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H.264 Mapping Strategies for Robust Video Streaming over IEEE 802.11e WLAN

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Abstract— **In this paper we propose several mapping schemes for streaming video generated by state-of-the-art H.264 codec over IEEE 802.11e enabled wireless LANs. The schemes take advantage of both 802.11e's QoS mechanism and some novel features of the H.264 codec, so as to protect the most important information in terms of visual quality and reduce distortion under network congestion. The proposed methods are evaluated by means of the H.264 reference software codec, network simulation, and objective video quality measurements. Results show that the proposed methods achieve a robust and error resilient H.264 video streaming over wireless LANs than traditional best-effort streaming.**

I. INTRODUCTION

Video streaming is one of the most promising applications of the next-generation wireless LANs. H.264/AVC (Advanced Video Coding) [1] offers several powerful features that make it especially attractive for streaming applications. These features can be complemented by network quality of service (QoS) techniques, so that the combined effect of application- and network-level mechanisms limits the visual distortion brought about by the inherent jitter, loss, and bandwidth dynamics of wireless networks.

A. QoS-Aware Video Streaming and Mapping

The general idea behind this concept is that the performance may be improved if applications are "aware"—i.e., *make use*— of the service differentiation provided by the IEEE 802.11e QoS architecture. Thus, a QoS-aware video application marks the outgoing packets with some priority, taking into account the type of video information they carry, in order for them to take advantage of the service differentiation offered by the network.

In this paper, we propose and evaluate several mapping schemes to adapt the QoS-aware video streaming concept to the state-of-the-art H.264 video codec. The service differentiation approach of IEEE 802.11e can best leverage the network adaptation and error resilience techniques of H.264.

B. Related Work

The idea of applying differentiated forwarding to different segments of coded video streams is not new. Such approaches can usually be classified in three categories. The first category consists of a straightforward mapping between frame types in the coded video stream and discard priorities. In the second category, mapping is done so that each layer is assigned to a specific IEEE 802.11e access category (AC) [2][3]. Finally in the third classification mapping is applied based on a distortion estimation [4].

C. Outline of the Paper

The remainder of this paper is organized as follows. Section II presents an overview of the main characteristics of both the H.264 video codec and IEEE 802.11e QoS mechanism. Our proposals of mapping strategies for H.264 video using IEEE 802.11e service differentiation are introduced in Section III. Section IV describes the performance evaluation carried out to study some of our proposals, followed by the conclusions and perspectives in Section V.

II. H.264 VIDEO CODING STANDARD AND IEEE 802.11E QOS MECHANISM

A. Overview of the H.264 Video Coding Standard

H.264 [1] offers an improved compression efficiency [5], network "friendliness", i.e., a better adaptation to the underlying network, and error resiliency. Network friendliness is introduced by means of separating the coded information into two layers: the Video Coding Layer (VCL) and the *Network Adaptation Layer* (NAL) [6]. Regarding error robustness, H.264 includes several advanced features that are closely related to the concept of NAL [7]. The key syntax elements of the H.264 structure are flexible-sized slices. H.264 also includes the concepts of Flexible Macroblock Ordering (FMO) and Data Partitioning (DP). Section III discusses these concepts in more detail.

B. Overview of the IEEE 802.11e QoS Mechanism

IEEE 802.11e uses enhanced distributed channel access (EDCA), a contention based channel access function, to support multimedia applications such as voice and video over the wireless medium [8][9][10]. EDCA is based on differentiating priorities at which traffic is to be delivered, and it works with four ACs (access categories), where each AC achieves differentiated channel access, with AC3 having the highest priority while AC0 has the lowest priority [8].

III. MAPPING STRATEGIES FOR H.264 VIDEO USING IEEE 802.11E SERVICE DIFFERENTIATION

Following an analysis of the existing proposals described in Section I-B, we decided to adopt an approach of straightforward mapping between coarse syntax elements (like frames or

TABLE I

MAIN MAPPING STRATEGIES FOR H.264 VIDEO

Codec Feature	Mapping Strategy
Slices	I slices → AC3 P slices → AC2 B slices → AC1
FMO	Slice group 1 (High Priority) → AC3 Slice group 2 (Low Priority) → AC2
DP	A-type partitions → AC3 B-type partitions → AC2 C-type partitions → AC1

slices) to IEEE 802.11e ACs. Next, we describe our proposals for performing such a mapping, assuming an IEEE 802.11e based wireless network scenario with ACs reserved for video streaming.

