An Adaptive TXOP Allocation in IEEE 802.11e WLANs

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Abstract: In legacy 802.11e, It proposed polling for transmitting allocated TXOP for real-time traffic and proposed multi-polling to reduce overhead and transmit similar data type which exist different frame, together. In existing multi-polling method, they first allocate CBR traffic that became admission control, and then allocate VBR traffic. However, this method may not transmit the data because of delay although TXOP through admission control is allocated in End-to End network. Therefore, we are the novel multi polling method that first allocates the VBR traffic which has low delay rather than the CBR traffic which has high delay. Our method allocate delay-sensitive traffic in advance, so that it can increase the efficiency of transmitting traffic and QoS(Quality of Service). To validate our method, we carried out a simulation study, so that we observed that our proposed method is higher than legacy method at the aspect of throughput and utilization.

Key-Words: IEEE 802.11e, QoS, TXOP, Multi-polling

1 Introduction

Wireless network has advantages in scalability, mobility and low cost in communication network construction than wire network. Because of these advantages, WLAN(wireless LAN) has gradually been important and it is necessary for QoS (Quality of Service) to data with multi-media file of video or audio and so on [1]. However, wireless network has restriction of delay, jitter and limited bandwidth by wireless product's physical characteristic and environment. Therefore, WLAN must consider these restriction items to support effective multi-media services that are required for QoS.

To guarantee QoS, WLAN standard is extended from IEEE 802.11 WG(working group) to IEEE 802.11e WG. IEEE 802.11 [2] MAC(medium access control) is designed for best-effort service and is clarified two MAC mechanism. One is DCF(distributed coordination function) based competition and the other is PCF(point coordination function) based competition-free. However, these mechanisms are difficult to guarantee QoS for real-time services such as multi-media. Therefore, IEEE 802.11e MAC proposes two ways using HCF(hybrid coordination function) [3]. One is EDCA(enhanced distributed channel access) that is channel access way based competition, the other is HCCA(HCF controlled channel access) that is channel access based competition-free. EDCA method is a prioritize QoS way to support channel connection. This method is categorized by traffic of 8 user priority is extended from DCF in legacy IEEE 802.11 MAC. HCCA method is a parameterized QoS way and allows TXOP by polling based contract between AP(access point) and QSTA(quality station).

IEEE 802.11e defines TXOP(transmission opportunity). TXOP means the allocating right that can transmit to QSTA and this value is given in each QSTA's TSPEC(traffic specifications). When only one TXOP is allocated, QSTA can transmit some frames without any competition with other QSTAs and additional polling by AP. IEEE 802.11e uses polling method when TXOP is allocated in HCCA's CFP(contention free period). Multi-polling method transmit the data of similar type which exist different frame together while polling method is the method which separately polls for QSTA during contention free period.

In this paper, our method allocates TXOP using multi-polling for type of similar data that become

admission control in HCCA. Also, our method allocates TXOP using multipolling about multimedia data such as CBR(constant bit rate) and VBR(variable bit rate). It must consider delay to guarantee user's QoS in End-to-end network. If the boundary of VBR traffic's TXOP delay is short, it first allocate CBR traffic and then allocate VBR traffic, since the priority of VBR traffic is lower than CBR traffic which has high delay boundary. In this case, the delay value of VBR traffic is exceeded. If delay boundary of VBR traffic is less than delay boundary of CBR traffic, It must first allocate VBR traffic rather than CBR traffic.
The organization of this paper is as follows. Section 2 reviews IEEE 802.11, IEEE 802.11e standard and multi-polling. Section 3 describes an efficient multi-polling allocation mechanism in HCCA. We compare our method with legacy method by simulation study in section 4. Section 5 concludes the paper.

