Efficient Distributed Video Coding based on principle of syndrome coding

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Abstract: Distributed video coding is a new video coding paradigm, the main objective of which is to reduce the encoder complexity to support a separate class of uplink friendly applications like wire-less video applications, besides achieving the rate distortion performance of conventional video coders. In this paper we describe and present the simulation results of the video coding method based on the principle of distributed source coding using Golay codes and then propose an improvement to it. In this, the side information is improved by performing a very coarse motion search at the encoder and transmitting the position of the side information block as the hash information to the decoder which will help the decoder to perform motion estimation.

Keywords: Syndrome, coset, wireless video, distributed video coding (DVC)

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1 Introduction

Advancements in VLSI technologies and computing capabilities have made many complex video applications like video phony, video conferencing, HDTV, DVD etc a reality. With increasingly complex video services such as 3D movies, 3D games, high quality video such as HDTV, amount of image and video data to be handled is enormous. This poses the requirement of having an efficient and advanced video and image compression techniques. Current video standards like ISO MPEG and ITU-H.26X schemes, popularly called as conventional video coders have made an effort in accomplishing the enhanced compression performance needs and providing a network friendly video representation, addressing “conversational” applications such as video telephony and “non conversational” application such as storage, broadcast or streaming. These applications belong to a class of “downlink” friendly applications, in which the data is compressed once but decoded multiple times. These conventional video coders work on the principle of predictive coding which exploits the source statistics at the encoder. The encoders of these conventional coders perform motion search in the reference frame to find a best predictor. This is the motion estimation and compensation technique which amounts to 80% of the encoder complexity and computational resources, resulting in a bulky encoder with higher power consumption.

However certain application require an inverse architecture where the encoder is constrained in complexity and computation, while the decoder can afford higher complexity. Such architectures are called “Uplink” friendly architectures. The typical examples of this architecture are wireless sensor networks, mobile camera, wireless PC camera, video surveillance system etc. where the power and computational resources at the encoder are of primary concern. Hence the conventional coders are not suitable for these up link friendly architectures. Distributed video coding is a new video coding paradigm, that shifts the motion search module to the decoder thus reducing the encoder complexity at the expense of increased decoder complexity. DVC is based on the information theoretic bounds established in 1970’s by Slepian-Wolf (Slepian and Wolf, 1973) for distributed loss less coding and by Wyner-Ziv (Wyner, 1974) for lossy coding with decoder side information, which states that efficient compression can also be achieved by exploiting source statistics partially or wholly at the decoder. Unlike conventional video codecs, distributed video coding exploits source statistics at the decoder alone, thus interchanging the traditional balance of complex encoder and simple decoder, thus making it suitable for uplink friendly architectures. Distributed video coding paradigm is thus very promising for wireless video applications (Girod et al., 2005), (Pereira et al., 2008), (Tonoli et al., 2009).

Distributed video coding has advantages in an typical application scenario, where in future multimedia systems use multiple video input and output streams. These streams may be captured using a network of distributed devices and transmitted over a bandwidth-constrained, noisy wireless transmission medium to a central location for processing. These architectures demand for :

- Low power and low complexity encoder
- High Compression rates.
- Robustness to packet losses caused by channel errors..

Conventional video coders have a good rate-distortion performance but they fail to fulfill the needs of low-complexity encoder and robustness to channel errors. As these coders work on the principle of predictive coding, any error caused by packet drop will be propagated throughout unless some measures are taken to handle them. To cater these channel errors some error detection and correction mechanisms should be added at the cost of compression efficiency. On the other hand intraframe coders like motionJPEG exploit only the spatial redundancies and hence have a low complexity encoder. These coders are robust to packet losses as the frames are coded independently. But these coders don’t exploit the temporal redundancies across the frames and hence have a very poor compression performance. Distributed video coding is a new paradigm that tries to achieve good rate-distortion performance of conventional coders with a low complexity, robust encoder. Recently intense research is going on in this new area of distributed video coding and a lot of practical coders have been suggested by many research groups (Girod et al., 2005). Inspite of research efforts put by many groups, there is still a wide gap in the rate-distortion performance of distributed video codecs and conventional interframe coders and there are still many open problems waiting to be solved.

