A Survey of WLAN QoS Systems Based on IEEE 802.11

Wu Xing-feng , Liu Yuan-an

Telecommunication Engineering College, 171 mailbox, Beijing University of Posts and Telecommunications, Beijing, China. 100876

Abstract

This paper discusses the QoS problems we facing in real-time applications of Wireless LAN's(WLAN) environment, the essential parameters and various optimization algorithms are classified, some ideas about QoS guarantee in WLAN based on IEEE 802.11 are specifically addressed.

Key words

QoS ; WLAN; IEEE 802.11；

1. Introduction

In global market, both equipments and applications of WLAN are bullish. While in very the beginning, IEEE 802.11 was drafted out to support data applications and did not consider much about quality of service (QoS) guarantees for throughput-sensitive and delay-sensitive multimedia applications..

Presently, IEEE 802.11e workgroup is working on the supplementary projects of QoS guarantees aiming at real-time problems. Besides IEEE 802.11e, there are lots of other ideas focus on the QoS series based on IEEE 802.11, it is necessary to make the classification and compare of these methods for the farther research.

Structure of this paper: Section 2 is a brief introduction of IEEE 802.11; Section 3 details a classification of various QoS guarantee ideas in IEEE 802.11 based WLAN; Finally, section 4 concludes this paper.

2. Brief introductions of IEEE 802.11

IEEE 802.11 workgroup formulated the 802.11 protocol in June 1997, and added 802.11a and 802.11b supplements in August 1999, and 802.11g was formally ratified by the IEEE Standards Association's Standard Board in June 2003, similar to the IEEE 802.3 Ethernet protocol which used in data transmission by twisted-pair and coaxial cable, IEEE 802.11 provides optimized physical layer (PHY) and medium access control(MAC) sublayers for wireless communication.

Being different from CSMA/CD (Carrier Sense Multiple Access /Collision Detected) applied in Ethernet, IEEE 802.11 protocol uses CSMA/CA (Carrier Sense Multiple Access /Collision Avoided) with the consideration of the complexity in wireless environment; for example, stations can not listen to the channel for collisions while transmitting. Under IEEE 802.11, data frames have to be retransmitted if source STA does not receive ACK no matter what causes it. It is the existence of ACK that makes the transmission efficiency of CSMA/CA is less efficient than CSMA/CD's.

IEEE 802.11 defines that there are two basic medium access protocols in Basic Service Set（BSS）: DCF and PCF. Because PCF is seldom implemented, let's take DCF for example to introduce IEEE 802.11 MAC in the following.

In figure 1, after source STA sending out data, destination STA will send back an ACK if it receives the data after one SIFS(short interframe space). While other STAs have to wait for at least one DIFS(DCF interframe space) time to send out their own MSDU(MAC Protocol Data Unit), here is a point that DIFS>SIFS.

IEEE 802.11 also introduces the CW window, every STA randomly chooses a backoff time slot in the interval [0, CW) to avoid a great deal of conflicts that caused by several STAs accessing the channel and sending out data right after a DIFS at the same time.

In addition, IEEE 802.11 defines RTS/CTS system, source STA will send out a short RTS frame before it transmits a data frame, and then receiver will send back a CTS frame immediately when it receives the RTS, RTS and CTS frames contain the information of the time how long the channel will be occupied to transmit the next data frame, so that other STAs nearby won't send out data in the time declared by setting their NAV timer. RTS/CTS system is enabled if MSDU is longer than the RTS_Threshold.

When error takes place, there are two retry counters that is short retry count and long retry count used in retransmission course. The former is used by those packets that are shorter than RTS_Threshold, and the latter is used by those longer than RTS_Threshold. The counter increases each time when packet is retransmitted, and the packets with the overflowed counter will be discarded immediately.

Another significant parameter in IEEE 802.11 is fragmentation threshold. IEEE 802.11 defines a transmitting method called *fragmentation burst*. MSDU that longer than fragmentation threshold will be divided into several short sections and each section is sent out consecutively with the interval of one SIFS time instead of additional waiting, backoff and sending out. It saves the cost of system by only retransmit the short section where errors take place instead of retransmitting the whole MSDU.

