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Original Article

HEVC Compatible Multiple Description Coding for Robust Video Transmission over Lossy Networks

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Abstract: In this paper, we propose a novel multiple description coding (MDC) method, which offers benefits of the new H.265/HEVC video coding standard combined with path diversity systems for robust video transmissions. In the proposed method, two descriptions including odd and even video subsequences are encoded using H.265/HEVC coder and then transmitted over two distinct channels of a path diversity system. At the receiver, the proposed MDC decoder is designed using a novel concept of distributed video coding (DVC) to provide a high image quality for the reconstructed description. Experimental results show that the proposed method can achieve a wide range of tradeoffs between coding efficiency and error resilience, and provide much better H.265/HEVC quality of experiences (QoEs) for users than other conventional MDC methods results.

Keywords: Multiple description coding (MDC), HEVC, Wyner-Ziv (WZ) coding, Distributed video coding (DVC).

1. Introduction

Recently, multiple description coding (MDC) has emerged as an attractive framework for robust video transmission over packet lossy networks [1]. The basic idea underlying MDC is to encode the source video data into two (or more) correlated descriptions, which are then transmitted over distinct channels to the decoder. If both the descriptions are received without error, the decoder provides a high-quality reconstruction of the source data. On the other hand, if one of the descriptions is lost during the transmission, the decoder estimates it from the other description, and then provides a lower but acceptable video quality reconstruction.

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Several algorithms have been proposed for MDC methods [2-4]. In [2], Kim et al., employed the H.263 video coding standard to generate multiple descriptions for the MDC system. In this work, the motion vectors (MVs) and residual data over all the macroblocks (MBs) in a frame are split into two descriptions using subsampling scheme and then these descriptions are transmitted to the receiver over two network paths. Su et al., [3] proposed another MDC method that utilized the main slice group (MSG) and side slice group (SSG) available in H.264/AVC to create two balanced descriptions. In [4], Costamagna et al. proposed an efficient combination of scalability and multiple descriptions while preserving compatibility with a standard H.264/SVC coder. In this scheme, rateless codes such as Raptor codes were employed as the effective forward error correction (FEC) codes for streaming descriptions over network paths. These methods can provide an effective error resilient coding solution for the MDC codec. However, it is the fact that the best available coding standard recently is not any more H.263 or H.264/AVC but rather the H.265 with high efficiency video coding (H.265/HEVC) [5]. This leads to the reduction in coding efficiency achieved for the H.263 or H.264/AVC based MDC as compared to the H.265/HEVC based MDC coders, especially for the application supporting high user's quality of experience (QoEs) like 4K/8K video quality services [5].

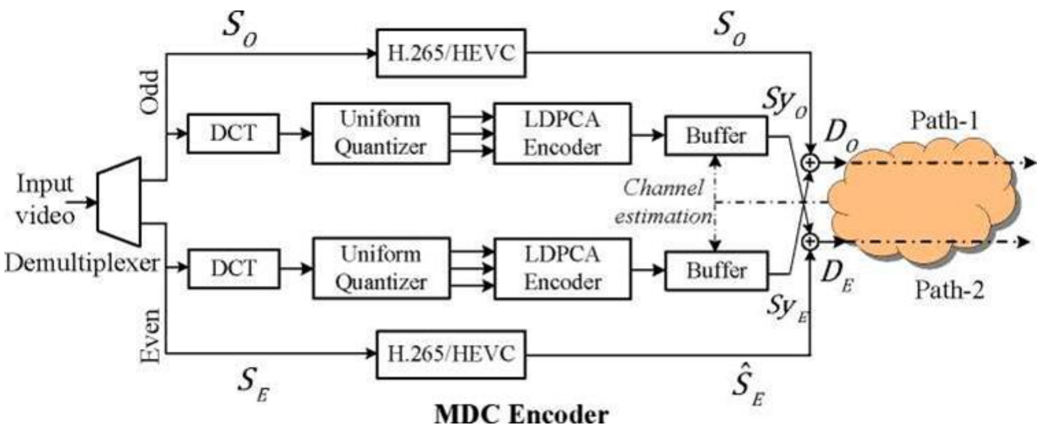

Figure 1. Proposed MDC Encoder.

