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Source: Till Halbach
Norwegian University of Science and
Technology (NTNU)
Trondheim, Norway

Tel: +47 - 73 59 44 88
Fax: +47 - 73 59 62 40
Email: halbach@tele.ntnu.no

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RWTH Aachen, Germany.)

Title: **TML-8.4 error resilience performance**

Purpose: Information

Introduction

The TML has undergone significant changes from version 6.x.x to the current 8.4. This document is meant to keep track of the TML's error robustness performance, to encourage further research on error robustness, and to provide anchor sequences for further testing. Previous reports with regard to error resilience are [J53] and [M56]. The first one discusses data partitioning under erroneous transmission, and the latter one shows the error resilience performance of TML-5.9 in an H.324 environment.

Applications & profiles

There exists a number of documents with partly confusing specifications. [L34d1] knows eight possible applications (PLE – Packet loss error, RBE – Residual bit error, EFC – Error-free case). One single document containing an overview of profiles and corresponding error robustness requirements/specifications would be desirable.

Profile	Description	Errors	Testing specs.
A	H.32x series systems (H.320, H.323, H.324)	PLEs	I62
B	3GPP conversational IP/RTP/SIP case	PLEs	M55
C	3GPP conversational H.324/M	RBEs	M55
D	3GPP streaming IP/RTP/RTSP	PLEs	M55
E	H.323 conversational, Internet/unmanaged/best-effort IP/RTP	PLEs	I60, I61
F	Streaming IP/RTP/RTSP, TCP-fallbackless	PLEs	
G	Entertainment, satellite/DVD.	EFC	
H	File format	EFC	

Table 1: Application overview

Concluding, we have mainly packet-wise transmission and packet loss errors on the channel. There is further one case with residual bit/burst errors which has not been investigated yet. The two cases of interest, profile A/E and profile C, are therefore considered in the following. The question is how the TML-8.4 performs when confronted with packet losses and residual

bit errors. These kinds of errors cover most of the errors encountered in today's mobile transmission systems. Packet loss errors mean that the channel works in nontransparent mode as erroneous packets (detected as such by the protocol's CRC check) are discarded, i.e. not delivered to the receiver. Residual bit/burst errors occur when the channel works in transparent mode as also packets marked as damaged are delivered to the receiver, resulting in bit or burst errors in the bit stream to decode.

There are a lot of parameters that affect the performance of the codec under error conditions. Generally, by means of a number of add-ons like FEC codes, a codec may reach a very robust status. However, the basic functionality of a system is of primary interest if the complexity has to be kept low. In order to keep the scope of this paper limited, too, this document thus intends to investigate the working of the latest TML in a very basic mode, i.e. with only 1 slice / picture, 1 partition / slice and without intra update.

This document follows mainly the error testing specifications as mentioned in [160]. Instead of looping the sequences, different starting positions for reading the error bit patterns are chosen. This can be interpreted as a certain seed when compared to a pseudo random number generator. For video sequences with a frame rate of 15 fps, 30 different seeds are applied, resulting in 4500 tested pictures. Accordingly, 7.5 fps and 30 fps correspond to a seed of 50 and 15, respectively. This is equal to testing 3750 and 4500 pictures. Because of the bit pattern looping, the requirement of skipping the first 256 bytes does not have to be followed. The QP was fixed in all experiments with the value 24 for both I-frames and P-frames. No B-frames were used. For the two profiles A/E and C, in total 16 permutations were investigated which are the ones mentioned in [160] and the corresponding error-free cases.

In order for the mux/demux simulator to be able to divide the bit stream into SDUs, the NAL had to be changed slightly. The packetizer is only able to read 4-byte picture/slice markers. Since the NAL writes a 31-bit code word as the appropriate header marker (the info being zero), a further 1-bit code had to be appended. The complete marker is then 0x00 00 00 03, and the packetizer was modified such that this marker could be read. Further, the packetizer was changed such that it does not longer copy also the marker itself into the SDU which is a superfluous bandwidth-requiring procedure. In future versions of the TML, the info will be different from zero, and the SDUs are written directly by the NAL.

