ISO/IEC JTC1/SC29/WG11
MPEG 93/.....
November 1, 1993

Document AVC-585

October 27, 1993

Telecommunication Standardisation Sector
Study Group 15
Experts Group for Video Coding and Systems in
ATM and Other Network Environments

SOURCE : Stuart Dunstan, Siemens Ltd, (Australian UVC consortium)

TITLE : ATM network adaptation performance parameters

PURPOSE : Discussion

1. INTRODUCTION

This document discusses performance parameters in ATM network adaptation of real time audio and video signals. Two network adaptation modes of operation are discussed. A network adaptation example based upon the ATM Adaptation Layer type 3/4 Segmentation And Reassembly sublayer is compared to one based upon the MPEG-2 Systems Transport Stream. The former is shown to be superior in terms of the identified performance parameters.

2. PERFORMANCE PARAMETERS

2.1. Delay

Some audio-visual applications, such as telecommunications, have a low end to end delay requirement. In MPEG-2 a major proportion of the delay will be due to the video coder bit rate control buffer. Media multiplexing, packetisation strategies, and other aspects of network adaptation should be chosen such that they have little impact on delay.

2.2. Error performance

In traditional data systems, user data is considered to be delay insensitive and error sensitive. Data link layers use error detection, and discard the packet when an error is detected. Re transmission of the discarded packet is controlled from a higher protocol layer. In contrast to data systems, coded audio and video is delay sensitive and can tolerate some error. Re transmission of errored data is not an option for real time signals.

A suitable error strategy for real time video signals, is to pass the errored data unit to the decoder, along with error indication flags. The decoder can use all good macro blocks within a slice, up to the first errored macro block, and use concealment techniques for those that are lost. A minimum requirement is therefore to detect packet loss and to detect bit errors within packets.

2.3. Efficiency

Robust error recovery techniques may come at the expense of lower packing efficiency. A careful trade off between performance and packing efficiency is required.

3. OPERATIONAL MODES

3.1. Pipelining

An important mode of network adaptation, with respect to delay, may be that of *pipelining*. In this mode, at the coder, a segment of the user packet may be transmitted before the complete user packet is available. At the receiver a segment is delivered to the decoder before the complete user packet is received. Pipelining is possible only where a segment multiplex is available, and where mechanisms that operate at the packet level do not prohibit such operation. This mode of operation may be particularly important at lower bit rates where the time to fill a particular data unit is critical.

3.2. Alignment of user data

The capability to *align* user data with network adaptation structure is a desirable feature. For example, the slice is the unit of error control within MPEG video. Alignment of the start of each video slice to the start of an ATM cell payload provides good spatial error localisation [1].

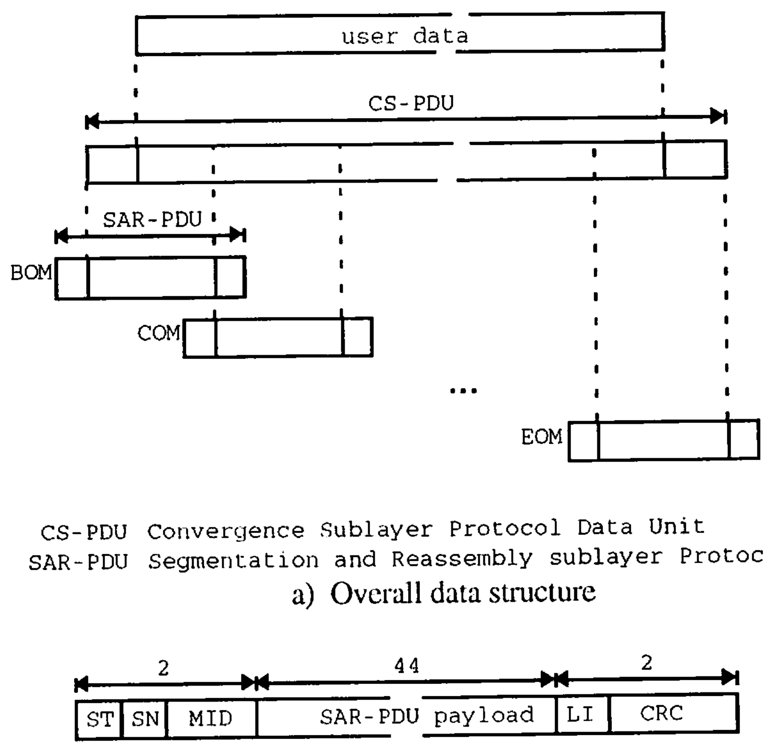
Consideration must be given to the packing efficiency of this method, since the last cell of the slice may be only partially filled.

