High Efficiency Video Coding (HEVC) test model HM-16.12 vs. HM-16.6: objective and subjective performance analysis

ZORAN MILICEVIC(1), ZORAN BOJKOVIC(2)
[1]Department of Telecommunication and IT GS of the SAF, 11000 Belgrade
[2]University of Belgrade, Studentski Trg 1, 11000 Belgrade
REPUBLIC OF SERBIA
e-mail: [1]zmilicko@yahoo.com, [2]z.bojkovic@yahoo.com

Abstract: - High Efficiency Video Coding (HEVC) is the state-of-art-video coding standard which significantly improved the coding efficiency of a coded video signal with its preceding video coding standards. This paper presents technical aspects of HEVC thought objective and subjective performance analysis of different versions of HM software test models in different configurations in Main profile. We compared two models HM-16.12 and HM-16.6 through three fundamental parameters: signal-to-noise ratio, bit rate and time saving, while two test sequences in different resolutions are processed. Simulations results have shown that we have none, small or obvious differences in SNR values and bit rate, while encoding time saving is increased from 13,5% up to 48,3% depending on configurations and tested sequences. Beside objective results, subjective video assessments for all tested sequences and configurations are presented, too.

Key-Words: - Bit-rate, encoding time saving, HEVC standard, Main profile, signal to noise ratio.

1 Introduction

High Efficiency Video Coding (HEVC) as a standard introduced by ITU-T Video Coding Experts Group (VCEG) and ISO/IEC Moving Picture Experts Group (MPEG) was first approved in 2013 in the ITU-T as Recommendation H.265 and ISO/IEC as International Standard 23008-2. This standard offers a new degree of compression capability for a great variety of applications and recently, it has been extended in some important ways to broad scope [1]. To meet the ultra-high-definition (HD) video compression demand, high efficiency video coding (HEVC) uses a hybrid coding scheme similar to that of H-264, consisting of inter-and intra-frame prediction, transform units, an in-loop filter and entropy coding. Also, it displays an improvement over H.264 in several aspects, such as: large hierarchical units, advanced productions, simplified structure HEVC standard has been designed to address the existing applications of H.264/MPEG-4 AVC standard and to focus on two key issues: increased video resolution and increased use of parallel processing architectures [2]-[5]. Anyway, coding efficiency, ease of transport system integration, data loss resilience and implementation using parallel processing architectures remain goals for designing HEVC standard [6], [7].

In our previous work [8], it was indicated that HEVC standard HM-16.6 in lowdelay configurations of encoder have numerous challenges, when signal-to-noise ratio, bit rate as well as encoding time saving are measured and analyzed in the case of different resolution test sequences and picture formats, i.e., IPPP vs. IBBB. Also, simulation results have shown differences in bit rate and encoding time saving, as well as small difference in SNR values for luma component of picture.

This paper is organized as follows. After short background, performance evaluation of the HEVC test model HM-16.12 encoder vs. HM-16.6 is provided through experimental results and brief discussion. Three fundamental parameters such as: signal-to-noise ratio, bit rate and time saving will be taken into consideration in different environments.

2 HEVC Background

The video coding layer of HEVC employs the same hybrid approach (inter-/intrapicture prediction and 2-D transform coding) used in all video compression standards since H.261 [2].

The various features involved in hybrid video coding using HEVC are highlighted as follows [2]: Coding tree units and coding tree block (CTB) structure; Coding units (CUs) and coding blocks

(CBs); Prediction units and prediction blocks (PBs); Transform units (TUs) and transform blocks; Motion vector signaling: Advanced motion vector prediction (AMVP); Motion compensation; Intrapicture prediction; Quantization control; Entropy coding: CABAC; In-loop deblocking filtering; Sample adaptive offset (SAO).

A number of design aspects new to the HEVC standard improve flexibility for operation over a variety of applications and network environments and improve robustness to data losses. However, the high-level syntax architecture used in the H.264/MPEG-4 AVC standard has generally been retained, including the following features [2]: Parameter set structure, NAL unit syntax structure, slices, Supplemental enhancement information (SEI) and video usability information (VUI) metadata.

Finally, three new features (Tiles, Wavefront parallel processing, Dependent slice segments) are introduced in the HEVC standard to enhance the parallel processing capability or modify the structuring of slice data for packetization purposes. Each of them may have benefits in particular application contexts, and it is generally up to the implementer of an encoder or decoder to determine whether and how to take advantage of these features [2].

Many advanced coding tools have been newly adopted in HEVC to improve the coding efficiency. Among these, HEVC adopted a hierarchical coding structure, which is one of most powerful tools to improve coding efficiency of HEVC. The hierarchical coding structure of HEVC is based on the quad-tree structure of coding unit (CU) where each CU block and has the prediction unit (PU) blocks of symmetric or asymmetric sizes and transform unit (TU) blocks of quad-tree partitions.

