ERROR RESILIENCE OF H.264/AVC CODING STRUCTURES FOR DELIVERY OVER WIRELESS NETWORKS

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ABSTRACT

Video content represents a large portion of global network traffic, and it is expected that this trend will continue as 4K video streaming becomes more popular and more applications such as entertainment and surveillance become available. Wireless networks are becoming the most important technologies for delivering cost-effective content, including video. The unpredictability of wireless channels, as well as the sensitivity of video content to packet losses, errors, and delays makes video delivery over wireless network difficult. Furthermore, when compared to wire links, congestion and complex traffic patterns make wireless channels much worse. Packet losses and network errors can be mitigated with the help of modern codecs. This study looks at the modern video codec H.264/Advanced Video Coding (AVC) and how to use the built-in error resilience tools to improve end-to-end video quality over simulated wireless networks. Network Simulator 3 (NS-3) was used and a framework for video quality assessment based on EvalVid 2.7 tools was employed. We tested the performance of several coding structures in the presence of different intra coding techniques. Results for less active video sequences showed that the IBP coding structure with intra period of 18 achieved best performance at lower loss rates. The addition of an intra MB line or extra random intra MBs did not seem to offer extra protection against errors for these sequences. For more active video sequences, IBBBP coding structure without or with an intra MB line performed better than all other configurations at all loss rates.

KEYWORDS: H.264/AVC, Video Coding, Error Resilience, Wireless Communication, NS-3

1. INTRODUCTION

During the last two decades, the development of high-quality video coding to support existing and future visual communication systems has increased dramatically. For both academia and industry, the non-guaranteed quality of service in real-time video delivery is a difficult task. Therefore, in the field of video communication systems, approaches to error resilience at the video coding layer are of particular interest. In fact, as video coding efficiency improves, inter-prediction and motion compensation processes become more complex.

A highly compressed bit-stream means that more redundant video information is encoded. Consequently, then compressed video content becomes more sensitive to bit errors (Flynn et al. 2015). When transmitted over a wireless link, the assessed objective video quality is affected by many parameters like video resolution, encoding/decoding technologies and transmission link quality (UHRINA et al. 2014). As a result, sending a highly compressed video bit-stream over an unreliable transmission channel causes degraded perceived visual quality or decoding failure for the entire video sequence if errors occur in sensitive encoded data like slice headers (Psannis 2016).

Fig.(1) show the video transmission scenario for sending video over an unreliable wireless channel.

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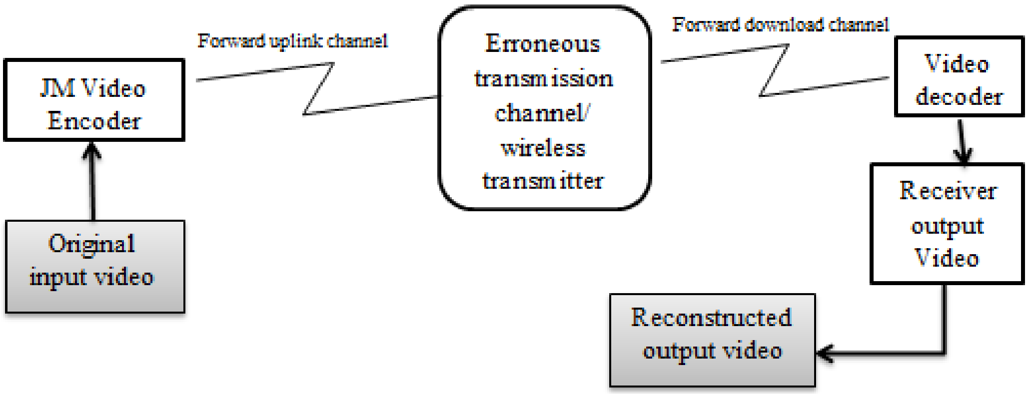

Fig.(1):- Scenario for sending H.264/AVC video

There are mainly several error control categories for reducing the impact of transmission errors on interpreted visual quality. Error resilience techniques are used to effectively reduce the effects of transmission errors on the video decoder side. In this work, we evaluated several strategies to achieve more robust video encoding for delivery over wireless network like the impact of several intra-coding techniques on different coding structures.

The remaining sections of the paper are organized as follows: The second section contains some related work. Section 3 goes over some video coding guidelines. Section 4 discusses the video quality assessments. Section 5 discusses the features of robustness and error resilience. Section 6 discusses our evaluation framework and network topology. Section 7 discusses and presents the simulation results for Stefan and Foreman video sequence delivery over wireless networks. Finally, Section 8 comes to the conclusion of the overall work presented in this paper.

2. RELATED WORK

There has recently been an increase in interest in research into the error resilience methods particularly for video streaming over wireless networks. Anthony O. Adeyemi-Ejeye, et.al (Adeyemi-Ejeye et al. 2019a) studied two current standard video codecs: H.264/AVC and H.264/High Efficiency Video Coding (HEVC). After accounting for relative coding gain, they compared the two codecs' robustness to packet loss. Despite their differing coding efficiencies, the H.264/AVC codec is less affected by packet loss than H.265/HEVC, even at low levels of packet loss.

A.O Adeyemi-Ejeye, et.al (Adeyemi-Ejeye et al. 2019b) gave an overview of research into real-time high-resolution video transmission over wireless links. Their results were shown at 4K UHD resolutions, demonstrating the likely video quality over low packet loss channels over a short distance. Their findings show that motion complexity has a significant impact on the quality that can be achieved at a given CBR. It is possible to reduce the impact of any packet loss by using a less efficient codec, such as H.264/AVC, rather than H.265/HEVC.

C. M. Calafate, et.al (Calafate and Malumbres 2003) developed a framework for tuning and evaluating the H.264 codec's performance in 802.11b wireless ad-hoc networks. The error-resilience features of the codec are tested under stress conditions that are typical of these networks, and the most critical parameters were presented. They also demonstrated how to quickly recover from packet loss bursts and presented solutions to the problem of random packet losses.

The results of evaluating H.264/AVC video quality in the presence of packet losses were presented by the author in (Dai and Lehnert 2010). The findings show that even a single packet loss in an I-frame can cause video impairment and degrade video quality significantly. Within a short time, the impact of single packet loss was evaluated with various frequencies and loss distances. They discovered that if there are more than two single losses in a short period of time, the video quality will deteriorate.

Hui-Seon Gang, et.al (Gang, Kwon, and Pyun 2016) proposed a network-aware reference frame control system that, based on channel status, maintains a balance between coding efficiency and error resilience. Their experimental results show that the proposed video streaming system has a PSNR of 0.2 to 0.5

Decibels (dB) better than a conventional video streaming system using a single reference frame, and a PSNR of 0.3 to 3 dB better than a conventional system using seven reference frames when video frames are damaged. Furthermore, to improve error robustness, the proposed system can use channel adaptive intra-refresh methods.

