Recovering Single Lost Description Using DCT-MDC Based on Network Coding

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***Abstract*—Multiple Description Coding (MDC) is one of the source coding methods for providing several quantized, independent and identically distributed (*iid*) streams of data while Network coding (NC) is a method to recover the loss which occurs in the network. NC applies algebraic mathematic operation on independent data sequences in the intermediate nodes within a network. This paper attempts to transmit the higher value coefficients of image description to the channel and recover any loss happens in the network by joining the DCT-MDC and network coding. First, input image is zero padded and then DCT-MDC is performed on subimages. Next, downsampling block is used to create 4 multiple descriptions. These 4 descriptions are transmitted over the network and once the disconnection happens in the primary links, by using p-cycle NC lost data is reconstructed. In this method there is no need of retransmission (feedback). Results show that the PSNR and subjective evaluation factors for the proposed method are higher and clearer than the previous work which leads to have higher throughput.**

Keywords-Multiple Description Coding, Network Coding, DCT, Zero padding, Quantization.

I. Introduction

MDC relates to source compression in which the encoder creates multiple descriptions of the source data. The various descriptions are carried over different routes in an unreliable network. The decoder could rely on any obtained kind of the descriptions to rebuild the carried message. MDC is a fascinating application for effective communication across lossy networks for instance, the Internet and sensor [1], [2], [3].

MDC affords an appealing structure for data transmission in cases where packet loss is unavoidable. In particular, in real-time multimedia communications systems, packet retransmission is impossible because of serious latency limitations. In these circumstances, the receiver should trust on the packets accessible at the decoder to restore the transmitted data. The quality of the retrieved signal will rely on the level of packet loss on the channel.

MDC offers a process to recover signals with lower but fair quality also while several number of the descriptions have been damaged or corrupted. This strategy is essentially apart from the use of scalable coding, where a particular enhancement layer can be utilized to increase the quality of the decoded signal provided that the base layer, and all its lower-level enhancement layers have been retrieved by the receiver [1], [2]. This function has formed MDC quite interesting method for multimedia communication over multi channel network that uses network diversity to enhance the transmitted source signal quality. Numerous correlated illustrations of the signal are produced and transmitted along different independent channels.

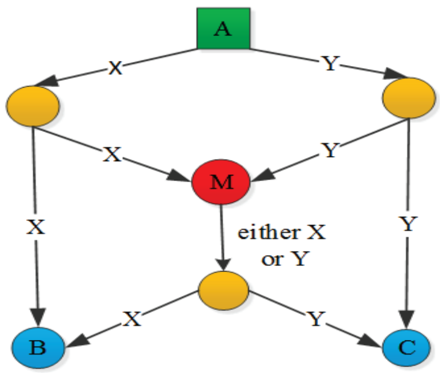
Practical techniques to MDC include scalar quantization [4], [5] and vector quantization [6], [7], [8]. Moreover MDC based on transform coding is also useful method of preparing multiple description which is investigated by [9], [10]. Later, after preparing descriptions using MDC, these coded descriptions should be transmitted along the communication networks.

Having lots of low throughput and distortion on transmitted multimedia information in the network is a challenging problem. In order to combat distortion or absence of any data in the network, Network Coding (NC) is proposed [11], [12], [13]. NC is a technique which can be used to improve networks throughput and efficiency as well as resilience to attacks and eavesdropping.

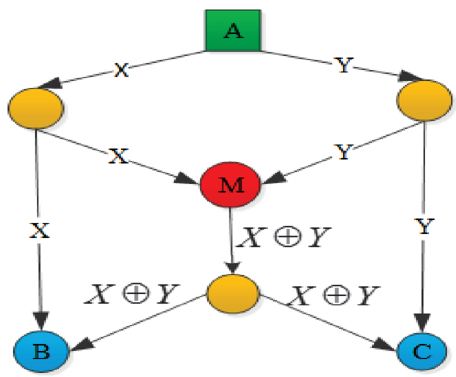
The intermediate node combines several input messages into each output message. From what they have received, the destination nodes then decode the original messages. Fig. 1(a) shows delivery of data by the conventional store-and-forward mode over the butterfly network. Two-time slots need to deliver two data symbols X and Y from A to both B and C. In contrast, Fig. 1(b) uses (linear) NC to achieve the data delivery in just one-time slot. The symbol ⊕ (*Xor*) represents for the linear network coding process.