3. QoS system in WLAN

Generally, there are four parameters of QoS:

a) Throughput or bandwidth,
b) Delay or latency,
c) Delay jitter,
d) Loss or error rate.

In WLAN environment, except relatively low data rate and high errors caused by RF characteristics such as multi-path fading and so on, CSMA/CA system of IEEE 802.11 also causes some new problems, correspondingly, some new optimize ideas appear.

Although there are lots of corresponding QoS systems in every layer of networks, in this paper, we only discuss the QoS systems based on IEEE 802.11 that relating to these four parameters. Various ideas about WLAN QoS guarantees are classified into four blocks which will be detailed separately as following:

- Differentiation serving system,
- Information extracting system based on physical layer,
- Resource reserving and admission control in MAC layer,
- IEEE 802.11 parameters tuning system.

3.1 Differentiation serving system

Differentiation serving bases on the thought that different requirements of different applications should be served distinctively in different classes. There are two modes of differentiation service In IEEE 802.11：priority based service and fair scheduling service. The classification mechanism identifies and separates traffics into different flow, Therefore, each flow can be handled selectively. Priority based service always serve those flows with the highest priority in the remaining ones. Fair scheduling service fairly schedules the bandwidth on the basis of weight of each flow, so it can avoid that lower priority flows cannot get service all the time.

For example, In figure 2, IEEE 802.11e defines that inside of each STA there are eight different classes of TC in form of virtual queue, and each class is assigned different priority QoS guarantee parameters. Besides, Each STA with different priority has to wait for different AIFS time to access the channel. After waiting for a AIFS time, counter of each STA sets a random number from［0, CW+1］ and begins to backoff, the minimum of CW depends on TC. Further more, IEEE 802.11e has different CW adjusting system, when collision happens, traditional DCF doubles CW simply, while EDCF modifies the former CW based on PF.

3.2 Information extracting system based on PHY layer

If we can get the exact status report of transmission environment periodically from PHY layer, some parameters of MAC layer can be tuned to achieve maximum throughput and minimum delay, in another words, it needs a information extracting system based on PHY layer of dynamic wireless environment to optimize QoS guarantee.

The most direct way is using SNR of channel, because IEEE 802.11 supports to get SNR parameter from PHY layer. In [5], assuming that RSS and SNR have linear relationship, each STA is assigned different RSS threshold so that they use different transmission rate to make whole WLAN system efficient.

In [6], the foundation of the algorithms is that combining SNR parameters, payload length and retransmission counters to estimate the situation of the wireless channel. And it also can be used as the basis of judging the quality of wireless channel that how many times it succeeds to or fails to send out continuously. Generally speaking, STA should decrease its transmission rate when the wireless environment is not good.

In [7], estimating quality of wireless channel from SNR, every STA passes its SNR information to AP by SNR frames periodically, and there are SPS monitor and SPS transfer in each AP. Using these information, AP updates the SNR table maintained by its own. The table maintains pairs of STA ID with its SNR, and arranges bandwidth for each STA overall to maximize WLAN throughput.

3.3 resource reserving and admission control in MAC layer

Service classification is useful to support high QoS guarantee for real-time multimedia applications, but in the situation of heavy loading, it cannot work efficiently. So it needs to reserve resource and control accessing in MAC to ensure QoS of running applications.

Resource reserving: in IEEE 802.11 WLAN, it is hard to support resource reserving in WLAN based on CSMA/CA. Many projects of resource reserving advise that IEEE 802.11 should do some modifications. For example, [11] defines a series of accessing systems which can support resource reserving in MAC layer by enable multi-channel accessing.

Accessing control: as AP or STA, it is hard to know the exact situation of the loading at present because of wireless environment, so it is difficult to decide to choose which kind of accessing controlling. There are two foundational methods, one is to pick up parameters of present network situation, and the other is to conclude network situation based on the calculation.

In [8], there are some ideas to check channels passively by virtual frame in MAC, estimate the present service level by virtual frame, and adjust applicable parameters dynamically basing on the change of channels situation by means of virtual MAC and Virtual Source algorithm.