2 Related Works

In the IEEE 802.11e, it is the most important thing to guarantee QoS, TXOP allocates properly for QSTA with requiring QoS. In this section, it explains for legacy transmission process of IEEE 802.11e[2].
The IEEE 802.11e prescribed HCF (Hybrid Coordination Function) that is based on legacy IEEE 802.11, and HCF can transmit QoS traffic both contention period and contention-free period. In figure 1 with HCF uses a contention based channel access method, called EDCA, that operates concurrently with polling based HCCA method[3].

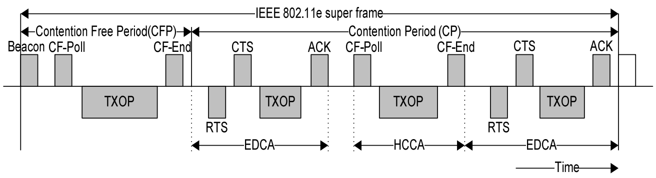

Fig. 1. superframe structure of IEEE 802.11e.

EDCA and HCCA are controlled by HC (Hybrid Coordinator) that is situated to AP, and become compatible with legacy 802.11 MAC protocol that use DCF and PCF[4]. While EDCA is used in contention period only, HCCA is available both contention-free period and contention period.
In IEEE 802.11e, QoS parameters are offering and exchanging that connection established between STA (station) and AP according to TSPEC. Using HC exchanged QoS parameter information that allocate bandwidth in the each STA and frame transmission scheduling for polling frame and downlink frame transmission. Also, IEEE 802.11e MAC uses TXOP to give a scheduling time that can transmit frame to specification STA and guarantee this. TXOP obtained via contention-based medium access is referred to as EDCA-TXOP and via controlled medium access is referred to as Polled-TXOP by HC. Transmission beginning time and maximum transmission time of TXOP are depended on AP, which is notified in the STA at the case of EDCA TXOP by Beacon frame, and Polled-TXOP case by QoS CF-Poll frame.

2.1 HCF-Controlled Channel Access(HCCA)

The IEEE 802.11e MAC with HCCA protocol is controlled wireless medium by AP and using polling method for a taking away competition among QSTAs. Because the HCCA protocol manages wireless medium configurationally at central using HC, reduce the competition among QSTAs wireless medium as efficiency of network increase. Therefore, transmission delay time is not increase between frames even if traffic increased in network, as well as it is seldom collision probability between transmission frames. And, it applies independent QoS parameter for particular QoS traffic of application service and strict transmission delay and scheduling control[5][6].
If HC acquires control rights of wireless medium after PIFS, transmit QoS CF-Poll frame as to QSTA that have data to transmit. This polling frame has TXOP duration value of QSTA and allocates TXOP to QSTA. QSTA is received a polling and must send data, then it transmits with figure 2 for this time. That is, HC achieves function that control assignment of medium access time using TXOP, and TXOP duration value is decided by TSPEC. QSTA which have QoS traffic requests QoS polling to HC establishing TSPEC value, and HC decides acceptance or rejection according to network situation. If decide acceptance, take correct polling period to TSPEC and transmit CF-Poll frame.
In HCCA, the contention-free period is not only HC has whole control right for transmission medium but also it can acquire control right of medium transmitting QoS CF-Poll frame to allocate polled TXOP at contention period. Polled station has authority for channel connection for time as TXOP limitation value as that receive QoS CF-Poll frame and can transmit several frames for this time. At that time, other stations are establish own NAV (Network Allocation Vector), and do not competition for channel connection for this time.

Finally, HC can decide acceptance or rejection of required QoS traffic to satisfy contracted QoS requirement, and need to control transmission of QoS CF-Poll frame through suitable scheduling of QSTA that request polling.

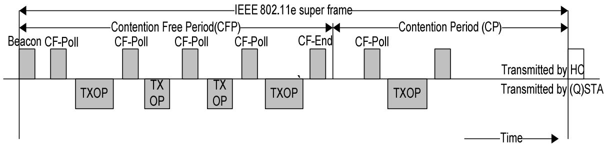

Fig. 2. IEEE 802.11e HCCA structure.

