

Performance Analysis of Error Resilience Wireless Image Transmission Using H.264/AVC I-Frame

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Abstract—H.264 is the latest video coding standard designed to provide better coding efficiency and error robustness compared to previous standards. However, H.264 can also be used to encode still image by using I-frame coding. In this paper, we evaluate the performance of error resilience features of H.264 I-frame for image transmission over Rayleigh fading channel. Objective and subjective results are presented in terms of error resilience performance of the standard. The results show that an image quality of service (QoS) in relation of channel errors can be significantly improved by using error resilience source coding.

Keywords—H.264; error resilience; wireless transmission; Rayleigh fading channel; QoS

I. INTRODUCTION

The quality of service (QoS) required to guarantee multimedia contents transmission, will play a key factor in future generation wireless communication systems success. However, the effects of transmission errors on the reconstructed bitstream posing a major problem for QoS guarantee. To this end, more reliable transmission systems need to be investigated.

H.264/AVC is developed to provide efficient coding and high reliability in video transmission [1]. For noisy channels, unfortunately the coding efficiency of the standard makes the encoded data more sensitive to transmission errors. To prevent the degradation caused by error-prone channels, H.264 utilize some error resilience features to reduce distortion resulting from errors and their propagation. H.264/AVC focuses on the coding of video sequences, but can also compress images by using the Intra-coding mode. The possibility to use the H.264/AVC in complete I-frame, gives the opportunity to use it for transmitting still images over wireless channels. The error resilience performance analysis of H.264/AVC I-frame have not been thoroughly studied in the literature.

Some research works on the coding efficiency of H.264/AVC in comparison to other standards have been reported [2], [3], and [4]. In [5] the authors have investigated the performance of Motion-JPEG 2000 and MPEG-4 in wireless transmission. Error resilience features provided by Motion-JPEG 2000 are only limiting the effect of transmission errors and thus not attempt to correct them. Mochnac and Marchevsky [6] investigated the error resilience features in H.264 and MPEG-4 on video sequences. The effect of IDR slice, picture segmentation (PS), data partitioning (DP), and Flexible Macroblock Ordering (FMO) have been evaluated.

This study showed that the usage of error resilience features comes with the increase in output bitrate. More recently, Jiao [7] compare the coding performance of JPEG 2000 and H.264/AVC I-frame. The study concluded that, H.264 is much better for high bitrate application and for low bitrate application JPEG 2000 has more advantages. In those studies nothing was done regarding the error resilience features in still image transmission.

In this paper, we mainly focus upon evaluating various error resilience features employed by H.264/AVC for wireless image transmission. The effect of transmission errors on the reconstructed images encoded by H.264/AVC I-frame with and without error resilience source code was evaluated. A number of tests were done to determine the improvement in subjective and objective QoS on transmission images having different error resilience features, such as DP and FMO.

The reminder of this paper is organized as follows. Section II reviewed I-frame coding technique. Error resilience tools in H.264 standards are discussed in Section III. Section IV presents the system setup of the wireless image transmission system. Simulation results are presented in section V. Finally conclusions are drawn in Section VI.

II. H.264/AVC I-FRAME CODING

An intra coded picture in a video coder refers to the case where spatial redundancies are exploited by using only information that is contained within a video picture itself. The resulting frame is referred to as an I-frame. To carry out spatial redundancy in intra frames transform coding is applied using the discrete cosine transform (DCT) followed by quantization and entropy coding [8]. In contrast to some previous video coding standards such as MPEG-4 visual or H.263, where intra prediction has been conducted in the transform domain, intra prediction of H.264/AVC is formed based on previously encoded and reconstructed blocks and is subtracted from the current block prior to encoding.

For luminance samples, prediction blocks are formed for each 4x4 blocks or 16x16 macroblock. Therefore, there are two prediction modes for the luminance samples, i.e., Intra_4x4 mode and Intra_16x16 mode. In the case of using Intra_4x4 mode, there are nine prediction modes for luma samples where each 4x4 blocks is predicted from spatially neighboring samples.

