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Combined Approach for Error Resilient Video or Image Transmission

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Abstract- **Live video streaming is widely used in our daily applications. Virtual class rooms, remotely assisted surgery, tele-medicine are some of the important applications where loss on data is intolerable. Error resilience technique plays vital role in these kinds of applications. Error resilient technique is a classical area of research for which several techniques are already devised and are in use in various error resilient applications. There is a room still to improve the performance. Here a combined error resilience technique is proposed which balances the tradeoff between compression ratio and quality of the transmitted video in an error prone communication network. It is obvious that not all the portions of an image are equally important. Some portions of the image are more important than the other, so in the proposed method important portions of the image are transmitted using the technique to yield a high quality output ignoring the compression ratio. The other portions of the image are transmitted to give higher compression ratio compromising the quality. The experimental results confirm the hypothesis.**

Keywords — Error Resilience, Video Coding, Image Transform, encoder, decoder

I. Introduction

Today's communication network transacts more number of videos and images. It can be easily observed even in social media. The video or images are consuming the major portion of the bandwidth of the communication network than the textual messages. Amble number of online live TV channels are active and are using videos which takes a lot of bandwidth, In broadcasting channels retransmission is not possible and are also not allowed in order to avoid flooding the network and making it more congested. Error resilient technique is a solution to these kinds of problems. These error resilient techniques[1],[2] make the transmission system error tolerant and acceptable. There are many classical methods[3],[4],[5] available for error resilience transmission. Most of them are using multiple channels for transmission. Each channel carries different descriptions about the data in an interleaved manner, so that all the channels get details about each block of data transmitted. This arrangement of data enables recovery of lost channels in order to reconstruct the unavailable block data.

Remotely assisted surgery is becoming popular and in such cases the video transmission should be taken with much care so that the process is not disturbed with any interruptions. Thus error resilient transmission is vital in such cases. In order to get uninterrupted video, multiple channels are used by ignoring the bandwidth efficiency and even redundancy in transmission. The Multiple Description Video Coding(MDC) concepts are implemented in such cases.

In this paper a combined approach for error resilient transmission for video images is proposed. This method aims to provide a smarter approach for error resilience in transmission of video. The smartness came in to the algorithm to classify the image portions into two classes called significant and not so significant. Then the significant portions of the image are transmitted with higher error resilience with lesser compression ratio and not so significant portions are transmitted with desirable error resilience with not necessarily higher compression ratio.

Having a brief introduction in this section, the remaining sections of the paper is organized as mentioned below. A related literature review is given in section II. A detailed account of the proposed work is explained in section III. The experimental results and relevant descriptions are discussed in section IV. The concluding statements and the scope for future expansion is given in section V.

II. RELATED WORK

With the quick and advanced development of electronic and communications technology, multiple view video

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coders are realized. However, error free robust transmission of many views in the error-prone channels is a quite challenging process. Because of the recent development in distributed video coding, Wei Xiang et.al 2015 presented two alternative error-resilient schemes[6] for multiple view video transmission based on the Wyner–Ziv coding technique. A simple encoder error-resilient scheme does not require transmission between the cameras at the transmitter, but the temporal and inter-view redundancy can be investigated to spawn the side information at the receiver. In this case, it is not only robust to channel losses but also has independent encoders with low encoding complexity. On the other hand, a complex-encoder error-resilient scheme refers to the scheme that employs an auxiliary redundant stream encoded according to a WZ video coding approach to protect a primary stream encoded with a standard multiview video coding codec. At the receiver, the error-concealed reconstructed frames are used as the side information by the WZ decoder. Therefore, this method maintains the original multiview bitstream unaltered by simply adding WZ bits for protection. Experimental results conducted over a simulated error-prone channel reveals that the two proposed schemes have better performance than the forward error correction by means of the Reed–Solomon and intra refresh approaches.

