# Collision-Free WLANs: From Concepts to Working Protocols. A PhD. Proposal

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**Abstract.** In the upcoming years the number of devices that exchange data wirelessly is though to increase dramatically, even nowadays home environments no longer lack the wireless network congestion only seen before at office/public spaces (like wireless hot-spots). The current Medium Access Control (MAC) protocol is known to be prone to collisions, which increase with the number of stations in the wireless network. Many proposals have been made to amend the current standard, but at the time of this writing the drawbacks related to collisions have not been fixed. One of the reasons why implementing new MAC protocols is a challenging task relates to the need for really fast processing speed (which can only be achieved at hardware level) and the need for more realistic channel conditions and traffic scenarios.
This PhD Thesis Proposal aims at designing and prototyping next-generation MAC protocols for IEEE 802.11-like networks, going from concept proposals to hardware implementation.

## 1 Introduction

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is the protocol used in Wireless Local Area Networks (WLANs) to coordinate transmissions. Nodes should avoid simultaneous transmissions because the medium is shared, so concurrent transmissions attempts will result in indecipherable messages to the receivers. This event is referred to as a *collision*.

For CSMA/CA, time is slotted. As a result, there are three kind of slots: *empty*, *successful* and *colllision* slots, where successful and collision slots contain successful transmissions or collision events. While the remaining are just tiny empty slots of a fixed time length.

Every time there is a contend for transmission, CSMA/CA forces contenders to count down from a randomly generated number (from now on referred to as backoff counter), decrementing it by one per every passing empty slot. When the backoff expires (reaches zero), contenders will attempt transmission. Nevertheless, because the backoff counter is generated at random, there might be cases where two or more contenders simultaneously attempt transmission and a collision occurs, significantly degrading the throughput of the system as more nodes join the contend for the medium.

It is possible to obtain greater levels of throughput than the achieved by CSMA/CA under optimal parameter configuration by picking a deterministic backoff counter after successful transmissions. This approach is called Carrier Sense Multiple Access with Enhanced Collision Avoidance (CSMA/ECA) [1]. Results also show that by making simple modifications on the behavior of the current protocol, CSMA/ECA is able to allocate more contenders in a collision-free fashion while preserving the system fairness by equally distributing the system throughput among all nodes.

Many years of testing have settled CSMA/CA as the default protocol for this type of networks, even-though many other proposals claim to outperform it [1–4]. Nevertheless, their proposed adjustments tested by simulation are not included in the current standard.

Recent approaches to design and implement MAC protocols on cheap commodity hardware [5, 6] opened the possibility to construct more realistic scenarios. Although at an early phase and steep learning curve, this alternative allows researchers of all levels to make substantial contributions.

### 1.1 Motivation

As mentioned before, many and more proposals to amend the collision problem in CSMA/CA have been made and none is included in the current standard.

Taking a guess-look at what is to come in a few years time, WLANs are expected to be as crowded as never before. From tablets, laptops, smart phones, watches, smart health/activity monitoring devices; to traffic prioritization, accommodating these many devices and services will soon out-challenge CSMA/CA.

Even-though CSMA/CA in theory is able to coordinate medium access for many contenders, it does so at the price of a reduced throughput induced by collisions. This is completely leveraged by CSMA/ECA, which in fact provides greater throughput than CSMA/CA in almost every testable scenario.

The goal of this PhD Thesis is twofold: 1) further analyze CSMA/ECA behavior considering unsaturated scenarios, and 2) to write the protocol into cheap commodity Wireless Network Interface Cards (WNICs) using the principles proposed in [5]. The expected results from this work will provide a complete overview of CSMA/ECA and sufficient documentation to make an amendment proposal to CSMA/CA.

## 2 State of the Art

For the following paragraphs, an overview of the state of the art is presented. Ranging from the current standard passing through other proposed protocols to end at the description of CSMA/ECA and the Wireless MAC Processor architecture [5].

It is worthwhile to note that the words *node*, *contenders* and *stations* my be used interchangeably without any different implication.

