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The Improved Research on IEEE 802.11 Mac Layer Access Mechanism

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Abstract. The mechanism of IEEE 802.11 is random access, which exhibits a significantly increased probability of collision when there are too many access points, thereby diminishing the performance. This paper introduces a distribution mechanism to improve the current random MAC layer access mechanism involving a combination of distribution and competition with dividing one working cycle into two parts by managing the transmitting sequence. The simulation experiment indicates that the improved protocol can increase network throughput while maintaining a relatively lower end-to-end delay.

Introduction

With the development of society and the economy, smart terminal devices, such as smart phones and PDAs, are now widely used. People's demand for network technology is steadily increasing. As an extension of the traditional wired network, the wireless Local Area Network (WLAN), with its advantages of flexible networking, convenience, efficiency and ability to easily expand, is universally adopted at such locations as public areas, houses, and companies. Currently, linking to the Internet via WLAN at various public places is notably popular. However, at crowded areas, where there are a limited number of APs but a large group of users, such as a business circle, exhibition hall and airport, the current access mechanism of IEEE 802.11 has a high collision probability, which greatly restricts the efficiency of the WLAN.

The MAC layer controls network nodes access to the wireless channel in WLAN; it is the direct distributor of sending and receiving controlling messages and data messages via the wireless channel. The performance of the MAC has direct impact on the usage rate of the wireless channel and the performance of the entire system. As a result, it is crucial to have the MAC layer use the band-limited signal in the wireless channel efficiently.

This paper introduces a new access scheme in the MAC layer that addresses the problem of lower throughput under a highly competitive system using the CSMA/CA protocol. Letting the access point (AP) control the all the activities in the basic service set (BSS), effectively increases the throughput of the system.

The rest of the paper is organized as follows. In section 2, we introduce the 802.11 MAC protocol and its problems. In section 3, we provide a brief summary of the improved schema currently proposed. We introduce our improved schema in section 4. Section 5 describes our simulation experiment and provides a summary of the results.

IEEE 802.11 Wlan Mac Layer Protocal

802.11 MAC layer protocol. The original version of the standard IEEE 802.11 was released in 1997 for the fixed WLAN infrastructure. 802.11 adopts the standard star topology; the center is the

AP. The down link data broadcasted to all sites by the AP is accessible to all the sites in the BSS system; the up channel sites sending to the AP are shared by all the sites.

The 802.11 standard MAC layer determines the time when the wireless sites in the BSS transmitting and receiving data use the coordination function. The MAC layer can be further divided into the distribution coordination function and the point coordination function. The DCF adopts distributed access algorithm based on the CSMA mechanism rather than using the central control model. In this way, each site competes for a channel to acquire the transmission right. According to 802.11, every site has a DCF function.

Operating procedure of the CSMA/CA protocol DCF. Readers can refer to [1] to learn about the operating procedure of DCF. DCF is the basic channel sharing mechanism in the IEEE 802.11 MAC layer. DCF is required to be executed in all sites; it adopts carrier sense multiple access/collision avoidance (CSMA/CA), a random access method, which includes two access models: Basic Access Model and Request to Send/ Clear to Send (RTS/CTS) Model.

1. Basic Access Model. When the sending site detects continues idle time signal reaches to the DIFS in the wireless channel, it starts sending the data frame to the destination sites. If this data frame is correctly received, then the destination sites wait for SIFS time before sending the ACK frame to the sending site to indicate that this frame was successfully received. The sending site regards the data frame as successfully received only if the sending site receives the ASC frame in a given time; otherwise, it determines that there is collision, and then applies the Binary Exponential Back-off (BEB) algorithm to back off and resends this frame when it finishes backing. This cycle continues until this data frame is successfully transmitted or it discards this frame when reaching the attempt limit.

When a sending site uses the BEB algorithm and chooses a time slot for the contention window, a back-off timer is set according to the address of the time slot. While the back-off timer is reduced to 0, the sending site begins to send a message. If the channel returns to the busy condition before the back-off timer is reduced to 0, then freezing of the back-off timer occurs until the channel becomes idle. Restart back-off timer (start from what is left last time) occurs after the DIFS time.

