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Source: M. Biggar (Telecom Australia)
CHAIR, Ad-hoc Group on ATM Cell Loss and Error Resilience

Title: Report of Ad-hoc Group on ATM Cell Loss and Error Resilience

Status: Information and Proposal

Establishment and Mandate

The Ad-hoc Group on ATM Cell Loss and Error Resilience was established at the Rome meeting to study means by which the MPEG-2 syntax can provide for robustness in the presence of cell loss on ATM networks, and other errored transmission or storage conditions.

Meetings

No meetings were held.

Participation

A large number of people (35) registered their interest in the ATM cell loss resilience ad-hoc group, but only 7 contributed to the email exchanges.

Experiments

Experiments on Cell Loss Resilience proposed after the Rome meeting cover error concealment, spatial and temporal localisation methods.

Results

No experimental results were compared during the period of the ad-hoc group's existence, but AT&T distributed initial AC-Leak results.

Discussions

Topics discussed by email covered:

- The impact of isolated uncorrected bit errors (or "erasures"), and whether they could be treated the same as lost cells or packets.

The consensus seemed to be that bit errors could be immediately identified (by causing invalid codewords) or go undetected (but cause serious picture degradation) by a decoder, depending on where the error occurred. While it is probably better to introduce distortion in a controlled way (through concealment techniques) than risk serious visible errors, the action should not be restricted and should be left as a decoder option. Therefore, errored video data blocks should be forwarded to the decoder with an error indication, rather than just being deleted.

- Loss in a multiplexed bitstream.

Sakae Okubo discussed the general case of multiplexed packetised bitstreams, and points out that packet header errors could cause misinserted packets and corrupted packets that the demultiplexer cannot assign to any single medium and so cannot advise the decoder of the error/loss.

- The necessary interdependence between network interface and coder to facilitate structured packing or adaptive slice size techniques of spatial error localisation.

The extent of this interdependence was discussed, and it is yet to be resolved whether an appropriate transmission structure can be generated entirely by postprocessing or whether the encoder must encode with a view towards cell-based transmission. (Perhaps there is little or no penalty in this anyway.)

- Proposed text on error concealment for the WD.

Kiyoshi Sakai prepared text describing a reference system for error concealment by motion compensated prediction of lost macroblocks. This text has been combined with that offered in Rome for the WD, and is presented in the attached Annex.

Proposal

It is proposed that the following Annex be added to the MPEG Video WD at the Sydney meeting.

Annex - Text offered for Working Draft

D.3 Error Resilience

The coded video bitstream generated by this Recommendation | International Standard may be carried by different transport systems including packet systems. The Asynchronous Transfer Mode (ATM) of B-ISDN is an example of a packet system. ATM uses relatively short, fixed length packets, called cells, consisting of a 5 byte header containing routing information, and a user payload of 48 bytes. The nature of errors on ATM is such that some cells may be lost, and the user payload of some cells may contain bit errors. At the receive terminal, the network interface forwards received cells plus indications of lost cells. Indication of cells containing bit errors may also be available, depending on AAL (ATM Adaptation Layer) functionality.

As an indication of the impact of cell loss in an ATM environment, the following table summarises the average interval between cell losses for a range of CLR and service bit rates (assuming a cell payload of 376 bits = 47 bytes). Note, however, that this summary ignores cell loss bursts and other shorter term temporal statistics.

	Average interval time of error			
CLR	5 Mb/s	10 Mb/s	50 Mb/s	100 Mb/s
10^{-2}	$7.52*10^{-3}$ s	$3.76*10^{-3}$ s	$7.52*10^{-4}$ s	$3.76*10^{-4}$ s
10^{-3}	$7.52*10^{-2}$ s	$3.76*10^{-2}$ s	$7.52*10^{-3}$ s	$3.76*10^{-3}$ s
10^{-4}	$7.52*10^{-1}$ s	$3.76*10^{-1}$ s	$7.52*10^{-2}$ s	$3.76*10^{-2}$ s
10^{-5}	7.52 s	3.76 s	$7.52*10^{-1}$ s	$3.76*10^{-1}$ s
10^{-6}	1.25 s	37.6 s	7.52 s	3.76 s
10^{-7}	12.5 m	6.27 m	1.25 m	37.6 s
10^{-8}	2.09 h	1.04 h	12.5 m	6.27 m

Other error conditions, such as isolated bit errors, bit error bursts or larger packet losses may be treated similarly. It may be appropriate to treat a known erasure (uncorrected bit error(s) known to exist somewhere in a data block) as a lost data block, since the impact of bit errors cannot be predicted. However, this should be a decoder option.

Bit Error Ratios (BERs) corresponding to the above mean times between errors can be calculated easily for the case of isolated bit errors, since the BER is related to CLR by the cell payload size. ie. BER = CLR/376.

The following techniques of minimising the impact of lost cells and other error/loss effects are provided for reference, and indicate example methods of using the various tools available in this Recommendation | International Standard to provide good performance in the presence of those errors. Note that the techniques described may be applicable in the cases of packets of other sizes (eg. LANs or certain storage media) or video data with uncorrected errors of different characteristics, in addition to cell loss.

The error resilience techniques are summarised in three categories, covering the restriction of the influence of a loss or error in both space (within a picture) and time (from picture to picture), and the methods of concealing the error once it has occurred.

