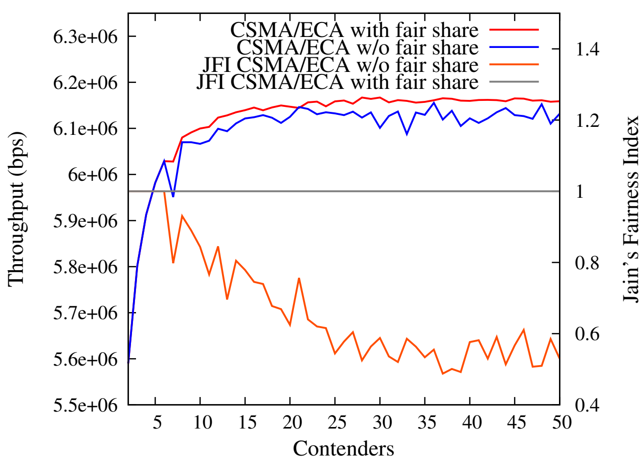


Fig. 2. Throughput and Jain's Fairness Index when implementing fair share in CSMA/ECA

The concept of stage stickiness and fair share, was first introduced by Fang et al. in [3]. This work evaluates the performance of CSMA/ECA when implementing the concepts in a customized C++ simulator.

### *Evaluation*

CSMA/ECA preserves backward compatibility with CSMA/CA (details in [1]), which is paramount for the coexistence and progressive adoption of the protocol. Many other performance evaluations, like a semi-analytical framework modeling the enhanced collision avoidance mechanism and comparing it with other access schemes (like Basic Access and RTS/CTS), are provided in [4].

Implementation is performed on a customized version of the COST [5] simulator. The system was set to be under saturation (nodes always have packets to transmit) during a period of a hundred thousand seconds at a maximum throughput of 11Mbps. The number of contenders ranges from 2 to 50. Further MAC-related parameters can be found under *stats/stats.h* in [6]; as well as the code for the whole CSMA/ECA implementation.

Figure 1 and Figure 2 are results derived from the evaluation platform.

## III. Future Directions

Test

## References


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