Improved Error Correction Techniques for Digital Multimedia Broadcasting (DMB) Service

Xiaoming Chen & Yuk Ying Chung
School of Information Technologies, University of Sydney, NSW 2006, Australia

Wei-Chang Yeh
Advanced Analytics Institute, Faculty of Engineering and Information Technology
University of Technology Sydney, PO box 123, Broadway NSW 2007, Australia

Neil Bergmann
School of Info. Tech. and Elec. Eng. University of Queensland, Brisbane 4072 Australia

Noorhaniza Wahid
Faculty of Computer Science and Information Technology
University Tun Hussein Onn Malaysia, Malaysia

Mohd Afizi Mohd Shukran
Department of Computer Science, National Defence University of Malaysia (NDUM), Sungai Besi Camp
57000 Kuala Lumpur, Malaysia

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Abstract

This paper focuses on error correction and concealment technologies for the modern video encoding/decoding standards. In this paper, we present a subblock error concealment method for intra-frames based on an error detection scheme in error prone network environments such as the application of digital multimedia broadcasting (DMB). The proposed method has been implemented in H.264/AVC codecs (JM98). Experimental results show that the proposed method can overcome the drawbacks of the existing methods and therefore can improve the PSNR when compared with the traditional Weight Pixel Averaging (WPA).

Keywords: Error handling, Error correction, DMB

1. Introduction

Video communications over error-prone networks is a topic that has attracted significant attention recently due to the rapid development of video consumer devices such as mobile terminals for digital multimedia broadcasting (DMB) service. H.264/AVC (Wiegand, T., Sullivan, G. J., Bjontegaard, G. and Luthra, A.) is the state-of-the-art video coding standard that offers enhanced network adaptation capability and significantly improved video coding efficiency. Error resilient video coding has been an active research field since the unreliability of the internet, particularly in the wireless environment, can generate errors during data transmission. When the error is introduced into the data stream, packet loss will occur. As a result, visual distortion starts to appear, making the video content at the decoder unrecognizable.

One of the approaches to combat this problem is called error concealment. This approach hides the visual artifacts and residual errors at the decoder, improving the visual quality and avoiding the need to modify the encoder and its transmission environment. For I-frames, spatial error concealment is applied. Previous spatial error concealment approaches suffer from the inability to conceal the errors in detailed areas.

In this paper, a new algorithm has been proposed which can improve the PSNR by up to 2dB when compared with the traditional Weighted Pixel Averaging (WPA) algorithm. Early results of this algorithm have been presented in our previous work (Y.Y.Chung, L.L.F.Chen, X.Chen, W.Yeh. C.Bae, 2008).

2. The problems of existing Error Concealment Algorithm for Intra-frames in H.264/AVC

Error Concealment (EC) techniques(Kim, D., Yang, S. and Jeong, J., 2005)(Peng, Q., Yang, T. and Zhu, C., 2002) can be classified into two categories, temporal EC and spatial EC. Temporal EC is concerned with estimating the missing motion vectors based on available information whereas spatial EC is concerned with estimating the missing pixel values based on available information. These two methods are typically isolated in the sense that they are applied to different type of frames. B or P frames for temporal EC and I-frames for spatial EC.

Weight Pixel Averaging (WPA) algorithm (Wang, Y., Wenger, S., Wen, J. and Katsaggelos, A.K.) does not work very well at object edges. To respond to that, Xu in (Xu, Y. and Zhou, Y. H.) proposed a new spatial EC algorithm that improves the WPA algorithm by considering object edge directions. For example, instead of concealing the damaged pixels using the horizontal and vertical pixels in the neighbouring blocks like in WPA algorithm, the proposed algorithm calculates the object edge direction from the neighbouring blocks. The object edge direction with the largest magnitude is chosen as the direction to be used to conceal the damaged MB. An example is given in Figure1.