4. NETWORK ADAPTATION EXAMPLES

To illustrate relationships between the above performance parameters and operational modes, two network adaptation structures are described.

4.1. Reference system

Figure 1 illustrates a structure based upon the AAL type 3/4 Segmentation and Reassembly (SAR) sublayer, and is referred to here as the *reference* example. Figure 1a) shows the overall data structure, while Figure 1b) shows proposed fields within the SAR header and trailer.



CS-PDU Convergence Sublayer Protocol Data Unit
SAR-PDU Segmentation and Reassembly sublayer Protocol Data U

a) Overall data structure

ST Segment Type
SN Sequence Number
MID Mulitplex ID
LI Length Indicator (?)
CRC Cyclic Redundancy Check

b) SAR-PDU fields

Figure 1. Reference network adaptation data structure

The reference example is examined in relation to the above performance parameters as follows:

- delay

  A segment multiplex is proposed. Since there are no CS operations requiring the whole CS-PDU to be stored, pipelining is allowed.

- error performance

  The reliable reassembly of the CS-PDU is handled by the Segment Type field, whose values are Beginning Of Message (BOM), Continuation Of Message (COM), End Of Message (EOM), and Single Segment Message (SSM). Cell loss is detected using the Sequence Number field. Bit errors are detected using the Cyclic Redundancy Code.

  The performance of the CRC code must be examined. Note that while length indication is shown as a SAR sublayer field, it is mandatory only for the last SAR-PDU of the CS-PDU, and hence could be placed within the CS-PDU trailer. This would allow a more powerful error detecting code in the SAR trailer.

This structure can indicate the position of cell loss within a CS-PDU, and segments within a CS-PDU that may contain bit errors. The decoder decides how to deal with a CS-PDU containing errors.

Table 1 shows possible logic for a SAR reassembly state table at the receiver. The state machine has two states, being IDLE and REASSEMBLY. In the particular example shown here, all leading segments of a CS-PDU, that have been received without error, are delivered to the CS sublayer.

state	illegal SAR-PDU [1]	ST	SN error	next state	output [4]
IDLE	0	BOM	x	REASSEMBLY	- [2]
		COM	x	IDLE	-
		EOM	x	IDLE	-
		SSM	x	IDLE	INDICATE
	1	x	x	IDLE	-
REASSEMBLY	0	BOM	x	IDLE	INDICATE + ERROR [5]
		COM	0	REASSEMBLY	- [3]
			1	IDLE	INDICATE + ERROR
		EOM	0	IDLE	INDICATE
			1	IDLE	INDICATE + ERROR
		SSM	x	IDLE	INDICATE + ERROR [5]
	1	x	x	REASSEMBLY	-

Notes:

1) An illegal SDU-PDU is defined as one in which
   - there are bit errors in the SAR-PDU
   - the MID field value does not match

2) The receiver sequence number state variable is set to 1 greater than the received sequence number.

3) The receiver sequence number state variable is incremented by one (after comparison with the received sequence number).

4) Outputs:
   - INDICATE - indication is given to the CS sublayer that reassembly of the current CS-PDU is complete.
   - ERROR - the current CS-PDU is missing one or more trailing segments. (The SAR-PDU responsible for the early termination of the CS-PDU is not included).

5) The current SAR-PDU is held, and used as input in the next state machine cycle.

Table 1. SAR reassembly state table at receiver.