In this paper, we propose a novel MDC method which utilizes the new H.265/HEVC coding standard for robust video transmission. Based on the H.265/HEVC, the proposed MDC codec not only satisfy the requirement of fully standard compatibility, but also provide high coding efficiency for the compressed bitstreams. In the proposed method, the input video sequence is split into odd and even subsequences, which are independently encoded using H.265/HEVC encoder to generate odd and even descriptions, respectively. These descriptions are then transmitted over two distinct channels to the decoder. At the receiver, the proposed MDC decoder is designed to provide an acceptable quality image, even if one of the descriptions is lost during the transmission. Specifically, in our proposed MDC method, when a description is lost, this description will be effectively recovered using a novel concept of Wyner-Ziv (WZ) coding scheme introduced in the distributed video coding (DVC) technique [6]. Experimental results show that the proposed method can achieve a wide range of tradeoffs between coding efficiency and error resilience, and provide much better H.265/HEVC quality of experiences (QoEs) for users than other conventional MDC methods.

The rest of the paper is organized as follows. Section 2 describes the proposed method in detail. Experimental results are discussed in Section 3. Finally, Section 4 concludes this paper.

2. Proposed Multiple Description Video Coding

2.1. Proposed MDC Encoder

Figure 1 shows a video streaming framework of the proposed MDC encoder. In Figure 1, the input video sequence is separated into two parts: the odd and even subsequences including the odd and even frame indexes of the input sequence, respectively. As shown in Figure 1, instead of using the conventional video coding standards like H.263 or H.264/AVC, our proposed MDC encoder utilizes H.265/HEVC which provides several advanced video coding techniques to encode the odd and even video frames [5]. This make the proposed MDC coder not only satisfy the requirement of fully standard compatible codec but also can provide an effective solution to improve the coding efficiency.

Let so and SE denote the odd and even subsequences, respectively. As shown in Figure. 1, at the encoder, both so and SE are independently encoded using H.265/HEVC to achieve two encoded bitstreams, so and SE, respectively. so and SE are then encapsulated into two corresponding descriptions named Do and DE to transmit to the receiver.

Thought based on the H.265/HEVC standard, the proposed MDC encoder can achieve high performance for the description coding, it would also be suffered from the predictive mismatch and predictive error propagation which are general problems inherent in the most conventional standard compatible MDC coder [7]. To solve these problems, in the proposed MDC encoder, we employ a novel concept, namely WZ coding introduced in the DVC technique [7] to encode the descriptions, so and SE. As shown in Figure 1, together with the H.265/HEVC coding, the odd and even subsequences so and SE, are also transformed using Discrete cosine transform (DCT). The resulting DCT coefficients are then quantized with a quantizer performing an uniform quantization for the DCT coefficients.

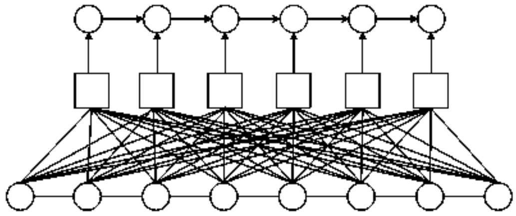

Figure 2. LDPC Encoder.

The quantized coefficients are then encoded using entropy (bitplane per bitplane) and LDPC coding. LDPC code is described in [8] as an efficient way of using low-density parity-check (LDPC) code for a rate adaptive scheme. An LDPC encoder consists of an LDPC syndrome-former concatenated with an accumulator as shown in Figure 2. In our proposed MDC encoder, for each bit plane, syndrome bits, Sy_0 and Sy_E, are created using the LDPC code and accumulated modulo 2 to produce the accumulated syndrome.

