Controlling Contention Window to Ensure QoS for Multimedia Data in Wireless Network

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Communication: received 8 November 2019, revised 11 August 2020, accepted 1 September 2020

Digital Object Identifier: 10.32913/mic-ict-research.v2020.n1.896

Abstract: The IEEE-802.11e standard was published with the goal of ensuring quality of service, especially with multimedia data. However, this standard only assigns different priorities for different types of data but does not control the sharing of bandwidth among different data flows. In this paper, we will propose a method of sharing bandwidth for proportional data flows and controlling Contention Window of each priority flow to achieve that ratio.

Keywords: *Ad hoc network, IEEE 802.11e EDCA, service differentiation, traffic differentiation.*

I. INTRODUCTION

For the purpose of providing QoS for multimedia data, IEEE-802.11e was introduced in 2005 [1] and approved in 2012 [2]. The work was done with the objective of ensuring quality of service for multimedia data. However, this standard has not yet ensured on-demand differentiation between flow's traffics. For example, the ratio between data types such as voice, video, and best-effort is always kept at the highest level for voice, and the lowest level for best-effort. But this fixed ratio does not meet the flexible proportional division, in saturation state, high priority Traffic Class (TC) flows often gets all bandwidth, and low priority TC flows are hard to access channels.

Some studies have shown that although IEEE-802.11e has focused on improving QoS, there are still many issues to be resolved [3, 4]. The research [3] investigates EDCA performance in presence of voice and data integrated traffic, and observes the inefficiencies that arise when access differentiation is performed on the basis of traffic type only. In [4], authors investigate the use of the 802.11e MAC EDCF to address transport layer unfairness in WLAN.

In this paper, we will perform the evaluation by simulation to show that although IEEE 802.11e can provide proportional bandwidth distribution for different types of multimedia data, that division is fixed. For example, voice data is always the largest ratio and background data is the smallest. Therefore, in some cases, for example real–time data, which provides service differentiation for best effort and variable-rate real-time traffic, 802.11e cannot provide adequate QoS [5]. And hence it is necessary to have a more flexible division mechanism. We will solve the problem by measuring actual data each node received over a period of time, and then comparing it to theoretical data to determine whether to increase or decrease the Contention Window (CW) value. Our proposed algorithm will control the increase or decrease of this CW value to achieve flexible ratio to adapt user's on-demand with various types of data such as voice, video and background.

Next parts of this paper include the following sections: Section 2 summarizes some related research around the issue we are going to solve; In Section 3, we analyze the lack of 802.11e in adapting different throughput ratio for different data types; Section 4 and 5 will describe our proposed solution, the methods used to accomplish our goal and the simulation scenario evaluating the results achieved according to the outlined criteria.

II. RELATED WORKS

Some research papers focus on designing a Medium Access Control (MAC) and channel usage algorithm in multi-rate Wireless Local Area Networks (WLANs) for improving efficiency and sharing fairly channel resources among contending nodes [6]. Aiming to address problems that the high collision is often caused by Binary Exponential Backoff (BEB) mechanism in the legacy IEEE-802.11 and the shared channel can be overused by low bit-rate nodes, authors proposed a Differentiated Reservation (DR) algorithm to reduce the collision among contending nodes by setting their back-off counter as a deterministic value once successfully accessing the channel. Furthermore, to eliminate the performance anomaly, some nodes are permitted to send multiple packets in one transmission opportunity according to their feature. Moreover, the algorithm presented the implementation of the DR algorithm that is readily applied to both the existing IEEE 802.11 DCF and 802.11e EDCA networks with the minimum modification. In addition, we also investigate the limitation of DR algorithm and propose a Group-Based Differentiated Reservation (GDR) algorithm applied to high density scenarios. The results of theoretical analysis and simulation validate that the proposed algorithms (DR and GDR) can obtain high throughput, good airtime fairness and low collision rate.

In the research about a fair access mechanism in IEEE-802.11e networks [7], some proposed mechanisms are evaluated. According to their evaluated strengths and weaknesses, authors proposed a new mechanism for TXOP determination. This algorithm considers data rate, channel error rate and data packet lengths to calculate adaptive TXOPs for the stations. The simulation results show that the proposed algorithm leads to better fairness. It also achieves higher throughput and lower delays in the network.

Some previous paper on IEEE-802.11 QoS has proved that 802.11 parameters can be adjusted to get better network performance by maximizing throughput based on current network situations [8] [9]. 802.11 also allows parameter tuning such that some services can be accommodated and provided some QoS guarantees [10]. But these approaches do not provide different priority levels then lead to the development of 802.11e which has been done to dynamically adjust 802.11e parameters to provide better performance and QoS.

In research [11] the effects of different CW sizes are explored. This work shows that CW_{min} default in 802.11 leads to worse network performance, and finds that in situations with small numbers of stations, CW_{min} with small values greatly increased the collision probability, reduced overall throughput, and increased delays. However, when the network is fully utilized, the probability of transmission when the medium was free of a station also increases because the number of stations was increased. This research also finds out that when a single station is transmitting, throughput is greatly increased when CW_{min} values are small since a physical transmission medium is less idle time.

