Low complexity H.264 list decoder for enhanced quality real-time video over IP

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Outline

- Introduction
- Problem statement
- Literature review
- Proposed approach
- Experimental setup and results
- Conclusions

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Problem statement

Unreliable Channels ⇨ **Transmission Errors** ⇨ **Visual Quality Degradation**

- Corrupted Video Packets (bit errors)
  (e.g. attenuation, multi-path fading)
- Lost Video Packets
  (e.g. network congestion)

- **Compressed video streams are very vulnerable to errors**

Time

Motion-compensated prediction process ⇨ **Error propagation** in compressed video!

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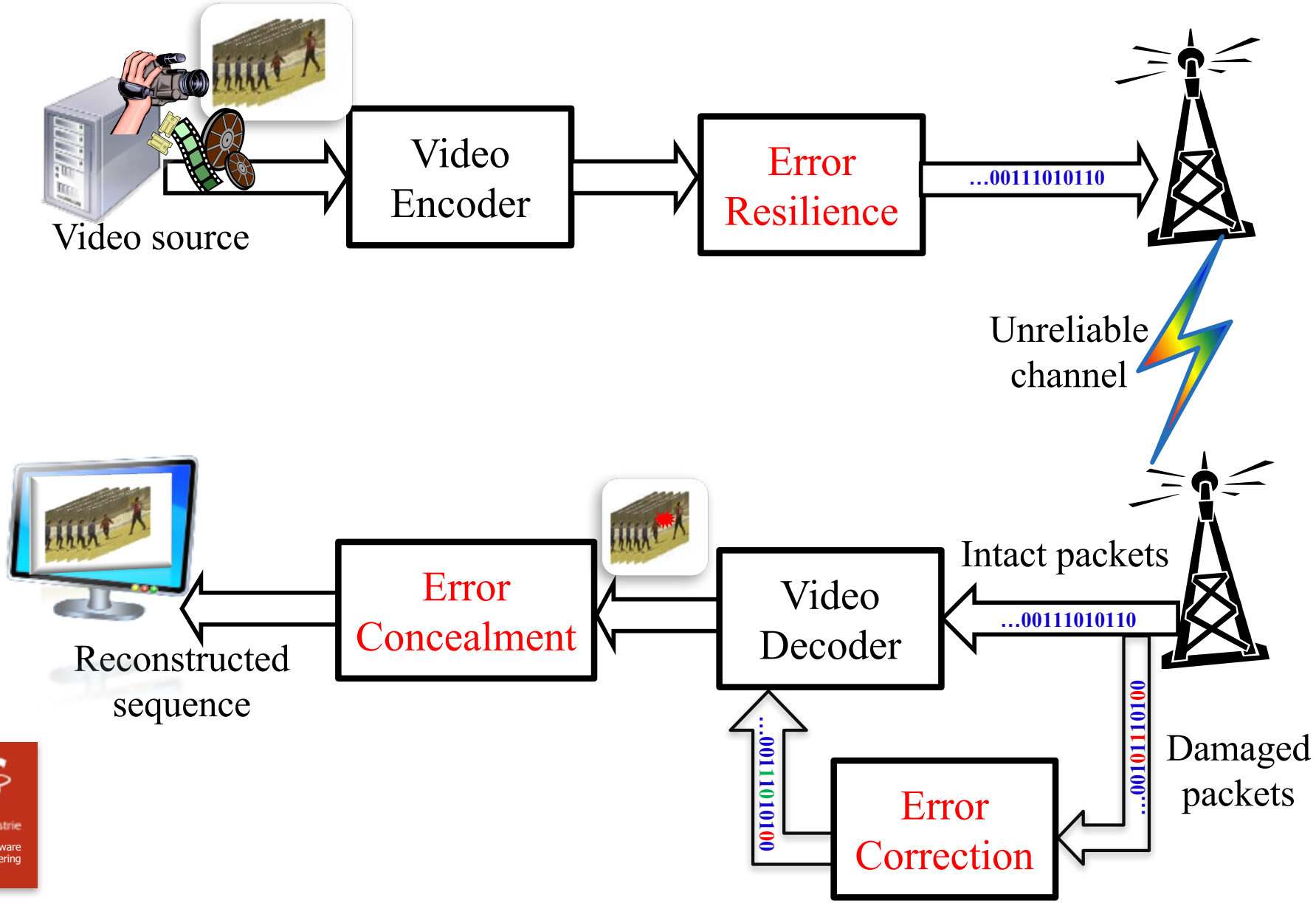
Literature review

