Retry Limit Based ULP for Scalable Video Transmission over IEEE 802.11e WLANs

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***Abstract*— We investigate the packet loss behavior in the IEEE 802.11e wireless local area networks (WLANs) under various retry limit settings. Considering scalable video traffic delivery over the IEEE 802.11e WLANs, our study shows the importance of adaptiveness in retry limit settings for the Unequal Loss Protection (ULP) design. Based on the study, we present a simple yet effective retry limit based ULP which adaptively adjusts the retry limit setting of the IEEE 802.11e medium access control protocol to maintain a strong loss protection for critical video traffic transmission. The simulation results illustrate significant advantages in the delivered video quality for our proposed design.**

***Index Terms*— Wireless LAN, multimedia communication, computer network performance.**

I. Introduction

THE IEEE 802.11e standard development [1] has enabled Quality of Service (QoS) support for the IEEE 802.11 Wireless Local Area Networks (WLANs). Aiming to better deliver multimedia traffic over the IEEE 802.11 WLANs, the IEEE 802.11e standard introduces Enhanced Distributed Channel Access (EDCA) where four Access Categories (ACs) are proposed to carry four different types of traffic, specifically, voice, video, best effort and background traffic. Each of these ACs implements a different backoff parameter set for packet transmission to achieve service differentiation.

This letter considers scalable video transmissions over the IEEE 802.11e WLANs. As a unique characteristic of scalable video codec (SVC), each generated video packet carries a relative priority index (RPI) indicating its importance to the final video quality. To enable the benefit of this scaling characteristics, an effective unequal loss protection (ULP) that offers different transmission handling for different RPI values of scalable video packets must be employed. Such ULP remains absent from the design of EDCA.

The design of a ULP often employs cross-layer design approach which makes use of differentiated services available in the networks for scalable video traffic delivery. In IEEE 802.11e WLANs, using different ACs to carry different RPI values of scalable video packets has been considered in [2]. Precisely, different RPI values of scalable video packets are mapped onto different ACs which mainly use the contention window (CW) and arbitrary interframe space (AIFS) to achieve prioritized transmissions. While this solution may achieve a certain level of ULP, it is recently detailed in [3] that such a mechanism that mainly uses different CW and AIFS settings for service differentiation suffers from many restrictions in transmission optimization. Exploration to other parameters for better service differentiation is necessary.

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In this letter, we propose use of adaptive retry limit settings to provide an effective ULP for scalable video traffic delivery. It is commonly known that video traffic transmission is sensitive to delay but tolerable to loss. The retry limit setting is one of the main parameters in EDCA governing the packet loss while others such as CW and AIFS merely affect the queueing delay. Controlling the retry limit setting adaptively helps scale the video traffic to match the network available bandwidth. This can be achieved by preemptively dropping low prioritized scalable video traffic locally when necessary via adjusting the retry limit setting. In Section II, we study impact of the retry limit setting on the packet loss, and present our retry limit based ULP. The PSNR performance advantage of our design is demonstrated in Section III.

II. Retry Limit Based Unequal Error Protection

Our proposed ULP scheme for scalable video traffic delivery over WLANs is based on the control of the retry limit setting in EDCA. In such a design, scalable video packets are divided into a number of groups based on their RPI values. To avoid implementation complexity, we recommend two groups, namely G_1 and G_2, where G_1 carries higher prioritized video packets than that of G_2. Each group uses a particular retry limit setting for its packet transmissions. Differentiating the retry limit settings ensures ULP among various groups.

We first study the packet loss behavior in EDCA. Based on our earlier performance study on EDCA in [4], the packet loss probability, $P(r)$ as a function of the retry limit, r, can be expressed as

$$P(r) = p^r \tag{1}$$

where p is the *collision probability* of a packet transmission. The quantity p is also commonly used as an indication of network load conditions since networks with higher loads lead to higher collision probabilities during packet transmission.

In Fig. 1, we plot $P(r)$ versus p for several r values. Consider a simple ULP scheme implementing fixed retry limit setting where traffic of G_1 (resp. G_2) uses the retry limit setting of $r_1 = 7$ (resp. $r_2 = 3$) for packet transmission. The packet loss probabilities for the two traffic streams of G_1 and G_2 under various network load conditions are plotted

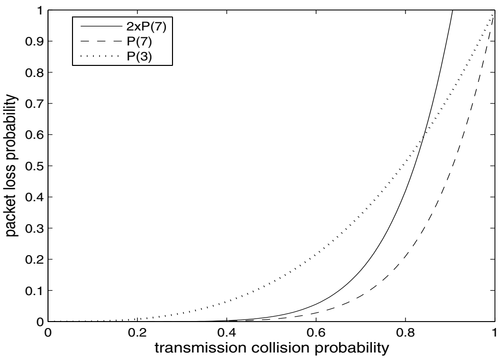

Fig. 1. Relationship between packet loss probability, retry limit, and transmission collision probability.

as $P(7)$ and $P(3)$ respectively in Fig. 1. A comparison between $P(7)$ and $P(3)$ shows that $P(7) \leq P(3)$ for any p. While this indicates ULP for the two traffic streams, the ULP differentiation between the two traffic streams is, however, uneven across p. Moreover, we see that under a heavy load condition where the collision probability is high, their levels of loss protection become less differentiated.