The increasing demand for real-time applications with high and ultra-high-definition video urged the ITU-T and the ISO/IEC to join their forces to develop the next-generation video coding standard. The new coding standard that has been produced is known as High-Efficiency Video Coding (HEVC). The proposed HEVC standard fulfilled its target to achieve more than 50% improvement in video compression over the existing H.264 Advanced Video Coding standard, keeping comparable image quality, at the expense of increased computational complexity. Advances in wireless communications and mobile networking have dramatically increased the popularity of video services for mobile users, with video delivery at their fingertips. Delivering high perceptual quality video over wireless environments is challenging due to the changing channel quality and the variations in the importance of one source packet to the next for the end user's quality of experience. Kostas E. Psannis 2016 provided an overview over the new characteristics which are likely to be used in HEVC in wireless environments[7] and discusses several research challenges. Experimental results demonstrate that for low-delay wireless video communications, the HEVC codec is more effective compared to previous H.264 codec and shows better overall performance. Both subjective and objective visual quality comparative study has been also carried out to validate this approach.

The deployment of 3G/LTE networks and advancements in smart mobile devices had led to high demand for multimedia streaming over wireless network. The rapid increasing demand for multimedia content poses challenges for all parties in a multimedia streaming system, namely, content providers, wireless network service providers, and smart device makers. Content providers and mobile network service providers are both striving to improve their streaming services while utilizing advancing technologies. Smart device makers endeavor to improve processing power and displays for better viewing experience. Ultimately, the common goal shared by content providers, network service providers, and smart device manufactures is to improve the QoE for users. QoE is both an objective and a subjective metric measuring the streaming quality experience by end users. It may be measured by streaming bitrate, playback smoothness, video quality metrics like Peak to Signal Noise Ratio, and other user satisfaction factors. There have been efforts made to improve the streaming experiences in all these aspects. Guan-Ming Su et.al 2016 conducted a survey on existing literatures [8] on QoE of video streaming to gain a deeper and more complete understanding of QoE quality metrics. The goal is to inspire new research directions in defining better QoE and improving QoE in existing and new streaming services such as adaptive streaming and 3D video streaming.

Video streaming over wireless network poses a great challenge because the high packet error rate usually decreases the quality of video streaming. Forward error correction (FEC) mechanism is generally used to protect the video quality. However, the recovery performance of the FEC mechanism decreases when burst packet loss is larger than the added FEC redundant packets. The forward-looking forward error correction (FL-FEC) mechanism [9] is presented by Jiyan Wu et.al 2017 to recover lost packets for video streaming over wireless networks. The FL-FEC mechanism recovers not only the lost packet from its FEC block but also the previous FEC block from the recovered packet, repeating the recovery procedure until recovering the first FEC block. If the play-out buffer at the receiver is large, the FL-FEC mechanism can execute a chain of recovery procedures to ultimately recover all lost packets without any negative impact on application performance. The FL-FEC mechanism selects non-continuous source packets in previous FEC blocks to generate FEC redundancy with the FEC block. Hence, the FL-FEC mechanism can significantly disperse burst packet loss into different FEC blocks. The FL-FEC mechanism uses an analytical model to decide the number of FEC redundant packets in order to obtain the minimum recovery overhead. The FL-FEC mechanism is tested to show the benefits of high recovery performance and low recovery overhead in improving the peak signal-to-noise ratio and the decodable frame rate of video streaming over wireless networks.

The near-optimal resilient control strategy design problem is investigated for a class of discrete time-varying system in simultaneous presence of stochastic

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communication protocols (SCPs), gain perturbations, state saturations, and additive nonlinearities. In the sensor-to-controller network, only one sensor is permitted to get access to the communication media so as to avoid possible data collisions. Described by a Markov chain, the SCP is employed to determine which sensor should obtain the access to the network at a certain time. Furthermore, two kinds of well-recognized complexities (i.e., state saturations and additive nonlinearities) are considered in the system model and the phenomenon of controller gain perturbation is also taken into special consideration. Accordingly, the resilient control strategy is designed by: 1) deriving a certain upper bound on the associate cost function of underlying systems and 2) minimizing such an upper bound through the utilization of the completing-the-square technique and the Moore-Penrose pseudo inverse. The resilient control strategy is obtained in an iterative manner by solving a set of coupled backward Riccati-like recursions. Furthermore, based on these control strategies, the infinite horizon case is considered and the corresponding upper bound of the cost function is explicitly provided[10]. Finally, numerical simulations are carried out on power systems in order to verify the validity of the resilient control algorithms presented by Yuan Yuan et.al 2018.

