INTELLIGENT VIDEO ENCODER SELECTION SYSTEM FOR SMART DEVICES

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ABSTRACT: The advancement in technologies has provoked the trend of multimedia data exchange with smart devices. The smart devices have variant characteristics like low processing power, small computational capabilities and memory capacity etc. Therefore, there was a need to transmit video with maximum compression and security by minimal utilization of processing power and network bandwidth. Two widely used encoders for the video compression i.e. Advanced Video Coding (H.264/AVC) and Highly Efficient Video Coding (HEVC) were used for device selection. H.264/AVC was energy efficient but provided less compression rate than HEVC. However, due to differing capabilities of smart devices in terms of energy and storage, there was a need to devise a mechanism to automatically detect a video encoder as per device requirements. This paper has proposed two novel schemes: firstly, a Fuzzy Rules Based (FRB) system to auto detects encoder by taking the smart devices with their genuine capabilities like energy, storage and bandwidth etc. at destination and secondly, a lightweight Selective Encryption (SE) scheme to secure the output video produced by each encoder. This FRB implementation system proved to be a pioneer work in this field of exchanging secure compressed multimedia for smart devices and provided average 95% accuracy in choosing correct encoder with security.

Keywords: Fuzzy Rules; H.264/AVC; HEVC; IoT; Smart devices; Video encoders.

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INTRODUCTION

For last two decades, the video based communications over the internet are gaining popularity in many fields including education, research, entertainment, business, defense, and military etc. (Wu *et al.,* 2000). As per Cisco statistics, it can be predicted on the basis of observations that the video transmission is likely to consume overall 80% - 90% of the network bandwidth by the year 2018 (Garudadri *et al.,* 2017). Moreover, in the modern age, the advancement in computer and communication technologies provokes the trend of multimedia data exchange with smart devices in IoT environment. The IoT defines the interconnection between smart devices/objects of daily life to collect and exchange their data (Al-Fuqaha *et al.,* 2015). The interconnection occurs among the objects with the help of particular identifier, so the data exchange on the network can take place without any kind of human cooperation. The object with a unique identifier is called the smart object or smart device. Each and every smart object in the IoT depends on three entities, (1) interaction, (2) awareness and (3) representation. The first one is related to the communication between objects, the second one about understanding of these smart objects and the last one is presentation of these objects (Gubbi *et al.,* 2013). Due to day by day development in IoT, there are, approximately, 80 billion smart devices/objects interconnected with the help of internet (Meulen, 2017). The IoT environment provides many applications which are used in daily life such as in intelligent monitoring system, transportation, agriculture and many other industries.

The smart devices in IoT environment have variant characteristics like different energy levels, low processing power and small computational memory capacity etc. Thus, the efficient video transmission from source to destination becomes more important these days. On one side, data is required to be sent efficiently from source to destination, while on the other side, data compatibility and security is also an important issue to handle (Asghar *et al.,* 2017). To address the aforementioned issues, video compression technique along with security mechanism is used for broadcasting. Therefore, for video compression; video encoders are utilized to empower more efficient utilization of transmission and storage capacity (Gubbi *et al.,* 2013). If, a high bitrate transmission channel is accessible, then it is a more alluring suggestion to send high-resolution compressed videos rather to send individual, low-resolution and uncompressed stream. Indeed, even with consistent advances in storage and transmission limit, compression is liable to be a key component of multimedia services (Sicari *et al.,* 2015).

Now a days, the most useable video encoding technique is H.264/AVC (Ostermann *et al.,* 2004); which is developed by ITU T/ISO/IEC by Joint Video Team (Islam *et al.*, 2014). H.264/AVC provides the development in compression and also provides network friendly description of video for informal (like video telephony) and formal (like streaming) type of applications. The major function of H.264/AVC is to provide high rate of coding in efficient way with very low bitrate.

Currently used video coding standard namely, highly efficient video coding (HEVC) has been used for video encoding since 2013 (Bougacha *et al.*, 2016). HEVC performs more accurately and efficiently as compared to the old video encoding tool. HEVC/H.265 also uses the same technique which is based on the predictions and these predictions are based on the motion estimation among the frames. This new video coding standard (HEVC/H.265) has more complexity in coding, but provides better performance (Sze and Budagavi, 2012).

