Evolution of CSMA Protocols for the IEEE 802.11 Standard

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***Abstract*—In this paper we present the requirements of candidate protocols to replace the pervasive CSMA/CA medium access control. We discuss the possibility of further preventing collisions and provide an overview of the related work. We specify protocols that are candidates of replacing CSMA/CA in pseudocode and use simulation to assess performance metrics such as throughput, fairness and collision probability.**

I. Introduction

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A candidate to replace CSMA/CA should

- Provide performance advantages, either in the form of throughput or short term fairness.
- Be backward compatible with current implementation.
- Be simple a simple evolution implementation to ease the transition and reduce time to market (Optional but desirable).

II. Related Work

Since the popularization of IEEE 802.11, several papers have proposed modifications to the contention protocol that is used for sharing the medium. They can be categorized in three groups regarding the approach they use. The first one prevents that the contention window is reset to its minimum value after successful transmissions. Examples of this first group include [1], [2]. This solution improves throughput in saturation conditions at the price of lowering short term fairness.

The second groups involves the accurate estimation of the number of contenders to adjust the contention parameters. Two examples of this group are [3], [4]. This approach offers some throughput and fairness gains at the expense of increased implementation complexity. As the number of contenders is estimated relying on the number of collisions, the presence of channel errors further complicates the estimation. Furthermore, there is a fundamental trade-off between the accuracy and the reaction time of the estimation.

The aforementioned solutions are not able to fairly share the medium with legacy devices. In fact, these proposals are, generally speaking, less aggressive than the currently implemented protocol. Consequently, in a hypothetical mixed network in which the new and old protocols coexist, the new stations would receive a smaller share of the available bandwidth in a scenario.

A more important limitation of the solutions exposed so far is that the throughput is bounded by that of CSMA/CA with optimal configuration [3], [5]. In the present paper we focus on a third group of solutions that delivers throughput above the maximum attainable by CSMA/CA.

This third group of solutions uses a deterministic backoff after successful transmissions to further reduce the chances of collisions. Under certain conditions, collision-free operation is reached. It was introduced in [6] and a more detailed analysis that includes both saturated and non-saturated conditions is presented in [7]. A more in-depth study is carried out in [8], including realistic elements such as clear channel assessment errors. Different aspects of fairness are addressed in [8]–[10]. The performance in realistic channels taking into account the Auto Rate Fallback mechanism is evaluated [11], [12].

Even though initial research efforts where focused on the WLAN collision problem, more recent papers try to extend the idea to multi-hop networks. In [13], the multi-hop slotted case explored. The more realistic situation in multi-hop networks in which the time is not slotted is studied in [14].

The same principles that we exploit to prevent collisions in WLANs can be used in other areas of radio resource management in wireless area networks [15]–[18].

In all the previous work on collision-free operation in WLANs mentioned so far, there is the limitation that the number of contenders should not exceed the value of the deterministic backoff used after successful transmissions. If this value is exceeded, it is no longer possible to achieve collision-free operation. A first solution to solve this problem is presented in [19], but it requires the presence of a central entity (typically the access point) that instructs the other nodes to adjust the value of their deterministic backoff.

In the present paper, we study a completely distributed solution to accommodate a large number of contenders in a fair collision-free fashion.

```
b ← U[0, CW_min − 1];
while there is a packet to transmit do
    a ← 0 ;
    while a < A do
        while b > 0 do
            wait 1 slot ;
            b ← b − 1 ;
        end
        Attempt transmission ;
        if success then
            /* Random backoff.                    */
            b ← U[0, CW_min − 1];
            break ;
        else
            /* Random backoff.                    */
            a ← a + 1 ;
            b ← U[0, CW_min 2^min(a,m) − 1];
        end
    end
end
```

Algorithm 1: CSMA/CA

```
b ← U[0, CW_min − 1];
while there is a packet to transmit do
    a ← 0 ;
    while a < A do
        while b > 0 do
            wait 1 slot ;
            b ← b − 1 ;
        end
        Attempt transmission ;
        if success then
            /* Deterministic backoff.             */
            b ← CW_min/2;
            break ;
        else
            a ← a + 1 ;
            /* fall to random backoff.            */
            b ← U[0, CW_min 2^min(a,m) − 1];
        end
    end
end
```

Algorithm 2: CSMA/ECA

III. Enhanced CSMA

IV. Performance Evaluation

V. Conclusion

The conclusion goes here.

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```
b ← U[0, CW_min − 1];
/* Hysteresis: The backoff stage is
   reset only when a node joins the
   contention or the queue is empty.  */
a ← 0 ;
while there is a packet to transmit do
    while a < A do
        while b > 0 do
            wait 1 slot ;
            b ← b − 1 ;
        end
        Attempt transmission ;
        if success then
            /* Deterministic backoff.     */
            b ← CW_min/2;
            break ;
        else
            a ← a + 1 ;
            /* fall to random backoff.    */
            b ← U[0, CW_min 2^min(a,m) − 1];
        end
    end
end
```

Algorithm 3: CSMA/ECA with hysteresis

```
b ← U[0, CW_min − 1];
/* Hysteresis: The backoff stage is
   reset only when a node joins the
   contention or the queue is empty.  */
a ← 0 ;
while there is a packet to transmit do
    while a < A do
        while b > 0 do
            wait 1 slot ;
            b ← b − 1 ;
        end
        /* Fair-share: 2^a packets are
           transmitted.                   */
        Attempt aggregate transmission of 2^min(a,m)
        packets;
        if success then
            /* Deterministic backoff.     */
            b ← CW_min/2;
            break ;
        else
            a ← a + 1 ;
            /* fall to random backoff.    */
            b ← U[0, CW_min 2^min(a,m) − 1];
        end
    end
end
```

Algorithm 4: CSMA/ECA with hysteresis and fair-share

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