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Low Latency UHD Adaptive Video Bitrate Streaming Based on HEVC Encoder Configurations and Http2 Protocol

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Abstract

Applying 4K, (Ultra HD) Real-time video streaming via the internet network, with low bitrate and low latency, is the challenge this paper addresses. Compression technology and transfer links are the important elements that influence video quality. So, to deliver video over the internet or another fixed capacity medium, it is essential to compress the video to more controllable bitrates (customarily in the 1-20 Mbps range). In this study, the video quality is examined using the H.265/HEVC compression standard, and the relationship between quality of video and bitrate flow is investigated using various constant rate factors, GOP patterns, quantization parameters, RC-lookahead, and other types of video motion sequences. The ultra-high-definition video source is used, down sampled and encoded at multiple resolutions of (3480x2160), (1920x1080), (1280x720), (704x576), (352x288), and (176x144). To determine the best H265 feature configuration for each resolution experiments were conducted that resulted in a PSNR of 36 dB at the specified bitrate. The resolution is selected by delivery (encoder resource) based on the end-user application. While video streaming adapted to the available bandwidth is achieved via embedding a controller with MPEG DASH protocol at the client-side. Video streaming Adaptation methods allow the delivery of content that is encoded at different representations of video quality and bitrate and then dividing each representation into chunks of time. Through this paper, we propose to utilize HTTP/2 as a protocol to achieve low latency video streaming focusing on live streaming video avoiding the problem of HTTP/1.

Keywords: HEVC/H.265, GOP, QP, RC-lookahaed, MPEG DASH, low-latency streaming, HTTP/2, PSNR

زمن وصول منخفض للفديوعالي الوضوح مع تدفق معدل بت الفيديو التكيفي بناءً على تكوينات تشفير (HEVC)وبروتوكول التصفح النسخة الثانية

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الخلاصة

يعد تطبيق دفق الفيديو في الوقت الفعلي بدقة (Ultra HD) 4 K عبر شبكة الإنترنت بمعدل بت منخفض وزمن انتقال منخفض هو التحدي الحقيقي لهذه الورقة. تعد تقنية الضغط وروابط النقل من العناصر المهمة التي تؤثر على جودة الفيديو. لذلك ، لتقديم الفيديو عبر الإنترنت أو أي وسيط آخر ذو سعة ثابتة ، من الضروري ضغط الفيديو إلى معدلات نقل أكثر يمكن التحكم فيها (عادةً في نطاق 1–20 ميجابت في الثانية). في هذه الدراسة ، يتم فحص جودة الفيديو باستخدام معيار ضغط HEVC / H.265 ويتم التحقق من العلاقة بين جودة الفيديو وتدفق معدل البت باستخدام عوامل معدل ثابت مختلفة وأنماط GOP ومعلمات التكميم و RC–lookahead وأنواع أخرى من تسلسل حركة الفيديو. يتم استخدام مصدر الفيديو فائق الدقة ، والاختزال والتشفير بدقة متعددة (3480 × 2160) ، (1920 × 1080) ، (1280 × 720) ، (704 × 576) ، (352 × 288) ، (176 × 144). لتحديد أفضل تكوين لميزة H265 لكل تجارب دقة ، تم إجراء تجارب نتج عنها PSNR قدره 36 ديسيبل عند معدل البت المحدد. يتم تحديد الدقة من خلال التسليم (مورد التشفير) بناءً على تطبيق المستخدم النهائي ، بينما يتم تكييف دفق الفيديو مع النطاق الترددي المتاح من خلال تضمين وحدة تحكم مع بروتوكول MPEG DASH على جانب العميل. تسمح طرق تكييف دفق الفيديو بتسليم المحتوى المشفر في تمثيلات مختلفة لجودة الفيديو ومعدل البت ثم تقسيم كل تمثيل إلى أجزاء من الوقت. من خلال هذه الورقة ، نقترح استخدام HTTP / 2 كبروتوكول لتحقيق تدفق منخفض للفيديو مع التركيز على البث المباشر للفيديو لتجنب مشكلة HTTP / 1.

1. Introduction

In recent years, the production of digital video has advanced quickly. Video streaming, which transformed the Internet, would have been impossible without video compression [1]. By converting a raw video sequence to a coded video stream, video compression has advanced, allowing for the reduction of unnecessary digital information [2]. Video compression methods must include both an encoder and a decoder to compress the video and reconstruct the original [3]. A codec is made up of an encoder and a decoder working together. Video compression cuts down on memory usage and transmission costs [4,5].