It is noted that in our MDC encoder, to improve the coding efficiency for the MDC coder, only a minimum rate of accumulated syndromes Sy_0 and Sy_E is estimated, and then put into two descriptions, D_o and D_E, to send to the MDC decoder.

After encoding, two descriptions, D_o and D_E are transmitted over two distinct paths, Ph_0 and Ph_E, of a path diversity system to the MDC decoder as shown in Figure 1.

2.2. Proposed MDC Decoder

MDC Center decoder: At the receiver, the proposed MDC includes two types of decoders, namely central and side decoders. The central decoder is utilized when all descriptions are correctly received as shown in Figure 3. Otherwise, when only one description is available and correctly received, it is decoded using the corresponding side decoder.

At the MDC central decoder, both descriptions Do and DE, which are correctly received without errors are decoded by using H.265/HEVC. In this case, Do and DE are jointly decoded, thus leading to a higher reconstruction quality for the reconstructed frames. Compared to the single description coding like H.264/AVC or H.265/HEVC, at the same image quality, the coding efficiency of the center decoder is decreased since the additional data, Sy0 and SyE, received at the center decoder in this case is not the decoded video data but the redundant data. However, the cost of these redundant data is acceptable because these data are essencial for the error resilient scheme provided for the proposed MDC coder.

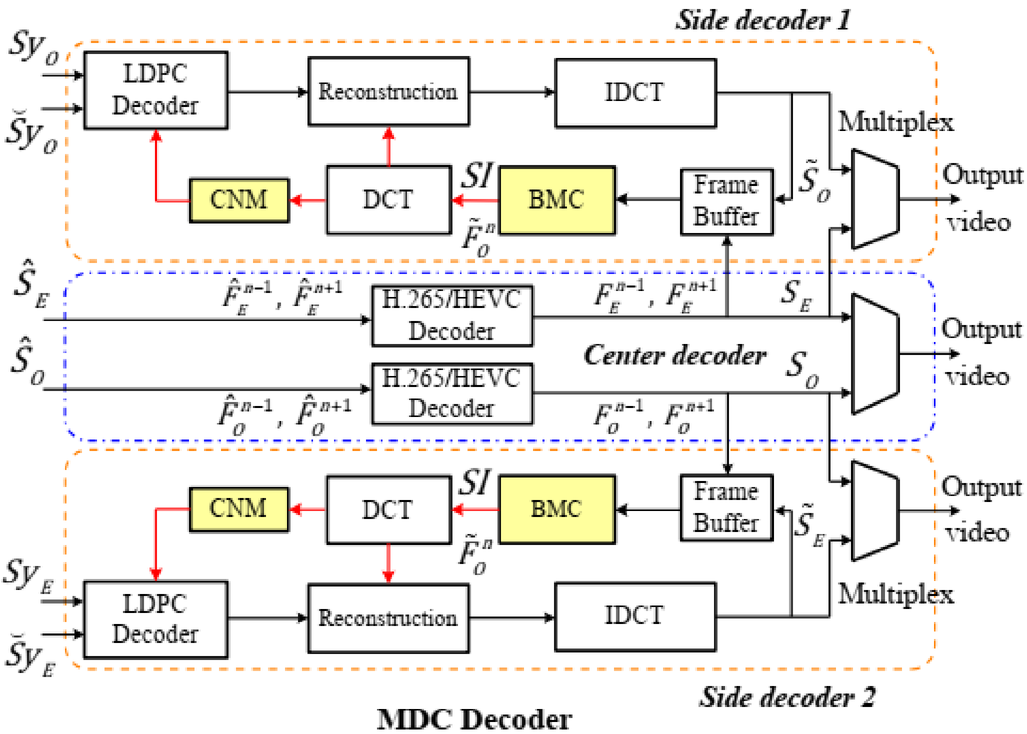

Figure 3. Proposed MDC Decoder.

MDC Side decoder: When only one description, Do or DE, is available and correctly received at the receiver, it is decoded using the corresponding MDC side decoders as shown in Figure 3.