This breaks the procedure of 16x16 MB coding structure in H.264/AVC [9]. HEVC coding structure has been extended from a traditional macroblock concept to analogous block partitioning scheme that supports block sizes up to 64x64 pixels [10]. In this way, content-adaptive scheme can be efficiently adjusted between large homogeneous and highly texture regions of the picture. To improve the coding efficiency many advanced coding methods such as hierarchical coding structure have been proposed in HEVC [2].

The increased complexity is a major problem especially for power constrained devices or real time applications. Thus, while maintaining the coding efficiency of HEVC it is desirable to optimize the encoding process for computational complexity reduction. HEVC employed a coding unit (CU), prediction unit (PU) and transform unit (TU) based on the quadtree coding tree unit (CTU) structure to improve coding efficiency. The computational complexity increases quality because the rate distortion (RD) optimization process should be performed for all CUs, PUs and TUs to obtain the optimal CTU partition. The quadtree structured coding unit (CU) is adopted in HEVC.

During the HEVC standardization process, the JCT-VC also developed a reference Software HEVC test model (HM). The aim of the reference software was to provide a basis upon which to conduct experiments in order to determine coding performance.

In the HEVC test model (HM), pictures are first divided into slices and slices are divided into sequence of treeblocks. A treeblock is a square block (64x64 pixels) of luma samples together with two corresponding blocks of chroma samples. The CU is a basic unit of the splitting region used for inter/intra predictions. The CU concept allows treeblock recursive splitting into four equally sized blocks. This process generates a content-adaptive coding tree structure comprised of CU that may be as large as a tree block as small as 8x8 pixels. The PU is the basic unit used for caring the information related to the prediction processes. During the HEVC standardization, the HEVC test model reference software adopted same fast encoding algorithm [11]-[13].

For intra prediction, HEVC specifies 35 different prediction modes for luma samples. In HEVC, there are 33 angular modes, a DC mode and an interpolation mode.

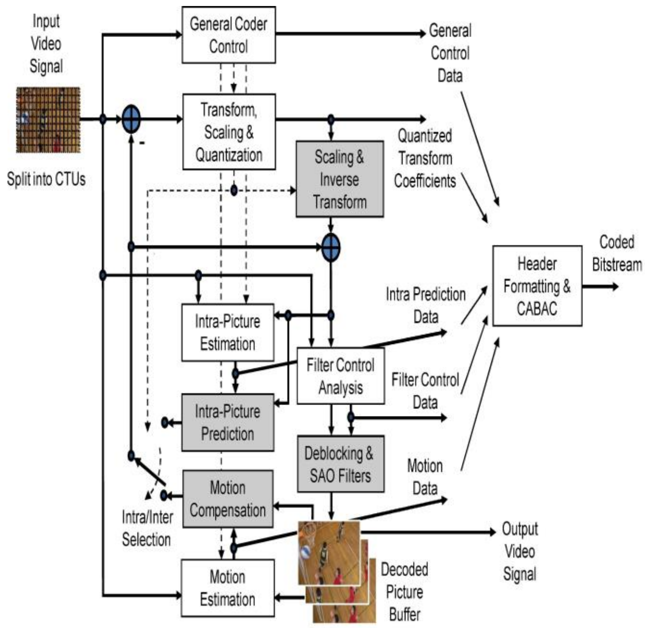


Fig. 1. Typical HEVC video encoder [2].

Inter prediction, or motion compensation, is conceptually very simple in HEVC, but comes with some overhead compared to H.264/AVC [5]. Similar to H.264/MPEG-4 AVC, HEVC supports quarter sample precision motion vectors. HEVC also supports multiple reference pictures, and the concepts of I, P, and B slices are basically unchanged from H.264/MPEG-4 AVC [5].

Fig. 1 depicts the block diagram of a hybrid video encoder which could create a bitstream conforming to the HEVC standard. The block diagram of a HEVC codec consists of: video source → partition → predictor (subtract) → transform → entropy encoder → compressed HEVC video → entropy decoder → inverse transform → predictor (add) → reconstruct → output video.

3 Simulation Results

Simulation results represent the continuation of our experimental work on performance evaluation for two versions of HM software test model in different conditions [14]. We evaluated the performance of the HEVC model HM-16.12 vs. model HM-16.12 [15], when encoder_intra_main,encoder_lowdelay_main and encoder_lowdelay_P_main configurations were used. The system platform was the Intel(R) Core(TM) i3-2328M Processor of speed 2.2 GHz, 6 GB RAM, and Microsoft Windows 7 Professional. The HEVC software configurations were as follows: Main profile, two values of Levels: 4.0 and 5.0, I pictures, P pictures, hierarchical B pictures, period of I-pictures: only first (for P and B pictures), Hadamard transform was used, MV (Motion Vectors) search range was 64, SAO (Sample Adaptive Offset), AMP (Asymmetric Motion Partitions) and RDOQ (Rate-Distortion-Optimized Quantization) were enabled, GOP (Group of Pictures) length 8 (4) in IBBB (IPPP) format was used. The QP (Quantization Parameter) used was 32.

All processed configurations are adopted to Main profile.

Experiments were carried out on the tested 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 setup configuration.

