Chapter 12
Intra-Refresh and Data-Partitioning for Video Streaming over IEEE 802.11e

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ABSTRACT

Intra-refresh macroblocks and data partitioning are two error-resilience tools aimed at video streaming over wireless networks. Intra-refresh macroblocks avoids the repetitive delays associated with periodic intra-coded frames, while also arresting temporal error propagation. Data-partitioning divides a compressed data stream according to the data importance, allowing packet prioritization schemes to be designed. This chapter reviews these and other error-resilience tools from the H.264 codec. As an illustration of the use of these tools, the chapter demonstrates a wireless access scheme that selectively drops packets that carry intra-refresh macroblocks. This counter-intuitive scheme actually results in better video quality than if packets containing transform coefficients were to be selectively dropped. Dropping only occurs when in the presence of wireless network congestion, as at other times the intra-coded macroblocks protect the video against random bit errors. Any packet dropping takes place under IEEE 802.11e, which is a quality-of-service addition to the IEEE 802.11 standard for wireless LANs. The chapter shows that, by this scheme, 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 shown to be consistently advantageous in indoor and outdoor wireless scenarios over other ways of assigning the partitioned data packets to different access categories. The chapter also contains a review of other research ideas using intra-refresh macroblocks and data-partitioning, as well as a look at the research outlook, now that the High Efficiency Video Codec (HEVC) has been released.

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INTRODUCTION

Video compression depends for most of its coding gain on temporal predictive coding, involving motion estimation followed by motion compensation. Consequently, errors in a distorted frame will propagate to the following frames, as error concealment (backward error correction) at the decoder may not repair some distorted areas. As video compression efficiency improves with successive codec standards, error sensitivity increases, which in turn results in quality degradation when transmitting over wireless channels. Thus, ways are sought to arrest spatio-temporal error propagation and intra-refresh techniques provided by the video codec itself are a way to do so (as discussed in this Chapter), along with other forms of error resilience (Stockhammer & Zia, 2007) such as data partitioning (Stockhammer & Bystrom, 2004) (as also discussed in this Chapter). Data-partitioning divides a compressed bitstream into prioritized data. This allows packetisation strategies and/or unequal error protection to improve the reconstruction quality of the video. This Chapter examines intra-refresh techniques and data-partitioning by means of a detailed case study in the context of IEEE 802.11e wireless LAN (Grilo & Nunes, 2002) quality-of-service provision.

Intra-Refresh Methods

To protect the stream against temporal error propagation, it is becoming common to distribute intra-refresh macroblocks (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. Macroblocks are the smallest predictive unit within a conventional video codec. As intra-coding relies on spatial predictive referencing and not on motion prediction, its coding efficiency is reduced resulting in the extra data mentioned. However, if a complete video frame is intra-coded (an I-frame), i.e. is coded with no reference to other frames then spatio-temporal error propagation is halted, as the I-frame breaks all dependencies arising from previously coded frames. Nevertheless, the reduced compression efficiency of intra-coded video frames normally makes them unsuitable for continuous use. Only for real-time super high-definition video streaming, when there is no time to complete the prediction calculations, is a continuous stream of intra-coded frames recommended. For normal spatial resolutions, it is preferable to mainly employ the compression-efficient inter-coded (predictively-coded) frames with some periodic intra-coded frames or intra-refresh MBs to limit any potential error propagation that might occur.

When periodic I-frames are transmitted, the increased number of I-frame packets leads to periodic delays (Schreier et al., 2006) due to buffering and transmission overheads. In order to prevent error propagation in the H.264/Advanced Video Codec (AVC) (Wiegand et al., 2003) some macroblocks (MBs) in each pre-dominantly inter-coded frame may be intra refreshed. The ability to intra-code some MBs was originally provided in H.264/AVC to allow the encoder to naturally use intra-coding for places in the frame that could not be temporally predicted from previous frames. For example, if a new object appears in view of the camera, it cannot be inter-coded. However, intra-coded MBs can also be exploited to improve the reconstruction of a frame even when no naturally encoded intra-coded MBs are needed. Wang et al. (2005) and Nunes et al. (2009) developed adaptive methods of selection of which MBs to intra-code for the purpose of intra-refresh. Alternatively, a frame sequence can be automatically refreshed, avoiding the complexity (and delay) from customized selection of MBs for intra-coding. Automatic MB refresh may be accomplished in a cyclic manner such that after a number of frames have been displayed (Schreier & Rothermel, 2006) the whole frame is updated, as occurs in this Chapter's example. Suppose one row or line of MBs within a video frame is intra-refreshed in a