Finer Tuning Of QoS Mechanisms for Performance Enhancement of Wireless Networks

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ABSTRACT
WLAN is supported by almost all of the modern communication devices. These devices are largely used for communication of multimedia data including real time data. There is limited QoS support in WLANs, which will become an impediment in deploying multimedia applications. The important QoS metrics for multimedia applications are delay, jitter, loss, and throughput. There are different mechanisms and techniques for controlling these metrics. A lot of work has been carried out as far as loss and throughput is concerned. This paper focuses mainly on reducing the delay and jitter. A study of the various QoS support mechanisms for wireless networks is carried out and suggestions for improvement have been proposed particularly pertaining to the MAC parameters which will lead to a more precise and finer tuning of the already available mechanisms.

General Terms
Wireless Computer networks

Keywords
QoS in wireless networks, MAC parameters for wireless networks, AEDCF.

1. INTRODUCTION
In order to support a variety of applications and to provide differentiated service quality, QoS mechanisms are required at the link or medium access control (MAC) layer of WLANs. Distributed Coordination function (DCF) is a contention-based medium access control (MAC) protocol implementing carrier sense multiple access/collision avoidance (CSMA/CA) to arbitrate channel access among wireless stations. With 802.11 DCF, all stations associated with the same access point (AP) operate independently and share channel bandwidth equally. Therefore, it is hard to satisfy the low delay and jitter requirements of real time applications like video streaming over WLANs.

To expand support for applications with quality-of-service (QoS) requirements, the 802.11E task group was formed to enhance the original IEEE 802.11 medium access control (MAC) protocol. However, the problem of choosing the right set of MAC parameters and QoS mechanism to provide predictable QoS in IEEE 802.11 networks remains unsolved.

In an 802.11 network that contains an access point time is split into two types of periods -- a contention-free period (CFP) and a contention period (CP) -- that alternate at regular intervals. Together both of these periods constitute a superframe. The 802.11 MAC defines two functions for access to the medium. The Point Coordination Function (PCF)

is used by the access point (AP) during the contention-free period to poll stations that associated with the AP. On the other hand the Distributed Coordination Function (DCF) is used by stations to gain access to the medium during the contention period.

The 802.11 legacy MAC does not support the concept of differentiating frames with different priorities. Basically, the DCF is supposed to provide a channel access with equal probabilities to all stations contending for the channel access in a distributed manner. However, equal access probabilities are not desirable among stations with different priority frames. . The EDCF is designed to provide differentiated, distributed channel accesses for frames with 8 different priorities (from 0 to 7) by enhancing the DCF. As distinct from the legacy DCF, the EDCF is not a separate coordination function. Rather, it is a part of a single coordination function, called the Hybrid Coordination Function (HCF), of the 802.11e MAC. The HCF combines the aspects of both DCF and PCF.

Each frame from the higher layer arrives at the MAC along with a specific priority value. Then, each QoS data frame carries its priority value in the MAC frame header. An 802.11e STA shall implement four access categories (ACs), where an AC is an enhanced variant of the DCF 0.

Each AC has a separate queue within each station along with different contention window parameters. In addition, each access category has to sense the medium for a different interframe space time prior to beginning a transmission. This time value is defined as an Arbitration Interframe Space (AIFS). Basically, the smaller AIFS[AC] and CWmin[AC], the shorter the channel access delay for the corresponding priority, and hence the more capacity share for a given traffic condition. However, the probability of collisions increases when operating with smaller CWmin[AC]. These parameters can be used in order to differentiate the channel access among different priority traffic.

EDCF is better than DCF because it provides differentiation to different flows. An increase in either AIFS or CWmin for the low priority access category (AC) results in a decrease in the latency for higher priority ACs. AIFS has a greater effect on reducing bandwidth variance and jitter.[1]

The rest of this paper is laid out as follow. The modified schemes of the 802.11e,i.e. AEDCF and AEDCF-CW/PF are then discussed in section 2 which a base for the new scheme is proposed. The proposed scheme is presented in section 3.Conclusions and comments are in section 4.