For the experiments two different test sequences are selected. The selected test sequences are in different resolution and frame rates. We used the first 50 frames of test sequences Traffic and Kimono1. The test sequence Traffic in resolution 2560x1600 pixels belongs to class A, while test sequence Kimono1 in Full High Definition (full HD) resolution (1920x1080 pixels) belongs to class B [4]. All the test videos are in YUV 4:2:0 format and progressive. Details about the test sequences and sequence classes that are used for the comparisons in the paper are summarized in [4].

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.

Comparisons with the case of exhaustive search were performed with respect to the change of Signal to Noise Ratio (SNR), the change of data bit-rate (Bit-rate), and the change of encoding time saving (Time), respectively.

Table 1 shows the performance and comparison of the reference codecs for I pictures processing in the I format in intra configuration, for hierarchical B pictures processing in the IBBB format in lowdelay configuration and for P pictures processing in the IPPP format in lowdelay_P configuration for QP=32, respectively, based on our simulation results.

For both test sequences there are not differences in SNR values for luma component of picture in intra tested configuration when the test model HM-16.12 is compared to HM-16.6.

For Kimono 1 test sequence there are small differences in SNR values for luma component of picture in the both lowdelay tested configurations when the test model HM-16.12 is compared with HM-16.6. On the other hand, for Traffic test sequences there are approximately 11% differences in SNR values (denoted by „-”) for both tested configurations when two test models are compared.

From bit rate point of view, for both test sequences there are negligible differences in values for luma component of picture in intra tested configuration. On the other hand, for Kimono 1 test sequence there are very small differences in values in both lowdelay configurations when two test models are compared. Also, for Traffic test sequences bits rate is decreased the little bit over 12 % in the test model HM-16.12 when the both tested configurations are compared.

Finally, for Kimono1 test sequence the encoding time saving is increased 35,75% for intra, 13,5% for lowdelay and 32,2% for lowdelay_P when the test model HM-16.12 is compared with HM-16.6. Also, for Traffic test sequence the encoding time saving is increased 19,78% for intra, 33,5% for lowdelay and 48,3% for lowdelay_P when the test model HM-16.12 is compared with HM-16.6.

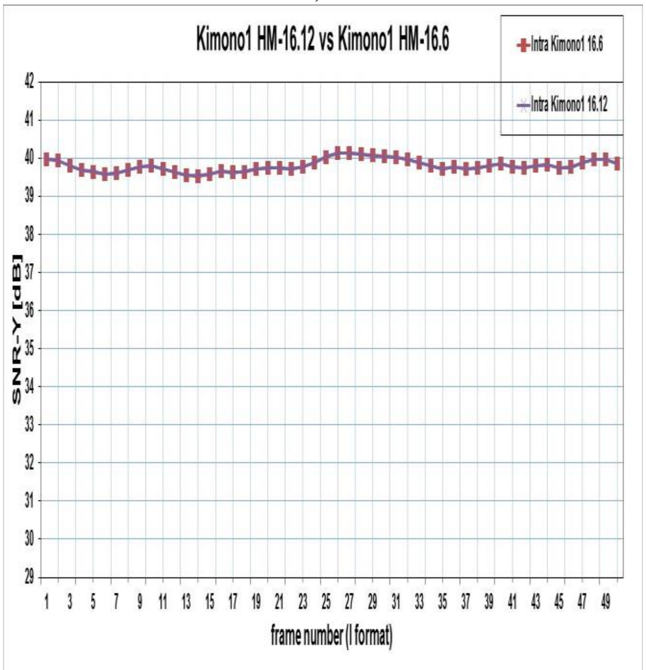
In Fig. 2 SNR curves are depicted for Kimono1 and Traffic test sequences for all test models in which the SNR-YUV is plotted as a function of the frame number for intra configuration in I picture format, for lowdelay configuration in IBBB picture format and for lowdelay_P configuration in IPPP picture format. Presented curves represent SNR for all tested models. In Fig. 2 a) and b) SNR shows on objective way that there are not differences in SNR values for both processed test sequence between the HM-16.6 and the HM-16.12. On the other hand, Fig. 2 c) and e) SNR shows small differences for Kimono1 processed test sequence between the HM-16.6 and the HM-16.12. Finally, Fig. 2 d) and f) for SNR show obvious differences in values for Traffic test sequence.

In Fig. 3 bit-rate savings curves are depicted for both typical tested sequences. Fig. 3 represents the bit-rate differences between both HEVC HM tested model, tested configurations and picture formats (I, IPPP and IBBB) which have same or different bit-rate trends as it is shown in Table 1.

