Protocol Design Issues in WLAN

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Abstract *- IEEE 802.11 wireless LAN (WLAN) is the most widely used WLAN standard today, but it cannot provide QoS support for the increasing number of multimedia applications. Thus, a large number of 802.11 QoS enhancement schemes have been proposed, each one is focusing on a particular mode. This work summarizes all these schemes and presents current research activities. We are proposing in this work to adapt the concept of Quality of Service (QoS) issues in wireless LAN scenario. A deep comparative analysis has been done with leader based schemes and results have been verified using OPNET simulator.*

Keywords: IEEE 802.11, Wireless LAN (WLAN), Quality of Service (QoS), Medium Access Control (MAC), 802.11e

1 Introduction

During recent years the IEEE 802.11 WLAN standard has been widely deployed as the most preferred wireless access technology. Due to the inherent capacity limitations of wireless technologies, the 802.11 WLAN easily becomes a bottleneck for communication. In these cases, the Quality of Service (QoS) features of the 802.11e standard will be beneficial to prioritize, for example voice and video traffic over more elastic data traffic.
IEEE 802.11e is an approved amendment to the IEEE 802.11 standard that defines a set of Quality of Service enhancements for wireless LAN applications through modifications to the (MAC) layer. The standard is considered of critical importance for delay sensitive applications such as voice over wireless IP and streaming Multimedia. EDCA has received most attention recently, and it seems that this is the WLAN QoS mechanism that will be promoted by the majority of vendors

Quality of service is the ability to provide different priority to different applications, users, or data *flows*, or to guarantee a certain level of performance to a data flow.

2 Literature Review

The 802.11 WLAN technologies provides people with ubiquitous communication and computing environment in offices, hospitals, campuses etc. Simultaneously, people start to look at their laptops or PDAs to deliver the broadband multimedia applications currently being developed. These applications include streaming media, interactive collaboration, videoconferencing and downloadable content such as multimedia messaging. However, multimedia applications require a certain quality of service (QoS) support such as guaranteed bandwidth, delay, and jitter and error rate. Guaranteeing those QoS requirements is a challenging task with regard to 802.11 WLAN protocols and Medium Access Control (MAC) functions.

Wireless networks have proven their ability to send data at higher rates and robust in so many environments. However, providing QoS, to delay sensitive data is still a challenging task. Several proposals have been presented in order to enhance the performance and providing guarantee QoS in IEEE 802.11e in order to transmit data those required high bandwidth in addition with their delay sensitive nature.
In [1], authors have proposed a new MAC scheme that dynamically adapts to traffic changes without degradation of delay in the case of low traffic load. Focusing on the aggregate throughput and potential QoS support. The key idea is to divide the virtual frame into two parts, i.e., schedule part and contention part which is named as Scheduled Random Access Protocol (SRAP), and also to enable each node to reserve a slot in schedule part. Nodes either transmit in schedule period without collision or contend for the channel to transmit in contention period but are not allowed to transmit in both of two periods in one super frame.

In [2], authors have proposed a MAC protocol based on 802.11 which can provide QoS to real time applications. A global solution for MAC QoS improvement based on integrating the information from the PHY layer and information from the Network layer. The PHY and MAC layers interactions uses information obtained from PHY layer, and distinguish between measured value parameters (BER, SNR, etc.) and those with values defined by the Standard according to the concerned physical layer (aSlotTime,aCWmax, aCWmin, DIFS, SIFS, PIFS, etc.). MAC protocol provides priority to real time traffic by using contention window based service differentiation method.
In [3], authors have proposed the MMPP/G/1/K (Markov Modulated Poison Process) queuing model with the MAC layer service time to analyze the throughput and the delay performance of IEEE 802.11 MAC protocol in wireless LAN.

Finally, the 802.11 MAC layer provides for two other robustness features: CRC checksum and packet fragmentation. Moreover, packets may be dropped either due to the buffer overflow or serious MAC layer contentions and the packet delay increases dramatically when the number of active stations increases. Since Internet traffic has busty and unpredictable characteristics the use of the MMPP as the input traffic model well describing the burstiness.

In [4], authors have proposed a novel algorithm for channel allocation in bandwidth WLAN and an improved resource reservation mechanism applied into IEEE 802.11 MAC protocol. WLAN channel is utilized in sequence according to the traffic delay.

In [5], authors have proposed a new mechanism of IEEE 802.11 MAC protocol over wireless mesh networks that support integrated voice and data services. . MAC is distributed and cooperative and works for multipoint-to-multipoint communication.