In this paper, we present two approaches used for syndrome coding of video based on the principle of distributed source coding. In the first method, multilevel coset coding and syndrome coding based on Golay codes is explained. In the second method side information is improved by performing a very coarse motion search at the encoder and transmitting the position as the hash information to the decoder which will help the decoder to perform motion estimation. In this paper we present the simulation results of these two methods and compare this with our previous implementation based on LDPC (Aparna et al., 2009). We also compare our results with H.263+ intra coder (Cote et al., 1998), H.264/AVC intra coder (Wiegand et al., 2003), H.263+ interframe coder (Cote et al., 1998). We also compare the encoder complexity of distributed video coder with other methods in terms of its encoding time.

2 Fundamental Theories of distributed video coding

Figure 1 Lossless Decoder with Side Information

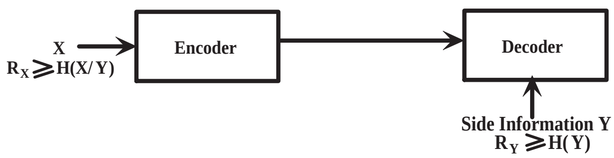
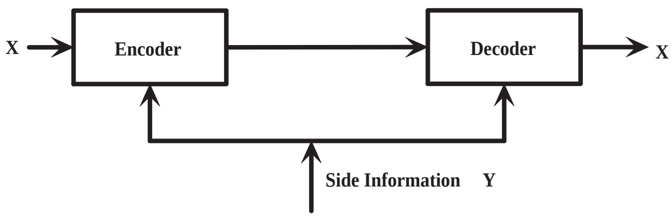


Figure 2 Conventional Coding System



Let X and Y be two correlated information sources. Figure 1 is a case of distributed coding with side information, where in encoder encodes the two sources independently, but the decoder jointly decodes them. Figure 2 is a case of conventional coder where the side information Y is available both at the encoder and decoder. Considering separate encoder and the decoder for X and Y, the rate required is $R_X \geq H(X)$ and $R_Y \geq H(Y)$ where $H(X)$ and $H(Y)$ represents the entropy of X and Y respectively. The problem that Slepian-Wolf theorem addresses is, to determine the minimum number of bits per source character required for encoding the message stream in order to ensure accurate reconstruction at the decoder. Slepian-Wolf (Slepian and Wolf, 1973) showed that good compression can be achieved with joint decoding but separate encoding if

$$R_X + R_Y \geq H(X,Y) \tag{1}$$

and

$$R_X \geq H(X/Y), R_Y \geq H(Y) \tag{2}$$

or

$$R_X \geq H(X), R_Y \geq H(Y/X) \tag{3}$$

Thus Slepian-Wolf (Slepian and Wolf, 1973) showed that equation (1) is the necessary condition and equation (2) or equation (3) are the sufficient conditions required to encode the data in case of joint decoding.

Aaron Wyner and Jacob Ziv (Wyner, 1974), (Wyner and Ziv et al., 1976) extended Slepian-Wolf theorem and showed that conditional Rate-MSE distortion function for X is same whether the side information is available only at the decoder as in Figure 1 or both at encoder and decoder as in Figure 2; where X and Y are statistically dependent Gaussian random processes. Encoder encodes X without access to side information Y and the decoder reconstructs $\hat{X}$ using Y as side information. Let $D = E[d(\hat{X}, X)]$ is the acceptable distortion. Let $R_{X/Y}(D)$ be the rate required for the case where side information is available at the encoder also and $R^{WZ}_{X/Y}(D)$ represent the Wyner-Ziv rate required when encoder does not have access to side information . Wyner-Ziv proved that Wyner-Ziv rate distortion function $R^{WZ}_{X/Y}(D)$ is the achievable lower bound for the bitrate for a distortion D