- efficiency

  Figure 2 shows the efficiency of the reference example in the aligned mode of operation, for increasing user data packet size, N. The efficiency approaches 91.67% as the length of the PES packet payload increases, and for reasonably large packet sizes equals this when the CS-PDU is an integral number of SAR payloads in length (see Appendix).

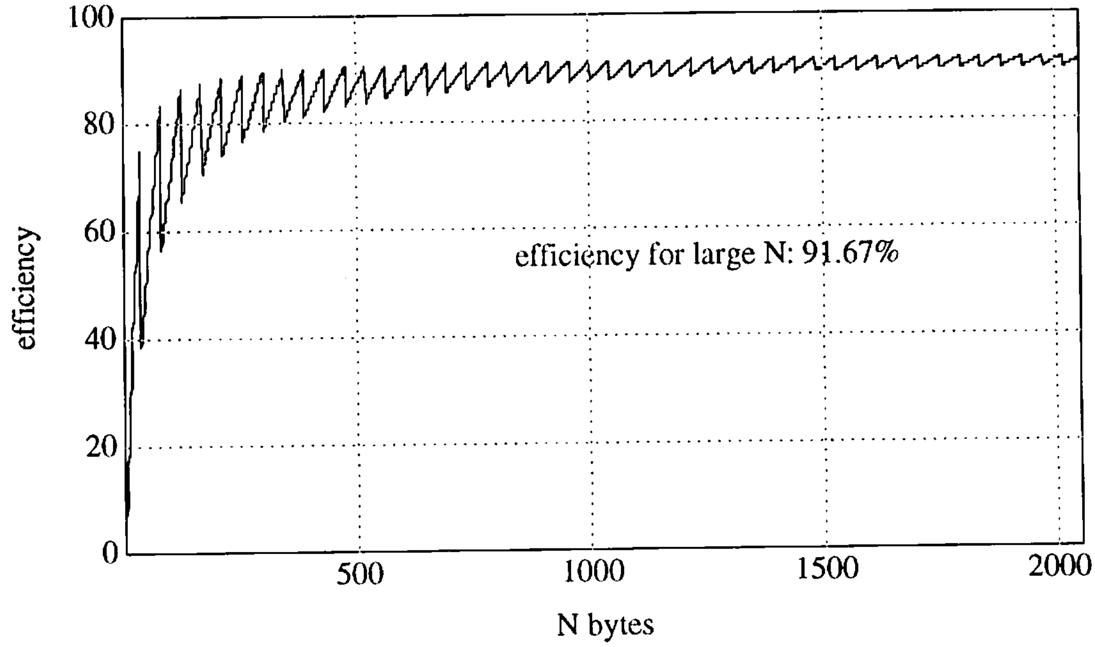
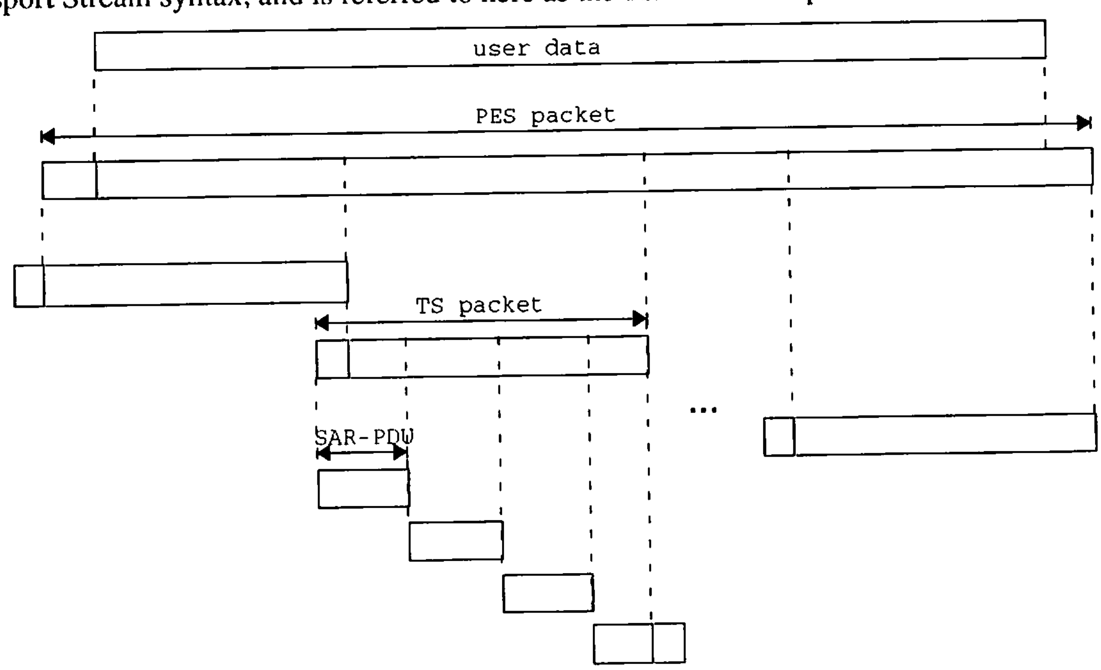