Without loss of generality, it is assumed that D_o is transmitted to the decoder over the path-1 and D_o is lost due to the transmission errors. In this case, the side decoder 2 is employed not only to decode the correctly received description, D_E, but also to interpolate for the lost description, D_o, to provide an acceptable quality for the entire video sequence. Since D_o is not available, the side decoder 2 need to employ the correlation between D_E and D_o to obtain the interpolated description D_o for D_o.

In this work, we propose to use an algorithm named Bi-directional motion compensation (BMC) which can effectively employ the high correlations between D_E and D_o to obtain a good image quality for $\widetilde{D}_O$.

Bi-directional motion compensation (BMC) for frame interpolation: the main concept of BMC is introduced in [9] and it has been successfully applied to many applications. In this work, based on the high correlation between odd and even frames included in D_o and D_E, respectively, the BMC algorithm is employed to obtain the interpolated frames for D_o. Specifically, let F^n denote the nth frame in the original input sequence, F^{n-1} and F^{n+1} be the previous and next frames of F^n, respectively. The input video sequence is split into S_E and s_o as shown in Figure 1. Thus, after splitting and H.265/HEVC encoding, the frames F^{n-1}, F^{n+1}, and F^n become $F'E^{r\cdot 1}$, F_E^{+1}, and Ffl, respectively, where F_E^{-1}, F_E^{+1} are located in S_E, and Ffl is located in s_o. S_o and S_E are then encapsulated into D_o and D_E to transmit to the receiver as explained in the previous section.

At the receiver, when D_o is lost due to the transmission errors, s_o and thus Ffl are lost also. In contrast, D_E is correctly received, then F_E^{-1} and $F£^{+1}$ can be correctly decoded to obtain F_E^{-1} and $F£^{+1}$, respectively as shown in Figure 3.

In the BMC algorithm, the high temporal correlation between successive decoded frames, F_E^{-1} and $F£^{+1}$, are employed to obtain the interpolated frame Ffl for FQ . To this end, we predict and interpolate every pixels in Ffl using a Bi-directional motion estimation (ME) scheme performed on F_E^{-1} and F_E^{+1} as shown in Figure 4.

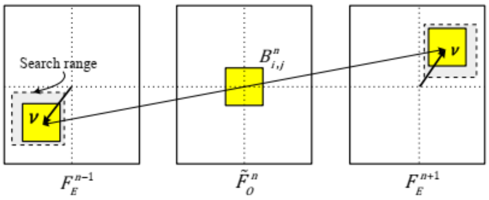

Figure 4. Bidirectional motion compensation scheme.

Let u be a 2D co-ordinates presenting a pixel location and be a motion vector of this pixel in FQ. Then, the value of the interpolated pixel at the location u in FQ is given by:

$$\tilde{F}_O^n(\boldsymbol{u},\boldsymbol{v}) = \frac{1}{2}[F_E^{n-1}(\boldsymbol{u}-\boldsymbol{v}) + F_E^{n+1}(\boldsymbol{u}+\boldsymbol{v})]. \quad (1)$$

After LDPC decoding, the LDPC decoded frames are inverted using the invert quantization and invert DCT transform to obtain the reconstructed description Do which is then combined with the reconstructed description DE to obtain a full resolution for the output video sequence as shown in Figure 3.

3. Experimental Results

Several experiments have been performed to illustrate the effectiveness of the proposed MDC method. The experiment results are reported for several video sequences using HM 16.2 reference software of the H.265/HEVC standard. The HM 16.2 is configured to provide the coding tree unit (CTU), quantization parameter (QP), and group of pictures (GOP) with the sizes of 64x64, 32, and 8, respectively. The test sequences including Foreman, Soccer, and Stefan are in YUV 4:2:0 format with QCIF (176x144) and CIF (352x288) resolution.

For video transmission over path diversity system, we set target PLRs of path-1 and path-2 as p1 and P2, respectively. The values of parameters which are characterized for the two-state Markov model corresponding to the target PLR of each path-i (i = 1, 2) are shown in Table I. p1 and p2 are defined by the Third generation partnership project - Radio access networks 1 (3GPP-RAN1).

