Evaluation of performance and complexity comparison for coding standards HEVC vs. H.264/AVC

Zoran M. Milicevic and Zoran S. Bojkovic

Abstract—In order to compare the performance and complexity without significant rate-distortion performance degradation, the HEVC coder vs. H.264/AVC coder are tested for the fixed Quantization Parameter (QP) value, when Main profile, appropriate motion vector (MV) search ranges and hierarchical B pictures are used. Simulation results have shown that the encoding time saving is reduced up to 50%, while the bit-rate is reaching over 69% depending on the tested video sequences, when reference HEVC software HM-15.0 is compared to reference H.264/AVC software JM 18.6. However, there was negligible loss in term Signal-to-Noise Ratio (SNR).

Keywords— Bit-rate reduction, encoding time saving, HEVC standard, signal-to-noise ratio.

I. INTRODUCTION

AN increasing diversity of services, the growing popularity of HD video, and the emergence of beyond HD formats (e.g., 4k×2k or 8k×4k resolution) are creating stronger needs for coding efficiency superior to H.264/MPEG-4 AVC's capabilities. Need for codec superior than H.264/AVC was result in newest video coding standard High Efficiency Video Coding (HEVC). HEVC is the video coding standard of the ITU-T Video Coding Experts Group and the ISO/IEC Moving Picture Experts Group [1]. The HEVC standard is designed to achieve multiple goals, including coding efficiency, ease of transport system integration and data loss resilience, as well as ease of implementation using parallel processing architectures. The new codec offers a much more efficient level of compression than its predecessor H.264, and is particularly suited to higher-resolution video streams, where bandwidth savings with HEVC are around 50% [2], [3]. The improved efficiency that this codec brings will help to ease traffic load in networks and enable the creation of new and advanced video-based services.

This paper is organized as follows. After an introduction section 2 describes shortly H.264/AVC standard and HEVC background. Section 3 contains experimental results and discussion. Section 4 provides closing remarks.

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II. H.264/AVC AND HEVC BACKGROUND

In order to provide better compression of video, compared to previous standards, H.264 MPEG-4 part 10 video coding standard was developed by the Joint Video Team (JVT) [4]. H.264 fulfills significant coding efficiency, simple syntax specifications, and seamless integration of video coding into all current protocols and multiplex architectures [5], [6]. Thus, H.264 can support various applications like video broadcasting, video streaming, video conferencing over fixed and wireless networks as well as over different transport protocols, where subjective video quality becomes hot topic [7].

H.264 outperforms over the previous standards by introducing the special coding algorithms such as intra-prediction, 4x4 integer transform, several block size, quarter-per accuracy motion vector, and multiple reference prediction, and weighted prediction for motion compensation, deblocking filter, CAVLC and CABAC. For error resilience, parameter setting, flexible macroblok ordering, redundant slice, and SP and SI slices are employed [8, 9]. Also, H.264/AVC defines a set of Profiles and Levels [10], [11].

During evolution, JVT added new extensions known as the Fidelity Range Extensions (FRExt). The Scalable H.264/AVC extension is applied, as well as, Multiview Video Coding (MVC).

HEVC standard represents a number of advances in video coding technology. Its video coding layer design is based on conventional block-based motion compensated hybrid video coding concepts, but with some important differences relative to prior standards [3].

The macroblocks used in H.264/AVC are replaced by Coding Tree Units (CTU's) in HEVC. CTU has a size selected by the encoder and can be larger than a traditional macroblock. The CTU consists of a luma Coding Tree Block (CTB) and the corresponding chroma CTBs and syntax elements. The size $L{\times}L$ of a luma CTB can be chosen as $L = 16$, 32, or 64 samples. HEVC then supports a partitioning of the CTBs into smaller blocks using a tree structure and quad tree-like signaling. The CTU is further partitioned into multiple CUs to adapt to various local characteristics. A CU can be split into one, two or four Prediction Units (PUs) according to the PU splitting type. HEVC defines two splitting shapes for the intra coded CU and eight splitting shapes for inter coded CU. Similar with the PU, one or more TUs are specified for the

CU. The TU is a basic representative block having residual or transform coefficients for applying the integer transform and quantization [1].

