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IEEE 802.11: Throughput Improvement of Medium Access Control Employing Frame Aggregation Method

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Abstract

Along with many emerging applications and services over Wireless Local Area Networks (WLANs), the demands for faster and higher-capacity WLANs have been growing fast. However, MAC layer restrains the performance improvement due to its different overhead. We proposed an efficient MAC scheme 'Frame Aggregation Method' that would mitigate the overhead inefficiency and increase the throughput of MAC significantly. The principle of 'Frame Aggregation Method' is to aggregate as many as possible packets from the upper layer into large frames. Thus, the frames will be very large as long as there are enough packets to be aggregated. To support various functionalities provided by 'Frame Aggregation Method', new MAC frame formats and the corresponding dynamic logic such as queuing mechanisms are designed precisely.

Keywords: *Frame aggregation, Inter-frame space, WLAN, Fragmentation, Frame check sequence, MAC.*

1. Introduction

In recent years, IEEE 802.11 Wireless LAN (WLAN) has emerged as a prevailing technology for the broadband wireless networking. Along with many emerging applications and services over WLANs, the demands for faster and higher-capacity WLANs have been growing fast. This project aim is to propose a new medium access control (MAC) mechanism for the next-generation high-speed WLANs such that it can ensure high throughput of IEEE 802.11.

In this paper we are going to present a MAC scheme for high speed WLANs named as 'Frame Aggregation Method'. Section 3 gives the overview of frame aggregation approach. The rationale of aggregation method is to aggregate as many as possible packets from the upper layer into large frames. Thus, the frames will be very large as long as there are enough packets to be aggregated. The large frames are divided into fragments before transmission. Section 5 shows frame format and section 6 describes fragmentation procedure for the proposed method.

2. Literature Review

2.1 IEEE 802.11 Standards

In 1990, the Institute of Electrical and Electronics Engineers (IEEE) formed a committee to develop a standard for wireless LANs operating at 1 and 2 Mbps. In 1992, the European Telecommunications Standards Institute (ETSI) chartered a committee to establish a standard for higher performance radio LANs (HIPERLAN) operating in the 20 Mbps range. Recently, wireless LAN standards targeted for specialized applications in the home have emerged. Unlike these standards, the development of the IEEE 802.11 standard was heavily influenced by existing wireless LAN products already available in the market. Hence although the standard took a relatively long time to compete (due to numerous competing proposals from different vendors), it is by far the most popular standard to date.

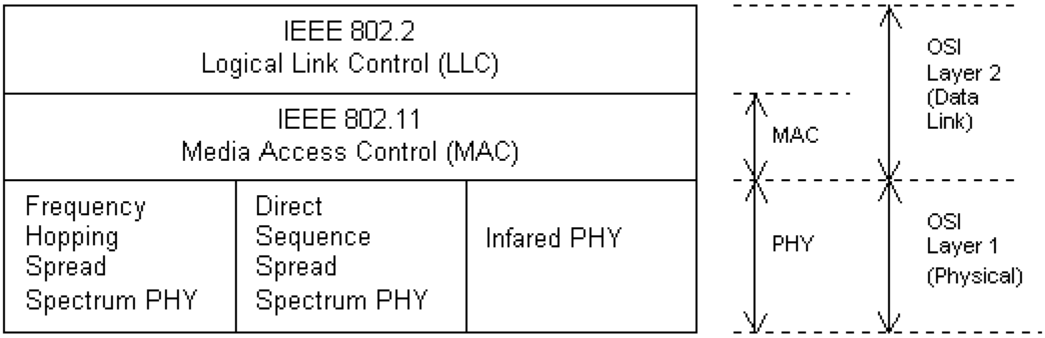

Figure 1: IEEE 802.11 standards mapped to the OSI reference model.

