A Cross Video-MAC Layer Approach for Generating Adaptive FMO Map

Tien Huu Vu[1] and **Supavadee Aramvith**[2], Non-members

ABSTRACT

Recent researches in video transmission over heterogeneous networks move toward cross-layer design to realize the optimal video quality. In this work, we investigate the cross layer approach between H.264 video coding layer and IEEE 802.11e Medium Access Control (MAC) layer on the issues of how to improve error resiliency of H.264 video using Flexible Macroblock Ordering (FMO), and how to reduce packet dropping rate at MAC layer. We propose an adaptive FMO map generation to separate high and low important macroblocks to different priority queues based on the overflow state of MAC layer queues. The arrival rate of packets to queues is thus changed to reduce the queue overflow and to decrease of the packet dropping rates at queues. Experimental results show that using the proposed scheme can reduce the packet drop rate at the queues resulting in the reduction of packet loss rate and the improvement of the average PSNR.

Keywords: H.264, Flexible Macroblock Ordering (FMO), Error Resilience, Cross Layer, MAC Layer

1. INTRODUCTION

As a new tool of H.264/AVC, Flexible Macroblock Ordering (FMO) enables an image to be divided into regions called slice groups. Each slice group can be divided in several slices and a slice can also be decoded independently. An identification number for each Macroblock (MB) is given by a MacroBlock Allocation map (MBAmap) to specify which slice group MB belongs. Because of independency between slice groups, if a slice group is in error, the important MBs in the other slice groups are not affected. Beneficial from using FMO map is the reduction of the number of undecodable MBs. To design slice group maps, the previous approaches use indicators to evaluate the importance of an MB. The works in [1] proposed the indicator to express the importance of MBs but do not involve network consideration. Another work in [2] considers the network feedback and calculates the prediction of the future network state to help generate more meaningful FMO map and to select appropriate parameters such as intra refresh rate in video encoding. It has been shown that cooperatively utilizing information across layers could optimize the system performance and video quality indeed.

Cross layer video coding has been proposed in the research community to improve Open Systems Interconnection (OSI) model in controlling the parameters and operation of each layer in conjunction with the others to achieve the optimum system performance. There are many researches related to the interaction between Application (APP) and MAC layer with the main objective to reduce the packet loss rate.

In [3], a method is proposed to support Quality of Service (QoS) in wireless LAN (WLAN) by using data partition (DP) in the video coding layer. In this method, the video packets are classified into different priority queues depending on the importance of partitions. However, the number of bits spent for higher important partition such as the slice header is less than the number of bits spent for the coefficients and the inter/intra coded block pattern in that slice. Hence, the number of packets arriving at higher priority queue is smaller than the number of packets arriving at lower priority queue. Consequently, the high priority queue is always empty while the others are full. This causes the unnecessary packet dropping and delay in the lower priority queue. To overcome this issue, the work in [4] proposes a method to balance the number of traffic coming to queues. In this method, video traffic and other best effort traffic are mapped into separated queues. However, if the queue length is greater than the upper threshold, the video traffic is directly mapped to the lower priority queues of the best effort traffics. Thus, the loss rate of video packets is reduced.

For other cross-layer approaches, in [5]-[6], different FMO types are varied to find out which pattern provides the best video quality for a given packet loss scenario. The results show that the "dispersed" FMO type provides the best PSNR for the case of moderate packet loss. In addition, the length of slice is selected to achieve the highest average PSNR. However, in these works, the FMO map at APP layer is not changed to adapt with the requirements of the lower layers.

In this paper, we consider the case where FMO map will be adapted to the MAC layer status to reduce the number of dropped packets. In other words, this work focuses on the generation of an explicit FMO map based on overflow state of queues at MAC

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[1,2] The authors are with Department of Electrical Engineering, Chulalongkorn University, Bangkok, Thailand. , E-mail: Supavadee.A@chula.ac.th

layer. The changing FMO map of the current frame results in the changes of the encoding order of the high and low important slice groups. Consequently, the rate of the packets to the queues is changed in such a way that the arrival rate of packets to the full queue is reduced and the arrival rate of packets to the empty queue is increased.