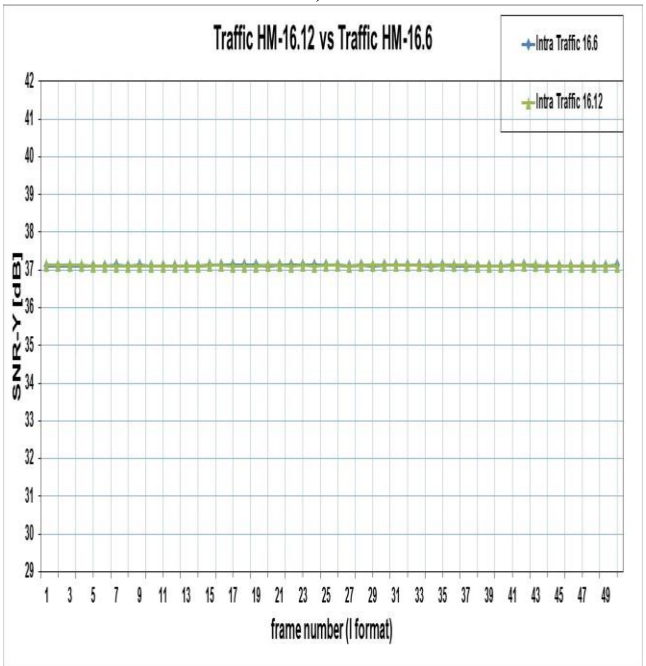
Table 1: Experimental results when HM-16.12 is compared with HM-16.6 in Main profile and different picture formats

Test sequences (resolution)	Profile	HM-16.6	HM-16.12	HM-16.12 vs HM-16.6	HM-16.6	HM-16.12	HM-16.12 vs HM-16.6	HM-16.6	HM-16.12	HM-16.12 vs HM-16.6
	Main	SNR-Y (dB)	SNR-Y (dB)	SNR-Y (dB)	Bit-rate (kbps)	Bit-rate (kbps)	Bit-rate (kbps)	Time saving (sec)	Time saving (sec)	Time saving (sec)
Traffic (2560x1600)	Intra	37,12	37,12	**0,00**	32789,68	32786,73	**-0,01**	2748,26	4277,63	**35,75**
	Lowdelay	36,05	32,17	**-10,76**	2448,58	19649,16	**87,54**	11328,50	17041,54	**33,52**
	Lowdelay_P	36,00	32,18	**-10,60**	2504,76	20120,58	**87,55**	7279,74	14080,44	**48,30**
Kimono1 (1920x1080)	Intra	39,81	39,81	**0,00**	6172,67	6174,31	**0,03**	1228,42	1531,26	**19,78**
	Lowdelay	37,54	37,54	**0,00**	1635,71	1634,97	**-0,05**	7300,13	8439,25	**13,50**
	Lowdelay_P	37,38	37,37	**-0,02**	1707,93	1703,47	**-0,26**	5036,93	7432,07	**32,23**

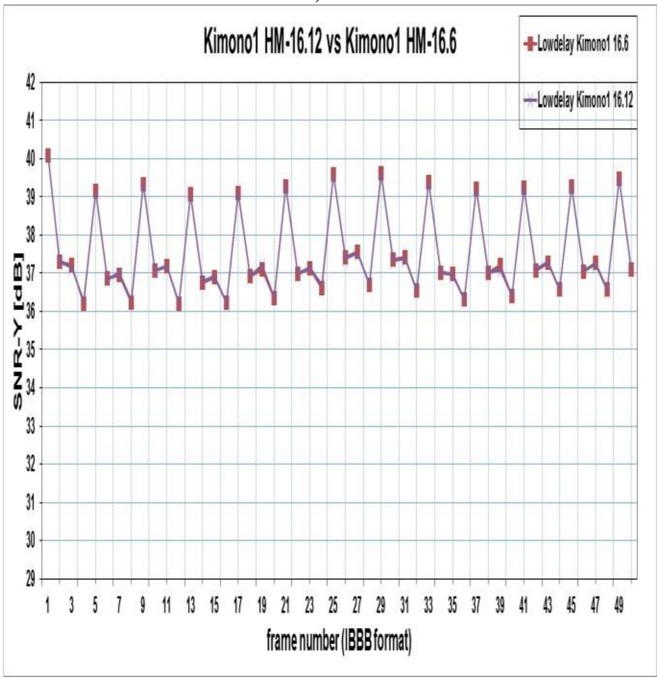
a)



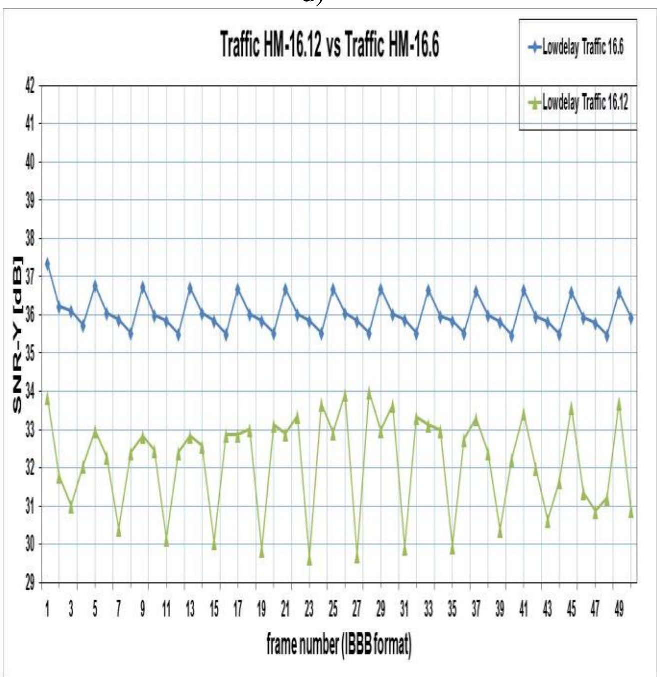
b)