The effect of controlling dynamically to QoS prioritization was presented in [12]. The authors show that IEEE-802.11e designation increases the possibility of collisions and increases delay by adding an extra contention layer. In normal IEEE-802.11 networks the only collisions which can occur are those between stations as they try to gain access to the medium to transmit the packet at the head of the single send queue. In contrast with 802.11, there is only one type of data, because 802.11e divides into multiple classes of data and each class has its own queue, then virtual collisions can occur when each Traffic Class (TC) queue must contend for access within the station's queue manager, while real collisions occur when the winning queue is allowed to transmit. The results in [12] show that throughput in 802.11e is decreased and latency is increased when compared to 802.11a networks due to this extra contention. Hence, dynamic and aggressive tuning of the network parameters is required to achieve benefit from prioritization.

In the paper [13], authors extend the approach for the IEEE-802.11e network, where different QoS classes are defined and show how to find the class-specific optimal Contention Window sizes that yield the maximum aggregate throughput while maintaining the target throughput difference between classes. However, this approach is mainly based on mathematical models with assumptions that are difficult to realize by simulation or in practice.

Another method uses a two-level protection and guarantees a mechanism for voice and video traffic in IEEE 802.11e wireless LANs [14]. In first-level protection, existing voice and video flows are protected from new and other existing voice and video flows. In second-level protection, the voice and video flows are protected from best-effort data traffic. For each protection level, a couple of protection mechanisms are proposed. Extensive simulation results show that the proposed two-level protection and guaranteed mechanism are very effective in terms of protecting and guaranteeing existing voice and video flows as well as fully utilizing the channel capacity

IEEE-802.11e parameters can be tuned based on network conditions to allow better performance than a single setting [15]. Although these settings are not changed dynamically in this study, they do show that changing network conditions require changing parameters to use the channel efficiently. These optimizations are evaluation in a testbed under realistic conditions. The authors investigate two methods of choosing CW_{min} in IEEE-802.11e networks based on proportional fairness and time-based fairness. They conclude that proportional fairness in a network based on weights provides higher throughput than time based fairness. Their work shows that CW_{min} is an important parameter and can be tailored to a network in the case of nodes with or without ensuring fairness or traffic differentiation.

From the above research studied, we find that sharing of traffic by different data types without permanently assigning QoS parameters will be more effective for multimedia data, which is the type of data that always varies according to users' needs. The next sections of the paper will present our approach to achieving that goal.

III. ANALYZING OF EDCA THROUGHPUT

TABLE I
USER PRIORITY AND ACCESS CATEGORY [2].

Priority	UP	AC	Designation
lowest	1	AC_BK	Background
-	2	AC_BK	Background
-	0	AC_BE	Best effort
-	3	AC_BE	Best effort
-	4	AC_VI	Video
-	5	AC_VI	Video
-	6	AC_VO	Voice
highest	7	AC_VO	Voice

EDCA parameters for each AC are shown in the Table III.

TABLE II
CALCULATION OF CONTENTION WINDOW BOUNDARIES.

AC	CWmin	CWmax	AIFSN	TXOP limit (ms)
AC_BK	15	1023	7	0
AC_BE	15	1023	3	0
AC_VI	7	15	2	3.008
AC_VO	3	7	2	1.504

IEEE 802.11e introduced some enhancements to existing DCF and PCF of IEEE 802.11 with Hybrid Coordination Function (HCF) [1] [2]. The HCF includes two mechanism: Enhanced Distributed Channel Access (EDCA), which is an enhanced DCF, and HCF Controlled Channel Access (HCCA), which is an enhanced PCF. Both EDCA and HCCA could work separately or together, in contract of 802.11, where DCF is mandatory and PCF is optional. While the fundamentals of the original functions were not changed, augmented information allows HCF to provide QoS to specific flows and/or stations. In EDCA, MAC-layer parameters provide priority to each *Traffic Class* (TC) in a contention access manner similar to DCF. The parameters that can be manipulated are the *Arbitration Inter-Frame Space* (AIFS), the *Transmission Opportunity* (TXOP), the *CWmin*, and the *CWmax*. These parameters are given default values at each station for each TC, or they can be overridden by an Access Point using special coordination frames.

EDCA uses differentiated, distributed and contention-based medium access mechanism to enhance the original DCF by providing prioritized QoS for each type of data flow. EDCA mechanism defines four *Access Categories* (ACs) to provide support for delivery of traffic with *User Priorities* (UPs) at the stations. There are four traffic types corresponding to the four ACs: AC_BK, AC_BE, AC_VI and AC_VO stand for background, best effort, video, and voice traffic, respectively. For example, voice data should be sent with highest priority, so AC_VO is selected for this type of data. Default values of ACs are described in Table III. Note that although in this Table III, 802.11e EDCA defined eight default priorities for different data types [2], however, eight is not fixed and 802.11e EDCA allows less or more than the number of eight.