The rest of the paper is organized as follows. In Section 2, the concept of FMO and 802.11e standard are introduced. The proposed method to generate FMO map is described in Section 3. Section 4 gives the experimental results and analysis. Finally, conclusions are drawn in Section 5.

2. BACKGROUNDS

In this section, the method to generate an explicit FMO map is introduced. In addition, the classification mechanism for the queues at IEEE 802.11e MAC layer is explained.

2.1 Flexible Macroblock Ordering

In H.264/AVC standard, there are six default types of FMO maps from type 0 to type 5. FMO type 6 is called the explicit FMO. This type allows the full flexibility of assigning MBs to any slice, as long as the mapping is specified in the MBAmap. The procedure on how to use explicit FMO to design a specific MB-to-slice group mapping is as follows:

- Parameter Specification: Find a parameter to quantify the importance of a MB.
- MB Classification: Classify the MBs to slice groups using the chosen parameter.
- MBA map design: The result of the classification process determines the MB-to-slice group map.

In this work, the role of FMO in mitigating the packet dropping rate at MAC layer is taken into account. Thus, for simplicity, residual is used as the indicator to evaluate the importance of the MBs. Further details of FMO can be found in [1].

2.2 The IEEE 802.11e Standards

In the 802.11 standard, the operation of the MAC layer is controlled by a mechanism named Distribution Coordination Function (DCF), which is based on carrier sense multiple access with collision avoidance. In the DCF scheme, each station contends for the channel access by using a parameter, called backoff time, that is a random number in the interval [0, CW]. Initially, if channel is busy, Contention Window, CW, is set to CWmin. The wireless station (WS) starts a counter at value CWmin and reduces the value of the counter. When the value of the counter reaches zero, the WS transmits packets. If a collision occurs, CW increases its value (up to the value of CWmax). On a successful transmission, CW is reset to the value CWmin. Whenever the packet is not correctly acknowledged by the receiver, the WS retransmits the value until the maximum number of retry-limit (RL) is reached.

To support QoS in WLAN, the 802.11e standard is proposed with the operation of the Enhanced Distributed Channel Access (EDCA), replacing DCF. In DCF, all WS compete for the wireless medium with the same priority. However, in EDCA, this mechanism is extended to four levels of priorities or access categories (AC). Each AC has its own transmission queue and its own set of channel access parameters. ACs are differentiated by setting different CWmin, CWmax, arbitrary inter-frame space (AIFS) which is the period of time the WS has to wait for starting counter when the medium is idle, and RL. If one AC has a smaller [AIFS, CWmin, CWmax, RL], the AC has more chances in competing medium access.

3. GENERATING FMO MAP USING CROSS-LAYER APPROACH

In this method, firstly, the overflow state of queues is computed. Based on this information, encoder generates an explicit FMO map for the current frame to adjust the arrival rate of packets coming into the queues.

3.1 Overflow Rate

At the MAC layer, packet losses occur due to two reasons: link erasures and queue overload. In the scope of this work, we assume that link erasure is zero. The queues used in MAC layer are drop-tail queue. Thus, the packet drop rate at the queues depends on the arrival rate and the service rate of the queues. If the arrival rate is greater than the service rate, the queue is occupied quickly by the waiting packets. If this state occurs for a long time, the queue is considered to be in a full state and the arrival packets are dropped. This state is overflow state of the queue.

In this work, we use a simplified buffer analysis based on the fluid model. Let L_r be the link retry limit, and P_e be the packet error rate (PER) of the link (without retry), then the mean number of transmissions for a single packet until it is either successfully received or it reaches its retry limit can be calculated as shown in Eq. (1) [7]:

$$s(L_r, P_e) = 1(1-P_e) + 2P_e(1-P_e) + \ldots + (L_r+1)P_e^{L_r} = \frac{1 - P_e^{L_r+1}}{1 - P_e} \tag{1}$$

Let λ be the arrival rate (in packets/s). In the fluid model, we calculate the overflow rate, as shown in Eq. (2),

$$\sigma(L_r, P_e) = \frac{s(L_r, P_e)\lambda - C}{s(L_r, P_e)\lambda} \tag{2}$$

where C is the service rate of the link (packets/s). Eq. (2) shows that overflow occurs only when . By substituting Eq. (1) into Eq. (2), we have

$$\sigma(L_r, P_e) = 1 - \frac{1}{\rho(P_e)} \frac{1}{1 - P_e^{L_r+1}} \quad (3)$$

where $\rho(P_e) = \dfrac{\lambda}{C(1 - P_e)}$ is the effective utilization factor of the link.