Modern coding techniques such as MPEG-4 Part 10 Advanced Video Coding (H264)/AVC [6], H265/High-Efficiency Video Coding (HEVC) [7], and H266/VVC are used to compress video. HEVC, on the other hand, provides efficient video compression, reducing video file size by up to 50% when compared to H264 [8] with lower complexity. The goal of this paper is to investigate video streaming compression with H265 and video streaming adaptation with low latency using MPEG DASH and HTTP/2 protocol over a channel with an unlimited number of users sharing limited bandwidth. To identify the best quality and bitrate for each representation, the H265 parameters that directly affect the bitrate and quality, such as quantization parameter, constant rate factor, group of pictures, RC-lookahead, and others, are utilized. The client-side controller embedded in the MPEG DASH protocol selects the appropriate representation based on the channel situation.

Most of the major online browsers now support HTTP/2, a new version of the Hypertext Transfer Protocol (HTTP). Standard. HTTP/2 was created to make the most of network resources, deliver and receive data as quickly as possible. Only the push function, which allows the server to push content to the client before the client requests it, has attracted the interest of academics in the multimedia field. HTTP/2, on the other hand, includes a novel mechanism for multiplexing structured data delivery known as HTTP/2 streams [9].

Over the top (OTT) platforms are increasingly using HTTP Adaptive Streaming (HAS). The video content is encoded at several quality levels, which are referred to as representations. The client has a rate adaptation algorithm that determines the optimum representation to request based on a bandwidth prediction in real-time. Inaccurate forecasts, on the other hand, can occur, resulting in a reduction in the Quality of Experience (QoE) [10].The first service is for live streaming of traditional/non-immersive videos in restricted networks when HAS throughput forecast can be inaccurate [11]. In this instance, rebuffering events and a rising delay between the original video flow and the displayed video flow may occur, lowering the QoE.

2. Application Layer Protocol

With a small number of available video qualities (one Standard Definition (SD) and one High Definition (HD)), and low latency, streaming on the Internet used multicast and Real-Time Streaming Protocol (RTSP). Over the last decade, HAS has served as the most important technology for streaming live and VOD contents over the Internet. The use of CDNs to optimize client-server communications is possible with HTTP-based streaming. Furthermore, as the video streaming technology is built on top of HTTP, the packets simply pass through possible barriers like firewalls and NAT [12]. Additionally, by selecting a suitable representation, the client can optimize the quality of the video by using the available bandwidth.

3. Network video streaming

This system will deal with bandwidth reservations of video streaming with high-quality video representation especially due to an unusually large number of users on the channel that causes a variety of bandwidth availability. Video adaptive streaming methods, especially DASH, offer dynamical video quality adaptation to the channel condition factors. In April 2012, the MPEG-DASH protocol was released as ISO/IEC 23 009-1[13].The following are its main tenets:

The audiovisual content is encoded into many formats, each with its own video quality level and resolution. After that, each representation is segmented to make the video sequence available as a series of web objects. In DASH-based content delivery, the server generates two types of files: the Media Presentation Description (MPD), which contains metadata information about the video content and, the video chunks, which include the media data that is received by viewers as web objects (with HTTP GET requests). At each new request, a DASH client uses a rate-adaptation mechanism to match the video representation bitrate to the network bandwidth.

The rate adaption methods aren't part of the standard, thus they're up to the vendors to implement. Some input information, such as throughput prediction, buffer fullness state [14], and network parameters, can be taken into consideration by rate adaptation algorithms.

4. System Model Design

The H.265 encoder, together with its features and characteristics that impact Bitrate and PSNR, is utilized to determine the best value for these parameters for various representations. The raw video which is 3840x2160 is subsampled into (1920x1080), (1280x720), (704x576), (352x288) and (176x144) as seen in Figure 1. All representations are processed with H265 using its features mentioned in the previous sections. The MPEG DASH protocol with embedded control at client side achieves adaptive streaming. Each of these representations is optimized for Bitrate and PSNR as design steps, which can be re-constructed at the end-user by means of interpolation to the required resolution. Adapting the bitrate sent over the internet necessitates changing the network layer syntax to accommodate the sent format.