2. ADAPTING TO NETWORK CHANGES
EDCF is an attractive channel access method because it is decentralized, and simple. A method called Adaptive EDCF (AEDCF) was proposed, that adjusts the size of the contention window based on the number of collisions that a station

experiences. Adaptive EDCF (AEDCF) aims to provide real-time support in 802.11 ad-hoc networks. To improve the performance under different load rates and to increase the service differentiation in EDCF-based networks, this method was proposed. AEDCF-CW/PF (Adaptive EDCF) is a scheme which varies CWmax and Persistence Factor).

2.1 Adaptive Enhanced Distributed Coordination Function

Please use a 9-point Times Roman font, or other Roman font with serifs, as close as possible in appearance to Times Roman in which these guidelines have been set. The goal is to have a 9-point text, as you see here. Please use sans-serif or non-proportional fonts only for special purposes, such as distinguishing source code text. If Times Roman is not available, try the font named Computer Modern Roman. On a Macintosh, use the font named Times. Right margins should be justified, not ragged.

In order to efficiently support time-bounded multimedia applications, use a dynamic procedure to change the contention window value after each successful transmission or collision. This adaptation will increase the total goodput of the traffic which becomes limited when using the basic EDCF, mainly for high traffic load.

In the basic EDCF scheme for ad-hoc networks, the CWmin[i] and CWmax[i] values are statically set for each priority level. After each successful transmission, the CW[i] values are reset to CWmin[i]. In this scheme reset the CW[i] values more slowly to adaptive values (different to CWmin[i]) taking into account their current sizes and the average collision rate while maintaining the priority-based discrimination. At each instant, the highest priority class has the lowest contention window value so that it has the highest priority to access the media. The adaptive slow CW decrease is a tradeoff between wasting some backoff time and risking a collision followed by the whole packet transmission.

After each collision, the source has to wait for a timeout to realize that the packet has collided, and then doubles its CW to reduce the number of collisions. Change the mechanism and differentiate between classes using different factors to increase their CWs.

1) Setting CW After Each Successful Transmission:

Here every class updates its CW in an adaptive way taking into account the estimated collision rate f^{j}_{curr} in each station. Indeed, the collision rate can give an indication about contentions in a distributed network. The value of f^{j}_{curr} is calculated using the number of collisions and the total number of packets sent during a constant period (i.e. a fixed number of slot times) as follows:

$$f^{j}_{curr} = \frac{E(collisions_j\,[p])}{E(data\_sent_j\,[p])},$$

where $E(collisions_j\,[p])$ is the number of collisions of station p which occurred at step j, and $E(data\_sent_j\,[p])$ is the total number of packets that have been sent in the same period j by flows belonging to the station p.

Note that the above ratio f^{j}_{curr} is always in the range of [0, 1]. To minimize the bias against transient collisions, use an estimator of Exponentially Weighted Moving Average (EWMA) to smoothen the estimated values. Let f^{j}_{avg} be the average collision rate at step j (for each update period) computed according to the following iterative relationship:

$$f^{j}_{avg} = (1 - \alpha) * f^{j}_{curr} + \alpha * f^{j-1}_{avg}$$

where j refers to the j^{th} update period and f^{j}_{curr} stands for the instantaneous collision rate, α is the weight (also called the smoothing factor) and effectively determines the memory size used in the averaging process. The average collision rate is computed dynamically in each period T_{update} expressed in time-slots. This period should not be too long in order to get good estimation and should not be too short in order to limit the complexity.

To ensure that the priority relationship between different classes is still fulfilled when a class updates its CW, each class should use different factor according to its priority level (we denote this factor by Multiplicator Factor or MF). Keeping in mind that the factor used to reset the CW should not exceed the previous CW, limit the maximum value of MF to 0.8. This limit has been fixed according to an extensive set of simulations done with several scenarios. In AEDCF, the MF of class i is defined as follows:

$$MF[i] = \min((1 + (i * 2)) * f^{j}_{avg}, 0.8).$$

This formula allows the highest priority class to reset the CW parameter with the smallest MF value (i.e., priority level 0). After each successful transmission of packet of class i, CW[i] is then updated as follows:

$$CW_{new}[i] = \max(CW_{min}[i]\,,\, CW_{old}[i] * MF[i])$$

The equation above guarantees that CW[i] is always greater than or equal to $CW_{min}[i]$ and that the priority access to the wireless medium is always maintained.

