Study of Virtual Admission Control Scheme in Wireless LAN

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Abstract

With the promotion of wireless technologies, more and more devices are built-in wireless capabilities. The traditional wireless technology confronted with some shortcomings in practical use, such as insufficiency for bandwidth, and lack of guaranteed the QoS (Quality of Services). In order to provide differential qualities for various kinds of services, several researches were proposed by scheduling traffic with priority or reservation at packet level. In this paper, we study the QoS issue at connection level and propose an algorithm, named VAC (Virtual Admission Control), to regulate the call request for the provisioning of QoS in wireless LAN by measuring the performance through virtual MAC and virtual source. VAC can admit some requested demands without deteriorating the wireless medium too much. And simulations are performed to analyze the performance of the proposed scheme.

I. Introduction

Wireless LAN is getting widespread with more and more mobile devices. It is convenient to use wireless LAN to attach to the Internet as long as you want to .The bandwidth in wireless LAN is more valuable than that of in wired LAN. However, the bandwidth requirements for both environments in accessing Internet services are the same and, therefore, the effective utilization of the limited bandwidth in wireless environment has become an important issue when deploying wireless services.

With the fast promotion of the mobile communications, there are more applications running on wireless devices. At first, people use radio sets to communicate with each other. Gradually, people find that it's more convenient to do some works such as transmitting data and controlling electric equipment by using wireless technologies. Many wireless technologies have been developed to provide variable services to people. For example, General Packet Radio Service (GPRS) combines the characteristics of telecom and datacom to transmit voice and data at the same time. Some technologies suitable for small ranges, such as Bluetooth and wireless LAN, are also popular recently. Each technology has its own advantages and disadvantages. Compared to Bluetooth, wireless LAN has more advantages than Bluetooth due to its higher data rates and large transmission coverage range. Wireless LAN has been proposed and standardized by the IEEE 802.11 Working Group [1, 2]. IEEE 802.11 project has many Task Groups (TGs) that build up standards for some important issues.

Two basic operation scenarios, named DCF (Distributed Coordination Function) and PCF (Point Coordination Function), are provided in 802.11 for the access in wireless environment. Although both of PCF and DCF functions are defined in 802.11, PCF is optional. Many vendors do not implement the function of PCF owing to the complexity of managing the pooling list. In DCF, the IFS (inter-frame spaces) is defined as the interval between two consecutive frames (including management, control and data frames). And several types of IFS are applied to achieve the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) objective. The relationship among various types of IFS is shown in figure 1. In this paper, the proposed admission control scheme is considered to be applied for DCF operation.

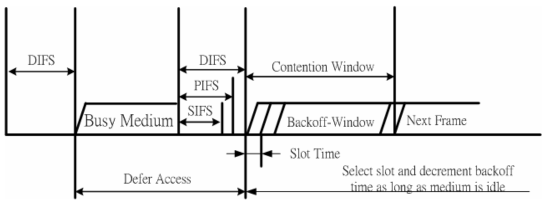

Figure 1. Relationships among various IFS

II. QoS issue in WLAN

As mentioned in previous section, we can find some ways to provide priority or QoS in wireless LAN. First, from the concept of the PCF functions, the shorter the IFSs are, the higher the priority is. So we can adjust the inter frame duration of a mobile station that has to wait until the medium is idle. We can also change the backoff time after a mobile station has been waiting for a DIFS time duration. On the contrary, we can let the higher priority station have shorter backoff time. In [3], they use two methods, one is shorter random backoff time and the other is shorter IFSs. They divide the stations into high priority and low priority. For the high priority stations, the IFSs are changed from DIFS to PIFS and random backoff time generation function are from $\lfloor ranf() \cdot 2^{2+i} \rfloor * slot\_time$ to $\lfloor ranf() \cdot 2^{2+i}/2 \rfloor * slot\_time$, where i is the number of consecutive times a station attempts to send a frame, *ranf()* is a uniform variation in (0,1), and $\lfloor x \rfloor$ represents the largest integer number less than or equal to x. For the low priority stations, the IFSs are still DIFS and the random backoff time is $2^{2+i}/2 + \lfloor ranf() \cdot 2^{2+i}/2 \rfloor$. In [9], they assume the traffic can be sorted as TCP and UDP flows and they also change the backoff generation function and IFSs. The item " 2^{2+i} " in the backoff generation function $\lfloor 2^{2+i} \cdot rand() \rfloor * slot\_time$ has been replace by P_j^{2+i} where P_j is a priority factor of the wireless terminal *j*. As for the IFSs, they use different DIFS, say $DIFS_j$ where $DIFS_{j+1} < DIFS_j$. Except for the modifications from the MAC specification, some other schemes are described in the following paragraphs.