3.2 Adaptive FMO Map Generation

For simplification, we assume that there are two queues in the MAC layer: AC2 and AC1. The priority of AC2 is higher than that of AC1. Assuming that L_r and P_e are constant, from Eq. (2) and (3), we can see that $\sigma(L_r, P_e) \sim \frac{\lambda}{C}$. Therefore, to reduce the overflow rate of a queue, the arrival rate of that queue should be reduced.

To adjust the order of the arrival packets, we can adjust the encoding order of MBs in a frame by using explicit FMO map. If the higher important MBs are encoded first, the higher important packets are encoded and are mapped into the high priority queue first. The lower important MBs are encoded later, and thus the lower important packets are mapped into the low priority queue later than the higher important packets. Inversely, if the lower important MBs are encoded first, the lower important packets will be mapped into the low priority queue sooner than the higher important packets mapped into the high priority queue.

Fig. 1 describes the architecture of system using the cross-layer scheme to generate the explicit FMO map. In this system, after encoding, sequences of video packets are mapped into queue AC1 and queue AC2, respectively. After encoding each frame, the overflow states of both queues are sent to the encoder. Based on this information, encoder decides the FMO map for the next frame to adapt with the states of the queues.

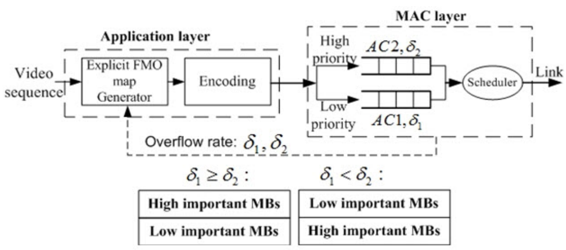

Fig.1: *Cross layer architecture of the proposed method.*

In case that the overflow rate of queue AC1 is higher, i.e., $\sigma_1 \geq \sigma_2$, to reduce the arrival rate of the packets coming to the queue AC1, FMO map is generated in such a way that the higher important MBs are encoded before the lower important MBs. Therefore, the lower priority packets will come to queue AC1 later than the higher priority packets coming to queue AC2. In other words, the arrival rate, λ_1, is decreased but the arrival rate, λ_2, is increased. Consequently, σ_1 is decreased but σ_2 is increased.

If $\sigma_2 > \sigma_1$, the arrival rate of packets to the queue AC2 needs to be reduced and FMO map is changed. The lower important MBs are encoded first. And thus the higher priority packets will arrive at the queue AC2 later than the lower priority packets arrived at the queue AC1. Hence, λ_2 is decreased but λ_1 is increased. Consequently, σ_2 is decreased but σ_1 is increased.

Table 1 shows that the residual value of MBs in frame 10^{th} of the "akiyo" sequence. In this case, the importance is measured by the residual of MBs. MBs having importance level equal to zero imply that the MBs belong to the background of the frame. Like-

Table 1: *Residual values of MBs in frame* 10^{th} *of the "Akiyo" Sequence*

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	461	936	479	0	0	0	0
0	0	0	0	1268	1769	771	0	0	0	0
0	0	0	1	3056	2253	1120	219	0	0	0
0	0	0	0	789	2238	684	347	0	0	0
0	0	0	179	510	2023	1595	678	700	51	0
0	3	81	4	229	1186	812	438	163	471	0
0	0	250	301	157	1092	510	267	282	800	0
0	124	250	6	6	610	752	402	609	147	0

Table 2: *The importance of the MBs in frame* 10^{th} *of the "Akiyo" Sequence after macroblock reordering*

