A Wireless LAN MAC Protocol for Supporting Multiclass Traffics

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Abstract

The IEEE 802.11 wireless Local Area Network (LAN) provides high bandwidth for data transmission in low tier wireless networks. However, the access method of IEEE 802.11 cannot meet the Quality of Service (QoS) requirements for all kinds of traffics. In this thesis, we propose some modifications and mechanisms for the IEEE 802.11 Medium Access Control (MAC) protocol to provide the QoS guarantee according to the characteristics of the traffic. We adopt four different traffic classes: namely conversational class, streaming class, interactive class, and background class, proposed by the UMTS [3]. The Connection Admission Control (CAC) and the scheduling algorithm provide the guarantee of the QoS requirements for real-time traffic (conversational and streaming classes) based on the polling in Point Coordination Function (PCF) mode and for non-real-time traffic (interactive and background classes) based on the modified CSMA/CA with different access priorities in the DCF mode.

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CHAPTER 1

INTRODUCTION

There are more and more people using mobile devices for communications or obtaining information in their daily lives. The trends in wireless networks are not only to provide real-time voice transmissions in the present day, but also to support more real-time multimedia data transmissions (e.g. video) in the future. It is an important issue that the wireless networks should meet the Quality of Service (QoS) requirements for real-time applications.

The IEEE 802.11 Local Area Network (LAN) has become a popular wireless network because of its high bandwidth and simple installation. In the IEEE 802.11 wireless LAN standard, the physical layer can adopt Direct Sequence (DS) or Frequency Hopping (FH) spread spectrum transmissions [1]. The maximum data rate of original standard is 2 Mbps by adopting one of above two spread spectrum mechanisms. Recently, the IEEE 802.11b specification allows the maximum data rate up to 11 Mbps by using the DS spread spectrum, and the IEEE 802.11a specification based on the orthogonal frequency-division allows the maximum data rate up to 54 Mbps. The bandwidth of IEEE 802.11 wireless LAN is high enough to support most of multimedia traffic applications. The IEEE 802.11 standard MAC protocol provides two kinds of access methods: namely Distributed Coordination Function (DCF) and Point Coordination Function (PCF). However, the DCF mode adopting (contention based) CSMA/CA protocol cannot meet the QoS requirements of real-time multimedia data traffic. All of the connections cannot expect next transmission within a certain time. In other words, the DCF mode that is the basic access method of IEEE 802.11 is not suitable for real-time traffic applications. We should have some mechanisms to guarantee the QoS requirements for real-time data traffics in optional PCF mode. In this thesis, we make use of both DCF and PCF to provide the QoS guarantee for different classes of traffic in the wireless LAN environment.

In the high tier wireless networks, the popular cellular networks have a tendency to support both real-time multimedia data and non-real-time text data transmissions in the near future. Mainly based on how delay sensitive the traffic is, the UMTS [3] proposes four QoS classes for 3G systems to provide voice transmissions, data and text data transmissions. In this thesis, we adopt four different traffic classes: namely conversational class (e.g., voice), streaming class (e.g., video), interactive class (e.g., web browsing) and background class (e.g., E-mail), proposed by the UMTS [3]. We design our MAC protocol according to the characteristics of above four different QoS classes in the 802.11 wireless LAN environments.

We adopt the simple Round-Robin (RR) scheme for scheduling the traffic of conversational and streaming classes in the Contention Free Period (CFP), and simulate three kinds of priority schemes (BackOffRange, DIFS and RollBack schemes) for transmitting the traffic of interactive and background classes in the Contention Period (CP). By using our schemes, the simulation results show that the traffic of conversational and streaming classes transmitted in the CFP will not be interfered with the increasing of the traffic of interactive or background classes. Besides, the transmission priority between interactive and background classes can be discriminated in the CP. The delay of the sources of interactive class can be bounded in a certain range while the sources of background classes are increasing, because the RollBack scheme can quarantine the interference between different traffic classes.

The remainder of this thesis is organized as follows. In Chapter 2, we discuss the background and related works. In Chapter 3, we present the proposed wireless LAN MAC protocol for supporting multiclass traffics. In Chapter 4, the simulation model and simulation results are presented to investigate the performance of our proposed MAC protocol. Finally, we give some concluding remarks in Chapter 5.

CHAPTER 2

BACKGROUND AND RELATED WORKS

Many priority schemes and medium access technologies were proposed for the wireless networks. In Chapter 2.1, we describe the background knowledge of four different QoS classes proposed by the UMTS [3]. And then we discuss the medium access technologies and present the priority schemes in Chapter 2.2 and 2.3, respectively.

2.1 QoS Classes

As mentioned above, we adopt four different QoS classes proposed by the UMTS [3] to be the types of traffic in our thesis. The characteristics and QoS requirements of conversational class, streaming class, interactive class, and background class are discussed in [3]. For conversational class traffic, the representative applications that generate real-time and bi-directional traffic are VoIP and video conferencing. The transfer delay time of the conversational class traffic must be strict restricted within a certain boundary. If the transfer delay is not low enough, it can result in unacceptable QoS for the human perception. For streaming class traffic, the representative applications that generate real-time and unidirectional traffic are real-time video or audio. The transfer delay time of the streaming class traffic is not required, but the delay variation (jitter) of the end-to-end data flow must be rigorous limited within a certain boundary. For interactive class traffic, the representative applications are web browsing, data base retrieval, and server access. The characteristics of interactive class traffic are low response time that must be limited within a certain boundary and low bit error rate, so the round trip delay time is one of the important attribution. For background class traffic, the representative applications are background delivery of E-mail, SMS, and download of databases. Background class traffic is characterized by that the response time is not expecting within a certain boundary, but the bite error rate of the data muse be low. We will design our MAC protocol according to the characteristics and requirements of above four different QoS classes in this thesis.

