S-EDCF: EDCF based on SuperSlot and Pseudo Collision

Jiho Ryu*, Yongho Seok*, Yanghee Choi*, Taekyoung Kwon* and Jean-Marie BONNIN**
* Seoul National University, Seoul, Korea, ** ENST Bretagne, France

ABSTRACT

The IEEE 802.11e EDCF mechanism cannot guarantee the QoS of high-priority traffic as the bandwidth consumption of the low-priority traffic increases. Also, the existence of high priority traffic undermines link utilization of low priority traffic. To solve these problems, we propose the *S-EDCF* scheme that extends IEEE 802.11e EDCF by introducing a *SuperSlot* and *Pseudo Collision*. Compared to EDCF, *S-EDCF* has two advantages: (a) Higher priority traffic achieves QoS regardless of the amount of low priority traffic, and (b) Low priority traffic experiences a higher throughput with the same amount of high priority traffic.

1. BASIC IDEA

To date, the IEEE 802.11 wireless LAN protocol [1] has become the de facto standard. It is based on Carrier Sense Multiple Access/Colllision Avoidance (CSMA/CA). In IEEE 802.11 DCF (CSMA/CA), a station transmits a packet if it has observed an idle medium during a DIFS interval. Otherwise, it chooses a backoff time in the range of [0, *cw*-1], where *cw* is the contention window size. Then it starts to decrease the backoff timer. If the medium becomes busy during the backoff, the backoff timer is frozen. When the medium become idle after a DIFS interval, the node unfreezes the backoff timer and starts to decrease it again. When the backoff timer expires, the node transmits its packet. If the backoff timers of more than one stations expire at the same time, they will experience a packet collision. This kind of collision will make these stations double their contention windows and start the backoff process again, which wastes the wireless link bandwidth. As the number of competing stations increases, there will be more collisions, hence resulting in severe performance degradation.

IEEE 802.11e EDCF proposed in [3] is designed to offer QoS differentiation in wireless LANs. However, it cannot differentiate prioritized traffic absolutely. If the low priority traffic increases, the perceived QoS (e.g. delay) of the high priority traffic is hindered. Also, in IEEE 802.11e EDCF, the existence of high priority traffic undermines the aggregate throughput of low priority traffic, which decreases the overall link utilization.

To solve these problems, we introduce the concepts of *SuperSlot* and *Pseudo Collision*, on which the proposed *S-EDCF* is based.

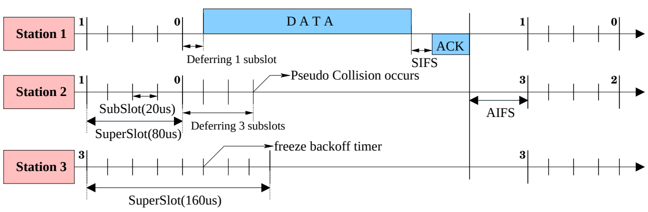
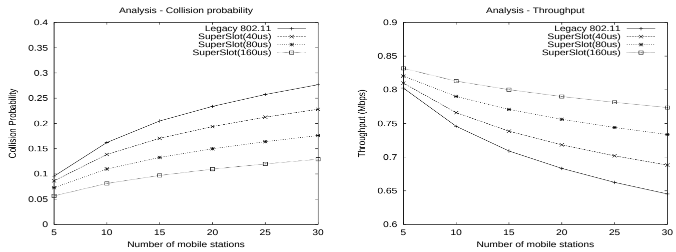