III. Combined Approach

Now a day's high definition video is very popular and commonly used even for ordinary purpose. The resolution of high definition video is much higher than the normal video and requires large storage and high bandwidth for transmission. The resolution of images is getting higher as technology grows day by day thus results in higher bandwidth requirement. It is obvious that not all portions of the image are equally important, for instance if considering an image of human, the face portion is highly important since it carries lot of minute details used to recognize or identify a person and is unique with variations and expressions. Image of ornaments consists of large background than the vital minute detailed elements. In general the foreground portion of the image is considered significant.

A. *Image Portions*

Considering the significance of image portions, a combined approach for error resilience is proposed, based on the observations made from the earlier work. It is proposed to find the significant and insignificant portions of the image and to use smaller or larger macro blocks with different techniques during the error resilient transmission, in order to get higher quality significant portions of the image. Identifying significant portion of the image depends on the type of objects present in the image and the type of application behind the system. Several algorithms are available for real time face detection [11],[12],face recognition[13],[14],[15], object detection[16], edge detection[17],[18],[19],[20] and similar kind of applications. Experiment is carried out using mask to identify significant portion of the image, in reality those proven standard algorithms may be used. Intensive experiments are carried out in the simulated environment to use different scenarios for the analysis.

'I' frame and 'P' frame are used for the experiment. Initially the significant and insignificant portions of I frame are identified. The significant portions are encoded using lower macro block size and by the technique which yields high quality reconstructed image, whereas the non-significant portions are encoded using larger block size and by the technique which yields higher compression ratio, moderate quality and faster transmission. Similarly the P frame is also encoded. That is to vary the block size used for transmission and to simulate different settings for data transmission and data loss. Four channels are simulated for transmission. Channel disconnection or disruption is also simulated. The received data are used to reconstruct the original image or data transmitted. Since the channel data are interleaved before transmission the lost data is taken from the neighboring locations.

a	b	a	b	a	b	a	b
c	d	c	d	c	d	c	d
a	b	a	b	a	b	a	b
c	d	c	d	c	d	c	d
a	b	a	b	a	b	a	b
c	d	c	d	c	d	c	d
a	b	a	b	a	b	a	b
c	d	c	d	c	d	c	d

(a)

a	a	a	a	b	b	b	b
a	a	a	a	b	b	b	b
a	a	a	a	b	b	b	b
a	a	a	a	b	b	b	b
c	c	c	c	d	d	d	d
c	c	c	c	d	d	d	d
c	c	c	c	d	d	d	d
c	c	c	c	d	d	d	d

(b)

Figure 1 – 8x8 Macro block into interleaved four 4x4 sub-blocks

In this method the frame image is divided into macro blocks of size 8x8. The macro blocks are further divided into four 4x4 sub blocks by interleaving rows and columns as shown in figure 1(a) and figure 1(b). DCT is applied to all the four sub blocks and are quantized using suitable quantization table. The DCT coefficients are rearranged in the zigzag order as shown in figure 2(a) and 2(b). The rearranged DCT coefficients are encoded and transmitted through all four respective channels where no duplication is on the DC or AC coefficients.

B. *Transmission of Significant Portions*

Steps adopted for error resilient transmission of significant portion of the frame is given as follows

1. Divide the frame into 8x8 macro-blocks.
2. Divide the 8x8 macro-block into four 4x4 sub-blocks extracting values interleaving rows and columns starting at (1,1), (1,2),(2,1) and (2,2).
3. Apply DCT for each sub-block and quantize the DCT coefficients using quantization table

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4. Arrange the DCT coefficients for each sub-blocks in the zigzag order and drop out last successive coefficients having magnitude values less than one.
5. Construct four channel data by copying arranged DCT coefficients of respective sub-blocks.