2) Setting CW After Each Collision:

In the EDCF, after each unsuccessful transmission of packet of class i, the CW of this class is doubled, while remaining less than the maximum contention window $CW_{max}[i]$:

$$CW_{new}[i] = \min(CW_{max}[i]\,,\, 2 * CW_{old}[i])$$

In AEDCF, after each unsuccessful transmission of packet of class i, the new CW of this class is increased with a Persistence Factor PF[i], which ensures that high priority traffic has a smaller value of PF[i] than low priority traffic:

$$CW_{new}[i] = \min(CW_{max}[i]\,,\, CW_{old}[i] * PF[i])$$

In this version of AEDCF scheme the PF is used because by this way can reduce the probability of a new collision and consequently decrease delay. [4]

2.2 Adaptive Enhanced Distributed Coordination Function with varying Contention Window and Persistent Factor

In AEDCF under high loads the highest priority traffic class have retransmission attempts per frame. If each AC was allowed to pick a backoff counter from a larger interval the collision rate might be reduced. Thus AEDCF-CW/PF (Adaptive EDCF) is a scheme which varies CWmax and Persistence Factor). The contention window was increased by a factor called the persistence factor, PF. It also allows stations to select some of their MAC parameters independently. Since EDCF is a distributed function, stations should be able to compute some of their MAC parameters without relying on the hybrid coordinator to broadcast those values. [2]

Stations implementing the AEDCF-CW/PF algorithm operated as shown below. Each station was to check its average collision probability, $f_{avg}(j)$, prior to executing the exponential backoff algorithm. If $f_{avg}(j)$ was greater than some threshold value, γ, the station was allowed to increase $CW_{max}[i]$ temporarily. If $f_{avg}(j)$ was greater than another threshold value, β. the persistence factor – the factor, PF, used to increase the contention window – was set to 4, otherwise it was set to 2.

Adaptive EDCF with varying CW and PF can be implemented at each station with minimal impact. In addition to the four additional registers mentioned in to store the values for α, PF[i], $f_{avg}^{(j-1)}$ and T_{update}, this scheme will require two additional registers to store the values of β and γ. Computing the new persistence factor will take one comparison operation. In the event of a collision, determining whether or not to double CW_{max} will take two comparisons. Choosing to double CW_{max} will take one addition and one multiplication operation. The other multiplication and addition operations are a normal part of the standard EDCF procedure; therefore, they do not add to the complexity of the function. [5]

3. PROPOSED CHANGES

A few modifications are proposed to the schemes above to adapt more finely to the network conditions.

3.1 Finer Tuned Adaptation Based on Collision Probability

If the AC could pick a Backoff counter from a larger interval the collision rate might reduce. However increasing the CW_{max} to a larger value will increase the delay. Thus instead of choosing the backoff counter from a very large CW_{max} after the β value has been encountered we could still increase CW_{max} only by a moderate amount as it is yet not a very high probability of collision.

As in AEDCF-CW/PF each station was to check its average collision probability, $f_{avg}(j)$, prior to executing the exponential backoff algorithm. In this scheme which we propose if $f_{avg}(j)$ is greater than some threshold γ it is considered to have high collision probability and hence, increase CW[i] by a factor randomly between a range of CW values which are close to CW_{max}. If $f_{avg}(j)$ is lesser than some threshold value, γ, but greater than another threshold value β, it is considered to have a medium collision probability and hence the station was allowed to increase CW[i] randomly between a range of contention window values which are average CW values. If $f_{avg}(j)$ was lesser than another threshold value, β then increase the CW[i] by a small factor.