2.2 Multi-polling mechanism

IEEE 802.11e HCCA transmits each polling frame for QSTA that request QoS polling. However, this can assume as overhead to transmit polling frame. So, multi-polling mechanism transmits making polling frame for each QSTA by one with figure 3 is presented. Multi-polling adds TXOP of sequential polling value consecutively to poll frame that HC transmits and establishes each transmission time of QSTA for total polling cycle. This method is similar to manage schedule of frame.
Multi-polling method can permit that does polling using one poll frame to whole QSTA, or reduce IFS time to exchange polling frame after TXOP end. However, one polling frame is prolonged because of added TXOP. If allocate TXOP of same size to supplement, the problem do not use all allocated TXOP time for QSTAs that receive polling. It allocates correct TXOP value to frame that wish to transmit of QSTA to keep away waste of bandwidth. This paper can reduce overhead and using effective multi-polling that can increase the using rate of bandwidth and efficiency of network resources.

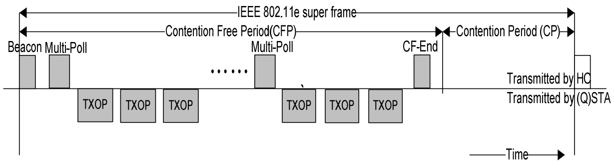

Fig. 3. Multi-polling process.

2.3 Admission Control

The scheduler and admission control unit use the minimum set of mandatory TSPEC parameter as specified in figure 4[8]. The schedule for an admitted stream is calculated in two steps. The first step is the calculation of the scheduled SI. In the second step, the TXOP duration for a given SI is calculated for the stream[3].

Element ID	Length	TS Info	Nominal MSDU Size	Maximum MSDU Size	Minimum Service Interval	Maximum Service Interval	Inactivity Interval	Suspension Interval

Service Start Time	Minimum Data Rate	Mean Data Rate	Peak Data Rate	Maximum Burst Size	Delay Bound	Minimum PHY Rate	Surplus Bandwidth Allowance	Medium Time

Fig. 4. TSPEC parameters.

The calculation of the scheduled service interval is done as follows:
Step 1) the scheduler calculates the minimum of all maximum Sis for all admitted streams. This value m is minimum SI of maximum Sis.
Step 2) the scheduler chooses a number lower than m that is a sub-multiple of the beacon interval. This value will be the scheduled SI for all wireless stations with admitted streams. See figure 5(a).

The scheduler uses the following parameters for the calculation of the TXOP duration for an admitted stream : Mean Data Rate(ρ) and Nominal MSDU Size(L) from the negotiated TSPEC, the Scheduled Service Interval(SI) calculated above, Physical Transmission Rate(R), Maximum Allowable Size of MSDU, i.e., 2304 bytes(M), and Overheads in time units(O). The physical transmission rate is the minimum PHY rate negotiated in the TSPEC. If the minimum PHY rate is not committed in the ADDTS Response frame, the scheduler can use the observed PHY rate as R. The overhead in time includes IFSs, ACK frames and CF-Poll frames.

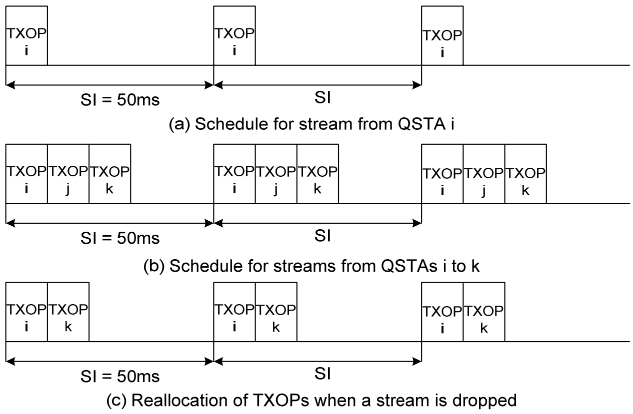

Fig. 5. TXOP allocation.

