The Impact of Successive B Frames on TV Signal using Different Compression Techniques and Video Resolution

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Abstract — **The aim of this paper is to examine the impact of successive B frames using compression techniques (H.264 and H.265) and resolution (4K, 2K, Full HD and SD) when changing their quality in a television system. The analysis was done for a case when the number of successive B frames in the Group of Pictures (GOP) was B = 0 and B = 4. The results obtained for analysis parameters: compression ratio, Peak Signal Noise Ratio (PSNR), bitrate, P frames and B frames are presented by tables and graphics, based on which conclusions were made.**

Keywords — **compression, H.264, H.265, I frames, P frames, B frames, GOP.**

I. Introduction

As technology evolves rapidly, smart devices, intelligent systems, the Internet of Things, security systems that require real-time video (image) processing are increasingly represented. However, it is required that the resolution and the quality of video (images) is high, take less memory and process the images in real time as fast as possible. It is necessary to find a method that will optimally adapt the compression algorithm to be optimized for intelligent systems.

Using different compression techniques there is a noticeable difference in video quality but also spent bitrate. Today's television broadcasting is mostly based on H.264/AVC technology, but due to the increase in resolution and user need, broadcasters increasingly switch to H.265 compression technology. However, with the development and availability of mobile phone, television has come practically to every user. In order to play content on a mobile phone, it is often necessary to reduce the resolution as well as bitrate. For this reason, video content is transcoded into lower resolutions. Transcoding is a technique for the adaptation or conversion of one encoding format into another. In television systems, the process of transcoding is mainly done in the encoder itself by using certain compression techniques. In addition to the compression technique, it is important to choose the compression profile and allocation of I, P and B frames [1]. Fig. 1 shows the process of distributing a television signal and the encoder location in the chain of television signal transmission.

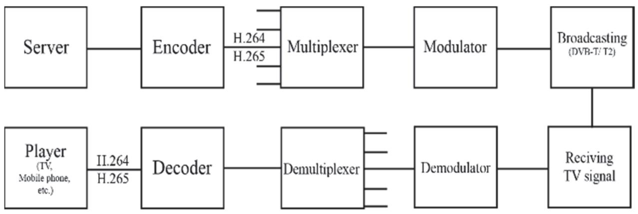

Fig. 1. Block diagram for distributing TV signals in the broadcast system.

The encoder is very important in the transmission system, and therefore it is very important to adjust the compression techniques and its parameters. One of these parameters is the method of calculating the bitrate usage, very often it is a Constant Bitrate (CBR) and a Variable Bitrate (VBR). The advantage of the CBR encoding method is that a bitrate is constant, and it is easy to transmit a video signal via communication channels. CBR means that for each segment of the image the same bitrate for encoding is used, ie the same bitrate is used for each frame. This means that the quality of video is the same regardless of the content of video itself. This coding method spends many bits on unnecessary parts of the video, because when a small number of details is in the figure the same bitrate does not need to be used. To improve this, VBR is used. The VBR method spends as many bitrates as it is needed dependent on the complexity of content (videos). This means that for segments where the complexity of the image is large, it will spend more bitrates, while for segments where complexity is small, it will spend much fewer bitrates. [2].

The bitrate of the original video signal is constant and depending on the used modulation format , the bitrate of the original video signal can be several Gb/s. However, depending on the content of the video signal, the bitrate of

Paper received March 28, 2019; revised June 18, 2019; accepted July 04, 2019. Date of publication July 31, 2019. The associate editor coordinating the review of this manuscript and approving it for publication was Prof. Zorica Nikolić.

This paper is revised and expanded version of the paper presented at the 26th Telecommunications Forum TELFOR 2018 [21].

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the compressed signal changes during time, and if it is necessary for the transmission to be without loss of quality, it needs to be transferred as it is. In one multiplex, at some specific time, different TV programs have different and independent bitrate changes [3].

Statistical multiplexing is based on speed control algorithms that use the concept of feedback. This is produced by coders through changes in compression in the information bitstream. Generated statistics are used as input parameters in the encoder control process before the compression of image. This statistical codification along with the information status of buffers from the channel, are used for dynamic processing of the bitrate allocation in each encoder.

The total bitrate in the multiplex has less dispersion due to the application of the statistical multiplex and compression coders, which leads to better utilization of the channel capacity, and thus to the increase in the number of TV programs that are stored in a channel. Although the Bit rate of individual TV programs is variable over time, the total bitrate in the multiplex is almost constant due to the fact that the changes in the bit rate of the TV programs are independent and to achieve a statistical balance in the multiplex due to the large number of TV programs that can be stored. The total bitrate depends on the bitrate of individual TV programs, primarily on their format, or the nature of the video content that is being transmitted [4].

