A Dynamic Priority Adjustment Scheme for the Next Generation WLAN Supporting Delay Sensitive Services

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Abstract. With the rapid development of wireless communications, Wireless Local Area Network (WLAN) has entered thousands of households and has become one of the most important ways of carrying data business. In recent years, delay sensitive applications and services such as real-time game and wireless meeting have been increasing sharply. These applications and services require low latency. However, the traditional WLAN can hardly satisfy the needs of this requirement. The next generation WLAN standard: IEEE 802.11be which was established in 2019 regards low latency as one important technical objective. In this paper, we propose a delay sensitive priority adjustment scheme for the next generation WLAN to improve the latency performance of delay sensitive services. In the Media Access Control (MAC) layer, if there is still some time left before deadline, the priority of delay sensitive packets will be normal. Conversely, as the deadline approaches, the priority of delay sensitive packets will be upgraded. The priority related mechanisms in MAC layer include queuing policy, channel access parameters, and Modulation and Coding Scheme (MCS) selection.

Keywords: WLAN · 802.11be · EDCA · Low latency

1 Introduction

With the popularization of wireless network and the rapid growth of global user business, Wireless Local Area Network(WLAN) has become one of the most important data service carriers. However, as the number and demand of users increases, the performance requirements for business transmission are also steadily increasing. In order to meet the increasing user demand, both academic and industrial circles are paying attention to the key technology research and standardization of next-generation WLAN.

With the rapid development of IEEE802.11 WLAN, the demand of users for Quality of Service(QoS) is increasing. As the diversity of service types and the number of delay-sensitive services increased, it is necessary for network

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transmission to keep pace with the times and provide corresponding QoS guarantees for various services. Therefore, the improvement of QoS becomes the direction that the device business or the terminal mobile device is striving to improve. In 2005, IEEE 802.11e proposed a Hybrid Coordination Function (HCF) based on the Distributed Coordination Function (DCF) and Point Coordination Function (PCF) in the original IEEE 802.11 protocol, which included Enhanced Distributed Channel Access (EDCA) mechanism. EDCA can provide business priority service and provide QoS guarantee to some extent.

However, the EDCA mechanism has its limitations. Although it divides the business into 4 types and 8 priority levels, as new low delay business rises, its disadvantage has gradually exposed. At present, such network service as on-line game, VR and automatic drive, which have very high request to the low delay, are gradually increasing. The demand for such services is growing fast. But for these derived delay-sensitive services, the existing mechanisms cannot meet their transmission performance requirements, and there is no guarantee that they will complete the transmission within the specified time. Even in the transmission, there are often discarded packets and so on, resulting in an extremely bad result. Clearly, the EDCA does not provide sufficient protection for delay sensitive services.

The next-generation WLAN Protocol IEEE802.11be has taken low latency guarantee as a key technology target, aimed at solving the problem of low latency service in the EDCA mechanism of IEEE802.11e.

The current literature on WLAN delay performance and IEEE 802.11be standards for next-generation WLAN is as follows:

Hyame Assem Alameddine et al. [1] described the service types, development prospects and requirements of ultra-low latency, and then, based on the fifth generation of cellular network, proposed a method to enhance the performance of cellular network based on routing scheduling.

Yu Y U et al. [2] explored the delay problem in mobile and wireless networks, a FPP with spatial diversity and coding redundancy was proposed to enhance the delay performance as much as possible.

Engelstad P E et al. [3] proposed a method to predict the total packet transmission delay, which can be used to improve the performance of the EDCA priority scheme of IEEE 802.11e standard.

Khorov E et al. [4] analyzed hundreds of features proposed based on the new technology of IEEE 802.11be, including the description of low delay guarantee and real-time requirements.

In Yang M et al. [5], the key technologies such as delay and jitter guarantee of IEEE 802.11be are systemized and prospected.

The main features of IEEE 802.11be are described in detail in López-Pérez et al. [6] and the potential throughput gain it provides is evaluated.