2. RTS/CTS Model. If the channel is idle, then the source site sends RTS, including the source address, destination address and duration of this communication (including corresponding confirm frame) before sending data frame (after waiting for DIFS time). If the destination site correctly receives the RTS frame and the channel is idle, then after waiting for the SIFS time, the CTS frame is sent. The source site is permitted to send the data frame only if it receives the CTS frame and waits for the SIFS time. The destination site receives the data frame, and then waits for the SIFS time before sending the source site ACK frame to confirm this data frame was successfully received. If there is a collision, similarly, this model adopts the BEB algorithm to retard the time.

Open question of the CSMA/CA. The CSMA/CA protocol proposed many effective approaches for WLAN; however, there are two main open questions:

First, CSMA/CA adopts the BEB back-off algorithm. The BEB is simple but too intense for adjusting the back-off time. Once a collision is detected, the back-off time increases with binary exponential growth; while successfully transmitting at the first attempt, the back-off time reduces to a minimum. This behavior leads to considerable back-off time fluctuation. For example, for one-time successful transmission, back-off time is restored to its minimum, while the back-off time of the other sites is relatively larger, during the next time competition, the sites with a small back-off time easily obtain the chance to transmit; this site's back-off time returns to a minimum. As a result, such sites will have advantage in the next time's competition, whereas the other sites' back-off time increases again. This behavior causes serious unfairness. So, an improved algorithm should be developed to avoid such fierce fluctuations and to ensure fairness.

Second, DCF has an inherent flaw. The DCF model is effective when the network load is light. However, with the increase of load, there is large waste of time from adopting the back-off algorithm; as a result, the throughput will reduce step by step, thereby causing a lack of confirmation of the end-to-end delay. In addition, in the DCF model, all sites in a BSS have the same priority to compete for a channel, which results in no difference in delivering services for high priority sites.

Improved CSMA/CA Related Work

To tackle the problems of the IEEE 802.11 MAC access mechanism, currently, many algorithms have been proposed to improve the performance of CSMA/CA in throughput, fairness and delay. According to 2.3, the improvement for CSMA/CA is mainly conducted via two means: the back-off algorithm and the DCF model. To improve the back-off algorithm is to improve the size of the competition window. By setting a reasonable size of the competition window, the sites can make the most of a channel and reduce the probability of collision, thus increasing throughput. Regarding the DCF model, improvement can be focused at the performance of a channel or the manner in which sites utilize a channel via the combined distribution approach. The principle for improving the back-off algorithm is relatively easier and also more effective when the network load is light, whereas the improved DCF model is more suitable for a high-demand network or a high capacity network.

Each of these algorithms has its own characteristics; each can improve one or more performance metric of a network, but at the cost of reducing some performance in certain circumstances. The following is a brief introduction of some improved algorithms.

Improved Algorithm Based on the Competition Window. Apparently, the size of the Competition Window (CW) determines the performance of IEEE 802.11. When there is small number of competitors in the network, a small CW is preferred to reduce idle time of the channel and make good use of the channel bandwidth. When the number of competitors increases, a larger CW will reduce the number of collisions. Therefore, the choice of an appropriate size of the CW can optimize the performance of the protocol.

SETL Algorithm (Smart Exponential Threshold Linear): the author of [2] proposed an algorithm involving the setting of a threshold value to judge the network congestion situation, followed by application of different back-off algorithms according to the different conditions. While a collision occurs, if the CW is smaller than the threshold value, then the size of the CW is doubled; otherwise, linearly increase the CW by CWmin. For sites sending a telegram successfully S times, if the CW is smaller than the threshold value, then reduced the size of the CW in half; otherwise, decrease the CW by CWmin.