III. ERROR RESILIENCE FEATURES IN H.264/AVC

In order to achieve a high compression efficiency, compression algorithms aim to remove redundancy in the bitstream. In contrast, error resilient tools add extra information to the bitstream to limit the impact of errors. There are a number of error resilient tools in the current image/video standards that have been used to make the compressed bitstream more robust to transmission errors over noisy channels. H.264/AVC provides several error resilient tools that are mainly contained in the video coding layer (VCL), some of these have also been used in earlier video coding standards such as DP [9], [10]. Others are new standard features such as FMO [11].

A. Data Partitioning

Data partitioning (DP) of H.264/AVC allows partitioning of a normal slice into three parts (data partitioning A, B, and C), which are then encapsulated into separate network abstraction layers (NAL) [12]. Data partition is achieved by separating the coded slice data (macroblock, header information, motion, and texture information) into separate sections as shown in Fig. 1. The idea of data partition is that when one partition is lost, is still able to use information from the correctly received partitions. Data partition A contains the slice header, macroblock types, quantization parameters, prediction modes, and motion vectors. Thus, the loss of partition A means the data of other partitions becomes useless. Partition B contains residual information of Intra-coded macroblocks, so the loss of partition B will only effect the recovery of successive frames. Data partition C contains residual information.

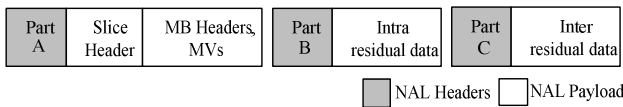


Figure 1. Data partitioning in H.264/AVC.

B. Flexible Macroblock Ordering

The flexible Macroblock ordering (FMO) is one of the most interesting error resilience tools adopted in the H.264/AVC standard. FMO allows to partition macroblocks (MBs) in one frame into separate groups of MBs known as slice groups (SGs). Using FMO, MBs are no longer assigned to slices in raster scan order. Instead, every MB is assigned freely to a specific SG using a Macroblock Allocation Map (MBAmap) [13]. In H.264/AVC, SG introduces a new layer between each picture and its slices, which means that the pictures are not divided into slices but into slice group instead [11]. At the decoder side, the decoder should know which macroblock is assigned to which slice group by transmitting the MBAmap together with the coded macro-blocks. The objective behind the FMO is to scatter possible errors to the whole frame to avoid error accumulation in a limited region [10]. Therefore, it is hard to conceal concentrated errors in a small region compared to scattered ones. H.264 specifies seven different types of FMO labeled type 0 to type 6 as depicted in Fig. 2 [14]. The first six types are patterns, which can be exploited when storing and transmitting the MBAmap. The last one is the most general type used, when the map cannot be illustrated by the first six ones and should be transport completely.

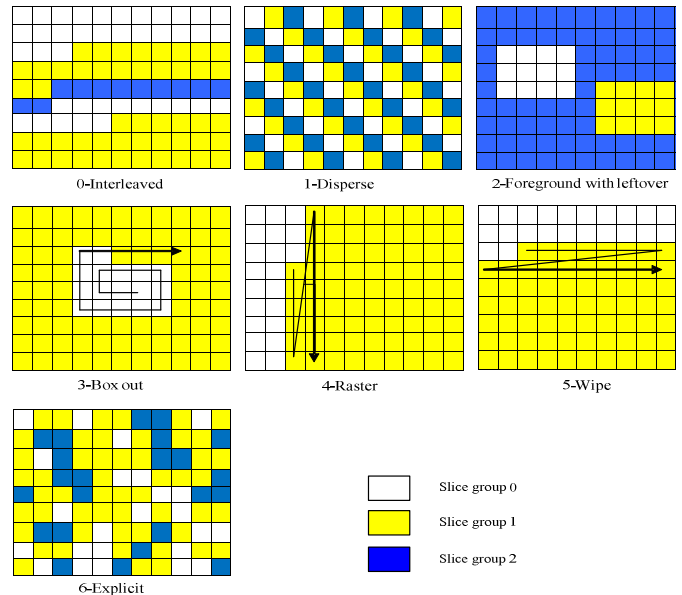


Figure 2. FMO techniques in H.264/AVC.