TML8-4 error resilience performance

For testing of the different permutations given in [160], the most important not mentioned parameters also affecting the error robustness performance of the TML are:

QP = 24 (fixed for the whole sequence)

Search range = 16

No. of reference frames = 1

No intra update

1 Slice / frame

No B-frames

CABAC code symbols

1 Partition / slice

Nontransparent channel mode (packet losses)

It should further be mentioned that the PSNR as an objective evaluation criterion is not an optimal measurement parameter since a single error usually propagates through the pictures. The main assumption for PSNR, that the error in different pictures is uncorrelated, is then not fulfilled anymore.

For each test sequence, there is a table with results for I-frames and P-frames. Additionally, another table is given with information about the stability of the used codecs.

Bit pattern	<i>Hall Monitor</i> PSNR [dB]				<i>Foreman</i> PSNR [dB]			
	Max.	Arit.mean	Min.	Std.dev.	Max.	Arit.mean	Min.	Std.dev.
0-64	32.23	32.23	32.23	0.00	31.87	31.87	31.87	0.00
3-64	32.23	32.23	32.23	0.00	31.87	31.87	31.87	0.00
4-64	32.23	32.23	32.23	0.00	31.87	31.87	31.87	0.00
5-64	32.23	32.23	32.23	0.00	31.87	31.87	31.87	0.00
6-64	32.23	32.23	32.23	0.00	31.87	31.87	31.87	0.00
7-128	=	=	=	=	31.87	31.87	31.87	0.00
8-384	=	=	=	=	=	=	=	=

Table 2: I-frames, TML-8.4

Bit pattern	<i>Paris</i> PSNR [dB]				<i>Irene</i> PSNR [dB]			
	Max.	Arit.mean	Min.	Std.dev.	Max.	Arit.mean	Min.	Std.dev.
0-64	30.68	30.68	30.68	0.00	34.40	34.40	34.40	0.00
7-128	-	-	-	-	=	=	=	=
8-384	30.68	30.68	30.68	0.00	34.40	34.40	34.40	0.00

Table 3: I-frames, TML-8.4

From the tables for I-frames, it can be seen that the quality of the sequence is always as in the error-free case. The reason for this is that, if an I-frame is damaged, the whole decoding operation is terminated, and the corresponding PSNR values do hence not appear in the statistics. Other error measurements have therefore to be discussed in the future. See also tables 6 and 7.

Bit pattern	<i>Hall Monitor</i> PSNR [dB]				<i>Foreman</i> PSNR [dB]			
	Max.	Arit.mean	Min.	Std.dev.	Max.	Arit.mean	Min.	Std.dev.
0-64	31.67	31.67	31.67	0.00	31.54	31.54	31.54	0.00
3-64	31.67	30.54	23.69	1.69	31.54	28.31	23.68	2.59
4-64	31.67	31.32	26.14	1.19	31.54	30.16	22.24	2.68
5-64	30.74	27.19	23.34	2.09	25.18	21.46	18.41	1.60
6-64	31.67	30.72	26.33	1.56	31.54	28.07	21.41	2.74
7-128	=	=	=	=	27.57	22.18	18.03	2.24
8-384	=	=	=	=	=	=	=	=

Bit pattern	PSNR [dB]				PSNR [dB]			
	Max.	Arit.mean	Min.	Std.dev.	Max.	Arit.mean	Min.	Std.dev.
0-64	29,71	29,71	29,71	0,00	33,81	33,81	33,81	0,00
7-128	-	-	-	-	=	=	=	=
8-384	29.71	26.73	21.47	2.54	33.81	30.37	26.48	2.00

Table 4: P-frames, TML-8.4

Table 5: P-frames, TML-8.4

The P-frames of the H.26L show a reasonable averaged performance except for the cases of the two error patterns that contain a high overall bit error rate and/or are of a very bursty character, 5-64 and 7-128. The 7-128 case for *Paris* discovered that, for each of the 30 different seeds, the decoder was terminated before the regular end of the sequence. Thus,

Bit pattern	<i>Hall Monitor</i>			<i>Foreman</i>		
	lost packets	Percentage of syst. breakd.	term. dec.op.	lost packets	Percentage of syst. breakd.	n. dec.op.
0-64	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %
3-64	5,3 %	0,0 %	3,0 %	0-7%	0,0 %	4,0 %
4-64	3,3 %	0,0 %	0,0 %	0-5%	0,0 %	2,0 %
5-64	2-12%	0,0 %	33,0 %	7-23%	0,0 %	46,0 %
6-64	0-3.3%	0,0 %	6,0 %	0-11%	0,0 %	4,0 %
7-128	=	=	=	5-25%	0,0 %	38,0 %
8-384	=	=	=	=	=	=

results are lacking completely. One can see that sequences containing a lot of motion (here: *Foreman*) are especially prone to errors.