To overcome the described uneven property of retry limit based ULP, a practical solution is to vary the retry limit setting based on the network load condition. The solid line presented in Fig. 1 shows an example of an even ULP that satisfies

$$P_2(r_2) = \max(\alpha P_1(r_1), 1) \tag{2}$$

where $P_i(r_i)$ is the packet loss probability for group G_i implementing retry limit of r_i, and α is a constant specifying the differentiation of loss protection between the two groups. To maximize protection for critical salable video traffic transmission, using the typical retry limit setting [2], our design chooses $r_1 = 7$. Consequently, to meet the condition in (2), r_2 must vary according to p.

In our design, we consider $\alpha = 2$ which ensures that traffic of G_1 experiences only half the packet loss probability compared to that of the traffic of G_2[1]. Since r_2 must be a positive integer, our objective is to compute r_2 such that it satisfies (2) given a particular p with $r_1 = 7$ and $\alpha = 2$. This involves in finding the solution for the following problem

$$\begin{cases} \text{Maximize} & r_2 \\ \text{subject to} & p^{r_2} \leq \max(\alpha p^{r_1}, 1) \\ & r_2 \in \mathbb{Z}^+, 0 < p < 1 \end{cases} \tag{3}$$

where $\mathbb{Z}^+ = \{0, 1, ...\}$. Given $r_1 = 7$ and $\alpha = 2$, with default values of $r_2 = 7$ (resp. $r_2 = 0$) for $p = 0$ (resp. $p = 1$), solving for r_2 in (3) yields

$$r_2 = \begin{cases} 7, & 0 \leq p \leq 2^{-1} \\ x, & 2^{-\frac{1}{7-x}} < p \leq 2^{-\frac{1}{8-x}}, x = 1, 2, ..., 6 \\ 0, & 2^{-\frac{1}{7}} < p \leq 1. \end{cases} \tag{4}$$

The very last result forms the basis of our design. The retry limit r_2 is adjusted based on the collision probability, p, of the packet transmission of G_1's traffic. Given p, based on (4), we determine the retry limit value for G_2's traffic that meets the condition of (2).

The value p can be easily obtained by monitoring the statistics of the past packet transmission experiences. According to the definition, p is the ratio of the total number of unsuccessful packet transmission to the total number of processed packets. For each event of either successful packet transmission or packet loss, the value p is updated, leading to the appropriate adjustment of r_2. The adjustment directly follows (4). To ensure stability, we apply a simple smoothing strategy that

$$p_u = \beta p_o + (1 - \beta) p_n \tag{5}$$

where p_u, p_o, and p_n are the updated value, old value, and new value for p respectively. In our design, we set $\beta = 0.2$ which ensures a quick reaction to the network load condition.

III. PSNR Performance Evaluation

We have developed a simple scalable video coding scheme [5] based on the integration of motion-compensated temporal filtering (MCTF) and JPEG2000. MCTF is used for temporal decomposition, and JPEG2000 is used to encode all the temporal subbands (T-bands) generated by MCTF. The final video bitstream consists of the motion vector (MV) information generated by MCTF and the JPEG2000 bitstream for each T-band. For the packetized video transmission, T-band streams and MV data are further assembled into individual network packets. The size of a packet is limited by a predefined maximum packet size (500 bytes). In addition, we use the loss impact of a packet to calculate its RPI. The loss impact of a packet is defined as the corresponding distortion increase in reconstructed video in the case that the packet is lost while all other packets are correctly received. We further map the loss impact values into integer RPI values (i.e. 0-63 with 8 bits representation), and also uniformly distribute the integer RPI values into different packets.

We further implement our ULP scheme in ns2 simulator for performance evaluation. In Fig. 2, we illustrate PSNR performance comparison of scalable video delivery over EDCA with (i) no ULP, (ii) fixed retry limit based ULP, and (iii) adaptive retry limit based ULP. Details of our simulation setup are described as follows. We consider a single hop WLAN where all senders and receivers are placed in the same Basic Service Set (BSS) which operates 11 Mbps of the channel data rate. All generated video traffic is carried by AC2 in EDCA as recommended by the IEEE 802.11e standard. The experiment begins with one sender. For every four seconds of operation, an additional sender is activated in the WLAN, until the number of senders reaches 15. Each sender repeatedly transmits the first 256 frames of the "Table-tennis" CIF sequence with 800 kbps source rate.

Since EDCA is unaware of the scaling property of SVC, the results presented in Fig. 2 indicate a low support for the number of senders. A simple calculation shows that EDCA supports only 5 senders before a congestion occurs. This is equivalent to 4 Mbps of goodput. A closer investigation by evaluating the packet loss rates of G_1's and G_2's traffic presented in Fig. 3 reveals that uniform packet loss appears

[1]Under very heavy network load conditions, inevitability, traffic of G_2 will experience 100% loss. When this upper bound reaches, the packet loss probability of G_1's traffic will purely depend on the network congestion, and the target that $\alpha = 2$ cannot be maintained.