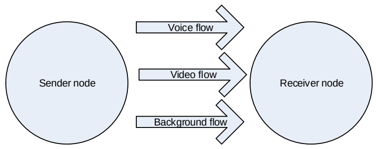

Figure 1. Two nodes with three data flows scenario.

The simulation parameters was shown in Table III.

TABLE III
SIMULATION PARAMETERS.

Parameter	Value
Channel data rate	11 Mbps
Antenna type	Omni direction
Radio Propagation	Two-ray ground
Transmission range	250 m
Carrier Sensing range	550 m
MAC protocol	IEEE 802.11e (EDCA)
Connection type	UDP/CBR
Packet size	1024 bytes
Send rate	incremental from 1 to 1000 (packets/second)
Simulation time	400 s

With proper tuning of EDCA parameters set, traffic performance from different access categories can be optimized and prioritization of traffic can be achieved. It means that, these parameters are simply intended to define a fixed priority for each type of data: voice is always of the highest priority, then lower for video, and background.

IEEE 802.11e EDCA uses different parameter sets leading to different priorities for data flows [2]. Therefore, although there is no contention of accessing channel, between the flows there will be a contention of using channel. This leads to different throughput of each flow. However, multimedia data does not always have a fixed priority. In many cases, we may need to change the priority flexibly, so assigning fixed EDCA parameters to each data type will not solve this flexible control priority problem. To clarify this issue, we will focus on analyzing the effect of Contention Window sizes to throughput in 802.11e EDCA.

We evaluate the performance of 802.11e by using simulation tool. There is a lot of software which is used to simulate wireless networks but is limited to the original 802.11. NS2 [16] is very popular for network simulations but it does not support 802.11e. Therefore, we have applied the extension patch for 802.11e from [17] which was integrated with NS2 to simulate and evaluate related 802.11e problems in this paper.

We consider a simple two-node model with the flows of the three data types (voice, video, best effort) as shown in Figure 1 to investigate the 802.11e parameters set for contention only between data flows with different priorities, there is no contention in accessing channel. This model will be used to evaluate the influence of Contention Window values to the throughput of different data types.

Multimedia data can use TCP or UDP, but in this paper, we perform simulations with UDP data only as shown in Table III because many video and multimedia applications, such as VoIP use UDP. These applications can tolerate some data loss with little or no noticeable effect. The reliability mechanisms of TCP is not suitable for real-time applications as the re-transmissions can lead to high delay and cause delay jitter, which significantly degrades the quality.

Figure 2 show the throughput of each Traffic Class according to offered load, with default IEEE 802.11e parameters, the offered load is increased with high priority.

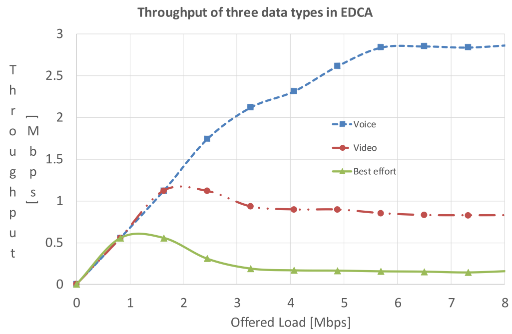

Figure 2. Simulation result of two nodes with three data flows scenario.

We demonstrate the relationship between Contention Window size of three data types (Voice, Video, and Background). To do that, we fixed two CW-size of the highest (voice data) and the lowest (background data) priorities and step-by-step changed the CW-size of video data. The range of CW values varies in many cases , for example {3 — 15} in default EDCA parameter as shown in Table III, or {7 – 31} with QoS Access Point/Basic Service Sets (BSS) [18], or {17 – 1023} for maximal fair throughput allocation with a toy WLAN scenario consisting of one Access Point and two associated stations [19]. In order to show that our proposed method can adapt to variable CW values, we will take CW values of three types of data which also change from 17 to 33, and CW size of the video data which will change in that range (17 to 33) to give an observation of how the throughput ratio of three data types changes corresponding to CW changes.

Looking at the simulation results in Figure 3. Here, the throughput of background data is considered as the basis (*Th BE*), the throughput ratios of Voice and Video compared to Background (*Th VO:BE* and *Th VI:BE*) are used to observe the effect of changing CW values to throughput of three data types. When CW increases, throughput decreases, whereas reduced CW increases throughput. As we see, the values of CW corresponding ratio *3:2:1* is *17:20:32*. We can see the change of throughput over different CW values, so in order to have flexible change ratio as user's demand, we will need many sets of CW values. It means that when assigning fixed CW values for data types, changing throughput ratio in 802.11e is very difficult to achieve.

