Quality Assessment Experiment for 4k SVT-AV1 Video Format

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Abstract — **The industrial consortium AOMedia has recently developed the AV1 (AOMedia Video 1) format considered as a successor of VP9. One of the main goals with the video coding and compression format is to enable efficient web based video content delivery, as in the case of OTT (Over-the-top) services. Nowadays, there are different AV1 software implementations available for experimental analysis besides the reference tool libaom. The Scalable Video Technology for AV1, or SVT-AV1 codec, is oriented towards further optimizations for specific Intel hardware. In this paper, we have performed a video quality assessment experiment with some of the SVT-AV1 implementations using 4k like video. The results show the advantages of SVT-AV1 format, as well as its performance for different quantization factors.**

Keywords — **SVT-AV1, Quality Assessment, Mp4, 4k, internet, VP9, HEVC, Streaming services.**

I. Introduction

THERE are many valuable markets where new video coding formats directly oriented towards web based delivery and internet video services are valuable [1]-[5]. IP (Internet Protocol) based video delivery for smart television and Over-The-Top (OTT) services that bypass standard broadcasting approaches are typical examples where there is a need for efficient video compression and distribution. Video and multimedia content providers are interested in new coding solutions that are able to adapt to requests made by consumers, as in Video on Demand (VoD) cases. Moreover, personalized video services should suit the requirements of the clients.

New coding and compression standards are expected to be widely adopted and enabled on numerous devices, such as smart phones and television receivers. Particularly, they should be enabled on web browsers used as standard User Interfaces (UIs).

Video based surveillance, video conferences, VoD services, usage of mobile/wireless delivery technologies and many other aspects contribute to the fact that the video content distribution takes a large part of telecommunication traffic. Thus, new standards should be guided by resolving memory bottlenecks and greater workloads. This means that scalable solutions are necessary for content delivery networks (CDNs), having in mind hardware based optimizations [3].

Advanced Video Coding (AVC) is still very popular for video coding and decoding, where the H.264/AVC standard video codecs are widely used in most of the applications [5]. Generally, the H.264/AVC format is considered as mp4 file with AVC coding implemented [6]. A multimedia container such as mp4 is one of the most popular formats famous for sharing multimedia content on internet, as well as for its support among devices and players [7]. Another standard proposed by MPEG (Motion Picture Experts Group) and ITU (International Telecommunication Union) is High Efficiency Video Coding (HEVC) or H.265.

On the other side, there are open-source standards like VP9 and AV1, which are considered as royalty-free [8-9]. Google's VP9 format made a major breakthrough compared to HEVC and licensing issues. Another open-source solution initially released by AOMedia (Alliance for Open Media) in 2018 is AV1 [8], [2]. This industrial consortium AOMedia developed a format called AV1 (AOMedia Video 1) as a successor of VP9. Leading companies, such as: Google, Microsoft, Intel, Netflix, Cisco, YouTube, Facebook, Amazon, share the same interest in video based internet traffic [2].

According to Cisco Visual Networking Index more than eighty percentage of world's internet traffic will be dedicated to video by 2022 [2]. So, open-source, royalty-free and interoperable solutions, like AV1, are important for the future of video streaming and the next generation media delivery.

In 2019, Intel and Netflix started their collaboration on Scalable Video Technology (SVT) solution [3, 10]. For example, decreasing the time needed for coding is one of necessities for high-performance implementations. The Open Visual Cloud project considers core building blocks for visual cloud services delivery, such as encoding and decoding [10]. SVT as a software-based video coding technology can be implemented for different compression formats, such as AV1. Video input resolutions of 4Kp60, with code words of 8/10bit are supported [11].

In this paper, an experiment is performed using SVT-AV1 and several high resolution or 4k like sequences in mp4 format. In addition, a comparison is made to some related coding formats, like VP9. The experiment is performed without using specific hardware intended for optimization. In the experiment, the behavior of an

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implementation of SVT-AV1 format is analyzed for different quantization levels.

The paper is organized as follows. After the introduction, in Section II the basics related to AV1 and SVT-AV1 formats are explained. In Section III, some of the quality assessments (QA) metrics have been considered. This is followed by a particular simulation explanation based on 4k like video sequences in Section IV. The conclusions and the possibilities for future work are given in Section V.