M-DCF Algorithm: the author in paper [3] proposed the M-DCF algorithm. Every node calculates the idle slot time since the last successful transmission, i.e., the slot time between the last time's successful transmission and the current time's successful transmission, denoted as , and then every node chooses the back-off slot time in . There is no back-off value of other sites within this range, thus avoiding collision. With the increase in the number of nodes, probably turns to 0, which may cause a collision next time. At that time, double the size of the CW using the BEB algorithm, and then repeat the above operation in a new back-off grade.

FCR Algorithm (Fast Collision Resolution): the author in papers [4][5] proposed a FCR algorithm that adopts a relatively smaller initial value of CW and a greater range of CW. In FCR, when a site is under the delay sending condition, if it detects a collision or frame in the channel, then double the size of the CW. When the idle slot time exceeds the default value, reduce the back-off time rapidly. This rapid back-off method results in a higher priority for sites that successfully send messages in a short time and can easily send messages successfully in a continuous manner.

Time Slot Distribution Algorithm. Super Slot Mechanism: the author in paper [6] proposed a method to reduce the number of collisions in DCF, known as the super slot mechanism. Two time slot are combined to form a super slot. When a site sends message in a super slot, it chooses a slot based on probability q; the site chooses the second time slot based on probability (1-q). When there is more than one site in a super slot, as long as one site chooses the first time slot, the other sites must choose the second time slot. As a result, those sites that choose the second time slot will find the busy channel and are unable to send messages. In this way, when more than one site is in a super slot, there is still a chance of successful transmission. The super slot mechanism reduces the probability of collision.

Improvement Schema

The mechanism of IEEE 802.11 is random access, which will greatly increase the probability of collision when there are too many sites, thus deteriorating the performance. Although many improved mechanisms have been proposed, the basic random idea still constrains the enhancement of performance. Hence, our improved mechanism is to introducing distribution access. This paper introduces a distribution mechanism to improve the current random MAC layer access mechanism and develops a mechanism combining distribution and competition. In this approach, one working cycle is divided into two parts by managing the transmitting sequence： competition time and distribution time. Every site sends RTS T1 to AP during the competition time; and then the AP notifies every site transmitting data frames successively during the distribution time.

Competition time: First, AP broadcasts NEWS1 to tell all sites in the station BSS that requests are accepted. Then the sites with data frames begin detecting a channel and send RTS to the AP after the DIFS waiting time; in the meantime, the timer is set. Once AP receives a RTS, it records the ID of the site and the length of the data (can be transferred into time); in the meantime, confirms with ACK. Only when this site receives CTS within the time limit, it is considered a successful application; otherwise, the site fails to send the data. When the request fails, the site, after a delay for a waiting period (refer to back-off algorithm), resends RTS to the AP while the channel is detected as idle. For sites with successful application, AP maintains a list to record information in RTS, including the source site ID, the destination site ID and the its sending data length in bytes, according to the sequence of the request.

Table 1: Sequence of Requesting Sites

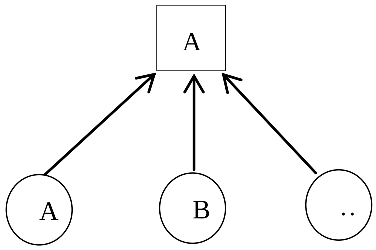
No.	Sequence Number	Source Site ID	Destination Site ID	Its Sending Data Length in Bytes	Transmission Duration Td
1	**	**	**	**	**
2	**	**	**	**	**
3					

In Table1, Td=Length of Data in Bytes/ Channel Bandwidth (sending rate)

Distribution time: After waiting for the SIFS time, the AP broadcasts a message in the channel according to the list. Sites in the BSS decide whether to send data according to the source site in the message. If it is not the turn of the site to send data, then make sure that during this sending time, the site does not send any data. If the destination site correctly received the data frames sent by the source site, then the destination site sends a confirm frame ACK to the AP. After receiving ACK, the AP waits for the SIFS time before the next broadcast occurs.