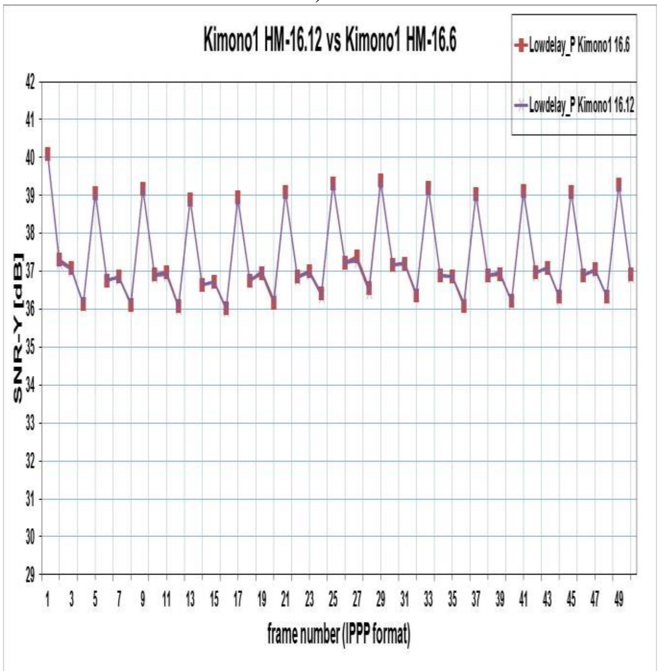
c)



d)



e)



f)

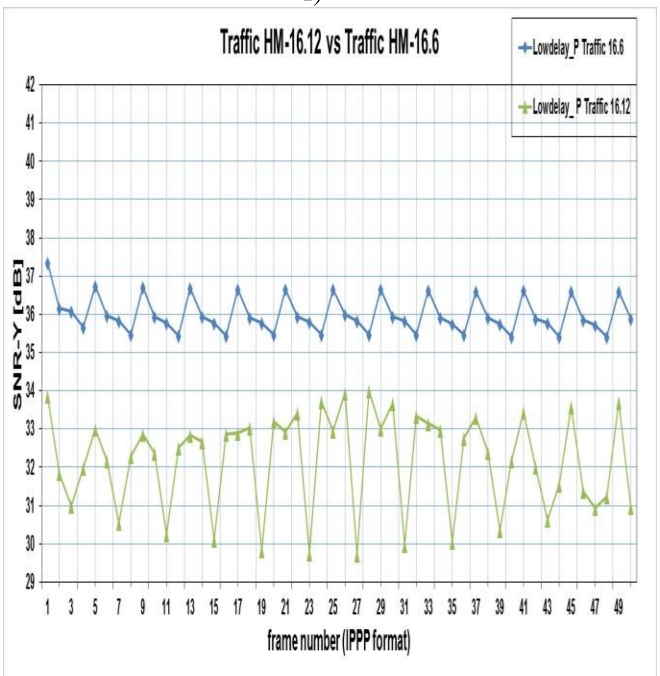
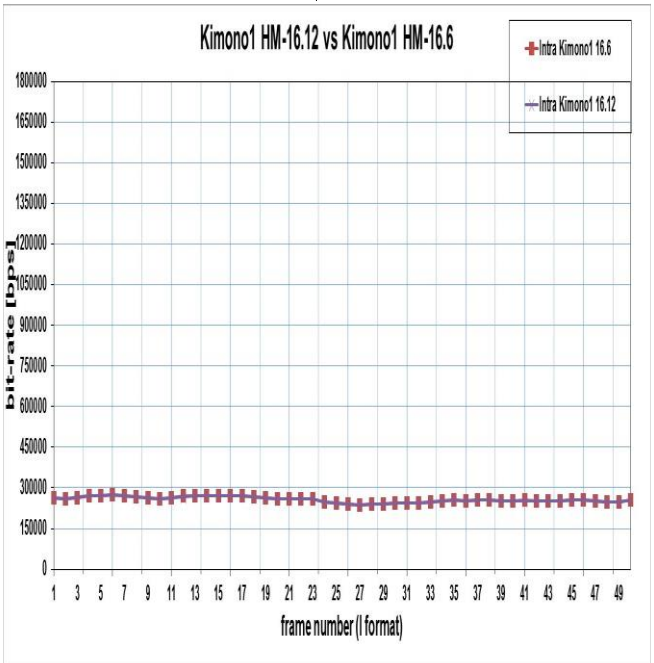
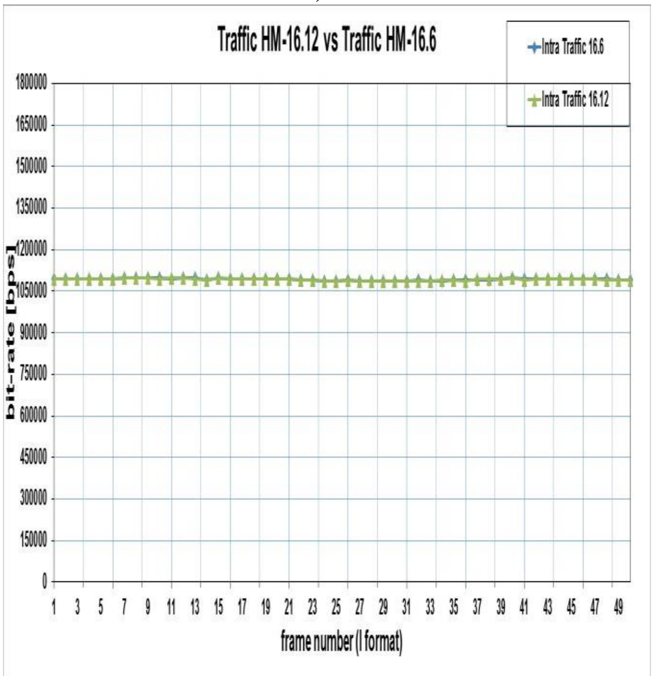