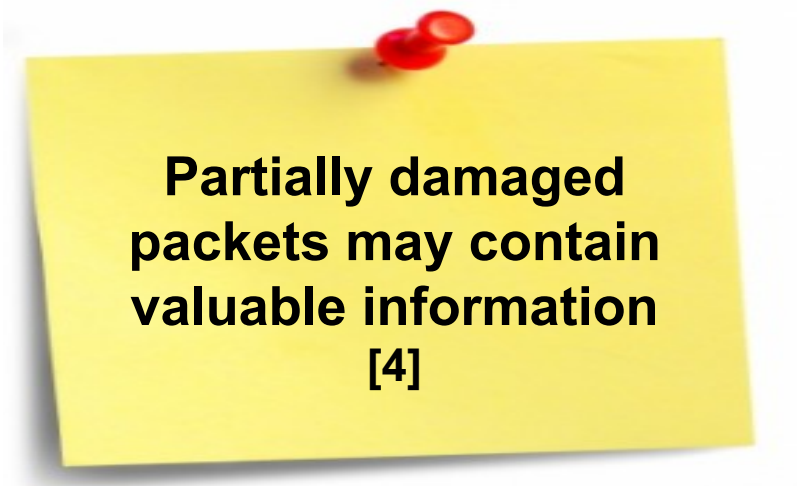


Literature review

❑ Error Concealment:

Estimates missing pixels by using

- **Spatial correlation [1]**
- **Temporal correlation [2]**
- **Both spatial and temporal correlation**
  - ➢ - spatio-temporal boundary matching and partial differential equation **(STBMA) [3]**



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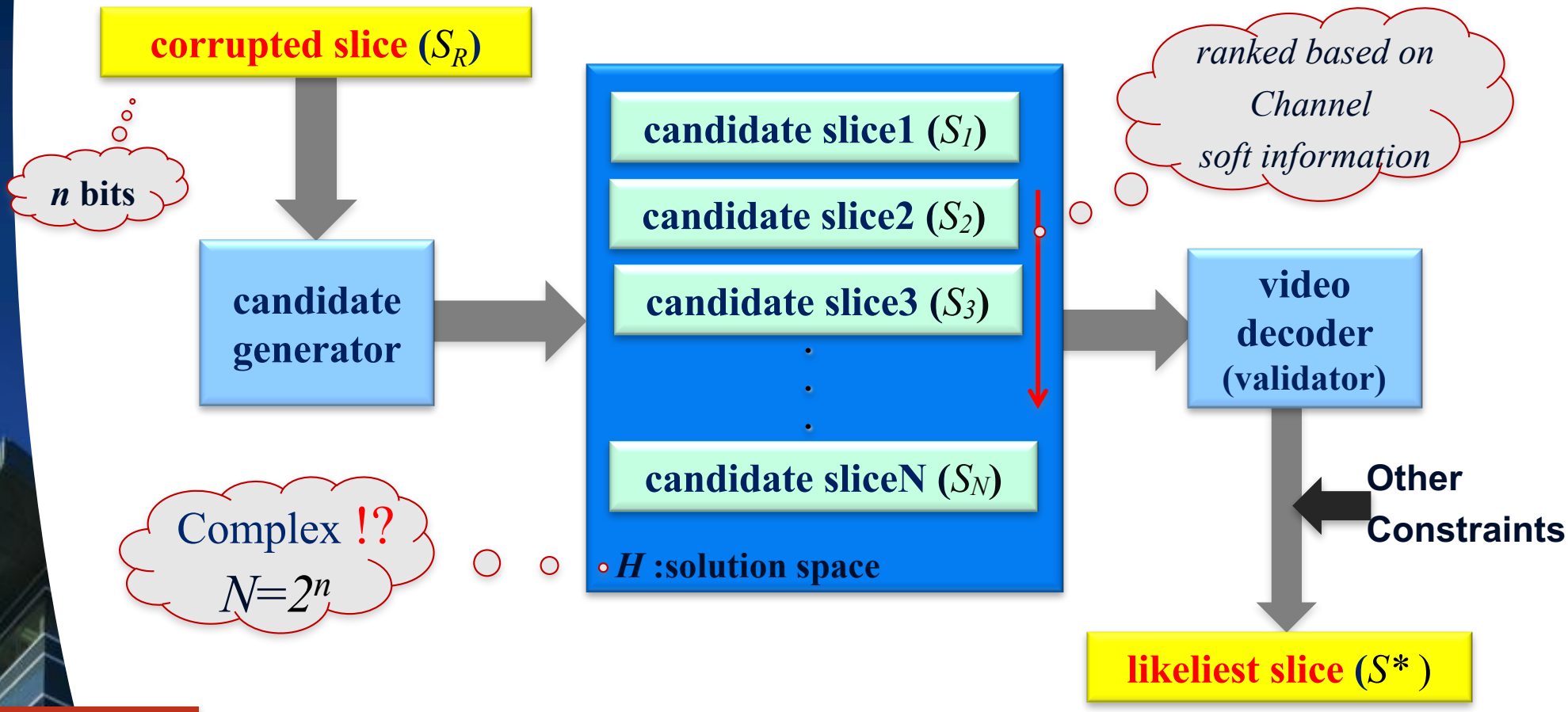
[1] J. Liu, et al., "Spatial error concealment with an adaptive linear predictor", 2015.
[2] J. Zhou, et al., "Efficient motion vector interpolation for error concealment of H.264/AVC", 2011.
[3] Y. Chen, et al., "Video error concealment using spatio-temporal boundary matching and partial differential equation", 2008.
[4] L. Superiori, et al., "Performance of a H.264/AVC error detection algorithm based on syntax analysis", 2006.