However, the existing literature can not analyze the EDCA mechanism to find out its problems in low-delay guarantee. Then according to the solution of the problem, raise a dynamic priority adjustment in detail.

Based on the analysis of the EDCA mechanism of IEEE 802.11e, this paper proposes a dynamic access priority adjustment strategy for protecting delay-sensitive services. In this scheme, the delay-sensitive service packets are analyzed, and the priority of the service and the transmission scheme are dynamically adjusted according to the time threshold of the waiting time. Finally, the delay-sensitive service transmission requirement is guaranteed.

In the first part of this paper, we present IEEE 802. 11e is difficult to guarantee delay-sensitive services. We investigate the current research situation at home and abroad, and describes the work done in this paper. In the second part, the traditional EDCA is briefly introduced and its principle is briefly analyzed, and then the problems of traditional EDCA in delay-sensitive service are pointed out. The third part, on the basis of the previous, leads to the low-delay guarantee strategy proposed in this paper, and gives the concrete realization ideas. In the fourth part, simulation experiments are carried out on the delay-time guarantee model proposed in this paper, and the simulation results are compared and analyzed. The fifth part is the summary of the full text.

2 Background and Motivation

2.1 The EDCA Mechanism

In IEEE802.11, the DCF mechanism adopts contention access mode, which can not provide accurate delay and bandwidth guarantee. So, the DCF can not guarantee QoS at all.

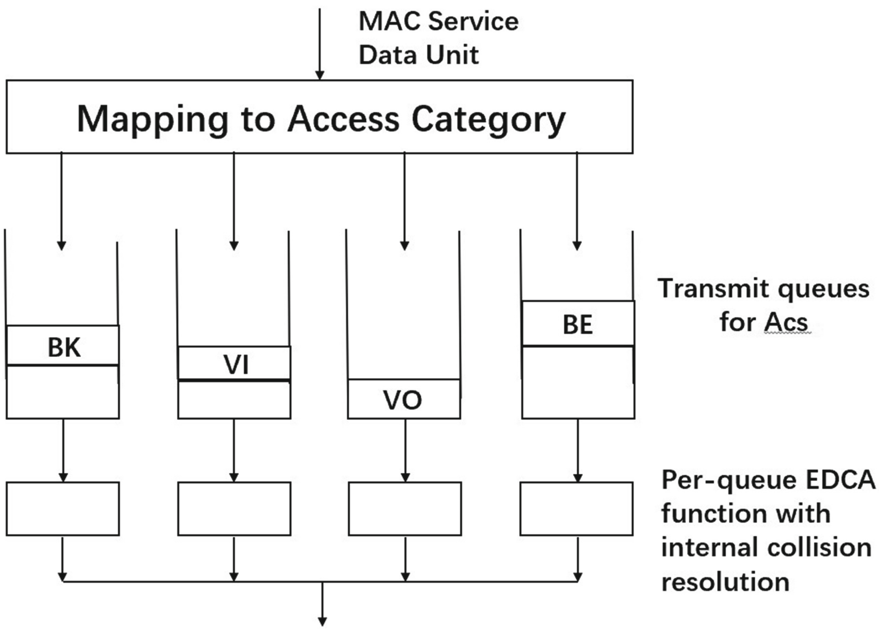

Fig. 1. Queue access for EDCA

To improve the QoS of the MAC protocol in IEEE802.11, IEEE802.11e raised EDCA which provides different levels of priority services. Figure 1 shows the basic queue access method for EDCA. The EDCA mechanism introduces the concept of Service Queue, which maps the service into four access categories. The four access categories are prioritized from top to bottom: voice (AC_VO), video (AC_VI), data (AC_BE), background flow (AC_BK). Four access categories were divided into eight priority. EDCA access categories and priorities are shown in Fig. 2.