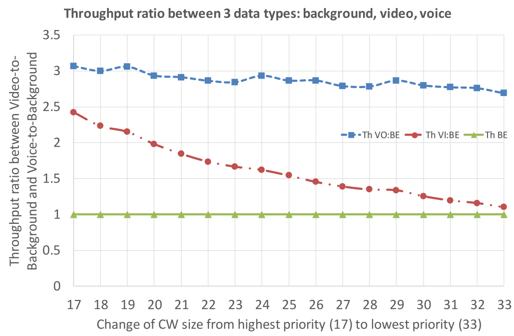

Figure 3. Estimation throughput by priority level (CW_{min}) between Voice and Video with Background data.

In the next section, we will propose a method to achieve this ratio with dynamic controlling CW size.

IV. PROPOSED METHOD TO ACHIEVE THROUGHPUT BY RATIO

1. Define the ratio share between traffic class

IEEE-802.11e provides priority level for each traffic class, but it cannot guarantee throughput ratio suitable for each traffic class [20]. We propose the weighted number for each priority different from defined settings of IEEE-802.11e, these numbers will correspond to throughput ratio in our proposed solution. It means that, with a proposed numbers *3:2:1:1* shown in Table IV.1, our proposed method will get the ratio shared of throughput [of 2 Mbps total] in Figure 5.

Our previous work shows that the fairness between different data flows in 802.11e can be achieved via changing *CW* value with simple simulation scenario with two nodes sender–receiver [21], and the achieved result of fairness mainly limited aspects allocate resources between flows in a traffic class (the same services).

In this paper, we improve the mechanism by flexibly assigning *CW* values to different data flows to achieve flexible ratio with more complex simulation scenarios. It means that users can simultaneously use different types of data and still achieve a fair share ratio of all traffic classes.

TABLE IV
NUMBERS FOR THROUGHPUT RATIO WITH DIFFERENT DATA TYPES.

Priority	UP	AC	Data type	Weighted number
lowest	1	AC_BK	Background	1
-	2	AC_BK	Background	1
-	0	AC_BE	Best-effort	1
-	3	AC_BE	Best-effort	1
-	4	AC_VI	Video	2
-	5	AC_VI	Video	2
-	6	AC_VO	Voice	3
highest	7	AC_VO	Voice	3

Our proposed method will control *CW* size to adapt to different throughput ratios of {*background*, *best effort*, *video*, *voice*} such as {10:10:30:40} or {15:15:30:40} percentage (%) of total bandwidth.

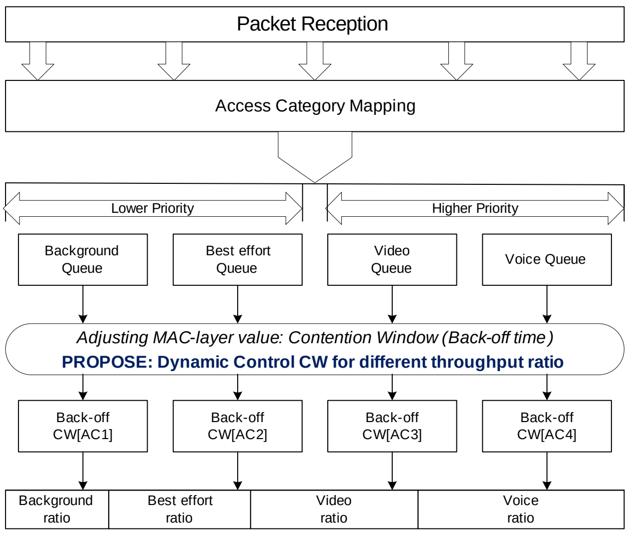

Figure 4. Controlling CW size to adaptive different throughput ratio.

With the proposed mechanism as shown in the processing module in Figure 4, after receiving input packets, the Access Category Mapping will put these packets into different priority queues, for example Background and Best Effort data onto low priority queues, Voice and Video data into high priority queues.

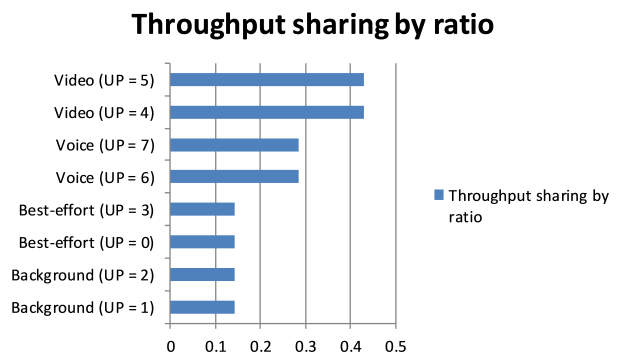

Figure 5. Expected throughput sharing by ratio with weighted numbers.

Then the control mechanism at the MAC sub-layer is proposed to control the corresponding Contention Window value (*CW*) for the throughput ratios corresponding to the different Access Types (*AC*) according to the parameters $CW[AC]$, since a large/small *CW* value will result in a short/long timeout (backoff) and consequently the corresponding larger/smaller throughput ratios, but will still not exceed network bandwidth. An example of the result would look like Figure 5, where bandwidth 2 [Mbps] is divided among different data types (Video:Voice:Best-effort:Background) in a ratio of 4:2:1:1).

