A LOW-COMPLEXITY PACKET CLASSIFICATION ALGORITHM FOR MULTIPLE DESCRIPTION VIDEO STREAMING OVER IEEE802.11E NETWORKS

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ABSTRACT
The robust transmission of video sequences over wireless LANs presents several challenging problems concerning the presence of packet losses, delays, and bandwidth limitations. Their effect on the visual quality of the sequence reconstructed by the end user can be mitigated by adopting a wireless architecture that is able to support different levels of Quality-of-Service (QoS), like the IEEE 802.11e standard, and by compressing the video sequence to be transmitted using a robust source coder, like a Multiple Description Coding (MDC) scheme. This paper presents a MDC-based video streaming architecture that tries to adaptively optimize the performance of both solutions by assigning the RTP video packets produced by the MDC encoder to the different QoS classes of IEEE 802.11e. Simulation results show that the performance is significantly improved with respect to a non-adaptive solution.

Index Terms— Multiple Description, IEEE 802.11e, cross-layer optimization, packet classification.

1. INTRODUCTION
The widespreading of IEEE 802.11 networks has enabled the possibility of distributing rich media content anywhere, anytime, and from any device. However, the streaming of video sequences over wireless networks still presents several issues due to the presence of delays, packet losses and bandwidth limitations that affect the transmission performance. In order to improve the quality of the reconstructed sequence, video coding experts have been focusing on error concealment algorithms and robust video coding paradigms. Among these, Multiple Description Coding schemes [1] have proved to be significantly efficient for wireless scenarios where channel conditions are time-varying and the bursty nature of packet losses can lead to a significant distortion. At the same time, network designers have been involved in defining network architectures that are able to provide different classes of service.

In particular, the emerging IEEE 802.11e medium access control protocol [2] defines different levels of Quality-of-Service (QoS) that permit handling and transmitting video packets according to different priorities and policies.

As a consequence, this differentiation poses the problem of assigning the most appropriate QoS class at the lower layers of the protocol stack to each video packet generated at application level. During the last years this possibility has lead to the design of several cross-layer (CL) optimization strategies that assign to each video packet the most appropriate QoS class according to the characteristics of the carried information and of the source coding scheme. As an example, the video coding setting in [3] divides macroblock headers and Motion Vectors from the coded residual signal generating different types of packets thanks to the Data Partitioning (DP) mode of the H.264/AVC standard. Each packet is then assigned to a different class of service according to the information it carries.

However, at high bit error rates (BER) the performance of the MDC-based schemes is significantly better than that of the DP mode since they permit a more gentle degradation of the visual quality (see [4]). As a consequence, in this paper we design an efficient adaptive classification strategy for packets generated by a Multiple Description coder taking advantage of the QoS differentiation provided by the IEEE 802.11e standard. More specifically, packets are distributed among the different service queues at MAC level according to the percentage of null quantized DCT coefficients. Experimental results show that this adaptive approach improves the average PSNR value with respect to a traditional MDC approach where each description is assigned to a fixed QoS class.

In the following, Section 2 presents the adopted cross-layer scheme, while Section 3 describes the classification algorithm that maps the RTP video packets to the QoS classes defined in the IEEE 802.11e specification. Section 4 reports the simulation results obtained on a set of sequences coded with different QP, while Section 5 draws the conclusions.
2. A CROSS-LAYER MULTIPLE DESCRIPTION SCHEME BASED ON THE IEEE 802.11E STANDARD

In this work we adopted the very simple 2-description MDC scheme shown in Fig. 1, where the application and the MAC layers are depicted in more detail with respect to other parts of the protocol stack. In fact, the implemented cross-layer strategy relies on adequately tuning the MD source coder at the application layer and the multiplexer for the queues at MAC layer in order to optimize the performance of the MD concealment unit at the receiver. In the next subsections, these two layers will be described more accurately.

2.1. The MD coder and decoder at the application layer

At the application layer, the odd and even rows of each input frame are sampled into two fields (descriptions) and sent to two independent H.264/AVC coders. Each coder generates a packet stream that is sent to the lower levels in the protocol stack. At the receiver, in case both H.264/AVC decoders correctly get all the packets, both fields can be correctly decoded, and the coded sequence can be reconstructed without any further quality loss. In case some parts of one description are missing, the MD Concealment unit estimates the lost rows through a bilinear interpolation of the rows from the other description, which have been correctly decoded and are interleaved with the lost ones. This estimation produces a less degraded approximation of the coded frame which reduces the loss in the PSNR value of the reconstructed sequence. In case both descriptions get lost, it is necessary to adopt the same error concealment techniques that are adopted by single description (SD) coding schemes. Therefore, the transmission conditions for the two descriptions must be varied in such a way that at least one description is correctly received. To achieve this, the proposed CL scheme takes advantage of the features offered by the IEEE 802.11e protocol, which will be described in the following subsection.

2.2. The IEEE 802.11e protocol

The basic 802.11 MAC protocol, named Distribution Coordination Function (DCF), operates according to the Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) access strategy. Before a station starts transmitting a queued MAC Protocol Data Unit (MPDU), the channel has to remain available for a random time interval, called backoff time, that varies in the interval [0, CW], where the Contention Window parameter CW is initially set to CW_{min} and is doubled any time the transmission fails (up to CW_{max}). Whenever the packet is not correctly acknowledged by the receiver, the station retransmits it until the maximum number RETRYLIMIT (RL) of trials is reached.