Figure1a shows a damaged MB. To conceal the pixel shown in black, the algorithm first finds the object direction with the largest magnitude from its neighbouring blocks. In this example, the chosen object direction is from top right to bottom left. As a result, the pixel in black will be concealed using the pixels circled in its top and left neighbouring blocks. After concealing every pixel in the damaged MB, the recovered MB will look like Figure 1b, which conceals the error a lot better than the WPA algorithm. A real example is shown in Figure2, as can be seen, Figure2 conceals a lot better than the block in WPA by considering object edge directions.

Both WPA and Directional EC can work well in many circumstances. However, a few problems on these 16x16 MB based algorithms have been identified which the proposed algorithm will address on.

The first problem is that these traditional algorithms may fail when concealing the damaged MB that is at the corner of the frame as shown in Figure3.

Figure3c shows the concealed block which is at the top right hand corner of the frame. The top right half of the block appears to be in gray colour because no pixel information can be used from its top and right neighbouring block. The result is a poor concealment of the damaged block as can be compared with the original block in Figure3a.

The second problem is that the traditional algorithms may fail when concealing the damaged MB that is near the border of the scene. Many movies have scene borders around the actual movie scene. If the damaged MB is near this area, the calculation of the object edge direction will not be accurate as shown in Figure4.

Figure4c shows the concealed block which is near the scene border. The scene border is the black vertical strip at the left hand side of the frame. The block was concealed using the vertical object edge direction due to the high contrast between the scene border and the actual scene. As a result, the outcome of the concealed block is significantly different to the original block. A better result could be produced without considering the scene border as it is an artificial element that is not part of the actual scene.

The third problem which will be raised by the traditional algorithms is that they are not suiTable for concealing detailed areas. If the damaged MB is in the detailed area, it is very hard to conceal the damaged MB in 16x16 MB region correctly which has shown in Figure5.

We may notice that most existing EC methods typically operate in 16x16 MB region or 8x8 subblock region. We expect the above problems caused by WPA and Directional EC algorithm would be solved or reduced by applying an EC method that is based on smaller blocks. This paper presents a new EC algorithm that is able to perform EC in 4x4 subblock region which can provide more accurate EC results.

3. The Proposed Algorithm

The proposed EC algorithm starts by detecting 4x4 subblock status at the frame scope and then conceals each 4x4 subblock from left top to right bottom. The 4x4 subblock status checking (error detection) is done by our previous work in (Y.Y. Chung, L.L.F. Chen, Z. Zheng and X. Chen). With the proposed method in (Y.Y. Chung, L.L.F. Chen, Z. Zheng and X. Chen), specific information will be embedded into the video stream at encoder. At the video decoder, the embedded information is extracted and then used to examine the status of 4x4 subblocks by a series of operations such as chain coverage, checksum and remainder coding. After applying the error detection, we will be able to obtain the status of 4x4 subblocks (i.e. healthy subblock or corrupted subblock) even in a corrupted MB for I-frames. Therefore, it is possible to apply a more accurate EC in 4x4 subblock region according to the obtained status.

The proposed spatial concealment algorithm is based on WPA. A neighbouring 4x4 subblock selection is made based on the condition of neighbouring 4x4 subblocks. Only non-corrupted neighboring 4x4 subblocks are used for concealment if at least more than two non-corruupted 4x4 subblocks are available. Otherwise, the neighboring MBs are used in the pixel averaging operation.

Each pixel in a corrupted 4x4 subblock can be concealed by a weighted sum of the neighbouring 4x4 subblocks. The weight associated with each boundary pixel is relative to the inverse distance between the pixel to the concealed and the edge pixel of select neighbouring 4x4 subblocks. The pixel averaging operation is done by estimating pixels of the corrupted blocks using non-corrupted neighbouring block's edge pixels.

The WPA algorithm fixes pixel errors in MB unit. Figure6 has illustrated how an error MB was replaced by a new estimated MB by using the neighbouring blocks(A,B,C or D), even the error MB is **not completely** corrupted. Since a sensitive error detection algorithm was introduced in (Y.Y. Chung, L.L.F. Chen, Z. Zheng and X. Chen), it is possible to detect the condition of each 4x4 unit and therefore apply EC based on the 4x4 block units. In another word, the non-corrupted 4x4 subblock (white block in Figure7) of a corrupted MB can be exploited to estimate the corrupted (shadowed block in Figure7) 4x4 subblock. As the estimation unit turned to smaller size, the estimated results can get more closer to the original one. Hence the problem stated in section II could be solved or reduced.