In [6], authors have proposed a fuzzy logic-based method for assessing and improving Quality of Service (QoS) in wireless networks. Fuzzy Inference System (FIS) is a mechanism which has been successfully used in several processes requiring decision making and control.

In [7], authors have proposed precise mechanism called Deficit-based Modified -Self-Clocked Fair Queuing (DM-SCFQ) into the relevant MAC protocol to avoid over saturating the medium via admission control (AC) and service differentiation through traffic scheduling.

In [8] authors have proposed an enhancement for in heritance of 802.11 MAC protocols which mitigate access point (AP) bottleneck effect and improve the VoIP transmission capacity.

3 Proposed Solution

The on going research on Protocol Design Issues in WLAN comprises performance implications due to different factors. The effects of these factors or problems areas have been addressed by using different tools, algorithms, models, simulations and design modifications. These approaches/methodologies are discussed in subsequent paragraphs:

Demanding for real-time multimedia applications in wireless access is increasing, and this has driven recent research in QoS. The upcoming IEEE 802.11e standard will give a firm impulse towards QoS provisioning in 802.11 wireless LANs. In parallel, during the last years, other enhanced MAC schemes have also been proposed to improve QoS metrics. Some of these approaches modify the 802.11e mechanism in providing guaranteed QoS.

Improvements can be provided over Enhanced Distributed Channel Access (EDCA) by tuning up the specific parameters of priority queuing like CW, PF and AIFS.

To improve the QoS capabilities provided on WLAN links, the IEEE 802.11 committee is crafting the 802.11e specification, which will provide QoS enhancements at the MAC layer that allow WLAN systems to efficiently stream audio and video data. We'll look at the existing 802.11 MAC layer and examine the challenges it provides. We'll further discuss by examining the MAC layer provided by 802.11e.

In general, the term QoS refers to set of qualitative and quantitative traffic characteristics (e.g. throughput, service interval, packet size, delay, jitter, priority, type, etc.), which describes a traffic flow in support of a specific application.

The proposed work is to describe the priority schemes of the EDCA mechanism of the IEEE 802.11e standard. EDCA provides class-based differentiated QoS to IEEE 802.11 WLANs. The main contribution of this work as opposed to other works is that the model predicts the throughput, delay and frame dropping probabilities of the different traffic classes in the whole range from a lightly loaded, non-saturated channel to a heavily congested, saturated medium. Furthermore, the model describes differentiation based on different AIFS-values, in addition to the other adjustable parameters (i.e. contention window sizes and persistence factor) also encompassed by previous models. AIFS differentiation is described by a simple equation that enables access points to predict at which traffic loads starvation of a traffic class will occur.

EDCA enhances DCF by allowing four different access categories (ACs) at each station and a transmission queue associated with each AC. Each AC at a station has a conceptual module responsible for channel access for each. Hence each of the four transmission queues (and the associated ACs) on a station is represented by one back off instance. The channel access between different back off instances on a station is not completely independent due to the virtual collision handling between the queues on the station. If two or more back off instances on the same station try to access the channel in the same timeslot, the station attempts to transmit the frame of the highest priority AC, while the lower priority frames will go through back off.

The traffic class differentiation of EDCA is based on assigning different access parameters to different ACs. First and foremost, a high-priority AC, i, is assigned a minimum contention window, W0, i, that is lower than (or at worst equal to) that of a lower-priority AC. At a highly loaded (or “saturated”) medium, the post-back off of the high-priority AC will normally be smaller than the post-back off of a low-priority AC. This results in an average higher share of the channel capacity, because the high-priority AC will on average have to refrain from the channel for a shorter period of time than the low priority AC.

Another important parameter setting is the AIFS value, measured as a Short Inter frame Space (SIFS) plus an AIFSN number of timeslots. A high-priority AC is assigned an AIFSN that is lower than (or at worst equal to) the AIFSN of a lower-priority AC. The most important effect of the AIFSN setting is that the high-priority AC normally will be able to start earlier than a low priority AC to decrement the back off counter after having been interrupted by a transmission on the channel. At a highly loaded channel where the decrementing of the back off counter will be interrupted by packet transmissions a large number of times, the back off countdown of the high priority AC will occur at a higher

average speed than that of the lower-priority AC. As the wireless medium gets more and more congested, the average number of empty timeslots between the frames transmitted by the higher-priority ACs might be lower than the AIFSN value of the low-priority AC. At this point, the AC will not be able to decrement its back off counter, and all packets will finally be dropped instead of being transmitted. This is referred to as "Starvation". Other differentiation parameters that may be adjusted in 802.11e (and which are also explicitly or implicitly included in the model proposed below) are the maximum contention window *Wi* and persistence factor (PF) of each AC, *i*.
In the non-saturation situation, our model accounts for "post-back off" of an AC, although the queue is empty, according to the IEEE 802.11 standard. If the packet arrives in the queue after the" post-back off" is completed, the listen-before-talk (or CSMA) feature of 802.11 is also incorporated in the model.