II. Compression algorithms

Compression is a method of reducing the number of bits used to encode individual elements of image. The Compression Ratio (CR) is defined as the ratio of the number of bits per element of the original image and the number of bits per element of compressed image [5].

H.264 is a method of encoding video content that has found great use. The initial idea of this standard was to provide good image quality at least twice as much data transmission without increasing the complexity of the system, making it impractical for implementation. H.264 is the first format that could encode High Definition (HD) video content (resolutions 1920x1080 and higher) efficiently and practically (with a low enough bitrate, but good enough quality) [6], [7].

The video compression standard that is the successor to the H.264/MPEG-4 version is High Efficiency Video Coding (HEVC), also known as H.265. Compared to the widely used Advanced Video Coding (AVC) standard H.264, the H.265 version has the ability to compress data transfer by an additional 50%, which is necessary for high quality video encoding. Data transfer rate is 40-50% higher, with a 1080p resolution, while maintaining the highest image quality. The H.265 standard allows compression of video content with high degree, with relatively fast review and low-throughput conditions. It is suitable for high-resolution compression such as 8K and 4K [8], [9].

The compression algorithm places video content in different types of frames, usually in I-Frames (Intra-frames) or key-frames, P-frames (Predicted-frames) and B-frames (Bi-directional frames) [10].

I-frames play a very important role and they are often called key-frames. They use intraframe compression. These frames contain a complete image record and they are completely independent of other types of frames. They serve as the basis for calculating other frames. The first frame in a compressed video content is always an I-frame. Each video content must contain key frames [10]-[12].

P-frames are complex frames consisting of parts that are predicted, i.e. they are recalculated based on previous frames. They use interframe compression. These frames contain only a description that tells the decoder what the difference is in relation to the previous frame and therefore they store considerably less memory space than I-frames. During the reproduction of video content, the decoder interprets the P-frame and the previous frame record and on the basis of these data creates the full image that will be displayed on the screen [11], [12].

B-frames are similar to P-frames, which, unlike them, can be recalculated from both the previous and the next frame, thus achieving the least possible occupancy of the memory space. Therefore, the use of B-frames is very important when it is necessary to achieve a high degree of video content compression. At a very low bitrate, without the use of B-frames, it is very difficult to achieve a satisfactory image quality [11], [12].

In order to maximize coding efficiency, it is important to determine the distribution of these three types of frames, also called the Group of Pictures (GOP) structure that refers to the frame sequence in the video file. The GOP consists of an initial I-frame and a series of P and B frames. The length of the GOP is the number of frames in each repeated sequence (one I-frame in each) [11]-[13].

The Constant Rate Factor (CRF) is the default quality (and rate control) parameter of the H.264 and H.265 encoders. It is possible to set values between 0 and 51, where the lower values give better quality, but the larger output file size [14], [15].

III. System Model

In this paper, the analysis of the impact of the B frame on the compression algorithms H.264 and H.265 was done over 4K, 2K, Full HD and SD video content [16], that is, the video content is a resolution of 3840x2160, 2048x1080, 1920x1080 and 720x576 pixels, respectively. The video content duration is 45 seconds or 1125 frames. The encoder settings for video compression was done in MediaCoder [17]. VBR [18] is used, and GOP size is from 25 to 250, so it has an adaptive mode of assigning B frames in GOP if B = 0. First, the number of B frames was set to B = 0, then 4K video content was encoded using H.264 and H.265 compression techniques, at different CRF values (from CRF = 20 to CRF = 36). In order to examine the impact of B frames, over the same video content and compression techniques, encoding for B = 4, i.e. the number of successive B frames in GOP, was performed for values from CRF = 20 to CRF = 36. After that, with the same settings, Full HD video content encoding was performed using H.264 and H.265 compression techniques for B = 0 and B = 4. Other encoder settings are at the default values and are the same for all tests. Considering that video content can be viewed as a sequence of images, Peak Signal Noise Ratio (PSNR) [6] is used as the objective measure for quality. The value obtained is in the range from 0 to 100 and as the value is closer to the maximum value, the quality is better [19].

Typical values for PSNR images which use compression with losses are between 30 and 50 dB. If the PSNR is above 40 dB, the compressed image is almost without difference from the original, and for an acceptable image quality, PSNR is above 30 dB [19]. PSNR values were obtained using ffmpeg [20].