461	936	479	1268	1769	771	1	3056	2253	1120	219
789	2238	684	347	179	510	2023	1595	678	700	51
3	81	4	229	1186	812	438	163	471	250	301
157	1092	510	267	282	800	124	250	6	6	610
752	402	609	147	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Table 3: *The explicit FMO map of frame* 10^{th} *of the "Akiyo" sequence*

16	17	18	27	28	29	37	38	39	40	41
49	50	51	52	59	60	61	62	63	64	65
68	69	70	71	72	73	74	75	76	80	81
82	83	84	85	86	87	90	91	92	93	94
95	96	97	98	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15	19	20	21
22	23	24	25	26	30	31	32	33	34	35
36	42	43	44	45	46	47	48	53	54	55
56	57	58	66	67	77	78	79	88	89	99

wise, high important MBs belong to the region of interesting (ROI) area of the frame. We can see that, the order of high important MBs and low important MBs are interlaced. Thus, the order of packets arriving at the high priority queue and the low priority queue is according its importance.

To adjust the order of arriving packets, we adjust the order of encoding MBs in a frame by using explicit FMO map. Table 2 shows an example of changing encoding order. Table 3 shows the explicit FMO map. According to this FMO map, MBs with high importance (gray MBs) are encoded first. After that, the low important MBs (white MBs) are encoded. Thus, the high important packets will be mapped into high priority queue first. The low important packets are mapped into the low priority queue. In the case of the explicit FMO map is chosen, the low important MBs are encoded first, and then followed by the high important MBs.

4. SIMULATION RESULTS AND ANALYSIS

4.1 Experiment Setup

In this work, a frame is divided into 8 slice groups. The higher important MBs are arranged in four slice groups while the other four slice groups are categorized for the lower important MBs. Each slice group is contained in a packet. As a result, there are two types of packets: the high priority packets and the low priority packets as shown in Fig. 1. The high priority packet is mapped into AC2 and the other is mapped into AC1.

In the simulations, video sequences are encoded for 100 frames at 20 fps with bitrates of 64 kbps, 128 kbps and 384 kbps. To examine the efficiency of the cross layer mechanism, we conduct experiments over an 802.11e WLAN by using network simulator (NS2) [8] and [9]. In order to evaluate the performance, the proposed method is compared with two other methods in terms of PSNR and packet loss rate. The first method uses data partitioning (DP) [3] and the second method uses FMO without adaptability. In the method using DP, there are 3 queues. However, the queue AC3 contains parameter set information with a very small number of bits. Thus, we can consider that all packets are mapped into two other queues in which packets containing partition A are mapped into the queue AC2. Packets containing partition B and C are mapped into the queue AC1. For the method using FMO without adaptability (non-adaptive FMO), the FMO map is fixed with 8 slice groups including 4 higher important slice groups followed by 4 lower important slice groups. Because FMO map is fixed thus the arrival rates of packets to the queues are considered as constant in this case.

We perform the experiments in a high loaded network with 0.3 Mbps background traffic including one voice source (using the highest priority queue AC3) with bit rate of 64 kbps, one video source (using the second and the third priority queue: AC2 and AC1), two applications CBR and FTP with bit rate of 300 kbps (using the fourth priority queue AC0).

4.2 Results Analysis

A. Average queue length

Fig. 2 describes the length of the queues in the method using DP [3]. The results show that AC1 (containing packets in partition B and C) is always in full state in contrary to AC2. This unbalance utilization causes unnecessary packet dropping at AC1. Fig. 3 shows the queue lengths for the method using non-adaptive FMO. It shows that the state of two queues always are unbalance.

The result in Fig. 3 shows that for the proposed method, because the arrival traffics depend on the overflow state of the queue, the fullness of AC1 queue (for high important packets) is reduced significantly. This is because when AC1 is near overflow state, the traffic of the packets to queue AC1 is relayed to AC2. Hence, the packet drop rate of AC1 queue from the proposed method is reduced. As a result, the average length of AC2 for the proposed method is increased. However, this increment is not significant therefore the drop rate of AC2 is not affected.