4. Testing Results

To evaluate the proposed EC algorithm, we have used two standard video sequences – Foreman (QCIF 176x144 pixels, 400 frames) and Carphone(QCIF 176x144 pixels, 100 frames). In the testing experiments, the first step is to do the encoding at a predefined Bit-Error Rate (BER). The BERs used in these experiments are 0.5, 1%, 5%, 10% and 25%. After encoding, the compressed video will be decoded using the original H.264 decoder (with WPA) and the enhanced H.264 decoder which is integrated with the error detection scheme in (Y.Y. Chung, L.L.F. Chen, Z. Zheng and X. Chen) and the proposed EC algorithm. Figure8 to Figure 17 is the comparison of the traditional Weight Pixel Averaging (WPA) and the proposed EC algorithm under different BERs.

From the experimental results, it can be seen that the proposed EC algorithm can achieve a better performance by increasing the PSNR up to 2 dB. Under the conditions of various BERs, the proposed 4x4 pixel region based EC algorithm can achieve better performance than the conventional WPA method in all cases. The above Figures also reveal that the proposed EC algorithm trend to significantly outperform WPA in low or medium BERs. In some cases, the performance of the proposed EC algorithm trend to be equivalent to WPA when the BER increasing. The reason of this trend is that the proposed EC method is based on exploiting the correct neighbouring 4x4 subblocks. When BER goes higher, the number of non-corrupted neighbouring subblocks becomes smaller and in some circumstances there may not have enough correct neighbouring subblock can be used to conceal the corrupted block.

Table 1 and Table 2 show some samples of the decoded pictures by WPA and the proposed EC algorithm. From these Tables, we can see that the proposed EC algorithm can provide more smooth pictures than the WPA, especially for the detailed areas as well as corner and boundary areas. According to our testing results, the proposed EC algorithm can obtain better subjective picture quality than WPA.

5. Conclusions

In this paper, we have presented a 4x4 subblock based EC algorithm which employs an error detection scheme. Compared with those traditional EC methods, the proposed algorithm can provide more accurate EC results as it can detect usable 4x4 subblocks in a corrupted MB and therefore the EC operation can be applied in 4x4 pixel regions. In the experiments, the objective results based on PSNR value were given. It is shown from these results that the proposed EC algorithm can improve the traditional WPA algorithm by up to 2 dB. Moreover, we have discovered that the proposed EC algorithm can obtain better subjective results over WPA. This proposed new algorithm is very suiTable for the video consumer device applications such as Digital Multimedia Broadcasting (DMB) services.

Acknowledgment

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Xu, Y., & Zhou, Y. (2004). H.264 video communication based refined error concealment schemes. *IEEE Transactions on Consumer Electronics*, 50 (4), 1135-1141.