Priority	AC	Designation Informative
1	AC_BK	Background
2	AC_BK	Background
0	AC_BE	Best Effort
3	AC_BE	Best Effort
4	AC_VI	Video
5	AC_VI	Video
6	AC_VO	Voice
7	AC_VO	Voice

Fig. 2. EDCA access category and priority

In IEEE802.11e, different levels of priority correspond to different channel intervention parameters. Channel intervention parameters include Arbitration Frame Intervals (AIFS) and Contention Windows (including CWmax and CWmin).

The transport backoff process of DCF/EDCA is shown in Fig. 3. AIFS does not use fixed frame intervals like DIFS (Distributed Frame Gaps) in IEEE 802.11. Different services use different AIFS, where the higher-priority services use smaller AIFS and the lower level of priority services use the opposite. When the channel idle time reaches an AIFS interval, the business can send the data. Therefore, high-priority services will send data ahead of time. The formula of the AIFS' calculation is as follows:

$$AIFS[AC] = SIFS + AIFSN * aSlotTime \tag{1}$$

As can be seen from the above formula, different businesses may have different AIFS[AC] according to different AIFSN.

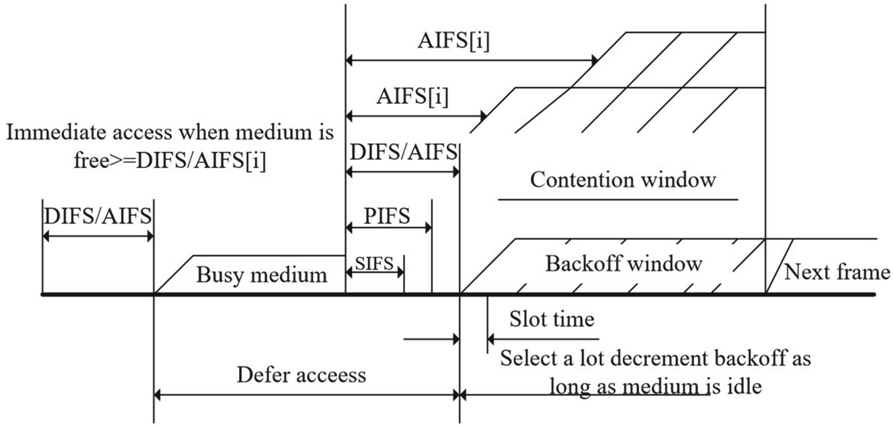

Fig. 3. Backoff Process of DCF and EDCA

Meanwhile, the higher the priority level is, the shorter the competition window will be. It also ensured that high priority services get better service.

Different types of traffic are differ in priority, so they can be transmitted according to different channel parameters and guarantee the QoS. In this way, EDCA provides a degree of QoS assurance to the business.

2.2 EDCA is Insufficient for Low Latency Service

With the development of network services, services with high requirements for low transmission delay have gradually become the mainstream. Such as online games, industrial control, VR, autopilot and so on, these services must be transmitted with very low delay to meet the users' needs. The question arises: for these low latency services, how should they be prioritized for transmission using traditional EDCA mechanisms?

We assume a simple scenario: during the transmission of an EDCA, the channel is in a relatively saturated state. At this point, there is a delay-sensitive packet to be sent, as shown in Fig. 4 below. To meet the needs of delay-sensitive businesses, it seems the easiest way is to configure all of these businesses to be high priority, such as VO.

If all delay sensitive services are treated as high priority services, the requirements of these services are guaranteed to some extent, but this will have a significant impact on the existing high priority services in the VO queue. As a result, the queue of high priority traffic is congested, which seriously affects the transmission quality. Furthermore, more business is assigned to the High Priority Queue, which means the high priority particularity is no longer existed. Obviously, this will have a bad effect on the transmission. So, it's not a viable strategy.