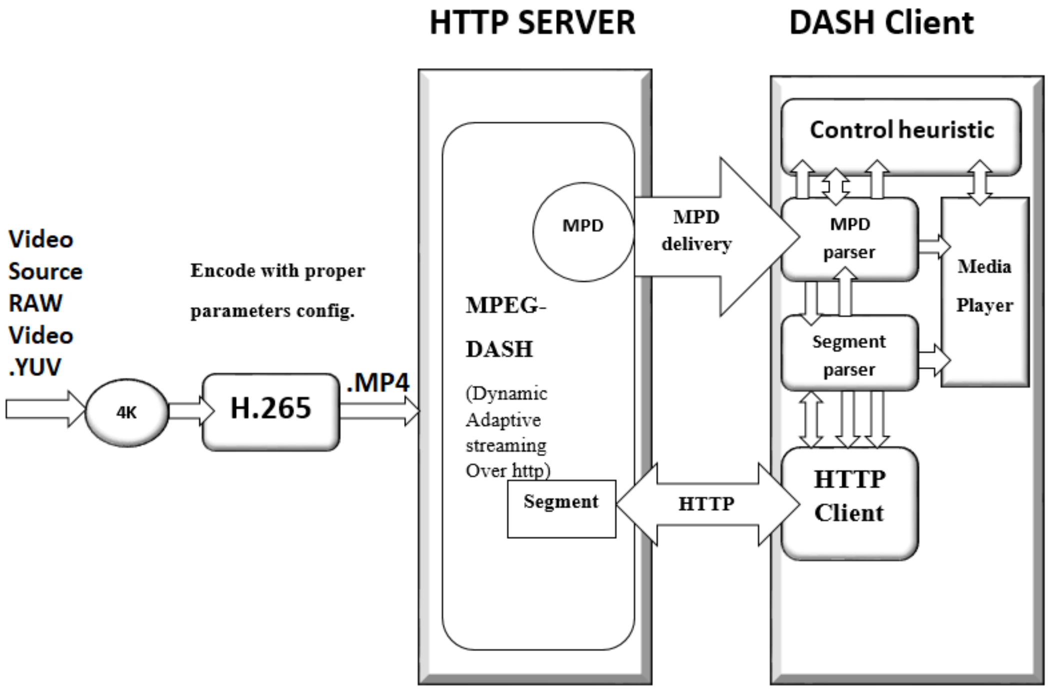


Figure 1- proposed system for video adaptation streaming with low latency.

5. Implementation procedure

The implementation consists of two parts; the first dealing with encoder configuration while the second is the server configuration. The main job of the first part is finding the optimal operation of HEVC standard at each resolution that keeps proper streaming with good quality. The second part is to install the server to work based on the results in the first part. This makes MPEG DASH protocol use the different resolution that works probably with channel condition.

5.1 Encoder configuration

This work uses libx265 and libavcodec, which provides a large number of codecs, as well as FFmpeg software package to convert, handle and stream videos. Because of the wide range of devices used by users and the limited bandwidth available, video resolution and bitrate streaming must be adapted. FFmpeg program applies a layering of HEVC/H.265 compressed representations to the raw video by utilizing the system parameters CRF, GOP, RC-LOOKAHEAD, and QP to produce a higher compression ratio according to the video's details. The QP doing a key role in enhancing the HEVC encoder's performance using Constant Rate Factor (CRF) of values 0-51.

GOP is also used for good quality and lower bitrate. There are two kinds of predictions in HEVC for reference pictures (Intra and inter). HEVC uses three types of slices (intra "I,”), (predictive "P,”) and (bi-predictive "B"), with the decoder putting up lists of reference pictures for the slice to be encoded when decoding a P or B slice.

5.2 The experiments design of the encoder configuration

In the experiments that were implemented, three test video sequences were utilized, each with a different dynamic state. The Beauty sequence features a tiny movement of one subject with a stationary lens. The Bosphour sequence features a dynamic scene with the camera moving to the left and the ReadySetGo sequence features a transition from rest to dynamic movement with the lens following. The work proposed utilizing six different resolutions of these video sequences, each with 600 frames (120 frames encoded) and a frame rate of 120 frames per second. Characteristics the compression ratio for each video in Table 1 at PSNR 36 dB for all resolutions. The three test sequences utilized in these investigations are shown in Figure 2.

Table 1- The compression ratio of video test with acceptable PSNR values for six representations.

Video	**Beauty/Low Details**		**Bosphour/Medium Details**		**Readysetgo/High Details**	
Resolution	PSNR	CR	PSNR (dB)	CR	PSNR	CR
4K	36.651	3235.08	36.459	9265.32	36.994	1775.4
HD	36.996	2510.58	36.626	3234.03	36.814	634.74
720p	36.776	2458.009	36.701	17337.78	36.966	317.34
4CIF	36.672	1724.6	36.588	1111.32	36.769	177.44
CIF	36.833	677.87	36.558	551.22	36.998	73.47
QCIF	36.929	268.72	36.938	346.08	36.751	46.53

(a) (b) (c)

Figure 2-Video test (a) Beauty (b) Bosphour (c) Readysetgo [15]

5.3 Constant rate factor

The performance of HEVC was verified using a variety of CRF numbers with a range values of six resolutions {4, 12, 20, 28, 36, 44 and 51}. In Tables 2-7, as can be seen the PSNR and Bitrate for different resolution are reduced when the CRF was growing.