Table 1. Sample concealed pictures for Carphone

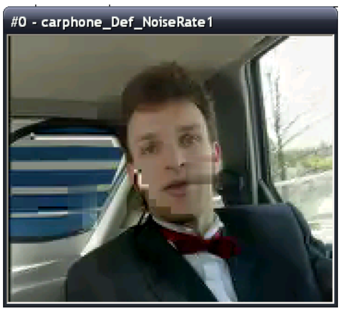
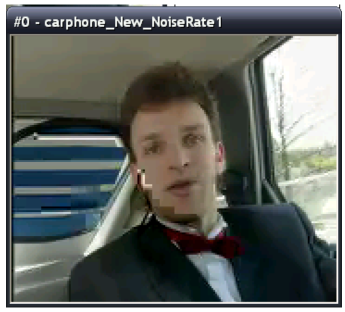
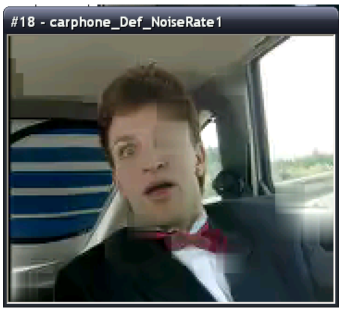
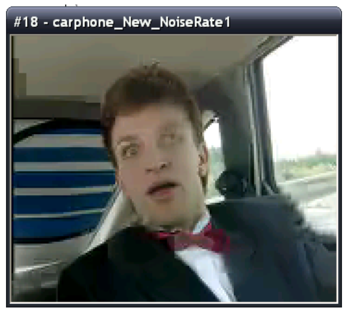
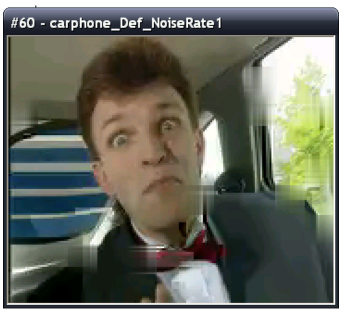
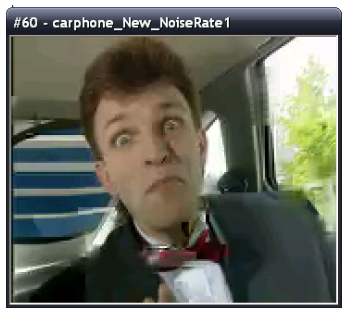
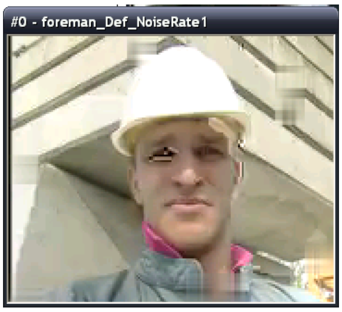
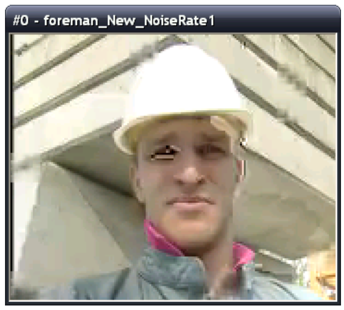
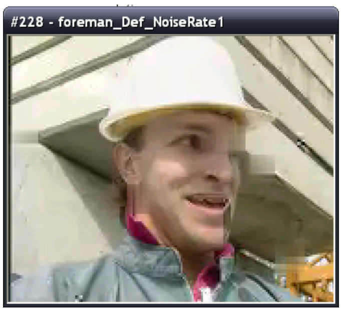
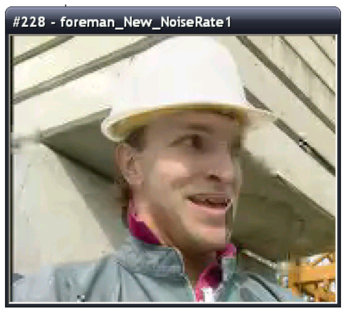
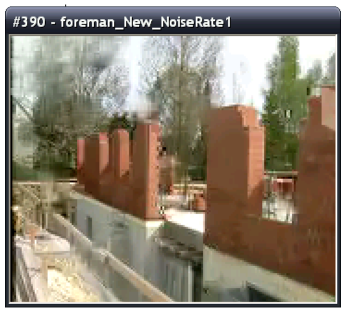
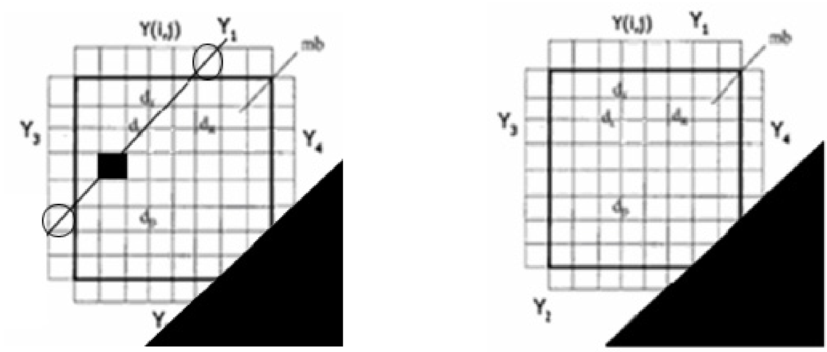
WPA, BER=1%	Proposed EC, BER=1%
	