Stockhammer Thomas, et.al (Stockhammer, Hannuksela, and Wiegand 2003) presented an overview of the tools that are likely to be used in wireless environments and went into greater detail about the most difficult application, wireless conversational services. On the basis of experimental results, appropriate justifications for the use of various tools are presented. They proved that error resilience is not always distinguishable from compression efficiency features like intra MBs or multiple reference frames. In the case of error-prone transmission, however, the selection methods must be altered, either by using expected decoder distortion or by limiting the number of coding options available.

Ismail Ali, et.al (Ali et al. 2011) presented a novel slicing technique for enhanced error robustness. They found that when intra refresh lines are used as an error mitigation tool, unequal error sensitivity appears within the video frame. Moiron, S., et al. (Moiron et al. 2011) used a modified slicing technique to boost video quality by up to 4 dB and improve error robustness.

Till Halbach, et.al (Halbach and Olsen 2004) proposed intra update refreshing regions with much motion more frequently. They found that it is not of advantage to choose intra coding for many temporally adjacent MBs at the same spatial location as then the coding gain will be considerably reduced. Except when a video sequence has adverse motion characteristics, Ismail Ali, et.al (Ali, Fleury, and Ghanbari 2012) proposed that the cyclic intra-refresh approach has an advantage over periodic I-frame refresh. It is also possible to detect disadvantageous motion directions that work against intra-refresh cleansing. They found that randomized insertion of intra-refresh MBs is always less suitable than a cyclic line of intra-coded MBs.

Kazemi, et.al (Kazemi, Ghanbari, and Shirmohammadi 2019) proposed the best intra coding strategy as a tool for error resiliency. In comparison to the traditional Selection Intra Mode (SIM) and Periodic Intra Refresh (PIR) methods, their experimental results show that the proposed method yields a lower VQM index. Bruno Zatt, et.al (Zatt et al. 2010) proposed a method for analyzing video content and determining the best location for inserting I-frames in video sequences. The proposed adaptive GOP can also be used on test sequences and real-world movies. In comparison to static GOP sizes of 32, 16, 8, and 4, the average bit rate reduction for real movies is about 8.6%, 15%, 24.7 percent, and 40.8 percent.

In this paper, we tested error resilience performance of different intra-periods of I-pictures, intra refresh MB line update, forced intra MBs and combinations of these coding techniques with different coding structures. This work is different in that it uses simple techniques with no additional computational complexity. Our results show that the proposed scheme is effective for a variety of loss rates and video content and can achieve a robust error resilient video streaming.

3. VIDEO CODING STANDARDS

H.264/AVC standard is a block based video compression with motion compensation. It is one of the most commonly used techniques for video distribution contents, compression and recording. H.264/AVC supports resolutions up to 8192 x 4320 (8K UHD) video. The H.264/AVC codec is used to provide efficient lossy coding of video content, allowing for a 30–70% reduction in bit rate when compared to previous video coding standards (Sullivan and Wiegand 2005; Lee, Han, and Sullivan 2006). An additional aim was to provide sufficient flexibility to enable the standard to be applied to an expansive variety of applications on a wide variety of systems and networks, for example, broadcast, high/low bit rates, DVD storage, recording, high/low video resolutions, IP/RTP packet networks, and ITU-T multimedia systems.

The encoder subtracts the original frame from a spatial (Key, I, Intra) frame or temporal (Inter, P/B) frame prediction of the current signal. After that, the residual is processed, converted, quantized, and entropy-encoded, yielding a bit-stream that may be broadcast over a network or recorded on a suitable medium. H.264/AVC uses the unit of macro blocks (MBs) to reduce complexity requirements. Depending on the amount of information and motion in the sequence, MBs can be divided into smaller units, or blocks. An anti-blocking filter effectively removes blocking artifacts along with the MB and block boundaries. H.264/AVC, MPEG-4 part 2, and MPEG-2 video codecs are compared in

Table(1.

Table(1):- Comparison of video codec standards: H.264/AVC, MPEG-4 part 2 and MPEG-2.

Encoding Parameter	MPEG-2	MPEG-4 Part 2	H.264/AVC
Picture type	I, P, and B	I, P, and B	I, P, B, SI, and SP
Error robustness	Data partitioning, FEC, Redundancy,	Synchronization, Data partitioning, Header extension, and reversible VLCs	Data partitioning, Parameter setting, FMO, redundant slice, SI and SP slices
Bidirectional prediction mode	Forward/backward	Forward/backward	Forward/backward, Forward/forward, and Backward/forward
Encoder Complexity	Medium	Medium	High
Interlaced Coding	No	Yes	Yes
Intra-prediction	No	Transform domain	Special domain
MB size	Fixed	Fixed	Variable
Block size	8x8	16x16, 16x8, and 8x8	16x16, 16x8, 8x16, 8x8, 8x4, 4x8, and 4x4
One Quarter pixel variant	No	Yes	Yes
De-blocking filter	No	No	Yes
Reference frame	One frame	One frame	Multiple frames
Transmission Rate	2 – 15 Mbps	64kbps – 2 Mbps	64kbps – 150 Mbps
Compatible with previous standard	Yes	Yes	No
Weighted Prediction	No	No	Yes
Entropy Coding	VLC	VLC	VLC, CAVLC, and CABAC
Motion Estimation/Compensation	Yes	Yes	Yes with more flexible
Transform coding	8x8	8x8	4x4
Profiles	5 profiles	8 profiles	7 profiles
Separate Picture Scaling	No	No	Yes
4:2:0 Sampling Format	Yes	Yes	Yes
Storage	2GB	1.3GB	700MB

4. VIDEO QUALITY ASSESSMENT

The quality of a video that has been encoded and streamed can be evaluated using subjective tests or objective quality metrics like the Peak Signal to Noise Ratio (PSNR) and SSIM (Zhou 2004). Alternative metrics like the Video Quality Metric (VQM) (Wolf and Pinson 2002) are also in use. PSNR is the most widely used objective quality metric for both video and still images. It is based on a byte-by-byte comparison that ignores the meaning of the data. PSNR is calculated by comparing and encoding the sender-side raw YUV format video file with the receiver-side raw YUV format video file. Mean Square Error (MSE) and PSNR are defined as equation 1 and equation 2 (Alfaqheri 2019) (university 2014). All notations in both metrics are listed in the

Table(2.

$$\boldsymbol{MSE = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} [A_o(i,j) - B_d(i,j)]^2} \qquad (1)$$

$$\boldsymbol{PSNR(dB) = 10 \log_{10} \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{[2^N - 1]^2}{MSE} = 10 \log_{10} \frac{(MAX)^2}{MSE}} \qquad (2)$$

Table(2):- MSE and PSNR notations

Parameters	Meaning in Equations
$m \times n$	Resolution or numbers of image pixels
A_o	Original assessed images
B_d	Distorted assessed images
n	Image height pixels
m	Image width pixels
MAX	The maximum pixel value of the input image

5. ERROR RESILIENCE FEATURES

Because of prediction and data compression, single bit and burst losses propagate through the bit stream. Adaptability to errors of video codecs, such as H.262 (Ze-Nian Li 2014), H.264, VP9 ('VP9 Video Codec' 2017; Grange, De Rivaz, and Hunt 2016), and H.265/HEVC has been the primary focus of video research. A significant amount of effort was put into the software of the associated methods for the H.264/AVC codec in particular. H.264/AVC offers several error resilience methods to enhance the reliability of compressed video delivery over wireless networks. These techniques generally need overhead bits to be added by the encoder. The research presented in this paper aims to use error resilience tools in the process of developing a video quality framework for the H.264/AVC video codec, as stated in the next sections.

