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Experts Group of ATM Video Coding

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Title:	Transport and Error Concealment for MPEG-2
Supplement to:	Proposal Package Description for MPEG Phase 2
Purpose:	Information and discussion
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1. Summary:

This contribution describes a packet-oriented transport format for a specific MPEG-2 proposal (refer to TCE-LA contribution entitled: "Proposal Package Description for MPEG Phase 2"). This data format is based on a cell relay asynchronous time division multiplexing concept similar to that being considered for the CCITT broadband ISDN/ATM standard.

To be responsive the Test and Requirements group's desire to see error performance, a bitstream conforming to the afore mentioned MPEG-2 proposal was passed through a end-to-end simulation of a communications system example. This continues to be a work in progress. Note that the particular example simulated is not strictly ATM/BISDN compatible, although it is representative of transport over cell-relay based transmission media. Demonstration tapes showing MPEG transport and error concealment performance at some relevant cell loss rates are accompany this document.

The transport data format consists of two distinct sublayers: "data link level" and "adaptation level". The MPEG video bit-stream is transported in the form of a series of fixed length L byte cells, each containing (L-8) video data bytes, a one-byte synchronization header, a one-byte data-link sublayer header, a four-byte adaptation level header and two-byte cyclic redundancy check (CRC) code for error detection. The data-link header contains generic transport information (e.g., priority indicator, service ID), while the MPEG-specific adaptation sublayer contains information fields which aid error recovery at the video decoder. This transport protocol supports the use of high priority (HP) and low priority (LP) data types, to allow for the possibility of partitioning the MPEG video into subjectively important and less important bit-streams when appropriate transmission facilities are available. A variety of error concealment approaches may be used as a receiver option in conjunction with the above transport format to ameliorate the effect of packet losses.

2. MPEG Transport Summary:

2.1. MPEG Data Prioritization:

Separation of MPEG video data into high and low priority bit-streams can provide improved robustness when appropriately prioritized transmission facilities are available. Priority transmission over packet networks can be achieved with suitable resource allocation algorithms; for conventional noisy channels, prioritized transmission may be obtained with multiple tiers of modulation and/or forward error correction (FEC) coding.

In considering the data prioritization function, it is observed that MPEG produces a bit-stream consisting of variable length codewords conveying information about different picture attributes such as headers (initialization values, adaptation parameters, etc.), motion vectors, DCT co-efficient values, run-lengths, etc. The subjective impact of losing each of these codeword types in the presence of channel errors can vary considerably. For example, loss of motion vector information may cause serious errors in decoding, whereas a few high frequency DCT co-efficients may be missed with relatively minor impact on the picture. Accordingly, separation of MPEG data into high priority (HP) and low priority (LP) streams may be carried out using an adaptive prioritization algorithm which takes into account: (a) the codeword type; (b) the MPEG frame type (i.e., I, B or P); and (c) the relative occupancies of HP & LP rate buffers at the output of the MPEG encoding system.

2.2. Data Transport Format:

The transport layer is a packet-oriented approach to reliable video delivery, consisting of two distinct sublayers: "data link level" and "adaptation level". The data link sublayer format is based on a "cell relay" asynchronous time division multiplexing concept similar to that being considered for the CCITT broadband ISDN/ATM standard, supporting features such as service multiplexing and error detection. The data link sublayer formats the HP/LP prioritized MPEG bit-streams into sequences of fixed length L byte cells, each containing (L-8) data bytes, a one-byte synchronization header, a one-byte data-link sublayer header, a four-byte adaptation level header and two-byte frame check sequence trailer. This fixed-length cell structure provides rugged data synchronization under fluctuating channel conditions. The data-link header contains generic transport information such as priority indicator, service ID and sequence number. The adaptation sublayer has been designed to permit rapid decoder resynchronization after error events that result in the loss of one or more cells. Adaptation headers contain video-specific information to aid error recovery at the decoder, e.g., frame type indicators, slice/macroblock IDs and re-entry pointers needed to support segmentation or chaining.