When a new flow requests for admission, the admission control process is preformed in three steps [3]:
Step 1) the ACU(admission control unit) calculates the number of MSDUs that arrives at the mean data rate during the scheduled service interval SI as

$$N_i = [\frac{SI \times \rho_i}{L_i}] \quad (1)$$

Note that the scheduled service interval SI must be a number lower than the minimum value of all the maximum service intervals for all the admitted flows, and must also be a sub-multiple of the beacon interval. Step 2) for a flow i, $TXOP_i$ is calculated as

$$TXOP_i = \max(\frac{N_i \times L_i}{R_i} + O, \frac{M}{R_i} + O) \quad (2)$$

where R_i is the minimum physical transmission rate, M is the maximum size of a MSDU, and O is the overhead in time units. The overhead includes interframe spaces, ACKs and etc. The same process is repeated continuously while the maximum SI for the admitted stream is larger than the current SI. An example is shown in Figure 5(b). If a new stream is admitted wit a maximum SI smaller than the current SI, the scheduler needs to change the current SI to a smaller number than the maximum SI of the newly admitted stream. Therefore, the TXOP duration for the current admitted streams needs also to be recalculated with the new SI. If a stream is dropped, the scheduler might use the time available to resume contention. The scheduler might also choose to move the TXOPs for the QSTAs following the QSTA dropped to use the unused time. An example is shown in Figure 5(c).

Step 3) the ACU determines that the stream is assuming there are k admitted flows, a new flow k+1 is accepted if it satisfies

$$\frac{TXOP_{k+1}}{SI} + \sum_{i=1}^{k} \frac{TXOP_i}{SI} \leq \frac{T - T_{CP}}{T} \quad (3)$$

Where T is the beacon interval and T_{CP} is the time for EDCA traffic.

3 An adaptive TXOP allocation scheme

HCCA protocol has advantage that HC can control each TXOP of QSTA through traffic control by CFP[9]. In this paper, propose for HCCA that used admission control and efficient TXOP assignment that use multi-polling. Also, traffic's type is considered that CBR data (i.e., audio) and VBR data (i.e., video). It utilizes 2 groups to transmit real-time traffic efficiently using polling in IEEE 802.11e HCCA. One is CBR traffic that consist of audio and the order is VBR traffic that is consisted of video [10][11]. In this context, the delay is important problem for real-time traffic transmit. Surely, at above process, traffic is transmitted under permission that may be accepted with using admission control. However, traffic can drop according to situation of QSTA, situation of network, or error can occur in transmission, if apply to End-to-End network aspect. Also, they have to think a priority of traffic. CBR traffic has a high priority order at transmission in traffic category than VBR traffic. Therefore, most CBR traffic send faster than VBR traffic. In this case, VBR traffic does not transmit by delay boundary. For example, let's try that delay boundary of CBR traffic is 100ms and delay boundary of VBR traffic is 20ms. Delay boundary of VBR traffic remains less than delay boundary of CBR traffic but because priority of VBR traffic is lower than CBR traffic, TXOP of CBR traffic is more preferentially allocated than VBR traffic. Thus, the frame loss or retransmission probability is high, because delay boundary of VBR traffic is short.

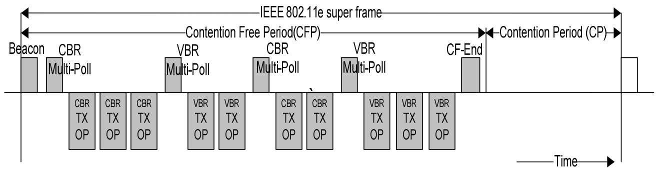

Fig. 6. An adaptive TXOP allocation scheme.

Therefore we proposed scheme is likely to figure 6. It considered the delay and allocation TXOP. Traffic tries to polling and transmit frame in CFP using admission control by HC.