IV. Results and Discussion

Controlling the CRF can directly affect the quality of the video that needs to be compressed with different compression standards. However, it is not enough to only increase and decrease the quality, it is necessary to adjust the encoder and examine the influence of each parameter in order to obtain as good a quality as possible with less data lost. When using H.264 and H.265 compression over resolution video 4K, 2K, FullHD and SD, for the number of B frames equal to 0 and equal to 4, results are obtained for parameters: compression ratio and total number of P and B frames and those results are shown in Table 1, Table 2, Table 3 and Table 4, respectively.

From Table 1 it can be seen that by degradation of quality, that is, by increasing the CRF parameter, the number of B frames mostly decreases, while the number of P frames increases. The obtained values for P and B frames in the all tables represent the total number of frames P and B of 1125 frames. Since the number of B frames is lower, CR is higher. It can be seen that the number of frames B is much lower than in H.264 compression. Even, as can be seen from Table 1, the number of frames B are in a certain range and its values do not decrease by increasing the CRF.

From Table 2 can be seen that B frames also decrease, or P frames increase, with increasing the compression ratio and there is much more variation in H.264 than in H.265 compression. By using both compression techniques, a very high compression ratio is achieved.

From Table 3 can be seen that the increase in CRF decreases the number of B frames, while the number of P frames increases with increasing CR. In Table 3 it can be seen that the CR is increased when the value was B = 4, especially in H.265 compression. Also, it can be seen that the number of B frames is higher compared to H.264 compression.

Although the H.265 compression technique is not primarily intended for SD resolution, a high compression ratio is achieved, as can be seen in Table 4.

Objective quality measures in Fig. 2 and Fig. 3 show the changes in PSNR values using H.264 and H.265 compression for 4K, 2K, Full HD and SD resolution when changing the number of B frames to 0 and 4, all depending on the CRF.

From Fig. 2 and Fig. 3 it can be seen that PSNR decreases with increasing CRF. The best PSNR value, in both cases, is achieved for the 2K resolution until CRF = 25 for H.264, and until CRF = 29 for H.265, and then by increasing the CRF, the better PSNR is for 4K resolution. It can be noted that SD resolution has the lowest PSNR values but still acceptable quality. For each of the resolutions, better PSNR values are achieved in the case when B = 4.

Table 1: Parameter values for H.264 and H.265 compression over 4K video for B = 0 and B = 4.

	H.264						***H.265***					
	B = 0			***B = 4***			***B=0***			***B=4***		
CRF	***CR***	***P***	***B***	***CR***	***P***	***B***	***CR***	***P***	***B***	***CR***	***P***	***B***
20	0.86:1	393	726	0.91:1	402	717	1.62:1	439	680	1.63:1	389	730
22	1.12:1	393	726	1.20:1	419	700	1.62:1	434	685	1.78:1	391	728
24	1.49:1	405	714	1.61:1	456	663	1.91:1	434	685	2.25:1	389	730
26	2.01:1	445	674	2.16:1	491	628	2.56:1	437	682	2.87:1	393	726
28	2.71:1	476	643	2.91:1	516	603	3.37:1	440	679	3.65:1	387	732
30	3.65:1	542	577	3.93:1	554	565	4.55:1	448	671	5.03:1	385	734
32	4.90:1	646	473	5.27:1	582	537	6.53:1	471	648	6.97:1	383	736
34	6.49:1	711	408	6.99:1	586	533	9.28:1	498	621	9.64:1	375	744
36	8.48:1	752	367	9.20:1	599	520	13.19:1	502	617	13.39:1	377	742

Table 2: Parameter values for H.264 and H.265 compression over 2K video for B = 0 and B = 4.

	H.264						***H.265***					
	B = 0			***B = 4***			***B=0***			***B=4***		
CRF	***CR***	***P***	***B***	***CR***	***P***	***B***	***CR***	***P***	***B***	***CR***	***P***	***B***
20	1.41:1	326	793	1.73:1	326	793	1.63:1	324	795	2.34:1	326	793
22	1.92:1	335	784	2.34:1	328	791	2.15:1	321	798	3.18:1	317	802
24	2.67:1	327	792	3.22:1	331	788	3.05:1	327	792	4.36:1	318	801
26	3.79:1	333	786	4.49:1	374	745	4.38:1	326	793	6.01:1	323	796
28	5.38:1	337	782	6.28:1	429	690	6.35:1	331	788	8.31:1	322	797
30	7.60:1	353	766	8.78:1	453	666	9.27:1	337	782	11.57:1	320	799
32	10.67:1	429	690	12.26:1	460	659	13.54:1	345	774	16.22:1	321	798
34	14.72:1	502	617	16.95:1	468	651	19.76:1	364	755	22.86:1	316	803
36	19.92:1	534	585	23.03:1	483	636	29.02:1	374	745	32.43:1	318	801

TABLE 3: PARAMETER VALUES FOR H.264 AND H.265 COMPRESSION OVER FULL HD VIDEO FOR B = 0 AND B = 4.