3.1 Priority based on Contention Windows (CWs) and Exponential Back off

For each AC, *i* (*i* = 0... 3), we let *Wi,j* denote the contention window size in the *j*-th backoff stage, i.e. after the *j*-th unsuccessful transmission; hence *Wi*,0 = *CWi*,min + 1, where the recommended values for
CWi,min are listed in Table 1.

Table 1. Recommended (default) parameter settings for 802.11e

	AC[3]	AC[2]	AC[1]	AC[0]
AIFSN	2	2	3	7
CWmin	3	7	15	15
CWmax	15	31	1023	1023
Retry Limit (long/short)	7/4	7/4	7/4	7/4

We also denote *j* = *mi* as the *j*-th back off stage where the contention window has reached *CWi*,max + 1; the window will no longer be increased in the subsequent back off stages. Hence, *mi* = log2((*CWi*,max + 1) / *CWi*,min + 1.

Wi,j= { 2jWi,0;
2m,I Wi,0 =CWi,max; (1)
j=mi,………Li (2)

(1) In the special case where *mi* ≤ *Li*, Eq. (1) is reduced to *Wi,j* = 2 *jWi*,0 for *j* = 0, 1, ..., *Li*.

3.2 Priority based on Inter-Frame Spaces (IFSs)

When a back off instance senses that the channel is idle after a packet transmission, it normally waits a guard time called the Distributed Inter-Frame Space (DIFS) during which it is not allowed to transmit packets or do back off countdown. The duration of DIFS is the sum of a SIFS and two time slots. The HC is allowed to enter the channel after only waiting one time slot (in addition to SIFS) and it does not need to go through "post-backoff" before accessing the channel. Moreover, certain packets – including the Clear-To-Send (CTS) and Acknowledgement (ACK) packets – can be sent after only waiting SIFS. This gives maximum priority to this traffic, and ensures that a data exchange (such as a data transmission followed by an ACK) can be considered nearly an atomic transaction. Instead of using DIFS, each AC[i] of 802.11e uses an Arbitration Inter-Frame Space (AIFS[i]) that consists of a SIFS and an AIFSN[i] number of additional time slots. In this work we define *Ai* as:

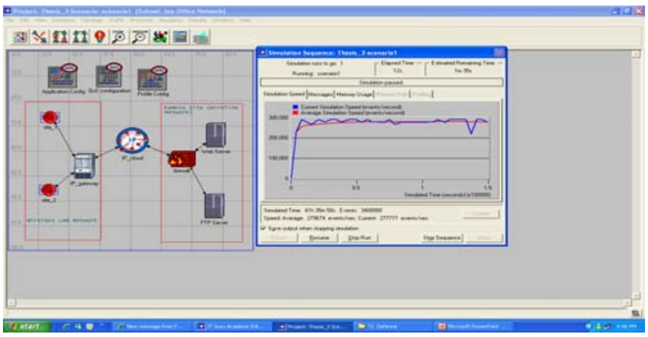
Ai = AIFS[i] – min (AIFS[i]) ≥ 0 i = 0... N – 1 (1)

Where *N* is the number of different ACs (i.e. normally four). The 802.11e standard mandates that *AIFSN*[*i*] ≥ 2, where the minimum limit of 2 slots corresponds to the DIFS interval. The use of AIFSN to differentiate between ACs has two consequences.

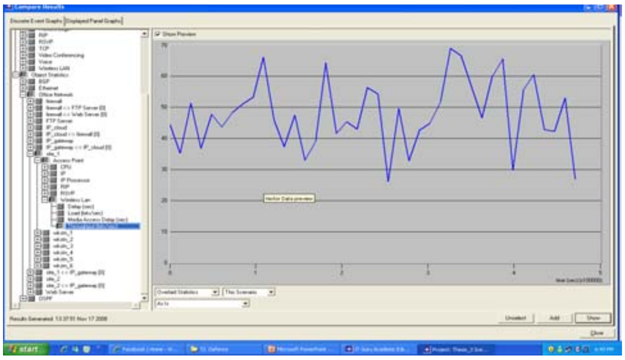
4 Result and Analysis

The results are calculated numerically and validated against simulations, using 802.11b and the default parameter settings for 802.11e. We observed that the expansion of the model to cover unsaturated conditions gave a relatively good match with simulations. AIFS differentiation and starvation did also match well.