Figure 1: Basic operation of *S-EDCF*

Fig. 1 illustrates the basic operation of S-EDCF, where a *SuperSlot* consists of multiple *SubSlot*s. Each *SubSlot* is equal to a slot ($20\mu s$) defined in IEEE 802.11 DCF. Thus, the duration of a *SuperSlot* is $20\mu s \times D$, where D is an integer, a pre-defined system parameter. For sake of convenience, the contention window sizes such as CW_{min} and CW_{max} in IEEE 802.11 DCF are the multiples of the *SuperSlot* size, which is again D *SubSlot*s. The backoff process is the same as the IEEE 802.11 DCF except that a *SuperSlot* is used as the decreasing time unit instead of the *SubSlot*. When the backoff timer (of *SuperSlot*) expires, the station does not transmit the packet immediately but it chooses another random *deferring* time, which is $k\times$ *SubSlot* ($0 \leq k < D$). If the medium is idle until the chosen *deferring* time expires, the station transmits the packet. Otherwise (if other station transmits a packet ahead), it regards this attempt as a *Pseudo Collision*. Therefore, it doubles its *cw* and starts a new backoff process. Both *SuperSlot* and *Pseudo Collision* decrease the real collision probability and hence increase the aggregate throughput.



(a) Collision Probability (Real) (b) Throughput

Figure 2: Analysis of S-EDCF

2. ANALYSIS

In order to prove the higher aggregate throughput, we model a single class in *S-EDCF* as follows, which is based on the discrete-time Markov chain analysis in [2].

$$\tau = \frac{2(1-2p)}{(1-2p)(W+1)+Wp(1-(2p)^m)}$$

$$p = \sum_{i=1}^{n-1}\left(\sum_{j=1}^{D} {}_{n-1}C_i \cdot \tau^i(1-\tau)^{n-1-i} \cdot \frac{1}{D}\left(1-\left(\frac{D-j}{D}\right)^i\right)\right)$$

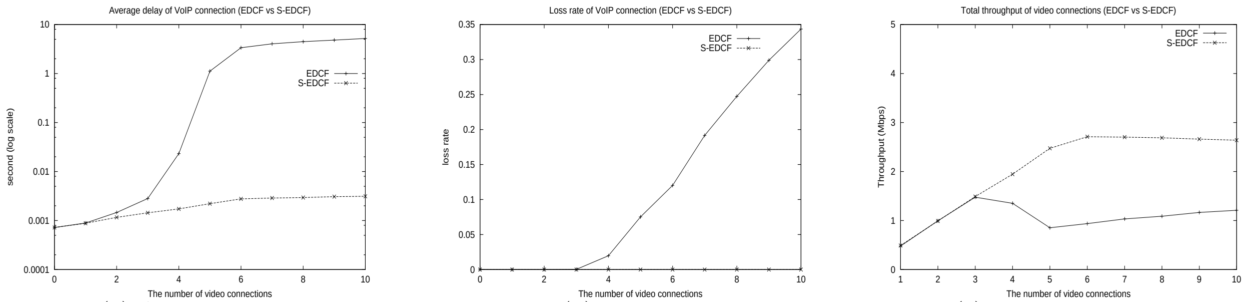
$$P_{tr}(j) = \sum_{i=1}^{n}\left({}_nC_i \cdot \tau^i(1-\tau)^{n-i} \cdot \left(\left(\frac{D-j+1}{D}\right)^i - \left(\frac{D-j}{D}\right)^i\right)\right)$$

$$P_{tr} = \sum_{j=1}^{D} P_{tr}(j)$$

$$P_{tr}P_s(j) = \sum_{i=1}^{n}\left({}_nC_i \cdot \tau^i(1-\tau)^{n-i} \cdot {}_iC_1 \cdot \frac{1}{D}\left(\frac{D-j}{D}\right)^{i-1}\right)$$

$$P_{tr}P_s = \sum_{j=1}^{D} P_{tr}P_s(j)$$

$$S = \frac{P_{tr}P_s \cdot E[P]}{(1-P_{tr})\cdot 20\cdot D + \sum_{j=1}^{D} P_{tr}P_s(j)\cdot((j-1)\cdot 20+T_s) + \sum_{j=1}^{D}(P_{tr}(j)-P_{tr}P_s(j))\cdot((j-1)\cdot 20+T_c)}$$



(a) Average delay (b) Loss rate (c) Total throughput

Figure 3: EDCF vs. S-EDCF

In the above equations, τ, W, m, n, P_s, P_{tr}, T_s, T_c, $E[p]$, and S have the same meaning as defined in [2]. p is the conditional probability of both real and pseudo collisions when a packet is transmitted. $P_{tr}(j)$ is the probability that there is at least one transmission in the j^{th} *SubSlot* time of the given *SuperSlot*. $P_{tr}P_s(j)$ is the probability that there is a successful transmission in the j^{th} *SubSlot* time of the given *SuperSlot*. Finally, D is the number of *SubSlot*s in a single *SuperSlot*. The real collision probability and the throughput by this analysis are plotted in Fig. 2.