Figure 2. Reference example packing efficiency against packet size N.

4.2. Transport Stream/ATM example

Figure 3 shows a second ATM network adaptation example, which employs the MPEG 2 Systems Transport Stream syntax, and is referred to here as the *TS/ATM* example.



PES Packetised Elementary Stream
TS Transport Stream
SAR-PDU Segmentation and Reassembly sublayer Protocol Data Unit

Figure 3. Transport Stream/ATM example.

In Figure 3 a Transport Stream packet is transported in four ATM cells. Four bytes per Transport Stream packet are available for ATM adaptation purposes, and are assumed to be used as follows:

- the four bytes are used entirely for bit error detection/correction across the whole TS packet.
- the ATM-layer-user to ATM-layer-user (AUU) parameter of the ATM layer primitives is used to synchronise to the four cell structure. A value of "0" indicates the first, second, or third cell, while a value of "1" indicates the last cell.

The TS/ATM example is examined in relation to the performance parameters as follows:

- delay

  In this example delay is dependent upon the mode of operation. If pipelining is not used then the delay is the time to fill one PES packet: the PES packet may be fixed length or variable length. Due to the PES header *PES_packet_length* field, pipelining may only be used where the PES packet length is known a prior i.e. PES packet unaligned and fixed length. In this case the delay is reduced to that of the time to fill one TS packet. Table 2 summarises these points.

pipelining	aligned	delay
0	x	PES packet
1	0	TS packet
	1	prohibited

Table 2. Delay of Transport Stream/ATM example, measured as time to fill indicated data unit, for different modes of operation.

  In the case of pipelining the delay could be further reduced to that of an ATM cell at the transmitter end. However the delay at the receiver is still one whole transport packet, since the TS packet cannot be released until bit error detection/correction over the whole TS packet is performed.

- error performance

  The bit error detection/correction and the AUU signal assist in reconstruction of the TS packet. Loss of any one ATM cell causes the whole TS packet to be lost. The bit error detection/correction code applied across the TS packet has not been specified here, and is not further discussed.

- efficiency

  Figure 4 shows the efficiency of the Transport Stream/ATM example in the aligned mode of operation, for increasing user data packet size, N. The efficiency approaches 95.83% as the length of the PES packet payload increases, and for reasonably large packet sizes equals this when the PES packet is an integral number of TS packets in length (see Appendix).