C. Picture Segmentation

A picture consists of one up to seven SGs, which are independently decodable and thus important to prevent propagation of errors. In picture segmentation (PS), slice may be encoded as I, predictive (P), or bidirectional (B) slices depending on the nature of MBs belonging to the slices. For I slices, all MBs are coded using intra prediction. For P and B slices, MBs can be coded using either intra or inter prediction. Slices are used as error resilience tools in H.264/AVC standard to prevent propagation of errors. However, error resilience tools introduce some overhead to compressed bitstream and reduce the coding efficiency, but in error-prone environment the quality of received data could be much improved.

IV. SYSTEM SETUP

This section gives a brief description of the simulation environment and the parameters used for H.264 encoder which based upon the JM reference software [15]. A MATLAB program was developed to simulate the wireless environment. We have arranged a series of tests to evaluate the robustness of compressed bitstream against transmission error. The resilience of bitstream is first presented without error resilience tools, and then the performance of DP, FMO, and PS on the transmitted bitstream is presented. Fig. 3 depicted the overall system configuration. To simulate the channel errors, Dent's model [16] has been used to model the Rayleigh fading channel with additive white Gaussian noise in the wireless image transmission system to introduce bit errors into bitstream.

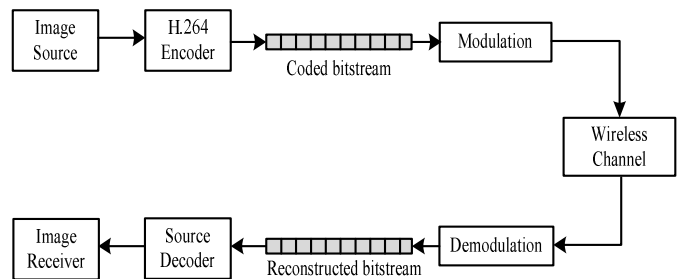


Figure 3. Image communication system

Rayleigh fading is a good model of wireless communication when there are many objects in the environment that scatter the transmitted signal before it arrives to the receiver. The Rayleigh fading channel is modeled using a modification of Jakes model which has been proposed by Dent *et al.* [16]. The objective of Dent's model is to remove the cross correlation between waveforms in the Jakes's model and can be mathematically expressed as:

$$S(t) = \sqrt{\frac{2}{N_0} \sum_{n=1}^{N_0} [\cos \beta_n + i \sin \beta_n] \cos(\omega_n t + \theta_n)} \quad (1)$$

where $N_0 = N/4$ is the number of complex oscillators and N the number of arriving rays. β_n is the phases and given as $\pi n / N_0$ and θ_n are the initial phases which normally set to zero.

V. EXPERIMENTAL RESULTS

The performance of the above error resilience features in Rayleigh fading channels using Dent's model will be evaluated and results will be presented in this section. JM software version 13.1 [15] was used as a codec for H.264/AVC. The quadrature amplitude modulation (QAM) and AWGN channel model was written in MATLAB. Two test images (monochrome), namely Lena and Boat in bmp format of resolution 256 x 256 pixels were used to simulate the proposed system.

The effects of DP, FMO, and PS error resilience features have been examined. Other error resilience features supported by H.264/AVC like IDR have not tested because they have not any effect on still images. The PSNR values and output bitrate have been calculated at the encoder output as detailed in Table I. From these results it is clear that the use of every error resilience feature increases the output bitrate. Also the usage of all error resilience features together increasing the bitrate significantly. The increased bitrate needed to transmit image is a trade-off for better image quality. The PSNR error performance of DP, FMO, and PS in H.264 are also evaluated and results are shown for Lena image. As we can see, all introduced error resilience tools improve the image quality in compare with no error resilience.

Fig. 4 compares the performance of DP, FMO, and PS error resilience for Lena image coded bitstream for arrange of SNR values. Enabling DP which is negligible overhead has significantly improved the resilience of coded image against channel errors by about 8.5 dB gains and the image quality is degraded compare to DP due to the introduced overhead. From the figure it is obvious that sliced significantly improves the performance at low SNR. At high SNR, adding more slices come with more overhead and reduce the quality.