II. AV1 and SVT-AV1 Coding Formats

A. *Video communication and AV1 format*

One of the global responses to the interruption due to spreading of COVID-19 is a greater usage of video communication. People across the globe found video communication as necessary for different kinds of work, connection with colleagues and friends, as well as for education purposes [12]. There has been a significant increase of video data due to video production trends. Video contribution has arisen around the world, and a greater amount of video data has been processed, distributed and stored. All of this resulted in a need for a higher video compression efficiency and new format besides HEVC and VP9. Novel web applications and services require ultra low latency and properly allocated resources for video processing tasks [13].

AV1 (AOMedia Video 1) bit stream (bitstream) already found its way for many applications and services [2], [14]-[15]. AV1 is considered as an open-source royalty-free format, where the next-generation solution is expected to bring 30 to 50 percent bit-rate savings at the same quality level compared to Google's widely adopted VP9. This can be of interest to high-quality video streaming, gaming, television, video calling, web browsers as well as to reality continuum services (AR- Augmented Reality, VR - Virtual Reality, MR - Mixed Reality). Moreover, intellectual property and digital rights management should be considered for the time to come.

AV1 is being primarily based on VP9 in order to be useful for video streaming, OTT, VoD, UHD (Ultra High Definition) and other cloud-based services. It supports a container-based approach with functionalities similar as in architecture found in HEVC [8]-[9]. The developers had in mind that the new format needs to be suitable for new technologies as well, like HDR (High Dynamic Range) and WCG (Wide Color Gamut).

AV1 brought many changes, which produced the gains of the new format [2], [8], [14]. To be more precise, not one but several different formats for compression efficiency have been developed under the umbrella of the AV1 format. Some of them are intended for browser and player support, media info and streaming platform support, for developers and ffmpeg implementations, for specific open-source encoding (like rav1e [16]) and decoding (like dav1d [17]), etc. For example, rav1e is considered as a fast (compared to reference libaom [18]) and safe solution for encoding, whereas for dav1d the goal is to provide a fast av1 decoder for most platforms. Google has recently announced another decoder named libgav1 [19]. One of the solutions is the Scalable Video Technology (SVT) for AV1 (SVT-AV1) for both encoding and decoding. Intel and Netflix started their collaboration in order to target VoD and Live encoding, while the decoder is considered as a part of secondary research activities [2], [20].

Moving towards AV1 has occurred at many platforms. There has been a support for AV1 in MP4 available in Chrome 70 and FireFox 63 builds [21]. Standard AV1 can be selected as a preferred one for SD (Standard Definition) or even HD (High Definition) content, or can be set to be chosen automatically [22]. So, nowadays, such AV1 changes can be observed on YouTube, as showed by Stats for Nerds in Fig.1 for Blender Foundations' Big Buck Bunny video [23]. Here, av1 codec is used for representations up to 1080p60 (red rectangle in Fig.1), whereas vp9 is found for higher quality (1440p60, 2160p60). For Sintel and Tears of Steel content [24]-[25] both av1 and vp9 usage is shown, for the automatic AV1 setting selected (Fig. 2).

Fig. 1. Big Buck Bunny 60fps 4K - Official Blender Foundation Short Film [23]; Stats for Nerds for: 720p60 (av1), 1080p60 (av1), 1440p60 (vp9), 2160p60 (vp9) representations, respectively (column-wise).

Fig. 2. Sintel (left) and Tears of Steel (right) - Blender Foundation [24, 25]; Stats for Nerds for: Sintel 480p (av1), Sintel 1080p (av1); Tears of Steel 480p (vp9), Tears of Steel (vp9), respectively (column-wise).

B. *AV1 format characteristics*

AV1 encoder is an open source solution characterized by scalability having in mind applicability on multicore platforms, using different lengths of code words, latency trade-offs, and similar [1]-[2], [13]. While VP9 uses blocks of 64x64 pixels, AV1 introduces superblocks (SBs) of 128x128 pixels. Also, VP9 uses four-way partitioning, whereas AV1 enables further partitioning with recursive (R) partitioning as shown in Fig.3. Superblock application and illustrated tree-based partitioning characterize AV1 approach.

