# Combating Network Collisions by Reservation in Wireless CSMA Networks

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## ABSTRACT

Network collision is a known problem in CSMA/CA networks. This work presents a new solution to mitigate the issue of network collision. Our solution is fundamentally different from traditional random backoff methods in that a station can reasonably reuse a time slot in consecutive backoff cycles to achieve resource reservation. This solution can be readily used to enhance 802.11 DCF/EDCA with minimum modification to existing implementation. Results show that it can significantly reduce network collisions and achieves near collision-free state in small to middle-sized 802.11e wireless LANs, at near zero costs.

## 1. INTRODUCTION

Resource reservation is a well known technique widely used in TDMA schemes to achieve high throughput and QoS provisioning for ATM networks. In a typical reservation TDMA (R-TDMA), the radio resource is organized as superframes with each superframe divided into multiple time slots of equal length. A station can subscribe one or more time slots in each superframe as its reserved radio resource. Resource reservation can also be achieved by reservation ALOHA (R-ALOHA) [1], in which a time slot is automatically reserved by the station that successfully used it in the previous superframe. Since channel access in the reserved slots suffers less network collisions, usually TDMA are more appropriate for QoS-aware applications than contention-based CSMA protocols.

This work borrows the idea of reservation from R-TDMA/R-ALOHA and applies it in wireless CSMA networks to enhance DCF and EDCA. However, achieving reservation in the context of CSMA networks is challenging due to its different idiosyncracy from TDMA networks. Most existing contention-based channel access protocols in CSMA networks, including 802.11 DCF and EDCA, employ fully random backoff methods to resolve network collisions. They emphasize on high availability and are designed to be plug-and-play, thus inherently they are resistent to reservation. The key idea of this work is to control the backoff process not so random to achieve reservation. That is, sometimes the backoff counter is decided deterministically rather than randomly. This new method, named as semi-random backoff (SRB), allows a station to reuse a time slot in consecutive backoff cycles by deterministic setting of its backoff counter upon successful data transmissions. Here a backoff cycle is a period of time when the backoff counter decrements from a maximal value to zero. Note that different from TDMA networks, in CSMA networks the duration of a time slot varies over time. It is defined as a continuous time period during which the backoff counter decrements by one. It can be as short as merely several microseconds when it is idle, or can be as long as hundreds of microseconds when it is busy. Such time-varying time slots lead to reduced wasted time in idle slots when achieving reservation in CSMA networks compared to TDMA networks.

## 2. THE SEMI-RANDOM BACKOFF

Whenever station $i$ completes a data transmission at time slot $n$, its backoff counter $slot_i(n)$ is updated as follows according to the transmission results to start a new backoff cycle,

$$slot_i(n) = \begin{cases} M & \text{for a successful transmission} \\ rand(0, CW) & \text{for a failed transmission} \end{cases} \quad (1)$$

where $CW$ represents the backoff window as defined in traditional random backoff methods, and $M$ is the reservation parameter that is shared among stations. Here a successful transmission means a transmission that is acknowledged by the receiver via ACK, nACK, block ACK or other appropriate signals.

Equation (1) states that, when the previous transmission is successful, the backoff counter is reset to a deterministic value $M$; otherwise, it is reset to a random value from the contention window, as a tradition random backoff method does. Therefore, SRB contains a random component and a reservation component. The random component is used to probe a different backoff counter from other stations to avoid collision, and when the probing is successful, indicated by a successful transmission at a time slot, the reservation component is used to reserve that time slot for transmission in next backoff cycle. This procedure can be best described by a service ring (with $M$ slots) as shown in figure 1, where station A and B probe unused time slots on the ring by random component at first and whenever successful, they reserve these unused slots by setting the backoff counter to $M$. If each station can lock onto a different slot in the ring for channel access, resource reservation can be achieved and collisions are avoided.

In Equation (1), $CW$ is a time-varying parameter among stations that can be controlled by different random backoff methods. For example, the change of $CW$ can follow a binary exponential increase fashion when applying SRB to DCF/EDCA, or follow other varying patterns like EIED or LILD. On the other hand, $M$ is a fixed parameter for a