Additionally, [14] proposes p-cycle NC in order to have two copies of the same signal on two disjoint paths. One path is the primary working path which carries main Data. The second path, however, is in fact a virtual path (protection links), which is still disjoint from the primary path. Protection links are set of links on which the signal is transmitted with other signals, but there is enough information to recover the target signal from those transmissions.

MDC is one of the source coding methods to reduce data redundancy and prepare multiple *iid* descriptions in the network in contrast, NC is a way to increase redundancy for



(a) Conventional store and forward.



(b) Linear network Coding.

Fig. 1: Multicasting over a communication network.

protecting against data loss in the network. consequently, by joining two methods, system can benefit from both advantages. It means efficiency of system increases, and also complexity reduces because retransmission (feedback) is not needed as long as NC recovers errors.

In the proposed algorithm, p-cycle links (protection links) are disjoint from main data links (primary links) which means it has no influence on the data rate of the network. Compared to [15] where averaging of received descriptions is calculated in order to substitute lost descriptions, in the proposed MDC p-cycle based NC method, p-cycle protection links are used to recover and conceal lost descriptions.

The remainder of the paper is organized as follows. Section II describes P-cycle network coding. Section III describes the proposed scheme based on joint MDC and network coding. Simulation results and figures are shown in section IV while Section V concludes the paper.

II. P-cycle Network Coding

p-cycle NC was first introduced by [14] for protecting against link failures. Optimization of joint p-cycle and working path routes is explained in [16]. Failure Independent Path-Protecting (FIPP) p-cycle is an extension of the basic p-cycle concept is proposed in [17], which is more efficient in terms of capacity network design than link protecting pcycle. Recently, a new 1+N protection scheme which is joint NC, and p-cycle is introduced against single link failure in [18].

Fig. 2 shows an example of p-cycle with three unidirectional connections from source S_i to the destination T_i, for $i = 1; 2; 3$. For simplicity of the example, it is assumed that sources and their corresponding destinations are sorted from left to right. The capacity of each unit links are assumed unity and also supposed that data units d_1, d_2 and d_3 are sent on those links. As shown in the Fig. 2, p-cycle is preconfigured to use all the three sources and destinations. Data units of d will be transmitted three times: once on the primary working path, and twice, in opposite directions on the p-cycle. First time original data unit is transmitted by S on one of the p-cycle protection links and second time data units is transmitted by the receiver T on the other p-cycle protection link. It is recognized between those two data units by referring to them as transmitted and received d_i units, d_i^t and d_i^r, respectively. On the p-cycle, the following procedure takes place:

1) Data unit d_i^t is transmitted from S_1 in the clockwise direction. Node S_2 will add and *xor* its own data unit, d_2^t to d_1^t that it is already received on the p-cycle (where the addition is modulo 2) then $d_1^t + d_2^t$ is transmitted in clockwise direction on the p-cycle. Node S_3 will repeat the same process, and will *xor* d_3^t to $d_1^t + d_2^t$ and transmits the result on the p-cycle. In this case node T_3 receives $d_1^t + d_2^t + d_3^t$ on the p-cycle, and in the clockwise direction.
2) On the same link of the p-cycle (clockwise direction), but at the destinations side, once node T_3 receives $d_1^t + d_2^t + d_3^t$ and also receives d_3 on the working path, it adds or *xor* d_3 to $d_1^t + d_2^t + d_3^t$ to get $d_1^t + d_2^t$ and forwards it to T_2 . Node T_2 also add d_2 , which is received on the working path, to $d_1^t + d_2^t$ to obtain d_1^t , and again it transmits the result on the same p-cycle to node T_1. T_1 receives d_1^t from the clockwise cycle.
3) Furthermore, in the same situation when node T_1 receives d_1 on the primary path (working path), it transmits d_1 on the p-cycle, but in the counter clockwise direction (second p-cycle link). It is defined as d_1^r . Same as previous scenario on first protection link, again node T_2 , when it receives d_2 on the working path, this node adds it to d_1^r , and transmits $d_1^r + d_2^r$ on the second p-cycle link, also in the counter clockwise direction.