Figure 1 below presents a summary of the specific data format proposed for MPEG video transport. Observe that in addition to the sync, data link and adaptation fields mentioned above, an optional number of Reed-Solomon error correcting parity bytes may also be appended to each cell. The particular example for which simulation demonstrations are provided is for L=128 bytes, so that each cell accommodates up to 120 bytes payload.

MPEG TRANSPORT FORMAT

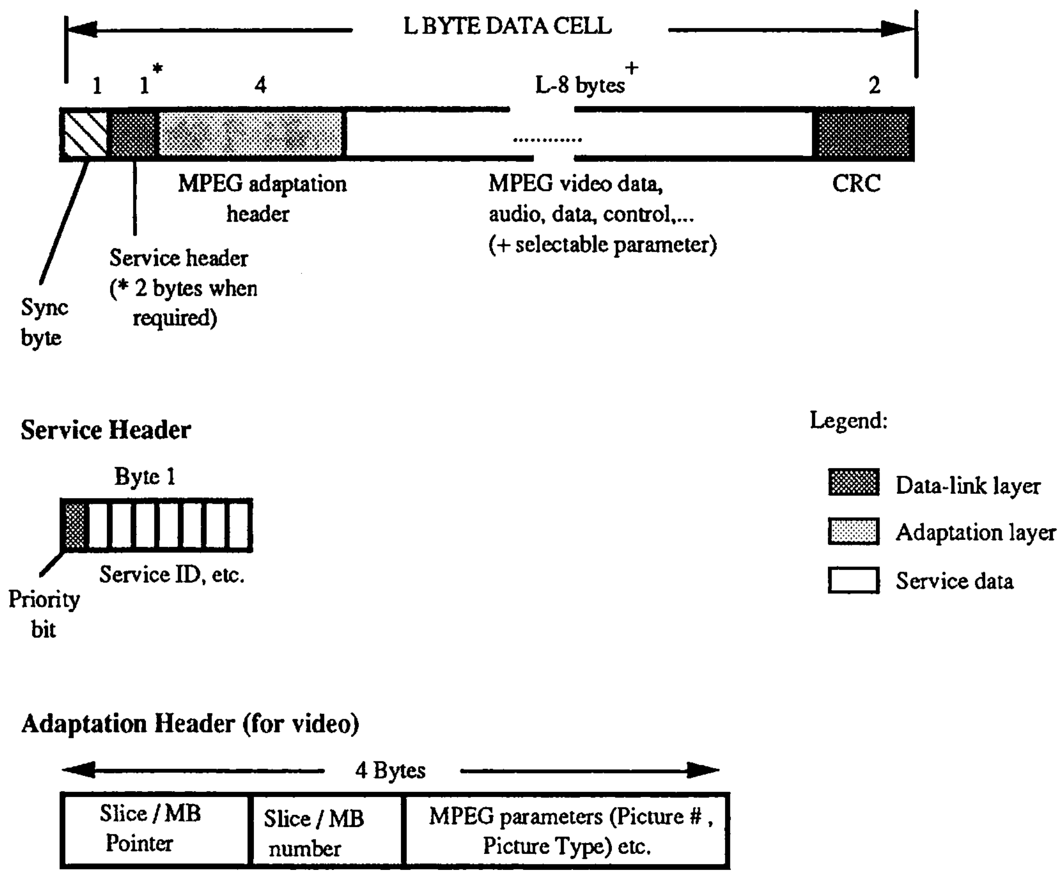

Fig. 1: Data format used for MPEG-2 Transport

2.3. Data-link sublayer:

The 1-byte data-link header contains generic transport information such as cell priority, service ID to support multiplexing, and a cell sequence number for positive identification of error events in each service stream. In this implementation the nominal 1-byte service header format provides an address space of 7 primary video, audio, data or control (e.g., timing, encryption) services per channel. Where needed, an optional extension to a 2-byte service header provides 256 additional service addresses per channel. The data-link sublayer format is shown in more detail in Fig. 1.