2. Control CW to achieve the ratio share between traffic classes

The basic feature of IEEE-802.11e is to ensure that fixed-level priorities i.e. voice data are always assigned higher priority than background data, which leads to low-level of fairness in network. In order to achieve a more flexible throughput sharing, our proposed mechanism will adjust Contention Window (*CW*) size, because the *CW* size is related to the back-off time, and the longer or shorter back-off time leads to the opposite of access time being smaller or larger. It means that network traffic will vary with *CW* sizes.

Based on the cross-layer scheme to ensure fairness in IEEE 802.11 [22], we propose a number of MAC layer improvements in IEEE-802.11e in order to achieve fairness between different data flows (video, audio, text, for example). In general, data flows should have different priorities of bandwidth. For example, video data will need more bandwidth than voice data, or when calling phone over Internet (VoIP), voice data will be more prioritized than video data. Therefore, we need to have the corresponding way to assign bandwidth usage for data flows. We did this work based on two modules named *TX Flow Estimation* and *Utilization Estimation*. In fact, it is very difficult to have any method to ensure fairness in different layers (application, network, MAC, etc.). Our proposed method will try to focus on ensuring fairness so that high-priority flows will not take all the bandwidth of low-priority flows.

Module *TX Flow Estimation* works in MAC layer to count the number of flows in the transmission range. We call these flows *TX flows*. A *TX flow* is determined by MAC addresses, IP addresses of source and destination and flow type (e.g. Voice, Video, BestEffort), by decoding the header of the packet. We define *TX flows* as $n_{TX[i]}$ where i stands for $\{Voice, Video, BestEffort\}$. Note that in this case, *TX flow* is end-to-end flows data type, and it can include some process-to-process flows.

Assume that, there are n data flows with k_i as the weighted number of the data types defined in IEEE-802.11e. E.g. throughput ratio of Voice, Video and Best Effort is 3:2:1, we have $k_{Voice} = 3$, $k_{Video} = 2$, $k_{BestEffort} = 1$.

We calculate the total flow n_{total} in $TXFlowEstimation$ module by the following formula:

$$n_{total} = \sum_{i=1}^{n} k_i \times n_{TX[i]} \quad (1)$$

Next we define the fair ratio share of the bandwidth for each flow by the formula:

$$Fair\_Share\_Ratio[i] = \frac{k_i}{\sum_{i=1}^{n} k_i \times n_{TX[i]}} \quad (2)$$

Utilization Estimation module evaluates real link utilization of the flow. The link utilization is determined by analyzing period $Active\_Time[i]$ of the flow in a predefined estimation period EP. The $Active\_Time[i]$ of the flow is defined as time used to transmit packets in $flowi$. The algorithm IV.1 is used to estimate the value of $Active\_Time[i]$ of the data flow i by sensing packets. We compute real time for sending data in given EP time by 80 percent of current sending time plus 20 percent of the past calculated time (before) as shown in Algorithm IV.1 below.

Algorithm IV.1: ($Active\_Time[i]$)

Initialization:
  $Active\_Time[i] = 0$
  $T_{Active[i]} = 0$
for each each interval time EP
    $Active\_Time[i] = 0.8 \times Active\_Time[i] + 0.2 \times T_{Active[i]}$
    $T_{Active[i]} = 0$
    for each each packet p
      if $p \rightarrow destID == localID$
        if $p \rightarrow Type == CTS$
          $T_{Active[i]} = T_{Active[i]} + T_{RTS} + T_{CTS}$
        if $p \rightarrow Type == ACK$
          $T_{Active[i]} = T_{Active[i]} + T_{DATA} + T_{ACK} + T_{Backoff}$

The $Real\_Share\_Ratio[i]$ is defined as the ratio of the $Active\_Time[i]$ to the estimation period EP as the below equation:

$$Real\_Share\_Ratio[i] = \frac{Active\_Time[i]}{EP} \quad (3)$$

In this equation 3, estimation period (EP) time is a given observation period, chosen so that it is neither too short to ensure evaluation process, nor too long because it will distort the simulation. In the simulation done in the next part of this paper, the EP value which we selected is two seconds. CW will be adjusted, and the throughput will be evaluated during this EP value.

Based on the CW size which has been defined in Table 2, adjusted value of CW will be determined by the formula:

$$CW'[i] = \frac{Real\_Share\_Ratio[i]}{Fair\_Share\_Ratio[i]} \times CW[i] \quad (4)$$

In the above formula, the fairness value $Fair\_Share\_Ratio[i]$ is used as a threshold of priority for accessing channel. If flows realized that the real value $Real\_Share\_Ratio[i]$ is less than its $Fair\_Share\_Ratio[i]$, it will use the CW size which is smaller than in the back-off state. Thus, the flow can increase its chance to access channels and bandwidth allocation. Vice versa, if flow realized that $Real\_Share\_Ratio[i]$ is greater than its $Fair\_Share\_Ratio[i]$, it will use a greater value than CW in back-off state. Therefore, it will reduce the chance to access channel, leading to other disadvantaged flows to have more opportunities to access the channel. In case some of the flows only have a small offered load, they will access channel more easily, and the remaining bandwidth will be shared by other flows. Thus, it allows more efficiently use of channel bandwidth and ensure fair bandwidth allocation among flows.

