A Video-Aware FEC-Based Unequal Loss Protection Scheme for RTP Video Streaming

César Díaz, Julián Cabrera, Fernando Jaureguizar and Narciso García
Grupo de Tratamiento de Imágenes, Universidad Politécnica de Madrid, Spain

***Abstract*-- A video-aware unequal loss protection (ULP) system for protecting RTP video streaming in bursty packet loss networks is proposed. Just considering the relevance of the frame, the state of the channel and the bitrate constraints of the protection bitstream, our algorithm selects in real time the most suitable frames to be protected through forward error correction (FEC) techniques. It benefits from a wise RTP encapsulation that allows working at a frame level without requiring any further process than that of parsing RTP headers, so it is perfectly suitable to be included in commercial transmitters. The simulation results show how our proposed ULP technique outperforms non-smart schemes.**

I. INTRODUCTION

In real-time video streaming through lossy IP-based networks, the introduction of data protection schemes becomes crucial. FEC-based schemes are the most suitable in certain real-time environments [1]. As resources might be limited, smart schemes are introduced to decide which part of the data should be protected and how, so that resource availability is not exceeded and overall quality after decoding is kept as high as possible. Those are called ULP schemes. Usually, in the literature, a distortion minimization problem is raised. However, there exist differences in the level at which decisions are reached (packet level, intra-packet level, layer level…) and in how data are prioritized (frame importance, macroblock ranking, video scalability exploitation…) [2]-[4] which may make them computationally costly.

In our scheme, decisions are reached at a frame level: all packets carrying information of a certain frame are either protected or not protected. For this decision, features of the video frames in terms of distortion and error propagation (type - I, P or B -, size, and distance to the end of the GOP) and the specified resources for the protection of the information, are considered. In this sense, a wise RTP encapsulation is previously performed, thus working at a frame level does not require any further process than that of parsing RTP headers. Therefore, the algorithm designed to carry out our strategy (VA-ULP algorithm) is fast, straightforward and efficient.

II. PROPOSED UNEQUAL LOSS PROTECTION SCHEME

A. Problem description

A block diagram of the transmitter, where the proposed scheme for protection is included, is presented in Fig. 1.

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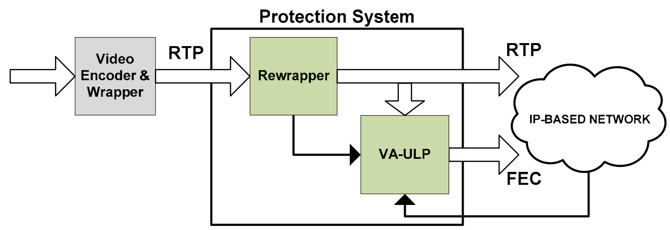

Fig. 1 Block Diagram of the Transmitter, including our protection scheme.

The input to the protection system is an RTP stream wrapping MPEG2-TS high quality video data. Through a rewrapping tool [5], data packets are regrouped, labeled and rewrapped in RTP packets according to the information contained, so that each packet contains data of a single video frame and all data packets corresponding to a frame are streamed sequentially. Moreover, an RTP header extension has been created with flags notifying the type of the information carried, the beginning and end of the frame and the distance to the end of the GOP (for video data).

The proposed algorithm uses the information included in the RTP header extension, as well as information about the channel, to decide which video frames among the whole set should be protected, fulfilling a given protection bitrate constraint. Optimal minimum distortion results can only be achieved if all the pictures belonging to the video are analyzed together, but, in real-time applications, suboptimal results are obtained by handling subsets of consecutive frames. These sets of pictures are called Decision Frame Sets (DFSs). The number of frames within a DFS is a trade-off between the accuracy on the decisions when trying to minimize distortion and the extra latency that it is added while waiting for all the packets involved in the current DFS to arrive.

As the loss of I-frame data may lead to error propagation within the whole GOP, the main aim of our algorithm is to protect the largest amount of this type of frames. For that purpose, we differentiate between DFS containing an I-frame (I-DFS) and DFS containing no I-frames (only P- and B-frames) (PB-DFS).

B. VA-ULP Algorithm

Given the value of the available bitrate for protection and the video frame rate, the nominal bit budget for the protection of each DFS (i.e. the distribution of the global available bitrate for protection among the DFSs) can be computed.

Nevertheless, it is very likely that I-DFSs require a larger bit budget than that of the nominal value, due to the large number of packets of I-frames. Thus, we propose to devote a portion of the resources for PB-DFSs to protect I-DFSs.