2.4. Adaptation sublayer:

An MPEG-specific adaptation sublayer has been designed to permit rapid decoder resynchronization after error events that result in the loss of one or more cells. Adaptation headers contain information fields which aid error recovery at the video decoder; for MPEG encoded video, these fields include frame type indicators, slice/macroblock IDs and reentry pointers needed to support segmentation, chaining and error control in variable length coded video. Interpretation of these header fields enable the decoder to locate slices and/or macroblocks received in error, and then resume decoding soon after error events. It is noted that the particular transport format implementation demonstrated is based on slice pointers/numbers for high-priority data, since isolated MPEG macroblocks by themselves are not generally useful to the decoder due to MQuant, differential encoding of motion vectors and DC Difference. On the other hand, macroblock (MB) pointers/numbers are used to recover from low-priority data loss, since header data, etc.

for those MB's will generally be received over the more reliable HP bit-stream. It is also observed that these slice/MB pointers in the adaptation header serve the resynchronization function of the slice start code, which may be removed from the MPEG bit-stream to improve transmission efficiency (assuming fixed and known slice size). In the example communications system, the Slice Start Code is removed, and the a field necessary to remerge the HP and LP bitstreams is inserted in its location. Alternatively, this information could have been carried as Slice User Data. The adaptation sublayer format (as currently planned) is also shown in Fig. 1.

2.5. <u>Error concealment</u>

The decoder applies a set of error concealment algorithms which are supported by the transport-level error detection and video re-entry features of the proposed MPEG transport format. The error concealment approach implemented by a typical decoder is summarized below:

(a) Detect cell (packet) errors using the cyclic redundancy check code (CRC), and identify the spatio-temporal position of MPEG slices which are in error.
(b) Discard received video data corresponding to macroblocks and/or slices received in error. It is noted that the transport format supports macroblock level recovery for low-priority errors, and slice level recovery for high-priority errors.
(c) For two-layer MPEG transmission, low priority errors which result in the loss of DCT co-efficients are handled by forcing EOB's in affected macroblocks.
(d) For high-priority errors (or for one-layer transmission), each errored macroblock is replaced with an estimate of the macroblock obtained from the surrounding spatial region and/or the previous frame;
(e) Estimates for lost macroblocks are obtained using an appropriate interpolation algorithm which exploits an appropriate combination of spatial data and motion information.

It is remarked here that error concealment is a decoder design option, and possible approaches span a range of complexity and performance.

2.6. <u>Simulation Results</u>

A demonstration tape showing the end-to-end performance of the described MPEG-2 compression and transport system is provided. Coding parameters used in the experiments are:

Sequence: Table Tennis (720x480 @ 30 Frames/sec)
Coding Algorithm: MPEG-I
Bit Rate = 4 Mbps
M = 3, N = 12

The results shown in the tape are:

(a) System performance at cell loss rate (CLR) = 10^{-3}, with:
  - no transport priorities
  - no error concealment.
(b) System performance at cell loss rate (CLR) = 10^{-3}, with:
  - no transport priorities
  - error concealment algorithm with adaptive interpolation, etc.
(c) System performance at cell loss rate (CLR) = 10^{-4}, with:
  - no transport priorities
  - error concealment algorithm with adaptive interpolation, etc.
(d) Two-layer system performance at low priority cell loss rate (LP-CLR) = 1.33×10^{-3}, with:
  - two transport priorities (HP/LP) with 25% data HP
  - error concealment algorithm with adaptive interpolation, etc.
(e) Two-layer system performance at low priority cell loss rate (LP-CLR) = 1.33×10^{-4}, with:
  - two transport priorities (HP/LP) with 25% data HP
  - error concealment algorithm with adaptive interpolation, etc.