ADAPTIVE AIFS IN WIRELESS LAN

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Abstract: The new medium access protocol proposed by the IEEE 802.11e group, namely EDCF (Enhanced Distributed Coordination Function) provides a best way to guarantee a QoS for real time and multimedia applications. However the parameters used in EDCF are static and don't take into account the instantaneous wireless link fluctuation, and applications requirements. In this work, we propose a new MAC access protocol AAIFS (Adaptive Arbitration InterFrame Space), which dynamically adjusts the intrinsic MAC parameters to fit both the transported stream relevant priority and wireless link overload. AAIFS protocol provides (1) a wireless link conditions aware scheme based on the measured packet loss rate (2) a differentiate QoS provisioning scheme at the mobile node side, which aggregate the different traffic into 3 service classes (3) a fair medium exploitation between the some service class belonging to different nodes.

Key words: QoS, wireless LAN, ad hoc network.

1. INTRODUCTION

In the past decade, IEEE 802.11 WLAN standard [7] is being accepted rapidly for many different environments. IEEE 802.11 is now considered as

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a wireless version of Ethernet by virtue of supporting a best-effort service. Recent advances in wireless communication and mobile computing technologies have been trying to push WLAN even further towards providing real-time multimedia services to mobile users. However, the strict requirements on timing delay, jitter and high bit error rate and insufficient bandwidth in WLAN posts different problem in supporting multimedia services.

To solve this problem, the IEEE formed the 802.11e Task group to develop different schemes based on the original 802.11, MAC (Medium Access Control) to enhance support for QoS sensitive applications.

The task group e defines a new standard named IEEE 802.11e [1], who introduce the Enhanced Distributed Coordination Function (EDCF) adds transmission prioritization to CSMA/CA. On the other hand, a new coordination function named Hybrid Coordinator (HC) located at the Access Point (AP) to start polling based contention-free access at any time during the contention period as needed to conform to the QoS parameterization.

The current proposed, IEEE 802.11e MAC enhanced try to provide a traffic prioritization and discipline at the MAC level. Some early research had proposed on.

In this paper, we propose an adaptive scheme, which takes into account both network conditions and application requirements, in order to guarantee a QoS in IEEE 802.11 wireless LAN under different load.

The remainder of this paper is organized as follow, section II gives an overview of the IEEE 802.11 networks and a survey on related researches about 802.11 MAC enhancements for real-time traffic. In section III we describe our proposed scheme called AAIFS and the adaptation algorithm, the section IV, shows the performance evaluations through simulation results. Our conclusion and future works are presented in Section V.

2. RELATED WORK

2.1 The legacy IEEE802.11 MAC:

The IEEE 802.11 MAC defines two transmission modes for data packets: the Distributed Coordination Function (DCF) based on CSMA/CA and the contention-free Point Coordination Function (PCF) where the Access Point controls all transmissions based on a polling mechanism. The DCF and PCF modes are time multiplexed in a superframe, which is formed by a PCF

contention-free period (CFP) followed by a DCF contention period (CP), positioned at regular intervals (see Fig. 1).

Figure 1 Beacons and contention free periods

The DCF mode is based on a CSMA/CA mechanism. The access control scheme is shown in Fig. 2.

Figure 2 Backoff mechanism in DCF

A terminal that intends to transmit and senses the channel busy waits for the end of the ongoing transmission, then waits for a time period of DIFS (Distributed coordination Function InterFrame Spaces) length, and then randomly selects a time slot within the backoff window. The backoff length is calculated as follows:

$$\text{Backoff} = \text{Random}(0, \text{CW}) * \text{aSlotTime}$$

The slot duration, aSlotTime , depends on the network round-trip propagation delay. The number of backoff slots is derived from a uniform distribution over the interval $[0, \text{CW}]$, where the contention window (CW) parameter ranges from a minimum value of aCWmin up to a maximum value aCWmax . Initially, the CW parameter is set to aCWmin and can be increased up to 255. Collisions can only occur in the case that two terminals have selected the same slot. For each unsuccessful transmission the contention window is updated as follows:

$$\text{CW} = 2^{2+i} - 1$$

Where i is the number of transmission attempts.

If another terminal has selected an earlier slot, transmission is deferred and its backoff counter is frozen. Then, the terminal waits for the channel to become idle and then waits for the backoff slots remaining from the previous competition. In order to guarantee undisturbed transmission even if hidden terminals are present, an RTS/CTS (Request To Send/Clear To Send) mechanism is used. When this mechanism is applied, the contention winner does not transmit the data immediately. Instead it sends an RTS frame to which the receiver answers with a CTS frame. This guarantee that all terminals in the range of both the sender and the receiver know that a packet will be transmitted, remaining silent during the entire transmission. Only then the sender transmits the data frames. While the two extra messages present additional overhead, the mechanism is particularly useful in the case of large data frames because the RTS and CTS frames are short. The PCF mode is based on a polling mechanism controlled by the AP as depicted in Fig. 3.