2.2 Medium Access Technologies

Several TDMA and CDMA MAC protocols for the wireless networks are discussed and analyzed in [2]. According to the methods of resource assignment, the medium access technologies can be classified into dedicated assignment, random access, and demand-based assignment. The method of dedicated assignment allocates a predetermined and fixed resource for each user, so there has no interference from other users. Dedicated assignment schemes suit with continuous traffic, but may waste the bandwidth for bursty traffic because they disregard the user's requirements. In contrast, the method of random access allows all users to contend for the medium and to send the packets as soon as possible. Random access is appropriate for the bursty traffic, but is not suitable for the delay-sensitive traffic. The method of demand-based assignment allocates resources according to the reservation requirements submitted by users. Demand-based assignment schemes are fitting for the variable rate traffic and the hybrid conditions of multimedia traffic. However, the waste of bandwidth and additional delay of reservation procedure may degrade the performance. We should take the characteristics of traffic into consideration as analyzed in [2], when we design an appropriate MAC protocol with high bandwidth utilization.

2.3 Priority Schemes

In order to provide different traffic classes in the 802.11 DCF mode based on the CSMA/CA protocol, the authors of [1] propose a mechanism that controls the maximum and minimum contention windows (CW) of the packets to cause the different back-off times in different traffic classes. Under this mechanism, the packets with high priority get statistically an opportunity of transmission superior to those with low priority. The mechanism of [1] is based on the CSMA/CA to provide QoS guarantee, so the collision may occur in data transmission. If we want to transfer data in a contention free environment, we should adopt the PCF mode based on polling schemes. However, the mechanism of the PCF mode causes the lower throughput when the data rate is variable. The PCF mode is suitable for the constant and continued data transmission (e.g. isochronous traffic). In contrast, the DCF mode is favorable for the bursty data traffic. RSVP and SBM mechanisms for signal routing and network resource management are also proposed in [1] to guarantee the end-to-end QoS.

The analysis of the back-off mechanism was presented in [14][18][20]. In [14], their simulation results show that the proper choice of the CW parameters has substantial influence on the network performance. We should choose some appropriate values of $CW_{max(min)}$ according to the number of mobile stations in the wireless network system. In addition, [18] concludes that the back-off mechanism performs well with UDP but does not work with TCP traffic. We called those kinds of access methods ‘BackOffRange scheme’ in this thesis.

Moreover, [18][20] introduce another access scheme that each priority level is assigned a different DIFS. We named those kinds of access methods ‘DIFS scheme’ in this thesis. The DIFS scheme is superior to BackOffRange scheme while the Request To Send (RTS)/Clear To Send (CTS) mechanism is enabled or the connection is TCP flows. However, the BackOffRange and DIFS schemes, which provide the service differentiation, cannot quarantine the interference between different traffic classes. We will introduce a mechanism (RollBack scheme) to solve this problem. We can use RollBack scheme to separate the resources into isolated partition for every traffic class, and use BackOffRange and DIFS schemes to provide relative priority levels in the same traffic class. For example, the web browsing and server access traffics belong to interactive class. We can use BackOffRange and DIFS schemes to make the server access traffic has higher priority to access the medium, and use the RollBack scheme to quarantine the interference from background class traffic.

In the IEEE 802.11 wireless LAN, the DCF and PCF modes usually deal with asynchronous and isochronous traffic patterns, respectively. [8][19] show that a larger superframe length provides more voice traffic capacity or a higher data throughput. However, if the CFP repetition interval is set too long, the video-delay performance deteriorates drastically. We should carefully select the superframe length when the MAC protocol supports voice and video traffics at the same time in the 802.11 wireless LAN.

In summary, we studies some issues about priority schemes and medium access technologies in Chapter 2.2 and 2.3, and introduce the characteristics of four different QoS classes in Chapter 2.1. An ideal wireless MAC protocol should take the characteristics of traffic into consideration as analyzed in Chapter 2.2 and 2.3 when we design an appropriate MAC protocol with high bandwidth utilization. Therefore, we design our MAC protocol according to the characteristics of above four different QoS classes in next chapter for the 802.11 wireless LAN environments.

CHAPTER 3

THE PROPOSED MAC PROTOCOL

The MAC protocol proposed in this thesis is based on the fundamental IEEE 802.11 MAC protocol [15]. The IEEE 802.11 MAC protocol provides two kinds of access methods: Distributed Coordination Function (DCF) and Point Coordination Function (PCF). Figure 1 depicts a superframe that includes Contention Free Period (CFP) and Contention Period (CP) as defined in the 802.11 MAC protocol.

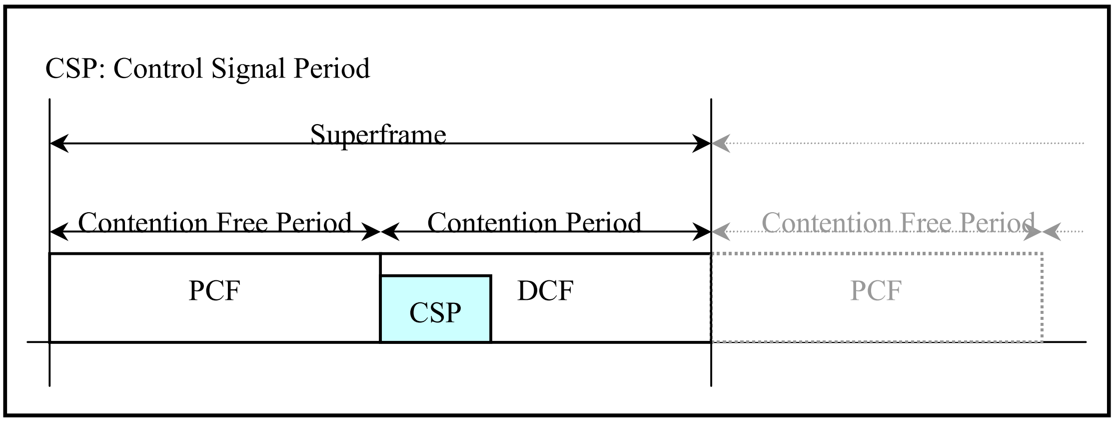

Figure 1. The Channel Access Scheme.

The PCF mode should be supported by a Point Coordinator (PC) in the Basic Service Set (BSS). The PC will generate the CFP according to the parameter of Contention-Free Repetition Rate (CFPRate). In the DCF mode, the mobile hosts

(MHs) contend the channel access based on the CSMA/CA protocol, which is not suitable for real-time traffic. However, in the optional PCF mode, the MHs are free from contention by the polling mechanism. The PCF mode can only work in an infrastructure network where a PC exists. The DCF and PCF modes usually deal with asynchronous and isochronous traffic patterns, respectively [8][19].