Fig. 5 describes the average length of queues compared among three methods when the "akiyo" sequence is used. From these measurements, we can see that the higher priority queue AC1 from the method using non-adaptive FMO and DP are always in full state. While AC2 is not utilized effectively. This unbalance causes unnecessary in packet dropping of AC1.

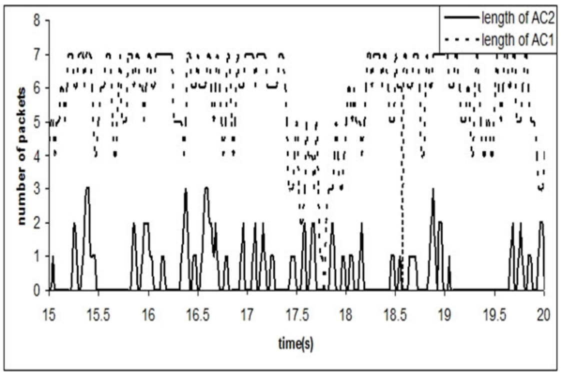

Fig.2: *Queue Length of the Method using Data Partition with "Coastguard" Sequence at 64 kbps*

B. Drop rate and Average PSNR

Table 4 shows the packet drop rate compared among three methods for "Coastguard" sequence at different bitrates. The results show that the drop rates at AC1 from non-adaptive FMO and DP methods are much higher than the drop rate at AC2. This is because, in DP method, AC2 has higher priority

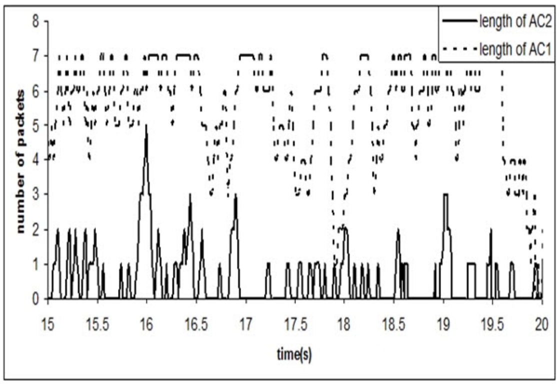

Fig.3: *Queue Length of the Method using FMO Without Adaptability with "Coastguard" Sequence at 64kbps*

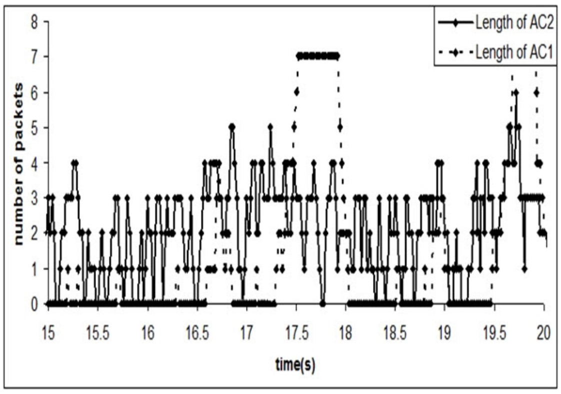

Fig.4: *Queue Length of the Proposed Method using Adaptive FMO with "Coastguard" Sequence at 64kbps*

while the number of packets coming to this queue is smaller to the number of packets coming to queue AC1. It results in the drop rates at AC2 are almost zero while the drop rates at AC1 are larger. In non-adaptive FMO method, the numbers of packets arriving two queues are equal. Nonetheless, there is no scheme to handle such case when the queues are overload. Thus, the drop rates at both queues from this method are higher than the other methods. In the proposed method, the arrival rates of packets are adapted with the state of the queues. Thus, the drop rates at both queues are almost the same and are lower than the drop rates of the other methods.

Table 5 shows the average PSNR of three methods. Because the decrease of drop rate at both queues, the average PSNR of the proposed method compared to other methods is the highest. However, the average PSNR tends to decrease when the bit rate is increased. Because the arrival rate of packets is increased while the serving rates at output of the queues are constant. Hence, the drop rates at queues are increased, as shown in Table 4.