Fig. 2. SNR curves when in HM-16.6 and HM-16.12 reference software for Kimono1 and Traffic test sequences are compared in all tested formats.

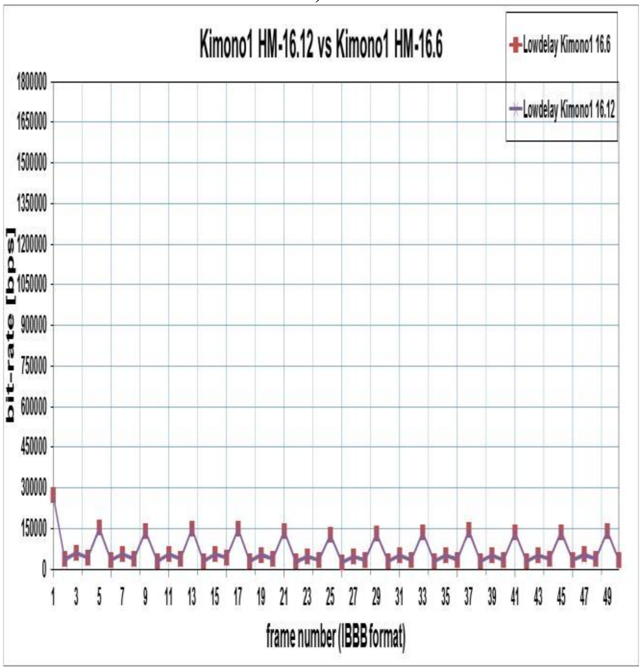
a)


Kimono1 HM-16.12 vs Kimono1 HM-16.6
Intra Kimono1 16.6
Intra Kimono1 16.12
bit-rate [bps]
frame number (I format)

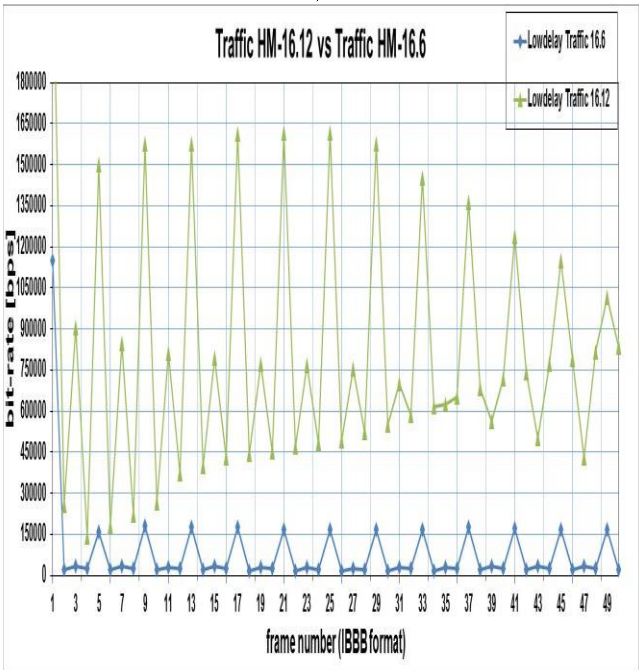
b)


Traffic HM-16.12 vs Traffic HM-16.6
Intra Traffic 16.6
Intra Traffic 16.12
bit-rate [bps]
frame number (I format)