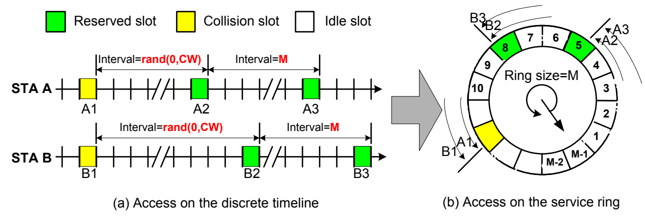


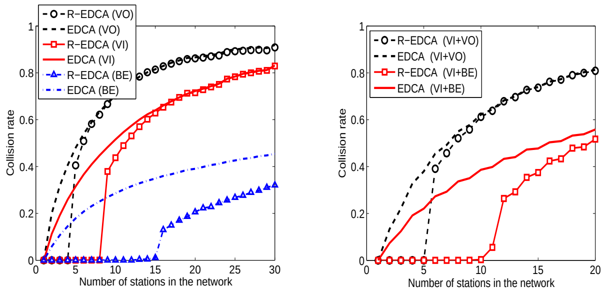
**Figure 1: Reservation achieved by SRB on discrete timeline (a) and service ring (b). All slots are represented as equal-length slots for clarity.**

station used for reservation. In the context of DCF/EDCA, $M$ is set to $\frac{CW_{min}+1}{2}$ so as to keep the average delay of SRB equal to the smallest delay in binary exponential backoff (BEB). $M$ can also be different for stations, in which case the service ring size is defined by the greatest comment divisor (gcd) of different $M$ in the network.

## 3. INITIAL RESULTS

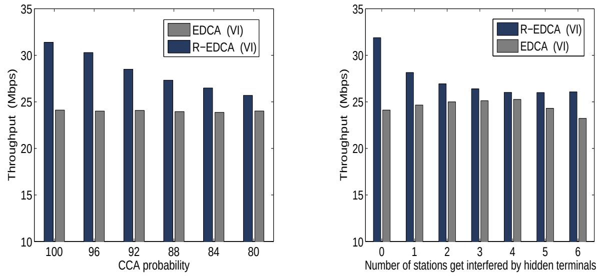
Fig. 2 shows collision rate of a 802.11e wireless LAN using *ns2* simulations. We use R-EDCA (reservation EDCA) to represent EDCA with SRB capability. In Fig. 2(a), all stations generate the same type of traffics: voice (VO), video (VI) and best-effort (BE) traffic. In Fig. 2(b), we consider two cases of mixed traffics: VI+VO and VI+BE. In each case, half of stations generate high-priority traffic, and the remaining stations generate low-priority traffic. We see that, for both single traffic and mixed traffic cases, the collision rate of EDCA increases quickly with the number of contending stations. However, R-EDCA has a near collision-free phase before the number of stations in the network reaches a threshold. As long as stations in the network can be accommodated by the service ring, the network can achieve extremely low collision rate. On the other hand, when they cannot be accommodated, the collision rate rises considerably and converges to that of EDCA.

We also studied the performance of R-EDCA in multi-hop networks and error-prone networks on *ns2*. In such nonideal situations, a station often can not successfully lock on to the reserved time slot due to unsynchronized change of backoff counters when carrier sense errors exist or hidden terminals present. To study these cases, we consider a 6-node 802.11g network with a data rate of 54Mbps. Each station generates saturated traffic to AP via the video access category (AC-VI). In Fig. 3(a) we show how the network throughput evolves when this network has its clear channel assess (CCA) probability decreases from 100% to 80%, and in Fig. 3(a) we investigate the network throughput when only a partial of stations in this network get interfered by hidden terminals. Our results reveal that R-EDCA has degraded performance in such non-ideal environments. However, its performance is always better than that of the legacy EDCA. A key feature of R-EDCA is, the functioning of reservation is automatically adapted to the network condition (hidden terminals, errors, etc.). A better condition leads to higher performance gain over legacy EDCA, while a a worse condition results in smaller performance gain over legacy EDCA.



(a) single traffic case (b) mixed traffic case

**Figure 2: Network collision rate versus the number of stations in the network.**



(a) carrier sense error (b) hidden terminals

**Figure 3: Performance of R-EDCA and EDCA in unsynchronized networks.**

## 4. CONTRIBUTIONS AND FUTURE WORK

Our contribution is a novel approach to combat network collisions, particularly in single-hop network paradigms such as wireless LANs. Compared with traditional methods to improve DCF/EDCA such as reservation CSMA [2], SRB has three appealing features.

- It achieves reservation at near zero costs. It requires neither feedbacks of channel conditions nor negotiation with any central coordinators, as well as time synchronization as TDMA and [2] do.
- It can be readily applied to 802.11 DCF and 802.11e EDCA, with minimum modification to the existing DCF/EDCA implementation.
- It is backward compatible with current DCF/EDCA.

Currently we are in the progress of implementing and testing SRB on commercial products.

## 5. REFERENCES

[1] W. Crowther, R. Rettberg, D. Walden, S. Ornstein, and F. Heart, “A System for Broadcast Communication: Reservation-ALOHA, ” in *Proc. 6th HICSS*, Honolulu, Jan. 1973.

[2] I. Joe, and S. G. Batsell, ”Reservation CSMA/CA for Multimedia Traffic over Mobile Ad-hoc Networks,” in *Proc. ICC*, pp. 1714-1718, 2000.