A. SWAN(Service Differentiation in Stateless Wireless Ad Hoc Networks)

SWAN is proposed by Gahng-Seop Ahn, Andrew T. Campbell, Andras Veres, Li-Hsiang Sun in [5].The main idea is that if each mobile station can govern itself then the traffic condition in wireless medium will be much better. There are many methods mentioned in the SWAN model as shown in figure 2.

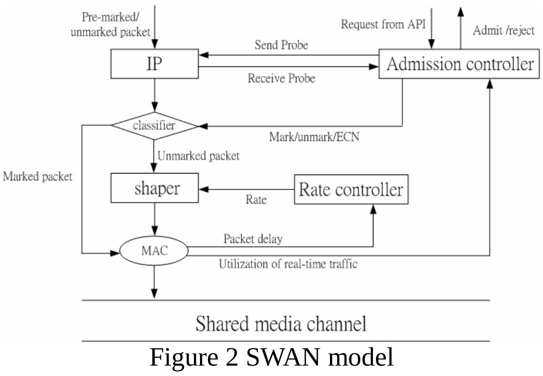

Figure 2 SWAN model

In figure 2, the classifier is capable of differentiating real-time and best effort packets, forcing the shaper to process best effort traffic but not real-time packets. The shaper is similar to a leaky bucket and its goal is to delay best effort packets in conformance with the rate calculated by the rate controller. The admission controller tests only at the source by estimating local available bandwidth availability. The admission controller probes the network between the source and the destination to determine whether the end-to-end bandwidth is sufficient or not.

Among the methods mentioned above in SWAN, the most important methods are the rate controller and the admission controller. The rate controller is used for the management of UDP and TCP best effort traffic and sender-based admission control for UDP real-time traffic. The rate controller determines the departure rate of the shaper using the AIMD (Additive Increase Multiplicative Decrease) rate control algorithm based on the feedback from MAC. The feedback information used by the rate controller represents the packet delay measured by the MAC layer. The admission controller will send probe to the IP network and make decision according to the receiving probe.

SWAN is a simple, distributed and stateless network model that can support soft real-time services and service differentiation in wireless ad hoc networks. It is independent of the underlying MAC layer and can be suited for various physical and data link wireless standards.

B. VS/VMAC

In [10] and [11], the VS/VMAC (Virtual Source/Virtual MAC) methods are proposed based on traffic statistics. The main idea is to construct a VMAC whose behaviors are mostly like the real MAC including contention, backoff and drop mechanism, but there are some differences. For example, the collision detection is determined in real MAC by the expiration of the timer. However, the collision detection determined in VMAC is by detecting if the medium is busy or not, the packet is not actually sent. Whenever the VMAC encounters collision, it will also retry to send the packet until reaching the retry limit. The packet delay could be affected by various factors including packet transmission rates and packet sizes. The faster the packet rates, the smaller the packet size is. Higher rate of packet makes the radio channel busier and causes more collisions and, therefore, increases the average contention window. In addition, higher packet rates mean small data packets, which result in larger protocol overhead. Thus at the same bit rate, there is always a tradeoff between packetization delay and MAC delay for network applications.

C. IEEE 802.11e

802.11e is working in progress and currently has been developed to Draft 8.0 in February 2004 before the thesis is completed. The purpose of 802.11e is to solve the shortcomings of the legacy MAC for QoS. The MAC of 802.11e architecture is shown in figure 3. 802.11e adds some features that can support QoS and service differentiation. Conceptually speaking, the differences between 802.11e MAC and legacy MAC are the quantification of the QoS. Traffic has been differentiated into 8 priorities (also called traffic categories: TC) and these 8 TCs are mapped into 4 ACs (access categories) as list in table 1. Besides, there are multiple queues, instead of one queue in legacy MAC in order not to let the former lower priority data block the latter higher priority data as shown in figure 4.