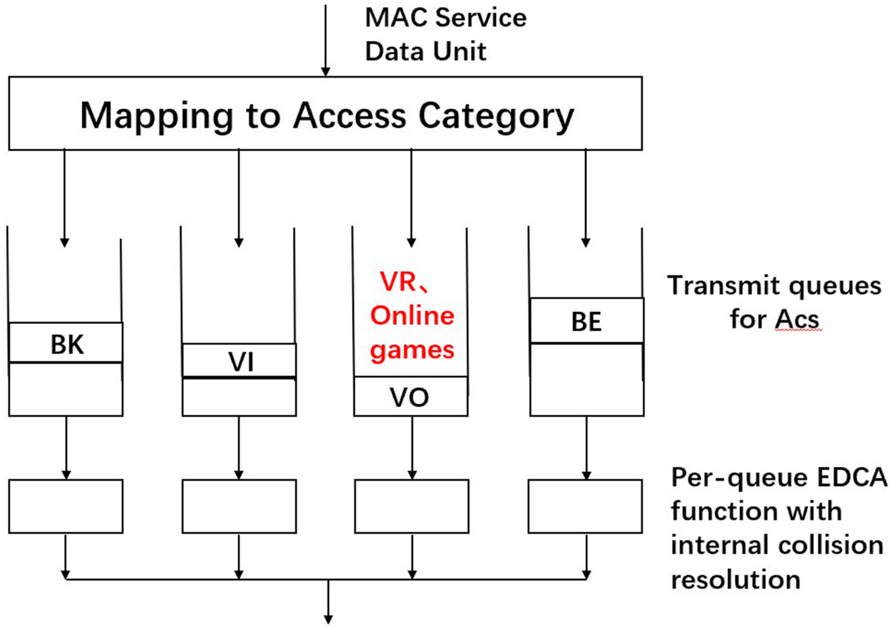

Fig. 4. Example

If the delay sensitive business is all set to low priority, such as BE. That doesn't work either. While this approach protects the transmission quality of traditional high-priority services, the problem of delay-sensitive Services has not been solved at all. Low-priority queues, which are inherently inefficient, will only become more crowded and will certainly not meet the needs of delay-sensitive services.

The above analysis is only a simple case. We can see that the EDCA mechanism has been unable to meet the transmission needs of a single delay-sensitive business. As a matter of fact, with the rise of delay-sensitive business, business is becoming more and more differentiated. Today, latency is no longer exclusive to certain packets. Packets of different services may have low latency demand, the only difference is the degree of the demand.

For example, an AC_BE type packet does not require much delay when entering the queue. But if it can not compete with the channel for a long time, and can not send, then its delay will become more and more sensitive. That eventually caused the packet to fail.

It is obvious that in reality, when more and more packets require low delay, the traditional EDCA will only fail more and more. A simple high-low priority configuration will only result in more and more serious errors. Clearly, it does not meet the needs of the user.

3 Low Delay Safeguard Strategy

3.1 Low Delay Guarantee Strategy for Dynamic Priority Adjustment

In this paper, a low delay guarantee strategy based on dynamic priority adjustment is proposed to provide dynamic priority adjustment for delay-sensitive services, so as to guarantee the emerging delay-sensitive services without affecting the transmission quality of the traditional four services as much as possible.

3.2 The Core Idea of Dynamic Prioritization

In order to simplify the analysis, high priority VO and low priority BE are set. The high priority VO and low priority BE are connected to a single channel in the EDCA way. Within the node, VO and BE are divided into two queues, which perform queuing and retreating access independently.

Supposing that packets of a delay-sensitive service need to be sent, in order to meet the needs of users, there is a time T as the deadline for dispatching. That is, after such packets are queued for sending, they must be dispatched within time T, otherwise the packets will be lost. Assuming that after a packet is queued, its waiting time in the queue is recorded from zero at t. It is obviously that the packet is sent at t<T according to business requirements.

The implementation process is shown in Fig. 5.

First of all, in order to save channel resources as much as possible, when the delay sensitive class packet just arrived, it was queued according to the traditional EDCA idea, placed in the low priority BE queue to wait for sending, and then executed the backoff according to the channel access parameters of the low priority service.