### 2.1 CSMA/CA: the current standard

Each node in a WLANs runs an instance of CSMA/CA protocol. As briefly mentioned in Section 1, in this time-slotted networks nodes draw a random backoff counter $B \in [0, CW(k)]$ everytime they have a packet to transmit; where $CW(k) = 2^k CW_{\min}$ is the contention window at backoff stage $k \in [0, m]$ with $m$ its maximum value, and $CW_{\min}$ being the minimum contention window.

Every passing empty slot decrements the backoff counter in one, and freezes when another node's transmission is detected. When the backoff expires ($B = 0$), the contending node attempts transmission.

Because the backoff is computed at random, it is possible that two or more nodes pick the same value. When the corresponding stations attempt transmission, none will receive an *ACKnowledgement* (ACK) from the receiver given that they attempted transmission at the same time. This is considered a collision.

The way CSMA/CA handles collisions is summarized in the following bullets:

- A collision is assumed if no ACK is received by the transmitter.
- CSMA/CA instructs colliding nodes to double their contention window by increasing the backoff stage $k$ in one. This measure doubles the range of possible values drawn when computing the backoff counter, thus reducing the probability of two stations picking the same value.

If a node successfully transmits (receive an ACK from the receiver):

- Resets its backoff stage ($k = 0$).
- If it has another packet to transmit, the node generates a backoff counter and the process is restarted.

CSMA/CA uses a Binary Exponential Backoff (BEB) technique in order to reduce the collision probability (or the event of two stations picking the same backoff counter). Nevertheless, this technique does not eliminate collisions, in fact, stations that have successfully transmitted in the past may collide in the future. Figure 1 provides and example of CSMA/CA's behavior.

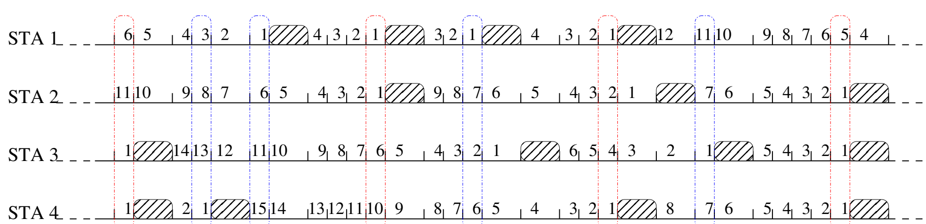


**Fig. 1.** For stations running CSMA/CA ($CW_{\min} = 16$)

### 2.2 Going beyond CSMA/CA's throughput

There have been many works proposing modifications to CSMA/CA [1–4, 7–13]. Nevertheless, and as pointed out in [14], there is a group among them that considers backwards compatibility with legacy users and at the same time provides levels of throughput beyond the provided by CSMA/CA.

The increase in throughput is the result of choosing a deterministic backoff counter instead of a random one. This approach was first introduced in [11] and then tested under different conditions such as saturated and unsaturated scenarios [1–4]. It is called Carrier Sense Multiple Access with Enhanced Collision Avoidance (CSMA/ECA) and its similarities and differences with CSMA/CA are described in the following.

CSMA/ECA is a collision-free MAC protocol that allows many contenders to coordinate access to the medium in a totally distributed manner. It starts from the simple idea of picking a deterministic backoff counter $B_d = CW(k)/2$ after successful transmissions. By doing so, nodes that successfully transmitted in the past, will do so without collisions in future cycles. Hence the collision-free state.

Nevertheless, when the number of contenders ($n$) is greater than the deterministic backoff ($n > B_d$), collisions reappear. CSMA/ECA handles collision much more like CSMA/CA does, but in order to restore the collision-free state with this increased number of contenders, CSMA/ECA instructs nodes **not** to reset their backoff stage ($k$), resulting in a increased $B_d$. This is called *Hysteresis*, and ensures that many more contenders can be allocated in a collision-free state.

Hysteresis has the undesired effect of instructing some nodes to have greater backoff counters than others, unevenly sharing channel access time. This unfairness issue is leveraged by instructing nodes at backoff stage $k$ to transmit $2^k$ packets on each attempt, thus proportionally compensating those nodes at higher backoff stages. This measure is called *Fair Share* [14]. Figure 2 shows and working example of CSMA/ECA.

