

# Error Resilient Transmission of MPEG-II over Noisy Wireless ATM Networks

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## Abstract

We consider the transmission of MPEG-II compressed video over noisy wireless ATM channels. This has applications in mobile digital video, where high cell loss ratios are observed. We propose techniques for substantially improving the resilience of MPEG-II to cell losses without the addition of any redundancy. Using the techniques outlined in this paper, graceful degradation performance appears possible to cell loss ratios exceeding 1 in 10, long after unprotected MPEG-II pictures are lost.

## 1. Introduction

The massive growth in telecommunications during the last few years has created a demand for many video services. These services are only viable with substantial video compression.

Whereas existing video standards such as MPEG-II[1] facilitate the transmission of high quality video over error-free channels, they tend to suffer greatly from error propagation effects when transmitted over noisy channels. ATM links subject to congestion or channel noise suffer from cell losses.

## 2. Error Control Schemes

Noise performance can be greatly enhanced using automatic repeat request (ARQ) systems [2]. ARQ may not always be possible due to the real time nature of the problem, as the it takes time for lost cells to be requested and re-transmitted, yet the video pictures must be displayed in real time. In this case the decoder may still inform the encoder of lost image portions, so that the encoder may recode these regions as intra portions one or two pictures later [3]. In many wireless ATM links, ARQ back channels may not always be available. In broadcast and one-to-many applications recoding strategies will not always be possible.

The noise performance of MPEG-II over wireless ATM channels can be improved using forward error correction (FEC). If the link is subject to loss of complete cells, cell interleaving may be required, which can cause delay.

Layered coding can be a useful tool for gaining resilience [4], as can the protection of I and P pictures at the expense of the less important B pictures [5].

However, these techniques add redundancy thereby lowering the coding efficiency, and so the error-free picture quality is lower for a fixed bitrate channel. FEC can also cause the failure mode to become more abrupt, as FEC can add more errors to a bitstream once the error correcting capability of the code has been exceeded.

We consider a different approach of the lossless 'black box' approach of figure 1 where MPEG-II data is transcoded into a more resilient structure, transmitted, and finally re-coded to be read by an MPEG-II decoder. The 'black box' is lossless, and does not significantly alter the bit-rate, while providing substantial resilience to errors. The black box is of particular benefit to wireless applications where the channel characteristics are complicated, unpredictable, or non-stationary.

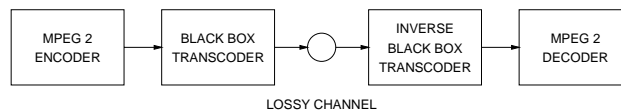


Figure 1: The MPEG-II Transcoder

## 3. Synchronisation

In [6, 7] we conclude that it is the loss of bitstream synchronisation which is the primary cause of corrupted pictures. We find the most useful resynchronisation points to be at the beginning of each block and before each *independent* piece of control information, ie following the macroblock address increment, the coded block pattern, and the motion vectors.

Synchronisation may be achieved using a macroblock locator at the beginning of each ATM cell. This locator indicates the position and location of the first macroblock in a cell [8]. Although powerful, schemes of this kind add redundancy, particularly is resynchronisation is required more frequently than at the macroblock layer.

We obtain synchronisation using a technique known as er-

ror resilient entropy coding [9], whereby all variable length datablocks always start at known positions in the bitstream. The bitstream is then re-ordered without adding redundancy such that longer blocks fill up the spaces left by shorter blocks. Thus synchronisation can be guaranteed for minimal coding overhead.

We make several enhancements to the EREC. We code predicted pictures to give one EREC slot per macroblock. Intra macroblocks, on the other hand, are coded such that each block is mapped to separate slots for DC and AC coefficients, and additional information such as quantiser scale codes, and macroblock type information. When a cell has been lost, this information is flagged to the EREC process, by an unexpected sequence number (SN). Gains are made by prohibiting any EREC shifts to or from slots which have suffered erasures from lost cells. This has the effect of reducing the number of error extensions in high frequency DCT coefficients.