Frame 0	Frame 0
	
Frame 18	Frame 18
	
Frame 60	Frame 60

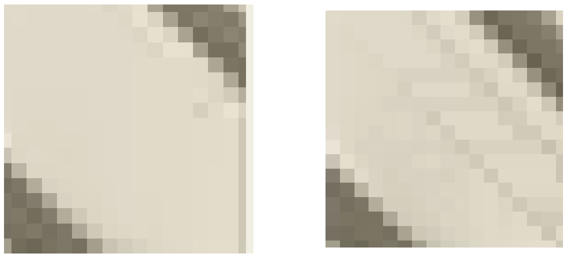
Table 2. Sample concealed pictures for Foreman

WPA, BER =1%	Proposed EC, BER=1%
	
Frame 0	Frame 0
	
Frame 228	Frame 228
	
Frame 390	Frame 390



(a) Before Directional EC (b) After Directional EC

Figure 1. Directional EC Algorithm



(a) Original Block

(b) Block after applying Directional EC Algorithm.

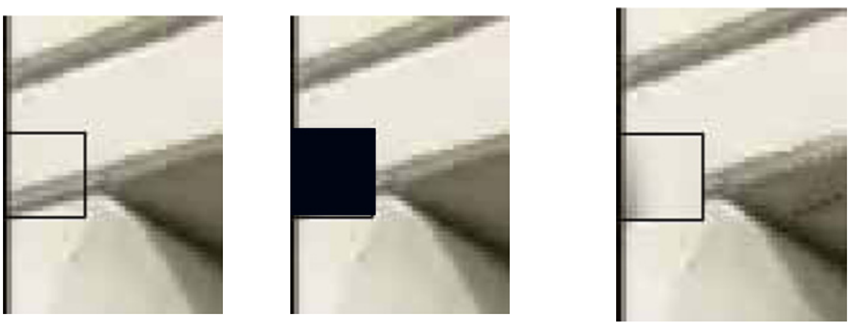
Figure 2. Real Example of Directional EC Algorithm

(a) Original Block

(b) Damaged Block to be concealed

(c) Block after traditional EC algorithm (without the black border)

Figure 3. Problem of Directional EC at the Corner of the Frame

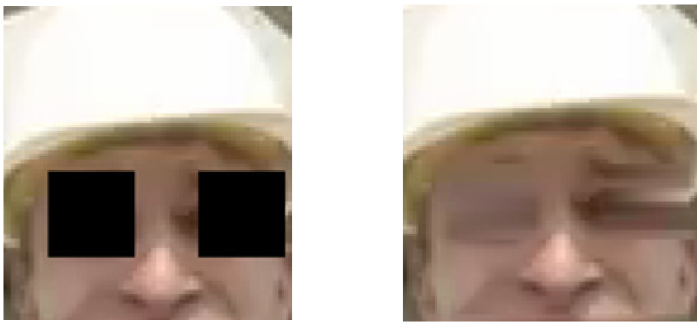


(a) Original Block

(b) Damaged Block to be concealed

(c) Block after traditional EC algorithm

Figure 4. Problem of Directional EC near the Scene Border



(a) Original Block (b) Block after traditional EC algorithm.