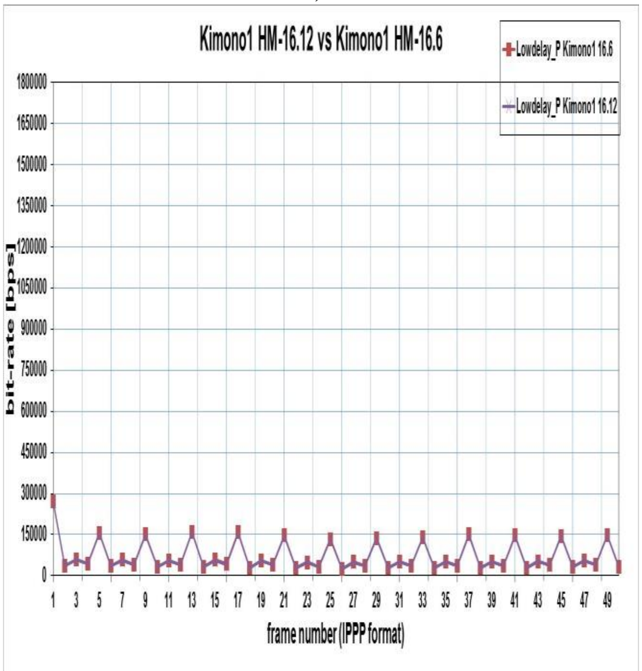
c)


Kimono1 HM-16.12 vs Kimono1 HM-16.6
Lowdelay Kimono1 16.6
Lowdelay Kimono1 16.12
bit-rate [bps]
frame number (IBBB format)

d)


Traffic HM-16.12 vs Traffic HM-16.6
Lowdelay Traffic 16.6
Lowdelay Traffic 16.12
bit-rate [bps]
frame number (IBBB format)

e)



f)

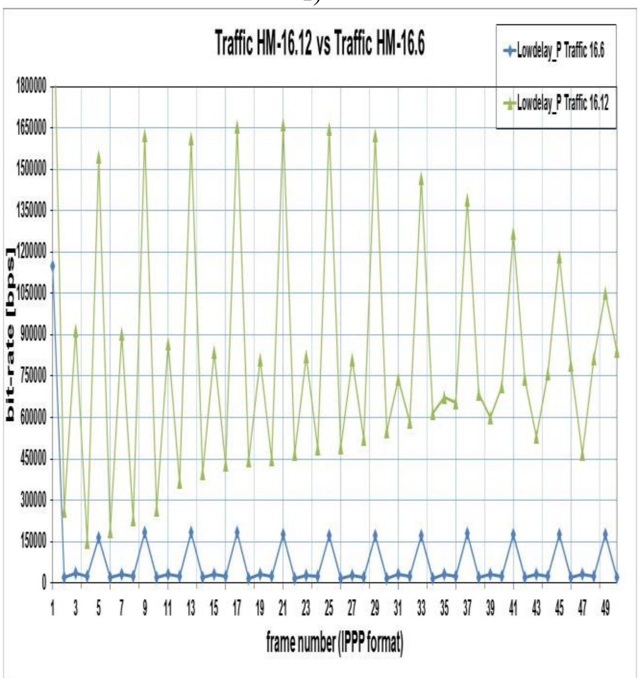


Fig. 3. Bit-rate curves when in HM-16.6 and HM-16.12 reference software's for Kimono1 and Traffic test sequences are compared in all tested formats.

Beside objective analysis of the HEVC encoders for two different resolution test sequences, subjective video quality is analyzed, too.

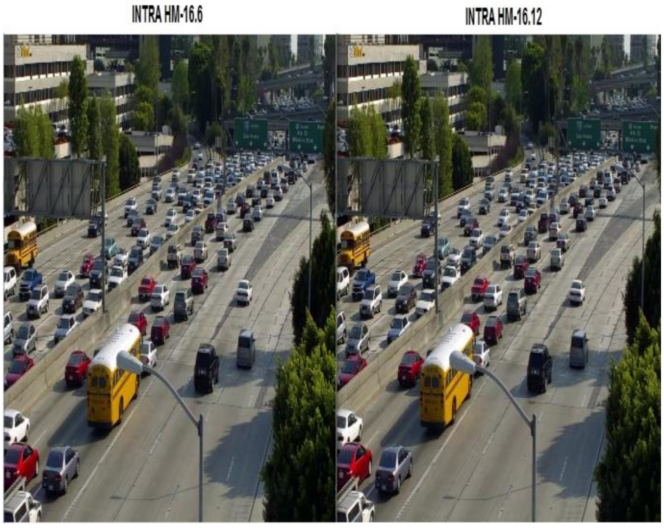
a)

b)

c)

Fig. 4. HEVC subjective video assessment for Kimono1 test sequence when all tested configurations between HM-16.12 and HM-16.6 reference software's are compared.

a)



b)

c)

Fig. 5. HEVC subjective video assessment for Traffic test sequence when all tested configurations between HM-16.12 and HM-16.6 reference software's are compared.