Furthermore, Fuzzy logic is adopting popularity among the researchers for the expert systems development almost in industries such as agriculture, transportation, ecological monitoring system etc. (Shahzadi *et al.*, 2016). To explore further about the popularity of FRB systems in other science areas, the authors worked on the underwater vehicles and mention the issues of development and design of robotic system by using the FRB control algorithms (Johnson *et al.*, 2016). The FRB system is the expert system that provides the solution using different knowledge based artificial intelligence (AI) algorithms. The expert systems in IoT are different from the traditional experts system in such a way that they are capable of taking decision by manipulating the various parameters of the real time environment. Therefore, in this research work, we have proposed an FRB system to automatically select the video compression encoder for the constrained smart device and ensure the minimum bandwidth utilization. The fuzzy rules are devised by taking the genuine IoT devices like PCs, laptops, tablets, mobiles and servers with their genuine capabilities like energy, storage, Frames per Second (FPS), screen resolution, bandwidth and throughput etc. The proposed FRB system selects the best encoder for specific smart device and compresses the video with chosen encoder.

MATERIALS AND METHODS

The research work investigated the way out to resolve the issue of effective secure video compression/storage system along with FRB decision system to choose suitable encoder for IoT devices. The proposed framework resolved the key problem of selecting the best suitable encoder for hybrid infrastructure i.e. the devices like mobiles, tablets, laptops and servers with differing requirements such as energy, storage, screen resolution and frame rate. Following steps were taken to solve the above research problems.

1. Detection/Selection of IoT based smart devices.
2. Identification of destination device resources.
3. Identification of the source to destination network characteristics.
4. Identify the need of encoder as per destination device and network characteristics:

H.264/AVC
HEVC/H.265

5. Automatic expert system for the selection of specific encoder as per step 2 &3.
6. Lightweight encryption scheme was proposed to secure the produced output.

Two encoders of video standards H.264/AVC and HEVC/H.265 were investigated and Fuzzy rules based decision system was developed for the selection of any of these two compression algorithms for IoT devices. The series of applied steps were as follows:

Step 1: Input video selected in Raw (YUV) video format.
Step 2: Different IoT devices were selected to get their capabilities.
Step 3: Prediction of using compression standard by applying Fuzzy rules. Prediction was based on device and network specifications.
Step 4: As per prediction, the devices used H.264/AVC or HEVC/H.265 compression video coding standards along with selective encryption scheme for encoding.
Step 6: Exclusive-OR (XOR) based lightweight encryption scheme was implemented on colour pixels of videos to make output secure.
Step 7: Efficiency of proposed encryption was measured with video encoding time.
Step 8: Decoded YUV video was in the output.

Fuzzy Rules: The proper selection of parameters to define the fuzzy rule was an important factor for the accurate section in the real-time and dynamic environment of IoT. In the proposed system the fuzzy rules for the smart devices and network capabilities were formulated by taking energy, storage, Frames per Second (FPS), screen resolution, bandwidth and throughput parameters/characteristics. Those parameters with their real data values are listed as in Table 1.

A. Fuzzy Rules for Encoders

If ‘energy’=5
AND ‘storage’=16
AND ‘fps’=30
AND ‘size’=3.5
THEN the action in step 1 was complete.
If step 1 was complete
AND the ‘bandwidth’ was =2
AND the ‘throughput’ was=20
AND the ‘compression’ was =H.264
AND the ‘quality’ was =medium

Then the action in Step 2 was complete.
If step 2 was complete
AND the ‘security’ was implemented with = Exclusive OR (XOR) THEN the action in step 3 was complete.

B. Fuzzy Rules Based Pseudo Code Algorithm for encoders system

1. Set result to false
2. Input the energy level of the device
3. Input storage of the device
4. Input the frame rate
5. Input the screen size
6. If energy equals to 5
7. If storage equals to 16
8. If frame rate equals to 30
9. If the screen size equals to 3.5
10. Set result to true
11. If result equals to true
12. Display step 1 to complete
13. Display enter the network properties
14. Input bandwidth
15. Input throughput of the medium
16. Input compression mode
17. Input quality regarding delay
18. If bandwidth equals to 2 GHz
19. If throughput is equals to 20
20. If compression mode equals to H.264
21. If quality level equals to 1
22. Set result to true
23. If result equals to true
24. Display step 2 was also complete
25. Input security level was XOR
26. Apply XOR algorithm for security

Exclusive OR Encryption: It is a basic encryption algorithm that is a type of additive cipher. It uses exclusive disjunction operation. It is a stream cipher in which by using a key, bitwise XOR operator was applied to every character of the string of plaintext for its encryption. Decryption was done by XO Ring the key with cipher text to get the original text.