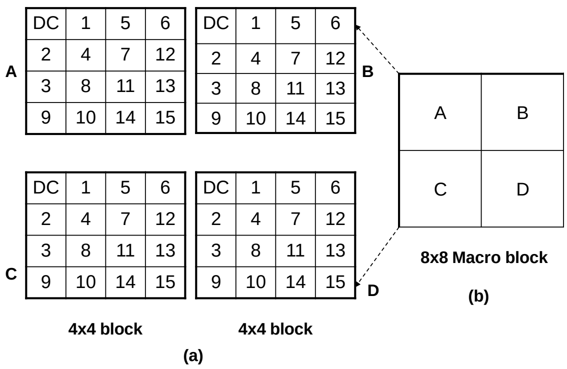

Figure 2 – Zigzag Arrangement of 4x4 DCT matrices.

In receiving side the decoder receives data from all the four channels. If all the channel data is received successfully then put back the DCT coefficients in the zigzag order to reconstruct the four sub-blocks of size 4x4. If some of the channel data is corrupted or unavailable, then the lost channel data is estimated from the next available channels. If only one channel data is available then unavailable channels are replaced by the available channel data. Since DC coefficients are having the average detail of the block, even if three of the four channels are lost, it is possible to reconstruct the lost blocks approximately using the DC coefficient received from the available channel data. The sub-blocks are then de-quantized by the quantization table and inverse DCT is performed. Then the macro block is constructed by using the four sub-blocks in the reverse manner as shown in figure 1(b) and figure 1(a).

C. *Transmission of Other Portions*

The other portions of the frame adopted the following steps for error resilient transmission.

1. Divide the ROI into 16x16 macro-blocks
2. Divide the 16x16 macro-block into four 8x8 sub-blocks extracting values from macro block interleaving rows and columns starting at (1,1), (1,2),(2,1) and (2,2).
3. Apply DCT for each sub-block and quantize the DCT coefficients using quantization table
4. Arrange the DCT coefficients for each sub-blocks in the zigzag order and drop out last successive coefficients having magnitude values less than one.
5. Construct four channel data by copying arranged DCT coefficients of respective sub-blocks

In the receiving side the decoder works in the reverse order, to decode the received packets and reconstruct the frame, similar to the procedure followed for 8x8 macro blocks. Here the macro block size is 16x16 and sub blocks are of size 8x8.

D. *Metrics Used*

Compression ratio and bit rate are the two metrics to measure the quantity of compression. Compression ratio is the ratio of uncompressed original image size and compressed image size. The compression ratio(cr)

cr = uncompressed size / compressed size … (1)

The bit rate (bpp-bits per pixel) is the average number of bits required to represent a pixel in an image.

bpp = compressed size in bits / number of pixels. … (2)

In addition to this other important metrics to measure the quality difference of the image reconstructed from the original image are Peak Signal to Noise Ratio (PSNR), Structural Similarity(SSIM) and Complex Wavelet Structural Similarity (CWSSIM)[21]. The PSNR value is higher for high quality reconstructed image and is lower for low quality reconstructed image. Structural Similarity measures the similarity between original image and reconstructed image, the value varies between 0 and 1. If the SSIM is 1 then both the images are similar with no difference. Error resilient transmission may be ranked based on both quality of the image and the compression ratio. Transmission with no loss reproduces the original image with no distortion so only the quantity of compression is used to rank them.

If *x* be the original frame image transmitted and *y* be the reconstructed image after receiving then PSNR can be computed by equation (5). The quantitative distortion of the reconstructed image is commonly measured by the *mean absolute error* (MAE), *mean square error* (MSE), and *peak-to-peak signal to noise ratio* (PSNR).

$$\mathrm{MAE}(x, y) = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}|x(i,j)-y(i,j)|}{MN} \quad \dots (3)$$

$$MSE(x,y) = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[x(i,j)-y(i,j)]^2}{MN} \quad \dots (4)$$

$$\mathrm{PSNR}(x, y) = 10 \cdot \log_{10}\left[255^2 / \mathrm{MSE}(x, y)\right] \quad \dots (5)$$

The SSIM can be computed by equation (6)

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad \dots (6)$$

where μ is the mean, σ is the standard deviation of pixel values in the image, C_1 and C_2 are constants

Structural similarity metric in the complex wavelet domain is straightforward and is described. As more

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wavelet-based image coding techniques are coming into use, it makes sense to implement image quality metrics in wavelet domain. Since it has low sensitivity to small translations if an application requires an image quality metric that is irresponsive to spatial translation, this extension of SSIM can be adapted. Given complex wavelet coefficients C_x and C_y that correspond to images x and y that are being compared, the complex wavelet structural similarity (CWSSIM) is given by (7) where K is a small positive constant(set to 0.03).