Table 1. 802.11e Priority and Access Category

	(UP - Same as 802.1D User Priority)	Designation	Category (AC)	(Informative)
lowest	1	BK	AC_BK	Background
	2	—	AC_BK	Background
	0	BE	AC_BE	Best Effort
	3	EE	AC_VI	Video
	4	CL	AC_VI	Video
	5	VI	AC_VI	Video
	6	VO	AC_VO	Voice
highest	7	NC	AC_VO	Voice

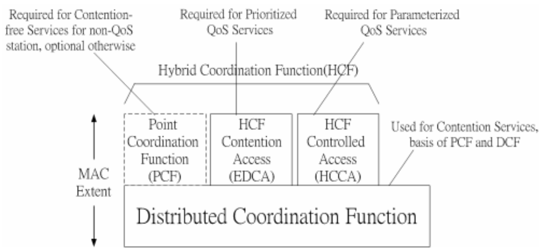

Figure 3. MAC architecture

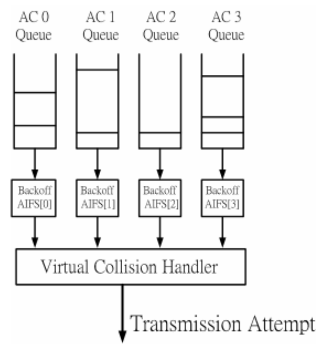

Figure 4. Reference implementation model

III. Virtual Admission Control

802.11e prioritized QoS can provide service differentiation by using traffic categories and VS/VMAC algorithms can provide a channel status estimation without loading the wireless medium. Each traffic session has its own interval or session time and it is not infinite. If there are many multimedia sessions which are established at the same time, the estimation of the VS/VMAC algorithm will be much inaccurate. We propose an algorithm called Virtual Admission Control (VAC) to provide better QoS to multimedia traffics.

A. D Factor

From our simulation [12], we found that the delay difference (i.e. the gap between the RMAC and VMAC) is gradually increasing as the number of the mobile node is increasing and the VMAC delay is always higher than the RMAC. If we use the VS/VMAC to estimate the delay of the channel, it will be more and more inaccurate. To make VS/VMAC more precise, we define a "difference factor (*D*)" to indicate the ratio of the RMAC delay to the VMAC delay. With the *D* factor, we can use VS/VMAC to estimate the $delay_V$ closer to the $delay_R$. *D* factor will have influences on how the VAC operates loosely or tightly. If the VAC operates more conservative, the admitted demands will be low and the MAC delay will not increase too much. In the simulation, we will use different *D* factor to see the MAC delay.

B. FP Traffic

As we mentioned before, we use the best effort traffic to be upgraded as the high priority as demanded traffic to detect the MAC delay. We define this kind of traffic as "fake priority (*FP*)" traffic. There are some reasons that we use best effort traffic as the high priority traffic to probe the channel status. One of the reasons is that people would rather see the connection being rejected instead of being admitted with a poor QoS. If the channel is crowded, the *FP* traffic will be dropped during probing instead of the real high priority data. Another reason is that if the *FP* traffic can be transmitted successfully, the algorithm wastes no extra resources to estimate channel status. If there is no best effort traffic, we will only use the results estimated by VS/VMAC to do VAC.

C. VAC Algorithm

The proposed VAC algorithm regards the the *FP* (best effort) traffic or the VS/VMAC as the "virtual admitted" traffic stream to measure whether the received QoS complies with the requirement of the request connection. The proposed VAC algorithm is illustrated as follows:

Start

$rate_V = (session_R + 1) * rate_R$

New_traffic

Step 1:

if $(delay_R < delay\_tolerance$ *AND* $D*delay_V < delay\_toleranc)$

then admit;

else

go to step 2;

Step 2:

if $(delay_R < delay\_tolerance$ *OR* $D*delay_V < delay\_toleranc)$

then go to step 3;

else

reject;

Step 3:

if there exists best effort traffic

then go to step 4;
else
admit;

Step 4:
Swtich AC of new traffic use FP traffic to probe for CET time
then go to step 5;

Step 5:
If ($delay_{R\_before}$ + $delay_{R\_after}$)/2 < delay_tolerance
then admit;
else
reject;

End

$Session_R$ is the current session counts of the real traffic. *D* is the difference factor. *Delay_tolerance* is the delay tolerances of the demanded traffic.