$$R^{WZ}_{X/Y}(D) - R_{X/Y}(D) \geq 0 \tag{4}$$

They also showed that for Gaussian memoryless sources

$$R^{WZ}_{X/Y}(D) - R_{X/Y}(D) = 0 \tag{5}$$

As a result source sequence X can be considered as the sum of arbitrarily distributed side information Y and independent Gaussian Noise. Distributed video coding is based on these two fundamental theories, specifically works on the Wyner-Ziv coding considering a distortion measure. In such a coding system the encoder encodes each video frame separately with respect to the correlation statistics between itself and the side information. The decoder decodes the frames jointly using the side information available only at the decoder. This video paradigm is as opposed to the conventional coding system where the side information is available both at the encoder and decoder as shown in Figure 2.

In distributed video coding environment Y is treated as the noisy version of X such that $X = Y + N$. Statistically dependent side information Y, is available only at the decoder and let X be a source that is to be transmitted using least average number of bits. The encoder must therefore encode X in the absence of Y, where as the decoder jointly decodes X using Y. In this context we compress X to syndrome S of channel code (Pradhan and Ramachandran, 1999). These syndromes identify the coset to which X belongs to. The receiver on receiving the syndromes S identifies the code word from the corresponding coset that is close to the side information Y.

3 Proposed Schemes

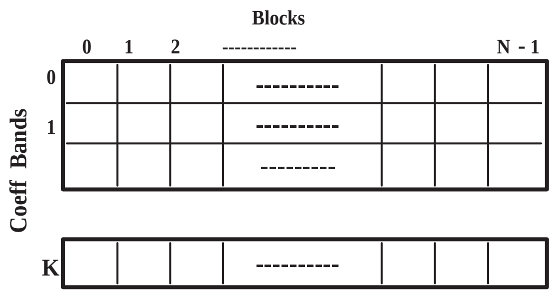
3.1 Syndrome Coding with multilevel coset coding of individual coefficients(DVC Method 1)

3.1.1 Encoder

The encoder block diagram of the current implementation is as shown in the Figure 3. The first frame is coded as the intra frame. Each of the consecutive frames are intercoded. An intra frame is introduced after an interval of $i(15 or 30)$ frames.

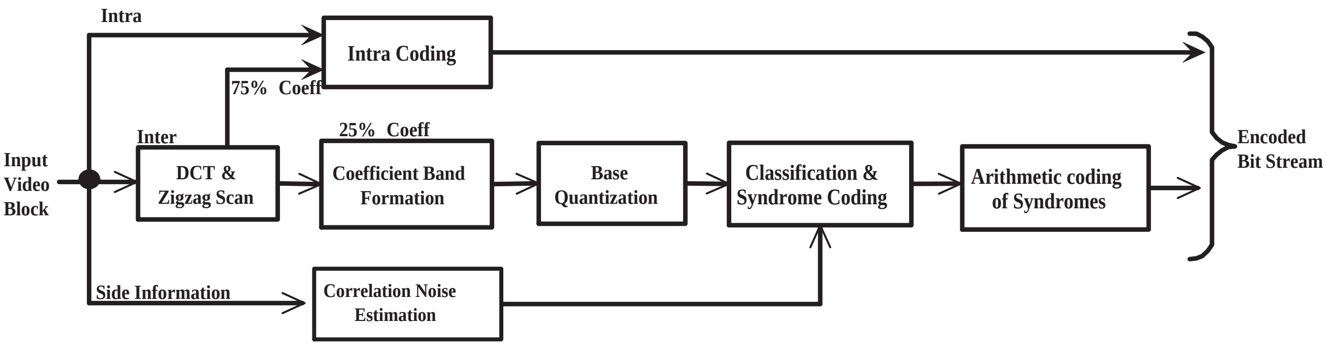
Intracoding: Each 8X8 block of the frame is transformed using Discrete Cosine Transform and then these coefficients are zig zag scanned. These coefficients are then quantized and entropy coded using Huffman and run length coding.