5.1 Slice Coding

H.264/AVC uses slices to keep parallel encoding/decoding processes and also presents robustness error resiliency. A slice corresponds to a contiguous group of MBs in a video frame, as detailed in Fig.(2**)** One or more slices are required to cover the entire frame. A-frame may include slices of different sizes and may be used as a reference for inter-prediction of subsequent slices. The slice is the fundamental spatial segment that is individually coded from its neighbors. In such a way, missing data or errors from one slice cannot propagate to any other slice within a frame.

Fig.(2):- MB line Intra update and slice boundaries of Stefan video

5.2 Intra Refresh

Although slice boundaries prevent spatial errors from propagating within a single frame, motion compensation or estimation over multiple frames can cause a potential transmission error to cross this boundary. Intra update is used to keep the error from spreading. Whole slices and individual MBs can be coded in Intra mode with the H.264/AVC codec.

Despite the fact that I-frame MBs are commonly used in CBR coding, the video quality is significantly reduced. P-frame slices have packet sizes that are typically 0.1 of I-frame slices (Halbach and Olsen 2004). As a result, frame slices are usually encoded in Inter mode, while single MBs are encoded in Intra mode. However, because of the MBs Intra updates, the propagation of a potential error at the decoder side may not be completely prevented. In (Nunes, Soares, and Pereira 2008) a rate control scheme is used to determine whether or not an intra-coded prediction block should be refreshed. Fig.(2) shows the MB line Intra update and slice boundaries for *Stefan* video reference while Fig.(3) shows the video sequence when 22 forced Intra MBs per picture are inserted. Fig.(4) shows a diagram of two complete cycles when using vertical intra-refresh line (Chen et al. 2015).

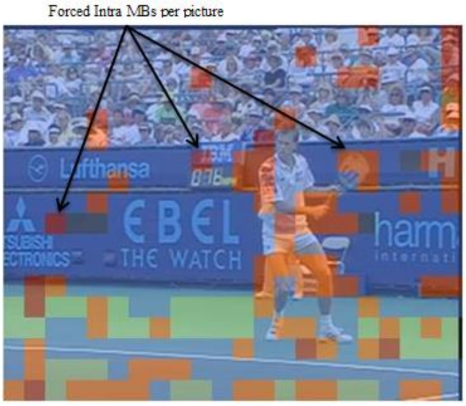

Fig.(3):- Forced Intra MBs per picture of Stefan video

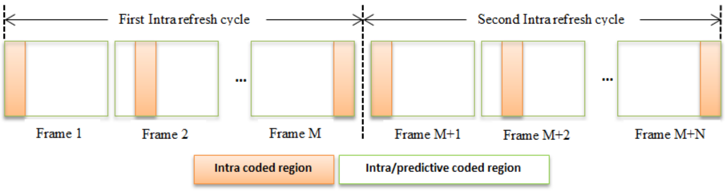

Fig.(4):- Two intra-refresh cycle regions are split vertically

5.3 Error Resilience Schemes Based on GOP Patterns

The corrupted and error-propagated GOP can be explained by an error resilience theory. When one frame type is corrupted, how will the errors spread to the other frames? Begin with, if the key frame (I-Frame) in a closed GOP is corrupted, all frames cannot be decoded, and if the key frame is partially corrupted, the errors spread to other frames. The frames may be decodable in this case, but the GOP may contain visual artifacts.

Secondly, if one predictive frame (P-Frame) is corrupted, the error may spread to other P-or B-frames. Finally, if the bi-directional frame (B-frame) is corrupted, the decoder can skip it without sacrificing video quality. Error propagation from previously decoded frames is more vulnerable to B-frames. If a P-frame only needs one reference frame, as opposed to two for a B-frame, and if B-frames are not used as reference frames, they might not help with error propagation. Using multiple reference frames can improve the bit-stream's error resilience.

Although B-frames use I-Frames and P-Frames as reference, using two reference frames may not improve compression efficiency because the reference frames become more expensive with bit overheads and out-of-date as more reference frames are included, especially for longer GOPs (Bing 2015). GOPs, which each contain a predetermined number of coded frames (I, P, and B), including one I-Frame, one or more B-Frames, and P-Frames.

The encoding process will begin with an I-frame as a starting point. The content determines how all frame types in a video sequence are interleaved. For example, sports content with frequent or rapid motion may require more I-frames in GOPs to maintain the best video quality, whereas some applications, such as video conferencing, may require more B-frames in GOPs because the video quality has little motion. This suggests that the compression efficiencies of new and legacy video coding standards for sports video content may be similar. Sports content also requires a higher bit rate than other types of content.

5.4 Error Resilience Approaches based on Correction Codes

Because real-time video communication systems are extremely sensitive to time delays, retransmission of corrupted slice segments generally is not an option. One solution is to include correction codes in the encoded bit-stream to enable error recovery or reduce their impact on the decoder. Although these techniques are effective at reducing error propagation in real-time video applications and wireless networks, the cost is increased processing complexity and bit overheads as which results a slight reduction in video coding efficiency.

5.5 Other Error Resilience Schemes

Several error resilience tools (Kumar et al. 2006) are included in H.264/AVC codec like Data Partitioning (DP), FMO, SP-/SI-Synchronization/Switching Frame, Reference Frame Selection, Parameter Sets, Instantaneous/Gradual, refreshing Error Concealing Schemes, and Redundant Slices. Slice data in a data partitioning tool can be divided into up to three parts (DP-A, DP-B, and DP-C) and, in terms of unequal error protection, the DP tool is more flexible than MPEG-4. Flexible Macroblock Ordering (FMO) is used to spread possible errors across the entire frame (Tan and Pearmain 2010). Rectangle mode, checker board mode, and interleaving mode are the most commonly used FMOs.

Multiple video bit streams of the same sequence are sent through the network in SP/SI-Synchronization/Switching Frame tools, each with a different parameter set. If there is no feedback channel, the Reference Frame Selection tool is used (see Fig.(5)). Both the encoder and the decoder in a parameter set tool should indeed share information on common parameters for a set of frames or slices. Also, the H.264/AVC design includes a new capability that allows an encoder to send redundant representations of regions of pictures, enabling a (typically degraded) representation of regions of pictures for which the primary representation has been lost during data transmission.