V. ANALYSIS OF SIMULATION RESULTS

1. The throughput by ratio and measurement to evaluate

For priorities shown in Table III, we will evaluate and simulate the weighted numbers *3:2:1* as shown in Table V.1.

TABLE V
THE WEIGHTED NUMBERS OF THREE DATA TYPES (VOICE, VIDEO, BEST-EFFORT) FOR SIMULATION.

Priority	UP	AC	Data type	Weighted number
lowest	1	AC_BE	Best-effort	1
-	2	AC_VI	Video	2
highest	3	AC_VO	Voice	3

To evaluate the effect of throughput sharing by ratio according to our proposed method, we use the *fairness index*, which is defined by R. Jain [23]. In this paper, the Fairness Index is evaluated based on the goodput at the destination station. We propose the equation for calculating fairness by priorities as follows:

$$FairnessIndex = \frac{(\sum_{i=1}^{n} \frac{x_i}{k_i})^2}{n \times \sum_{i=1}^{n} (\frac{x_i}{k_i})^2} \quad (5)$$

Here, n is the number of flows, x_i is the end-to-end throughput of *flow* i, and k_i is the weighted number with the corresponding types of data. The result ranges from $1/n$ (worst case) to 1 (best case), and it is maximum when all flows receive the same allocation. This *fairness* value will be used to evaluate the sharing ratio of different bandwidth data types, meaning that the closer the value is to one (1), the more likely the ratio will be achieved.

2. Simulation models

We evaluate proposed method with different simulation models. The simulation parameters are described in Table III with NS-2 simulator. The EDCA CW used values of three data {*Voice, Video, Background*} are {17, 20, 32} as shown in Fig. 3 will ensure the ratio *Voice:Video:Background* = 3:2:1. For more complex models, we use the simulations below, this ratio is only achieved with our proposed mechanism but not with IEEE-802.11e, as in sections: V.2.a(2 senders), V.2.b (3 senders), and V.2.c (multiple senders with random model).

a) Three nodes model

The first model includes a chain of three nodes with six flows corresponding with three types of data (Voice, Video, Background) in Fig. 6. This model was known with *large-EIFS* problem [24]. According to IEEE 802.11 specifications, before a station starts the transmission, it should defer for a distributed IFS (DIFS) or an EIFS delay time and then selects a random contention window (CW) counter for backoff. Once the backoff counter decreases to zero, the station starts its transmission. The choice between DIFS and EIFS depends on the event of the last transmission. If the last event is an unsuccessful transmission (e.g., a collision), the station waits for an EIFS, otherwise it waits for a DIFS. The station which waits for an EIFS is called a retry station. The EIFS in the IEEE 802.11 standard is the largest Inter-Frame Space (IFS) and is used to protect ongoing frame, especially acknowledge frame (ACK) from collisions. When stations detect a transmission but cannot decode it, they set their Network Allocation Vectors (NAVs) for the EIFS duration. However sometimes the EIFS duration is larger/smaller than ongoing frame duration, leading to considerable unfairness and throughput degradation [25].

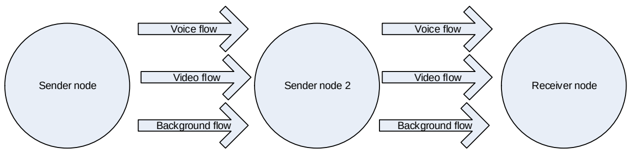

Figure 6. *Three nodes model.*

We examine network performance in this model by letting sender nodes 1 and 2 generate traffic at the same offered load to receiver node. The performance metrics Fairness Index and Total Throughput are evaluated with offered load.

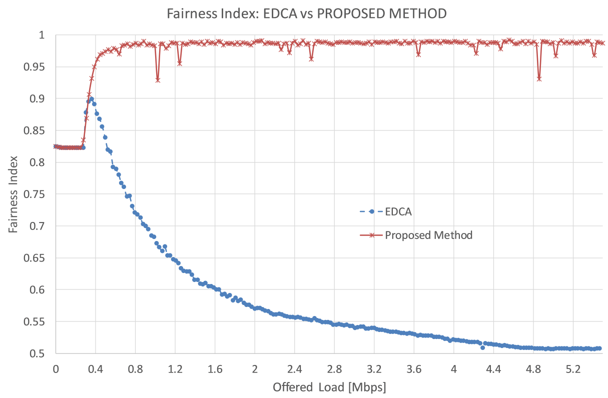

Figure 7. *Fairness Index in Three nodes model.*

In Fig. 7 and 8, "EDCA" means the result by using IEEE 802.11e and "Proposed Method" means our CW size adjustment shown in the paper (Section IV). Fairness Indexes are shown in Fig. 7. When offered load is small, all flows get its requirement. When offered load becomes larger, in EDCA, fixed priorities (corresponding fixed CW size) are assigned to different data types and higher priority flows can get more opportunity to transmit data, then Fairness Index might be worse. In our method, flexible CW size is controlled to different data types, abd the throughput of each flow becomes fairer and the bandwidth allocation at the MAC layer is also improved. Thus, our method achieves good Fairness Index.