Subjective results in Fig. 5 presents the objective results mentioned in the previous paragraphs of Boat image. Fig. 5 (a) illustrates the transmitted image over the same channel with SNR=21 dB with no error resilience tools, whilst Fig. 5 (b), (c), and (d) show the effect of DP, FMO, and PS respectively, on how the subjective quality of the received image is improved.

TABLE I
OUTPUT BITRATE VALUES AT H.264/AVC ENCODER FOR LENA IMAGE

QP	Output bitrate [Kbit]			
	No Error Resilience	Error Resilience Features		
		DP	FMO	PS
10	77.600	77.603	80.296	78.216
20	37.080	37.083	39.256	37.712
30	16.936	16.936	18.224	17.232
40	7.176	7.178	8.000	7.416
50	3.376	3.376	3.880	3.544

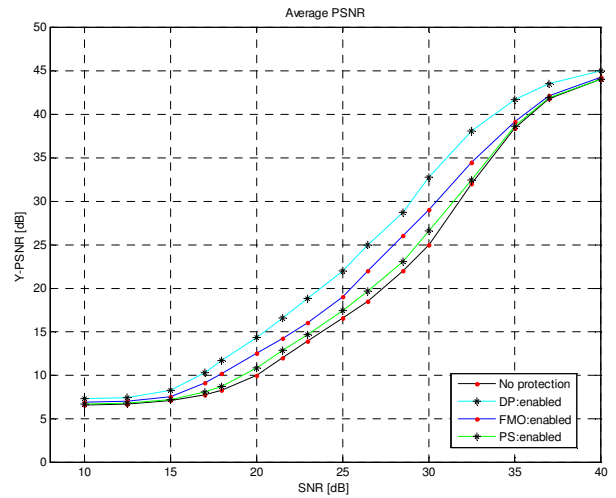


Figure 4 . PSNR vs. SNR for Lena image when FMO is enabled and disabled.

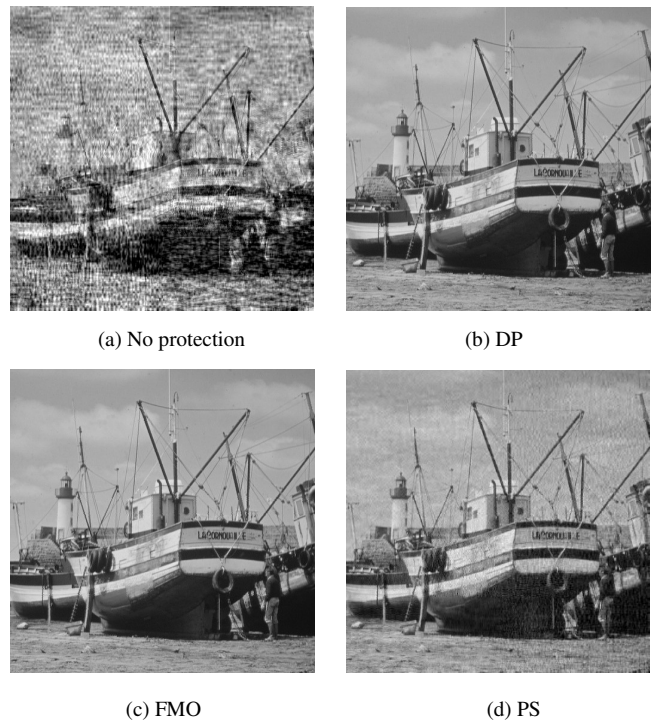


Figure 5. Subjective results of Boat image using: No protection, DP, FMO, and PS at SNR =21 dB.

VI. CONCLUSIONS

This paper focuses on evaluating error resilience performance of H.264. Comprehensive objective and subjective results are presented to examine the performance of error resilience features in this standard for wireless image transmission over Rayleigh fading channel. The results obtained indicate that the error resilience features can significantly improve the quality of reconstructed images. Although there is some overhead introduced to the coded bitstream to cater for error resilience, tradeoff is made for better quality.

This work has exposed the effect of error resilience H.264/AVC I-frame source coding on the quality of transmitted image. It has shown that allowing error resilience features can provide good quality image. Future work will concentrate on evaluating the error resilience wireless image transmission using H.264 and JPWL.

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