A Polling Scheme of TXOP Using Knapsack Algorithm in Wireless LAN

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Abstract: - The admission control mechanism developed for wireless LAN, HCCA (hybrid coordination function controlled channel access) is not adaptable to variable bit rate (VBR) traffic since it considers only the mean data rate and packet size for scheduling. In my paper, we propose a transmission opportunity (TXOP) allocation scheme by using a knapsack algorithm. Proposal results show that our scheme offers higher channel utilization than the wireless LAN standard.

Keywords: IEEE 802.11e, hybrid coordination function (HCF), HCCA, admission control.

1 Introduction

Recently, HCF which provides the flexibility of combining polling and contention access within a single cycle has been defined as the standard in IEEE 802.11e [1]. The polling operation is similar to the PCF, and the enhanced DCF called enhanced distributed channel access (EDCA) has been introduced to provide service differentiation, typically used for transporting real-time traffic at a higher priority. Although DCF-based protocols allow voice and data traffic to be transported by a common mechanism, they cannot guarantee quality of service (QoS) for voice traffic because of their contention nature. For HCCA, admission control is an important component for QoS provisions [1], [2].

However, this algorithm is somewhat inefficient because it assigns transmission opportunities (TXOPs) to one QoS station (QSTA) depending on its mean data rate. Video traffic has stringent delay and jitter requirements but it can tolerate packet losses to a certain extent. Furthermore, if packets are not lost consecutively, it is possible to regenerate the original video signal using packet-loss concealment algorithms [2]. A key advantage with using polling-based protocols is that a deterministic service can be provided to fulfill the abovementioned requirements more effectively. In this paper, we propose a TXOP duration allocation scheme based on the conventional knapsack algorithm. Our scheme can provide higher channel utilization than the IEEE802.11e simple scheduling scheme.

The remaining sections are organized as follows. Section 2 describes main operation of the IEEE802.11e as well as HCF scheduling scheme. Section 3 describes a proposed scheme using knapsack algorithm. In section 4, we explain our some simulation results. The final section concludes the paper.

2 Related Works

2-1 HCF Scheduling Scheme

In this section, we introduce a reference admission control scheme that the simple scheduling scheme in IEEE802.11e. A reference design of the scheduler and admission control unit has been proposed in the IEEE 802.11e. [10] This scheduler uses the QoS requirements of flows in Traffic Specification (TSPEC) to calculate TXOP duration for mobile stations on the basis of the mean data rate and mean packet size. TXOPs are allocated to each station during Service Interval (SI) in round robin fashion. In the scheduling of HCF, the QoS station (QSTA) requiring HCCA negotiates with QAP and creates a TSPEC which contains some QoS parameters of a traffic stream. Such a TSPEC parameters [4, 9] include : mean data rate (ρ , average bit rate for transfer of the packets), nominal MSDU Size (L, nominal size of the packets) and maximum service interval (SI : maximum time allowed between the start of successive TXOPs allocated to the station) or delay bound (D). The scheduler chooses a number lower than the minimum of all maximum service intervals for all admitted streams, which is a submultiple of the beacon interval. This value will be the scheduled service interval (SI) for all wireless stations with admitted streams. In this scheduling scheme, the scheduler calculates the average number of packets that has arrived at the mean data rate during the SI. For the traffic flow *i* in a station, the average number of packets arrived during SI is

$$N_i = \left\lceil \frac{SI \times \rho_i}{L_i} \right\rceil \qquad (1)$$

Then the scheduler calculates the TXOP duration as the maximum of (1) time to transmit N_i frames at R_i and (2) time to transmit one maximum size MSDU at R_i which is the minimum TXOP duration allocated to flow *i* for transmitting one maximum-sized MSDU. The TXOP duration for flow *I* is given by

$$TXOP_i = \max\left(\frac{N_i \times L_i}{R_i} + O, \frac{M_i}{R_i} + O\right) \qquad (2)$$

where M_i is maximum MSDU size of flow *i,* and R_i is the minimum physical transmission rate in the TSPEC. If the TSPEC does not contain this parameter, the observed physical transmission rate is used. *O* is the per-packet overheads of the packet transmission.

The TXOP duration for a station is the sum of the TXOP duration of individual traffic stream of the station. The TXOP duration of station *j* with n traffic streams is

$$TXOP_j = \sum_{i=1}^{n} TD_i + SIFS + t_{POLL} \qquad (3)$$

where $SIFS + t_{POLL}$ is the per-station overhead that is the shortest inter-frame space and the transmission time of a CF-Poll frame [7]. For each station, the TXOP duration is constant and allocated by AP periodically, spaced by *SI* as seen in Fig 1.