The process is as follows (in a cycle's time: T=T1+T2):

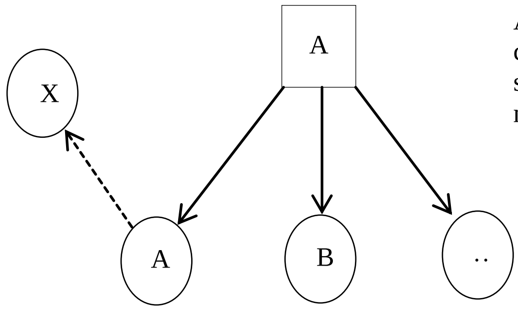
1. Start at T1, broadcast NEWS1
2. Sites sending request to AP after detecting channel, execute back-off algorithm once detecting collision
3. Record sequence of requesting sites according to the context of RTS
4. End of T1, T2 time starts
5. AP broadcasts NEWS2 to inform sits sending requests according to sequence table of sites
6. Sites detect NEWS2 and send data in its turn. The terminal site sends back ACK to AP after receiving data. The other sites do not send data according to NEWS2. And if AP receives ACK in the counted time, then broadcast NEWS2 to inform the next sites to send data
7. The end of T2, T1 time starts



Source	Destination	Duration
A	X	XXX
B	Y	YYY
...	...	......

Fig.1: Sites Send RTS to the AP

In Fig1 Sites with data frames send RTS to AP and AP maintain a list to record information according to the sequence of request.



AP broadcast message in channel according to list,non-send sites do nothing for the message.

Fig.2: AP Notifies the Sites to Send Data

Because all the sites with data to send should first ask the AP for sending rights the can AP notifies sites to send data successively, thereby avoiding collisions of sending data. Thus, our mechanism tackles the problem of hidden sites. In the meantime, only the order of sending is determined, without a priority distinction of the request, which ensures the justice of all the sites.

Simulation and Analysis Based on Omnet++

Simulation Parameters

Table 2 Simulation Parameters

Simulation parameter	value
AP rate	11 Mbit/s
Mobile site rate	1 Mbit/s
Transmission delay	1 μs
SIFS	28 μs
DIFS	128 μs
Length of data	1024 byte
Length of RTS	80 bit
Length of CTS	64 bit
Length of ACK	240 bit

Analysis of the Simulation Results

1.Throughput. Figure 3 shows a comparison of the throughput between the case of adopting the AP control channel mechanism and the DCF for various numbers of sites. We can see that when the number of sites increased to a certain number, the throughput of DCF rapidly decreased, while the improved mechanism maintains a sufficiently high throughput. Additionally, when there is large number of sites, the improved mechanism can largely maintain steady performance.