RESULTS AND DISCUSSION

In this section, the results were analyzed for both the encoding schemes i.e. AVC and HEVC at different parameters. The reference software implementation of H.264 Advance Video Coding (JSVM) 9.19.18 version encoder in AVC mode and H.265 High Efficiency Video Coding (HM) 12.1 version for HEVC mode were used for experiments. The experiments were performed on Common Intermediate Format (CIF) (352 × 288 pixels/frame) video resolutions. Three video sequences were chosen for experiments namely FOOTBALL, MOBILE and NEWS. For the ease of testing, the sequences were configured in CIF (352 * 288 pixels/frame) @ 30 Hz, with standard 4:2:0 sampling, the value of GOP size and INTRA-PERIOD taken as "8" and 90 frames of each were used to sift out the facts. The frame format in the experiments used only I and P frames, the reason for ignoring the B frames is removing the video drift because B frames deal with Motion Vectors Difference (MVD) residual signs which encounter drift problem in video. Selective Encryption (SE) applied on residual of motion (MVD) signs, colour pixel Discrete

Cosine Transformation (DCT)) signs and combined encryption (MVD signs + DCT signs) on all the encoded (AVC and HEVC) video sequences by using the exclusive OR (XOR) based encryption method. The machine used for experiments were Intel Core i3 Core 2 Duo (2.10 GHz) processor with 6GB RAM.

In the first run, the MVDs sign were encrypted with XOR encryption method, the encryption effect was analyzed and compared with original unencrypted videos. After that the encryption was applied on DCT signs and the effect on videos was analyzed as well. Then SE was applied with both parameters i.e. MVDs + DCTs, and the results were compared with previous two schemes.

SE was applied with different Quantization Parameter (QP) levels i.e. 12, 24, 36 and 48 on Football and mobile video sequences snapshots as shown in Figure 1 and 2 (in original). The visual quality of videos was measured by Peak Signal to Noise Ratio (PSNR) (Huynh-Thu and Ghanbari, 2012) and Structural Similarity Index (SSIM) (Wang *et al.,* 48 on Football and mobile video sequences snapshots as shown in Figure 1 and 2 (in original). The visual quality of videos was measured by Peak Signal to Noise Ratio (PSNR) (Huynh-Thu and Ghanbari, 2012) and Structural Similarity Index (SSIM) (Wang *et al.*, 2004) quality Metrics. The quality effect of each video sequence in the form of PSNR and SSIM are shown with each snapshot in Figure 1 and 2. QP defines the quality of video perception. QP values are reciprocal to video quality, as when QP value increases, the quality of video decreases and vice versa. The basic purpose of taking results was to show that even on less QP i.e. at QP = 12 videos quality was high as the SE destroyed the video quality. The quality as well as the size of the file decreases as the QP level increases.

Figure 3 shows that the SSIM of HEVC is higher than the SSIM of AVC in both the cases (SSIM of with/without SE). So it reflects that the video quality provided by HEVC encoding scheme is superior to the AVC encoding scheme, either it was used with simple encoding or encoding done with SE.

Graphs given in Figures 4 and 5 show that the encoding time of HEVC encoding scheme were higher than the AVC encoding scheme either it was done with simple encoding or encoding done with SE. It reflected that HEVC encoding scheme was much more complex as compared to AVC encoding scheme.