D.3.1. Concealment

Concealment techniques attempt to hide the effect of losses/errors once they have occurred. Some concealment methods can be implemented using any encoded bitstream, while others are reliant on the encoder to structure the data or provide additional information to enable enhanced performance.

D.3.1.1 Concealment as a decoder-only function.

Independent of whether any attempt has been made at the encoder to make the generated video bitstream error resilient, a decoder always has the option of providing concealment of the errors by estimating the lost data from spatio-temporally adjacent data. Techniques may range from simply not updating a frame store in the event of lost macroblock data (ie. concealment through estimation from the previous frame) to more sophisticated concealment methods that utilise motion compensation for the macroblock prediction.

Concealment methods work effectively when combined with spatial localisation, such as the small-slice method. A simple MB substitution from a previous frame combined with the small-slice method will provide adequate picture quality for most sequences in the presence of rather low error rates of around $CLR=10^{-5}$ when a system with the main profile at main level is used. In the case with higher CLR or critical sequences, however, more sophisticated concealment methods using motion compensation will be required.

The following is an example of motion-compensated concealment scenario especially for the case with n=infinite (n:number of pictures in a GOP). In the case with n=finite, a simple MB substitution from the previous frame may be used. According to the computer simulation results based on TM4, the scheme provides adequate picture quality at $CLR=10^{-3}$.

The basic operation at the decoder is as follows:

- Always store MB-types and motion vectors of above and below adjacent MBs (MBab and MBbl) as reference MBs. If one of the two MBs is lost, of "intra" type or out of picture, motion vectors and MB type for the reference MB (MBab or MBbl) are assumed to be the same as the other MB's. If both MBs are lost, these MBs are stored as intra MBs.

- If errors are noticed to the decoder (maybe from system layer or AAL), the decoder starts the concealment process according to the following criteria. A motion compensated interpolation is done using the motion vector of the above adjacent MB (MVab) in the same picture and the below adjacent MB (MVbl) in the same picture.

- Return to normal action when a bitstream is resynchronised without errors, usually at the next slice_start_code.

The criteria for deciding the concealment type and vector (MVcc) is as follows.

The concealment type for a lost MB is decided according to the table below. In the table, (MB1, MB2) can be (MBab, MBbl) or (MBbl, MBab). The concealment vector(MVcc) value is calculated from the following formulae. A lost MB is always concealed as a frame MB and if a reference MB is a field MB, field1_MV is used in the calculation. (This last sentence can be omitted if only frame MB is concerned)

forward_MVcc = (forward_MVab + forward_MVbl) // 2 backward_MVcc = (backward_MVab + backward_MVbl) // 2 where

forward_MVab : forward_motion_vector of the above adjacent MB

forward_MVbl : forward_motion_vector of the below adjacent MB

backward_MVab: backward_motion_vector of the above adjacent MB

backward_MVbl: backward_motion_vector of the below adjacent MB

Table D.1: Criteria for concealment type decision

MVs for MB1	MVs for MB2	Concealment type
forward	forward	forward prediction
backward	backward	backward prediction
forward	backward	interpolation: missing MVs are given the same value as that of the other MB
forward backward	forward	interpolation: missing MVs are given the same value as that of the other MB
forward backward	backward	interpolation: missing MVs are given the same value as that of the other MB
forward backward	forward backward	interpolation

D.3.1.2. Encoder-assisted concealment.

Layered Coding

The components produced by the coding process can be placed in a hierarchy of importance according to the effect of loss on the reconstructed image. By coding and multiplexing components of similar importance into independent bitstreams, and treating each bitstream with due importance, superior error concealment performance may be possible. The independent bitstreams may be treated differently at one or more of the following locations:

- coder - different channel coding might be used
- channel - the channel may be able to offer paths with different cell loss probabilities
- decoder - error concealment could be performed differently within each bitstream

[Reference system based on the scalability and compatibility enhancements for error concealment.]

D.3.2. Spatial localisation.

Spatial localisation encompasses those methods aimed at minimising the extent to which errors propagate within a picture, by providing early resynchronisation of the elements in the bitstream that are coded differentially.

[Reference text required on: Small slices, Adaptive slice sizes]

D.3.3. Temporal Localisation

Temporal localisation encompasses those methods aimed at minimising the extent to which errors propagate from picture to picture in the temporal sequence, by providing early resynchronisation of the elements in the bitstream that are coded differentially.

[Reference text required on: Intra pictures, Intra slices]

D.3.4. Summary table

The following table summarises the above error resilience techniques, indicating their applicability and range of CLR for which they provide effective resilience. Note that the range of CLR for which the resilience techniques are applicable must necessarily be somewhat subjective and application dependent, and so should be taken as nothing more than a guide. Of course, coded bit rate and type of video signal also affects this figure. Unless otherwise stated, these figures refer to Main Profile, Main Level coding at 4 Mbit/s.

Category	Technique	Profile/Applicability	Range of CLR
Concealment (decoder only)	Simple (previous picture)	All	$\leq 10^{-5}$
	Motion compensated	All	$\leq 10^{-3}$
Concealment (Encoder assisted)	Layered coding	Freq. scalability, Spatial scalability, Data partitioning	
Spatial Localisation	Small Slices	All	
	Adaptive slice sizes		
Temporal Localisation	Intra pictures		
	Intra slices		