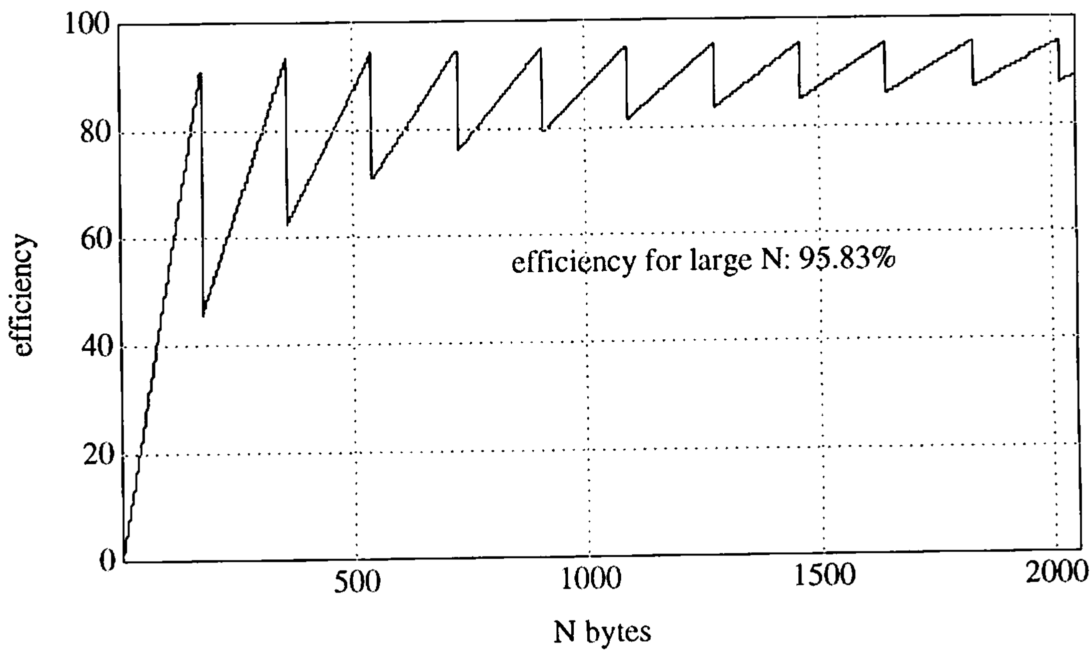


Figure 4. Transport Stream/ATM example packing efficiency against packet size N.

5. DISCUSSION

Figure 4 shows that the Transport Stream/ATM example has higher efficiency than the reference example where the PES packet is very large, or where the PES packet is an integral number of TS packets in length. However in the aligned mode at smaller packet sizes the packing efficiency of the TS/ATM example is not good. For example from Figure 4 the average packing efficiency at around 500 bytes is less than that of the reference system. For a 720x576 picture at 30 frames/sec, with a slice being one horizontal strip of macro blocks, the average number of bytes per slice is 462, for a 4 Mbit/s service.

Table 3 illustrates the effect of packet size upon delay; the delay is the time required to fill the given data unit at the specified bit rate. At moderately high bit rates the time required to fill an ATM cell or a TS packet is relatively small. However a PES packet of 2000 bytes in length takes a significant time to fill at even moderate bit rates. Pipelining allows such delays to be avoided.

Packet size	64kbit/s	384kbit/s	2Mbit/s
ATM cell (44 byte)	5.50	0.92	0.18
TS packet (184 byte)	23.00	3.83	0.74
PES packet (2000 byte)	250.00	41.67	8.00

Table 3. Packetisation delay in milli seconds for different packet lengths and bit rates.

In the reference example a MPEG-2 System Packetised Elementary Stream (PES) packet [2] could be mapped to one CS-PDU, and the CS sublayer made null. A difficulty with this is that the *PES_packet_length* field prohibits pipelining in the aligned mode [3]. A solution is to drop this field, as well as the two preceding fields, which are redundant in the reference system, saving 6 bytes of the PES header.

Table 4 summarises the performance parameters for the two network adaptation examples.

In Table 4 only one aspect of error performance is examined, being that of cell loss performance. Bit error detection/correction is also an aspect of error performance, but has not been considered here.

performance parameter	reference		TS/ATM	
	unaligned	aligned	unaligned	aligned
delay [1]	ATM cell [2]	ATM cell [2]	TS packet [2,3]	PES packet
packing efficiency	91.67%	87% approx [4]	95.83%	82% approx [4]
cell loss performance [5]	****	*****	***	****

Notes:

1) Delay is measured as the time required to fill the indicated data unit.

2) Pipelining mode is assumed.