Table 2 - CRF influence on the quality of video and Bitrate (Kbit/s) at 3840x2160 resolution

Video	**Beauty**			**Bosphour**			**Readysetgo**		
CRF	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)
4	47.008	3238779	150.22	48.459	1177332	99.87	47.862	1486195	103.34
12	40.307	1247564	119.55	44.927	175312	39.48	43.534	268984	43.83
20	36.083	151203	43.43	43.007	27664	18.51	41.588	36455	19
28	35.294	7603.68	13.64	40.521	6527.26	14.6	39.027	11864.61	13.85
36	34.425	2333.17	11.08	37.285	1877.57	15.61	35.451	4216.34	12
44	33.024	856.03	8.61	33.604	657.01	11.09	31.353	1709.83	9.47
51	31.841	780.96	8.29	31.557	471.15	7.65	28.818	1159.22	8.25

Table 3- CRF influence on the quality of video and Bitrate (Kbit/s) at 1920x1080 level

Video	**Beauty**			**Bosphour**			**Readysetgo**		
CRF	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)
4	47.378	609945.62	32.38	49.544	201422.2	15.68	48.308	225697.58	13.98
12	41.568	152660.27	19.08	46.286	41263.02	7.1	44.977	46407.81	6.27
20	39.331	10198.77	5.44	43.144	9979.75	4.23	41.658	14014.02	4.08
28	38.119	2662.01	3.47	39.493	2608.99	2.73	37.535	5031.48	3.04
36	36.085	786.14	2.57	35.753	725	2.24	33.222	1664.77	2.45
44	33.468	288.98	2.22	31.971	231.88	2.08	29.249	595.61	2.15
51	31.51	244.58	2.27	30.041	146.36	1.96	28.849	351.66	2.02

Table 4- CRF influence on the quality of video and Bitrate (Kbit/s) at 1280x720 level

Video	**Beauty**			**Bosphour**			**Readysetgo**		
CRF	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)
4	47.642	221353	13.57	49.684	81882.63	6.32	48.451	91344.84	5.96
12	42.604	39910.39	6.47	46.116	20573.12	3.45	44.729	25745.46	3.46
20	40.82	4629.04	2.57	42.415	5377.41	1.99	40.528	8662.71	2.43
28	38.843	1452.45	1.75	38.453	1418.26	1.23	36.015	2939.51	1.75
36	36.025	442.18	1.21	34.673	385.89	1.04	31.715	911.11	1.23
44	33.14	157.42	0.96	31.139	124.3	0.89	27.913	305.58	1.04
51	30.997	123.72	0.91	29.195	83.1	0.91	25.695	173.58	0.93

Table 5- CRF influence on the quality of video and Bitrate (Kbit/s) at 704x576 level

Video	**Beauty**			**Bosphour**			**Readysetgo**		
CRF	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)
4	47.965	70837.38	5.53	49.907	34764.53	3.07	48.474	43235.62	3.2
12	43.985	10335.43	2.49	45.946	10389.32	1.74	44.075	15284.82	2.14
20	41.794	2532.04	1.52	41.799	2900.87	1.01	39.322	5323.58	1.46
28	38.92	805.26	1.02	37.627	767.75	0.72	34.643	1699.82	1
36	35.684	239.72	1.39	33.911	207.3	0.64	30.471	497.45	0.71
44	32.336	89.71	0.64	30.542	69.26	0.6	26.812	155.68	0.62
51	30.099	69.24	0.6	28.598	48.5	0.59	24.73	88.9	0.58

Table 6- CRF influence on the quality of video and Bitrate (Kbit/s) at 352x288 level

Video	Beauty			Bosphour			Readysetgo		
CRF	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)
4	48.9	11162.45	1.58	50.22	9095.98	1.2	48.318	14388.11	1.38
12	45.411	2769.82	0.85	45.778	3150.61	0.73	43.097	6025.58	0.97
20	41.776	909.48	0.6	41.02	962.46	0.45	37.849	2167.55	0.65
28	37.927	287.83	0.39	36.321	357.19	0.27	33.042	642.59	0.39
36	34.15	97.83	0.27	32.617	74.13	0.21	28.953	176.36	0.25
44	30.561	41.82	0.21	29.196	32.46	0.21	25.476	53.52	0.21
51	28.258	31.32	0.2	27.676	25.02	0.19	23.604	38.59	0.19

Table 7- CRF influence on the quality of video and Bitrate (Kbit/s) at 176x144 level