In order to illustrate the effectiveness of the proposed MDC method, we compare the PSNR performance of the proposed method with that of the slide groups based MDC method (SGs-MDC) introduced in [3] and the conventional H.265/HEVC single description coding (SDC) [5]. In the SGs-MDC method, each description

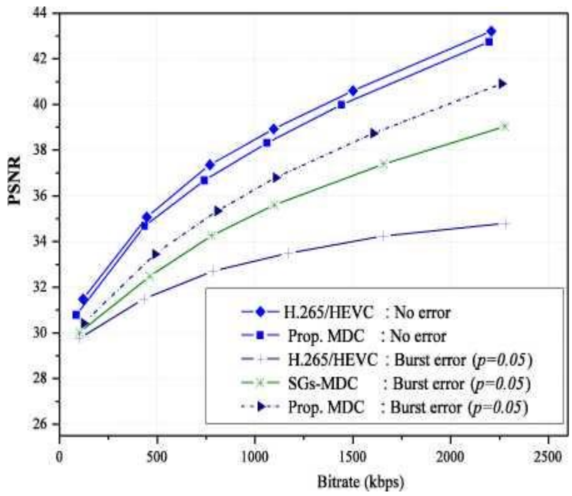

Figure 5. Rate-distortion performance for *Foreman* sequence when PLR=5%.

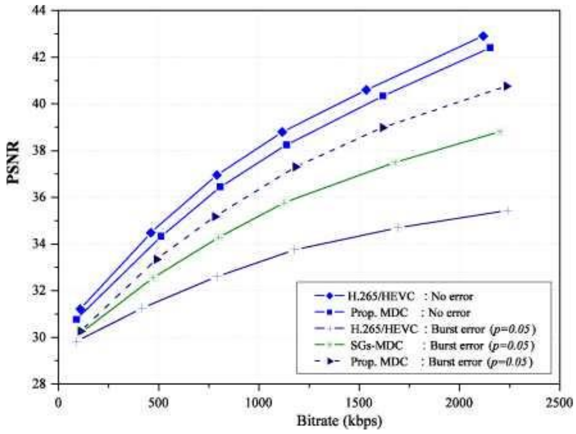

Figure 6. Rate-distortion performance for *Stefan* sequence when PLR=5%.

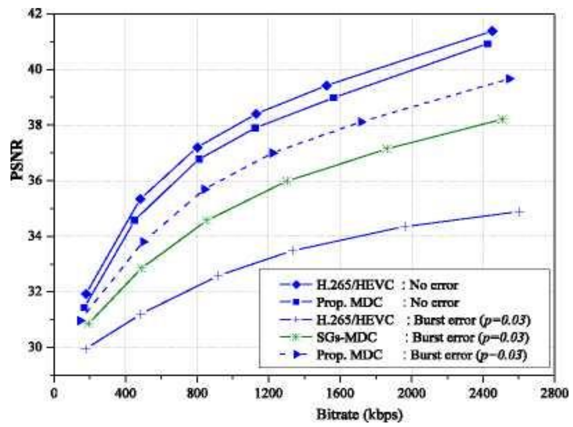

Figure 7. Rate-distortion performance for *Soccer* sequence when PLR=3%.

Figure 5 shows the PSNR performance of the proposed MDC, the conventional H.265/HEVC, and the SGs-MDC methods corresponding to a wide range of encoding bitrates. As seen in Figure 5, in the error-free condition, the PSNR performance obtained in the center decoder of the proposed method is about 0.5dB lower than that of the conventional H.265/HEVC SDC method. As mentioned previously, the proposed method requires more redundant data for the source video data protection. Thus, in the case of error-free where both descriptions are correctly received at the decoder, these redundant data might result in the degradation on the Rate-distortion performance of the proposed method. However, in cases of lossy packet networks where the encoded descriptions are suffered from the transmission errors, the proposed method outperforms the conventional methods by a large margin of performance. For example, with the packet loss rates (PLRs) of channels are equal to 5% (p1 = P2 = 0.05), at the bitrate of 2.0Mbps, the proposed MDC provides up to 5.3dB better performance than the conventional H.265/HEVC SDC as shown in Figure 5.