Based on the above explanations, it is clear that in the absence of failures, each destination node T_1, for $i = 1, 2, 3$ receives two copies of d_i :

1) One copy from the working path, and
2) The second one is recovered by adding $\sum_{j=1}^{i} d_j^t$ which is received on the clockwise p-cycle to $\sum_{j=1}^{i-1} d_j^r$, which is received on the counter clockwise cycle. This is a virtual copy of d_i as it is referred.

When a failure occurs, it affects working paths, e.g., working path i . In this case, it is supposed that T_i will receive an empty data unit on the working path. Therefore, T_i will be able to recover d_i by using the second virtual copy explained above, i.e., by adding $\sum_{j=1}^{i} d_j^t$ and $\sum_{j=1}^{i-1} d_j^r$.

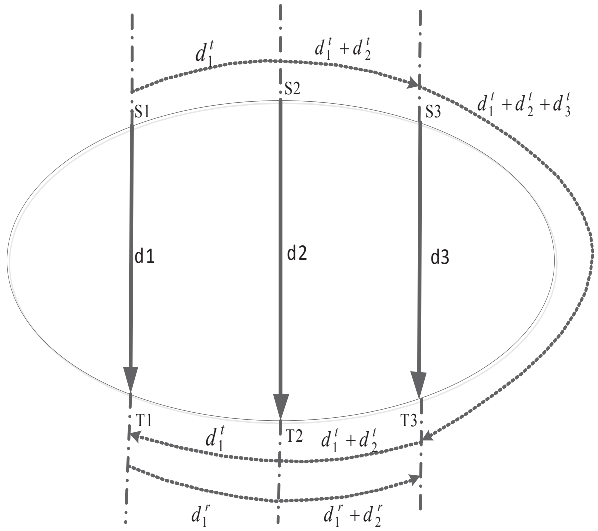


Fig. 2: An example of the use of NC on p-cycles to protect against link failures [18].

It can be concluded that a failure on the p-cycle will not interrupt communication on primary working paths because of independency of primary path and protection path. Also, it is supposed that there is no distortion or failure on the p-cycle protection links. In the following section, in order to reduce the traffic of data in the network which causes to have fast NC calculation, MDC based NC is applied.

III. Proposed Joint MDC Based on P-Cycle NC

The proposed method compress,quantize and divide the input data to multiple *iid* data streams by using MDC and transmit the description into the network. Later, the transmitted data are protected and recovered by applying the p-cycle NC. Additionally, traffic of the network is balanced since multiple descriptions are transmitted through network instead of single description. Block diagram of system is shown in Fig. 3.

At first the input 512×512 grayscale image is zero padded. The zero padding process is presented in [19] . Zero padding is pre-processing method which some zeros are added to the image until high quality of reconstructed image is achieved. By using zero padding, the correlation of the image pixels are increased. Therefore, If there are losses in the channel, by using received descriptions, lost descriptions can be constructed in high quality.

Later, MDC is applied to the zero-padded data to create 2 quantized descriptions [5], [19]. These 2 descriptions are downsampled to 4 descriptions in the next stage. Finally, these 4 quantized sequences are transmitted over the network and once the disconnection happens in the primary links (main data links), by using p-cycle NC links lost data is reconstructed. In the network there are two different paths (links). One is primary links (main data links $\hat{X}_1, \hat{X}_2, \hat{X}_3$ and $\hat{X}_4$) which carries data streams and the second one is p-cycle protection links which carries *xor* of the main links.

Any primary data links that lost in the receiver nodes, by xoring the entering p-cycle clockwise and counter clockwise protection links in the corresponding receiver nodes, the lost information is recovered and concealed. As an example if the main data links $\hat{X}_3$ is lost then in node 7 by xoring the incoming links $\hat{X}_1 \oplus \hat{X}_2$ and $\hat{X}_1 \oplus \hat{X}_2 \oplus \hat{X}_3$ the lost $\hat{X}_3$ is reconstructed. Finally, at the receiver, reverse action of the block diagram is performed to reconstruct the image.