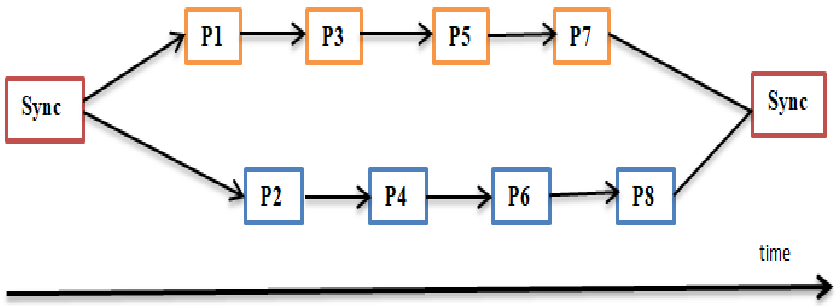

Fig.(5):- Reference frame selection error resilience tool

6. EVALUATION FRAMEWORK

We used Joint test Model version 19 (JM-19) H264/AVC reference software to encode standard raw YUV CIF videos using our encoder configuration. To convert encoded source video to an MP4 file, we used the MP4BOX (Jeanlf 2022). Then we used the (mp4trace) trace file to generate the trace file to be sent over the wireless network. This trace file is then used by the network simulator which will generate sender and receiver trace files. A filter program (etmp4) is then used to delete all the missing slices/frames from the original video and generate the distorted received video. Fast Forward MPEG (FFMPEG) (doxygen) ('FFMPEG ' 2013) decoder is then used to convert MP4 files back to YUV file which is then compare with the original YUV to assess the video quality using average PSNR values. The framework for evaluating PSNR values is shown in Fig.(6).

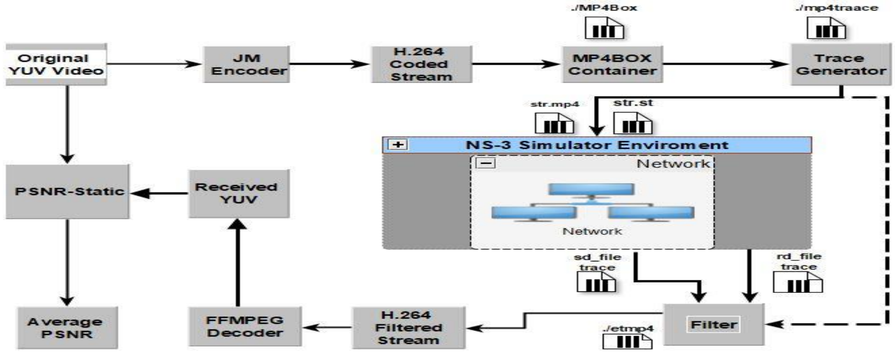

Fig.(6):- PSNR Evaluation through EvalVid

The network topology used in our tests is shown in Fig.(7). We employed the NS-3 LTE module. Carrier-Sense Multiple Access (CSMA) is used to connect each node in the NS-3/LTE network. The link has a bandwidth of 1 Mbps and a (10ms) delay. These values remain constant during all the tests. User datagram protocol (UDP) was used as the transport protocol.

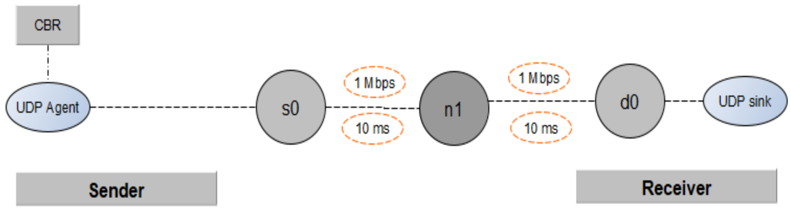

Fig.(7):- Network topology

7. Experimental Results

Three different intra-periods of I-pictures, intra refresh MB line update, forced intra MBs and combinations of these coding techniques were tested with different coding structures. We conducted six sets of tests for *Stefan* and *Foreman* test sequences. For each test, five different coding structures were used (IP, IBP, IBBP, IBBBP, and IBBBBBP). For test set 1 (Test1), intra period was set to 0 which means that no I-frames where inserted (except the first I-frame) and no MB line update or forced random MBs were included. For Test2, the intra period was set to 8 but no MB line was used and no forced random intra MBs were included.

For Test3, the intra period was set to 18 with no MB line of forced intra MBs included. For test Test4, the tests were conducted with an intra period set to 0 but with an intra MB line. For Test5, only 22 forced random MBs were included with no intra MB line and an intra period of 0. For last set of tests (Test6), we used a combination of MB line update and 22 forced intra MBs while the intra period was 0. The configurations for these tests are shown in Table (**3**, and other common encoding parameters for both tests are shown in

Table **(4**.

Table (3):-the video encoding configuration sequences for set of tests

Test	Intra-period	MB line	Forced random MBs	Coding structure
Test 1	0	No	0	IP, IBP, IBBP, IBBBP, and IBBBBBP
Test 2	8	No	0	
Test 3	18	No	0	
Test 4	0	Included	0	
Test 5	0	No	22	
Test 6	0	Included	22	

Table (4):- H.264/AVC coding structure encoding parameters

Parameter	Value
Resolution	CIF (352x288)
Profile	High (100)
Frame rate (fps)	30
Quantization parameter (QP)	29
Subsampling format	4:2:0
No of references frames	5
CBR Bitrate	735 kbps
Processing unit	Macroblock MB
Processing unit size	16x16
GoP size	12
GoP frame structure	IP,IBP,IBBP,IBBBP, and IBBBBBP

7.1 Results for *Stefan* Video Sequence

We first conducted tests using the more active *Stefan* video sequence. The simulation results for this video sequence are shown in figures 8 – 14. In Fig.(8), no I-frames were used and no MB line or random intra MBs were forced. At 3% loss, the results show that IBBBP coding structure can achieve about 0.9 dB above IBP, IBBP and IBBBBBP coding structures. At the same 3% loss rate, IBBBP coding structure achieved 1.6 dB better qualities than IP coding structure.