$$CWSSIM(C_x, C_y) = \frac{2\left|\sum_{i=1}^{N} C_{x,i} C_{y,i}\right| + K}{\sum_{i=1}^{N} \left|C_{x,i}\right|^2 + \sum_{i=1}^{N} \left|C_{y,i}\right|^2 + K} \quad \ldots (7)$$

Linear and uniform phase changes correspond to lighting (brightness and contrast) distortions to which CWSSIM is not sensitive because the structure is not disturbed.

IV. RESULTS AND DISCUSSION

The results obtained for different scenario are tabulated and analyzed. The performance measures are taken for both I-frame and P-frame.

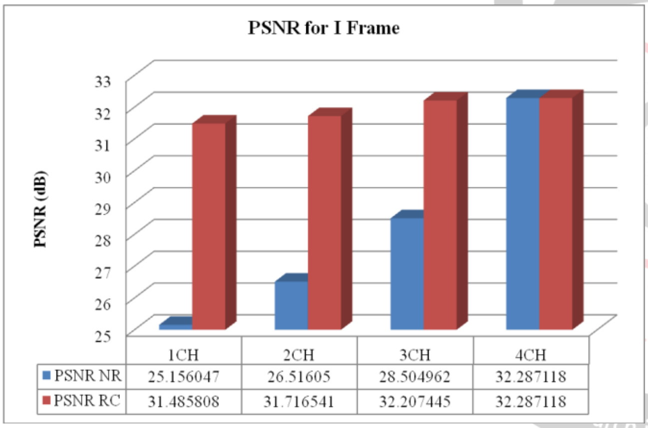

Figure 3 Peak Signal to Noise Ratio for I Frame

The PSNR for the I-Frame is given in the chart shown in figure 3. The PSNR of the received frame with no reconstruction (PSNR NR) and PSNR of the I-frame with reconstruction(PSNR RC) are displayed in the chart. This clearly reveals that the reconstruction process significantly improves the quality of the received frame even if it receives only one channel data. The performance measures PSNR, SSIM and CWSSIM [21] are computed to evaluate the performance of this technique.

Even if the channel availability is increased, only very small variation in PSNR is observed. When all the four channels are available (4CH) there is no need for reconstruction and the PSNR values of both the cases are same.

The structural similarity between the frame sent and the frame received is measured using SSIM and CWSSIM according to Aron et.al 2008.The SSIM and CWSSIM values observed for I-Frame is shown in figure 4.

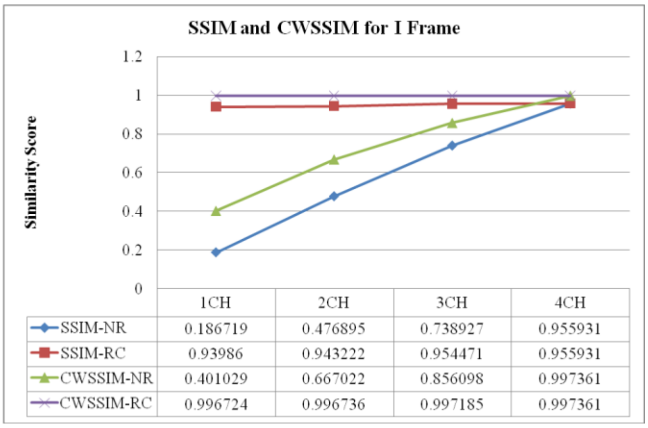

Figure 4 Structural Similarity for I Frame

Here also, it can be observed that the reconstructed frame quality (SSIM RC and CWSSIM RC) is much higher than not reconstructed frame quality (SSIM NR and CWSSIM NR). Very small variation is observed for reconstructed frames for the availability of one,two, three and four channels (1CH,2CH,3CH and 4CH).

