Compressed Block Ack, an efficient selective repeat mechanism for IEEE802.11n

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Abstract—The standardization of IEEE802.11n which aims to achieve 100Mbps at MAC-SAP (Medium Access Control - Service Access Point) is under work in IEEE802.11, Wireless LAN standardization committee. The Frame Aggregation scheme in which MAC (Medium Access Control) frames are aggregated into one PHY (Physical) frame is proposed for IEEE802.11n, because it decreases MAC overhead. In this paper, we propose the Compressed Block Ack mechanism as a selective repeat mechanism to be adapted to the Frame Aggregation scheme. We present simulation results to compare performance of the Compressed Block Ack mechanism and the Legacy Block Ack of IEEE802.11e and show that the proposed method improves the total throughput by 10% than the conventional method.

Index Terms—BlockAck, Compressed, Aggregation, 100Mbps, IEEE802.11n

I. INTRODUCTION

In recent years, Wireless LAN products are rapidly spread to homes and offices. And high-speed transmission is expected that the system have a lot of users. The IEEE802.11-1999[1] is widely known as a Wireless LAN standard and it has a number of amendments and supplements such as IEEE802.11a [2], IEEE802.11g [3], and IEEE802.11e [4] and also those under work in the current activities by the task groups (TGs). IEEE802.11a and IEEE802.11g are the enhancements in the PHY (Physical) layer and the maximum PHY layer data rate is 54Mbps. IEEE802.11e is the QoS amendment in the MAC (Medium Access Control) layer. The one now attracting great deal of attention is TGn which aims to achieve high throughput. It is to achieve more than 100Mbps at the MAC interface with the higher layer, i.e., at the MAC-SAP (Service Access Point). What is different from the former standards is that, TGn aims much higher throughput than the former standards. For this purpose, different technologies are expected in both the PHY and the MAC layer. MIMO (Multiple-Input Multiple-Output) is the main discussion point to increase the data rate in the PHY layer. The high data rate at PHY layer shortens the data transmission time itself, while the overhead times, i.e., preamble, PHY header, and IFS (inter-frame spaces), does not change. In order to increase throughput at the MAC-SAP, the MAC layer must increase the efficiency. The Frame Aggregation method is the main point to increase the MAC efficiency. This method is to transmit multiple MPDUs (MAC protocol data unit) in one PPDU (PHY protocol data unit), and reduces the overhead times. In most of the proposals in TGn, this Frame Aggregation method is combined with the Block Ack mechanism defined in IEEE802.11e. However, this conventional method, i.e., the combination of the Frame Aggregation and the Block Ack mechanism involves inefficiency problem in the selective repeat mechanism.

In this paper, we proposed the Compressed Block Ack mechanism which realizes higher efficiency selective repeat mechanism for the Frame Aggregation method. The basic idea of the proposed method is that, in the case of using the Frame Aggregation method, it is better not to fragment a MSDU to plural MPDUs. Then the receiving status of the BlockAckBitmap in the BlockAck frame which correspond to each MPDU can be compressed.

We present simulation results which are based on IEEE802.11n Usage Models [5] and Channel Models [6]. The simulation shows that the proposed method improves the total throughput by 10% than the conventional method.

II. OVERVIEW

A. IEEE802.11e MAC enhancement

IEEE802.11e provides MAC enhancement to support LAN applications with QoS (Quality of Service) requirements. The main feature is HCF (Hybrid Coordination Function) which provides two different medium access control methods enhancement: EDCA (enhanced distributed channel access) and HCCA (HCF controlled channel access). Another enhancement is the Block Ack mechanism of the selective repeat mechanism.

IEEE802.11e introduces TXOP (transmission opportunity) as a new concept for burst data transmission. The STA which acquires TXOP period can send several data
frames without carrier sense during the TXOP period. TXOP can adopt both access method EDCA and HCCA.

As shown in Figure 1, the EDCA uses Backoff method which is almost the same as DCF (Distributed Coordination Function) of IEEE802.11 basic medium access method. When the Backoff period is over, the STA acquires the TXOP which can send several data frames during the TXOP.