FP_VO is the *FP* traffic with the AC_VO traffic category while *FP_VI* is the *FP* traffic with the AC_VI traffic category. $Delay_{R\_before}$ is the $delay_R$ calculated before new traffic demands and $delay_{R\_after}$ is the $delay_R$ calculated after new traffic demands. $Rate_V$ and $Rate_R$ are the traffic rate input to the VMAC and RMAC respectively. Since we want to use VS/VMAC to estimate the MAC delay when a new session is admitted, we have to increase the traffic rate of the VMAC by 1 session to simulate the condition.In the first step, the sender has to check whether the previous $delay_R$ is smaller than *delay_tolerance* or not, and use $delay_V$ with the *D* factor modification to estimate the MAC delay if a new session is admitted. Step 1 is the strict condition. Step 2 is the loose condition of step 1. Step 3 checks if there exists best effort traffic. With best effort traffic, we can use the traffic to be upgraded as the high priority traffic to probe the channel for *CET* time. When *CET* time finishes, we calculate the previous MAC $delay_R$ and the $delay_R$ after the demands to see if there is sufficient resource. *FP_VO* is the *FP* traffic with the AC_VO traffic category while *FP_VI* is the *FP* traffic with the AC_VI traffic category. $Delay_{R\_before}$ is the $delay_R$ calculated before new traffic demands and $delay_{R\_after}$ is the $delay_R$ calculated after new traffic demands. $Rate_V$ and $Rate_R$ are the traffic rate input to the VMAC and RMAC respectively. Since we want to use VS/VMAC to estimate the MAC delay when a new session is admitted, we have to increase the traffic rate of the VMAC by 1 session to simulate the condition.

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IV Performance Simulations

The simulation architecture is shown in figure 5 and the simulation program is written in C. At the top of the architecture, there are some global variables to record much information about the simulation such as counters, timers and system status. The right side of figure 5 is the detailed portion of a mobile node. A mobile node consists of some parts such as 802.11 basic mechanisms, VS/VMAC, 802.11e multiple queues and the proposed VAC algorithm. Each node has its own traffic generator to simulate the background and the demanded traffic including best effort, video and voice.

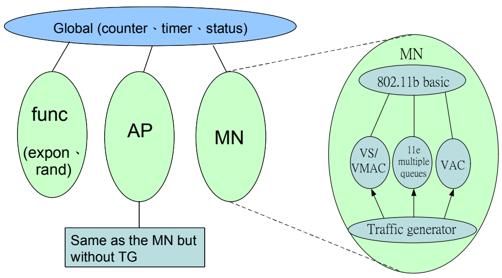

Figure 5. Simulation architecture

In our simulation, we assume that the channel is error-free and all of the mobile nodes are in the same BSS. The buffer of each mobile node concerned is infinite (i.e. the packet will never be dropped due to buffer overflow). The session time, when a new request is admitted, is Poisson distributed with mean 2 minutes to emulate a telephone call or a short video conference call. The tolerance of *CET* time, setup time, is defined as 1 second. The channel rate is 11 Mbps and other parameters used in our simulation are listed in table 2. Finally, the number of mobile nodes which transmits packets is from 1 to 20. We use the RTS/CTS mechanism to solve the hidden node problem. The collision will only occur when there are at least two stations choosing the same timeslot to send packets after backoff procedure and will never occur during transmitting. Voice traffic category is modeled as 32 Kbps CBR (constant bit rate) and video traffic is modeled as 200 Kbps CBR. Best effort traffic has infinite long traffic at 350 Kbps as the background traffic. The rate of voice and video are the same as in [4]. The background traffic will influence and load the channel. Under fewer mobile nodes condition, the total required bandwidth is less than the provided bandwidth. And when the number of mobile node increases, the demanded bandwidth is larger than the provided and the channel will go into saturation. We want to see if the prioritized QoS and the VAC mechanism work or not under over-load and non over-load conditions.