Literature review

❑ Error Correction: List decoding



[5] D. Levine, et al., "Iterative joint source-channel Decoding of H.264 compressed video", 2007.

[6] N. Nguyen, et al., "Iterative joint source- channel decoding for H.264 video transmission using virtual checking method at source decoder", 2010.

[7] G. Sabeva, et al., "Robust decoding of H.264 encoded video transmitted over wireless channels", 2006.

[8] C. Weidmann, et al.," Combined sequential decoding and error concealment of H.264 Video", 2004.

[9] R. A. Farrugia , et al.," Robust decoder-based error control strategy for recovery of H.264/AVC video content", 2011.

Literature review

❑ Error Correction: Syntax Level

Soft/Hard Output Maximum Likelihood Decoding (SO/HO-MLD) [10]

- Generate only a set of valid candidates at the correction process of each syntax element
- Any mistake in the decoding of a syntax element will propagate and reduce the performance

Lack of access to the soft information in the application layer

(complex to implement)

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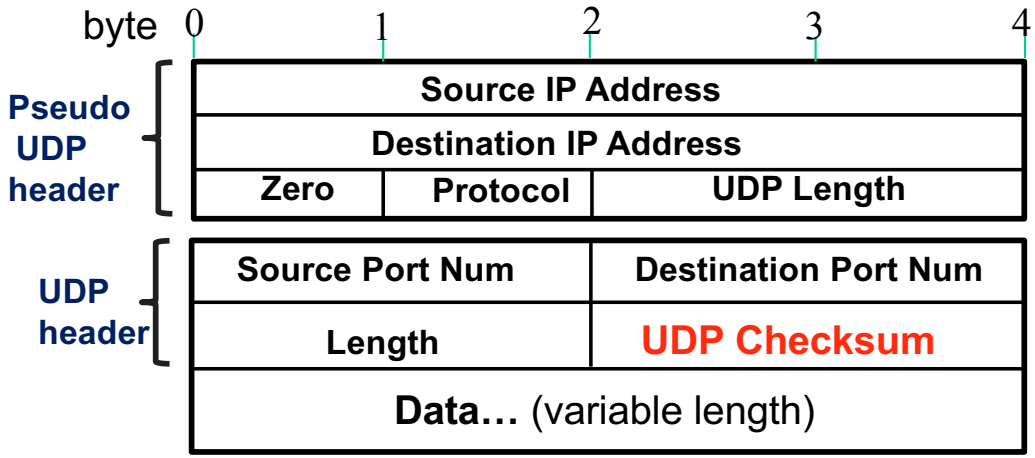
[10] F. Caron, et al., "Video error correction using soft-output and hard-output maximum likelihood decoding applied to an H.264 baseline profile", 2015.

Proposed approach

- Reduction candidate list by analyzing the calculated UDP checksum value at the receiver side.

Checksum: ***verify the integrity*** of the delivered message

UDP checksum: one's complement of the one's complement sum of a *pseudo UDP header*, *UDP header* and application *data message*.



Proposed approach

TRANSMISSION

Bit Position	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Packet 1	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**

Bit Position	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Second 16-bit word	0	0	1	0	0	1	1	0	1	1	0	1	0	0	0	1
First 16-bit word	1	1	0	0	1	1	0	0	1	0	0	1	1	0	0	0
Ones's compl. Sum	1	1	1	1	0	0	1	1	0	1	1	0	1	0	0	1
Checksum (C_T)	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**1**	**0**

$$C_T = \overline{\sum_{i=0}^{m-1} W_i}$$

16-bit word

UDP checksum calculation:

- Divide the packet into chunks of 16-bit words.
- Compute one's complement sum over all the words.
- Flip all the bits of the final sum (one's complement).

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Proposed approach

RECEPTION

Bit Position	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Packet 1	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**

Bit Position	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Second 16-bit word	0	0	1	0	0	1	1	0	1	1	0	1	0	0	0	1
First 16-bit word	1	1	0	0	1	1	0	0	1	0	0	1	1	0	0	0
Ones's compl. Sum	1	1	1	1	0	0	1	1	0	1	1	0	1	0	0	1
Checksum (C_T)	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**1**	**0**
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Checksum(C_R)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

The zero value of C_R validates the received packet.