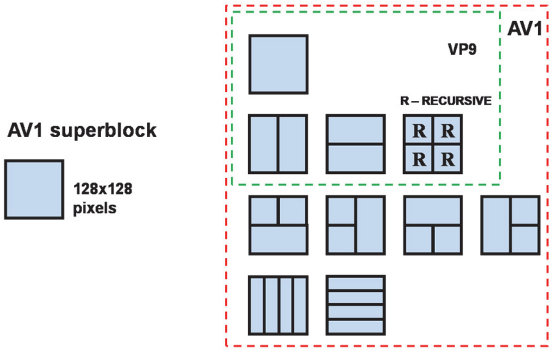

Fig. 3. AV1 superblock (SB) and new partitioning of blocks of AV1 (red dashed line) compared to VP9 (green dashed line).

Besides superblocks and partitioning, many other utilized characteristics make AV1 format a good choice. The characteristics are related to intra-prediction, inter-prediction, transform and entropy coding, in-loop filtering and post processing, tiles and multithreading [26]. For example, chroma is predicted from luma, eight intra-prediction directional mode and recursive-filtering based techniques are offered. Inter-prediction is also improved by introducing a higher number of references for a frame. Rectangular DCT (Discrete Cosine Transform) and asymmetric DST (Discrete Sine Transform) are used, as well as more filter options, parameters, adaptive techniques, etc. A code word (bit depth) greater than 8 bits is offered in AV1 profiles, so a professional profile may use up to 12bits. Superblocks are organized in large AV1 tiles, which can be independently used for obtaining greater flexibility with the new format, even for compute generated and VR applications [2].

From the general architecture point of view, AV1 codec resembles HEVC, while VP9 is the inspiration for enabling AV1 format [9]. AV1 compression approach can be applied for image files (AVIF - AV1 Image File Format) as well.

C. SVT-AV1 format

Transition between different quality and complexity is of importance. The high-quality codec is consisted of a large number of techniques. The complexity of the codec and used computational resources affect latency and the time needed for processing. This means that hardware support is of importance.

The SVT-AV1 approach is able to deal with various processing tasks having in mind available resources. It utilizes multicore CPU (Central Processing Unit) resources, and proves scalability from this point of view. Furthermore, scalability and efficiency for VoD and OTT services can be considered for SVT-AV1 from a multiresolution point of view, necessary for these applications/services [13]. Even though SVT-AV1 is a codec, the focus is on encoder design (SVT for AV1 encoder) [11].

The main components of high-level encoder architecture are illustrated in Fig. 4. The general idea behind the solution is to make a design around the processes that execute main encoder tasks [11].

Prediction structure is consisted of layers, where pictures of the input source video (YUV) are organized in groups (GOP - Group of Picture). In Fig.5 an example of five-layer prediction structure is presented, where frames noted with number 2*i+1, i = 0, 1, ..., 7, represent non-reference pictures in layer L4.

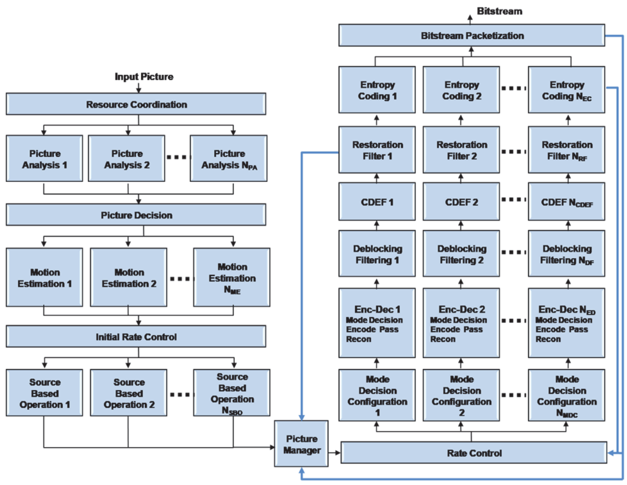

Fig. 4. Main processes in the SVT-AV1 high-level encoder architecture.

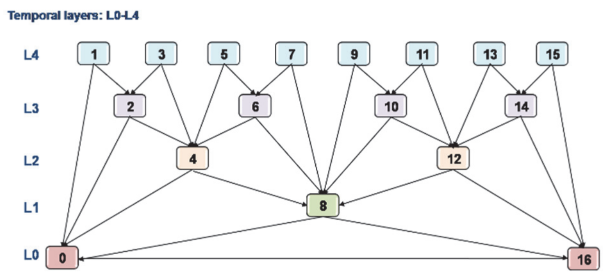

Fig. 5. Example of five-layer prediction structure.