Figure 3 Polling mechanism in PCF

During the CFP, the AP polls the terminals registered in its polling list and allows them undisturbed contention-free access to the medium. As already said, in order to become registered in the polling list, the terminals have to associate with the AP during the CP.

2.2 QoS (Quality of service):

Best effort service provided by WLAN suits data traffic very well. This has been proved by the success of the mobile Internet access. However, unlike data, multimedia application requires guaranteed high bandwidth and guaranteed maximum end-to-end latency constraint. Unfortunately, the delay and packet loss constraints for multimedia data are not supported by legacy 802.11. Although PCF aims at supporting real-time traffic, its application is limited due to its complexity and unsatisfactory performance. In addition, PCF is not applicable in wireless Ad hoc network context.

Many medium access schemes have been proposed for IEEE 802.11 WLAN to support a QoS requirement for real-time and multimedia applications. The whole of the made studies proposed, is to modify the MAC layer defines by the standard, in order to provide a QoS guarantees in 802.11 networks. Here some proposals and studies made in this direction.

In order to introduce priorities and differentiation mechanisms in the IEEE 802.11, Aad [6] proposes to combine the three following parameters:

- Backoff increase function: Each priority level uses a different backoff increment function,
- DIFS: Each priority level has a different DIFS,
- Maximum frame length: Each priority level has a maximum frame length allowed to be transmitted at once.

The great change is seen in the Backoff increase function, Aad propose to modify the formulate seen in section (II,A), by this one:

$$\text{Backoff_time} = [P_j^{2+i} * \text{rand}()] * \text{aSlotTime}$$

Where P_j is a priority factor for a given Wireless Terminal. So instead of multiplying the range by two each retransmission, the new formula multiply by P_j , thus the higher priority factor is, the larger backoff range, the lower is the throughput. Nevertheless this later proposition doesn't provide a QoS at stream level.

Another scheme named DFS (Distributed Fair Scheduling) [8] which utilizes the ideas behind fair queuing in the wireless domain. DFS uses the backoff mechanism of IEEE 802.11 to determine which station should send first. The backoff interval will be longer the lower the weight of the sending station is, so differentiation will be achieved, while fairness is achieved by making the interval proportional to the packet size. But in DFS each node has to monitor all transmission packets and read the so-called finish tag of each packet. In addition DFS requires the header format of 802.11 to be modified in order to include this finish tag in the packet header.

In [3,4] the TCMA (Tired Contention Multiple Access) scheme proposed to map eight traffic categories into four Urgency Classes (UC) according to the IEEE 802.1d. Each UC has its own backoff time setting. The station using UC was named ESTA(Enhanced Station) and the other stations STA, the STA uses the basic mechanism defines by the standard IEEE 802.11. TCMA define the UAT (Urgency Arbitrary Time), which by definition have the same role like DIFS, except that each UC has its own UAT.

The Backoff mechanism in the TCMA was different with others. Each CW_i take the initial value ($aCW_{size}-1$) for urgency class i , where CW_i size is obtained from the beacon frames emitted by AP. The ESTA decrease the CW for each unsuccessful attempt to transmit according a scaling parameter, $CWPFactor$ (Contention Window Priority Factor) is set according to traffic

priority. The relationship between the current CW and the new is shown in the next formula :

$$CW_{new} = [(CW_{current} + 1) * (CWPFactor/16)] - 1$$

The diminished CW is used to reduce the overhead of back off time. Never less, this scheme incurs more packet drops due to the enormous collisions in a higher traffic load.

The Task group E of the IEEE 802.11 working group have developed an extension to the IEEE 802.11 standard called IEEE 802.11e, the goal of this extension is to provide a distributed access mechanism that can provide service differentiation. EDCF combines two measures to provide differentiation. The minimum contention window (CW_{min}) can be set differently for different priority classes, yielding higher priority classes with the smaller CW_{min}. For further differentiation different interframe spaces can be used by different traffic classes. Instead of DIFS an interframe space called Arbitration Interframe Space (AIFS) is used. The AIFS for given class should be a DIFS plus some (possibly zero) time slots. Classes with smaller AIFS will have higher priority. To enhanced the performance and achieve a better medium utilization, the station how getting access to the medium can send as many frames its wish as long as the total access time does not exceed a certain limit TXOpLimit (Transmission Opportunity Limit).

All these schemes do not propose a dynamic adaptation of there parameter to the change of the state of network, and they can't provide a differentiation in heavy load scenario or, do not permit to serve all traffic classes. Some works have been done to propose a scheme, which offers an adaptive method to provide a QoS in 802.11. Here, some proposal scheme in this way:

ARME (Assured MAC extension) [2], in this scheme two type of service were proposed: the Assured Rate Service and Best Effort.