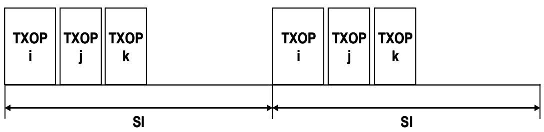

Fig. 1. conventional scheduling scheme

Each TXOP duration serve only the packets that have arrived during the time interval between the beginning of the previous TXOP and the current TXOP, that is, equal to *SI.* The *SI* is related to the most stringent delay bound among all streams. If TXOP is not long enough to transmit all packets that have arrived during the previous *SI,* the remaining packets in the queue will not be delayed to the next *SI* because the packets will exceed their delay bound. Thus, the remaining packets will be dropped so that the maximum delay is guaranteed to be lower than *SI* [5].

If there is a new traffic stream arrived, the N_i and $TXOP_i$ duration of that stream can be calculated by (1) and (3). Assuming that there are admitted streams in *k* stations and a new stream flow arrived in $k+1^{th}$ station, then the newly arrived stream can be admitted if and only if

$$\frac{TXOP_{k+1}}{SI} + \sum_{i=1}^{k} \frac{TXOP_i}{SI} \le \frac{T - T_{CP}}{T} \qquad (4)$$

where T indicates the length of super-frame, and T_{cp} is the time used for EDCA traffic (length of contention period). In (4), $\frac{TXOP_i}{SI}$ is the fraction of time the station *i* depends on the TXOP duration and $\frac{T-T_{CP}}{T}$ is the fraction of time can be used in CFP. If a new stream is admitted with a maximum service interval smaller than the current *SI,* the scheduler needs to change the current *SI* to a smaller number than the maximum service interval of the newly admitted stream. Therefore, the TXOP duration for the current admitted streams also needs to be recalculated with the new *SI.*

However, the scheduling scheme provides guarantee only to the flows with CBR traffic and does not take the rate and packet size fluctuation of VBR traffic into account. The packet drop rate of VBR traffic may be very large. Some previous researches tried to improve the scheduling algorithm.

3 Proposed Scheme

QSTA which needs to allocate TXOP transmits a request-message to the HC through ADDTS (ADD Traffic Stream) frame and waits the response for request-message. After the HC receives a TXOP allocation request from QSTA, it allocates the period for transmission by the admission control strategy with an instant response. Then, the HC can know the requested amount of time (TXOP duration) about resource allocation and the number of data frames that are waiting for an opportunity in queue for transmission by traffic category of each QSTA on ADDTS and data frame transferred from each QSTA. The HC decides the next starting time of polling through information contained in QoS+CF-Poll.

In our scheme, the QSTA transmits a frame in queue during the time of TXOP assigned by the knapsack algorithm. The HC compares the request-message collected from each QSTA with SI. Then, the HC allocates TXOP for each QSTA. At this time, the HC responses whether or not it can allocate a TXOP to QSTA depending on the remaining time of SI.

Let the service time SI of total admitted streams in CFP of a superframe be W which means the total capacity in the knapsack algorithm as depicted in Fig 2.

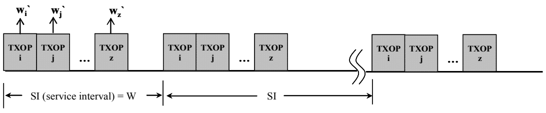

Fig. 2. Allocating TXOP using knapsack algorithm

And let TXOP allocated to each QSTA be w_i', w_j', …, w_z' that is analogy to each object in the knapsack algorithm. The profit value is equally assigned to every admitted stream. The optimal subset of QSTAs whose total weight does not exceed W can be obtained by

$$W \ge (w_i' + w_j' + \ldots + w_z') \qquad (6)$$

Our algorithm can be represented by the following pseudo-code.

```
[TXOP allocation Mechanism]

Determine TXOP duration
        While(TRUE){
        If(t = start of SI){
            Queue ← TXOP request
            Knapsack(0, 0, 0)
            Queue ← Queue – bestset
            Allocate TXOP
        }
    }
END
```

In the conventional scheduling scheme, HC allocates TXOP to QSTA 10 which has 5ms TXOP in the remained SI. In this case, the remaining 4ms in SI could be wasteful. In our scheme, however, HC allocates TXOP to QSTA 11 with a TXOP of 7ms. So, we can enhance the throughput as well as utilization.

4 Performance evaluation

To investigate the performance of proposed scheme, we vary the number of stations in a QBSS (QoS Basic Service Set) seen in Figure 4, each station offering the same traffic, and measure the performance per SI. Simulation is carried out on QBSS which consists of six QSTAs sending VBR video (H.261) streams and six QSTAs sending VBR video (MPEG 4) streams.

Each 6 QSTA uses the same QoS parameter Table 1 hows the mean transmission rate, mean packet size and mean inter-arrival time of each station. We used a fixed mean TXOP duration depending on SI.