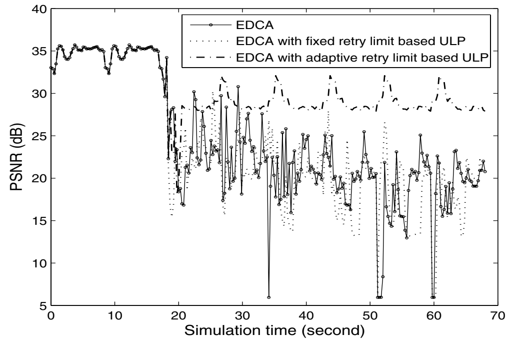

Fig. 2. PSNR performance of scalable video traffic delivery over EDCA and EDCA with various ULP schemes.

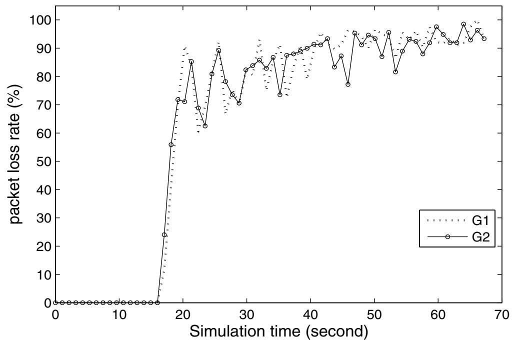

Fig. 3. Packet loss rate of scalable video traffic delivery over EDCA.

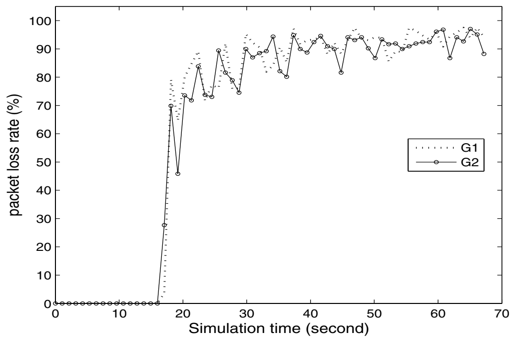

Fig. 4. Packet loss rate of scalable video traffic delivery over EDCA with fixed retry limit based ULP.

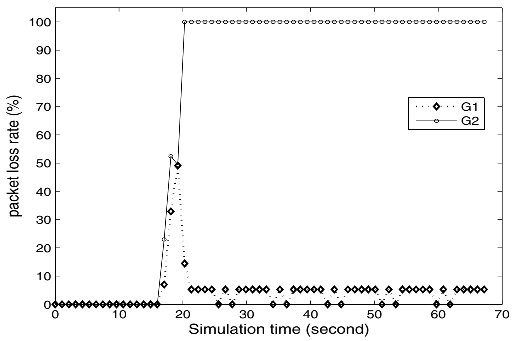

Fig. 5. Packet loss rate of scalable video traffic delivery over EDCA with adaptive retry limit based ULP.

among video packets of the two groups. This shows that scalable video delivery over EDCA is ineffective without additional handling.

Our second experiment uses fixed retry limit based ULP on EDCA whereby retry limit settings of $r_1 = 7$ and $r_2 = 3$ apply to the transmission of G_1's and G_2's transmissions respectively. Interestingly, as reported in Fig. 2, this setup does not have perceptible PSNR advantage over that of EDCA without ULP. Investigation on packet loss rates plotted in Fig. 4 also shows similar packet loss behavior with that reported in Fig. 3. This is because when congestion occurs, p becomes high which causes less differentiation in the loss protection between the two groups as illustrated in Fig. 1. This makes the fixed retry limit based ULP ineffective.

In the third experiment, we implement our ULP scheme on EDCA. G_1's traffic accounts for one third of the total traffic in terms of bytes[2]. As can be seen in Fig. 2, a clear PSNR performance benefit is reported. The packet loss rates of the two groups are depicted in Fig. 5 showing the effectiveness of ULP. The sacrifice of G_2's traffic allows the network to continue to support more senders. A spike in the G_1's packet loss rate indicates a network congestion event and the ability for our scheme to react quickly to the congestion. Since $r_2 \in \mathbb{Z}^+$, for a particular p that pushes r_2 to a value below 1, r_2 will be set to 0 according to (4), leading to the dropping of all G_1's packets. Consequently, the packet loss rate of G_2 becomes 100%, which immediately eases the packet loss rate of G_1 creating a spike in G_1's packet loss rate shown in Fig. 5.

IV. Conclusion

This letter illustrated the packet loss behavior of EDCA under various retry limit settings, and suggested an adaptive retry limit based ULP scheme to improve the effectiveness of ULP for scalable video traffic transmissions over the IEEE 802.11e WLANs. The simulation results showed significant PSNR performance advantages of our design compared to the existing method.

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[2]This selection is based on the observation that the full protection of G_1's traffic gives just above 28dB of PSNR which is our predefined target for QoS requirement.