If no error:

$$C_R = \overline{\sum_{i=0}^{m-1} \hat{W}_i + \hat{C}_T}$$

$$= \overline{\sum_{i=0}^{m-1} \hat{W}_i + \overline{\sum_{i=0}^{m-1} W_i}} = \overline{\sum_{i=0}^{m-1} (W_i + \overline{W}_i)}$$

$$= \overline{FFFF} = 0000$$

the received versions of W_i and C_T are denoted as $\hat{W}_i$ and $\hat{C}_T$

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Proposed approach

TRANSMISSION

Bit Position	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Packet 1	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**

RECEPTION — **Corrupted**

Bit Position	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Packet 1	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**

Bit Position	15	14	13	12	11	**10**	9	8	7	6	5	4	3	2	1	0
Second 16-bit word	0	0	1	0	0	**0**	1	0	1	1	0	1	0	0	0	1
First 16-bit word	1	1	0	0	1	1	0	0	1	0	0	1	1	0	0	0
Ones's compl. sum	1	1	1	1	0	**1**	1	1	0	1	1	0	1	0	0	1
C_T	0	0	0	0	1	1	0	0	1	0	0	1	0	1	1	0
	1	1	1	1	1	**0**	1	1	1	1	1	1	1	1	1	1
Checksum(C_R)	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Non-zero value of C_R : received packet is corrupted.

The checksum is indication the position of the error in modulo 16.

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Proposed approach

Error Type	C_R	C_R Patterns
$1_j \longrightarrow 0_j$	000 . . . 010 . . . 000 Col. 15 j 0	1000 0000 0000 0000 0100 0000 0000 0000 . . 0000 0000 0000 0001
$0_j \longrightarrow 1_j$	111 . . . 101 . . . 111	0111 1111 1111 1111 1011 1111 1111 1111 ⋮ 1111 1111 1111 1110

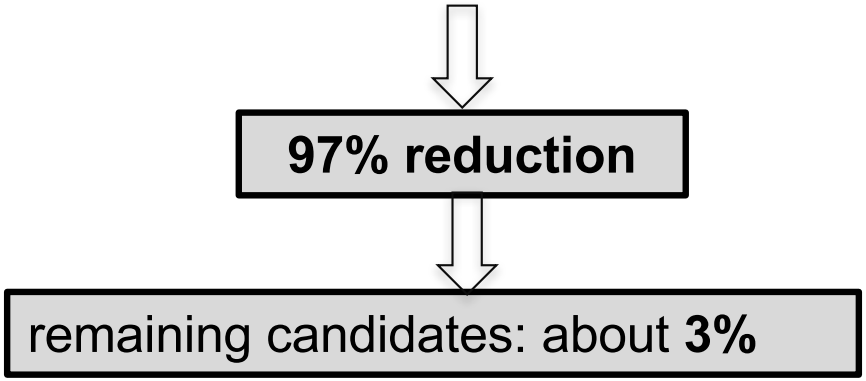
The C_R pattern :

- **potential error columns in the words**
- **type of the flipped bits**

Candidate Reduction

One bit in error in a packet of *N* bits:

- Traditional list decoding approaches: ***N*** candidates
  - proposed approaches: ***N/32*** candidates.



Packet length (bits)	Average number of candidates		Eliminated candidates
	List Decoding	Proposed	
272	272	9	97%
768	768	24	97%
1120	1120	35	97%
5280	5280	165	97%

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Simulation setup

❖ Coding Parameters:

- **Baseline** profile of H.264 (simulator: **JM** software v.18.5)
- First 60 Frames of sequence: *Foreman* (352x288), *Crew* (704x576), *Opening Ceremony, Walk* (720x576).
- Coded in **IPPP…** format, Intra refresh rate of **30** frames, quantization parameters (QPs): 22, 27, 32, and 37
- Each slice (= a single row of MBs), encapsulated into RTP packets.
- UDP checksum calculated on RTP packet

❖ **Corrupted frame: 31th-59th randomly**

❖ **Channel bit error rate (BER): [10^{-7}, 10^{-6}]: one bit error**

❖ Decoding Options :

Error Concealment: Frame Copy (**FC-JM**)
Spatio Temporal Boundary Matching (**STBMA**)

Error Correction: Maximum likelihood Decoding (**HO-MLD**)
Proposed List Decoding (**Proposed**)