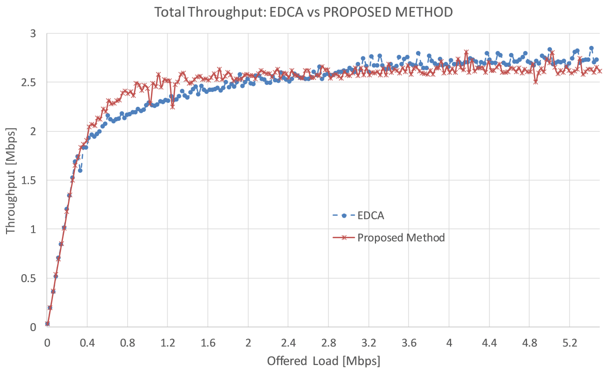

Figure 8. *Total throughput in Three nodes model.*

The Total Throughput of all flows is shown in Fig. 8. When the offered load is small, Total Throughput of all methods is similar. When offered load becomes large, in EDCA, bandwidth utilization is less efficient than others because EDCA gives some advantages to traffics of higher priority flows. In our method, by changing the flexibility of CW size, the lower priority flows chance to access channel can be increased by reducing CW size (back-off time). Therefore, the throughput of different data flows remains at a stable level for most of simulation time. It means, the Fairness and Throughput are often opposite. Figures 7 and 8 show that our proposed method achieves better fairness and there is still has a slight difference in throughput compared with EDCA.

b) Three pairs model

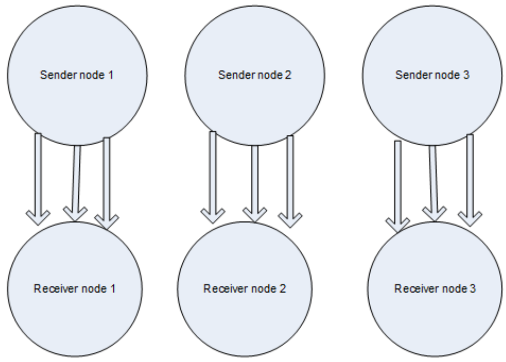

Figure 9. *Three pairs model.*

Figure 9 shows three pairs of sender and receiver nodes. The problem in this scenario is also known as *three-pair* problem which was first investigated in [26]. In this scenario, sender nodes 1-2 and 2-3 are out of the transmission range but in the carrier sensing range. Senders nodes 1 and 3 are out of the carrier sensing range, hence the two external pairs Sender 1 – Receiver 1 and Sender 3 – Receiver 3 are completely independent, i.e., they can send packets simultaneously without interference with each other. Thus, the two external pairs contend bandwidth only with the central pair Sender 2 – Receiver 2, while the central pair contends with both external pairs. In this topology, the central pair cannot access the medium in the saturated state in the original IEEE 802.11 [26].

We examine the network performance in this model by letting the sender nodes 1, 2 and 3 generate traffic at the same offered load to receiver nodes. The performance metrics Fairness Index and Total Throughput are evaluated with offered load.

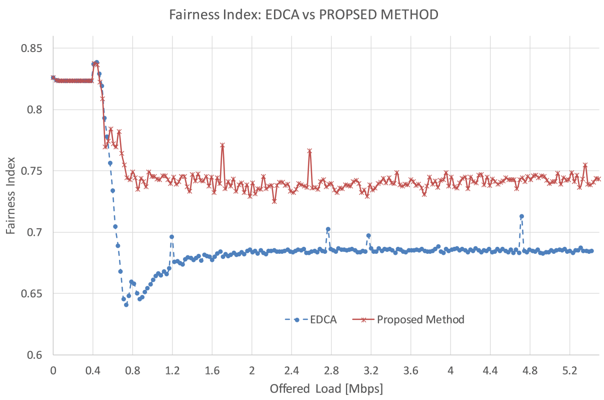

Figure 10. *Fairness Index in Three pairs model.*

Fairness Index is shown in Fig. 10. When offered load becomes large, EDCA cannot help the central pair access the medium, because scheduling queue in EDCA only works at the link layer, so it does not have information of flows out of the transmission range. Therefore, it cannot improve MAC layer fairness. In our Proposed Method, the central pair finds out that its bandwidth is less than fair bandwidth allocation. Then Proposed Method tries to improve its chance to access channel by decreasing CW Size and therefore reducing the back-off time of station Sender 2. Thus, Proposed Method can achieve a better fairness than EDCA.