The PSNR performance obtained in the SGs-MDC method is higher than that obtained for the H.265/HEVC SDC method. However, with the same amount of redundancy data required, the SGs-MDC method yields worse performances than the proposed MDC method at all values of bitrates as shown in Figure 5 and 6.

Table 1 shows more details on the average PSNR performance of the conventional and proposed methods performed on different video test sequence, PLRs and QPs. As shown in Table 1, the proposed MDC method consistently provides better performance than the H.265/HEVC and SGs-MDC methods.

Table 1. Comparisons of the average psnrs performed on different test video sequences and different plr (p1, p2)

Sequence	*(p1,p2)*	H.265/HEVC	SGs-MDC[3]	Prop. MDC
Foreman	(0.01, 0.05)	33.45	36.53	37.81
	(0.03, 0.06)	31.92	35.06	36.15
Soccer	(0.05, 0.05)	30.68	32.63	34.55
	(0.01, 0.04)	32.07	33.90	35.67
Stefan	(0.10, 0.05)	34.54	36.69	38.44
	(0.03, 0.07)	34.89	36.72	38.67

Generally, the better PSNR performance obtained for the reconstructed video frames, the higher QoE can be achieved for the experienced users. In this work, to illustrate better image quality and better QoEs achieved for users when applying the proposed MDC method, we perform the subjective evaluation for the reconstructed video frames obtained at the MDC decoder. Specifically, we compare the subjective image quality of the recovered frames which are lost due to the transmission errors, using the SGs-MDC and proposed MDC methods, respectively as shown in Figure 8. In Figure 8, the recovered image quality of the 45th frame in the Foreman sequence of the SGs-MDC and proposed MDC methods are reported in Figures. 8(b)-(c), respectively. As shown in Figure. 8, the QoEs of the SGs-MDC method is critically degraded due to annoying blocking artifacts seen around the face of the Foreman. In contrast to the SGs-MDC, the proposed method yields the most satisfactory image quality and significant reduction of blocking artifacts as can be observed from Figure 8c.

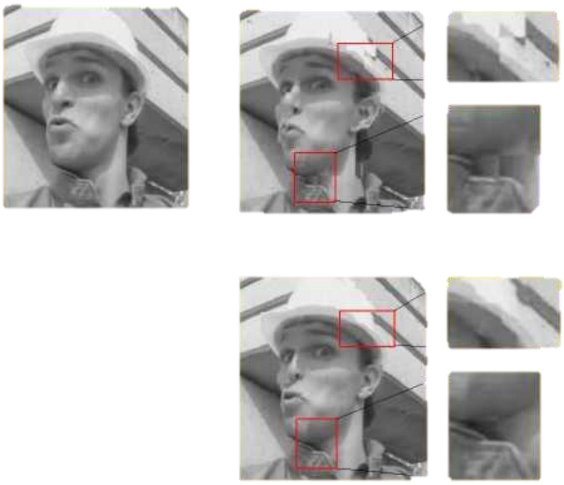

Figure 8. Comparison of the image quality and QoEs forthe 45th recovered frame in the Foreman sequence: (a) Original. (b) SGs-MDC. (c) Proposed MDC.

4. Conclusion

In this paper, we have proposed a novel multiple description motion coding method which offers benefits of the new H.265/HEVC video coding standard combined with path diversity systems. In the proposed method, two descriptions including odd and even video subsequences are encoded using H.265/HEVC. At the receiver, the proposed MDC decoder is designed using a novel concept of distributed video coding (DVC) to provide a high image quality for the reconstructed description.

Experimental results show that the proposed method can achieve a wide range of tradeoffs between coding efficiency and error resilience, and provide much better H.265/HEVC quality of experiences (QoEs) for users than other conventional MDC methods.

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