Intra coding in HEVC is considered as an extension of H.264/AVC, as both approaches are based on spatial sample prediction followed by transform coding. The basic elements in the HEVC intra coding design include: quad tree-based coding structure following the HEVC block coding architecture, angular prediction with 33 prediction directions, planar prediction to generate smooth sample surfaces etc. In chroma intra prediction, quite often structures in the chroma signal follow those of the luma. HEVC introduces a mechanism to indicate the cases when chroma PU utilizes the same prediction mode as the corresponding luma PU. Angular intra prediction in HEVC is designed to be able to efficiently model different directional structures typically presented in video and image contents. In reference pixel handling the intra sample prediction process in HEVC is performed by extrapolating sample values from the reconstructed reference samples utilizing a given directionality.

The major changes in the inter prediction of HEVC compared to H.264/AVC are in PB partitioning and fractional sample interpolation. Compared to intra picture-predicted CBs, HEVC supports more PB partition shapes for inter picture-predicted CBs. The partitioning modes of PART−2N×2N, PART−2N×N, and PART−N×2N indicate the cases when the CB is not split, split into two equal-size PBs horizontally, and split into two equal-size PBs vertically, respectively. PART−N×N specifies that the CB is split into four equal-size PBs, but this mode is only supported when the CB size is equal to the smallest allowed CB size. In addition, there are four partitioning types that support splitting the CB into two PBs having different sizes: PART−2N×nU, PART−2N×nD, PART−nL×2N, and PART−nR×2N. These types are known as asymmetric motion partitions (AMP) [1].

As in H.264/MPEG-4 AVC, HEVC supports motion vectors with units of one quarter of the distance between luma samples. For chroma samples, the motion vector accuracy is determined according to the chroma sampling format, which for 4:2:0 sampling results in units of one eighth of the distance between chroma samples. The fractional sample interpolation for luma samples in HEVC uses separable application of an eight-tap filter for the half-sample positions and a seven-tap filter for the quarter sample positions.

The deblocking filter is applied to all samples adjacent to a PU or TU boundary. HEVC applies the deblocking filter only to the edges that are aligned on an 8×8 sample grid. SAO (sample adaptive offset) filter is applied after deblocking. SAO add offset to pixels depending on their categorization (band, edge). Two SAO types that satisfy the requirements of low complexity are adopted in HEVC: edge offset (EO) and band offset (BO). SAO syntaxes are restricted to one CTB and can be merged with other CTUs.

Unlike the H.264/AVC specification that features CAVLC and CABAC entropy coders, HEVC defines CABAC as the single entropy coding method [1].

III. EXPERIMENTAL RESULTS AND DISCUSSION

We evaluated the performance of the HEVC model (HM-15.0 [12]) and compared it with that of the Main profile H.264/AVC standard (JM18.6 software [13]). The configuration of H.264/ AVC was as follows: Main profile, two values of Levels: 4.0 and 5.0 Quantization Parameters (QP) value was 32, hierarchical B pictures were used, MV search range was 16, period of I-pictures: only first, reference frame number equals to 4, Hadamard transform was used, CABAC entropy coding was enabled and group of pictures (GOP) format IBBP (with 7 B pictures between I and P pictures) was used.

On the other hand, for testing HEVC, the random access main configuration was used. The HEVC configuration was as follows: Main profile, two values of Levels: 4.0 and 5.0, hierarchical B pictures, period of I-pictures: only first, Hadamard transform was used, MV search range was 64, SAO, AMP and RDOQ were enabled, and GOP length 8 in IBBB format was used. The QP used was 32.