Figure 5. Problem with Spatial EC

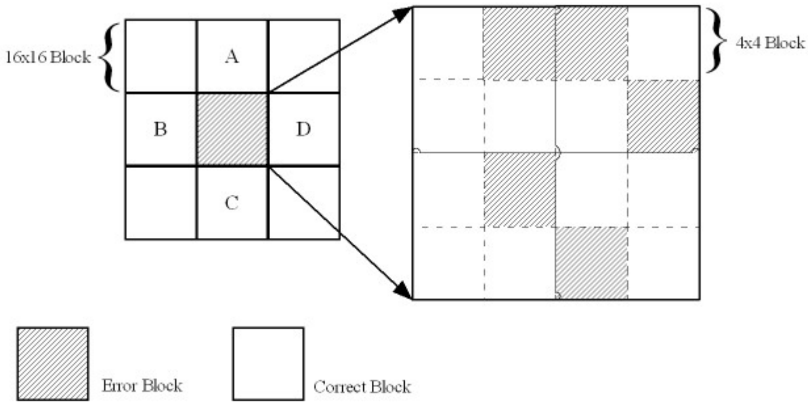


Figure 6. 16x16 block region EC by WPA

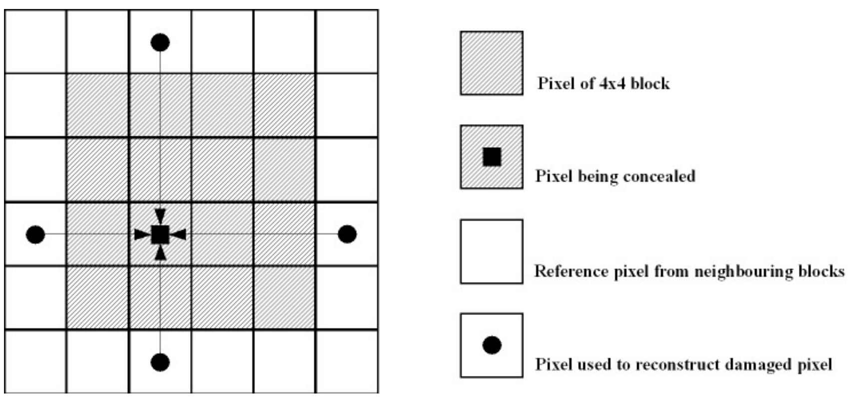


Figure 7. Proposed 4x4 pixel region based EC

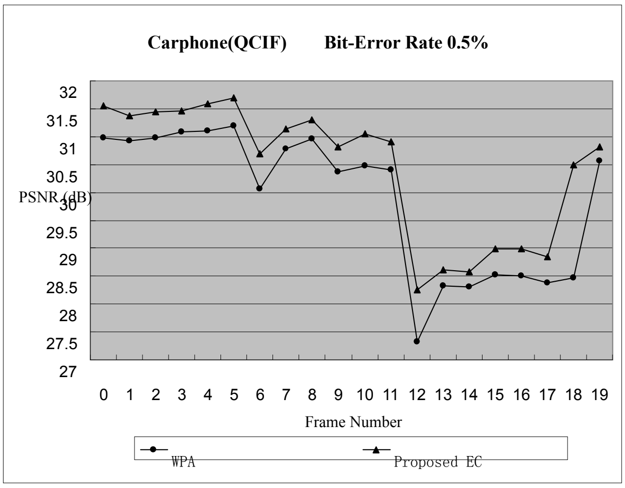


Figure 8. PSNRs for Carphone, BER=0.5%

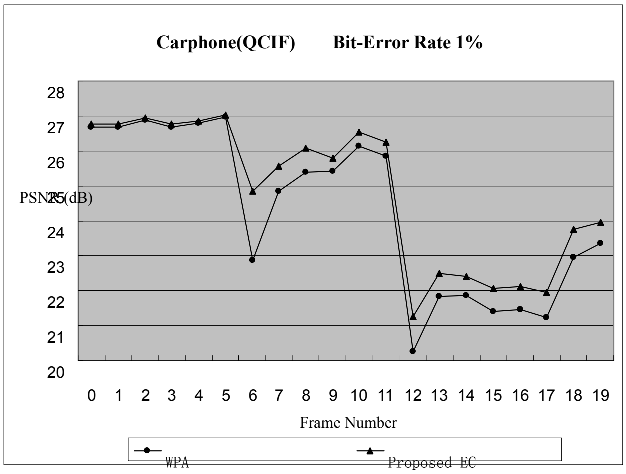