It is best if the delay-sensitive packets are sent successfully in the BE queue. More often than not, t (the waiting time) is near T (the deadline for sending), but there are still many packets in the queue ahead of delay-sensitive packets. If we don't act now, the delay-sensitive packets will not be sent in time.

Through many experiments, the parameter $\alpha(0< \alpha <1)$ is chosen as the threshold of the waiting time of delay-sensitive packets in the low-priority Queue. That is, when t arrives αT, if the delay-sensitive packet is still not sent in the BE queue, it is urgent. To ensure the demand of service transmission, dynamic adjustment should be taken. At this point, the channel access parameters of delay sensitive packets are changed from BE queue to high priority VO queue, which increases the possibility of receiving the packet delivery service.

When the delay sensitive packets enter the high priority VO queue, it is best if the packets can be sent smoothly. But if the waiting time t is very close to the deadline T, and at this point the delay sensitive packets are still queued in the VO queue, which makes it more urgent.

Through many experiments, the parameter $\beta(\alpha < \beta <1)$ is chosen as the threshold of the waiting time of delay-sensitive packets in the high-priority queue. That is, when t reaches βT, if the delay sensitive packet is still waiting to be sent

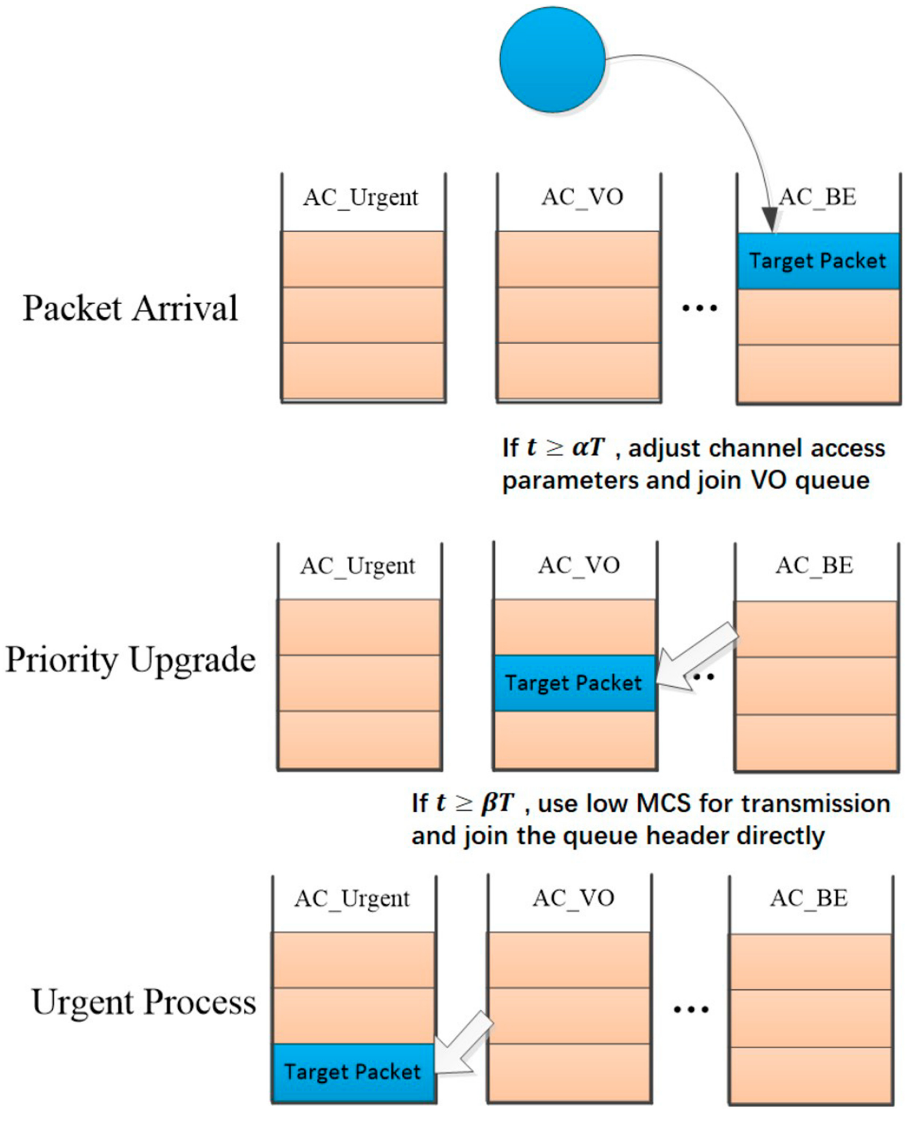

Fig. 5. Core idea

in the VO queue, it is more urgent. To ensure the service transmission requirement, dynamic adjustment measures should be taken again. The packet will be transferred to the head of the queue directly, and the low MCS(Modulation and Coding Scheme) is used for transmission to ensure that the delay-sensitive packets are sent before T time and to make the transmission more reliable.

The entire delay-sensitive business dynamic assurance process is shown in Fig. 6.

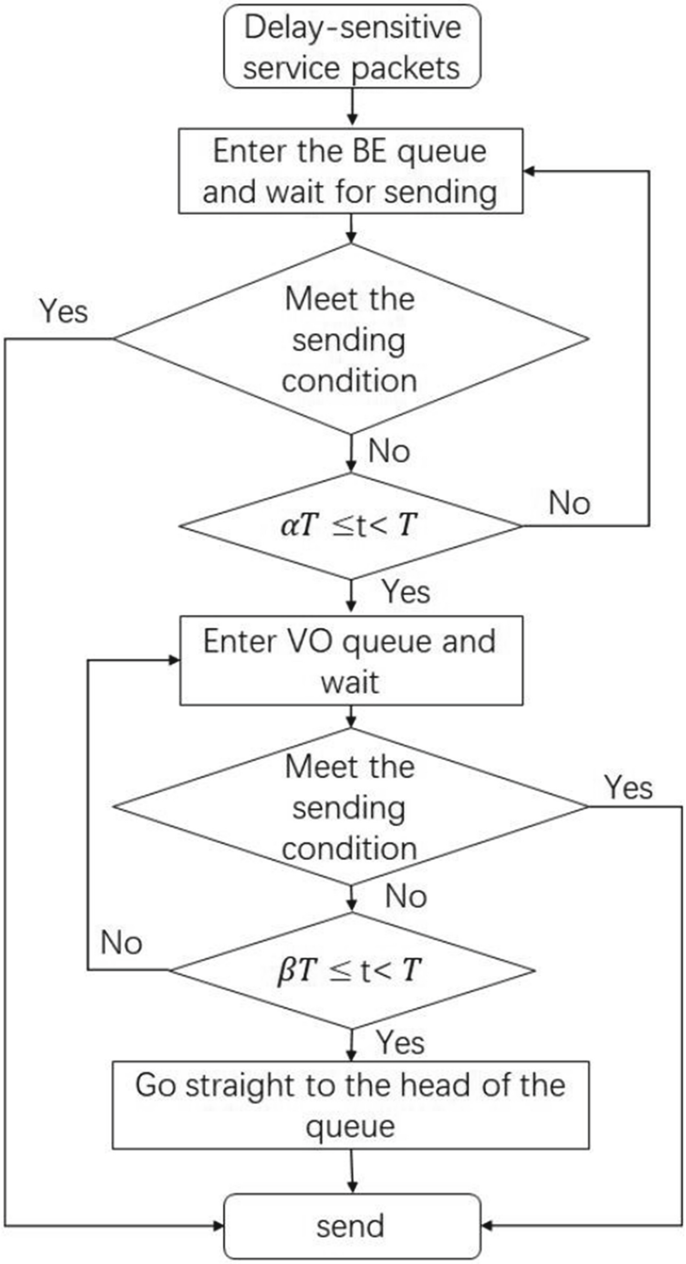

Fig. 6. Core idea' process

Through this process, the channel and slot resources can be utilized to a greater extent, and the transmission quality of the original four types of services can be guaranteed to guarantee the performance of the emerging low delay demand services. This strategy is undoubtedly more applicable now and in the future, when low latency becomes the mainstream of network services.