The initial MAC parameters used in this scheme will be the same as in AEDCF[2]. Here the new notations lmid and hmid are introduced. These are the medium range of CW values with lmid(lower mid) being the lower limit and hmid(high mid) being the upper limit. Here the CW sizes will be varied based on the collision rate and not on the success or failure of a current transmission. There also may be some factor to be multiplied to the random value generated to ensure that the priority relationship with the other classes will be maintained. This value will be decided based on experimental analysis.

3.2 Increase in Frame Dropping Rate at High Loads

In addition to AEDCF-CW/PF excellent response time performance under heavy loads, AEDCF-CW/PF also drops frames at a lower rate than both EDCF and AEDCF. As a result of this AEDCF-CW/PF does have one flaw – it introduces higher jitter values for the traffic under heavy loads. Once each of these medium access functions attains its maximum throughput, AEDCF-CW/PF begins to display poor jitter performance. This degradation in performance is a result of the lower tendency of AEDCF-CW/PF to drop frames.

The frame dropping function, the same as used in EDCF, has different frame dropping probabilities based on the number of frames in the queue. It drops 1 in 100 frames when the source's queue contained less than 5, 3, or 10 frames for sources with class 0, 1 or 2 traffic respectively. If the queue contained more than 5, 3 or 10 frames respectively the frame dropping probability was raised to 1 in 10. However, at high loads with more than 30 competing stations random frame dropping reduces the system response time. If an exact tradeoff could be achieved between and the system response time then this could be an improvement in reduction of jitter. Hence this can be modified only for high loads where the frame dropping probability can be increased to reduce the jitter.

3.3 Binomial distribution for backoff value

In the IEEE 802.11 distributed coordination function (DCF), the binary exponential backoff algorithm selects a random backoff number from a uniform probability distribution to avoid the problem of packet collision. [8] presents a novel backoff algorithm that uses a binominal distribution rather than a uniform distribution to determine the backoff value. Simulation results show that this proposed algorithm outperforms the original IEEE 802.11DCF algorithm. The collision is noticed only at the beginning of contention however this is eliminated once the initial phase is over. This same method can be included in AEDCF. Hence the random function will now be the binomial algorithm specified in [8]. Use of Binomial distribution could prove helpful in reducing the collision thus increasing the overall performance of the network.

4. CONCLUSION

The throughput in ADECF and the proposed mechanism is almost comparable as a collision does not always indicate a collision in the next transmission. However there is an improvement in the access time since the window is now limited compared to the previous method. This method therefore performs better in comparison to the previous method.

The basic is the DCF that works well however it does not favour multimedia data and real time traffic since there is no service differentiation in this scheme. Hence the enhancement of this scheme i.e the EDCF provides service differentiation that is designed especially for multimedia data. Further enhancements to this scheme are the AEDCF and the AEDCF-CW/PF which adapt according to the probability of collision. These schemes are much better for transmission of multimedia data compared to the initial DCF as they provide service differentiation. However there are areas where modifications are possible. Adjusting the MAC parameters such as CW_{min}, CW_{max} and the backoff counter (BI) are probable contenders for change.

The working of AEDCF-CW/PF proves to be fairly effective. However there are MAC parameters that can be adjusted as given in the proposed schemes that can be a finer tuning of the AEDCF-CW/PF algorithm. This is so since this scheme tries to strike a right balance between the delays to access the medium and the possibility of a collision taking place. It does so by dividing the increments to the contention window to be dependent on three different collision probability conditions. Thus even though the CW_{max} is increased it is increased by a factor in such a way that the delay will be not very high. The jitter is controlled at lower loads. However at high loads the jitter increases which is due to the limited dropping of frames. If the frame dropping is increased at high loads as proposed in the scheme then though the farmes will be lost the jitter will be reduced which is fair and not very disastrous incase of transmission of multimedia data. Also the collision can be reduced by incorporating the binomial distribution for choosing the random backoff counter value by limiting the scope of two AC to choose the same backoff counter value altogether. If this chance is eliminated then the collision will reduce significantly.

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