Table 2. Simulation arameters

Slot time	20 us
SIFS	10 us
DIFS	50 us
PHY Header	192 us
AirPropagationTime	1 us
CWmin	31
CWmax	1023
RetryLimit	4
PacketSize	1500 bytes
Length of RTS	PHY Header+20 bytes
Length of CTS	PHY Header+14 bytes
Length of Ack	PHY Header+14 bytes

The results of using VAC are shown in the following. We change the delay threshold of voice and video to see the results. In the following simulation, we use thd_voice and thd_video to represent the delay threshold of voice and video respectively. For example, “thd_voice = 10ms” means that the delay tolerance of voice is no more than 10ms. From figures 6 and 7, we found that the specific QoS can be maintained by restricting the requested demands. It is the tradeoff between the connection number and the QoS but, in fact, we can admit small number of requests and do not deteriorate the QoS too much. Without admission control, the delay will increase to an unacceptable degree that all of the applications, including background traffic, will be with poor QoS.

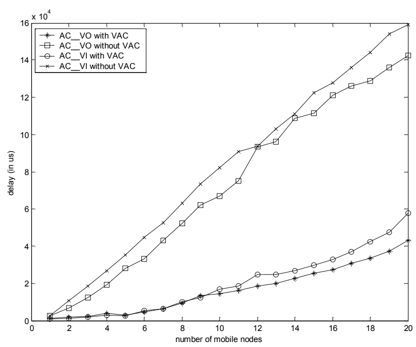

Figure 6. Delay comparison of VAC and none-VAC with *thd*_voice =20ms and *thd*_video = 30ms

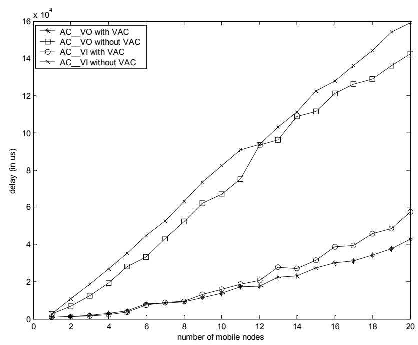

Figure 7. Delay comparison of VAC and none-VAC with *thd*_voice =30ms and *thd*_video = 50ms

Besides, the relationships between blocking rate and request demands counts are shown in figures 9 and 10. For example, the blocking rate of voice and video will increase from 11 nodes and 13 nodes respectively as shown in figure 9. In figure 9 the delay threshold of voice and video is 20ms and 30ms. Take figures 9 and 10 for comparison, the voice delay threshold is 20ms and 30ms, respectively. The blocking rate is increasing from 11 to 15 nodes. The smaller the delay threshold is, the faster the blocking rate increases. Also take a look at the requested demands counts in figure 7, before the blocking rate increases the VAC algorithms have admitted about 70 requests (voice requests + video requests) and do not have much influences on the MAC delay.