4 Simulation and Analysis

4.1 NS3 Platform

NS3 simulation platform is a discrete event simulator, which can simulate network transmission and service model by configuring the corresponding modules of it.

4.2 Design of Simulation

In order to meet the requirements of the experiment, the EDCA model is simulated on the NS3 platform, and three kinds of services are generated at the same time. One is VO, the other is BE, and another is low delay. Put them into the model to carry out simulation experiments.

The design of the experiment is UDP transmission. During the experiment, the low delay service was first processed according to the high priority VO type in the common EDCA mechanism at different data generation rates, which was used as the control. Then, the low-delay guarantee strategy with dynamically adjusted priority is used to deal with the problem. The performance of the delay and the change of the throughput of the two processing methods are collected respectively. Finally, the advantages and disadvantages of the two methods are compared and analyzed. Parameter Settings are shown in Fig. 7.

PHY	IEEE 802.11ax
MAC header	56bit
ACK frame	Physical layer header +112bit
a slot time	20μs
SIFS	10μs
AIFS[VO]	10μs+2*20μs
AIFS[BE]	10μs+3*20μs
CW[VO]	[3,7]
CW[BE]	[15,1023]
Packet size	1500Byte

Fig. 7. Parameter Settings

In the simulation of the dynamically adjusted model raised in this paper, the last contract period T of the low delay service is set to 10 ms. Through a large number of experiments, the optimal effect is selected, so that the configuration parameters $\alpha = 0.5$, $\beta = 0.92$. That is, before 5 ms, services with low latency requirements were transmitted as BE. After 5 ms, it's transmitted as VO. Transmission should be completed by 9.2 ms at the latest.

4.3 Analysis of Simulation Results

Using two different processing methods, when the packet rate is different, the transmission delay of the low-latency service are shown in Fig. 8.

Using two different processing methods, the total throughput of the network changes with different packet rates are shown in Fig. 9.