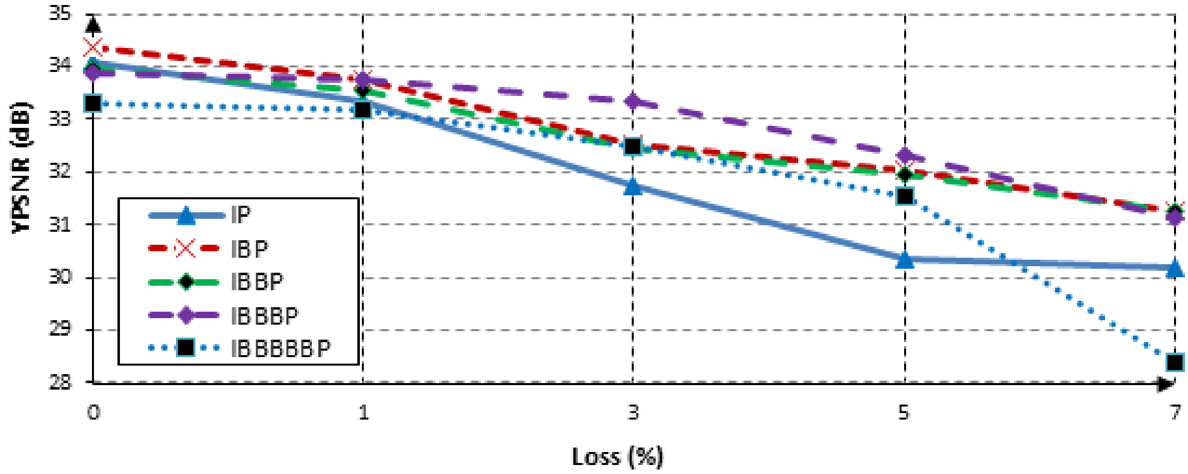

Fig.(8):- YPSNR vs % video frame loss with intra period of 0 for Stefan sequence

Fig.(9) shows our simulation results for the case when intra period was set to 8 but no intra MB line or random intra MBs were forced. Again, the results at 3% loss show that IBBBP coding structure can perform 0.7 dB better than IBP and IBBBBBP coding structures and 2 dB better than IBBP coding structure.

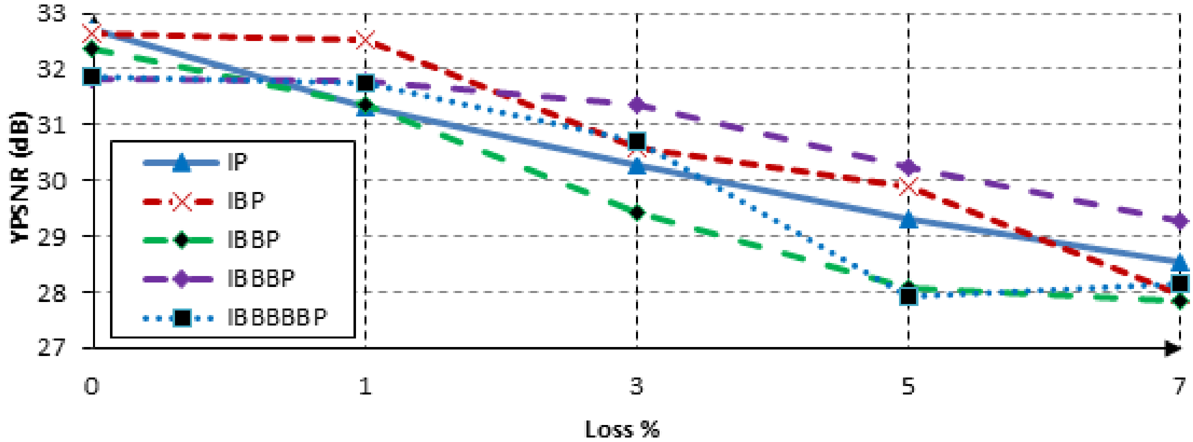

Fig.(9):- YPSNR vs % video frame loss with intra period of 8 for Stefan sequence

When introducing MB line update (Fig.(10)), the IBBBP coding structure performed better than all other coding structures when packet losses occurred. At 3% packet loss, the IBBBP structure performed 2.45 dB better than IP coding structure.

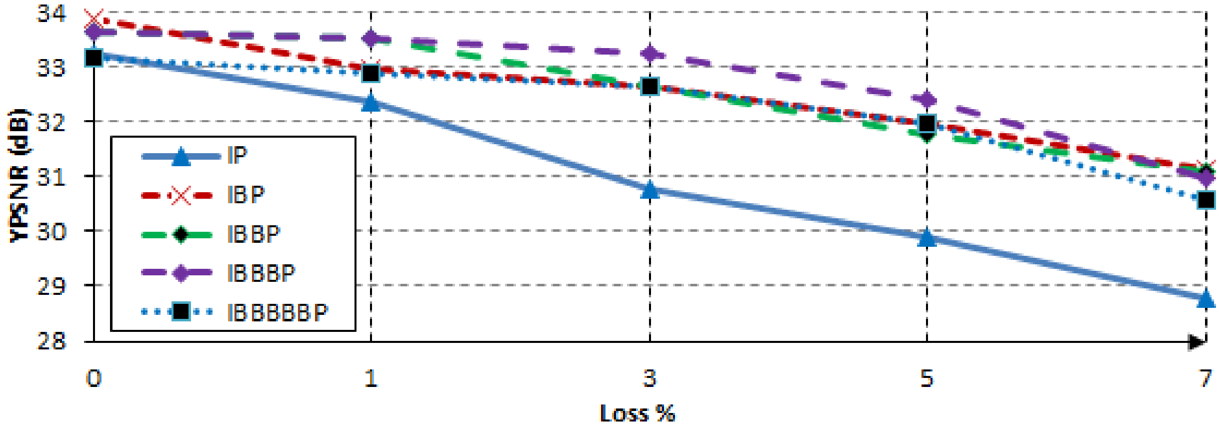

Fig.(10):- YPSNR vs % video frame loss with intra MB included

Fig.(11) and Fig.(12) show the results when including random intra MBs and a combination of random MBs with intra line. The results show that the IBBBP coding structure is still performing better than all other coding structures when there are losses. However, we can clearly see the penalty of forced random MBs on quality when compared with Fig.(10) (when intra MB line was used).