As there are many challenges posed by IoT environment, many solutions have been proposed to address different aspects of coding, transmission and efficiency of the systems. However, some optimized approaches had been presented by researchers to address the configuration and compatibility issue in the diverse environment. The authors (Roodaki *et al.*, 2017) proposed the idea of power of the mobile devices, in which they discussed the issues of the high resolution devices consuming more power which caused quick battery drains. The H.264/AVC receiver aware encoder was developed to overcome the complexity in an excellent way. Thus, the solution has been addressed in proposed FRB system by auto selection of H.264/AVC encoder for the energy and power constrained smart devices and it worked more accurate than the proposed method in the research (Lee *et al.*, 2014). In another research work, the authors (Lee *et al.*, 2011) proposed dynamic image transmission by optimizing the transmission rate to increase the efficiency and save the energy over visual sensor networks. However, in this work transmission rate was adjusted by taking the flow and routing information of source node only which is less effective than this proposed work for smart system in the IoT environment. In another related study, the authors (Sonmez *et al.*, 2014) presented congestion control system based on fuzzy rules to improve energy efficiency across the multimedia sensor networks. In this work, the proposed methods affected the image quality badly while the proposed scheme has attained good results without affecting the quality.

The authors (Sharma *et al.*, 2014) implemented the advanced controllers using FRB logics control for the purpose of performance improvement of FLC. In this study, the researchers worked on the design of the FRB logic control of self-tuner process and how the FRB systems supervise all these processes with FRB supervisor Performance Improvement (PI) controller. However, in this work different FRB-PI logic controls were used to obtain the result of all this process, provided accuracy was 80%. If this work has been compared with the proposed work, the accuracy is much higher i.e. 95%.

In an older work, the researchers (Lovato and Oliveira, 2010) presented intelligent air- traffic management system by using FRB control. In their work they worked on the changes in airplane level to reduce the air traffic controller workload by implementing the FRB logic on the airport for making decision about the different levels, like traffic control with time, takeoff and landing of flight. However, this proposed research work is different from the said research on the basis of scope, functionalities and application domain.

Furthermore, there are various SE approaches proposed in the prior research of H.264/AVC and H.265/HEVC). The difference among the proposed schemes is the encoding, video quality; computation complexity and file size as well (Asghar et al., 2017). H.264/SVC has a base layer and multiple enhancement layers. Base layer of SVC was relative to H.264/AVC profile and all the encryption techniques of H.264/AVC could be applied on the base layer of SVC. SE can be applied on different stages of an encoder i.e. spatial or temporal fields, quantization field, inter frame or intra frame field, entropy coding field and so on. All the proposed schemes had some benefits and some drawbacks that were briefly compared with proposed scheme. In year 2010, authors (Lovato and Oliveira, 2010) proposed an encryption scheme of H.264/AVC for improvement of SE. This scheme was used to increase the security of video content. In this scheme Advanced Encryption Standard (AES) (Hamdan *et al.*, 2010) was used for encryption. However, AES was applied only on I frames, those were first drawn out of the stream and then placed encrypted I frames back into the stream. This scheme provided more security because AES was more powerful algorithm which has resistance against many attacks. This scheme helped to decrease the computational complexity due to encrypting only I frames. However, the proposed work was implemented on both I and P frames of H.264/AVC and HEVC videos. Moreover, in proposed work, at the first we had only encrypted the MVDs sign with XOR encryption and then encrypted only the sign of coefficients and texture and analyzed the effect in comparison with original unencrypted videos.

The authors (Zou *et al.*, 2006) proposed an encryption scheme based on H.264/AVC entropy coding and it is adapted to Digital Rights Management (DRM). In this scheme the Network Abstraction Layer (NAL) units were extracted from stream and encrypted to make a cipher text. By doing this computational complexity was reduced to some extent but compression efficiency was not improved. It provided different levels of security and gains a tradeoff between complexity and security. However, this scheme is suitable for multimedia storage and transmission but is not much effective for smart environment. Hence, in another study, the authors (Shahid and Puech, 2014) proposed SE of bit streams of HEVC. HEVC supports entropy coding module Context Adaptive Binary Arithmetic Coding (CABAC) (Sze and Budagvi, 2012). The bin strings of CABAC were encrypted using standard algorithm, AES in its cipher feedback mode without affecting its coding efficiency. This encryption has been applied on I and P frames. This generated the format compliant bit- streams in which there was no bitrate overhead and with low computational power. This scheme is suitable for real time applications as it demanded constant bitrate and has been adopted in proposed work. The entropy coder CABAC was selected for both encoders and their results were compared in this paper. The cryptanalysis of proposed selective encryption was also tested with the work of authors (Asghar *et al.*, 2014).