In our proposed MAC protocol, the traffic of conversational or streaming classes is transmitted in the PCF mode; and the traffic of interactive or background classes is transmitted in the DCF mode. In the CFP, the PC polls the MHs that have the traffic in conversational or streaming classes to meet the requirements of delay or jitter. In the CP, the techniques of interframe space (IFS) time interval and back-off time [15] are usually used to resolve the contention as depicted in Figure 2.

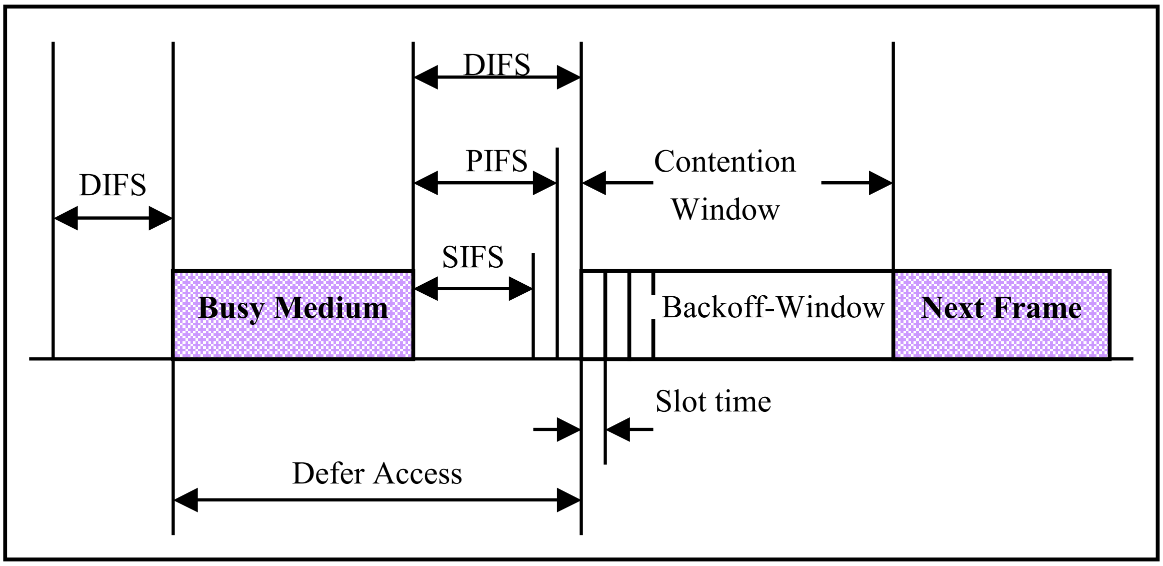

Figure 2. The techniques of interframe space (IFS) time interval and back-off time.

In order to discriminate the transmission priority between interactive and background classes, the DIFSs in different lengths (DIFS scheme) are used in our protocol where the DIFS of interactive class is shorter then that of background class. That is, the interactive class gets early start to countdown the back-off time. Furthermore, we adopt the ideas (BackOffRange scheme) proposed in [1][14] to generate different ranges of back-off time for these two classes by controlling the maximum and minimum contention windows (CW). By this mechanism, the packets with higher priority (corresponding to a small back-off time) get statistically an opportunity of transmission superior to those with lower priority (corresponding to a large back-off time). The relationship is given below:

$CW_{min}(_{max})$ of interactive class $<$ $CW_{min}(_{max})$ of background class

3.1 Connection Admission Control

As depicted in Figure 1, the MHs send the QoS requirements of the new connections to the PC within the Control Signal Period (CSP), which is before the CP. The PC will add a record into the appropriate table for each new connection. The CSP is dedicated to the transmission of control signals for reducing collision with other data traffic. All classes of new connections should send the QoS requirements to the

PC in the CSP.

The PC in the AP has a polling table that records the QoS parameters for all permitted connections of conversational and streaming classes. Besides, the PC also maintains a random access table that records the QoS parameters for all permitted connections of interactive class. The remaining resource can be calculated from the QoS parameters in the polling table and the random access table. The PC can permit or reject a new connection based on the resource calculation and the policies as defined in the system. The policies are the rules set by the network administrators (e.g. The requirement of the bandwidth for every new connection can not excess 100 Kbps).

Under the normal condition, the control signal for releasing the connection of conversational or streaming classes should be sent to the PC in the moment when it is polled or in the CSP. Then the PC will delete the related record in the polling table. Similarly, the PC will delete the record in the random access table after receiving the control signal for releasing the connection of interactive class in the CSP or CP.

3.1.1 The Algorithm of the Connection Admission Control

Step a. The MH receives the request of establishing a new connection from the upper layer. The MH will send the QoS requirements for the new connection to PC in the CSP.

Step b. The PC can permit or reject a new connection to be established by checking whether the remaining resources can meet the QoS requirements of the new connection and if the policies inspecting can pass. Go to Step c if the above condition is satisfied; otherwise the PC will send a rejection message to the MH to reject the request of establishing a new connection and go to Step d.

Step c. The PC will first assume that the new connection is added [6]. If the type of the new connection is conversational class or streaming class, add the record of the new connection's QoS parameters into the polling table; if the type of the new connection is interactive class, add the record of the new connection's QoS parameters into the random access table. And then the coordinator checks whether all of the connections that are recorded in the polling table or the random access table can still meet the QoS requirements. Permit the new connection if the checking is approved; otherwise reject the new connection and remove the record of the new connection from the polling table or the random access table. Go to Step d.

Step d. End of the CAC.