The IEEE 802.11 standard specifies wireless connectivity for fixed, portable, and moving nodes in a geographically limited area. As in any IEEE 802.x standard such as 802.3 (CSMA/CD) and 802.5 (token ring), the 802.11 standard defines both the physical (PHY) and medium access control (MAC) layers. However, the 802.11 MAC layer also performs functions that are usually associated with higher layer protocols such as fragmentation, error recovery, mobility management, and power conservation [18]. These additional functions allow the 802.11 MAC layer to conceal the unique characteristics of the wireless PHY layer from higher layers. Figure 1 shows how IEEE 802.11 standards mapped to the OSI reference model.

2.2 IEEE 802.11 Services

There are nine services defined by the IEEE 802.11 architecture. These services are divided into two groups, station services and distribution services. The station services are authentication, deauthentication, privacy and data delivery. The distribution services are association, disassociation, reassociation, distribution and integration. Table 1 gives an overview of these services [10].

Table 1: IEEE 802.11 services

Service	Provider	Used to support
Association	Distribution system	MSDU delivery
Authentication	Station	LAN access and security
Deauthentication	Station	LAN access and security
Disassociation	Distribution system	MSDU delivery
Distribution	Distribution system	MSDU delivery
Integration	Distribution system	MSDU delivery
Data delivery	Station	MSDU delivery
Privacy	Station	LAN access and security
Reassociation	Distribution system	MSDU delivery

2.3 Basic Access Mechanism

The basic access mechanism is carrier sense multiple access with collision avoidance (CSMA/CA) with binary exponential backoff

[10]. This access mechanism is similar to that used in IEEE 802.3, with some significant exceptions. CSMA/CA is a “listen before talk” access mechanism. In this type of access mechanism, a station will listen to the medium before beginning a transmission. If the medium is already carrying a transmission, the station that is listening will not begin its own transmission. This the CSMA portion of the access mechanism. This is implemented, in part, using a physical carrier sensing mechanism provided by the PHY.

As IEEE 802.11 implements this access mechanism, when a station listens to the medium before beginning its own transmission and detects an existing transmission is progress, the listening station enters a deferral period determined by the binary exponential backoff algorithm. The binary exponential backoff mechanism chooses a random number which represents the amount of time that must elapse while there are not any transmissions. The random number resulting from this algorithm is uniformly distributed in a range, called the contention window, the size of which doubles with every attempt to transmit that is deferred, until a maximum size is reached for the range. Once a transmission is successfully transmitted, the range is reduced to its minimum value for the next transmission. Both the minimum and maximum values for the contention window range are fixed for a particular PHY [13]. However, the values may differ from one PHY to another.

3. Frame Aggregation Method

Supporting rich multimedia applications such as high-definition television (20 Mbps) DVD (9.8 Mbps), etc. is the main goal for the upcoming Wireless Local Area Networks (WLANs). To support these applications, the physical layer (PHY) rate in such networks is expected to exceed 216 Mbps. Although some 802.11n proposals claim to support up to 600Mbps [2], MAC layer restrains the performance improvement due to its overhead [6]. The frame aggregation method addresses a solution for the MAC inefficiency and will provide high data throughput.

The basic idea of the frame conglomeration approach is to aggregate packets from the upper layer into large frames [7]. Thus, the frames will be very large as long as there are enough packets to be aggregated. Packets that exceed the fragmentation threshold are segmented into fragments. Then the MAC layer transmits the large frames and retransmits only fragments when errors are detected by their Frame Check Sequence (FCS). To support the functionalities provided by this method, new MAC frame format and the corresponding dynamic logic such as queuing, retransmission mechanism etc. are need to be designed and implemented.

4. Timing Interval

The IEEE 802.11 MAC recognizes five timing intervals or interframe spaces (IFSs). These are: slot time, short IFS (SIFS), point coordination function IFS (PIFS), distributed coordination function IFS (DIFS) and extended IFS (EIFS).

Slot time: Slot time corresponds to a time slot used for backoff purposes. Slot time is smaller than any other IFSs other than SIFS. Slot time is the sum of the channel assessment (carrier sensing) time, the transceiver turnaround time, the signal propagation delay, and the MAC processing delay [11].