**Figure 1 - EDCA TXOP method**

In HCCA method, when a STA receives a polling frame, it acquires TXOP instead of Backoff time. As shown in Figure 2, the STA receives a QoS Cf-Poll frame and acquires TXOP. The STA can send several data frames without carrier sense during the TXOP. The TXOP is described in a QoS Cf-Poll frame.

**Figure 2 - HCCA TXOP method**

Another feature in IEEE802.11e is Block Ack mechanism. In general IEEE802.11, a STA must receive an ACK frame to confirm the successful data transmission. The Block Ack mechanism improves channel efficiency by aggregating several acknowledgments into one frame. The Block Ack mechanism can be used in both EDCA and HCCA. Figure 3 shows the Block Ack mechanism, when the access method is using HCCA. When an initiator STA acquired TXOP by receiving a QoS Cf-Poll frame, it sends data frames within SIFS (short interframe space) interval and sends a BlockAckRequest frame to request acknowledges for data frames. When a responder STA receives a BlockAckRequest frame, it sends back a BlockAck frame which includes in the receiving status. The initiator STA looks up the receiving status of the BlockAck frame and selects retransmission data frames to be retransmitted, if necessary.

**Figure 3 - Block Ack method in HCCA**

B. Frame Aggregation

MIMO technique is proposed for PHY layer transmission method at IEEE802.11n in order to achieved 100Mbps at MAC-SAP. The transmission rate is higher rate than 54Mbps of IEEE802.11a or IEEE802.11g. The time which is needed to send a MAC frame is shorter than before, because the transmission rate is drastically higher rate than before. Therefore the ratio of several overhead times increases and MAC efficiency gets worse. The Several overheads are Preamble, Backoff, Polling frames, IFS, and Ack frames. In order to overcome the problem, the Frame Aggregation method is proposed.

The Frame Aggregation method is that several MPDUs (MAC protocol data unit) are aggregated to one PPDU (PHY protocol data unit). When several MPDUs are aggregated to one PPDU, transmission STA creates an Aggregation frame which is inserted MPDU Delimiter of 4 Octets length before each MPDU. When the STA receives an Aggregation frame, it divides the Aggregation frame to several MPDUs using MPDU Delimiter. In the conventional method, the Legacy Block Ack mechanism which is described in IEEE802.11e is used for the selective repeat mechanism of the Frame Aggregation.

In the conventional method, when the initiator acquires TXOP using RTS (request to send) - CTS (clear to send) frame exchange sequence after winning EDCA contention or receiving a polling frame in HCCA, it sends an Aggregation frame in which each MPDU is aggregated and the last part of an Aggregation frame attach a BlockAckRequest frame. When the responder receives an Aggregation frame which includes in a BlockAckRequest, it sends back a BlockAck frame which includes in the receiving status. The initiator looks up the receiving status of the BlockAck frame and selects retransmission data frames. This selective repeat mechanism is the same as the Block Ack mechanism IEEE802.11e.

As shown in Figure 4, the initiator wins the EDCA contention, does the RTS-CTS frame exchange sequence, sends an Aggregation frame, and receives a BlockAck frame.
III. EFFICIENT BLOCK ACK MECHANISM

We propose the Compressed Block Ack mechanism combined with the Frame Aggregation method as a new selective repeat mechanism.

The Block Ack mechanism of IEEE801.11e supports the Fragmentation of IEEE802.11. The Fragmentation is that MSDU (MAC service data unit) can be fragmented up to 16 MPDUs (MAC protocol data unit). The MSDU is the unit of the data sent from the LLC (Logical Link Control) layer to the MAC layer, and the MPDU is the unit of the data sent from the MAC layer to the PHY layer. If a MSDU is longer than the Fragmentation threshold, it is fragmented up to 16 MPDUs at the MAC layer.

In the Block Ack mechanism of IEEE802.11e, the Block Ack Bitmap of the BlockAck frame indicates the receiving status, and each bit of the Block Ack Bitmap indicates the receiving status of the corresponding one MPDU, because of the backward compatibility for the Fragmentation. That is to say that 16 bit of Block Ack Bitmap is required for the receiving status of 1 MSDU. And regardless of the number of transmitted data, the Block Ack Bitmap is 128 octets in length and is used to indicate the receiving status of up to 64 MSDUs. For that reason, the BlockAck frame length of IEEE802.11e is always fixed length and is equal to 152 octets. The BlockAck frame format of IEEE802.11e is shown in Figure 5.