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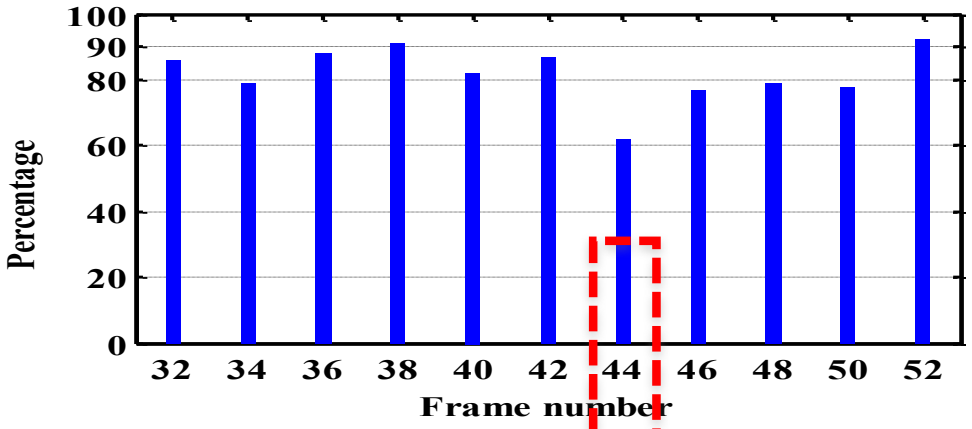
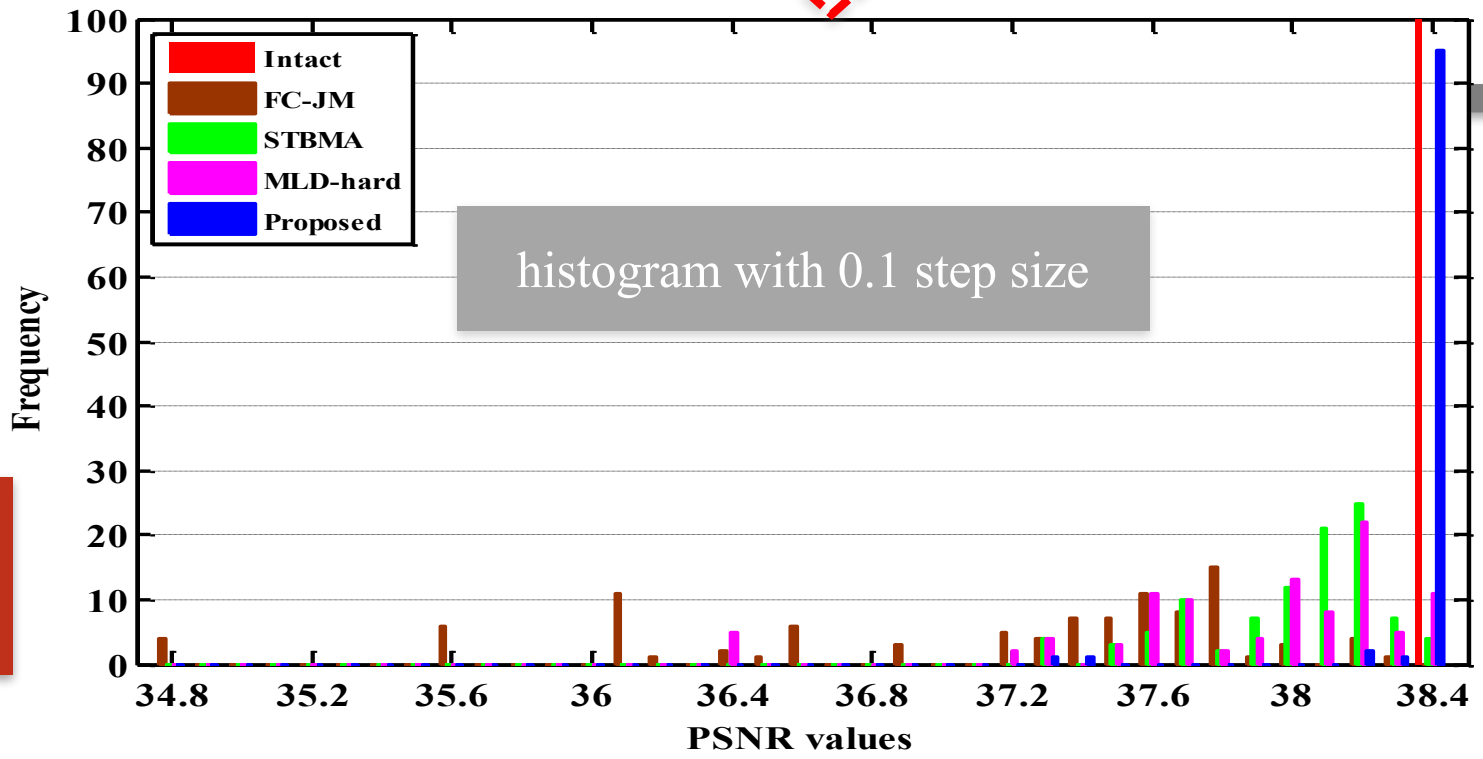
Seq: Crew, QP 27