In [9], based on the calculation, STA estimate the situation of network and make access control consideration.

4. Tuning IEEE 802.11 parameters

Tuning parameters defined in IEEE 802.11 will make great effects on performance of WLAN. These parameters are listed out in the [13]:Table 17-1. “summary of common tunable parameters."

As in the table 1, RTS_Threshold is a parameter frequently being quoted in research. It is the conclusion in [12] that RTS-CTS system is especially efficient when there are long MSDU packets needs to be transmitted. The author of [12] suggests that it is better to set RTS_Threshold as 0 that is using RTS_CTS system all the time than work out the amount of active STAs to adjust RTS_Threshold dynamically.

In addition, Fragmentation_Threshold is also a parameter worthy of further study. To get more throughputs in bad wireless environment, it’d better adjust RTS_Threshold dynamically based on the channel quality feedback from lower layer. Dynamical tuning Long Retry Limit and Short Retry Limit also can be used to optimize WLAN’s throughput and data rate.

5. Conclusions

It concludes four key classes of QoS guarantee systems that can be used in WLAN :

- Differentiation serving system,
- Information extracting system based on physical layer,
- Resource reserving and admission control in MAC layer,
- IEEE 802.11 parameters tuning system.

To maximize WLAN throughput, lots of algorithm has been developed, the most of these ideas focus on maximizing the throughput of WLAN, less is done on delay guarantee and delay jitter guarantee. No matter which algorithm is used, in order to support these ideas, it is always wanted that make a accurate information extracting system based on physical layer for source STA to make correct decision dynamically. More practical this extracting system is, more efficiently the dynamic optimizing algorithm will work in MAC or upper layers.

Thereby, the next step of the research is supposed to find out a accurate mapping system to get the information about RF link quality and take this information as a part of QoS algorithm which can auto-adapt to optimize network capability dynamically.

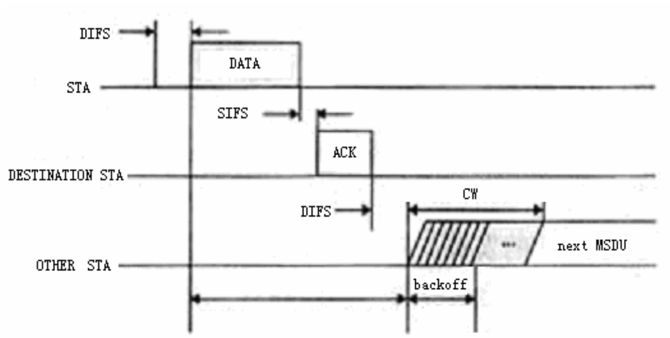

figure 1 DCF of IEEE 802.11

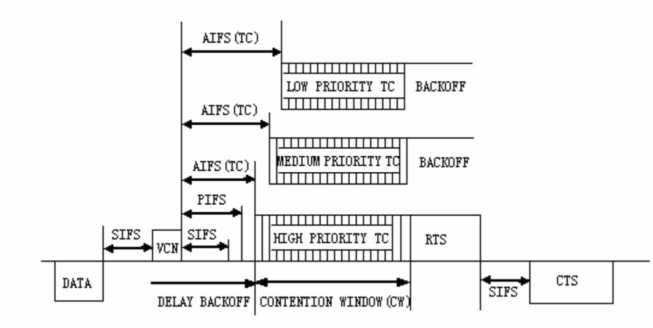

figure 2 EDCF of IEEE 802.11e

parameters	Meaning and unit	Effect when decreased	Effect when increased
RTS Threshold	Frames larger than the threshold are preceded by RTS/CTS exchange.	Greater effective throughput if there are a large number of hidden node situations	Maximum theoretical throughput is increased, but an improvement will be realized only if there is no interference.
Fragmentation Threshold	Frames larger than the threshold are transmitted using the fragmentation procedure.	Interference corrupts only fragments, not whole frames, so effective throughput may increase.	Increases throughput in noise-free areas by reducing fragmentation acknowledgment overhead.

Table 1

6. References

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