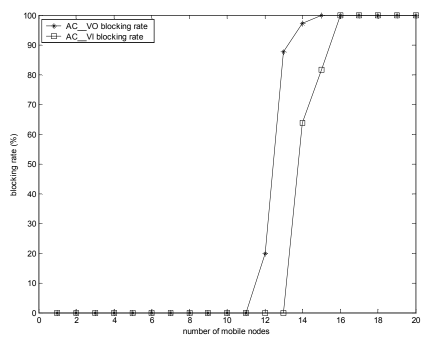

Figure 9. Blocking rate with *thd*_voice = 20ms and *thd*_video = 30ms

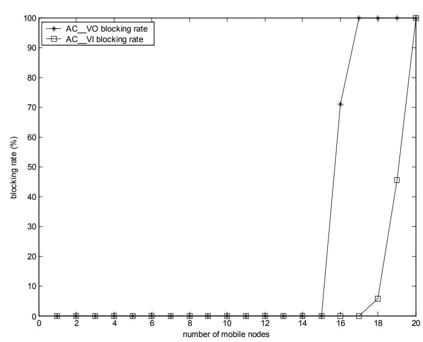

Figure 10. Blocking rate with *thd*_voice = 30ms and *thd*_video = 50ms

V Conclusions

In this paper, we propose VAC to do admission control by using the heuristics of traffic probe over the algorithm of 802.11e multiple queue architecture. The main concept is that whenever there is a traffic demand for some mobile stations, and the station will estimate the current QoS parameter by using traffic stream with FP priority or the VS/VMAC to see if there is enough bandwidth in the wireless channel. If the current resources are not sufficient then the demand will be rejected or admitted otherwise. Thus, the provisioning of QoS is achieved by self-governing mechanism. In order to estimate the current delay but not to load the wireless medium, we use VS/VMAC algorithm with *D* factor to estimate the current channel status as precise as possible. The experimental results show that the total admitted new requests with VAC is better than conventional WLAN. And the delay of VAC is much better than that without VAC. The reason is that, all requested demands will be admitted immediately and they will have much influences on the wireless QoS without VAC. In this paper, we only consider the admission control of new connections. However, in addition to providing new connection requests, an AP has to handle the handoff connections. Therefore, it is interesting to consider the admission control by using the QoS-aware in a multiple AP environment.

Acknowledgements

This research is supported in part by the grants from the Ministry of Transportation and Communications (MOTC-SATO-93-14) and the National Science Council (NSC 93-2213-E-008-034).

REFERENCES

[1].http://grouper.ieee.org/groups/802/11/index.html

[2].M.Visser and M.ElZarki, "*Voice and data transmission over an 802.11 wireless network*", Proceedings of PIMRC, Toronto, Canada, Sept. 1995.

[3].Dr-Jiunn DENG, Ruay-Shiung Chang, "*A Priority Scheme for IEEE 802.11 DCF Access Method*", IEICE Trnasactions on Communications, Vol.E82-B, No.1, Pages:96-102, Jan. 1999

[4].Gahng-Seop Ahn, Andrew T. Campbell, Andras Veres, Li-Hsiang Sun, "*SWAN: Service Differentiation in Stateless Wireless Ad Hoc Networks*", Proc. IEEE Infocom 2002, Jun. 2002

[5].Gahng-Seop Ahn, Andrew T. Campbell, Andras Veres, Li-Hsiang Sun, "*Supporting Service Differentiation for Real-Time and Best-Effort Traffic in Stateless Wireless Ad Hoc Networks (SWAN)*", IEEE Transactions on Mobile Computing, Vol.1, No.3, Pages:192-207, Jul. 2002

[6].D. Pong and T. Moors, "*Call Admission Control for IEEE 802.11 Contention Access Mechanism*", Proc. Globecom 2003, Pages: 174-8, Dec. 1-5, 2003

[7].http://www.merl.com/reports/docs/TR2003-122.pdf,"*A New Measurement- Based Admission Control Method for IEEE802.11*", Mitsubishi Electric Research Laboratory, 2003

[8].http://www.research.avayalabs.com/techreport/ALR-2002-021-paper.pdf, "*A New Admission Control Metric for VoIP Traffic in 802.11 Networks*"

[9].I. Aad, and Claude Castelluccia, "*Differentiation Mechanisms for IEEE 802.1.*", Proc. IEEE Infocom 2001, Pages:209-218, Apr. 2001

[10].Andras Veres, Andrew T. Campbell, Michael Barry, "*Supporting Service Differentiation in Wireless Packet Networks Using Distributed Control*", IEEE Journal on selected areas in communications, Vol.19, No.10, Pages: 2081-2093, Oct. 2001

[11].Barry, M., Campbell, A.T , A. Veres , "*Distributed Control Algorithms for Service Differentiation in Wireless Packet Networks*", IEEE Infocom 2001, Vol.1 , Pages:582-590, Apr. 2001

[12].Yuan-Long Lee, *A Study of Virtual Admission Control in Wireless LAN*, master thesis, Dept. of Communication Engineering, National Central University, June, 2004.