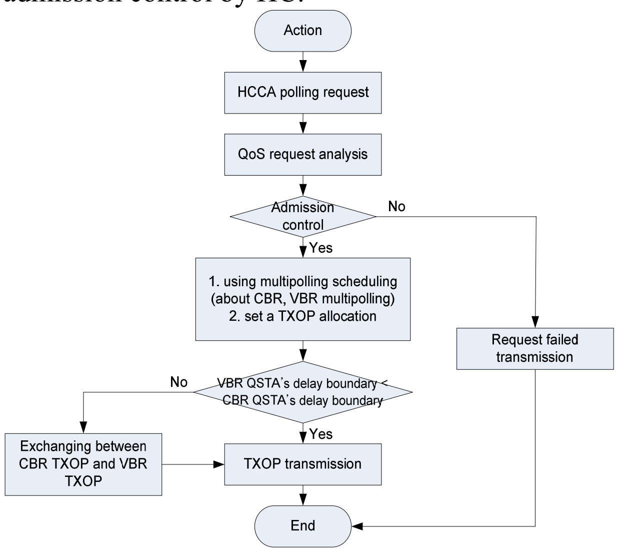

Fig. 7. flow chart for the effective multi-polling scheme.

Through Figure 7, expressed process that effective multi-polling scheme acts by flow chart. It ordered by time interval accepting information for CBR data and VBR data from beacon frame of HCCA. If data is going to send for CBR traffic after information for CF-Poll makes from HC of BSS(basic service set) at each QSTA, ordered by CBR Multi-Poll. And it ordered by VBR Multi-Poll if traffic's type is VBR traffic. After CBR traffic and VBR traffic have been guaranteed TXOP because it polling for CF period, it is going to more efficient polling considering delay. Among VBR traffics, it exchanges for compares small delay boundary of VBR traffic with huge delay boundary of CBR traffic. Thus, there are advantages that can increase throughput of CF period and reduce mean delay time. Also, it can reduce transmission error probability of traffic.

4 Simulation

Our simulation of proposed scheme is based on IEEE 802.11e standard. There are 20 QSTAs and HC placed in HCCA. Traffic parameters of the simulation are located to Table 1. In order to evaluate the performance of our proposed mechanism, we will use a scenario in our simulation.

In this scenario, we consider two traffic types. One is CBR data of an audio, the other is VBR data of a video. CBR and VBR traffic, generated by 20 QSTAs, are guaranteed TXOP by HC of CFP and by multi-poll for CBR and VBR order. CBR traffic generated in QSTA of 10 among 20 QSTAs and VBR traffic generated in QSTA of the 10 remainder. Each QoS of CBR traffic and VBR traffic are equal. It calculate TXOP duration for traffic that generated in each QSTA through simulation use parameter of Table 1, these values are Arrival Time, Service Time and Delay Time. And it can do to allocate TXOP for one SI(service interval) to Queue using TXOP duration that use calculated admission control of Table 2[12].

Among allocated TXOPs which consider delay, exchanges TXOP of VBR traffic that delay boundary is small and TXOP of CBR traffic that delay boundary is huge. When exchange TXOP, pay value of double to delay time of CBR traffic. Because priority of traffic category's CBR traffic is higher than VBR traffic. It compares and calculates throughput, drop rate, utilization with transmission in legacy IEEE 802.11e HCCA.

In Figure 8, this graph compares throughput of proposed scheme with throughput of IEEE 802.11e standard for SI. Throughput computed ratio of frame that is processed for total produced frame. When SI grows, throughput shows increasing state. Because it can be allocated TXOP period is prolonged when SI increases.

Table 1. PHY and MAC parameters.

Parameter	Value
SIFS	10 us
MAC Header size	32 bytes
QoS-ACK frame size	16 bytes
QoS-CF Poll frame size	36 bytes
PLCP Header length	4 bytes
PLCP Preamble length	20 bytes
PHY rate	11 Mbps
Minimum PHY rate	2 Mbps
QSTA	20

Table 2. TXOP duration of different SI.