## 4. Differential Coding

Given bitstream resynchronisation, we find that it is the MPEG-II differential coding of the DC coefficients and motion vectors which causes the most visible artifacts. These appear as corrupted horizontal stripes. In MPEG-II these coefficients are coded as 1D-DPCM, and so errors propagate. Although this may be eliminated by coding the coefficients as PCM, this does not achieve acceptable compression. Instead, we employ a hierarchical pyramid-based coding scheme using a four point hierarchical median predictor with quincunx subsampling to code these parameters. Every  $n$ -th coefficient is sent as PCM. This sets up a grid of points from which predictions can be made. From four PCM points, a point in the centre is predicted using a median predictor. The difference between the prediction and the actual value can then be sent as DPCM. Now other points may be predicted from the previous coefficients, and the process iterates until all the coefficients have been coded. At the edges, fewer than four coefficients are available from which to predict. In these cases, a three, or two, or one point predictor may be used.

Unlike the case of DC coefficients in intra pictures, not every macroblock in an inter picture has an associated motion vector. Indeed, many macroblocks are not coded at all. This makes it impossible to code the motion vectors using the quincunx scheme, because application of the code may cause an uncoded coefficient to be associated a value. To alleviate this problem, we make a modification to the quincunx code for use when not all the points in the lattice have a value. In our scheme, predictions are only made from coefficients which 'exist' or have a value. Coefficients which do not exist are not considered to be zero, but are barred from taking part in the prediction process. This has the added benefit that if a neighbouring macroblock is decoded incorrectly as not having a motion vector, then a realistic prediction from the other neighbouring macroblocks may still be possible.

Figure 3 shows a comparison of motion vectors coded using the 1D-DPCM scheme similar to that used by MPEG-II, and the modified quincunx code. It can be seen that enhanced error resilience is achieved with the quincunx code.

## 5. Results

In [6, 7] we reported results based on random channel bit errors in the MPEG-II video elementary stream. Here we give results for systems using 53-byte ATM cells where lost cells are known to be missing. We have assumed a cell payload size of 47 bytes. We assume that this layer provides sequencing, and an indication of which cells have safely arrived.

Lost cells are considered to be erasures and cells which are not lost are considered to have arrived with no bit errors. Lost cells are flagged to the decoder for concealment purposes. In intra pictures, the AC coefficients of lost blocks are removed, and only DC coefficients are used. The differential DC coefficients are set to zero, and so the DC coefficients are predicted from neighbouring blocks according to the quincunx predictor. This has the effect of spatially interpolating the DC coefficients. A similar prediction effect occurs automatically when predicted motion vectors are lost. In inter pictures, lost macroblocks are considered to be skipped (uncoded). This then corresponds to motion compensated temporal replacement.

Figure 2 shows the performance of our scheme compared to standard MPEG-II as a function of cell loss ratio (CLR). It can be seen that for a constant 30dB output PSNR, the transcoded scheme can withstand fifty times as many lost cells as standard MPEG-II. Figure 4 shows the same information for an intra picture from the 'calendar and mobile' sequence coded at 5Mb/s. Figure 4(a) shows the error-free decoded picture, 4(b) MPEG-II at cell loss ratio (CLR) = 1%, and 4(c) the transcoded scheme also at CLR = 1%. Figure 4(d) shows the transcoded scheme at CLR = 10%.

## 6. Bitrate and Computational Effort

Each picture is encoded using EREC frames of four MPEG-II slices. This produces a saving of four MPEG-II 32 bit slice start codes totalling 128 bits. At the beginning of each slice, it is not necessary to send a resynchronising code-word. Instead, we send a highly protected code at the beginning of each EREC frame. This data specifies the slot sizes used by the encoder, using a 128 bit code interleaved over all the cells in the whole EREC frame. This code contains a pseudo-random sequence to guarantee EREC frame synchronisation as well as to specify EREC slot sizes. As each picture is coded as a series of EREC frames of four slices, a delay of 64 lines is introduced. The transcoder adds little complexity to the encoder, but the EREC decode process adds complexity to the inverse transcoder. However, this additional complexity is small compared to the overall complexity of the whole decoder, as the black

box does not require any operations outside the DCT transform domain.