In this paper, we propose the Compressed Block Ack mechanism as a selective repeat mechanism combined with the Frame Aggregation. When the Fragmentation is not used in the Frame Aggregation, the Block Ack Bitmap can be compressed so that 1 bit expresses the receiving status of 1 MSDU. Concept of the Compressed Block Ack mechanism is shown in Figure 6.

STA select 243Mbps for PHY rate, the overhead ratio is higher than to use 54Mbps. The Frame Aggregation method is that multiple MPDUs are combined to one PPDU and decreases the overhead time.

On the other hands, when a MSDU which is sent from the higher layer to the MAC layer is larger than the Fragmentation threshold, the Fragmentation method fragments the MSDU to multiple MPDUs. And then the overhead times are needed between the MPDUs, and MAC header and CRC (cycle redundancy code) are needed to attach to each MPDUs. That is to say that using the Fragmentation method increases the overhead times.

If we select to use the Frame Aggregation, usually the Fragmentation method is not used.

In this paper, we propose the Compressed Block Ack mechanism as a selective repeat mechanism combined with the Frame Aggregation. When the Fragmentation is not used in the Frame Aggregation, the Block Ack Bitmap can be compressed so that 1 bit expresses the receiving status of 1 MSDU. Concept of the Compressed Block Ack mechanism is shown in Figure 6.

The purpose of the Frame Aggregation method of IEEE802.11n is to decrease the overhead times, i.e., preamble, PHY header, and IFS (inter-frame spaces). The transmission rate at the PHY layer of IEEE802.11n increase about four times from 54Mbps to 243Mbps. The overhead between the transmission data is fixed length. If the transmit
time which is required to transmit the BlockAck frame. For example, when 24Mbps is chosen as the PHY rate to transmit the BlockAck frame, the transmission time reduce from 72 micro sec to 32 micro sec.

On the other hand, the proposed method cannot coexist with the conventional Fragmentation method.

We propose a method to incorporate even this method which might rarely happen. IEEE802.11e Block Ack mechanism requires the setup procedure by the management frame exchange sequence (ADDBA.request – ADDBA.response). The proposal is to add the switching function to the sequence if to use the conventional fragmentation or not. If NO is selected, the proposed method is activated. Otherwise, the conventional Block Ack mechanism is activated.

Thus, the proposed Compressed Block Ack mechanism is expected to realize the higher efficiency than the conventional Block Ack mechanism, and can coexist with the conventional method using the BlockAck setup frame exchange sequence.

Figure 7 – Compressed Block Ack frame format

IV. PERFORMANCE EVALUATION

In this section, we show the performance evaluation by the computer simulation. In IEEE802.11n, we must show the simulation results which are required in the FRCC (Functional Requirement and Comparison Criteria). The simulation results are used to compare the performance of each proposal. Channel Model is defined as radio environment used in the simulation. And Usage Models is defined as simulation scenarios for MAC simulation.

In our simulation, we used the Channel Model as radio environment. The PHY layer transmission bandwidth is 40MHz and the data frame transmission rate is 243Mbps (2x3, 64QAM, 7/8). The Management frame and a Control frame transmission rate is the same 24Mbps (1x1, 16QAM, 1/2).

And this performance evaluation is using the Simulation Scenario 4 (Large Enterprise) which is described in the Usage Models of IEEE802.11n. The Scenario 4 has one AP and 30 STAs which associated with the AP. The AP is arranged in the center of the 20mx20m space. The 30 STAs are arranged around the AP in the space. The distance between the AP and each STA is from about 2m to about 13m.

As shown in Table 1, the Scenario 4 has nine types of Applications. Three kinds of Applications, “Video Conference”, “Internet Streaming”, and “VoIP” have the Delay Bound. And, another six kinds of Applications don’t have the Delay Bound.