	H.264						*H.265*					
	B = 0			*B = 4*			*B=0*			*B=4*		
CRF	***CR***	***P***	***B***	***CR***	***P***	***B***	***CR***	***P***	***B***	***CR***	***P***	***B***
20	1.14:1	322	797	1.26:1	330	789	1.11:1	315	804	1.55:1	321	798
22	1.52:1	330	789	1.70:1	343	776	1.53:1	319	800	2.11:1	316	803
24	2.07:1	328	791	2.32:1	368	751	2.17:1	319	800	2.92:1	321	798
26	2.88:1	336	783	3.22:1	411	708	3.12:1	323	796	4.06:1	320	799
28	4.07:1	347	772	4.54:1	458	661	4.52:1	336	783	5.68:1	327	792
30	5.77:1	379	740	6.42:1	459	660	6.60:1	360	759	7.94:1	322	797
32	8.14:1	435	684	9.07:1	467	652	9.64:1	368	751	11.17:1	327	792
34	11.31:1	491	628	12.68:1	468	651	14.05:1	375	744	15.72:1	238	791
36	15.38:1	547	572	17.48:1	457	648	20.66:1	376	743	22.26:1	327	792

TABLE 4: PARAMETER VALUES FOR H.264 AND H.265 COMPRESSION OVER SD VIDEO FOR B = 0 AND B = 4.

	H.264						*H.265*					
	B = 0			*B = 4*			*B=0*			*B=4*		
CRF	***CR***	***P***	***B***	***CR***	***P***	***B***	***CR***	***P***	***B***	***CR***	***P***	***B***
20	1.34:1	411	708	1.63:1	405	714	1.55:1	378	741	2.66:1	355	764
22	1.85:1	420	699	2.26:1	418	701	2.16:1	369	750	3.72:1	348	771
24	2.67:1	416	703	3.24:1	419	700	3.10:1	352	767	5.31:1	348	771
26	4.01:1	400	719	4.79:1	424	695	4.64:1	329	790	7.69:1	336	783
28	6.22:1	396	723	7.28:1	445	674	7.22:1	313	806	11.24:1	321	798
30	9.84:1	430	689	11.30:1	451	668	11.59:1	314	805	16.58:1	319	800
32	15.29:1	491	628	17.42:1	448	671	18.88:1	316	803	24.44:1	317	802
34	22.71:1	528	591	26.09:1	463	656	30.39:1	328	791	35.82:1	314	805
36	31.61:1	595	524	37.14:1	482	637	47.21:1	335	784	52.02:1	323	796

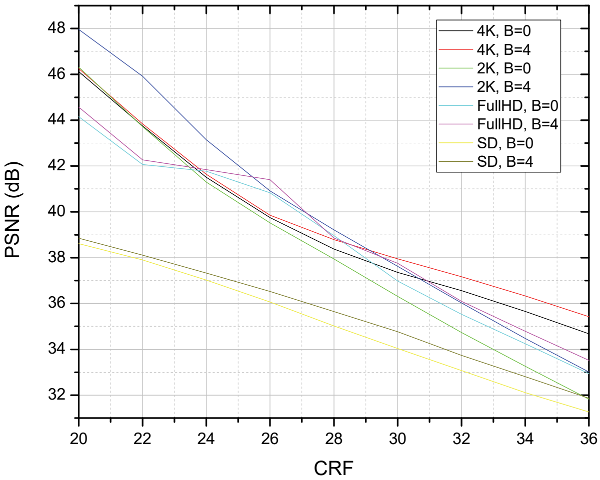

Fig. 2. PSNR changes for different resolutions and number of B frames depending on quality using H.264.

Comparing the obtained results from Fig. 2 and Fig. 3, it can be seen that for H.264 compression PSNR gives better values than for H.265 compression. However, considering that the difference is not large, and that H.265 provides a larger compression ratio, ie a much smaller output file, it can be said that the H.265 compression is better in terms of the compression ratio and the quality of the compressed video file.

In Fig. 4, bitrate changes are shown depending on the CRF.

By increasing CRF, bitrate exponentially decreases for all video resolutions. However, it can be noted that a much larger bitrate for a 4K video is required. From Fig. 4, it can be seen that by increasing the CRF, the bitrate drop is much smaller in 2K, Full HD and SD than in 4K video content.