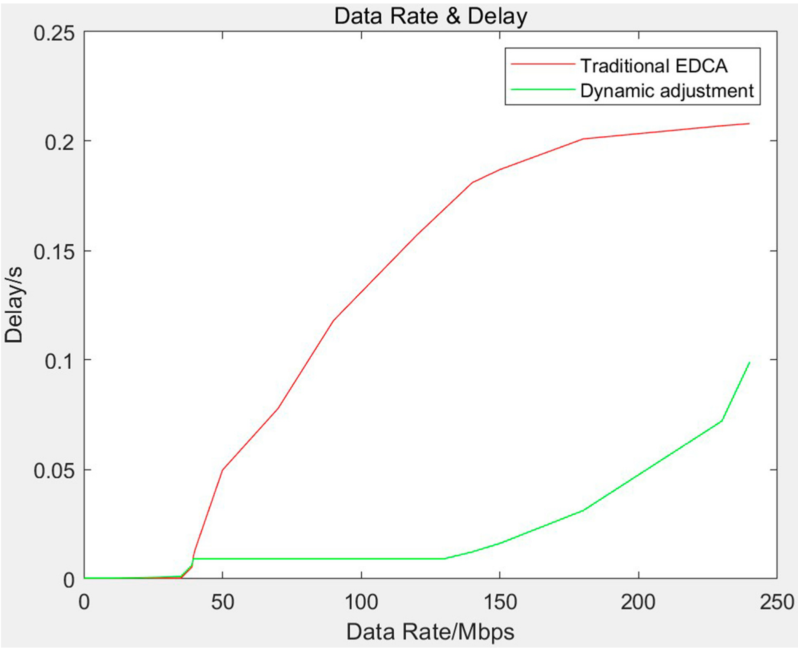

Fig. 8. Delay performance of delay-sensitive service

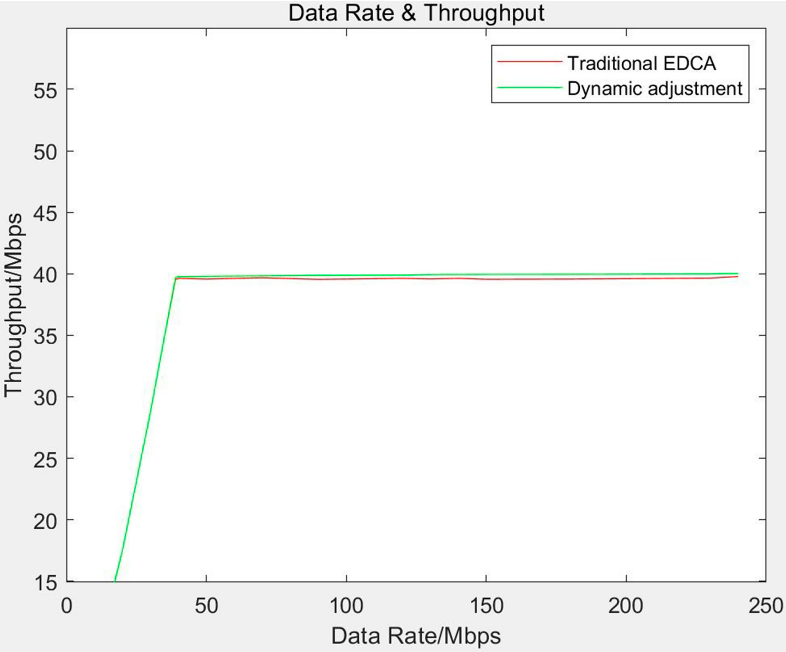

Fig. 9. Throughput performance

The results of the experiment were analyzed and compared.

The result shows that, compared with the traditional EDCA mechanism, the low delay guarantee strategy proposed in this paper can effectively guarantee the low delay demand of the service within a certain limit. As can be seen from the Fig. 8, when the packet rate is less than 130 Mbps, the traditional EDCA can't provide the delay guarantee for the delay sensitive service. The model proposed in this paper guarantees that data packets of delay sensitive service can be sent at 9.2 ms. When the data rate is higher than 130 Mbps, the low latency guarantee performance is affected due to the traffic increasing and exceeding the load carrying capacity, but it still performs better than the traditional EDCA.

As can be seen from Fig. 9, the throughput of the proposed model is higher than that of the traditional EDCA when the packet rate is higher than 39.5 Mbps. This is due to the low-delay dynamic adjustment strategy proposed in this paper, which can make use of both low-priority BE and high-priority VO. Therefore, the total throughput and transmission efficiency of the network are improved to a certain extent.

It is concluded that the dynamic priority adjustment model in this paper is effective, not only for the delay sensitive service, but also for network throughput efficiency.

5 Discussion

According to the simulation, the dynamic priority-based strategy proposed in this paper can provide better protection for the emerging low-latency services than the traditional EDCA. In the face of the booming low delay business, the traditional EDCA can't meet the needs of users. Using the strategy provided in this paper, the transmission of low delay traffic is guaranteed without affecting the traditional traffic.

6 Conclusions and Future Works

Based on the analysis of the latest progress of WLAN and the shortcomings of traditional EDCA mechanism in the new low-delay service transmission, a low-delay guarantee strategy with dynamically adjusted priority is proposed. This strategy not only guarantees the normal transmission of the traditional services, but also provides a solution to save the channel and slot resources for the emerging low-delay services. The results show that the low delay guarantee strategy proposed in this paper is better than the traditional EDCA mechanism.

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