## 7. Conclusions

We have considered techniques for improving the resilience of MPEG-II when transmitted over noisy wireless ATM links. Resilient techniques for gaining bitstream synchronisation, and for coding differential data are presented. Using these techniques, graceful performance degradation appears possible to cell loss ratios exceeding 1 in 10, long after un-protected MPEG-II pictures are completely lost. Our scheme has no extra coding cost and requires only modest computational effort.

## 8. References

- [1] ISO/IEC JTC1/SC29/WG11 N0702 Rev. Generic coding of moving pictures and associated audio.
- [2] J. B. Cain and D. N. McGregor. A recommended error control architecture for ATM networks with wireless links. *IEEE Journal on Selected Areas in Communications*, 15(1):16–28, January 1997.
- [3] P. Cherriman and L. Hanzo. Robust H.263 video transmission over mobile channels in interference limited environments. In *First International Workshop on Wireless Image/Video Communications*, pages 1–7, September 1996.
- [4] E. Ayanoglu, P. Pancha, A. Reibman, and S. Talwar. Forward error control for MPEG-2 video transport in a wireless ATM lan. In *International Conference on Image Processing 1996*, pages II.833–836, September 1996.
- [5] I. Richardson and M. Riley. Intelligent packetising of MPEG video data. *Proceedings of the SPIE*, 2501(3):1388–1395, May 1995.
- [6] R.E.M. Swann and N.G. Kingsbury. Techniques for improving the error resilience of MPEG2 codecs. In *Proceedings of the International Broadcasting Convention*, pages 450–455, September 1996.
- [7] R.E.M Swann and N.G. Kingsbury. Transcoding of MPEG2 for enhanced resilience to transmission errors. In *Proceedings of the International Conference on Image Processing*, pages II.813–816, September 1996.
- [8] J. Zhang, M. Frater, J. Arnold, and T. Percival. MPEG-2 video services for wireless ATM networks. *IEEE Journal on Selected Areas in Communications*, 15(1):119–128, January 1997.
- [9] D.W. Redmill and N.G. Kingsbury. The EREC: an error resilient technique for coding variable length blocks of data. *IEEE Transactions on Image Processing*, 4(5):565–574, April 1996.

## 9. Acknowledgments

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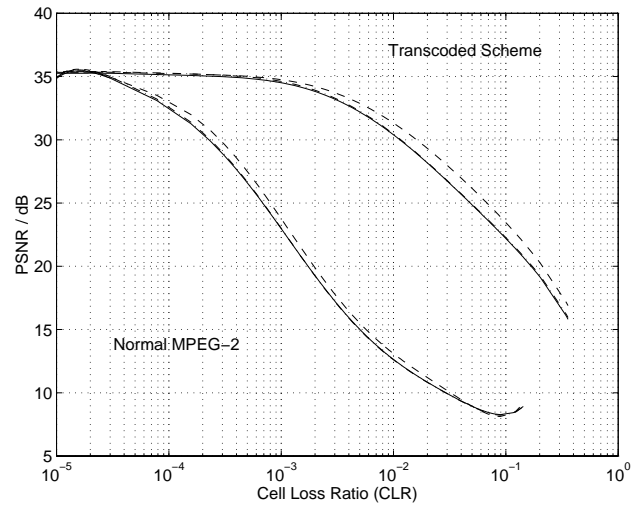


Figure 2: Degradation of signal to noise ratio vs. channel cell loss rate (CLR) for a group of pictures of ‘mobile and calendar’ coded at 5Mb/s. (--) denotes intra pictures, and (–) denotes an average over all pictures (I+P+B).



(a) 1D-DPCM



(b) Modified Quincunx

Figure 3: Rugby Sequence ‘B’ picture with corrupted Motion Vector coefficients. Only the motion vectors are corrupted with  $BER = 1\%$ .



Figure 4: (a): Error-Free Intra Picture



Figure 4(c): Transcoded Scheme, CLR=1%



Figure 4(b): MPEG-II, CLR=1%



Figure 4(d): Transcoded Scheme, CLR=10%