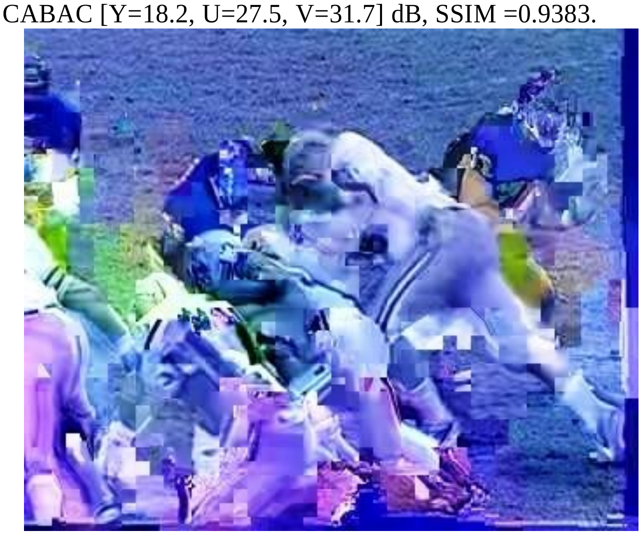
Table-1. IoT Devices Real Data.

DEVICE TYPE	Device Name	Device Capabilities				Network Capabiblities				Security Capabilities
		Energy(Hours) on wifi and 3G	Storage(GB)	FPS	Size(Inch)	Bandwidth(MHZ)	Throughput	Compression	Quality	XOR
MOBILE PHONES	Qmobile Noir 6	5	16	30	3.5	2 MHZ	20 kb	H.264	Medium	Yes
	Qmobile E 10	7	32	35	5.5	4 MHZ	40 kb	HEVC	Medium	Yes
	Vigo Tel 7	8	64	42	5.5	6 MHZ	60 kb	H.264	Medium	Yes
TABS	Huwei E 11	5	64	30	9.7	8 MHZ	80 kb	H.264	Medium	Yes
	Lenovo Plus 5	4	32	28	7	10 MHZ	100 kb	HEVC	Medium	Yes
LAPTOP	HP TU 1000	2.5	500	20	15.6	12 MHZ	120 kb	H.264	High	Yes
	DELL 6410	3	320	28	13.3	14 MHZ	140 kb	HEVC	High	Yes

AVC encoded video with SE at QP 12 for *Football* with CABAC [Y=9.3, U=14.2, V=21.1] dB, SSIM =0.4776.

HEVC encoded video with SE at QP 12 for *Football* with CABAC [Y=18.2, U=27.5, V=31.7] dB, SSIM =0.9383.

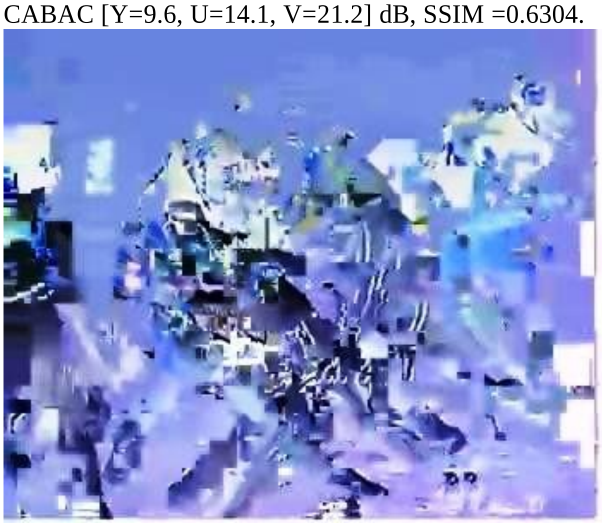
AVC encoded with SE at QP 24 [Y=8.8, U=14.4, V=21.1] dB, SSIM =0.4675.



HEVC encoded with SE at QP 24 [Y=16.1, U=16.1, V=19.6] dB, SSIM =0.8659.

AVC encoded video with SE at QP 36 for *Football* with CABAC [Y=9.6, U=14.1, V=21.2] dB, SSIM =0.6304.

HEVC encoded video with SE at QP 36 for *Football* with CABAC [Y=11.0, U=13.1, V=19.5] dB, SSIM =0.7238.



AVC encoded video with SE at QP 48 for *Football* with CABAC [Y=10.3, U=14.1, V=21.0] dB, SSIM =0.6433.