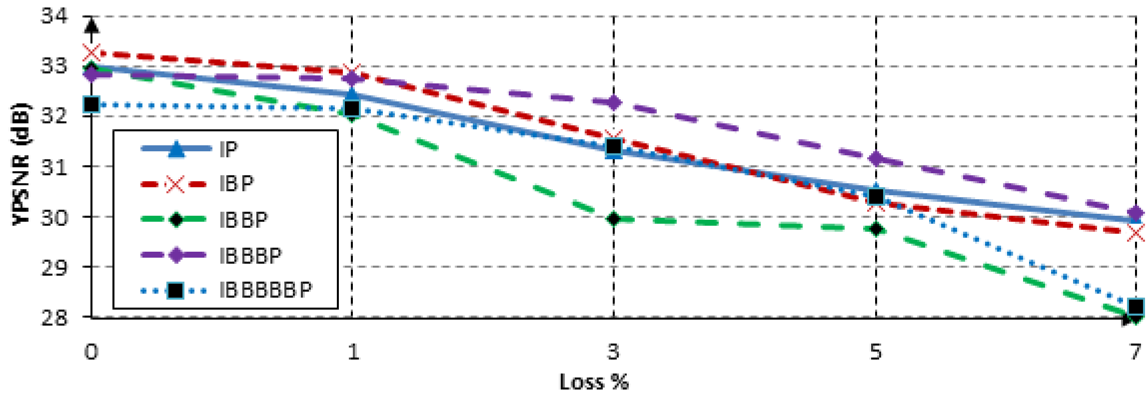

Fig.(11):-. YPSNR vs % video frame loss with 22 random MBs for Stefan sequence

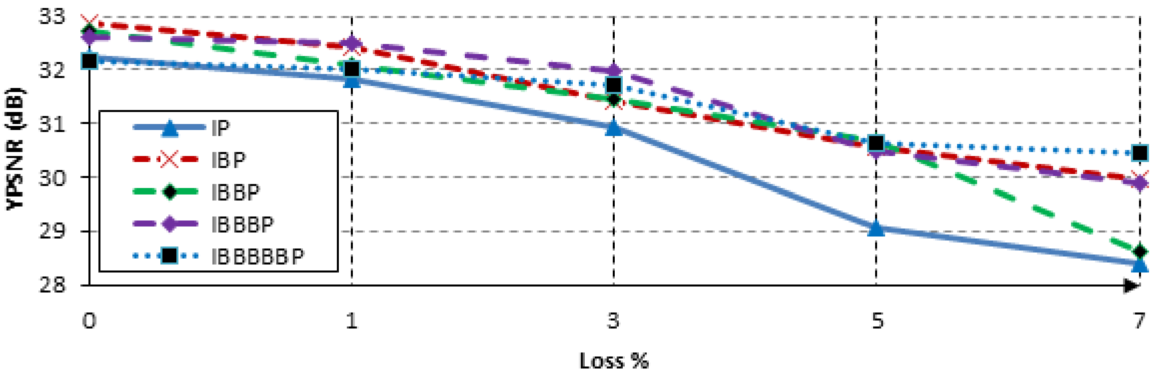

Fig.(12):- YPSNR vs % video frame loss with intra MB line and 22 random MBs for Stefan sequence

Fig.(13) shows the results when intra period was set to 18. Here, we can see that the IBP coding structure performed better than all other coding configurations. The IBP structure performed at least 0.6 dB better than all other configurations.

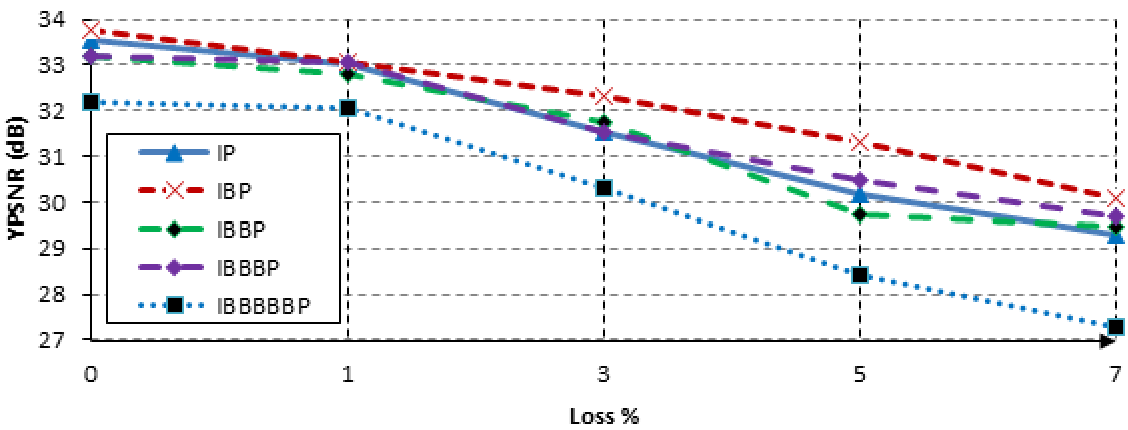

Fig.(13):- YPSNR vs % video frame loss with intra period of 18 for Stefan sequence

Fig.(14) shows all the top performing coding configurations at 3% video packet loss for *Stefan* sequence. It can be seen that among all the best performing structures, both IBBBP with intra period of 0 and IBBBP with intra MB line achieve the best video quality when video packet losses occur. They can achieve at least 1 dB better quality than other coding configuration at 3% or higher loss rates.

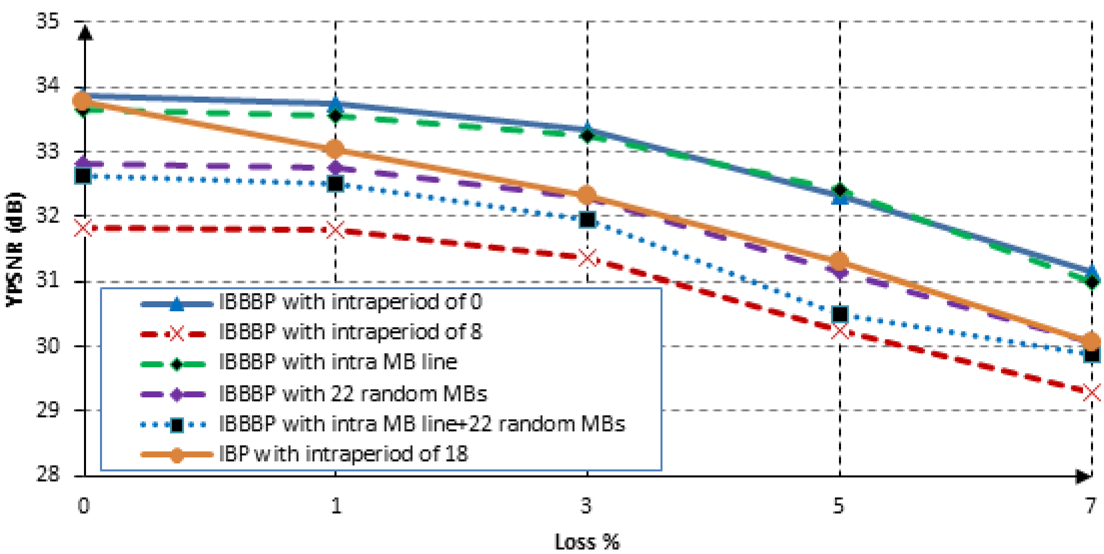

Fig.(14):- YPSNR vs % video frame loss for top performing coding structures for Stefan sequence

7.2 Results for Foreman Video Sequence

Another set of tests were conducted using the less active *Foreman* video sequence. The simulation results for this sequence are shown in figures 15 – 21. The results of the first test are shown in Fig.(15) were no I-frames are inserted and no MB line or random intra MBs were forced. At loss rates($< 2\%$), IBP coding structure performed the best performance. At loss rates($> 2\%$), the results show that IBBBBBP coding structure gives the best performance and can achieve at least 1.67 dB better than all other coding structures.