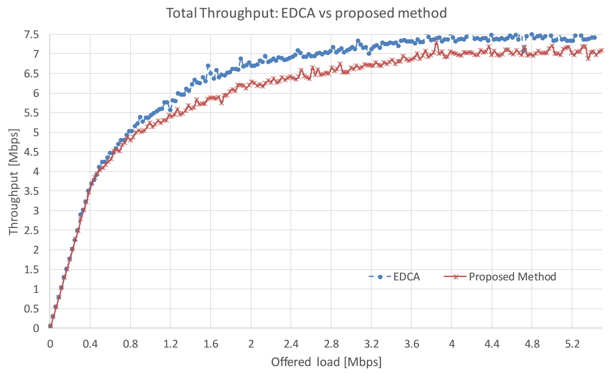

Figure 11. *Total throughput in Three pairs model.*

The Total Throughput of all flows is shown in Fig. 11. When offered load becomes large, EDCA achieves larger Total Throughput than our methods. This phenomenon is explained as follows. In EDCA, higher priority flows such as voice flow and video flow can use most of channel bandwidth with its CW value, so the throughput of the left and right pairs (numbered one and three) will take up most of the bandwidth, and the middle pair (numbered two) has very little bandwidth. In our method, with flexible CW size, we can give more opportunity for lower priority flows, so the throughput of the middle pair will increase and the throughput of the left and right pairs will decrease, leading to the total throughput of our method being possibly lower than EDCA.

c) Random model

The third model is a random topology. We make a topology with 50 stations at random positions in $1000[m] \times 1000[m]$ area. Among those 50 stations, m stations are chosen randomly and these n stations generate UDP traffic flows to one destination station. Total offered load of source stations is set equal to channel data rate 11[Mbps]. The average of Fairness Index and total end-to-end throughput are used as metrics to compare the throughput and fairness, respectively. These terms of network performance are examined versus the number of flows. Each data point is the average of over 50 simulations.

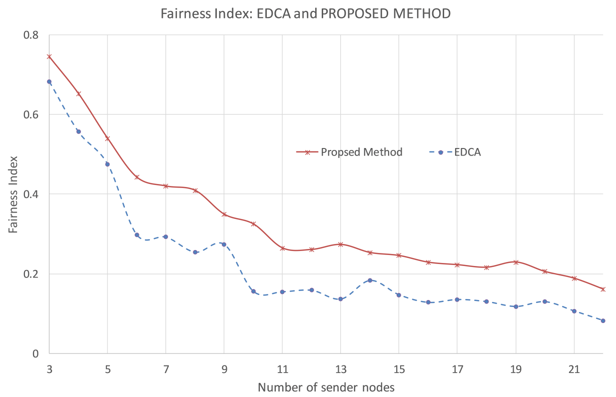

Figure 12. *Fairness Index in Random model.*

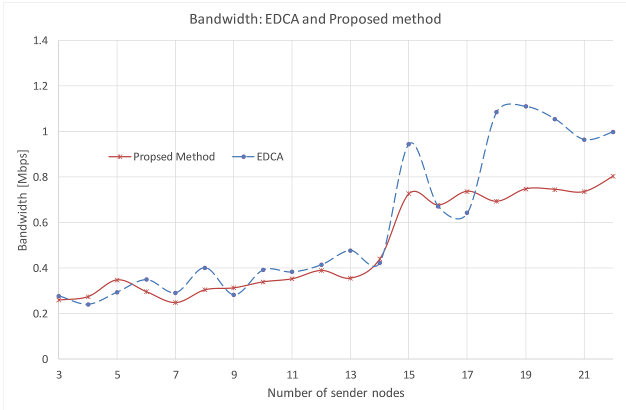

Figure 13. *Total throughput in Random model.*

These terms of network performance are examined versus the number of flows. The simulation results also prove that our proposed method achieves good fairness performance as in Fig. 12. Our throughput performance is slightly reduced by the trade-off with fairness performance as described in Fig. 13.

VI. CONCLUSION

Inheriting from IEEE 802.11, IEEE 802.11e standard was developed and published, partly satisfying QoS for multimedia data, but in terms of sharing fairness, this standard is still limited because it gives relatively fixed values to the QoS parameters. Our research has proposed a mechanism to improve the fair sharing of bandwidth between flows by adapting CW in a more reasonable way. Our algorithm is simple to implement, and it provides flexible CW value, corresponding to the value of priority of throughput for different data types to achieve a reasonable level of sharing between multimedia flows. The evaluated and simulated results by NS-2 have verified that our method is better than original IEEE-802.11e in some simulation models. Our future research is aimed at evaluating mixed data UDP and TCP based on the wireless testbed system.

ACKNOWLEDGMENT

This work was financially supported by Institute of Information Technology (IOIT), Vietnam Academy of Science and Technology (VAST).

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