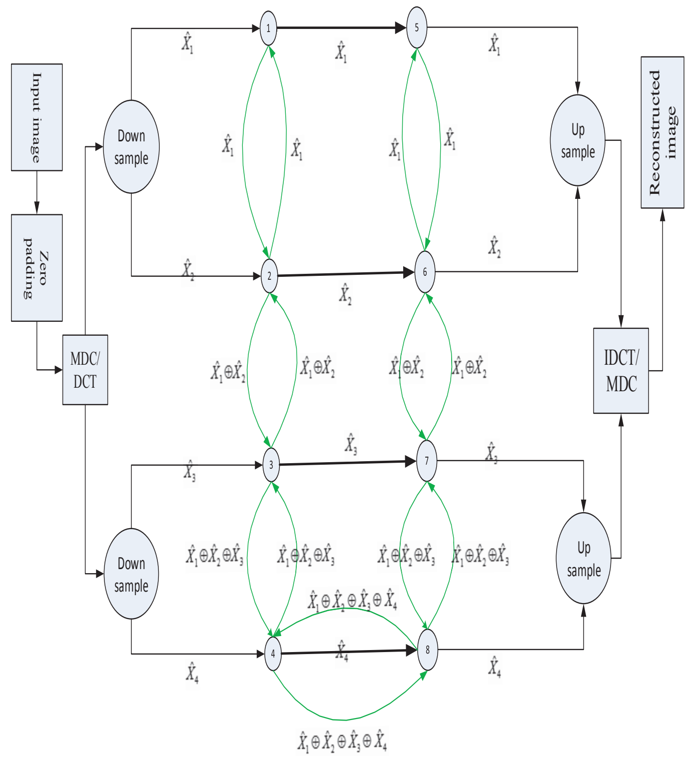


Fig. 3: Block diagram of DCT-MDC based on p-cycle NC.

IV. Simulation Results

Table I and Table II show average PSNR (peak signal to noise ratio) of [15] in one lost description for *Lena* and *dark hair woman* respectively. Table III and Table IV present PSNR of proposed method for *Lena* and *dark hair woman* respectively. PSNR formula for 8 bit image is:

$$PSNR = 20log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \tag{1}$$

Mean Square Error (MSE) for two $m \times n$ monochrome images I and K that one of the images is considered a noisy approximation of the other is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \tag{2}$$

By comparing tables I and II with tables III and IV we can observe that in the proposed method (tables III and IV), values of PSNR are higher than tables I and II in terms of fixed bit per pixel (bpp). Since all lost links are exactly reconstructed in proposed method so there could be no changes in the PSNR by losing different descriptions. In [15] average of received links is substituted instead of lost data to recover. Hower, in the proposed method instead of averaging, p-cycle network coding is used for recovering lost descriptions.

TABLE I: Average PSNR (dB) values for *Lena* image from [15].

number of	Bit Rate		
lost descriptions	2 bpp	1 bpp	0.50 bpp
1	29.77	27.99	26.36

TABLE II: Average PSNR (dB) values for *dark hair woman* image from [15].

number of	Bit Rate		
lost descriptions	2 bpp	1 bpp	0.50 bpp
1	34.95	32.92	31.50

TABLE III: Average PSNR (dB) values for *Lena* image from proposed method.

number of	Bit Rate		
lost descriptions	2 bpp	1 bpp	0.50 bpp
1	37.02	32.11	30.84

TABLE IV: Average PSNR (dB) values for *dark hair woman* image from proposed method.

number of	Bit Rate		
lost descriptions	2 bpp	1 bpp	0.50 bpp
1	40.88	36.92	35.09

Rate distortion plots are shown in Fig. 4 and Fig. 5 in order to compare the proposed method with [15]. It is obvious that in the fixed bpp the MSE of proposed method is significantly lower than [15].

In Fig. 6 for subjective evaluation, *Lena* reconstructed image with 0.5 bpp from proposed method is shown. In Fig. 7 same image is reconstructed from [15] with one lost description in 0.5 bpp. Comparison of Fig. 6 and Fig. 7 shows that by using p-cycle NC lost data can recovered clearly in terms of subjective evaluation. As an example small details of the image such as feathers, eyes, and eyebrows are reconstructed by proposed method with less blur.