HEVC encoded video with SE at QP 48 for *Football* with CABAC [Y=9.6, U=13.4, V=20.0] dB, SSIM =0.7063.

AVC encoded video with SE at QP 12 for *Mobile* with CABAC [Y=6.7, U=12.9, V=13.2] dB, SSIM =0.0637.

HEVC encoded video with SE at QP 12 for *Mobile* with CABAC [Y=14.2, U=15.5, V=8.6] dB, SSIM =0.3142.

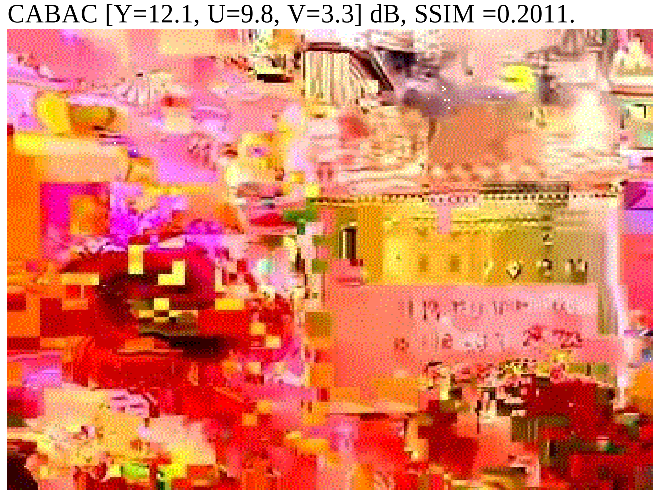
AVC encoded video with SE at QP 24 for *Mobile* with CABAC [Y=6.7, U=12.9, V=13.3] dB, SSIM =0.0698.

HEVC encoded video with SE at QP 24 for *Mobile* with CABAC [Y=12.3, U=16.0, V=4.0] dB, SSIM =0.2478.

AVC encoded video with SE at QP 36 for *Mobile* with CABAC [Y=6.6, U=12.9, V=13.4] dB, SSIM =0.0805.

HEVC encoded video with SE at QP 36 for *Mobile* with CABAC [Y=12.1, U=9.8, V=3.3] dB, SSIM =0.2011.

AVC encoded video with SE at QP 48 for *Mobile* with CABAC [Y=7.6, U=14.4, V=13.2] dB, SSIM =0.0690.



HEVC encoded video with SE at QP 48 for *Mobile* withCABAC [Y=9.9, U=10.5, V=3.7] dB, SSIM =0.1362