Video	Beauty			Bosphour			Readysetgo		
CRF	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)	PSNR	BR(Kbit/s)	Time(s)
4	49.558	2302.88	0.47	50.498	2097.7	0.65	48.216	4619.81	0.63
12	45.185	879.35	0.65	45.894	806.62	0.29	42.599	2054.84	0.45
20	40.68	310.08	0.23	40.659	268.39	0.19	37.156	765.95	0.3
28	36.456	105.8	0.16	35.699	79.88	0.12	32.311	233.71	0.18
36	32.533	43.69	0.11	31.661	32.23	0.1	28.181	66.34	0.12
44	28.61	24.04	0.1	28.527	19.27	0.09	24.7	25.18	0.08
51	26.489	18.83	0.09	26.631	17.75	0.08	23.108	21.22	0.09

5.4 Group of pictures (GOP)

The frame type is another important factor that affects video quality. Frames can be divided into three categories: I, P, and B. Because I (intra) frames are coded without reference to previous frames, a P frame is predicted through forwarding prediction, while B frames are inter-coded using motion-compensated prediction from two reference frames[16].
Encode and decode each test video under the HEVC compression technique with the FFMPEG software. The desired bitrate ranges from 2 Mbit/s to 10 Mbit/s, with 1 Mbit/s increment. The GOP pattern is determined by the code structures below, five group of pictures and 3 B-frame values were used shown in Table 8. The encoder was tested for the three video sequences at different objective metric utilized to evaluate PSNR and processing time, as shown in Figures 3-5.

Table 8- Five GOP sizes and three B-frame numbers

GOP (group of pictures) size	B-frame numbers
4	2
8	2
16	2
24	2
16	4
16	8

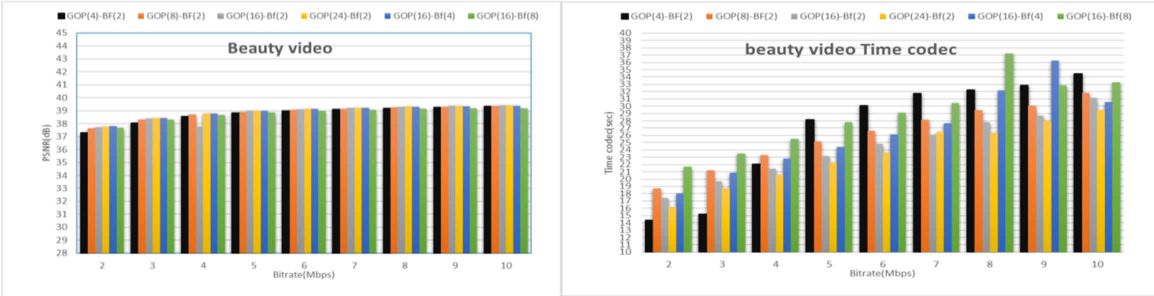


Figure 3- For the "Beauty" test sequences, the evaluation outcomes with various GOP structures and B-frame patterns

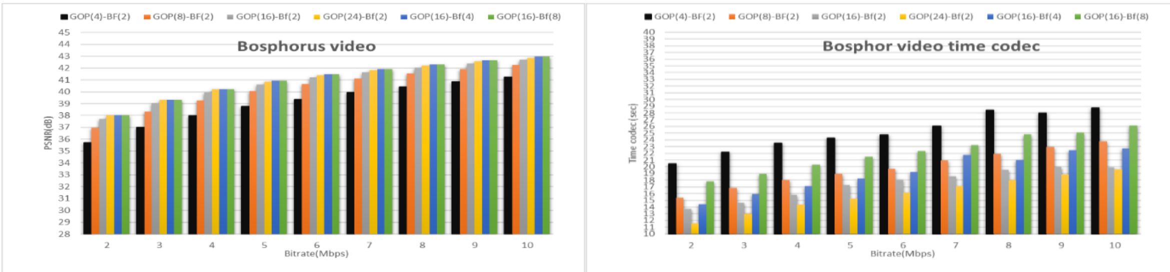


Figure 4- For the "Bosphorus" test sequences, the evaluation outcomes with various GOP structures and B-frame patterns