3.2 Scheduling

Each MH and the PC have four types of the traffic queues that are conversational class queue, streaming class queue, interactive class queue, and background class queue. Under the PCF mode in the CFP, the PC polls the MHs in the polling table by the simple round-robin method. Some more efficient polling schemes such as DDRR [12] will be investigated to increase the system utilization in the future. The download packets can be sent with the polling message because the IEEE 802.11 MAC protocol supports the DATA + CF–Poll mode of transmission. Also, if the MH has more pending packets due to the variable bit arrival rate, the MH can piggyback the buffered data size with the upload packet. The PC will poll the MH more times according to the size information. Under the DCF mode based on the CSMA/CA access method, the MH transmits the interactive class and background class traffic in the CP. The MH will not transmit the packets of background class until all the packets of interactive class are sent. Therefore, if no any packet of interactive class is arrived, the MH processes the back-off procedure for the packet, if any, of background class. In the normal back-off state, the back-off time is frozen if the channel becomes busy and continue the remaining back-off time if the channel becomes idle again. To increase the transmission opportunity of interactive class, we adjust the back-off mechanism for the background class. The countdown of back-off time for the background class is invalid if any packet of interactive class gets the channel access. In this case, the MH rollbacks the back-off time to the previous state as depicted in Figure 3 (RollBack scheme).

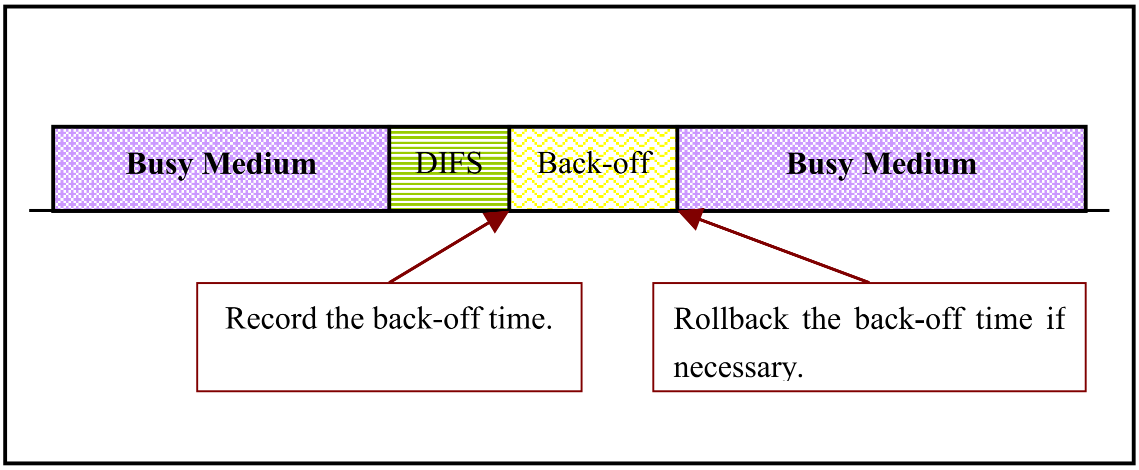

Figure 3. The scenario of rollbacking the back-off time.

Therefore, the MH can join the polling table of the PC to transmit the conversational class and streaming class traffic in CFP adopting the PCF access method, and can send the interactive class and background class traffic in CP using the DCF access method.

3.2.1 Traffic Classes

3.2.1.1 Conversational Class

Since the conversational class traffics are sent by the PCF access method, any new connection must join into the PC's polling table at first. The polling time can be dynamically adjusted based on the reflection of traffic state from the MH. That is, the MH can send a control signal piggybacked with the upload data packet to the PC for decreasing the polling times when the traffic load in the conversational class queues is low, and oppositely, for increasing the polling times when the traffic load in the conversational class queue is high. The PC can track the conversational class traffic statuses from the control signal sent by the MH.

3.2.1.2 Streaming Class

Since the streaming class traffics are also sent by the PCF access method, any new connection must request to join the PC's polling table at first. The PC must poll the streaming class traffic in regular time to minimize the delay variation (jitter).

3.2.1.3 Interactive Class

We use the DCF access method to transmit the interactive class traffic, which doesn't require the timeliness, to increase the whole throughput. The contention windows (include CW_{min} and CW_{max}) of the interactive class packets are smaller than the CWs of the background class packets. Therefore, the interactive traffic can obtain the media for transmission easily than the background traffic.

3.2.1.4 Background Class

We use the DCF access method to transmit the background class traffic whose transmission time is not important, to increase the whole throughput. The background class traffic has the lowest priority to access the media for transmission. The MH will not try to transmit the packets in the background class queue until all of the packets in interactive class queues are sent and the period is still in CP. Because the background class packets have larger contention windows (include CW_{min} and CW_{max}) when transmitting, compared with the interactive class packets in other MHs, the background class packets always lose the media for transmission under CSMA/CA access method.

3.2.2. The Algorithm of the Scheduling

As depicted in Figure 1, the superframe includes two periods of alternate contention free period and contention period. The discussions on the scheduling of the PCF access method in the contention free period and the DCF access method in the contention period are as follows:

3.2.2.1 Contention Free Period

Stage 1.

In the CFP, the PC will decide to poll some conversational class or streaming class connections recorded in the polling table according to the QoS parameters of the connections. The PC polls the MHs in the polling table by the round-robin method.

Stage 2.

The MH gets the data traffic from the conversational class queues or streaming class queues to transmit according to the polling message.

3.2.2.2 Contention Period

In the contention period, every MH will try to send the packets in the interactive class queues and background class queues.

Step a. In a CP, each MH always tries to transmit the packets in the interactive class queues while any one of the interactive class queues is not empty. If all interactive class queues are empty and still in the CP, go to Step b; otherwise, go to Step e.

Step b. If there has a packet of background class in the back-off state, set T_{bot} to the current back-off time, and then process the back-off procedure; otherwise, go to Step d. If the back-off time of the packet counts down to zero, transmit the packet and go to Step a; otherwise, the back-off time of the packet in other MH counts down to zero, go to Step c.

Step c. The other MH obtains the media for transmission in this state. If the packet in transmitting is a interactive class packet, set current back-off time back to T_{bot} and go to Step a; otherwise, directly go to Step a.

Step d. Get one packet in the background class queue and set the state to back-off state. Go to Step a.

Step e. The CP has terminated by the PC. Stop to send any packets in the interactive class queues or background class queue.