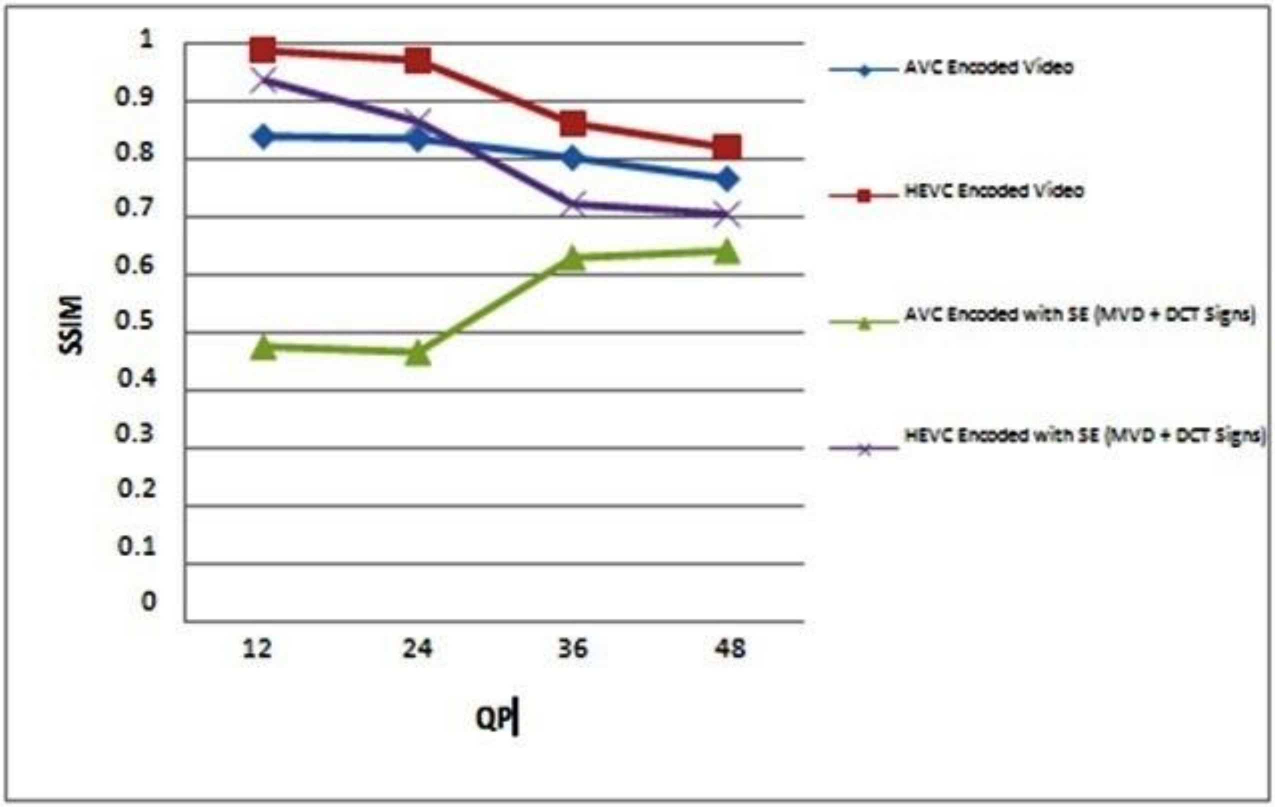


Figure-3: Difference of SSIM of with and without SE of H.264/AVC and HEVC encoding schemes.