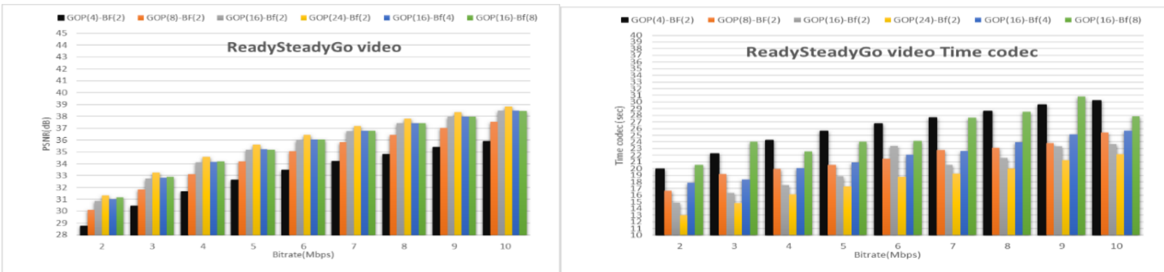


Figure 5- For the "Readysetgo" test sequences, the evaluation outcomes with various GOP structures and B-frame patterns

5.5 Quantization parameters (QP)

The performance of HEVC was certified with specified numbers of QP in the ranges of 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 51 to assess its suitability for their video sequences and information with six representations for the three test sequences, as shown in Figures 6-8.

(a) PSNR (db) (b) Bitrate (Kbit/s)

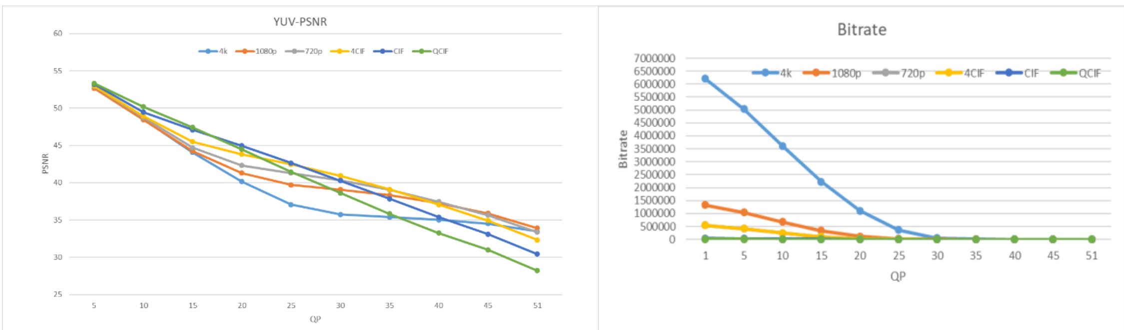
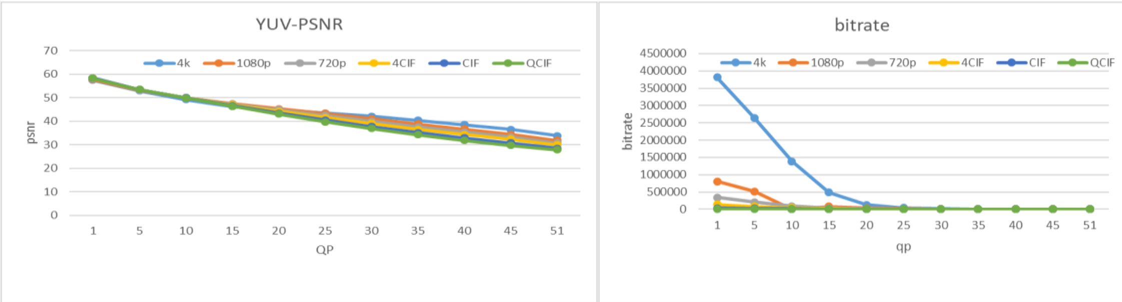
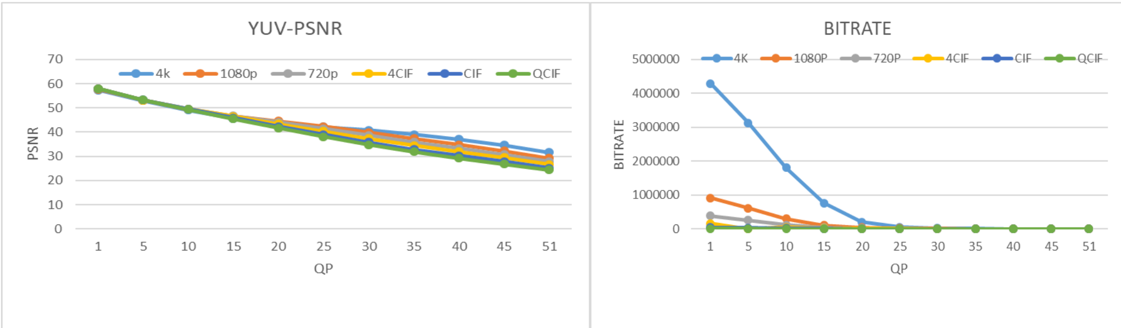


