Congestion Resiliency for Data-Partitioned H.264/AVC Video Streaming Over IEEE 802.11e Wireless Networks

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ABSTRACT

This paper examines the impact of data partitioning form on wireless network access control and proposes a selective dropping scheme based on dropping the partition carrying intra-coded macroblocks. Data partitioning is an error resiliency technique that allows unequal error protection for transmission over ‘lossy’ channels. Including a per-picture, cyclic intra-refresh macroblock line guards against temporal error propagation. The authors show that when congestion occurs, it is possible to gain up to 2 dB in video quality over assigning a stream to a single IEEE 802.11e access category. The scheme is consistently advantageous in indoor and outdoor wireless scenarios over other ways of assigning the partitioned data packets to different access categories. This counter-intuitive scheme for access control purposes reverses the priority usually given to partition-B data packets over that of partition-C.

Keywords: Congestion Control, Data Partitioning, IEEE 802.11e, H.264/AVC, Intra-Refresh

INTRODUCTION

Advances in source coding continue to encourage the growth of video streaming services. Thus, as the H.264/AVC (Advanced Video Coding) encoder can achieve up to 50% increase in compression ratio (Wiegand et al., 2003) compared to an MPEG-2 encoder, it is particularly appropriate for bandwidth-limited WLANs, which is why H.264/AVC has already been adopted for 3GPP’s Multimedia Broadcast Multicast Service (Afzal et al., 2006).

As part of its network-friendly approach (Liu et al., 2005), H.264/AVC introduced a set of error resilience tools (Stockhammer et al., 2003) to improve robustness to packet loss in transmission over error-prone networks.
Among those tools were data partitioning and distributed intra-refresh macroblocks (MBs). Data partitioning is a way of separating out data from a compressed bit-stream according to its importance in reconstructing a video stream. H.264/AVC Network Abstraction Layer units (NALUs) are per-slice containers for packet transmission. Data partitioning splits video content into three partitions: Data Partition A (DP-A), B (DP-B) and C (DP-C) (Wenger, 2003) of decreasing importance for decoder reconstruction purposes. This partitioning scheme allows the more important data to be given preferential treatment.

To protect the stream against temporal error propagation, it is becoming common to distribute intra-refresh MBs across the video pictures (Schreier & Rothermel, 2006) rather than provide periodic intra-coded frames (I-frames), as periodic refresh I-frames cause a sudden increase in the data rate. As a consequence, DP-B will become enlarged as it is this partition that contains the major portion of data from intra coded MBs. With or without an enlarged DP-B, protecting DP-A, -B, and -C in an unequal error protection scheme seems sensible. For example, in Barma et al. (2005) a combination of hierarchical modulation and forward error protection was applied.

In this paper, we show that when cyclic intra-refresh lines are applied then DP-B packets become a better candidate to drop at network access time than DP-C packets. Thus, in our scheme, DP-C packets are given greater protection than DP-B packets. To illustrate the proposed dropping scheme for data-partitioned, cyclic intra-refresh provisioned video streaming, we applied the IEEE 802.11e (IEEE, 2005) for priority-controlled access to a WLAN.

In Ksentini et al. (2006), the authors proposed a cross-layer architecture to improve H.264/AVC video delivery over IEEE 802.11e. Each partition of the compressed bit-stream was mapped to a different IEEE 802.11e access category (AC), allowing the prioritization of packets bearing the more important DP-A and DP-B data. However, their scheme was aimed at transmission issues, especially reduction of end-to-end delay and minimization of packet loss rate, rather than congestion during access to the network. Furthermore, unlike our scheme DP-B data is favored for protection over protection of DP-C.

In Bernardini et al. (2007), another protection scheme was compared to wireless transmission with multiple description coding (MDC). If DP-A data is well protected then partitioned data transmission results in over 10 dB improvement in quality over an MDC scheme but otherwise MDC is preferable. However, again that paper’s primary concern was transmission issues. Similarly, in Haywood et al. (2009) measurements indicated that using a single IEEE 802.11e AC was preferable over splitting the H.264 data-partitioned video packets across the IEEE 802.11e A/Cs. However, in their experiments DP-B and DP-C packets were assigned to the same IEEE 802.11e AC. Periodic Instantaneous Decoding Refresh (IDR)-pictures were used and given the same high priority as DP-A packets.

In Cranley et al. (2007), the TXOPLimit parameter that in part governs the relative access to other A/Cs was varied for the IEEE 802.11e designated video AC. It was found that the TXOP parameter could be dynamically varied when video packet bursts arrived. However, if video was given too much privilege then this could disadvantage voice traffic. Varying that parameter also requires modification of the configuration at all wireless stations. A preliminary conference version of this current paper (Ali et al., 2010) has been expanded to improve the presentation of data-partitioning and intra-refresh MBs in the methodology section. Extensive tests also have verified the operation of the proposed scheme for a range of settings and channel propagation models.

This paper’s contribution is a congestion-resilient scheme for data-partitioned video streams protected by intra-refresh MB lines. (An intra-refresh MB line is a row of intra-refresh MBs.) In these circumstances, DP-B is generally larger than would otherwise be the case. However, the data in DP-B that potentially helps to mitigate channel errors, intra-coded
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