At every DFS, it is performed as follows:

- **In the case of PB-DFS**: a portion of the nominal bit budget for the current DFS is reserved for the protection of the forthcoming I-DFS. The non-reserved portion is used for the protection of the frames contained in this PB-DFS. A cost minimization problem is then solved to decide which P- and B-frames should be protected.
- **In the case of I-DFS**: no bits are reserved. The whole nominal bit budget for the current DFS and the extra resources reserved from previous PB-DFSs are used for the protection of the I-frames of this DFS. Once I-frames are protected, the remaining bitrate is used for the protection of the P- and B-frames contained in this I-DFS. Again, a cost minimization problem is raised.

C. *Cost minimization problem*

A vector v of $N_{P\text{-}B}$ components is defined, where $N_{P\text{-}B}$ is the number of P- and B-frames in the DFS. It expresses the different protection policies within a DFS: $v(i)$ is equal to 1 if the i^{th} frame is decided to be protected, and equal to 0 otherwise.

At this stage, the bit budget available for the protection of the P- and B-frames is $R_{FEC\_available}$. It is introduced in (1):

$$R_{FEC\_available} \geq \sum_{i=1}^{N_{P-B}} v(i) R_{FECi} \qquad (1)$$

where R_{FECi} represents the resources needed to protect the i^{th} frame.

The cost of a certain policy is formalized in (2):

$$D_{DFS} = \sum_{i=1}^{N_{P-B}} \left[v(i) D_P(i) + (1 - v(i)) D_{NP}(i) \right] \qquad (2)$$

where D_P and D_{NP} are the expected distortion values associated to the i^{th} frame when it is protected and when it is not, respectively. Distortion only depends on the features of the video frames, the current availability of slots for protection and the state of the channel.

The combination of P- and B-frames which, fulfilling the protection bitrate constraint, introduces the minimum cost is selected to be protected.

III. SIMULATIONS AND RESULTS

We compare our proposal to the following two schemes:

- **Total Protection (TP) scheme**: all data packets are protected without any bitrate constraint. The protection rate depends on the parameters of the FEC technique.
- **Uniform Loss Protection (UP) scheme**: random sets of packets are protected (no prioritization is performed) as long as bitrate constraint is fulfilled.

Simulations were carried out using an HD video movie with an average bitrate of 11 Mbps. For the channel, a Gilbert-Elliot model was used [6] (whose parameters were chosen after analyzing real ADSL channels). The FEC technique applied was 2D-XOR, as it is capable of recovering from loss bursts.

Simulation results for packet loss recovery rate and PSNR are presented in Fig. 2 and Fig. 3. They show the good performance of the proposed strategy when compared to TP and UP schemes.

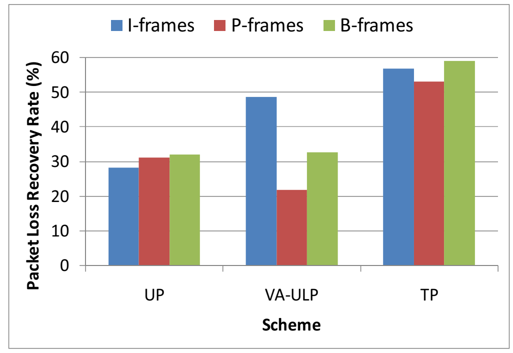

Fig. 2 Packet Loss Recovery Rate: UP and VA-ULP protection rate = 15% (usual rate in commercial digital television distribution); TP protection rate = 25% (due to FEC parameters). Channel parameters: PER = 0.91%, Mean Burst Length = 9 packets; 2D-XOR FEC parameters: 4x10 matrices.

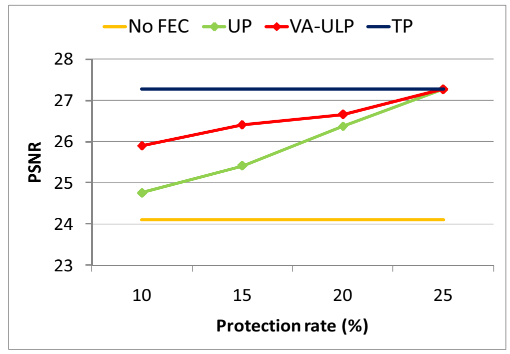

Fig. 3 PSNR measurement: results for different protection rates. Same parameters as in Fig. 2.

In Fig. 2, one can observe that, for our system, the packet loss recovery rate is dependent on the frame type. Indeed, the more important the type of frame, the higher the recovery rate achieved. In contrast, for TP and UP schemes, the recovery rate is practically the same for the three types. As illustrated in Fig. 3, that results, for our VA-ULP scheme, in an increase of PSNR with regard to UP (our strategy clearly outperforms this scheme) and in a closer performance to TP's, while devoting a lower bitrate to protection than the latter.

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