In order to support different levels of QoS, the 802.11e [2] standard introduces the Enhanced Distributed Channel Access (EDCA) strategy, where multiple backoff processes (up to 4) are allowed by distinguishing multiple packet queues within the same wireless station. Each queue is referenced as Access Category (AC), which can be characterized by a different set of parameters \([CW_{min}, CW_{max}, RL]\) and a different priority. It is possible to distribute the RTP packets among the different queues in order to optimize the quality of the sequence reconstructed at the decoder.

3. A CLASSIFICATION ALGORITHM FOR MDC RTP PACKETS

Previous works have shown that for SD-based video coders the distortion produced by the loss of a single packet strongly depends on the characteristics of the coded information. In [5] Qu et al. propose an Unequal Error Protection (UEP) strategy that increases the number of FEC packets according to the activity level of the original sequence. In [6], the authors propose a joint source-channel coding optimization algorithm that tunes the FEC coder according to the percentage \(\rho\) of null quantized transform coefficients (called zeros). It is possible to find a similar relation for MDC schemes, too. Figure 2
Algorithm 1 Packet classification using ρ
1: Naming \( p_{i,j}^{MD1} \) the \( j \)-th packet of MD1 for the \( i \)-th frame 2: and \( p_{i,j}^{MD2} \) the \( j \)-th packet of MD2 for the \( i \)-th frame 3: if the \( i \)-th frame is Intra coded then 4: \( AC_3 \leftarrow p_{i,j}^{MD1} \quad AC_2 \leftarrow p_{i,j}^{MD2} \) 5: else 6: if \( \rho_{i}^{MD1} < \bar{\rho}_{i}^{MD1} \) then 7: \( AC_3 \leftarrow p_{i,j}^{MD1} \) 8: else 9: \( AC_2 \leftarrow p_{i,j}^{MD1} \) 10: end if 11: if \( \rho_{i}^{MD2} < \bar{\rho}_{i}^{MD2} \) then 12: \( AC_2 \leftarrow p_{i,j}^{MD2} \) 13: else 14: \( AC_1 \leftarrow p_{i,j}^{MD2} \) 15: end if 16: end if

Algorithm 2 Description switching
1: if \( \bar{\rho}_{i}^{MD1} < \bar{\rho}_{i}^{MD2} \) then 2: MD2 becomes the highest priority description 3: else 4: MD1 remains the highest priority description 5: end if

4. EXPERIMENTAL RESULTS
In order to evaluate the performance of the presented CL algorithm, we adopted the same simulation setting of [4]. The video sequence is transmitted by a video RTP server in an IEEE 802.11e network implemented using the Omnet++ simulator (see Fig. 3). In our tests, we simulated the transmission of various sequences (coded with fixed QP ∈ \{18, 24, 30\},
Table 3. The adopted network scenario.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC0 (CW min, CW max, RL)</td>
<td>(31, 1023, 4)</td>
</tr>
<tr>
<td>AC1 (CW min, CW max, RL)</td>
<td>(31, 1023, 4)</td>
</tr>
<tr>
<td>AC2 (CW min, CW max, RL)</td>
<td>(15, 31, 8)</td>
</tr>
<tr>
<td>AC3 (CW min, CW max, RL)</td>
<td>(7, 15, 8)</td>
</tr>
<tr>
<td>Bit rate</td>
<td>11 Mbit/s</td>
</tr>
<tr>
<td>Mobile speed</td>
<td>5 m/s</td>
</tr>
<tr>
<td>Path loss α</td>
<td>[2.0, 2.3]</td>
</tr>
<tr>
<td>Transmission power</td>
<td>75 mW</td>
</tr>
</tbody>
</table>

Fig. 3. The adopted network scenario.

GOP IPP...P of 15 frames) varying the channel propagation condition. The plots in Figure 4 report the average PSNR vs. the BER value from a set of 10 trials per point. It is possible to notice that the Algorithm 1 allows us to improve the PSNR value for sequences coded at different quality levels whenever the BER value increases. For the sequence foreman coded with QP = 24, the average PSNR is increased by 2 dB with respect to the non-adaptive approach of [4] when the BER is $9 \cdot 10^{-4}$, but it is possible to notice a similar improvement for other sequences too (see the results with BER $= 8 \cdot 10^{-4}$ for table in Fig. 4(d) and for Paris in Fig. 4(e)). The use of Algorithm 2 slightly improves the quality of the reconstructed video sequence, as it is shown in Fig. 4(d) for BER $= 10^{-3}$. However, this increment is strictly dependent on the characteristics of the video sequence. For the sequence news coded with QP $= 30$ (see Fig. 4(f)) no significant differences can be appreciated between Alg. 1 and Alg. 1+Alg. 2.

5. CONCLUSIONS

The paper has presented a cross-layer packet classification algorithm for a Multiple Description Coding scheme based on the IEEE 802.11e protocol. The proposed strategy relies on assigning the highest-priority service classes to the packets of frames with a low percentage of null quantized transform coefficients, while the others are transmitted with a lower QoS level since the quality of the reconstructed sequence is not significantly affected by their loss. Simulation results show that is possible to improve the PSNR value up to 2 dB with respect to a similar approach where packet classification only depends on which description they are related to.

6. REFERENCES