Improving QoS of Video Transmitted Over 802.11 WLANs Using Frame Aggregation

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Abstract: 802.11 Wireless local area networks (WLANs) are widely used at home and enterprise as a connection to the Internet. In order to meet the quality service (QoS) demands for the increasing number of multimedia applications on these home and enterprise networks new features are included in the 802.11n draft. One of these features is frame aggregation at the medium access control (MAC) layer which adds the ability to the base station to serve two or more users in one frame simultaneously. In this paper we investigate how the quality of H.264 video sequences are affected when we aggregate a group of packets for one or multiple users. We show that the frame aggregation improves the video quality and the packet delay.

1. Introduction

IEEE 802.11 wireless local area networks (WLANs) [1] have been widely deployed for Internet access. The legacy 802.11a/g can support up to 54Mb/s data rate. In order to meet the increased demand of multimedia services such as streaming video and IP telephony, IEEE 802.11n was proposed as an amendment to the previous 802.11 standard to improve network throughput, aiming to provide data transmission rates of up to 600Mb/s. The version 9.0 draft specification was approved in March 2009 and it contains substantial enhancements for both the physical (PHY) and medium access control (MAC) layers for high throughput, efficiency and robustness [2]. The PHY layer, based on the Multiple Input Multiple Output - Orthogonal Frequency Division Multiplexing (MIMO-OFDM), can use multiplexing to transmit two or more data streams simultaneously. The increase in 802.11n physical layer rates and Internet connection speeds has led to many multimedia applications with different quality of service (QoS) requirements. Many video applications are now available such as YouTube, video conferencing and internet protocol television (IPTV) in standard and high definition. In order to meet the QoS requirements for multimedia applications the efficiency of the MAC layer has been improved by introducing two main mechanisms: (1) frame aggregation and (2) bidirectional transmission. Frame aggregation can improve MAC layer efficiency by reducing the transmission time for preamble and frame headers, and the random backoff periods for successive frame transmissions. This is particularly applicable to voice traffic and continuous traffic such as video streaming or large file transfer [3]. The aim of this paper is to investigate video transmission over 802.11 in order to show the benefit that frame aggregation can provide in terms of improving the video quality.

2. Frame aggregation

In IEEE 802.11n several new MAC features have been introduced to improve throughput efficiency. One approach is frame aggregation, the idea of which is to aggregate multiple MAC/PHY frames into a single frame for transmission. Aggregation mechanisms can be classified from many aspects: uplink versus downlink, PHY-level versus MAC level, single-destination versus multi-destination, etc [4]. At PHY level a train of n PHY frames are sent one by one with no interframe space (IFS). These frames can be transmitted to one or multiple users, and each station acknowledges the received frame in the same order after short IFS (SIFS). The PHY overhead can be further reduced by MAC level frame aggregations, in which n MAC frames for different destinations can be aggregated into one PHY frame. After the (shared) PHY preamble and header, stations receive the scheduling information. Based on that they can determine the time to receive their frames if there are any. Using downlink

multi-destination aggregation, the access point (AP) only needs to contend once to transmit an aggregated frame to multiple users.
In general, frame aggregation can increase the efficiency. However, a large aggregation frame will cause each station to wait for a longer time before its next chance for channel access and also may cause unfairness among stations. Furthermore, under error-prone channels, a large aggregation frame wastes a longer period of channel time and leads to very low efficiency. Therefore, there is a trade-off between throughput and delay for frame aggregation, and channel conditions should be taken into account when designing frame aggregation schemes [4].

3. System Model

In our system model we consider the downlink of an 802.11 system with one AP and five stations. In order to evaluate the QoS of delivered video over the 802.11 with frame aggregation we performed simulations using the Evalvid version of NS-2 simulator [5] modified to allow frame aggregation. The frame aggregation was done at the MAC layer by removing the SIFS during TXOP. This represents an efficient form of aggregation which is inspired by the 802.11n aggregation techniques but it is not the same. Three Video Quality Expert Group (VQEG) sequences were selected which have a range of characteristics. These sequences are 'Fries', 'Mobile & Calendar' and 'Rugby' and they were encoded at bite rate of 4 Mb/s as described in [6]. The enhanced distributed channel access (EDCA) parameters were set to default setting and the PHY layer data rate was set to 24Mb/s. For running the tests a similar procedure was used as in [6]. For each test the simulator was setup to transmit n video streams from the AP to the n receiving stations. An error file is generated for each video stream that shows which packets have been lost. A delay constraint of 2 second has been used. This is acceptable for linear TV broadcasting. The received video sequences were obtained by applying the error file to the original transmitted sequences. Each received video sequence is then decoded. The videos in each test are not synchronized so repeating a test can give different results each time. Therefore 3 runs of each test are performed. In each test every video has a start time that is randomly selected over the first 4 seconds of the test.
To assess the quality of video prepared with different aggregated frame sizes, the video quality estimation tool defined in the J.144 standard, Annex A was used [7]. This is a full-reference tool meaning that each received video sequence is compared to the original to calculate a predicted mean opinion score (pMOS) for the received video. The pMOS uses a scale ranging from 5 (excellent) to 1 (bad).