Experiments were carried out on the recommended sequences with fix quantization parameter value QP=32. We chose QP=32 as value of the QP, because it is approximately average value in reference software's.

For the experiments two test sequences with different resolution and frame rates are selected. We used the first 100 frames of the two different test sequences: Mobile Calendar and City test sequences in High Definition (HD) resolution (1280x720 pixels) and Park Scene and Kimono1 test sequences in Full High Definition (full HD) resolution (1920x1080 pixels). The HD test sequences belong to class E, while full HD test sequences belong to class B [1]. All the test videos are in YUV 4:2:0 format and progressive.

Next, we have used CABAC entropy coding method because this method is implemented in both video coding standards for Main profile. Also, The SNR values of luma (Y) component of pictures are used. We measured SNR only for Y because human visual system is more sensitive to luma then to chroma components of pictures. Finally, we have applied Hadamard transformation because it improves the encoder performance comparing to other transformations [10].

Comparisons were performed with respect to the change of average Signal to Noise Ratio - SNR (ΔSNR), the change of average data bit-rate (ΔBit-rate), and the change of average encoding time saving (ΔTime), respectively.

Table 1 shows the performance of the compared reference codecs for B pictures processing in the IBBP and IBBB structure for QP=32, respectively, based on our simulation results.

When HD test sequences are processed, bit-rate is reduced over 80%, while the encoding time saving is reaching 50%. On the other hand, when full HD test sequences are processed, bit-rate is reduced over 69 %, while the encoding time saving is reaching 44,5%. For all test sequences there is negligible loss in term SNR for luma component of picture by HEVC codec. Generally, when HM-15.0 is compared to reference software

JM 18.6 bit-rates are reduced in average 79,32%, while encoding time savings are reduced in average 46,30%.

Table 1. Experimental results for B pictures and QP=32, when HM-15.0 and JM-18.6 are compared

Test sequences	Format	Δ Time (%)	Δ SNR - Y (dB)	Δ Bit rate (%)
Mobile Calendar	HD (1280x720)	-50,52	0,54	-90,72
City	HD (1280x720)	-46,41	-2,61	-84,11
Park Scene	Full HD (1920x1080)	-44,58	1,29	-73,02
Kimono1	Full HD (1920x1080)	-43,70	1,89	-69,41
Average		-46,30	0,26	-79,32