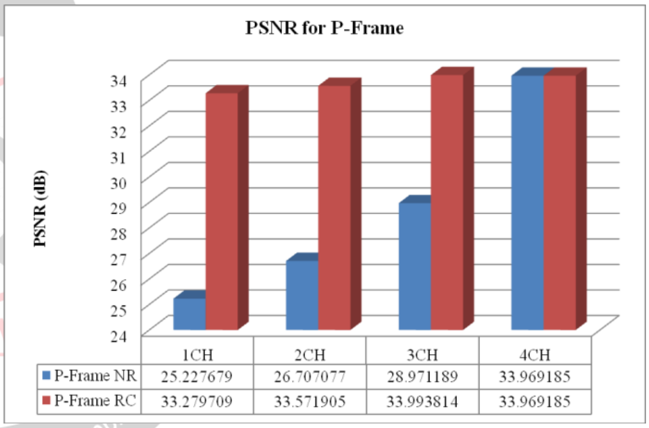

Figure 5 Peak Signal to Noise Ratio for P-Frame

The peak signal to noise ratio is calculated for P-Frame after reconstruction (PSNR RC) and with no reconstruction(PSNR NR) are shown in figure 5. The chart clearly reveals that the the reconstruction step improves the quality of the received P-frame significantly.

The similarity between the sent P-Frame and received P-Frame is computed as SSIM and CWSSIM and is displayed in figure 6. The chart clearly reveals that the reconstruction step plays a major role for higher quality reconstructed received P-frame also. Compression ratio obtained for both not reconstructed and reconstructed I-frame and P-frame are displayed in the chart shown in figure 7. It is observed that the compression ratio obtained for both non reconstructed and reconstructed I-frame are equal. But the compression ratio of reconstructed P-frame and non reconstructed P-frame gradually increases as the number of available channels are increased. This is because of the higher prediction error during only one channel (1CH) is available

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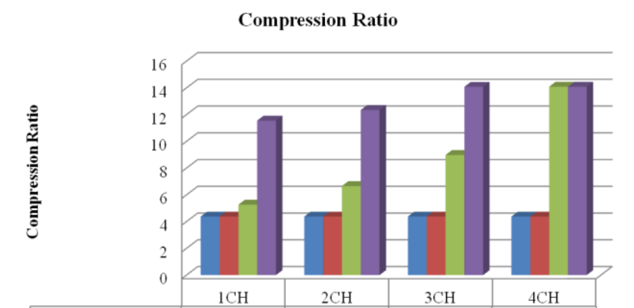
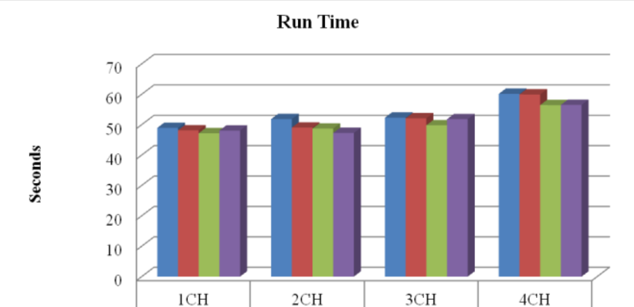
and the prediction error is reducing as the number of available channels are increased. Lower the prediction error higher the compression ratio.



	1CH	2CH	3CH	4CH
CR for I frame NR	4.372132	4.372132	4.372132	4.372132
CR for I Frame RC	4.372132	4.372132	4.372132	4.372132
CR for P Frame NR	5.261355	6.656382	8.977206	14.079859
CR for P Frame RC	11.549567	12.344092	14.073667	14.079859

Figure 7 Compression Ratio for I-Frame and P-Frame

The algorithm is implemented and simulated using Octave software in Microsoft® Windows 8 Operating System environment with Intel® Core ™ i5 processor. The run time or simulation time is obtained and diplayed in the chart shown in figure 8. It reveals that, there is a small variation in run time for reconstruction for both I-frame and P-frame. This may be because of the background activity in the system. It is clearly evident that the reconstruction process takes small computation time.



	1CH	2CH	3CH	4CH
I-Frame NR	48.922	51.814	52.297	60.141
I-Frame RC	48.124	49.03	52.078	59.952
P-Frame NR	47.155	48.704	49.796	56.437
P-Frame RC	48.031	47.265	51.796	56.499

Figure 8. Running time

The subjective measure is also taken by some observers and all the observers reported better quality in the reconstructed frame than non reconstructed frame. A sample frame portion is shown in figure 9. First column of the figure.9 shows the absolute difference between I-frame and P-Frame with mean absolute error of 6.94313 in the first row and not recovered I-frame received with one to four channel availability respectively.in the subsequent rows.