Figure 9. PSNRs for Carphone, BER=1%

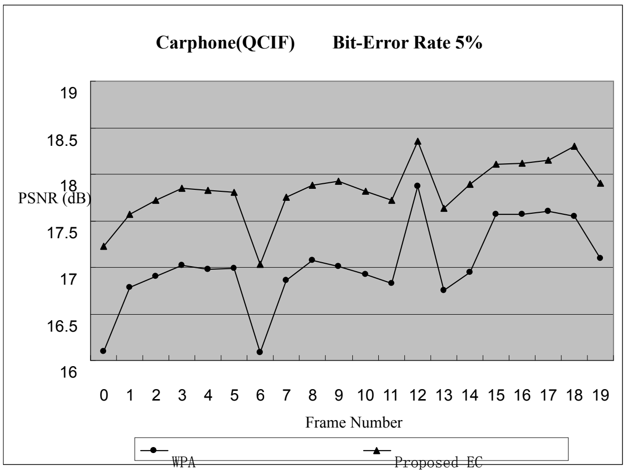


Figure 10. PSNRs for Carphone, BER=5%

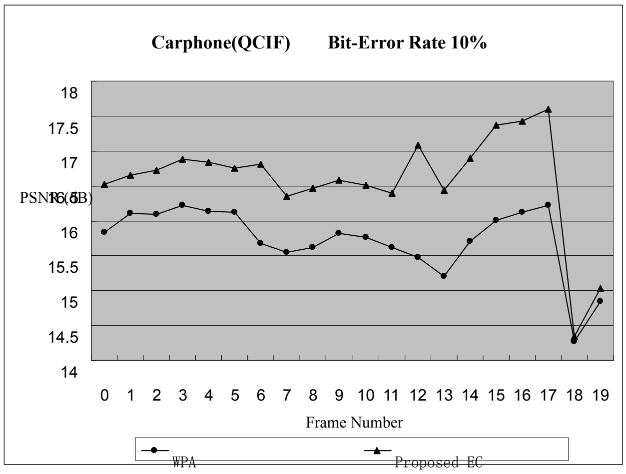


Figure 11. PSNRs for Carphone, BER=10%

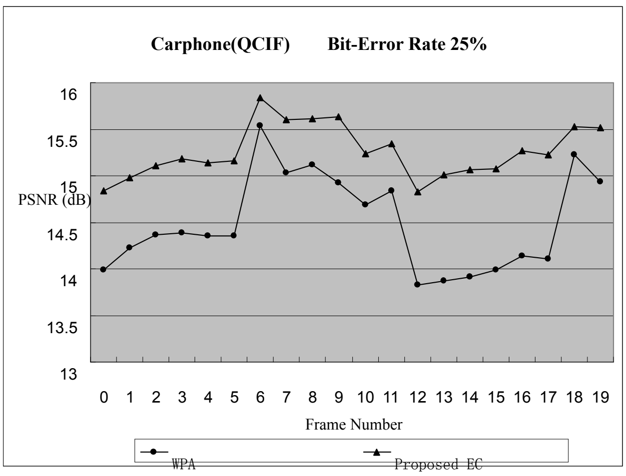


Figure 12. PSNRs for Carphone, BER=25%

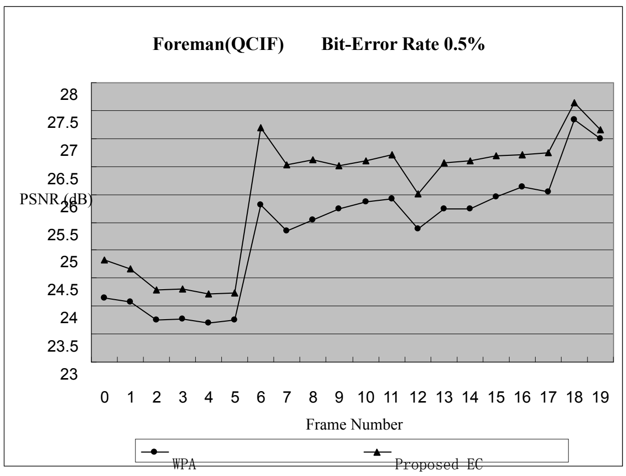


Figure 13. PSNRs for Foreman, BER=0.5%