In Fig. 1 (a) and (b) SNR curves are depicted for Mobile Calendar and City test sequences in HD resolution, in which the SNR-YUV is plotted as a function of the frame number for both tested encoders. Also, in Fig. 1 (c) and (d), curves are depicted for Park Scene and Kimono1 test sequences in full HD resolution.
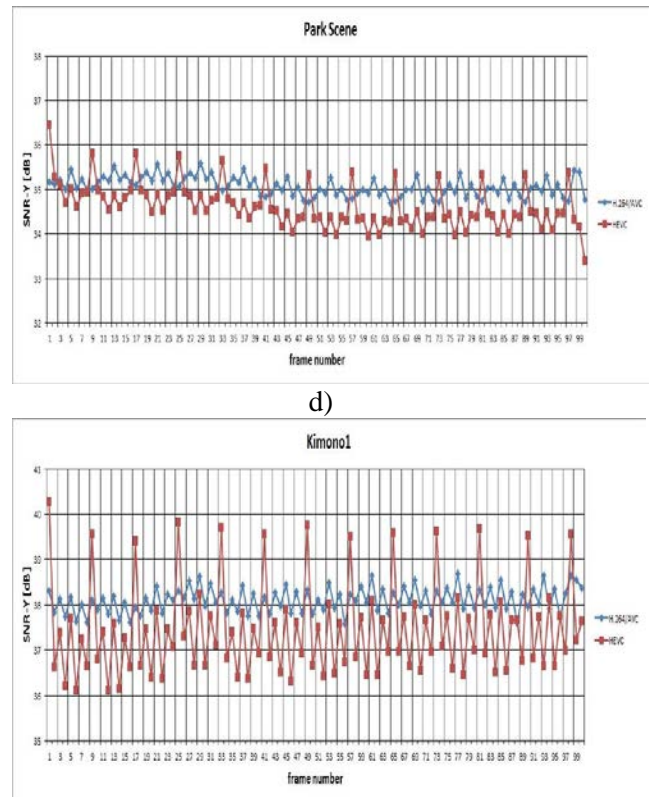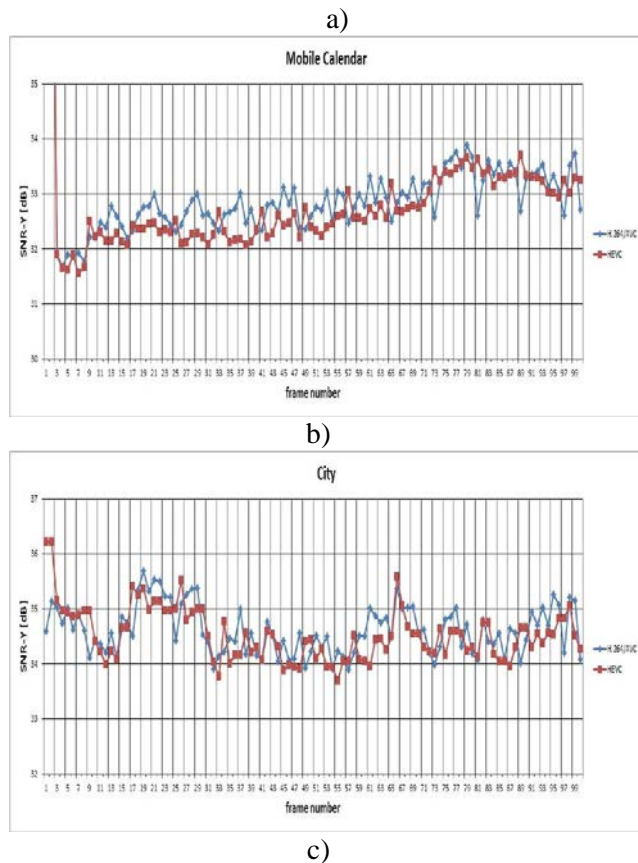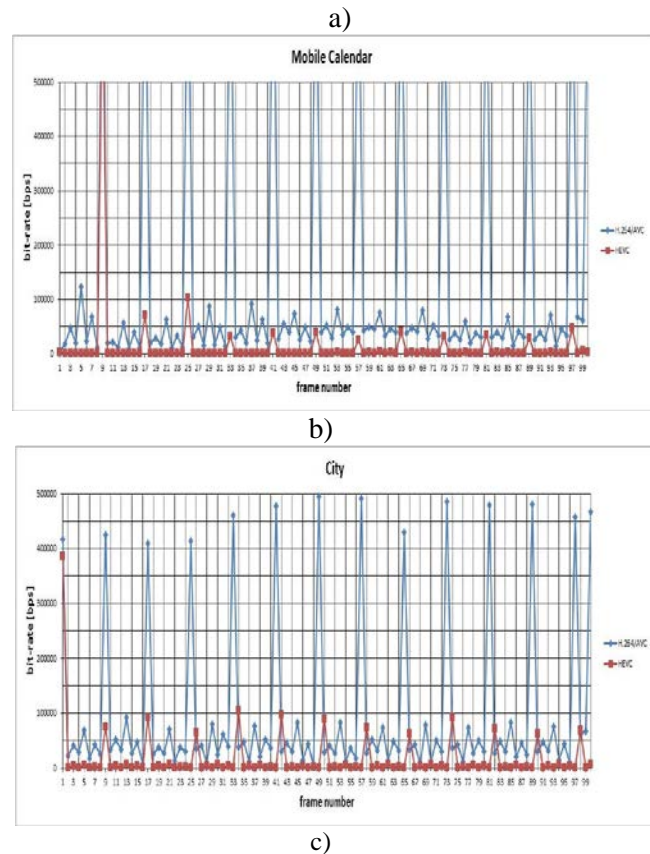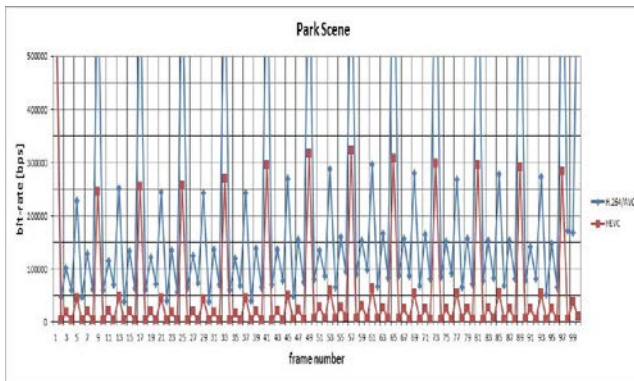
a)