Figure 6- Beauty video test with six levels of representation and changes in PSNR and Bitrate according to QP value



(a) PSNR (db) (b) Bitrate (Kbit/s)

Figure 7- Bosphour video test with six levels of representation and changes in PSNR and Bitrate according to QP value

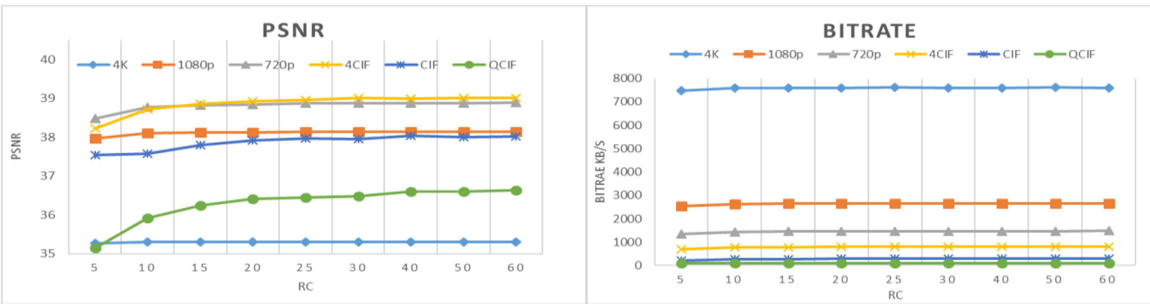


(a) PSNR (db) (b) Bitrate (Kbit/s)

Figure 8- ReadySetGo video test with six levels of representation and changes in PSNR and Bitrate according to QP value

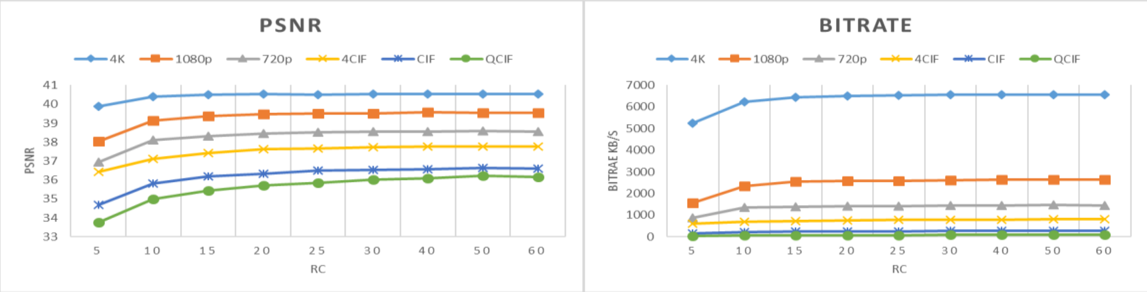
5.6 RC lookahead

Is the amount of frames used for slice-type decision lookahead, which is a major determinant of encoder delay. The longer the lookahead buffer, the more accurate scene cut judgments will be made and the tree will be more successful in enhancing adaptive quantization. It is not advisable to have a lookahead that is longer than the maximum keyframe interval. The range used in this work was {5, 10,15,20,25,30,40,50 and 60}. Default was 20 values, which is between the greatest consecutive bframe count and 250, see Figures 9-11.



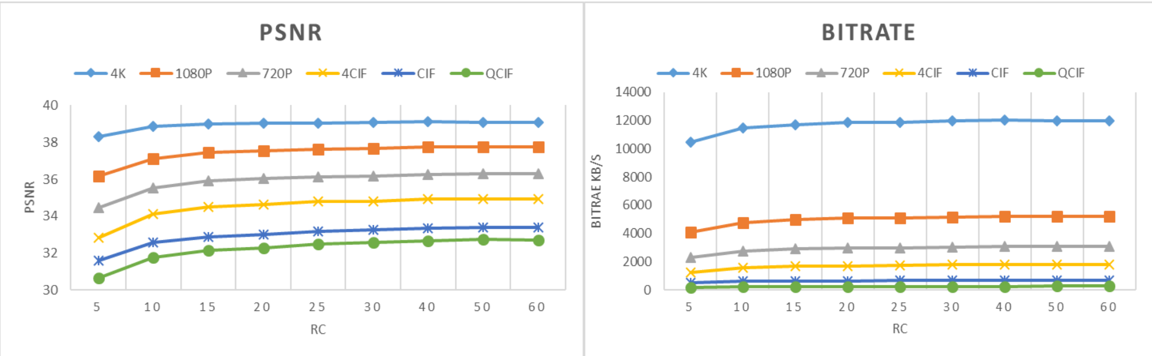
(a) PSNR (db) (b) BR (Kbit/s)