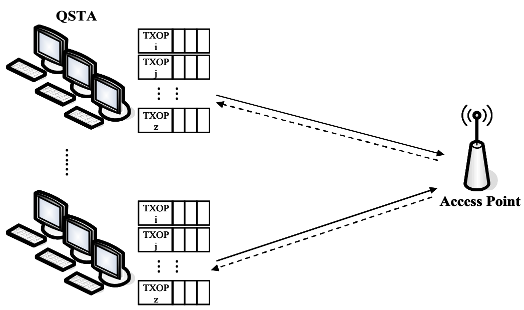

Fig. 4. Network configuration

Table 1. *Description of traffic streams*

Node	Arrival period (*ms*)	Packet size (*bytes*)	Sending rate (*Kbps*)
1~ 6	26	660	600
7~12	2	800	3200

PHY and MAC parameters are summarized in Table 2. According to [8], the PLCP (Physical Layer Convergence Protocol) preamble and header are transmitted at minimum physical rate to ensure that all stations can listen to these transmissions regardless of their individual data rates.

Table 2. *PHY and MAC layer parameters*

SIFS	10 μs
MAC Header size	32 *bytes*
CRC size	4 *bytes*
QoS-ACK frame size	16 *bytes*
QoS-CFPoll frame size	36 *bytes*
PLCP Header length	4 *bytes*
PLCP Preamble length	20 *bytes*
PHY rate	11 *Mbps*
Minimum PHY rate	2 *Mbps*

Note that QoS-ACK and QoS-CF_Poll frames in the table include the MAC header only. To simplify the simulation, we only consider communications between station and AP.

Figure 5 shows the utilization of two scheduling schemes when the length of SI is varied. Utilization is defined as the ratio of the sum of TXOP's assigned to the served QSTA's to the length of SI.

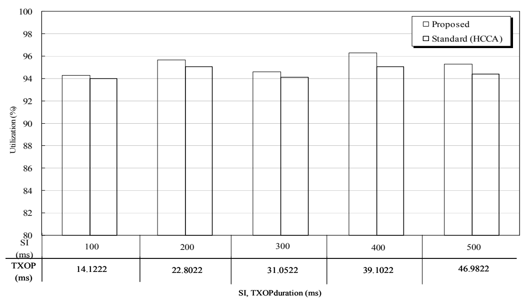

Fig. 5. Utilization versus mean TXOP

We can see that our scheme offers a higher utilization than the conventional scheduling scheme by HCCA mechanism at all times. This is because TXOP durations are allocated as much as possible while not exceeding SI in our scheme.

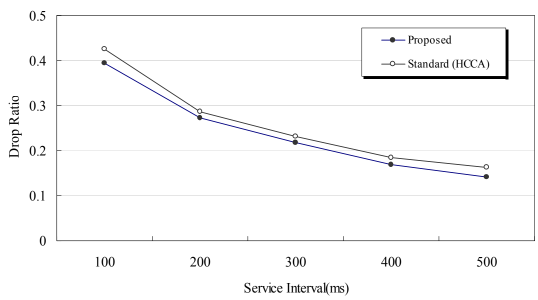

Fig. 6. Packet drop ratio versus service interval

Figure 6 shows the drop rate of two schemes. We find that our scheme also provides a better performance than the conventional scheduling in terms of the packet drop rate. So, we can say that the QoS performance will be very little degraded even when more flows are admitted to the network.

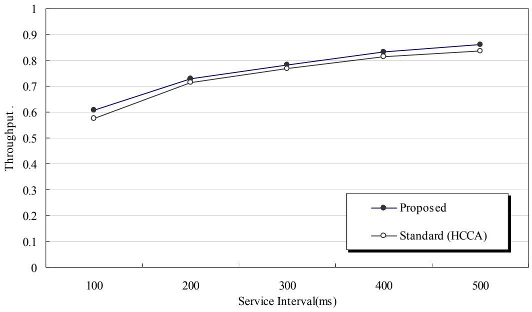

Fig. 7. Throughput versus service interval

Figure 7 presents the throughput of two schemes. We can see that the throughput is improved by about 3% on the average with our scheme. Also this figure indicates that our scheme may offer a higher throughput than the conventional scheduling scheme because our scheme can reduce the packet drop ratio.

5 Conclusion

In this paper, we proposed a TXOP allocation scheme using the knapsack algorithm by considering SI of each admitted stream. In simple scheduling scheme, the utilization in SI could not be optimal since an extra TXOP section could be existed. However, more TXOP duration of QSTA can be allocated in SI by using knapsack algorithm, and thus the QoS of wireless LAN is satisfied. And, simulation results show that our scheme offers better performance than simple scheduling scheme.

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