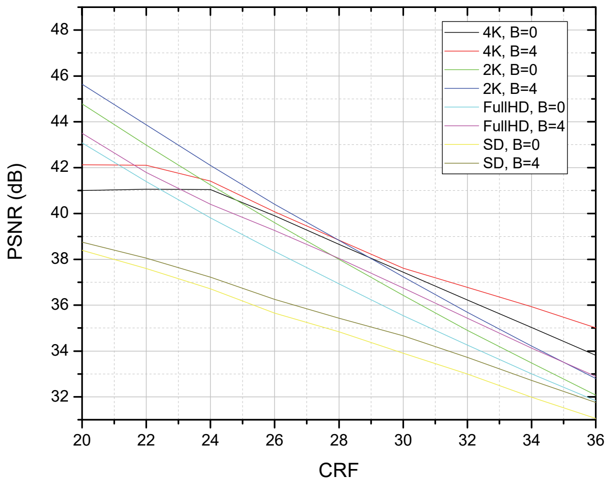

Fig. 3. PSNR changes for different resolutions and number of B frames depending on quality using H.265.

In Fig. 5, a bitrate changes graph is shown when the CRF is increased for 4K, 2K, Full HD and SD video resolution over which the H.265 compression is applied with values of the B frames 0 and 4. Unlike Fig. 4, it can be seen here that for 4K content, by increasing the CRF, the change in bitrate is not linear, or the values decrease steeper.

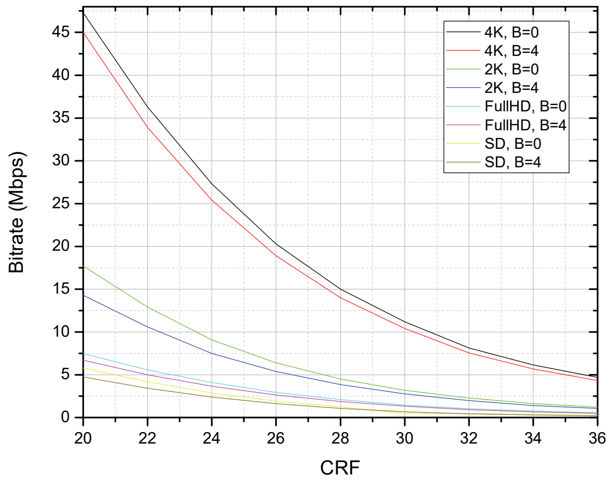

Fig. 4. Bitrate changes for different resolutions and number of B frames depending on quality using H.264.

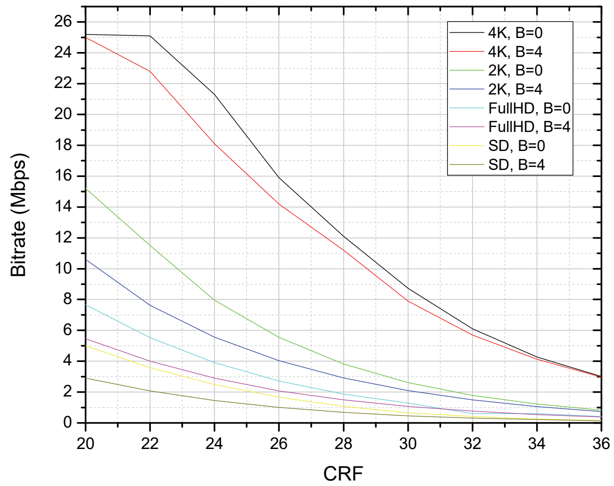

Fig. 5. Bitrate changes for different resolutions and number of B frames depending on quality using H.265.

Comparing the obtained results from Fig. 4 and Fig. 5, it can be clearly seen that almost every time H.265 gives better bitrate values for 4K video. With 2K, Full HD and SD video content, bitrate generally has similar values.

V. Conclusion

The paper analyzes the impact of successive B frames in GOP using H.264 and H.265 compression techniques at TV signals for resolutions 4K, 2K Full HD and SD with different CRF values. The results show that B frames significantly influence the compression ratio and file size. Based on the obtained results, it can be seen that using H.265 compression for 4K content requires a much larger bitrate than lower resolutions. Also, from the obtained results, it can be seen that in the case when B = 0, a larger bitrate is required when observing one of resolutions in relation to the case when B = 4. However, although H.264 in some situations gives better PSNR values than H.265, it requires a much larger bitrate but also the size of the output file. However, considering the compression ratio and the size of the output file, it is concluded that H.265 gives a better performance than H.264, which is very important in the statistical multiplex of the television signal and saves bitrate, or frequency band channel.

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