In our proposed MAC protocol, the CAC mechanism that reserves resources for permitted connections can be applied to guarantee the QoS requirements for existing traffics. Furthermore, we adopt the simple Round-Robin scheme for polling the traffic of conversational and streaming classes in the CFP, and introduce three kinds of priority schemes (BackOffRange, DIFS and RollBack schemes) for transmitting the traffic of interactive and background classes in the CP.

CHAPTER 4

SIMULATIONS

In our simulation experiments, we assume an IEEE 802.11 wireless LAN system (infrastructure network) with total bandwidth of 10 Mbps. The simulator has been written in the C language carefully. The setting of system parameters is listed in Table 1.

Table 1

System Parameters

PHY channel rate	10 Mbps
CFP repetition interval	20 ms
Maximum CFP duration	15 ms
SIFS	10 us
PIFS	30 us
Length of slot	20 us

Beside, some assumptions are made to reduce the complexity of the simulation model:

* There is no 'hidden terminal' and 'capture' problem between mobile hosts.

* The channel is error-free. Each transmitted packet was successfully and correctly received at its destination.

* Interference from the nearby BSSs is neglected.

4.1 Traffic Models

The four traffic classes considered in our simulation experiments are conversational class, streaming class, interactive class, and background class. Table 2 illustrates the parameters used in each traffic module.

In conversational class, we use a simple on-off speech model ([12], [13]) in our simulation experiments. The voice source can be modeled as a two-state Markov process with a talking (ON) state and a silent (OFF) state. The duration of talking state and silent state are assumed to be exponentially distributed with means 1 sec. and 1.35 sec., respectively. In the ON state, voice packets with fixed size are generated periodically at a constant rate of 20 ms while in the OFF state no packets are generated. The data rate of voice traffic is assumed 64 Kbps. In streaming class, the video source continues generating frames at a constant rate in its active period. For the attributes of the voice and video sources, we adopt the same parameters used in [12].

The sources of interactive and background classes are modeled as a Poisson process with mean inter arrival time 200 ms and 500 ms, respectively. The parameters (DIFS, CW_{min}, and CW_{max}) of interactive and background classes are set with different values as illustrated in Table 2.

Table 2

Traffic Models Parameters

	Items	**Values**	**Units**
Conversational class traffic (Voice)	Data rate	64	Kbps
	Frame duration	20	ms
	Maximum speech delay	35	ms
	Mean ON state duration	1	Sec.
	Mean OFF state duration	1.35	Sec.
Streaming class traffic (Video)	Data rate	25	frames/s
	Frame duration	40	ms
	Maximum video delay	100	ms
Interactive class traffic (WWW)	Mean inter arrival time	200	ms
	Average WWW document size	5	Kb
	DIFS	50	us
	CW_{min}	7	
	CW_{max}	255	
Background class traffic (E-mail)	Mean inter arrival time	500	ms
	Average size of e-mail	9	Kb
	DIFS	70	us
	CW_{min}	31	
	CW_{max}	1021	

4.2 Simulation Results and Discussions

We assume that the voice or video sources can be accommodated in the 802.11 simulation system when it satisfies the following QoS measures [12]:

* 99% of the voice packets must be transmitted with voice delay less than 35 ms.

* 99% of the video packets must be transmitted with video delay less than 100 ms.

The system capacity for the voice and video sources is shown in Figure 4 when the PC maintains the polling table using a simple RR scheme.

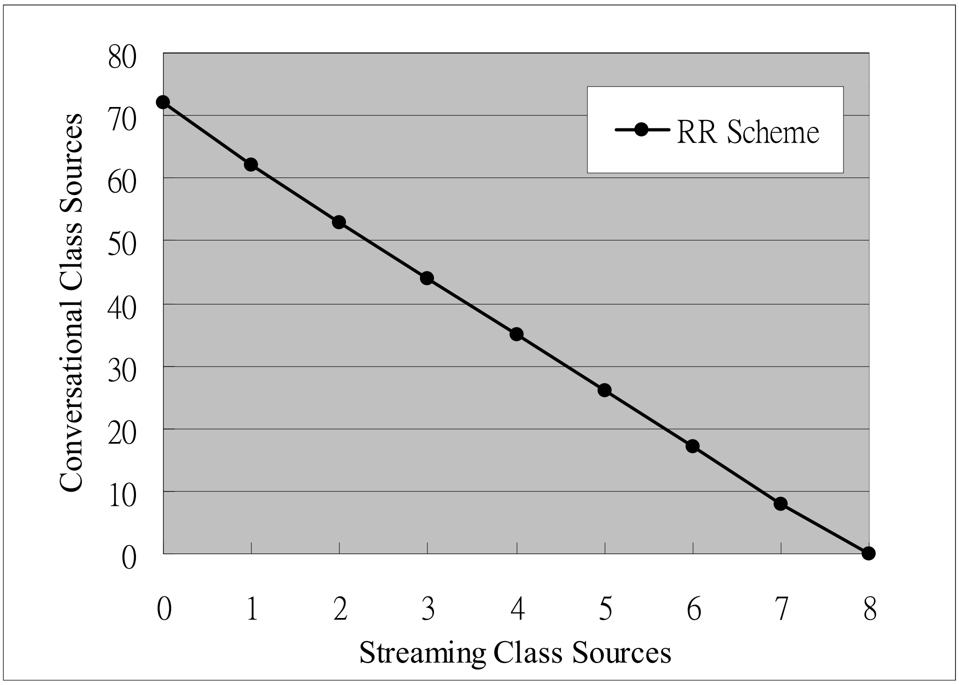

Figure 4. The system capacity in CFP.

We can figure out that the simple RR scheme can accommodate for example 53 voice sources and 2 video sources together in the CFP. We randomly choice this amount of voice and video sources in following experiments.

We simulate following three kinds of priority schemes in the CP:

1) BackOffRange scheme: The different ranges of back-off time are generated for interactive and background classes by controlling the maximum and minimum contention windows (CW). The relationship is given below:

$$CW_{min}(_{max}) \text{ of interactive class} \quad < \quad CW_{min}(_{max}) \text{ of background class}$$

2) DIFS scheme: The DIFSs in different lengths are used in the CP where the DIFS of interactive class is shorter then that of background class.