3) This data unit could be reduced to one ATM cell at the transmitter. However at the receiver the delay remains as one TS packet due to error detection/correction over the whole TS packet.

4) Packing efficiency is estimated from Figures 2 and 4 for a 500 byte packet. As the packet size increases the packing efficiencies in the aligned mode approach the packing efficiency possible in the unaligned mode.

5) Cell loss performance is indicated by the number of stars: the more stars the better.

Table 4. Performance parameters of the two ATM network adaptation examples

In Table 4, the relative cell loss performance of each method is estimated based upon the following:

- the aligned mode gives better error performance than the unaligned mode
- a method in which loss of one cell does not cause data already received to be discarded is preferable to one that does cause such data to be discarded.

Table 4 indicates that the TS/ATM example is capable of high packing efficiency in the unaligned mode. However this is at the expense of low error performance. The error performance improves in the aligned mode, but packing efficiency and delay suffer.

6. CONCLUSION

Two ATM network adaptation examples for real time audio and video signals have been examined with respect to delay, error performance, and packing efficiency. Two operating modes, being pipelining and user data alignment have been considered.

Packing efficiency is but one aspect of ATM network adaptation to be considered, when evaluating a particular network adaptation method: delay and error performance are also important.

The ATM network adaptation example based upon the AAL type 3/4 SAR provides superior performance compared to the TS/ATM example. One might choose to use the TS/ATM example for reasons of compatibility, however performance will be sacrificed.

REFERENCES

[1] ISO/IEC, "Generic Coding of Moving Pictures and Associated Audio", Third Working Draft (New York), Annex D.3 "Error Resilience".

[2] ISO/IEC MPEG, "MPEG-2 Systems Working Draft", 10 September, 1993.

[3] ISO/IEC MPEG 93/730, "PES packet length semantics", 6 September, 1993.

APPENDIX

This appendix shows the calculation of packing efficiencies for the reference system and the Transport Stream/ATM examples.

1 Reference system

The efficiency for the reference system of Figure 1, eff_{ref}, is calculated as follows:

$$N_{cell} = ceil\left(\frac{N + CS\_HDR\_LEN + CS\_TRL\_LEN}{SAR\_PAYLOAD\_LEN}\right)$$

and,

$$eff_{ref} = \frac{N}{N_{cell} \times ATM\_PAYLOAD\_LEN} \times 100\%$$

where N is the length of the user packet to be transmitted in bytes, and N_{cell} is the number of whole cells required to transport the user packet. For large N the CS overhead becomes small and the efficiency is given as:

$$eff_{ref\infty} = \frac{SAR\_PAYLOAD\_LEN}{ATM\_PAYLOAD\_LEN} \times 100\%$$

In Figure 2 the following values were used:

$$CS\_HDR\_LEN = 8$$
$$CS\_TRL\_LEN = 0$$
$$SAR\_PAYLOAD\_LEN = 44$$
$$ATM\_PAYLOAD\_LEN = 48$$

2 Transport Stream

The efficiency for the Transport Stream/ATM example of Figure 3, eff_{ts}, is calculated as follows:

$$N_{TS} = ceil\left(\frac{N + PES\_HDR\_LEN}{TS\_PAYLOAD\_LEN}\right)$$

and,

$$eff_{TS} = \frac{N}{N_{TS} \times (TS\_PACKET\_LEN + AAL\_OVERHEAD\_PER\_TS\_PACKET)} \times 100\%$$

where N is the length of the user packet to be transmitted in bytes, and N_{TS} is the number of whole TS packets required to transport the user data. For large N the PES packet overhead becomes small and the efficiency is given as:

$$eff_{TS\infty} = \frac{TS\_PAYLOAD\_LEN}{TS\_PACKET\_LEN + AAL\_OVERHEAD\_PER\_TS\_PACKET} \times 100\%$$

In Figure 4 the following values were used:

$$PES\_HDR\_LEN = 10$$
$$TS\_PAYLOAD\_LEN = 184$$
$$TS\_PACKET\_LEN = 188$$
$$AAL\_OVERHEAD\_PER\_TS\_PACKET = 4$$

- end -