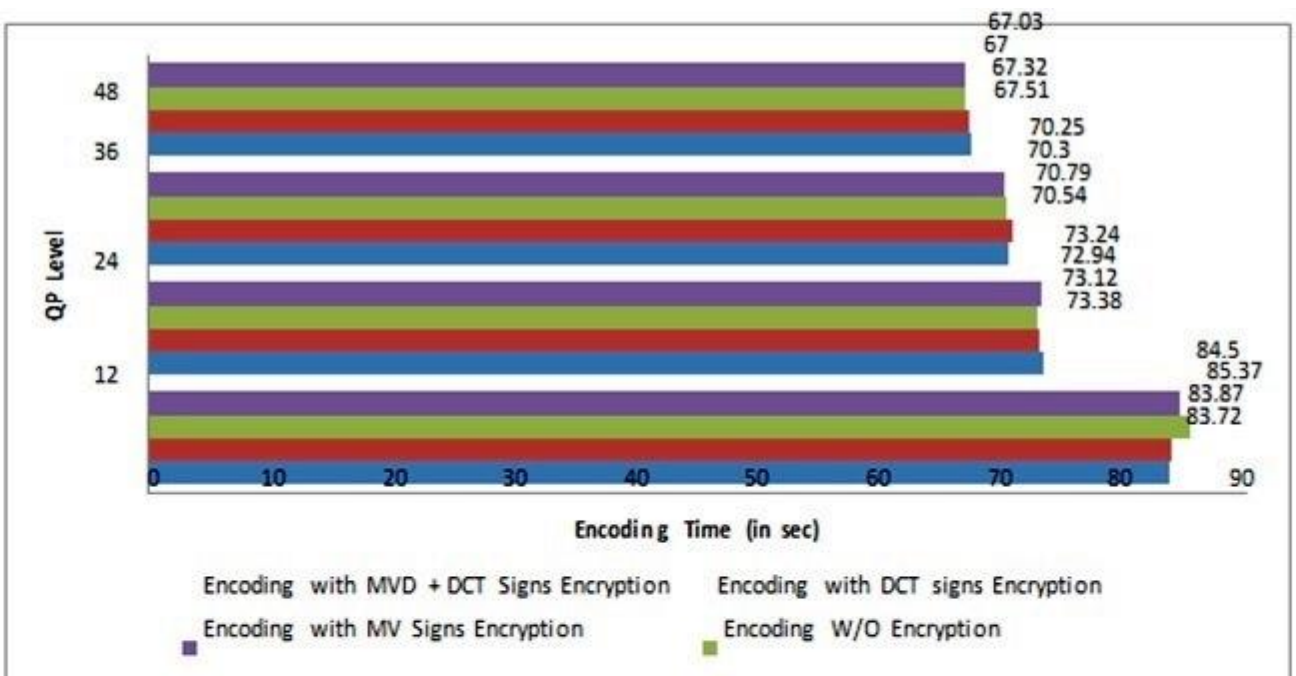


Figure-4. Effect of encoding time using H.264/AVC Encoder for Football Video

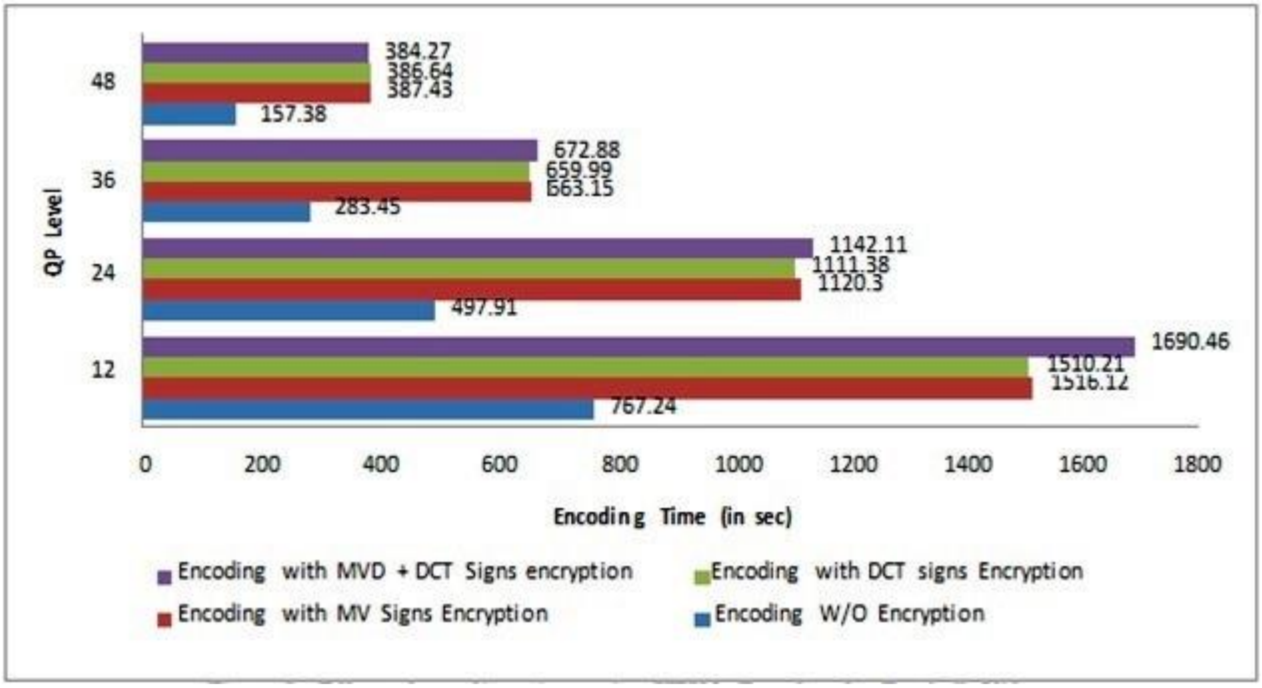


Figure-5. Effect of encoding time using HEVC Encoder for Football Video.

Conclusion: In an IoT environment, smart devices exhibited some real time constraints such as constant bitrate, small computational power, less energy consumptions, no compression overhead and sufficient security. Hence, in this research work, novel FRB expert system has been implemented. The proposed expert system intelligently selected the suitable video encoder either H.264/AVC or HEVC by judging the device and network requirements appropriate for the video transmission. The results from different sample videos confirmed the validity of proposed FRB system for encoder selection. As a research contribution, the implementation of proposed framework provided the minimum computational cost due to lightweight XOR based selective encryption. Furthermore, FRB system proposed better performance in terms of encoder selection time, maintained video format compliancy without generating network overhead for encrypted videos while ensuring medium level of security.

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