4. Results

In our experiment the simulator was setup to send 5 video sequences in the download direction from the AP to 5 stations. The average packet size was approximately 1250B and we start our experiment with no aggregation. We then increase the maximum frame size in steps of 2KB until the frame size reach 10KB. The MAC layer buffer size was set to 600 and the video sequences were sent through the video queue in the EDCA. Figure 1 shows the average packet loss rate (PLR). As it can be seen from the figure that as size of the frame increases the PLR decreases until there are no losses when the number of packets per frame equal to 8KB. Figure 2 shows the average delay of the video sequences and, as the figure shows, the frame aggregation can improve the delay from 0.33 seconds when there is no aggregation to 0.16 seconds with a 10KB frame. The average video quality results for the five video sequences, which included a mixture of the three different types of video content ('Fries', 'Mobile & Calendar' and 'Rugby'), is shown in figure 3. The results clearly show the improvement in the video quality starts from the frame size of 2KB and the trend is linear until the frame size of 8KB at which point the videos are all received with no noticeable impairments caused by packet losses. Figure 4 compares the same frame from the 4Mb/s 'Fries' sequence when there is no aggregation and in the case of an 8KB frame size. It is clear to see that when there is no aggregation noticeable impairments appear while the 8KB frame shows no significant impairments.

5. Conclusions

In this paper we have investigated the benefits provided by MAC layer aggregation in 802.11 WLANs by downloading multiple video streams through an access point. The video quality results demonstrate that there is a significant improvement in the video quality as the maximum frame size increases up to certain value. Also the benefit of introducing frame aggregation has been shown in terms of PLR and packet delay. Designing frame aggregation schemes that optimize the frame size when the channel conditions are taken into consideration is a subject for further studies by the authors.

6. Acknowledgment

We would like to thank British Telecommunications PLC (BT) for providing the H.264 encoder/decoder and their J.144 video quality estimation tool.

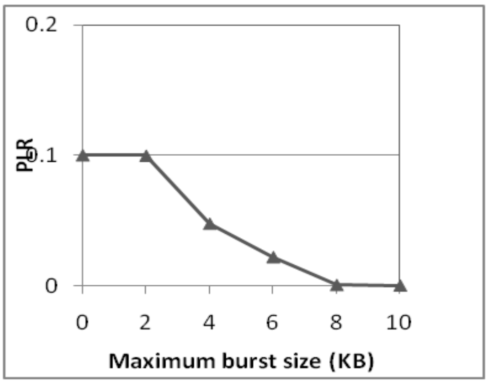

Fig. 1: PLR for different burst sizes

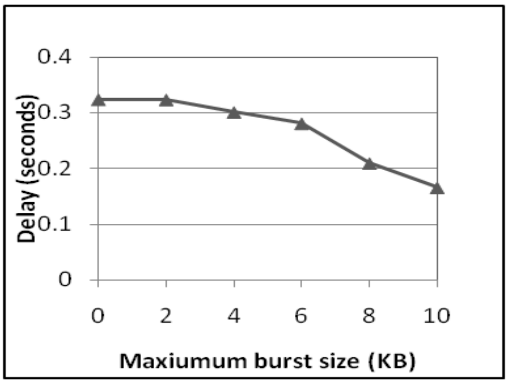

Fig. 2: Time delay for different burst sizes

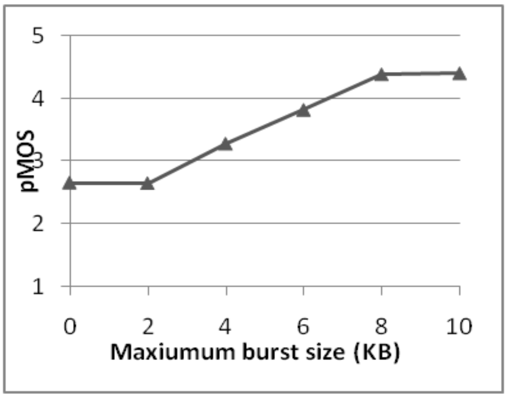

Fig. 3: Video quality for different burst sizes

Fig. 4a: Fries video sequence with no aggregation

Fig. 4b: Fries video sequence with 8KB aggregation

7. References

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