In Fig. 4 there are control processes (like Picture Manager process), picture based processes (like Picture Analysis process) and processing based processes (like Motion Estimation process). The processes are stateless and the communication between the processes should be at the lowest level possible in order to use parallel processing and various hardware architectures (having in mind: CPUs, GPUs (General Processing Units), etc.). Mainly, SVT-AV1 approach implements picture-level and segment-level parallelism, SB-based multi-pass partitioning, multi-stage mode and considers complexity reduction. Picture-level approach for partitioning is based on tiling and SBs, as previously described, whereas segment based partitioning is illustrated in Fig. 6. For example, yellow segments in Fig.6 are being processed in a parallel manner, and the green ones are already processed.

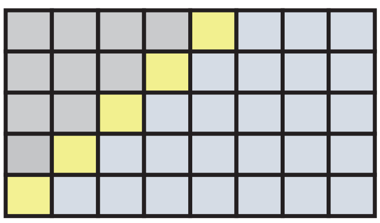

Fig. 6. Segment-level partitioning example.

In order to decrease the time needed for coding, different optimizations and predictions are adopted in order to obtain the final bit stream.

III. Quality Assessment

There is a growing demand for different video and multimedia quality evaluation. Some of the metrics can be classified as full-reference, partial-reference or no-reference. Here, two standard video metrics for Video Qaulity Assessment (VQA) have been used, both full-reference: PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity Index).

PSNR is described using mean squared error (MSE) as:

$$PSNR = 20\log_{10}\left(MAX / \sqrt{MSE}\right), \quad (1)$$

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[A_k(i,j) - A_{k,ref}(i,j)\right]^2. \quad (2)$$

PSNR is a standard image quality measure which is based on a pair of frames ($A_k(i,j), A_{k,ref}(i,j)$) corresponding to the coded and the reference video, respectively. Only sequences of the same duration (and *M x N* resolution) can be used for PSNR calculation, and *MAX* is a constant value. Another metric is SSIM, which is generally described as:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)}{(\mu_x^{'2} + \mu_y^{'2} + C_1)} \cdot \frac{(2\sigma_{xy} + C_2)}{(\sigma_x^{'2} + \sigma_y^{'2} + C_2)}, (3)$$

where C_1 and C_2 are set parameters, μ_x and μ_y are mean values, and σ_x , σ_y and σ_{xy} are standard deviation values and crosscorrelation of *x* and *y*. It can be also defined locally with empirically set parameters according to physiological experiments [27]. This index compares the structural information between the reference and the non-referent frame. Therefore, it can describe a possible perceptual difference perceived by a human. The range of SSIM is usually [0, 1]. Larger values of PSNR and SSIM usually correspond to higher video quality. Here, PSNR and SSIM are calculated automatically using ffmpeg as the general arithmetic mean [28].

The time needed for coding is also measured for the experimental purposes, as well as obtained file size.

IV. Simulation

In the experiment, typical test video sequences like Big Buck Bunny (bbb), Sintel (sin) and Tears of Steel (tos) are used [23]-[25]. Details for 4k and HD like versions are given in Table 1.

For each content, higher resolution is considered as 4k (or similar to 4k), and lower resolution is noted as HD or HD like. An experimental analysis was performed using ffmpeg 4.3.1 and FastFlix software version 2.3.2 [28], [29]. A lower frame rate was used, meaning up to 30 fps. Data is prepared according to Constant Quality or crf factor. For each sequence, output quality is set by CQ/crf values: 20, 24, 30, 34 [1]. PSNR is calculated for trimmed videos of 10 seconds duration (from 30s to 40s) automatically using ffmpeg as the general arithmetic mean for each crf. Results are compared to VP9 and HEVC format.