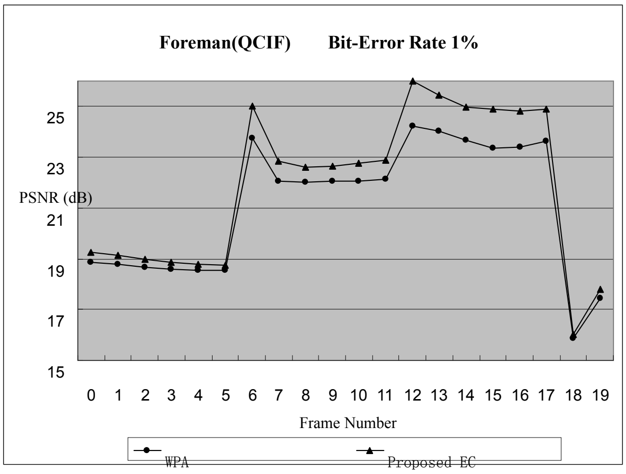


Figure 14. PSNRs for Foreman, BER=1%

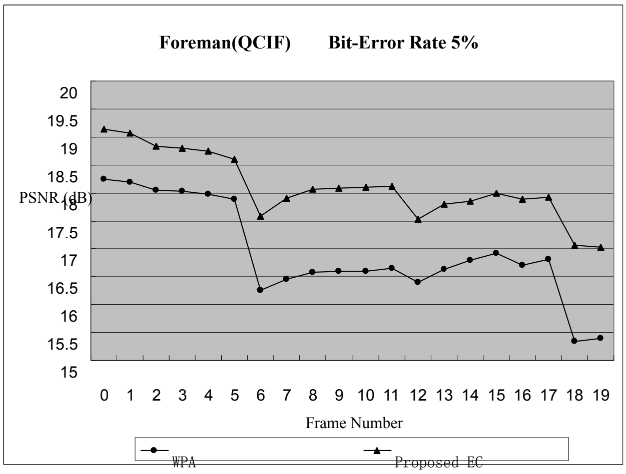


Figure 15. PSNRs for Foreman, BER=5%

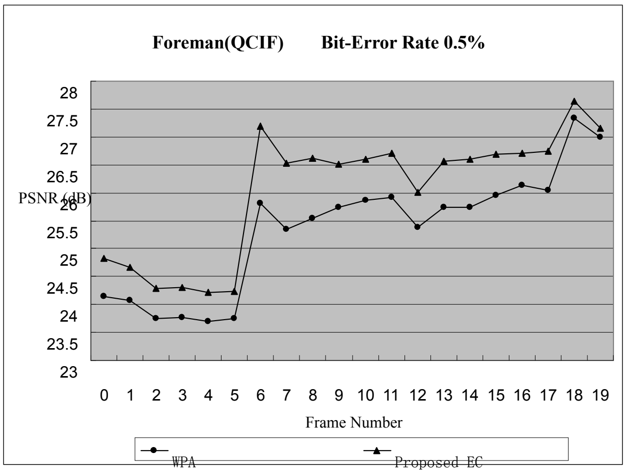


Figure 16. PSNRs for Foreman, BER=10%

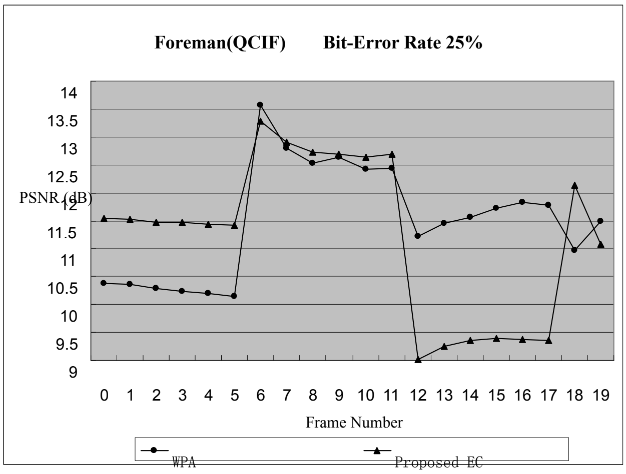


Figure 17. PSNRs for Foreman, BER=25%