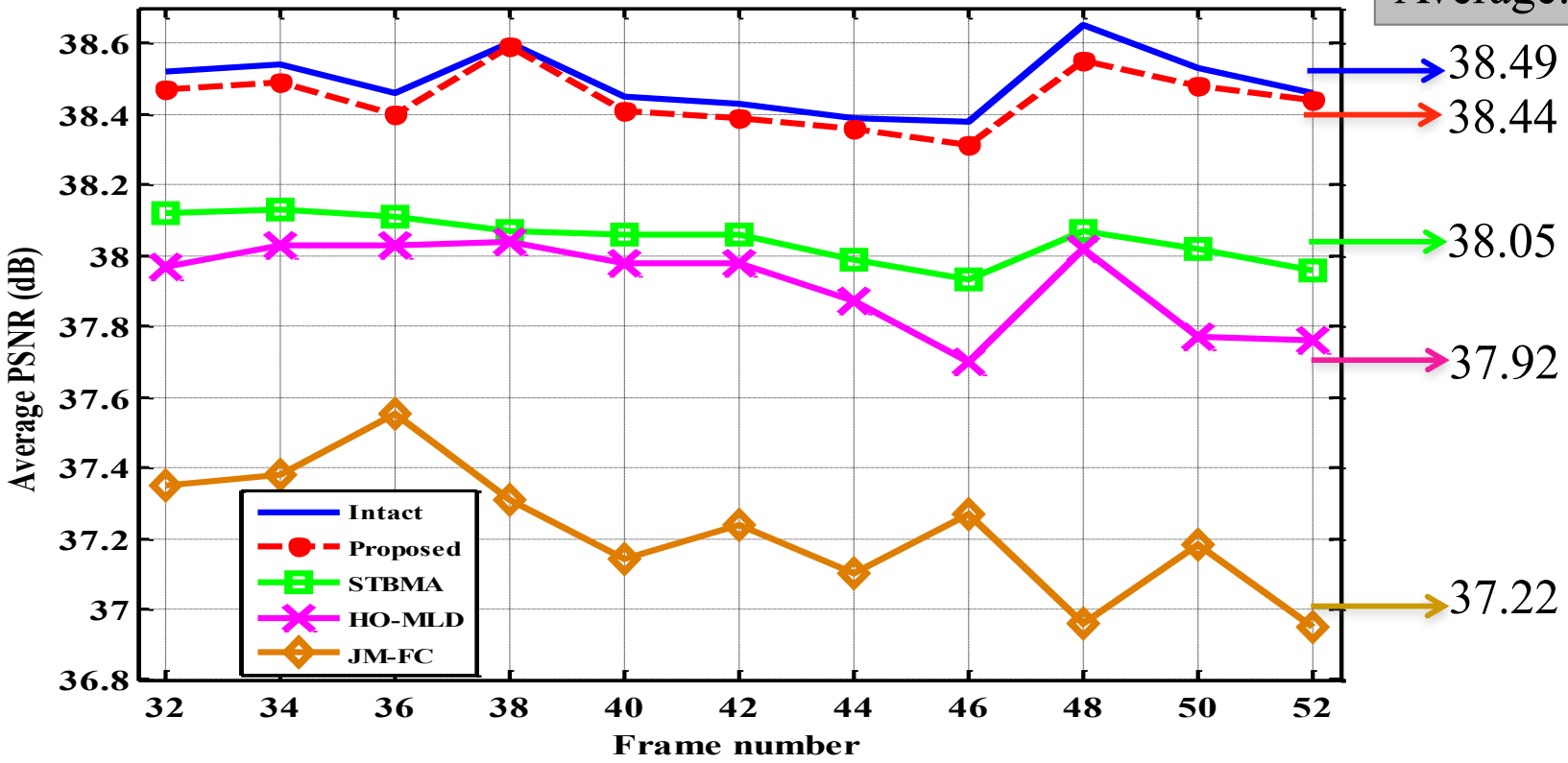


95% very close PSNR to the intact one.



histogram with 0.1 step size

Seq: Crew, QP 27



Average:

38.49

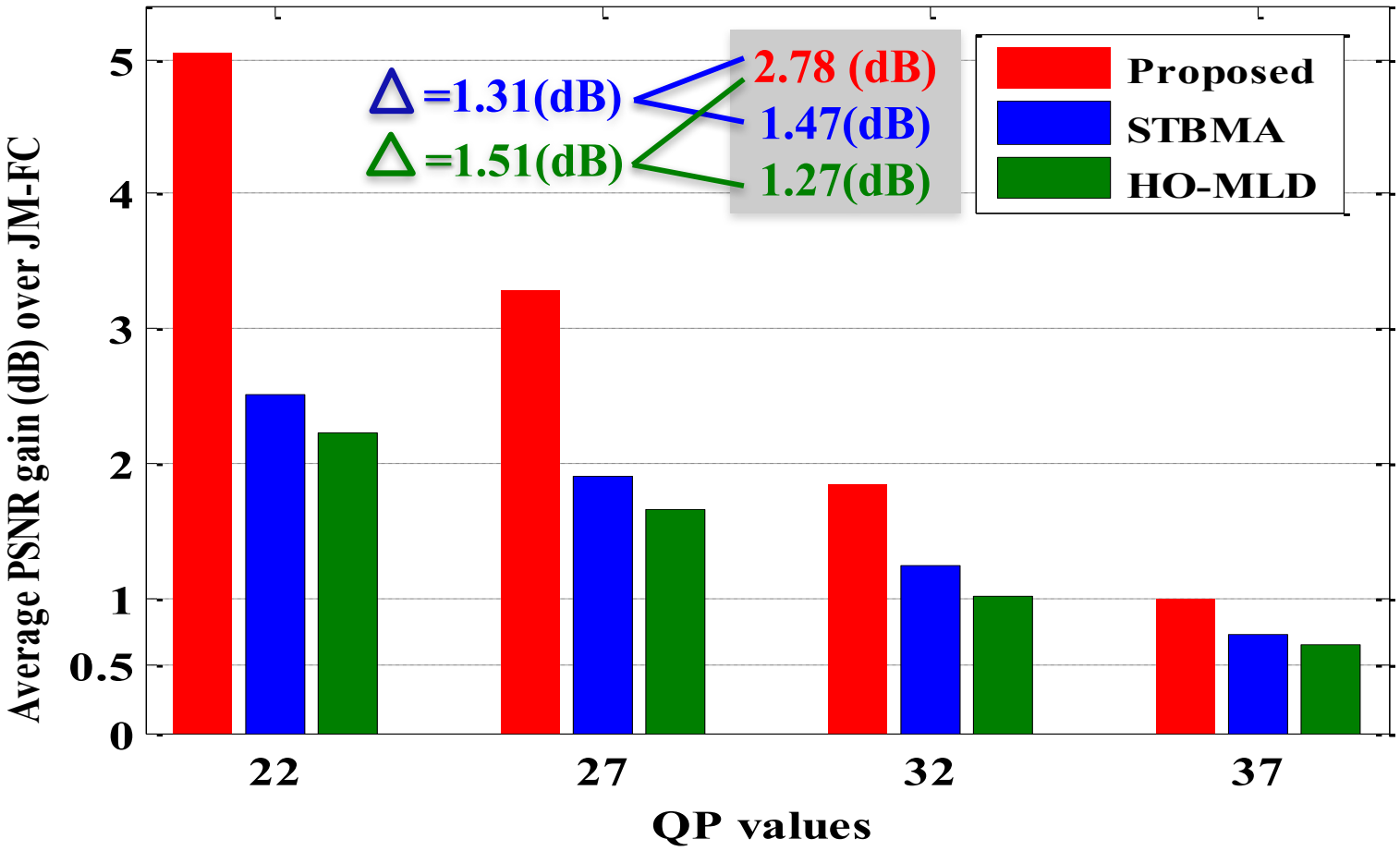
38.44

38.05

37.92

37.22

PSNR gain over JM-FC

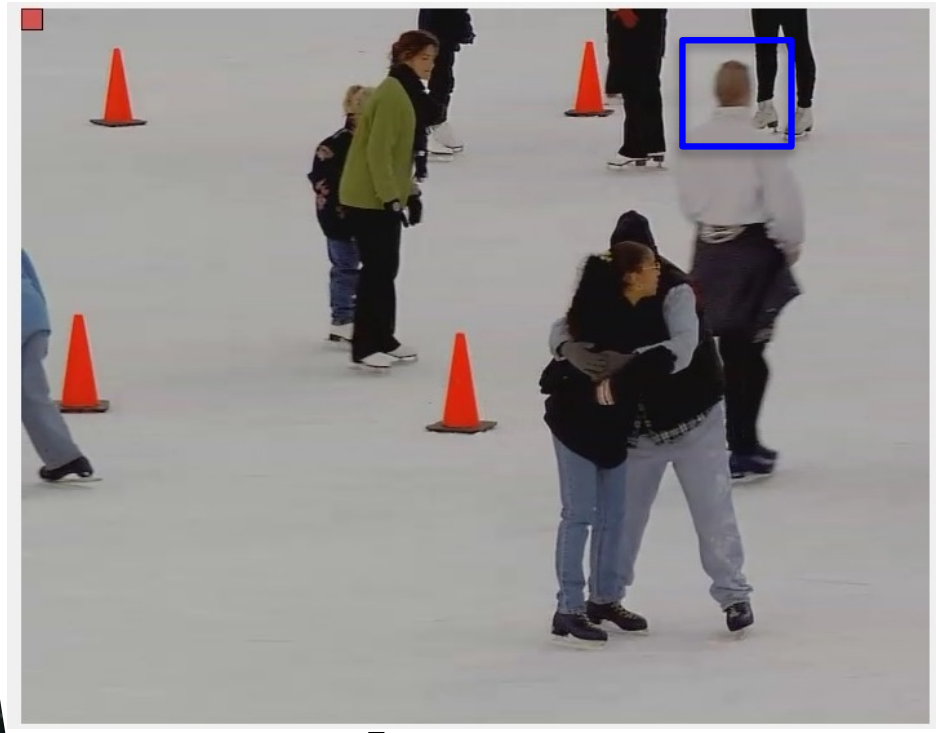


- Percentage of fully correcting bitstream:

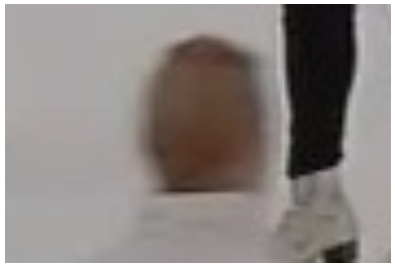
  Proposed approach: **80%**

  HO-MLD approach: **6%**

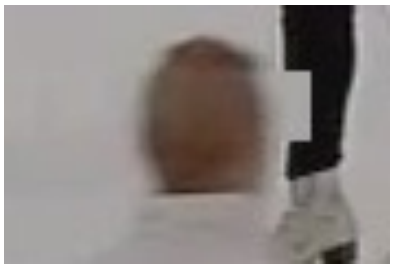
Visual quality comparison



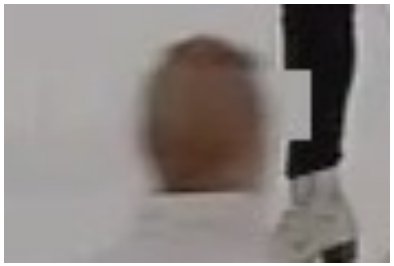
Intact



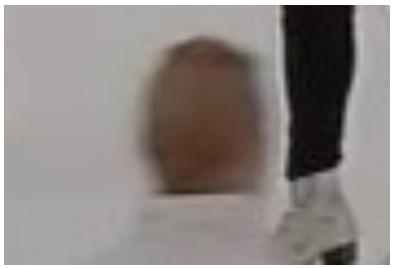
JM-FC



STBMA



HO-MLD



Proposed

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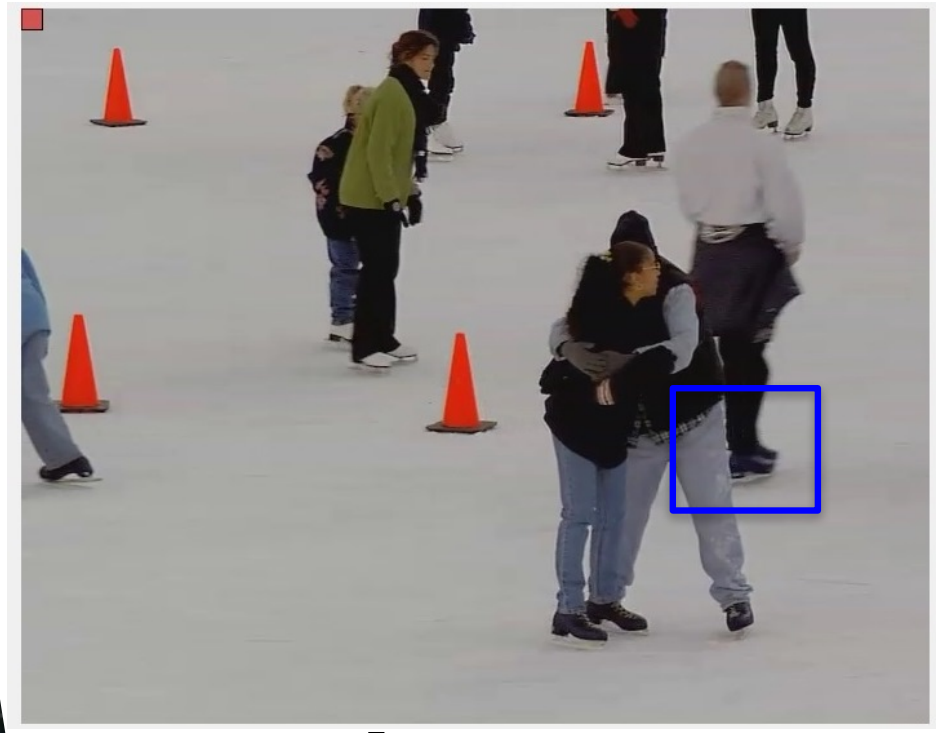
Visual quality comparison



Intact

JM-FC

STBMA

HO-MLD

Proposed

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Conclusions

One bit in error:

- Candidate reduction from *N* to *N/32*;
- Complexity reduction : **97%**

On average**:**

- ***2.78*** **dB** gains over **JM-FC**
- ***80%*** fully corrected packet

❑ Future step:

- The proposed approach can also be applied on HEVC coded sequences, and it can be extended to the case of more than one bit in error [1].

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[1] F. Golaghazadeh,, et al., "Checksum-filtered list decoding applied to H.264 and H.265 video error correction", 2017.

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