Table 1: Typical test video sequences

No.	Video (Abb.)	Frame rate	Resolution (Abb.)	Frame aspect ratio
1	Big Buck Bunny	30 fps	3840x2160	1.77:1
2	(bbb)	30 fps	1920x1080	1.77:1
3	Sintel	24 fps	4096x1744	2.35:1
4	(sin)	24 fps	1920x818	2.35:1
5	Tears of Steel	24 fps	3840x1714	referred as 2.4:1
6	(tos)	24 fps	1920x800	2.4:1

Since additional implementations have become available in the meantime, in the second part SVT-AV1 was tested using SVT-AV1 GUI (Graphical User Interface), version 4.1.2 and ffmpeg 4.4 [30], [28]. Video file size and coding time were measured for the first 10 seconds and already trimmed videos from the first part of experiment. Also, 1-pass and 2-pass coding was tested, for quantization factors of 24 and 34.

Finally, in the third part a relative PSNR (relative to quantization factor 10) was calculated for different quantization values: 20, 30, 40, 50. This was calculated for the first 10 seconds of typical test videos and another three 4k like videos [31]. Video test description is given in Table 2. The experiment is performed using 64 bit Win 10 Pro computer, i7-10750H CPU@2.60GHz, 16GB RAM.

Table 2: Video test description

Video No.	Resolution (width x height)	Total number of frames	Frame Rate [fps]
1	3840x2160	300	30
2	4096x1744	240	24
3	3840x1714	240	24
4	3840x2160	240	23.98
5	3840x2160	240	23.98
6	3840x2160	240	23.98

V. Experimental Results

A. CRF based analysis

The results obtained using FastFlix are given in Fig. 7. Four different crf factor values are used for comparing three formats in 4k and HD cases, showing advantages of the SVT-AV1 implementation. Coding time period for the new format was slightly longer compared to available codecs [1], [9], but the PSNR values were greater as expected. Higher PSNR values were obtained for higher resolution, where SVT-AV1 implementation had the similar trend as VP9. Moreover, it can be observed that an average PSNR for SVT-AV1 is higher than VP9, especially for lower quality, i.e. higher crf/CQ, for both HD and 4k content. In comparison to VP9 and AV1, HEVC has bidirectional prediction frames.

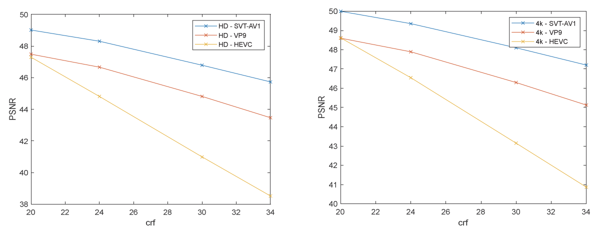

Fig. 7. Obtained PSNR values during coding for HD (right image) and 4k like (left image) content and three different formats: SVT-AV1, VP9, HEVC.

B. Coding time and file size

In Fig. 8 the coding time and file size of SVT-AV1 4k bbb files are presented. Files are in webm format. The results are shown for 1-pass and 2-pass coding, and factors 24 and 34. Blue and red bars represent periods 30-40 and 0-10 seconds of the bbb sequence, respectively.

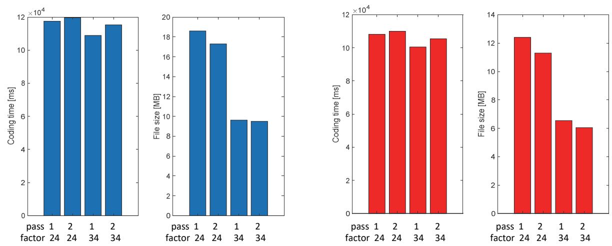

Fig. 8. Coding time and file size of SVT-AV1 4k webm files for 1-pass and 2-pass coding, and factors 24 and 34 (blue and red bars represent periods 30-40 and 0-10 seconds of the bbb source video, respectively).

C. Relative SVT-AV1 coding time, PSNR and SSIM for different quantization parameters

In the third part of the experiment a bitrate was collected for six different video contents, Fig. 9. In this part only 1-pass coding of 4k content was performed. The coding times needed for quantization values 10 to 50 are gathered and presented in Fig. 10, as well as relative coding time calculated compared to quantization factor 10. Since the first three videos are related to introduction content, oscillations in relative coding time are more obvious, as well as higher values for lower video quality. Coding time was much less than in tests with reference libaom software [9].