Bit pattern	<i>Paris</i>			<i>Irene</i>		
	lost packets	Percentage of syst. breakd.	term. dec.op.	lost packets	Percentage of syst. breakd.	n. dec.op.
0-64	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
7-128	-	0.0 %	100.0 %	=	=	=
8-384	0-10.7%	0.0 %	12.0 %	0-8.3%	0.0 %	6.0 %

Table 6: Other codec performance parameters, TML-8.4

Table 6: Other codec performance parameters, TML-8.4

The last two tables have been added to the PSNR results to provide a better robustness evaluation. They show that – in contrast to the case of residual errors which is addressed later- the decoder works without breakdown. However, it is quite often terminated before the end of the sequence. The H.26L's performance on this field can hence still be greatly improved. The column with the number of discarded packets documents that the decoder termination is correlated with the amount of lost packets.

UVLC vs. CABAC

When the TML-8.0 was released, a performance PSNR difference of 1-2 dB between the two symbol modes UVLC and CABAC could be observed in general for the packet loss case in favor for the universal code table. However, TML-8.4 improved greatly in terms of error robustness. This paragraph is meant to mirror the changes.

As mentioned before, the profiles A/E and C (packet loss errors and residual bit errors) are discussed. Other important codec parameters are:

Sequence: *Foreman*
 Format: QCIF
 Search range = 16
 No. of reference frames = 1
 No B-frames
 No intra update
 1 slice / frame
 1 Partition / slice

Frame rate = 10 fps
 QP = 24 (fixed for the whole sequence)

First, the channel is employed in nontransparent mode, i.e. damaged packets are not passed to the decoder.

Bit pattern	UVLC PSNR [dB]				CABAC PSNR [dB]			
	Max.	Arit.mean	Min.	Std.dev.	Max.	Arit.mean	Min.	Std.dev.
0-64	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
3-64	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
4-64	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
5-64	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
6-64	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
7-128	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
8-384	-	-	-	-	-	-	-	-

Table 7: I-frames, PLEs

One can see that the PSNR performance for I-frames of the two modes is almost equal. However, with the effective bit rate at 10 fps being 30.30 Kbps for UVLC and 28.42 Kbps for CABAC, the arithmetic codec gains approximately 2 Kbps. The reason for the same PSNR values also for the lossy transmission is the same as stated above.

Bit pattern	UVLC PSNR [dB]				CABAC PSNR [dB]			
	Max.	Arit.mean	Min.	Std.dev.	Max.	Arit.mean	Min.	Std.dev.
0-64	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
3-64	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
4-64	31.87	31.77	27.25	0.68	31.87	31.79	28.66	0.50
5-64	31.87	31.54	30.11	0.71	-	-	-	-
6-64	31.87	31.87	31.87	0.00	31.87	31.87	31.87	0.00
7-128	31.87	27.30	16.64	6.81	-	-	-	-
8-384	-	-	-	-	-	-	-	-

Table 8: P-frames, PLEs

It is observed here that the results for P-frames are inconsistent. Sometimes UVLC outperforms CABAC, but generally CABAC is slightly better. So the 1-2 dB gain of UVLC has vanished from the version release 8.0 to 8.4. Further information about the decoder's error robustness might give another table. It shows that CABAC and UVLC decoder use/discard different packets. This makes a direct comparison complicated. More, the different number of lost packets points to an inconsistency in the mux/demux software since the decision – whether or not to throw away a certain packet – is made there. One can see, however, that less packets are discarded and decoding is less often terminated in UVLC mode.