3) RollBack scheme: The countdown of back-off time for the background class is invalid if any packet of interactive class gets the channel access. In this case, the MH rollbacks the back-off time to the previous state.

Figures 5-9 show the mean packet transfer delay versus the number of active E-mail sources while there have 53 voice, 2 video and 60 WWW sources over the simulation duration. Figures 5-7 show the results by using BackOffRange, DIFS and RollBack schemes, respectively. From Figure 5 and Figure 6, we observe that the delay of the WWW source cannot be bounded in a certain range while the E-mail sources are increasing. In contrast, the RollBack scheme can provide the delay boundary for the WWW sources because the RollBack scheme can quarantine the interference between different traffic classes.

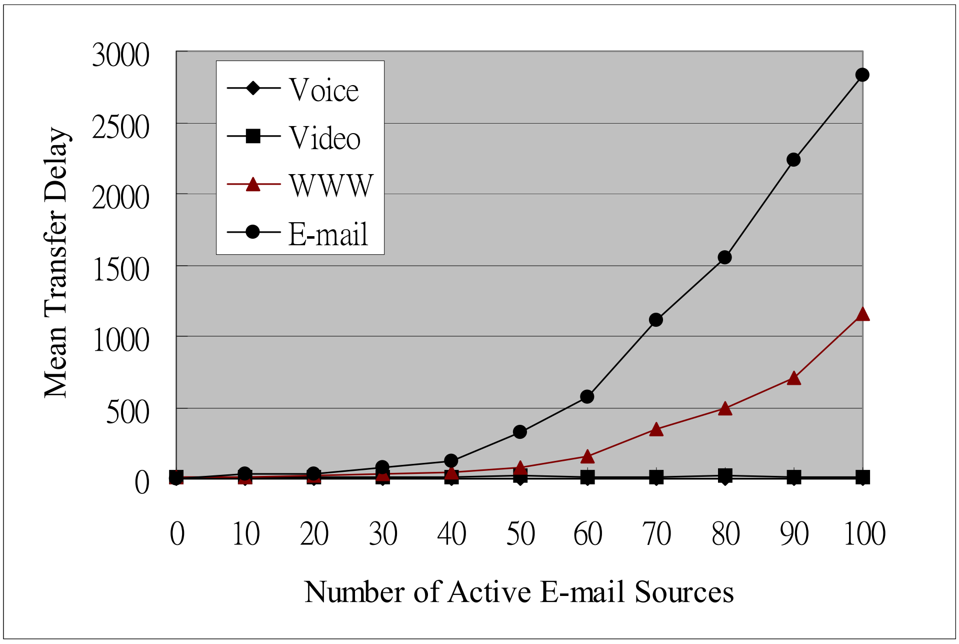

Figure 5. Mean packet transfer delay vs. Number of Active E-mail sources.

(BackOffRange scheme)

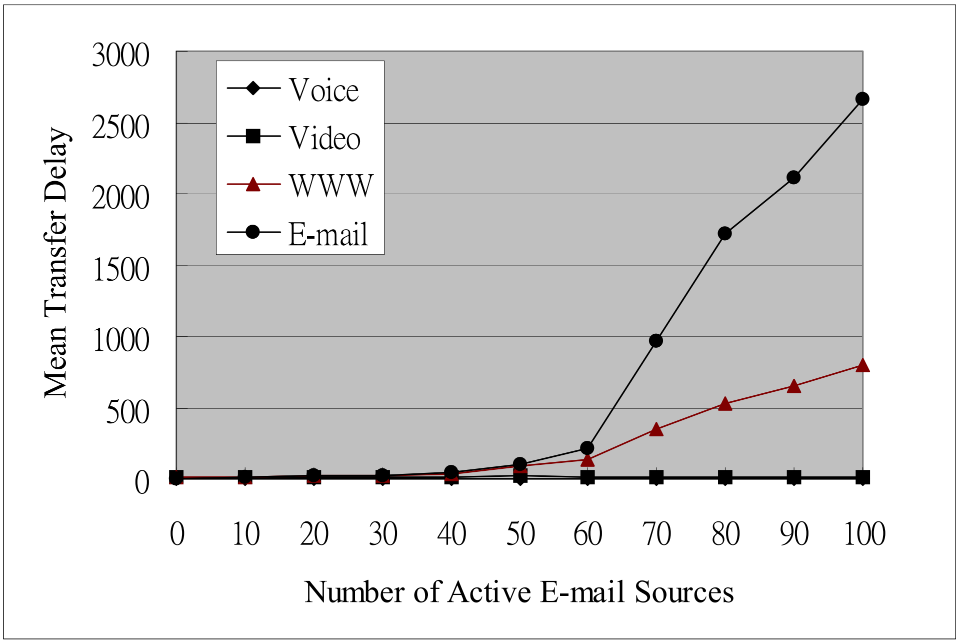

Figure 6. Mean packet transfer delay vs. Number of Active E-mail sources.

(DIFS scheme)