SIFS: The SIFS is the shortest IFS and is used for all immediate response actions (e.g., transmission of ACK, RTS, CTS packets). SIFS is a function of the receiver delay, delay in decoding the PLCP preamble/ header, the transceiver turnaround time and the MAC processing delay.

PIFS: The PIFS is an intermediate length IFS that is used for polling nodes with time bounded requirements. The PIFS is equal to the SIFS plus one slot time.

DIFS: DIFS is used as a minimum delay between successive data packets. The DIFS is equal to the SIFS plus two slot times.

EIFS: The EIFS is much larger than any other intervals. It is used when a frame that contains errors is received by the MAC, allowing the possibility for the MAC frame exchanges to complete correctly before another transmission is allowed [14].

Figure 2 describes various timing intervals. Through these five timing intervals, both the distributed coordination function (DCF) and point coordination function (PCF) are implemented.

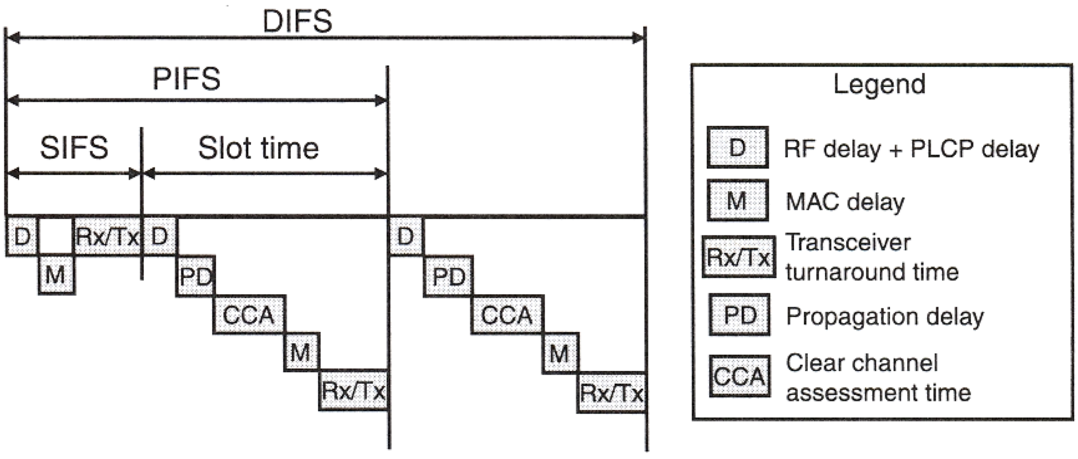

Figure 2: Interframe space definitions

5. Frame Construction

For the proposed aggregation approach, we need to define a frame format to support the functionalities. Figure 3 shows the frame format of the proposed scheme. It consists of two main parts – frame header and frame body. Frame header contains MAC header and frame body consists of fragment headers, data fragments and corresponding FCS (frame check sequence). Size of fragment headers in the MAC frame depends upon number of fragments in a frame. A frame may contain 1-256 fragment headers. On top of the MAC frame format the number shows the size of the fields in number of bytes.

37	8-2048	64-2048	2	64-2048	2	64-2048	2
MAC header	Frag headers	Frag 1	FCS	……..	FCS	Frag N	FCS

Figure 3: MAC Frame Format

New MAC header for the proposed method is shown in figure 4. The field length is shown on top the figure in number of bytes. This format is almost similar to traditional MAC header, just two extra fields added two support required functionalities. These are *fragment size and fragment number.*

fragment size – it represents the size of a fragment in the MAC frame.

fragment number – it represents the sequence number of the fragment in the current MAC frame.

Functions of other MAC header fields are as follows:

Frame control: It's a 16 bit field that contains various information of MAC frame such as protocol version, frame type and so on.

Duration/ID: The Duration/ID field is 16 bits long. It indicates the time (in microsecond) the channel will be allocated for successful transmission of a MAC frame. In some control frames, this field contains an association identifier.