b)

c)

d)

Fig. 1. SNR-Y curves when HM-15.0 is compared with JM-18.6 for Mobile Calendar (a), City (b), Park Scene (c), and Kimono1 (d) test sequences.

In Fig. 2 (a), (b), (c) and (d) bit-rate savings curves are depicted for all typical tested sequences.
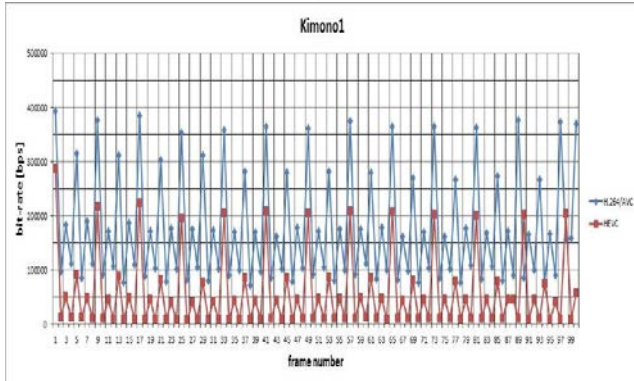
a)

b)

c)

d)

Fig. 2. Bit-rate curves when HM-15.0 is compared with JM-18.6 for Mobile Calendar (a), City (b), Park Scene (c), and Kimono1 (d) test sequences.

These bits-rate saving and SNR-Y curves indicate that the HEVC standard encoder clearly (HM-15.0) outperforms H.264/AVC standard encoder (JM 18.6) in terms of coding efficiency (it provides 50% bit-rate savings) for both tested applications.

Finally, Fig. 3, Fig. 4, Fig. 5 and Fig. 6 show HEVC (HM-15.0) vs. H.264/AVC (JM-18.6) video for the all test sequences, respectively.

Fig. 3. HEVC vs. H.264/AVC subjective video assessment for Mobile Calendar test sequence.

Fig. 4. HEVC vs. H.264/AVC subjective video assessment for City test sequence.

Fig. 5. HEVC vs. H.264/AVC subjective video assessment for Park Scene test sequence.

Fig. 6. HEVC vs. H.264/AVC subjective video assessment for Kimono1 test sequence.

From both figures it's obvious that when HEVC is compared to the corresponding H.264/AVC standard trough subjective assessment results clearly indicate that there is negligible loss in term SNR.

IV. CONCLUSION

The results presented in this paper indicate that the HEVC standard (HM-15.0) encoder clearly outperforms H.264/AVC standard encoder (JM 18.6). The results of objective tests are presented, where PSNR, bit-rate and encoding time saving are measured, indicating that the encoding time saving is reduced up to 50%, while the bit-rate is reaching over 70% with negligible loss in PSNR for HD and full HD test sequences. Also, results of subjective tests are provided comparing HEVC vs. H.264/AVC.

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