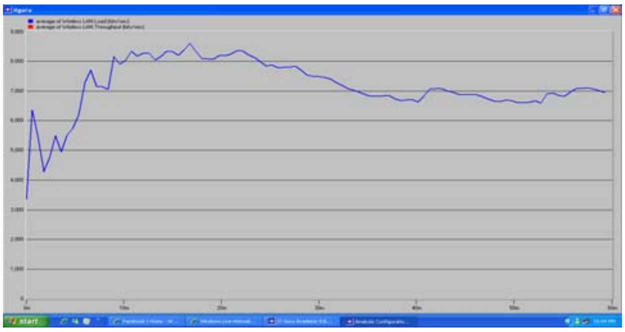
4.1 Speed vs. Time (events/seconds)



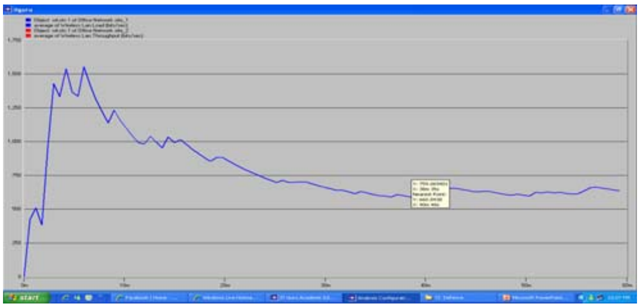
4.1.1 Throughput (bits/sec) from Site-1 Access Point (AP)



4.1.1.1 Load (bits/sec) from Site-1 Access Point (AP)



4.1.1.2 Object: wkstn1 of Office Network site 1



5 Conclusion and Future Work

This work provides an approximate expression to determine the starvation point of different access categories (ACs) at a given traffic load and at given channel access parameters, such as the AIFSN assigned to each channel. (The other differentiation parameters also play a role in this expression as they indirectly influence the traffic load on the channel.) By measuring the channel load and by knowing the AIFSN assigned to each AC, the access point is able to tell when the starvation conditions are present for any of the ACs, independent of whether packets of these ACs are attempted for transmission.

The aim in future work will be to further evaluate and enhance our solution. Regarding the enhancement, we plan to add support for e.g. dynamic resource reservation, removing and rescheduling reserved TXOPs for traffic streams that have completed their transmission and handling stations that move in to and out from the network.

References

[1] Xuejun Tian, Xiang Chen, Tetsuo Ideguchi and Takashi Okuda "SRAP: Scheduled Random Access Protocol Achieving High Throughput and Traffic Adaptively in WLANs". Proceedings of the Third International Conference on Wireless and Mobile Communications (ICWMC'07) 0-7695-2796-5/07

[2] Mayank Mishra and Anirudha Sahoo "An 802.11 based MAC Protocol for Providing QoS to Real Time Applications" 10th International Conference on Information Technology 0-7695-3068-0/07

[3] Chul Geun Park and Ho Suk Jung and Dong Hwan Han "Queuing Analysis of IEEE 802.11 MAC Protocol in Wireless LAN ". Proceedings of the International Conference on Networking, International Conference on Systems and International Conference on Mobile Communications and Learning Technologies (ICNICONSMCL'06) 0-7695-2552-0/06

[4] Liu Yanbing, Zhai Congcong and Sun Shixin "A Novel Algorithm of Channel Resource Allocation in IEEE 802.11 WLAN ". 2007 IFIP International Conference on Network and Parallel Computing – Workshops 0-7695-2943-7/07

[5] Tzu-Jane Tsai and Ju-Wei Chen "IEEE 802.11 MAC Protocol over Wireless Mesh Networks: Problems and Perspectives ". Proceedings of the 19th International Conference on Advanced Information Networking and Applications (AINA'05) 1550-445X/05

[6] Mohammad Saraireh, Reza Saatchi, Samir Al-khayatt, Rebecca Strachan"Development and Evaluation of a Fuzzy Inference Engine System to Incorporate Quality of Service in IEEE 802.11 Medium Access Protocol" 0-7695-2629-2/06/$20.00 (c) 2006

[7] José R. Gallardo a*, Paúl Medina a, Weihua Zhuang b "QoS Mechanisms for the MAC Protocol of IEEE 802.11 WLANs ". Proceedings of the 2nd Int'l Conf. on Quality of Service in Heterogeneous Wired/Wireless Networks (QShine'05) 0-7695-2423-0/05

[8] LU Yang1, ZHU Shengqing2, LIN Xiaokang1 "Enhanced MAC protocol for voice communication in IEEE 802.11 WLAN". Second International Conference on Digital Telecommunications (ICDT'07) 0-7695-2910-0/07