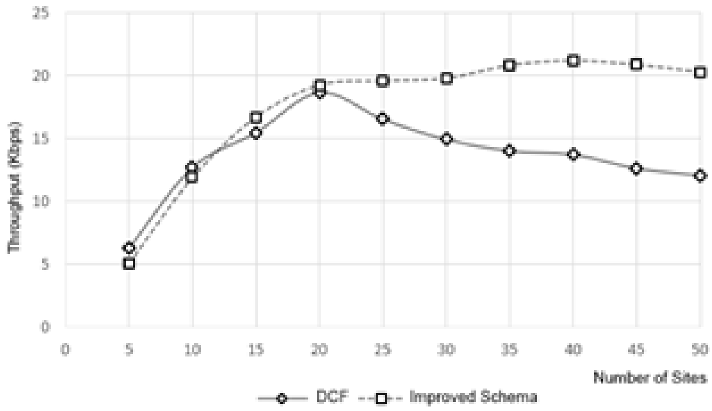


Fig.3: Comparison of the Throughput for Different Sites

2. Use Ratio of the Channel

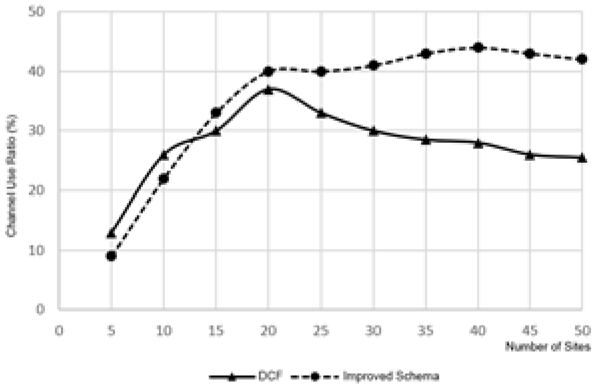


Fig.4: Use Ratio for Different Numbers of Sites

Figure 4 shows the use ratio of the channel for the use of two mechanisms for different numbers of sites. We conclude that the ratio decreased rapidly when using DCF, while the ratio for the improved mechanism remains steady for increasing numbers of sites. The main reason is that when there are too many sites in a service set, the sites attempt to send more data, which immediately causes more than one site to execute the back-off algorithm, resulting in the channel remaining idle. However, by using the improved mechanism, when the sites are executing the back-off algorithm, the AP is broadcasting the notify frame or other types of frames.

3. End-to-end Delay. Figure 5 shows the end-to-end delay versus the number of sites. When the number of sites is small, because the improved sites are able to send data frames only after the time slot of applying for the right of sending is complete and because the DCF has a lower chance of collision and can send data directly, the improved mechanism takes more time than the DCF. However, when number of sites increases, the probability of collision for the DCF mechanism increases greatly, which leads to a longer end-to-end delay; while in improved algorithm, the AP controls the data sending, collisions occur during the time for applying for resources and will not cause a long time delay after collision. As a result, the improved mechanism is able to maintain a steady end-to-end delay with an increasing number of sites.

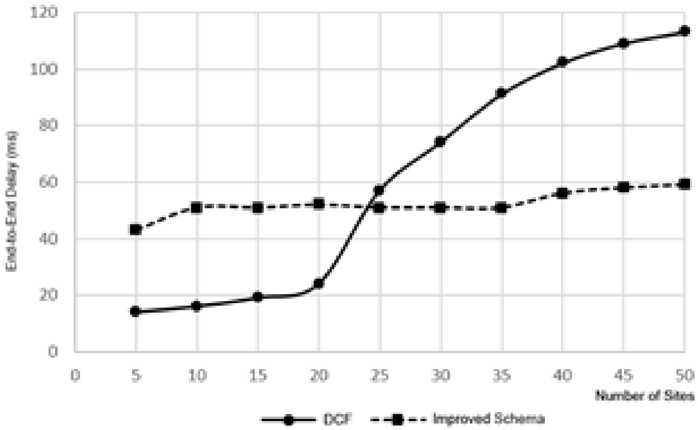


Fig.5: End-to-end Delay

When the number of sites reaches 30, the Super Slot Mechanism increased throughput by 12%, while our proposed mechanism increased throughput by 33%. The end-to-end delay of the improved mechanism, DCF, and FCR are 59 ms, 113 ms, and 180 ms, respectively (see table 2). To conclude, when the number of sites is large, adopting an AP controlling sites model not only achieves a higher throughput than DCF but also provides a shorter end-to-end delay compared to other mechanisms.

Table 3 Comparison with Other Mechanisms (30 sites)

Mechanism	Improved rate of throughput based on DCF	End-to-end Delay
Super Slot Mechanism	12%	46ms
SETL	13%	*
Our Mechanism	*33%*	*59ms*
DCF	——	113ms
FCR	51%	180ms

Concluding from the above simulation experiment, our proposed improved distribution mechanism has the advantages of high throughput, high ratio of channel usage and short end-to-end delay when the number of sites is relatively large. In addition, the lack of priority enables high fairness in the distribution mechanism.

Conclusions

Our paper proposed an improved distribution mechanism that combines competition with distribution based on the IEEE 802.11 WLAN protocol. The AP is entitled to manage the channel. Each of the sites sends data according to the sequence list in the AP after sending a request to AP, thereby reducing the probability of collision. According to the OMNET++ simulation experiment, compared with the traditional DCF mechanism, the improved protocol was determined to enhance the throughput and achieve higher channel usage ratio for the high competition circumstance. In our future research, we will further analyze and confirm this improved mechanism, and we will design a more reliable simulation experimental model.

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