Table 1 – Application list of Scenario 4

<table>
<thead>
<tr>
<th>Node</th>
<th>Application</th>
<th>Mean Rate (Mbps)</th>
<th>MSDU size (Octets)</th>
<th>Delay Bound (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STA1~3</td>
<td>Web Click</td>
<td>1</td>
<td>300</td>
<td>-</td>
</tr>
<tr>
<td>STA4</td>
<td>Internet file (uplink)</td>
<td>5</td>
<td>1000</td>
<td>-</td>
</tr>
<tr>
<td>STA5</td>
<td>Large email</td>
<td>1</td>
<td>300</td>
<td>-</td>
</tr>
<tr>
<td>STA5</td>
<td>Large email (uplink)</td>
<td>10</td>
<td>1500</td>
<td>-</td>
</tr>
<tr>
<td>STA6</td>
<td>Internet file</td>
<td>10</td>
<td>300</td>
<td>-</td>
</tr>
<tr>
<td>STA7~8</td>
<td>Video Conference</td>
<td>1</td>
<td>512</td>
<td>100</td>
</tr>
<tr>
<td>STA9~10</td>
<td>Internet Streaming</td>
<td>2</td>
<td>512</td>
<td>200</td>
</tr>
<tr>
<td>STA11~20</td>
<td>Local File transfer</td>
<td>30</td>
<td>1500</td>
<td>-</td>
</tr>
<tr>
<td>STA21~24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA25~30</td>
<td>VoIP</td>
<td>0.096</td>
<td>120</td>
<td>30</td>
</tr>
</tbody>
</table>

In the simulation of IEEE802.11n, the data which has the Delay Bound is called QoS Data, and the data which doesn’t have the Delay Bound is called non-QoS Data. For the traffic Load of this simulation Scenario 4, the summation of QoS Data is 9.152 Mbps, the summation of non-QoS Date is 451.024Mbps, and the Total Load (QoS Data + non-QoS Data) is 460.176Mbps.

The MAC function of our simulator can perform EDCA and HCCA for the medium access method. In the simulation IEEE802.11n, it is required that QoS Data meets the QoS requirement. Therefore, we select HCCA as a medium access method for QoS Data and EDCA as a medium access method for non-QoS Data. And also our simulator can perform the Frame Aggregation method of IEEE802.11n. The Frame Aggregation method is used in this performance evaluation.

In this performance evaluation, we compared the proposed method with the conventional method which consists of the Frame Aggregation and the IEEE802.11e Block Ack mechanism.
Other simulation parameters are shown in Table 2.

### Table 2 – Simulation parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beacon Interval</td>
<td>20 TU (time unit)</td>
</tr>
<tr>
<td>EDCA Parameter sets</td>
<td>Default value</td>
</tr>
<tr>
<td>DTIM Period</td>
<td>1</td>
</tr>
<tr>
<td>CFP Period</td>
<td>1</td>
</tr>
<tr>
<td>Max CFP Duration</td>
<td>13 TU</td>
</tr>
<tr>
<td>Max Aggregation</td>
<td>64 MPDU</td>
</tr>
</tbody>
</table>

![Figure 8 – Simulation Results](image)

The simulation results are shown in Figure 8. The simulation results have three types of throughput as QoS Data, non-QoS Data, and Total (QoS + non-QoS). In this simulation, we consider the proper Scheduling which was used in HCCA so that QoS Data meets the QoS requirement. Therefore, the QoS throughput for both methods, conventional and proposed, achieves the required throughput.

Namely, all the result led from the reduced overhead by the proposed method appears on the non-QoS throughput.

The proposed method improves the non-QoS throughput by 9Mbps from 83.221 to 92.221Mbps, and the Total throughput by almost 10% from 92.373Mbps to 101.373Mbps.

V. CONCLUSION

We propose the Compressed Block Ack mechanism combined with the Frame Aggregation method as a new selective repeat mechanism. The simulation results show that the proposed Compressed Block Ack mechanism improves the Total throughput by almost 10%. This 10% improvement only by the selective repeat mechanism, together with other improvement schemes, greatly contributes to realize faster and more efficient WLAN systems.

### REFERENCES