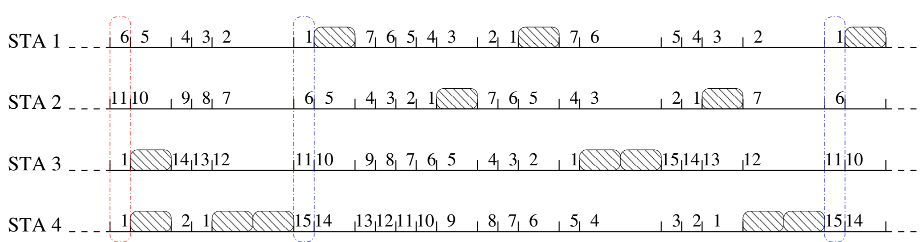


**Fig. 2.** For stations running CSMA/ECA ($CW_{\min} = 16$)

## References


1. Barcelo, J., Toledo, A., Cano, C., Oliver, M.: Fairness and Convergence of CSMA with Enhanced Collision Avoidance (ECA). In: 2010 IEEE International Conference on Communications (ICC). (may 2010) 1 –6
2. Barcelo, J., Bellalta, B., Sfairopoulou, A., Cano, C., Oliver, M.: CSMA with Enhanced Collision Avoidance: a Performance Assessment. In: IEEE VTC Spring. (2009)
3. Fang, M., Malone, D., Duffy, K., Leith, D.: Decentralised learning MACs for collision-free access in WLANs. Wireless Networks **19** (2013) 83–98
4. He, Y., Yuan, R., Sun, J., Gong, W.: Semi-Random Backoff: Towards resource reservation for channel access in wireless LANs. In: 17th IEEE International Conference on Network Protocols, IEEE (2009) 21–30
5. Tinnirello, I., Bianchi, G., Gallo, P., Garlisi, D., Giuliano, F., Gringoli, F.: Wireless MAC processors: Programming MAC protocols on commodity Hardware. In: INFOCOM, 2012 Proceedings IEEE. (march 2012) 1269 –1277
6. Bianchi, G.: FLAVIA Project: Flexible Architecture for Virtualizable future wireless Internet Access. Webpage (2010)
7. Bharghavan, V., Demers, A., Shenker, S., Zhang, L.: MACAW: a media access protocol for wireless LAN's. In: ACM SIGCOMM Computer Communication Review. Volume 24., ACM (1994) 212–225
8. Wang, C., Li, B., Li, L.: A new collision resolution mechanism to enhance the performance of IEEE 802.11 DCF. IEEE Transactions on Vehicular Technology **53**(4) (2004) 1235–1246
9. Cali, F., Conti, M., Gregori, E., Aleph, P.: Dynamic Tuning of the IEEE 802.11 Protocol to Achieve a Theoretical Throughput Limit. **8**(6) (2000) 785–799
10. Lopez-Toledo, A., Vercauteren, T., Wang, X.: Adaptive Optimization of IEEE 802.11 DCF Based on Bayesian Estimation of the Number of Competing Terminals. **5**(9) (2006) 1283
11. Barcelo, J., Bellalta, B., Cano, C., Oliver, M.: Learning-BEB: Avoiding Collisions in WLAN. In: Eunice. (2008)
12. Hui, K., Li, T., Guo, D., Berry, R.: Exploiting peer-to-peer state exchange for distributed medium access control. In: Information Theory Proceedings (ISIT), 2011 IEEE International Symposium on, IEEE (2011) 2368–2372
13. Barcelo, J., Bellalta, B., Cano, C., Sfairopoulou, A., Oliver, M.: Towards a Collision-Free WLAN: Dynamic Parameter Adjustment in CSMA/E2CA. In: EURASIP Journal on Wireless Communications and Networking. (2011)
14. Sanabria-Russo, L., Faridi, A., Bellalta, B., Barceló, J., Oliver, M.: Future evolution of csma protocols for the ieee 802.11 standard. CoRR **abs/1303.3734** (2013)