Addresses: General MAC frame format contains four address fields each of which is 48 bit long. Any particular frame type may contain one, two, three, or four address fields. Address types includes source, destination, transmitting station, and receiving station.

Sequence control: Contains a 4 bit fragment number subfield, used for fragmentation and reassembly, and a 12-bit sequence number used to number frames sent between a given transmitter and receiver.

FCS: Frame check sequence is a 32 bit cyclic redundancy check.

2	2	6	6	6	2	6	2	1	4
Frame control	Dur /ID	Add 1	Add 2	Add 3	Seq control	Add 4	Frag. Size	Frag. num	FCS

Figure 4: Proposed MAC header

Figure 5 shows the format of a fragment header. Each fragment header is 8 bytes long. It consists of the following five fields:

Packet ID: It indicates the ID of a particular packet. This field is 14 bits long.

Packet length: It represents the length of the packet. This field also consists of 14 bits.

Start position: This field indicates the starting position of a fragment in this frame. This field is 2 bytes long.

Offset: This field keeps sequences of fragments of a particular packet. It is 4 bits long.

FCS: Frame check sequence is 2 bytes long.

Packet ID	Packet length	Start position	Offset	FCS

Figure 5: Fragment header

6. Fragmentation Procedure

The idea of the aggregation method is to aggregate packets from the upper layer into large frames. A packet is segmented into smaller segments if its size exceeds the fragmentation threshold. Suppose we are using a frame which length is 4096 bytes and fragmentation threshold is 1024 bytes long. Now we want to transmit three packets packet 1, packet 2 and packet 3 which are 2049, 1000 and 500 bytes long respectively. Table 2 describes fragmentation procedure for the three packets.

Table 2: Fragmentation procedure for three packets

Fragment number	Packet ID	Packet length	Start position	Offset
Fragment 1	1	2049	0	0
Fragment 2	1	2049	1024	1
Fragment 3	1	2049	2048	2
Fragment 4	2	1000	2049	0
Fragment 5	3	500	3049	0

The sender divides packet 1 into three, packet 2 into one and packet 3 into one segment. Packet 1 segmented into three pieces because it exceeds threshold value of 1024 bytes. On the other hand, packet 2 and packet 3 is not divided since their size less then the threshold value.

We will see another example of fragmentation to clarify the process. Suppose we are using a frame of length 4096 bytes and fragmentation threshold is 2048 bytes long. Now we want to transmit three packets of length 500, 1000 and 300 bytes respectively. Table 3 describes the fragmentation procedure.

Table 3: Fragmentation procedure for second example

Fragment number	Packet ID	Packet length	Start position	Offset
Fragment 1	1	500	0	0
Fragment 2	2	1000	500	0
Fragment 3	3	300	1500	0

7. Details Of The Method

The main concept of this method is to combine packets from upper layers into large MAC frames. There is a fragmentation threshold for the packets to accommodate into MAC frame. If the packet size exceeds this threshold then packets will be segmented into small pieces according to the threshold value and then put into a sending queue (SQ).

For this method we need to maintain two finite queues which will serve as first in first out basis. Sending queue (SQ) locates at sending station and receiving queue (RQ) locates at receiving station. At the sender, the SQ could keep up to a maximum number (MAX sq) packet. MAC never receives new packet from upper layer if SQ is full.

At the sender, all outgoing packets are segmented according to the threshold value. Before transmission all of the fragments at the sending queue marked 'undelivered'. MAC protocol scan the sending queue for 'undelivered' fragments then put into MAC frame. This continues until either no 'undelivered' fragments available or the MAC frame size exceeds maximum capacity. At last frame transmits according to the Distributed Coordination Function (DCF) rules.