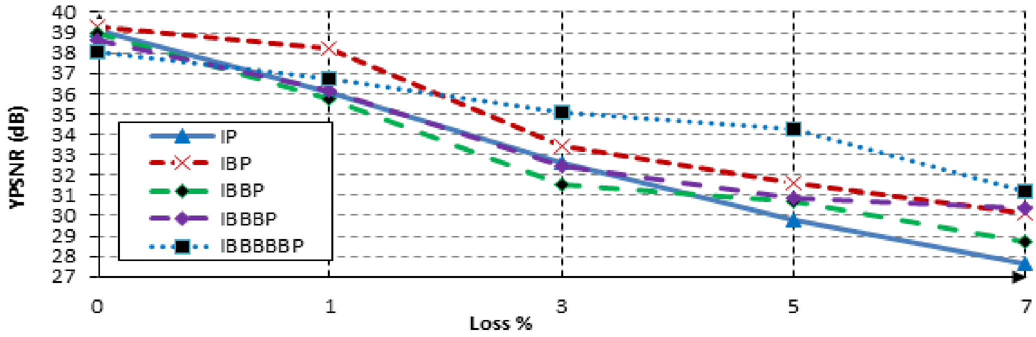

Fig.(15):- YPSNR vs % video frame loss with intra period of 0 for Foreman sequence

Fig.(16) shows our simulation results for the case when intra period was set to 8 but no intra MB line or 22 random intra MBs were forced. The results at 3% loss show that IBBBBBP coding structure is still performing better than other coding structures. However, when the loss rate is increased to 5%, we can see that IBBBP starts to outperform other coding structures. At lower loss rates however, the IBP coding structure performed better than other configurations. After introducing MB line update (Fig.(17)), the IBP coding structure performed better than all other coding structures for loss rates up to 5%.

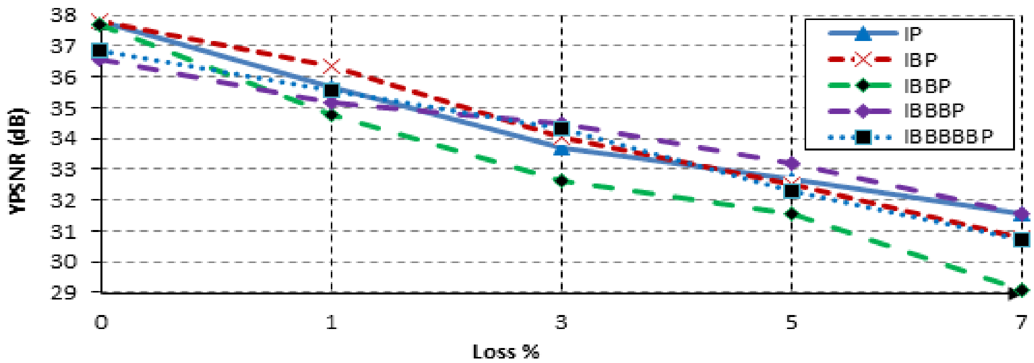

Fig.(16):- YPSNR vs % video frame loss with intra period of 8 for Foreman sequence

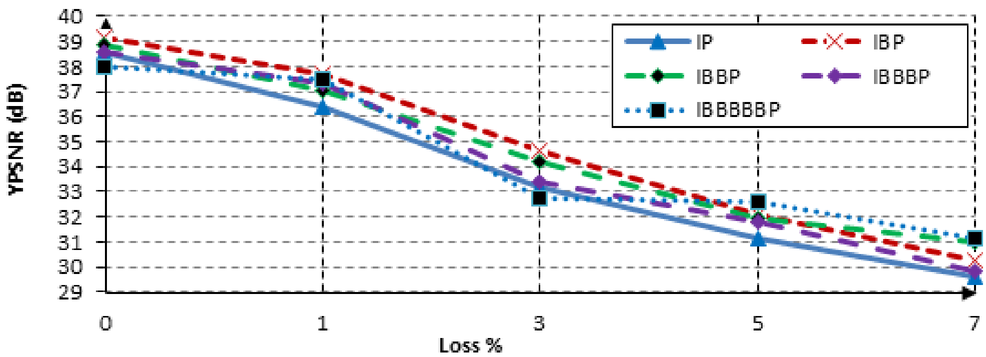

Fig.(17):- YPSNR vs % video frame loss with intra MB line for Foreman sequence

Fig.(18) and Fig.(19) show the results when including random intra MBs and a combination of random MBs with intra line. The results show that the IP coding structure performs better than all other coding structures when there are losses. However, including 22 forced random intra MBs results in noticeable quality penalty at 0 % packet loss when compared to IP coding structure with MB line only (Fig.(17)).