Furthermore, reconstructed image for *dark hair woman* is shown in Fig. 8 with proposed method in 0.5 bpp. Fig. 9 illustrates the received image from 0.5 bpp with one lost description from [15]. By comparing Fig. 8 and Fig. 9, it is clear that by using pcycle NC lost data can recovered clearly in terms of subjective evaluation. Small features of the face

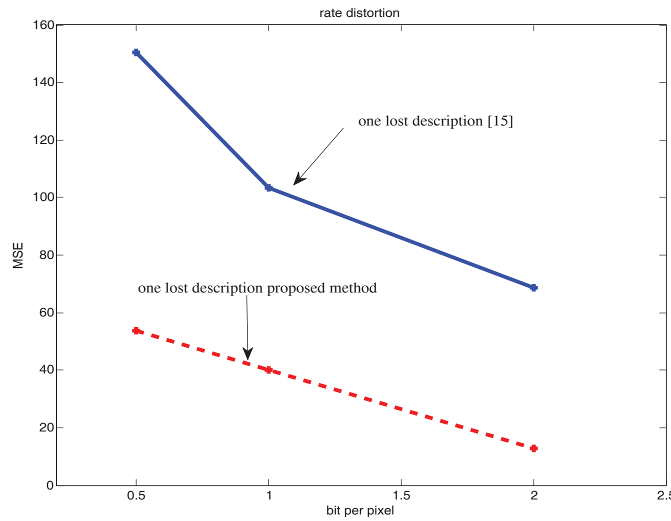


Fig. 4: Rate distortion plot of proposed method and method of [15] for *Lena*.

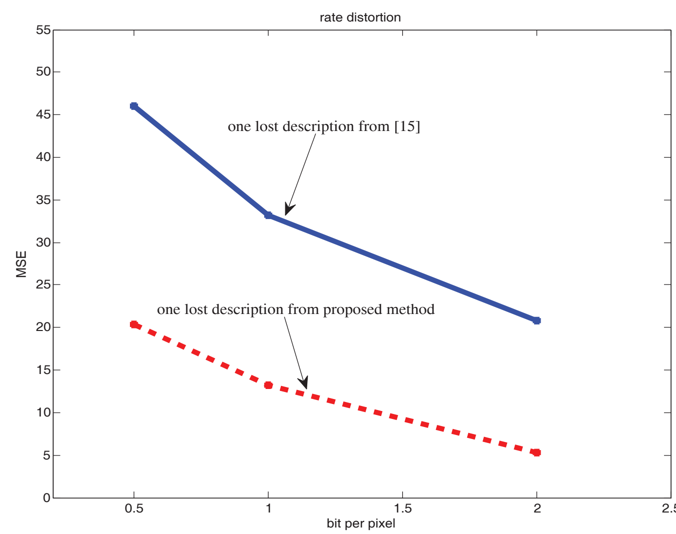


Fig. 5: Rate distortion plot of proposed method and method of [15] for *dark hair woman*.

such as hairs, eyes, and eyebrows are reconstructed clearly by proposed method.

V. Conclusion

This research is explained the transmission of the image using DCT-MDC based on p-cycle NC. The first part (DCT-MDC) is source coding to quantize and remove redundant information of the input image and prepare 4 multiple description streams of the data. The second part (the p-cycle protection) is actually for adding some redundant protection links in order to combat primary link lost in the network. To make a balance of these two systems is the challenging area in

Fig. 6: Reconstructed *Lena* image in 0.50 bpp from proposed DCT-MDC based on p-cycle NC.

Fig. 7: Reconstructed *Lena* image in 0.50 bpp from [15].

Fig. 8: Reconstructed *dark hair woman* image in 0.50 bpp from proposed DCT-MDC based on p-cycle NC.

Fig. 9: Reconstructed *dark hair woman* image in 0.50 bpp from [15].

joining MDC and NC. In the proposed method input image is zero padded first for increasing the correlation between pixels and reducing variance of quantization. later, it is downsampled and DCT-MDC are used to quantize and make 4 independent descriptions to transmit through network. In the network nodes, P-cycle network coding is applied in order to recover any lost link. The PSNR results show that the proposed method has higher values than the compared work in terms of the fixed bit rate. Finally, subjective evaluation shows that in the 0.5 bpp, proposed reconstructed image is clearer and less blur than the previous one.

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