Fig. 4 (a, b and c) and Fig. 5 (a, b and c) show HEVC HM-16.6 and HM-16.12 in all HEVC tested configurations and picture formats for subjective video assessment, respectively. All tested sequences are processed by YUV player, respectively. Subjective assessment results clearly indicate that none or small differences in term of SNR in Fig. 4. Also, there are some differences as shown in Fig. 5 in accordance with results in Table 1.

4 Conclusion

The results presented in this paper indicate that HEVC standard HM-16.12 and HM-16.6 are compared in intra and lowdelay configurations, when SNR, bit-rate and encoding time saving are measured for different resolution test sequences and picture formats (I, IPPP and IBBB). Simulations results have shown that for Kimono 1 test sequence there are not or there are small differences in SNR values for luma component of picture and bit rate, while encoding time saving is increase 35,75%, 13,5% and 32,2% depending on configurations. On the other hand, for Traffic test sequence there are not or there are approximately 11% differences in SNR values, while bits rate is decreased negligible or the little bit over 12 % and encoding time saving is increased 19,78%, 33,5% and 48,3% depending on configurations. Also, results of subjective video assessment for all tested sequences processed by YUV player are provided, when performance for HEVC HM-16.12 encoder are compared with HEVC HM-16.12 encoder.

References:

[1] T. Weigand, G. Sullivan, G. Bjontegaard and A. Luthra, "Overview of the H.264/AVC video coding standard", *IEEE Transactions on Circuits and System for Video Technology*, vol. 13, no. 7, pp. 560-576, July 2003.

[2] G.J. Sullivan, J. R. Ohm, W. J. Han, and T. Wiegand., "Overview of the High Efficient Video Coding (HEVC) Standard", *IEEE Trans. on Circuits and Systems for Video Technology,* vol. 22, no. 12, pp. 1649-1668, December 2012.

[3] H.265: International Telecommunication Union, Recommendation ITU-T H.265, High efficiency video coding, SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS, Infrastructure of audiovisual services – Coding of moving Video, April 2013.

[4] J-R. Ohm, G. J. Sullivan, H. Schwarz, T. K. Tan, and T. Wiegand, “Comparison of the Coding Efficiency of Video Coding Standard – Including High Efficient Video Coding (HEVC)”, *IEEE Trans. on Circuits and Systems for Video Technology,* vol. 22, no. 12, pp. 1669-1684, December 2012.

[5] F. Bossen, B. Bross, K. Suhring,and D. Flynn, “HEVC Complexity and Implementation Analysis”, *IEEE Trans. on Circuits and Systems for Video Technology,* vol. 22, no. 12, pp. 1685-1696, December 2012.

[6] V. Sze, M. Budagavi and G. J. Sullivan (Editors), *High Efficiency Video Coding (HEVC): Algorithms and Architectures*, Springer Cham Heidelberg New York Dordrecht London, Springer International Publishing Switzerland 2014.

[7] Z. M. Milicevic, Z. S. Bojkovic, "HEVC Performance Analysis for HD and Full HD Applications", Proceedings of Papers *22th Telecommunications forum TELFOR 2014*, Serbia, Belgrade, November 25-27, 2014, pp. 901-904.

[8] Z. M. Milicevic, and Z. S. Bojkovic, "Performance of the High Efficient Video Coding (HEVC) HM-16.6 Encoder", Proceedings of Papers *23th Telecommunications forum TELFOR 2015*, Serbia, Belgrade, November 24-26, 2015, pp. 712-715.

[9] M. Karczewicz et al., "A Hybrid Videocoder Based on Extended Macroblock Sizes, Improved Interpolation, and Flexible Motion Representation", *IEEE Transactions on Circuits and System for Video Technology*, vol. 20, no. 12, pp. 1698-1708, December 2010.

[10] J.K. Kim et al., "A Block Partition Structure in HEVC standard", *IEEE Transactions on Circuits and System for Video Technology*, vol. 22, no. 12, pp. 1697-1706, December 2012.

[11] R.-H. Gweon, Y.-L. Lee, J. Lim, "Early Termination of CU Encoding to Reduce HEVC Complexity", document Joint Collaborative Team on Video Coding of ISO/IEC, JCTVC-F045, Turin, Italy, July 2011.

[12] K. Cloi, S.-H. Park, E.S. Jang, "Coding Tree Pruning Based CU Early Termination", document Joint Collaborative Team on Video Coding of ISO/IEC and ITU-T, JCTVC-F092, Turin, Italy, July 2011.

[13] J. Jang et al., "Early Skip Detection of HEVC", document Joint Collaborative Team on Video Coding of ISO/IEC and ITU-T, JCTVC-6543, Geneva, Switzerland, November 2011.

[14] Zoran M. Miličević, Zoran S. Bojković “Performance evaluation of High Efficiency Video Coding (HEVC) test model HM-16.12 vs. HM-16.6” NAUN (North Atlantic University Union) *INTERNATIONAL JOURNAL OF COMPUTERS (ISSN: 1998-4308)*, vol. 11, pp. 18-22, 2017.

[15] svn://hevc.kw.bbc.co.uk/svn/jctvc-hm/, 2017.