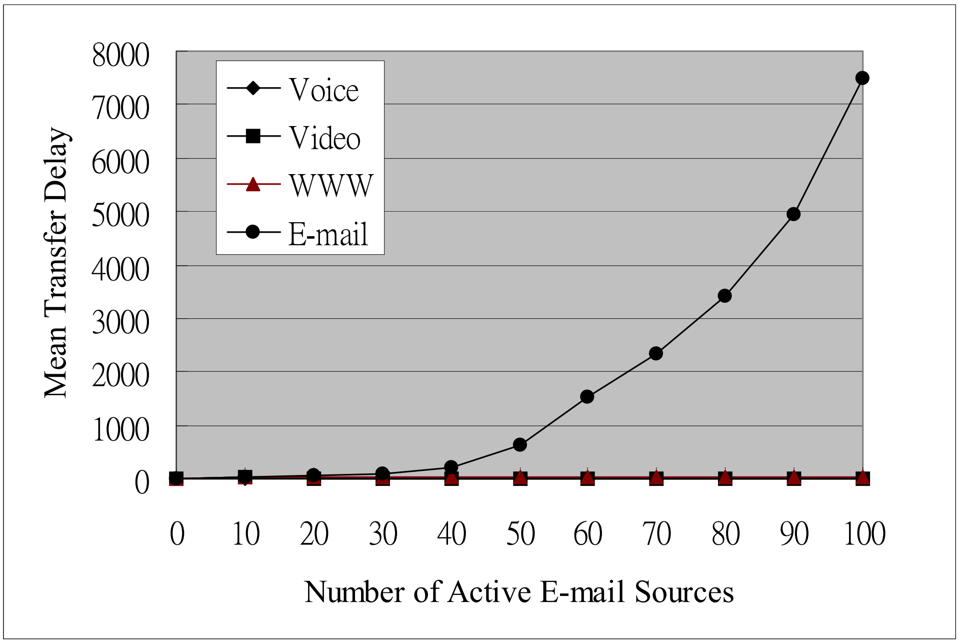

Figure 7. Mean packet transfer delay vs. Number of Active E-mail sources.

(RollBack scheme)

Figure 8 and Figure 9 show the results by combining above three kinds of priority schemes **(**BackOffRange scheme + DIFS scheme + RollBack scheme**)**. The voice and video sources experience the lower mean transfer delay, because the real-time data are transferred by the PCF mode that can limit the delay boundary. Beside, the voice sources have lowest mean transfer delay because the data rates of the voice sources are smaller then those video sources when the voice and video sources have the same polled rate. The mean transfer delay of E-mail source increases faster because the E-mail source has the lowest priority to access the wireless channel.

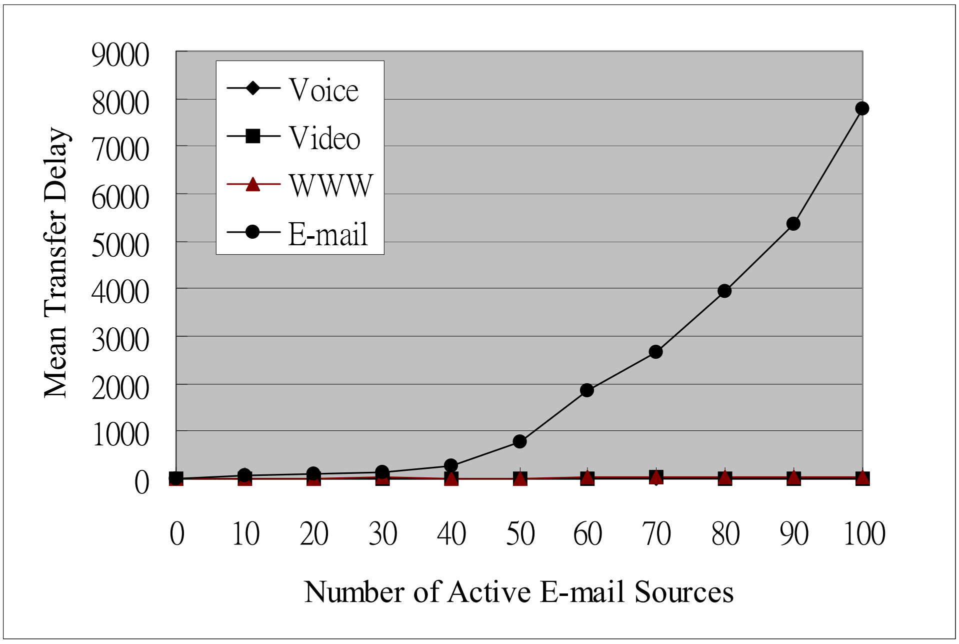

Figure 8. Mean packet transfer delay vs. Number of Active E-mail sources.

(BackOffRange scheme + DIFS scheme + RollBack scheme)

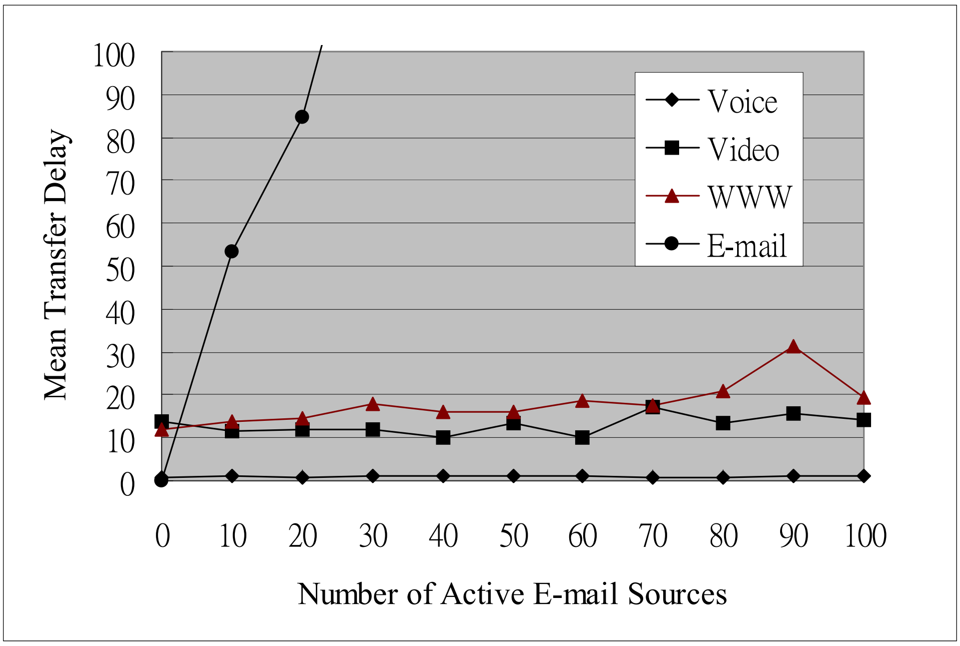

Figure 9. Mean packet transfer delay vs. Number of Active E-mail sources in detail.

(BackOffRange scheme + DIFS scheme + RollBack scheme)

The simulation results show that when the system is loaded to capacity in the CFP, the data like the voice and video sources transmitted will not be interfered with the increasing of WWW or E-mail sources. Besides, the transmission priority between WWW and E-mail sources can be discriminated in the CP. In order to meet the requirement of response time for interactive class traffic, the connection admission control mechanism should be applied to limit the delay of interactive class traffic, and then the response time of interactive class traffic can be limited within a certain boundary.