A. Mapping Strategy based on Slices

An H.264–coded video sequence is composed of Intra (I), Predicted (P), and Bi–directional predicted (B) slices. In addition, B frames can also be used as a reference for other B frames. Moreover, H.264 does not include a picture or frame syntax element; it's the slice header that carries the information on the type (I, P, or B) of frame it belongs to. Hence a mapping strategy can be based on slices. It consists of assigning highest priority to I slices, medium priority to P slices, and lowest priority to B slices. Thus I slices will be mapped to AC3, P slices to AC2, and B slices to AC1, as presented in Table I.

B. Mapping Strategy based on Flexible Macroblock Ordering (FMO)

Several mapping strategies based on FMO seem worthwhile exploring. To begin with, the different groups of slices may be assigned to the different ACs. Moreover, the way in which groups of slices are created might take into account explicit error concealment for hiding visual impairments. Thus for FMO resulting in two slice groups, the highest priority slice group will be mapped to AC3, while the lower priority slice group will be mapped to AC2, as shown in Table I.

C. Mapping Strategy based on Data Partitioning (DP)

DP is an error resilience feature that relies on the hierarchical separation of coded video data in different elements at a very low level. DP is also a natural candidate for IEEE 802.11e AC mapping. It offers a very granular semantic separation of the coded video, and this separation is done in three hierarchical levels, which can be directly mapped to the three ACs, as depicted in Table I.

IV. PERFORMANCE EVALUATION

An evaluation procedure is carried out using two of our proposed mapping strategies, namely slice–based and FMO–based, with the goal of verifying whether the syntax element–based QoS–aware H.264 streaming over IEEE 802.11e enabled WLAN yields a better visual quality than the regular best–effort WLAN streaming under different levels of congestion and channel degradation.

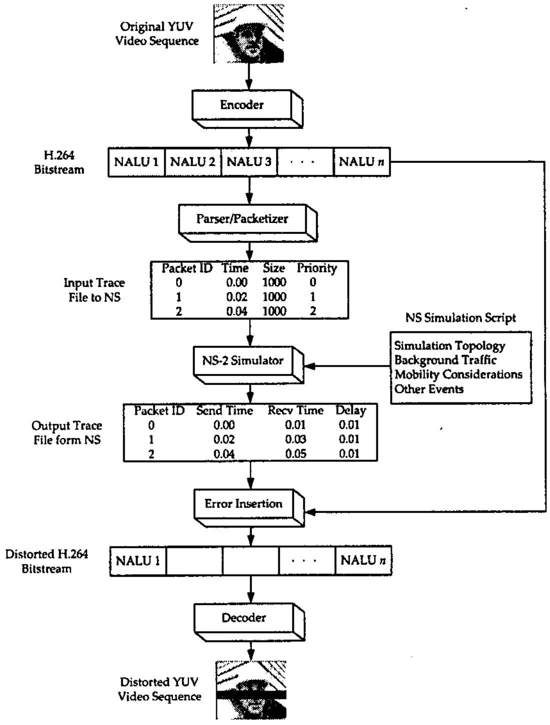

Fig. 1. H.264 evaluation process

TABLE II

AVERAGE PSNR OF RECEIVED FOREMAN VIDEO SEQUENCE

Method	Datarate	Average PSNR (dB)	
		Slice–based	FMO–based
Best–effort	High	31.59	32.04
	Medium	32.78	33.26
	Low	34.13	34.69
	Average	32.83	33.33
Proposed	High	35.87	36.17
	Medium	36.79	37.11
	Low	38.06	38.35
	Average	36.91	37.21