SI (ms)	CBR TXOP	VBR TXOP
50	3.29218	6.3922
100	4.41218	14.1222
200	6.39128	22.8022

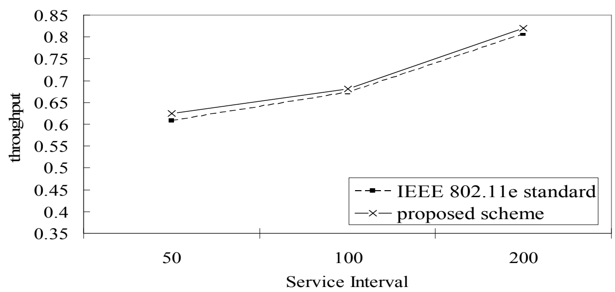

Fig. 8. Throughput.

There is traffic that generate within fixed extent, it can see that throughput increases SI value great. Because allocation of TXOP considers delay for a CFP, proposed scheme's throughput is measured higher than 802.11e standard's throughput. TXOP's throughput is high, because it is first allocation that delay boundary of VBR' TXOP is lower than CBR's TXOP.

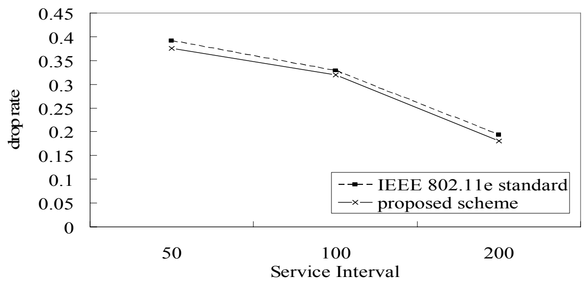

Fig. 9. Drop rate.

In figure 9, this graph compare drop rate of proposed scheme with IEEE 802.11e standard for each SI value. Drop rate calculate that produces whole frames ratio of drop rate. If SI grows on the contrary with Throughput, drop rate decreased. Because traffic is dropped that it can not allocate TXOP by delay boundary, throughput is increased if SI is long, but drop rate is decreased. And drop rate of proposed scheme knows lower than drop rate of 802.11e standard. Because the TXOP allocates for a delay, The TXOP that delay boundary has small VBR traffic is transmitted successfully increase.

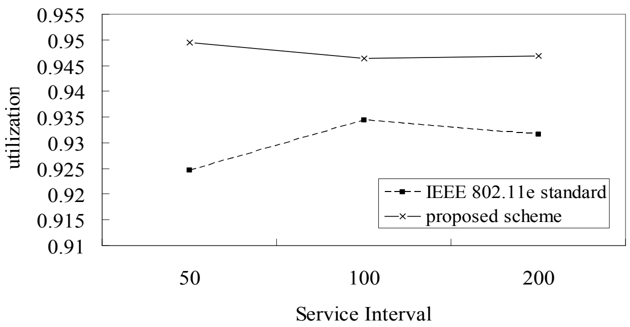

Fig. 10. Utilization.

In figure 10, this graph represent that calculate utilization for IEEE 802.11e standard and proposed scheme's SI. Utilization is defined as the ratio of the total of TXOP's assigned to serve QSTA's to the length of SI. Because allocate TXOP efficiently for delay of real-time traffic, it seems that utilization of proposed scheme is higher than 802.11e standard on the whole. Because our scheme's TXOP of VBR traffic that has low delay boundary is transmitted successfully than IEEE 802.11e standard for SI.

5 Conclusion

In this paper, we presented an effective multi-polling allocation in IEEE 802.11e through simulation. The proposed mechanism for effective multi-polling considers delay of CBR and VBR traffic and change TXOP allocation order in HCCA. Using this, it can not only reduce whole transmission error, but bring increasing throughput and decreasing drop rate. Also, utilization confirmed higher than legacy IEEE 802.11e standard.

It can transmit more effectively real-time traffic by advantage of effective multi-polling mechanism. Therefore, it brings that increase QoS. Also, it can reduce transmission cost for real-time traffic in WLAN.

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