To satisfy the assured Rate Service, ARME propose to compute dynamically the CW, because the CW determines the probability to win the contention. The smaller the CW is, the higher the probability of getting access to the channel. In this case, an assured Rate Service can therefore be provided by assigning to a station the CW corresponding to the bandwidth requested. For this purpose ARME proposes to adjust the CW until the bandwidth requested by a station is reached.

The TCMA scheme seen front, mentions to adjust dynamically the initial value of the CW (Cwsize), this value is updated by the AP, basing itself on the number of stations backlogged.

The distributed QoS D-QoS [5] approach proposes the use of different CWs and Contention Offsets (COs) for differentiation between classes, in order to provide relative differentiation between classes, and also propose

again the possibility of dynamically computing CW/CO values based on the monitored load. However, does not propose any algorithm for this dynamic computation.

Note that all these scheme propose only the dynamic adaptation of the CW parameter, and do not take into account the DCF (AIFS in IEEE 802.11e) parameter.

Motivated by the fact that the AIFS is an important parameter in the 802.11e, and hence the great correlation between this parameter and the concept of the differentiation frame with different priorities, we propose an adaptive scheme of the AIFS.

3. OUR PROPOSAL SCHEME AAIFS: AN EFFICIENT QOS PROVISIONING FOR MAC 802.11 PROTOCOL

Wireless LAN is characterized by low and fluctuation bandwidth link. In addition, the state of the wireless network is continually in change, due to the mobility of the wireless node and wireless intrinsic characteristics (fading, shadow node...).

Within AAIFS, we propose a new MAC 802.11 protocol to allow an efficient adaptation to the instantaneous wireless link fluctuation.

The Adaptive AIFS, behaves in the same manner than the EDCF protocol since it is based on distributed control. In fact, the adaptation is done at terminal level independently from the other terminals that share the medium. In other hand, AAIFS provides a service differentiation through combining the CWmin and the AIFS according to transported stream relevance and instantaneous network condition.

Otherwise, while EDCF assume a static value of AIFS obtained from the QoS beacon frame, which is broadcasted at initiation stage. Within our proposal, the AIFS value is calculated dynamically based on the traffic priority class and the measured application-level packet loss rate.

Note that the AIFS is the minimum time before the terminal can use the transport medium. Consequently, there is a correlation between the station assigned AIFS and the relative QoS accorded to this station. As a result, the smaller AIFS is, the higher probability of taking possession of the channel and thus, bandwidth used by the concerned traffic.

In this context, the difficulty resides, in the choice of the optimal AIFS, which satisfy the application exigency while remaining fairly with the other stations.

The approach we propose, for the computation of AIFS is dynamic and made as follows:

1. Based on the Quality of service consideration (i.e.: the priority of the flow).
2. Based on the numbers of dropped packets, consequently each station compute the percentage of packets dropped on the queues-level, we note this parameter α (α = Number of packed dropped/number of packet generated).

From these two parameters, the station adjusts the AIFS for the optimum value by report to the application requirement, that is to say by increasing or by decreasing the current value of AIFS.

The above explanation describes the basics of the algorithm. However, in the adjustments of AIFS, there are additional aspects to take into account:

- Each traffic or level of priority initializes the value of the AIFS with a value included in an intervals quite specific for each flow $AIFS_init[i] \in [AIFS_min[i], AIFS_max[i]]$,
- The interval define for each flow, should not overlap. In the best case we have $AIFS_max[i] = AIFS_min[i+1]$,
- Definition of percentage of packets dropped, to not exceed for each flow noted $pcg[i]$.

This algorithm is based primarily on the number packets dropped in the queues, motivated by the fact that parameter is a significant indicator on the state of the flow. Considering there is a close relationship between the number of dropped packets, the throughput and delays.