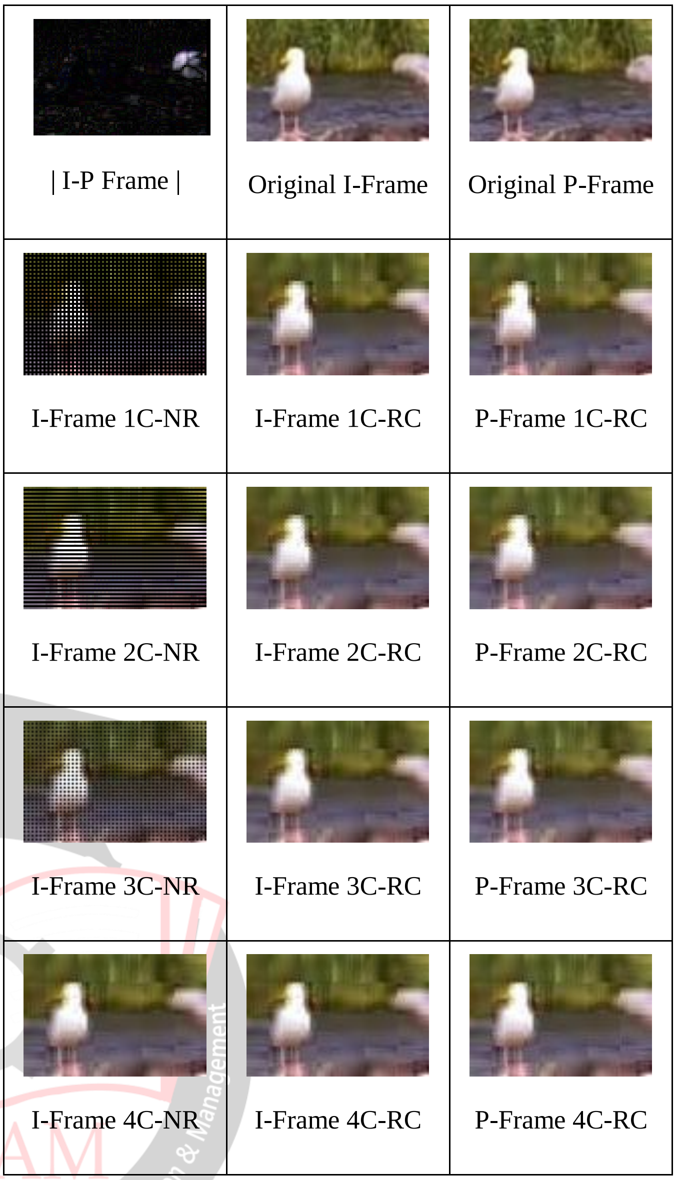


Figure 9 Portions of I-Frame and P-Frame Original, Not Recovered (NR) and Recovered and Reconstructed (RC) images

Similarly the second column of the figure 9 shows the recovered and reconstructed I-frame. The third column shows the P-Frame in the same manner. By comparing first column and second column, it can be confirmed that the recovered and reconstructed frame is highy error resilience even with one channel availability. By comparing the second column, second row to fifth row images, it can be observed that there is not much variation in the recovered reconstructed images from one channel availability to four channel availability.

V. CONCLUSION

The analysis leads to the conclusion that the combined approach gives a desirable quality reconstructed frame with reasonable compression ratio. About an average of 21% improvement is achieved in reconstructed I-Frame and P-Frame in terms of PSNR. About an average of 52% improvement is achieved in reconstructed I-Frame in terms of structural similarity(SSIM). Compression ratio is

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improved by 42%for P-Frame with no significant change in the run time. Thus the proposed error resilient combined approach performs better. In future new encoding and decoding methods can be suitably adopted to encode significant portions or the remaining portions of the frame. Based on the nature of the application new segmentation methods may be adopted to find the significant portions of the frame.

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