5. CONCLUSIONS

In this work, a new method using cross-layer approach is proposed to reduce packet drop rate. Based on the feedback information from queues at MAC layer, encoder changes FMO map in such a way that the arrival rate of packets is changed according to the overflow rate of queues. In particular, video packets are classified into two types of priority and are mapped into two queues at MAC layer. If the overflow rate of a queue is high, the arrival rate of packets to that queue is reduced by changing FMO map and vice versa. The proposed method is compared to method using data partitioning and non-adaptive FMO methods. The results show that the proposed method is effective in reducing the packet drop rate and can improve the PSNR up to 5 dB.

6. ACKNOWLEDGEMENT

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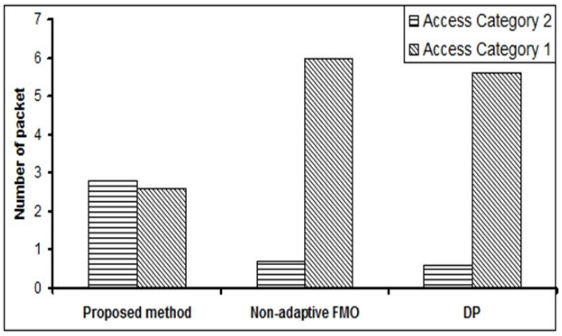

Fig.5: *Average Length of Queues for "Akiyo" Sequence at 128kbps*

Table 4: *Comparison of Drop Rate at Queues for "Coastguard" Sequence*

	64 kbps		128 kbps		384 kbps	
COASTGUARD	AC1	AC2	AC1	AC2	AC1	AC2
DP [3]	0.1	0	0.17	0.01	0.48	0.0
Non-adaptive FMO	0.22	0.02	0.28	0.03	0.45	0.07
Adaptive FMO	**0.03**	**0.01**	**0.03**	**0.01**	**0.3**	**0.07**
AKIYO						
DP [3]	0.24	0.0	0.2	0	0.3	0
Non-adaptive FMO	0.25	0.03	0.3	0.04	0.3	0.04
Adaptive FMO	**0.02**	**0.01**	**0.02**	**0**	**0.2**	**0.02**
FOREMAN						
DP [3]	0.2	0	0.2	0	0.3	0
Non-adaptive FMO	0.25	0.03	0.3	0.04	0.4	0.08
Adaptive FMO	**0.02**	**0.01**	**0.02**	**0**	**0.2**	**0.07**

Table 5: *Comparison of Average PSNR*

		64 kbps	128 kbps	384 kbps
Coastguard	DP [3]	25.15	22.25	21.2
	Non-adaptive FMO	25.95	24.86	22.19
	Adaptive FMO	**28.49**	**27.49**	**22.45**
Akiyo	DP [3]	38.52	38.20	36.20
	Non-adaptive FMO	37.38	35.20	33.32
	Adaptive FMO	**42.60**	**43.81**	**36.78**
Foreman	DP [3]	32.30	24.50	**29.16**
	Non-adaptive FMO	27.38	27.59	25.29
	Adaptive FMO	**40.33**	**29.56**	25.81

Tien Huu Vu received B. Eng. and M.S degrees in electrical engineering from Hanoi University of Technology, Hanoi, Vietnam in 2002 and 2004, respectively. He received Ph.D. degrees in electrical engineering from Chulalongkorn University, Thailand, in 2011. He is currently a researcher in Posts and Telecommunications Institute of Technology, Hanoi, Vietnam. His research interests are in the area of error resilient for video coding, cross-layer wireless multimedia.

Supavadee Aramvith received the B.S. (first class honors) degree in computer science from Mahidol University, Bangkok, Thailand, in 1993. She received the M.S. and Ph.D. degrees in electrical engineering from the University of Washington, Seattle, USA, in 1996 and 2001, respectively. She is currently an Assistant Professor at Department of Electrical Engineering, Chulalongkorn University, Bangkok, Thailand. She is IEEE Senior member and also serves as IEEE Thailand Section Secretary and Conference manager and Executive secretary of IEICE Bangkok area representative. Her research interests include video object segmentation, detection, and tracking, rate-control for video coding, joint source-channel coding for wireless video transmissions, and image/video retrieval techniques.