Table 9: Other statistics, PLEs

Bit pattern	UVLC Percentage of			CABAC Percentage of		
	lost packets	syst. breakd.	term. dec.op.	lost packets	syst. breakd.	term. dec.op.
0-64	0 %	0 %	0 %	0 %	0 %	0 %
3-64	0-7%	0 %	6 %	0-7%	0 %	4 %
4-64	0-5%	0 %	2 %	0-5%	0 %	2 %
5-64	9-24%	0 %	46 %	7-23%	0 %	46 %
6-64	0-9%	0 %	4 %	0-11%	0 %	4 %
7-128	4-19%	0 %	19 %	5-25%	0 %	38 %
8-384	-	-	-	-	-	-

Bit pattern	UVLC PSNR [dB]				CABAC PSNR [dB]			
	Max.	Arit.mean	Min.	Std.dev.	Max.	Arit.mean	Min.	Std.dev.
0-64	31.57	31.57	31.57	0.00	31.54	31.54	31.54	0.00
3-64	31.57	28.39	22.71	2.64	31.54	28.31	23.68	2.59
4-64	31.57	30.13	20.84	2.91	31.54	30.16	22.24	2.68
5-64	24.25	21.49	17.28	1.57	25.18	21.46	18.41	1.60
6-64	31.57	27.93	22.09	2.78	31.54	28.07	21.41	2.74
7-128	28.84	22.61	18.36	2.22	27.57	22.18	18.03	2.24
8-384	-	-	-	-	-	-	-	-

Table 10: I-frames, RBEs

Now, the channel is considered to be transparent, i.e. it allows residual bit errors but no packet losses anymore. There may be errors (see also tables 12 and 13) that are not recognized as such which leads to continuation of the decoding process and not its termination. When this happens, the decoder often crashes which clearly demonstrates a weakness of the TML-8.4 software. For the patterns 5-64 and 7-128, the damage of P-frames was too strong for the CABAC that not a single normal decoder termination could be accomplished. For I-frames, UVLC performs slightly better than CABAC. It is stressed that minimum and maximum values have been averaged over all seeds as well and can hence not be compared directly. Because of the terminations, a direct comparison between tables 11 and 8, and 12 and 9 is impossible.

Bit pattern	UVLC PSNR [dB]				CABAC PSNR [dB]			
	Max.	Arit.mean	Min.	Std.dev.	Max.	Arit.mean	Min.	Std.dev.
0-64	31.57	31.57	31.57	0.00	31.54	31.54	31.54	0.00
3-64	31.57	28.65	15.02	4.12	31.54	29.99	25.61	1.93
4-64	31.57	30.31	22.28	2.77	31.54	30.70	17.12	2.86
5-64	22.94	21.12	19.70	1.27	-	-	-	-
6-64	31.57	28.95	22.25	2.94	31.54	29.84	21.06	2.48
7-128	27.87	23.03	16.03	4.98	-	-	-	-
8-384	-	-	-	-	-	-	-	-

Table 11: P-frames, RBEs

Considering again P-frames, the CABAC performs surprisingly slightly better. Also, the PSNR results do not vary as much as for UVLC.

Bit pattern	UVLC			CABAC		
	lost packets	Percentage of syst. breakd.	term. dec.op.	lost packets	Percentage of syst. breakd.	m. dec.op.
0-64	0 %	0 %	0 %	0 %	0 %	0 %
3-64	0 %	32 %	0 %	0 %	52 %	0 %
4-64	0 %	8 %	0 %	0 %	19 %	0 %
5-64	0 %	88 %	0 %	-	100 %	-
6-64	0 %	18 %	0 %	0 %	56 %	0 %
7-128	0 %	90 %	0 %	-	100 %	-
8-384	-	-	-	-	-	-

Table 12: Other statistics, RBEs

Also here, the UVLC presents himself as more robust to residual errors. A reason for this behavior might be the fact that, for the UVLC, quite many info bits are affected which leads to only a single corrupted code word but no synchronization loss. In the CABAC, however, the error is by means of the contexts and the fractional code word length ability spread over several symbols at once which finally leads to synchronization loss.

Summary

This document discussed some of the error resilience performance abilities of the TML-8.4. It is especially stressed that UVLC performs more robust to residual bit errors due to its inherent code word structure, the resynchronization property, and the assumption of not correlated source symbols. However, since no advanced error concealment strategies are specified yet, further research is necessary to enhance the performance of the UVLC even further.

Also, as mentioned before, there are also other parameters of interest, like the intra update rate, the number of slices and the partitioning scheme which influence the performance of the decoder under error conditions and which should be included in future experiments.

References

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