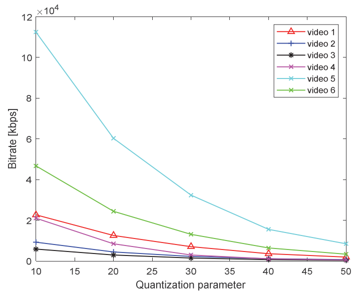

Fig. 9. Bitrate in kbps for video data from Table 2.

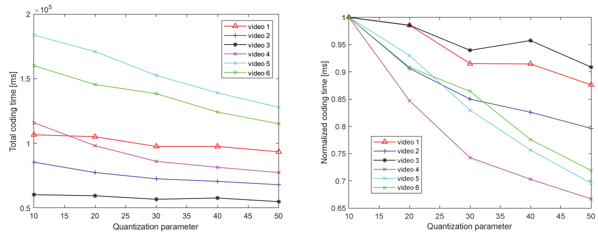

Fig. 10. Total and relative coding time having in mind different quantization factors.

The obtained results for relative $PSNR_Y$ (PSNR calculated only for Y component) and relative average PSNR are presented in Fig. 11. Similarly, relative $SSIM_Y$ (SSIM calculated only for Y component) and relative average SSIM are presented in Fig. 12, for different quantization factors. The "relative" again means that quantization factor 10 was used as a reference. Difference for successive PSNR and SSIM values are presented as boxplots in Fig. 13. It can be seen that changes in PSNR show a relatively linear trend, while changes in SSIM significantly decrease as quantization factor increases for 4k content.

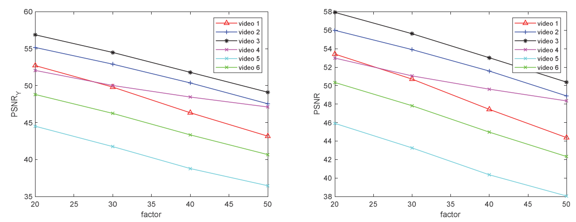

Fig. 11. Relative $PSNR_Y$ and PSNR values for different quantization factors.

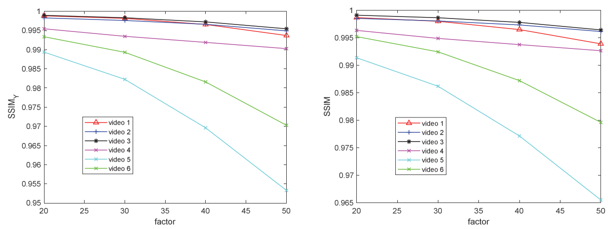

Fig. 12. Relative $SSIM_Y$ and SSIM values for different quantization factors.

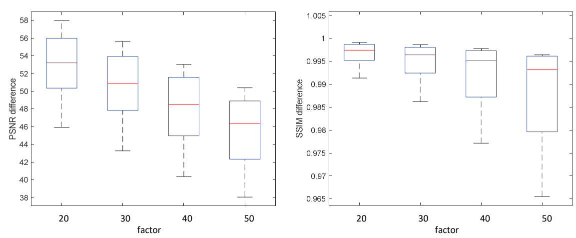

Fig. 13. PSNR and SSIM difference for successive values.

VI. Conclusion

AV1 coding format has been developed recently, and is still developing. There are different possibilities for AV1 implementation, where one of them is SVT-AV1 intended for further optimizations and usage on data center servers. In this paper a simulation using a local personal computer was performed in order to observe the trends in new developed implementations. The results show significantly less time needed for coding in comparison to libaom, and slightly more time compared to the tested VP9 an HEVC implementations. For both HD and 4k content lower PSNR content is obtained for higher CQ/crf [1]. Coding time and file size are different for 1-pass and 2-pass coding. Relative changes in PSNR for different quantization factors show similar behavior for Y and all components, as well as dependence on the content itself. Similar can be said for SSIM that shows decreased values for higher quantization.

Future work should be oriented to experimental analysis using multicore platforms in order to observe scalability and parallelization possibilities. Besides SVT-AV1 other AV1 approaches like aomenc or rav1e should be analyzed. Also, other solutions are expected to be valuable in the near future (e.g. H.266/VVC (Versatile Video Coding), MPEG-5 EVC (Essential Video Coding)) [1].

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