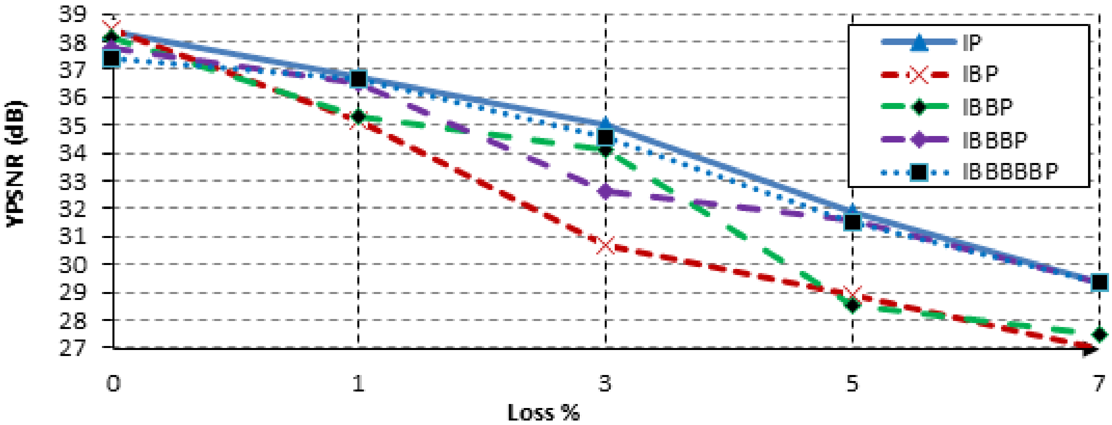

Fig.(18):- YPSNR vs % video frame loss with 22 random MBs for Foreman sequence

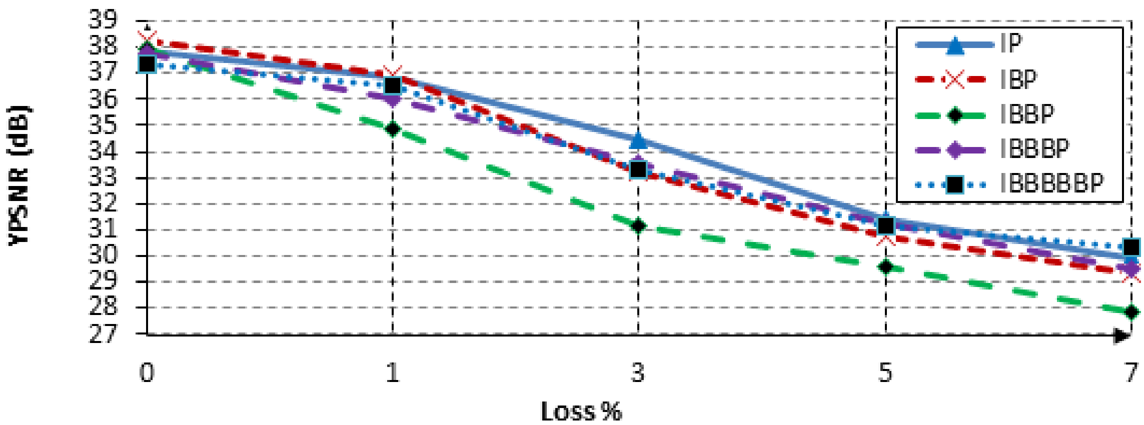

Fig.(19):- YPSNR vs % video frame loss with intra MB line and 22 random intra MBs for Foreman sequence

Fig.(20) shows the results when intra period was set to 18. Here, we can see that the IBP coding structure performed better than all other coding configurations. The IBP structure performed at least 1.96 dB better than all other configurations.

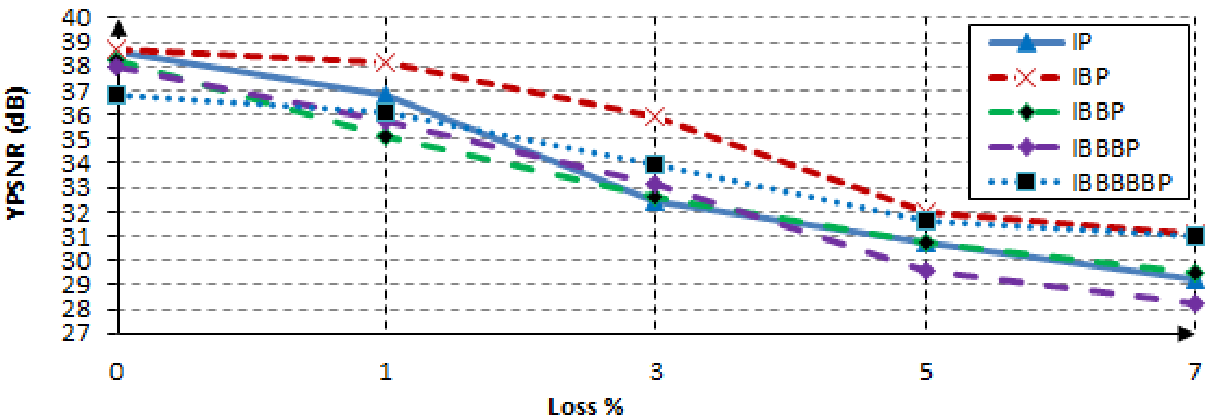

Fig.(20):- YPSNR vs % video frame loss with intra period of 18 for Foreman sequence

Fig.(21) shows all the top performing coding configurations at 3% video packet loss for *Foreman* sequence. At lower loss rates, the IBP with intra period of 18 and IBP with MB line performed better than all other configurations. However, when loss rates increased the IBBBBBP with intra period of 0 and IBBBP with intra period of 8 started to outperform other configurations.

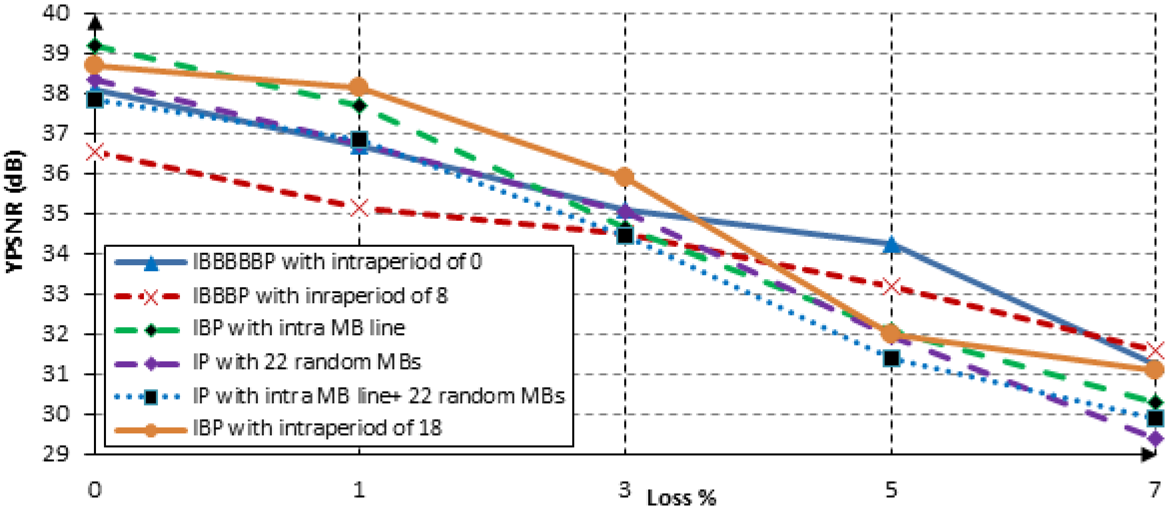

Fig.(21):- YPSNR vs % video frame loss for top performing coding structures for Foreman sequence

7 CONCLUSION

Delivery of video content over wireless networks proves to be challenging even with the advances in communication standards and hardware. This work tested different video coding structures with a combination of different intra-coding methods to find the best configuration for loss and error-resilient delivery. Many researchers have devised various methods for streaming video in order to improve error resilience of H.264/AVC coding structure for delivery over wireless networks. However, there are still a number of issues that need to be resolved. The main focus of this paper is on evaluating PSNR values for video delivery over wireless networks. We used the JM-19 encoding reference software, FFMPEG decoding package, NS-3 as a network simulator, and the EvalVild 2.7 framework tools to test the performance of video quality at the receiver side by changing coding configurations. We tested the performance of several coding structures in the presence of different intra coding techniques. Results for the more active *Stefan* video sequence showed that the IBBBP coding structure without or with an intra MB line performed better than all other configurations at all loss rates. However, at low loss rates, there was a slight quality overhead of the intra MB line. While results for less active *Foreman* video sequence showed that the IBP coding structure with intra period of 18 achieved best performance for loss rates up to 3%. At higher loss rates, structures with more B frames like IBBBP and IBBBBBP started to perform better. The addition of an intra MB line or extra random intra MBs did not seem to offer extra protection against errors for this sequence.

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