Adaptation algorithm {

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  If ( $\alpha \leq i * 10 / 2$ )
    {AIFS[i]=min (AIFS_max[i], AIFS[i]+SlotTime)}
  Else
    { AIFS[i]=max(AIFS_min[i], AIFS_curr[i]-(( $\alpha / i * 10$ )* SlotTime))}
}
```

Basically in AAIFS, the station begin to increase by a slotTime the AIFS, when the packet loss rate don't exceeds a certain threshold has to know ($i/2 * 10\%$), this gives the fairly consideration between the station. In other word, the flows of low priorities have more chance to take possession of the medium and consequently more probability to transmit.

However when the packet loss rate exceeds the threshold of packet loss define initially for the flow ($i * 10\%$), the station begin to decrease the AIFS by the integer value of ($\alpha / i * 10$) multiplying a slotTime. Note that scenario is more beneficial for the flow of high priorities, because flow of priority i will decrease his AIFS more quickly than the flow of priority $i+1$.

On the other hand, the computed value of the AIFS must be in the interval defined for this flow, if we reach the AIFS_max or the AIFS_min the value of the current AIFS is not updated.

Note that, we provide a different granularity for the AIFS, in the two situation of adaptation (decrease and increase the AIFS).

Typically, AAIFS should increase the performance of the network, because the different flows have more chance to transmit, due to the possibility given to adjust the AIFS to the true need of the flow. On other hand, the priority between the flows is respected.

4. SIMULATION AND RESULTS

To evaluate our approach and compare her performances with EDCF, we use NS-2 (Network Simulator)[9]. Our simulations consist of three traffics (High Priority, Low Priority and Best Effort), all of them generate a CBR (Constant Bit Rate) traffic over UDP (User Datagram Protocol):

- The high priority traffic with a data flows of 96 kbits/s,
- The low priority traffic generate a packet with a data flows of 600 kbits/s,
- The Best effort traffic generates a packet with data flows of 9.6kbits/s.

Each station initiates a flow to a sink station. We have had some fixed numbers of low priority stations (5 and 10), and gradually increased the number of high priority stations to increase the load of system.

In order to differentiate the three traffic flows, we use different CW and AIFS in the two mechanisms EDCF and AAIFS. Concerning the physical parameters, we use the same for each EDCF and AAIFS.

We summarize the different parameters used in the figures (Table. 1, Table. 2 and Table. 3)

Table 1. AAIFS Parameters

	Aifs_init(μ s)	Aifs_min(μ s)	Aifs_max(μ s)	CW_	i_
High Priority	30	30	70	15	1
Low Priority	90	70	110	31	3
Best Effort	150	110	150	64	7

Table 2. EDCF Parameters

	AIFS (μ s)	CW
High Priority	30	15
Low Priority	70	31
Best Effort	110	64

Table 3. Physical Parameters

SIFS (μ s)	SlotTime(μ s)
10	20

In figures (Fig. 4a and Fig. 4b), we can see that the AAIFS scheme gives, the best performances to the high an low priority with regard to throughput then EDCF, AAIFS improve the performance until 16% in some case. We see also that AAIFS gives more stability in it performance then EDCF,

because AAIFS is an adaptive scheme, and the wireless stations are continually adjusting her AIFS for the optimum value. Another observation is in figure (Fig. 4b), we see that adaptation is real, considering that AIFS used in EDCF is smaller then used in AAIFS for the low priority traffic, in spite of this important point, the AAIFS have a similar performances then EDCF, and exceed it in some case.

Figures 4a, 4b Throughput High and Low priority

Looking at the delay of the high priority in figure(Fig. 5a), we see that the two schemes have the same delay in the case where HP(High Priority)=5, and this delay not exceed the threshold of 20 ms. However in case where LP(Low Priority)=10, it is clearly seen that AAIFS gives a best result then EDCF. Note that, the delays are longer (over 50ms), and reach the 90ms in the EDCF scheme. In figure(Fig. 5b) who represents the delay of low priority, we see that AAIFS gives a best result than EDCF. On other hand, before the point HP=7, EDCF gives best result, because the initial value of AIFS in EDCF is smaller then that used in AAIFS, but from the point HP=7 (Heavy load) the station in AAIFS decreases her AIFS , by consequent the delay decrease and that explain the tendency changes. Note that tendency changes show the adaptation of AAIFS to the state of the network.

Figures 5a, 5b Delays High and Low priority

Figures 6a, 6b Packets dropped High and Low priority

Looking at the medium utilization figure (Fig. 7a), we see that the two schemes have almost the same medium utilization, but AAIFS exceed EDCF until 4% in some cases, the explanation of this can be found in figure (Fig. 7b), where the number of dropped packet in the MAC layer are little more important in EDCF than AAIFS, which impact the performance, because a packet dropped in MAC layer is a packet that cause a collision. But generally the two schemes have the same performance in the medium utilization.

5. CONCLUSION AND FUTURE WORKS

In this paper, we have proposed the AAIFS scheme for providing an adaptive mechanism to guaranties a QoS in Wireless LAN.

The AAIFS requires minor change in the MAC Layer proposed by the task group E, the only think to change is the computation of the AIFS.

The Simulation performed show that AAIIFS, efficiently differentiates the flows and gives better performance on throughput, packet dropped and delays compared to EDCF. Our proposal mechanism can achieve a stable performance regardless of the traffic load, which represents the most visible aspects of the dynamic adaptation of AAIIFS.

Future works includes adapting other parameter like CW and particularly the PFactor to achieve a better performance. Another important point to explore is to use an analytical model to compute dynamically the AAIIFS.

Figure 7a, 7b Packet dropped in Mac layer and Medium utilization

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