A. Overview of the Simulation Methodology

The evaluation is done following the simulation–based process depicted in Fig. 1. The point of departure is a raw YUV digital video sequence. We select a video sequence called 'Foreman' in CIF format (352 × 288 pixels). The sequence is encoded into an H.264 bitstream at 15 fps with a target rate of 451 kbit/s. The second block is a parser/packetizer that analyzes the bitstream, identifies the syntax elements (NAL units), applies a particular mapping strategy and generates a trace file for the network simulator. The parser embodies our proposals for QoS–aware semantic mapping of H.264 video. The third block is the simulation, which is performed by the ns–2 network simulator [11]. The result of the simulation is an output trace file which is used by the error insertion block to detect lost packets and erase

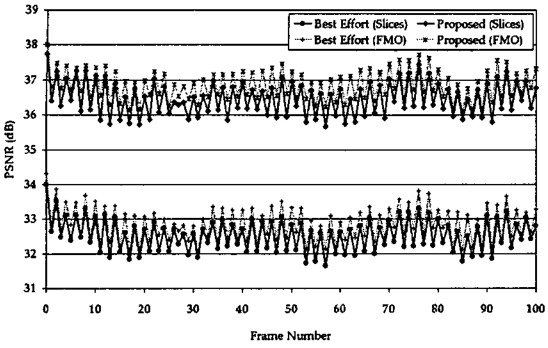

Fig. 2. PSNR values for the received Foreman sequence

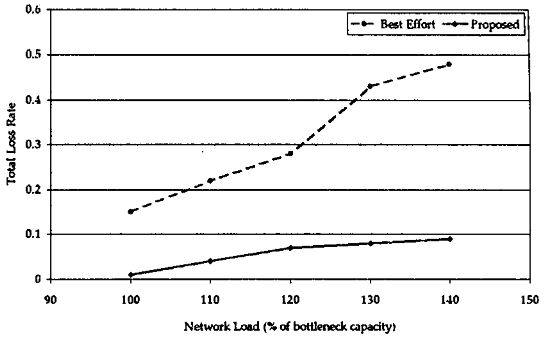

Fig. 4. Total loss rate

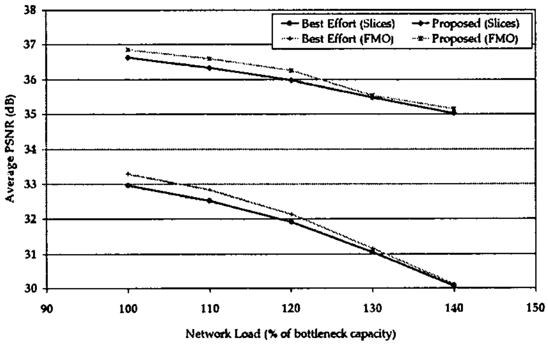

Fig. 3. Average PSNR

them from the original H.264 bitstream. Then, the distorted bitstream is decoded to a raw video file for visualization and quality evaluation.

This process requires the integration of several components, of which we developed the parser, the ns–2 extensions and the error insertion module. The reference code[12] for H.264 codec is modified to make it error resilient enough in order to enable it to decode the resulting distorted bitstream. This is one of the key accomplishments of this work.

B. Results

Table II shows the receiver–side video quality in terms of average PSNR of the 'Foreman (CIF)' video sequence in deteriorating channel conditions for both the proposed and the best–effort streaming scenarios. High values of average PSNR for the proposed streaming schemes, clearly demonstrate the effectiveness of our streaming solutions. Fig. 2 shows the plots of PSNR values for the proposed as well as the best–effort streaming scenarios, while the plots in Fig. 3 and 4 show the results of quality evaluation for all simulation scenarios. These plots clearly show that the proposed streaming schemes have outperformed the best–effort ones, with FMO–based mapping strategy giving slightly better performance than the slice–based mapping strategy.

V. CONCLUSIONS AND FUTURE WORK

In this paper we have proposed and evaluated several methods of QoS–aware streaming for the H.264 video codec over IEEE 802.11e enabled wireless LAN. According to evaluation results, the proposed methods help in reducing visual impairments in deteriorating channel conditions when compared to a best–effort network service.

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