CHAPTER 5

CONCLUSIONS AND FUTURE WORKS

This thesis has presented a medium access protocol that provides QoS guarantee for four different QoS classes according to the characteristics of the traffic in the wireless LAN environment. The DCF and PCF modes usually deal with asynchronous and isochronous traffic patterns, respectively. In our proposed MAC protocol, the traffic of conversational or streaming classes is scheduling based on the RR polling scheme in the CFP; and the traffic of interactive or background classes is transmitted based on the modified CSMA/CA schemes (BackOffRange, DIFS and RollBack schemes) with different access priorities in the CP. The simulation results show that the traffic of conversational and streaming classes transmitted in the CFP will not be interfered with the increasing of the traffic of interactive or background classes. Besides, the transmission priority between interactive and background classes can be discriminated in the CP. The delay of the sources of interactive class can be bounded in a certain range while the sources of background classes are increasing, because the RollBack scheme can quarantine the interference between different traffic classes. The CAC mechanism that reserves minimum transmission data rate for per interactive class traffic can be applied to limit the delay of interactive class traffic, and then the response time of interactive class traffic can be limited within a certain boundary.

The RR scheme is a simple method to maintain the polling table. However, it has a disadvantage in maintaining the jitter for the traffic of streaming class, when the traffic variance of conversational class is high. The more efficient polling scheme will be investigated to meet the QoS requirement of jitter in the future work. Furthermore, the relation between the reservations of minimum transmission data rate and the response time for interactive traffic will also be analyzed.

REFERENCES

[1] Arun Ayyagari, Yoram Bernet, and Tim Moore, "IEEE 802.11 Quality of Service – White Paper", http://grouper.ieee.org/groups/802/11/Documents/, Feb. 2000.

[2] I.F. Akyildiz, J. McNair, L.C. Martorell, R. Puigjaner, and Y. Yesha, "Medium Access Control Protocols for Multimedia Traffic in Wireless Networks", *IEEE Network Magazine*, vol. 13, pp. 39–47, July-Aug. 1999.

[3] "3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; QoS Concept and Architecture (Release 1999)", *3GPP*, 1999.

[4] C. Romans, and J. Tourrilhes, "A medium access protocol for wireless LANs which supports Isochronous and asynchronous Traffic", *Proc. IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, vol. 1, pp. 147–152, 1998.

[5] T.H. Le, and A.H. Aghvami, "A MAC protocol for asymmetric multimedia traffic with prioritized services in local wireless ATM networks", *Proc. 1999 IEEE 49th Vehicular Technology Conference*, vol. 1, pp. 123-127, 1999.

[6] Dongmei Zhao, Xuemin Shen, and J.W. Mark, "Efficient call admission control for heterogeneous services in wireless mobile ATM networks", *IEEE Communications Magazine*, vol. 38, pp. 72–78, Oct. 2000.

[7] D. Vali, and L. Merakos, "An efficient multiple access technique for wireless ATM networks with QoS guarantees", *Proc. 2000 International Zurich Seminar on IEEE Broadband Communications*, pp. 293-299, 2000.

[8] T. Suzuki, and S. Tasaka, "Performance evaluation of integrated video and data transmission with the IEEE 802.11 standard MAC protocol", *Proc. Global Telecommunications Conference*, vol. 1b, pp. 580–586, 1999.

[9] Nikolaos Georganopoulos, and A.H. Aghvami, "MAC Scheduler Using Polling with Priorities for Future Wireless Multimedia Networks", *Proc. Global Telecommunications Conference*, vol. 1b, pp. 580-586, 1999.

[10] Sihui Zhou, J. Deane, A. Lam, D. Skellern, and T. Percival, "An Efficient Media Access Control Protocol for Wireless ATM networks", *Proc. Global Telecommunications Conference*, vol. 2, pp. 1099-1104, 1998.

[11] Rui Tang, and Zhisheng Niu, "A Polling-Based Scheduling Scheme for Guaranteed Quality-of-Service Wireless Multiple Access to ATM Networks", *International Conference on Communication Technology Proceedings*, vol. 2, pp. 5, Oct. 22-24 1998.

[12] R.S. Ranasinghe, L.L.H. Andrew, and D. Everitt, "Impact of Polling Strategy on Capacity of 802.11 Based Wireless Multimedia LANs", *Proc. IEEE International Conference on Networks*, pp. 96-103, 1999.

[13] D.J. Goodman, and S.X. Wei, "Efficiency of Packet Reservation Multiple Access", *Proc. IEEE Transactions on Vehicular Technology*, vol. 40, pp. 170-176, Feb. 1991.

[14] M. Natkaniec, and A.R. Pach, "An Analysis of the Backoff Mechanism used in IEEE 802.11 Networks", *Proc. Fifth IEEE Symposium on Computers and Communications*, pp. 444–449, 2000.

[15] IEEE 802.11 Standard for Wireless LAN, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", Approved 26 June 1997.

[16] V.K.N. Lau, and Y.-K Kwok, "Multiple Access Control Protocol for Integrated Isochronous and Bursty Data Services", *IEE Proceedings-Communications*, vol. 147, pp. 311–316, Dec. 2000.

[17] Hong Liu, U. Gliese, and L. Dittmann, "Knowledge-Based Multiple Access Protocol in Broadband Wireless ATM Networks", *Proc. IEEE 50th Vehicular Technology Conference*, vol. 3, pp. 1685-1689, 1999.

[18] I. Aad, and C. Castelluccia, "Introducing Service Differentiation into IEEE 802.11", *Proc. IEEE Symposium on Computers and Communications*, pp. 438–443, 2000.

[19] M.A. Visser, and M. El Zarki, "Voice and data transmission over an 802.11

wireless network", *Proc. Sixth IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, vol. 2, pp. 648-652, 1995.

[20] I. Aad, and C. Castelluccia, "Differentiation mechanisms for IEEE 802.11", *Proc. INFOCOM 2001*, vol. 1, pp. 209-218, 2001.