Figure 9- RC-lookahead influence on video's PSNR and Bitrate on Beauty video sequence with six representations



(a) PSNR (db) (b) BR (Kbit/s)

Figure 10- RC-lookahead influence on video's PSNR and Bitrate at Bosphour video sequence with six representations



(a) PSNR (db) (b) BR (Kbit/s)

Figure 11- RC-lookahead influence on video's PSNR and Bitrate at Readysetgo video sequence with six representations

6. Server configuration

As shown in Figure 1, when the HTTP server FFMPEG package is installed, this produces the coded video resolutions with multiple bitrates. At the same time, it applies MPEG DASH protocol in FFMPEG package in the server by splitting the video into segments and storing these segments on the server also create MPD file as XML file then transmit MPD file to the client for the function of dynamic adaptive video streaming over HTTP.

When the client sends an HTTP request to the server where HTTP/2 protocol pushes the proper segment to the client as web objects based on MPEG dash control in the client after sensing the condition of the channel. As shown in Figure 1 the streamed data includes side information and encoded data, which are together managed by means of the protocol syntax. Based on the received syntax the decoder will produce the required resolution.

7. Discussion and results analysis

We must determine the ideal configuration of the source device's encoder settings for each resolution that may be applied to each video sequence delivered over the channel. Therefore, in experiments results from encoding three videos, when using the H265 encoder parameters, the video sequence with poor movement details has a larger compression ratio than the other two videos and vice versa. Where QP is the most important parameter in determining Bitrate. From changing the value of QP, by varying the value of QP, we discovered that the ideal range was 32-45, which kept the video quality satisfactory at (34-39) dB. The same QP configuration was implemented to three separate video test sequences with differing movement details and bitrate. For example, when encoding the ReadySetGo video sequence at 4k level with QP values of 30, 35, 40, and 45, the PSNR of encoded video to be sent across the channel was within an acceptable range, and at a compression ratio of 3473.73, the Bitrate with a greater reduction value of 45 has a lower acceptable quality of 34.628 dB. This situation was tested with three test video sequences to determine the optimal QP.

However, instead of using QP, CRF may be used to save PSNR and reduce Bitrate. The bitrate was chosen based on the buffer state. Thus, when the buffer is congested, the selected bitrate should be low to adapt to the available bandwidth. The video quality changes in direct relation to the bitrate of the video; as the bitrate is reduced, the quality decreases. However, with the right GOP selection, the video quality may be successfully improved even with a low bitrate. With the right RC-lookahead setting, video quality may be significantly improved at a low bitrate. Table 9 shows how these tests may be utilized to determine the optimal parameter setup.

Table 9- With six representations, the best parameter configuration for the ReadySetGo test video

Representations	RC	GOP	QP	Before hevc bitrate Kbit/s	After hevc bitrate Kbit/s	PSNR	Time encode(s)	CR
4K	20	100	40	11943936	6727.52	36.994	11.73	1775.38
1080i/ p	20	100	36	2985984	4704.24	36.814	3.03	634.74
720p	20	100	33	1327104	4181.86	36.966	1.93	317.34
4CIF	20	100	31	583925	3290.80	36.769	1.23	177.44
CIF	20	100	28	145981	1986.71	36.998	0.61	73.47
QCIF	20	100	27	36495	784.24	36.751	0.29	46.53

8. Conclusion and future work

The purpose of this paper was to provide an overview of the latest video coding standards through exploring their implications for multimedia communications. This was achieved by examining videos encoded with the new coding standard through studying the video quality under HEVC/H265 compression and the adaption of high-quality video transmission with low latency across the internet network while sending to end-users.

Two steps solve the limitation bandwidth problem when the number of users on the network is growing: First, streaming an H265 for each representation with optimal H265 configuration. Second, using MPEG dash protocol with embed controller to choose the most suitable representation. The tests assist us in identifying the appropriate setting for each layer to obtain a PSNR of 36dB. When the system is in operation, the controller embedded with MPEG dash protocol is continuously sensing the situation of the channel, using the feedback acknowledgment from client, to choose the suitable video representation to send over the remaining channel bandwidth.

To transfer a video with a resolution smaller than 4K, customers choose a resolution that is compatible with the application on the end devices. When the controller detects the channel status, it sends an instruction to the HTTP server to apply the optimum configuration for preserving video quality with proper BR that is appropriate for available channel bandwidth. However, the downside of this approach is that it requires fast processing and high device requirements due to the rapid changing of the channel status over time. Meanwhile, this study offers valuable advice on video compression techniques. Hardware implementation of the suggested encoder increases the processing speed that supports the diversity of applications.

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