3. NUMERICAL RESULTS

We use the NS-2 simulator to evaluate *S-EDCF* with the following configuration. The *SuperSlot* of each access category (AC) consists of D_{AC} *SubSlot*s, where D_0, D_1, D_2 and D_3 are set to 4, 8, 16, and 16, respectively. A backoff (of *SuperSlot* unit) is first performed with these parameters depending on the access category to which the packet belongs. Note that in Table 1, CW$_{min}$ has two *SuperSlot*s in all categories. When the backoff timer expires, a *deferring* time is chosen randomly in the range of [0, D_{AC}-1]. If the medium is idle until the deferring timer expires, it transmits the packet. Otherwise, it deems this situation as a *Pseudo Collision*, so that it performs an exponential backoff. In *Pseudo Collision*, the retry counter is not increased since nothing has been really transmitted.

In simulation experiments, there are 10 connections for voice and v connections for video, where v varies from one to ten. Under various network conditions, we observed the average delay and loss rate for voice traffic, and the throughput for video traffic. Basic parameters for the IEEE 802.11e EDCF are given in Table 1, depending on the priority (access category) of each flow type. Each VoIP traffic generates at 64 Kbps, and the average rate of video traffic is about 500 Kbps.

Fig. 3(a) shows the average delay of 10 voice connections. If the *S-EDCF* is used, it prevents the average delay from increasing as the number of video connections increases. When there are 10 video connections, the average delay experienced by voice connections is about 3 ms with *S-EDCF* while it is 5 seconds with EDCF. In EDCF, as there are more than 5 simultaneous video connections, the average delay experienced by voice connections becomes unacceptable.

Fig. 3(b) shows the average packet loss rate for 10 voice connections. When *S-EDCF* is used, there is no voice packet loss regardless on the number of video connections. However, in EDCF, voice packet loss rate continues to increase as the number of video connections increases. Fig. 3(a) and 3(b) show that the *S-EDCF* can guarantee the QoS for high priority traffic despite increasing low priority traffic.

Fig. 3(c) shows the aggregate throughput of v video connections. IEEE 802.11e EDCF and *S-EDCF* achieve the same aggregate throughput until the number of video connections become larger than 3, after which EDCF's aggregate throughput is much lower than that of *S-EDCF*. This signifies that low priority traffic utilizes the network resource more efficiently with *S-EDCF*.

Table 1: Basic Parameters for the IEEE 802.11e EDCF

Flow Type	AIFS(μs)	CW$_{min}$	CW$_{max}$
Voice	50	8	16
Video	50	16	32
Data	150	32	1024

4. CONCLUSION

We introduce the concepts of *SuperSlot* and *Pseudo Collision* that constitute *S-EDCF*, which enhances IEEE 802.11e EDCF. Unlike EDCF, *S-EDCF* provides strict QoS for high-priority traffic regardless of amount of low-priority traffic. *S-EDCF* is also able to achieve more efficient resource utilization for low-priority traffic even with high-priority traffic.

5. REFERENCES

[1] IEEE Computer Society. 802.11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, June 1997.

[2] G. Bianchi, "Performance analysis of the IEEE 802.11 distributed coordination function," IEEE Journal of Selected Areas Communications, vol. 18, pp. 535-547, Mar. 2000.

[3] IEEE WG, "IEEE 802.11e/D4.0, Draft Supplement to Part 11: Wireless Medium Access Control (MAC) and Physical Layer (PHY) specifications: Medium Access Control (MAC) Enhancements for Quality of Service (QoS)," November 2002.