The receiver keeps all the received fragments in the RQ. When receiver receives a frame it checks FCS (frame check sequence) of every fragment. After that it creates an ACK (acknowledgement) frame in which lost fragments are indicated (if any) and sends it back to the sender. When sender receives ACK frame it checks if every fragment sent successfully. If not it retransmits only the lost fragments. Sender MAC's also updates SQ as 'delivered' for successfully sent fragments.

8. Accomplishments

The main objective of upcoming WLAN is to support rich multimedia applications such as HDTV, DVD and so on. To support these types of applications, the physical layer rate in such networks is expected to exceed 216 Mbps. However, MAC layer restrains the performance improvement due to its different overhead such as distributed interframe space (DIFS), short interframe space (SIFS), acknowledgement (ACK) etc. In section 3 we proposed 'Frame Aggregation Method' scheme to mitigate the overhead inefficiency.

The main novelties of the project are as follows. A frame format (section 5) is designed for supporting all the functionalities of the 'Frame Aggregation Method'. This format allows for higher throughput with less overhead. In addition, we study a fragmentation technique (section 6), in which packets longer than a threshold are divided into fragments before conglomerated. This technique is very efficient for transmission of large frame.

Frame conglomeration method strictly follows the basic principle of CSMA/CA, therefore the same fairness characteristics hold as in the legacy DCF (Distributed Coordination Function). All improvements of fairness to the DCF are also appropriate for our proposed method.

In our proposed aggregation approach we focus only on the aggregation between one source-destination pair. The reason is that we can have a clear understanding of the pros and cons of the aggregation itself. However, our frame format can be easily extended to support multi-destinations. We could append a destination address field in each fragment header and remove off the destination address field in the MAC header. However, addition of more fields in fragment headers will create more overhead. But comparing to the solution in the paper [15], our method would still have smaller overhead.

9. Future Work

The objective of 'Frame Aggregation Method' is to show the potential and efficiency of the aggregation idea. As a consequence, we did not address several possible optimization techniques such as:

● Backoff optimization for wireless LANs: To curb the inefficiency caused by exponential backoff, much work already has done. To date, non-exponential backoff is also proposed [16].

● Aggregation can also be combined with block ACK of IEEE 802.11e to further improve efficiency, i.e., only one ACK is used for a train of large frames instead of one frame.

● Two level aggregation is another method, in which large frame piggyback in the ACK frames [1], [15].

Combined with the above techniques, an integrated solution of frame aggregation might be more effective.

Since IEEE 802.11 covers only the MAC and physical layer, fairness is not guaranteed at the network layer in multihop or asymmetric topology. Various aspects of the fairness issues could be examined. Competition between internal and external traffic in a user node brings about a unique challenge in WMN fairness implementation. It is needed to identify desirable fairness characteristics in WMN. The capacity analysis might be carried out on the assumption that ideal fairness is guaranteed.

Realization of WMN fairness is quite challenging because careful design of the algorithm is required so that it incorporates the uniqueness of the wireless medium into the fairness issues of WMNs. The fairness implementation can be either centralized or distributed. The details of such design remain to be tackled as a future research.

10. Conclusion

The basic impetus of this work is to enhance the MAC layer for very high speed WLANs. As a consequence, at first we proposed an efficient MAC scheme 'Frame Aggregation Method'. The objective of this method is to show the potential and efficiency of the aggregation idea. The principle of 'Frame Aggregation Method' is to aggregate as many as possible packets from the upper layer into large frames. Thus, the frames will be very large as long as there are enough packets to be aggregated. These giant frames will be divided into a number fragments before transmission. If any errors occur, only fragments that are acknowledged with errors will be retransmitted. To support various functionalities provided by the approach, new MAC frame formats and the corresponding dynamic logic such as queuing mechanisms are designed. We can draw the following conclusion about 'Frame Aggregation Method'. Firstly, the method is very effective in WLANs with very high speed PHY layer. Secondly, its behavior for applications with high sending rate, or large packet size, or both, is very promising. Thirdly, for low sending rate and small packet size applications, the performance of 'Frame Aggregation Method' would be better than that of DCF.

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