Figure 4 Coefficient Bands for each Frame



Intercoding: Block DCT of 8X8 is applied to each block in the frame that is to be intercoded. The transformed coefficients are zig zag scanned so that they are arranged in the order of their importance. These transformed coefficients are then formed into coefficient bands as shown in Figure 4. Each coefficient at the same spatial location within a block are combined together in one coefficient band. Coefficient band *coeffBand0* corresponds to all DC coefficients and hence is very significant. Around $1/4$ of the coefficients in a block are chosen for intercoding and hence number of bands is limited to 16 in a block of size $8X8$. The remaining $3/4$ th of the coefficients are less important and hence can be quantized and entropy coded like intra blocks. These coefficients are insignificant and hence contribute less to the compression performance. Each of the coefficient bands is assigned

Figure 3 Video Encoder



different number of bits for quantization. More number of bits are assigned to higher bands and less number of bits to lower bands. Proper decoding of the syndrome coded bits requires that the band step size is greater than the correlation noise. The bit allocation for each band is chosen based on the average of the correlation noise between each band and the corresponding coefficient band of the side information, such that the above criteria is fulfilled. Each of these coefficient bands are uniformly quantized with reference to the bits allocated for each band.

Classification and Syndrome Generation: Syndrome generation is based on the principle of multilevel coset code proposed in (Puri et al., 2007). Syndrome for each quantized coefficient is generated based on the correlation noise between the source and the side information. In this case syndrome corresponds to the bits that cannot be inferred from the best side information. The Figure 5 shows the quantization bin (Puri et al., 2007), where X_i represents the source, X_{q_i} quantized value of the source, Y_i represents side information, $\triangle$ represents the stepsize of the corresponding band. The N_i represents the correlation noise, given by $N_i = X_{q_i} - Y_i$. In the presence of side information Y_i the number of least significant bits that needs to be communicated to the encoder is given by

$$l_i = 2 + \lfloor log_2(\frac{|(N_i)|}{\triangle})\rfloor; N_i > \triangle \tag{6}$$

$$l_i = 0; else \tag{7}$$

The syndrome bits that is to be communicated to the decoder can be obtained by

$$S_i = X_{q_i} \& (2^{l_i} - 1) \tag{8}$$

where & represents bitwise AND operation.

The number of least significant bits l_i, for each coefficient should also be sent along with these bits. Hence for each coefficient the value l_i and l_i number of least significant bits are mapped to a unique symbol

$$S_{t_i} = 2^{l_i} + S_i \tag{9}$$

where $+$ denotes bitwise OR operation.

Transmitting syndrome bits is equivalent to dividing the quantization lattice into sub lattices as shown in the Figure 5 up to the level specified by l_i.

Figure 5 The quantization bin

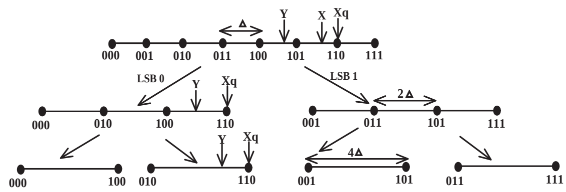
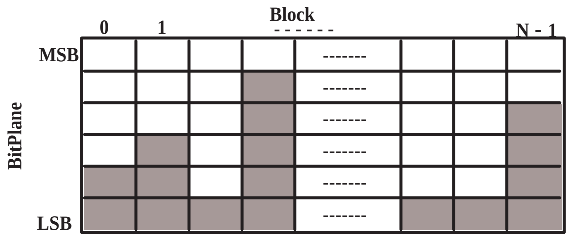


Figure 6 Bit planes marked in gray are transmitted to the decoder where as bit planes in white can be inferred from the side info.

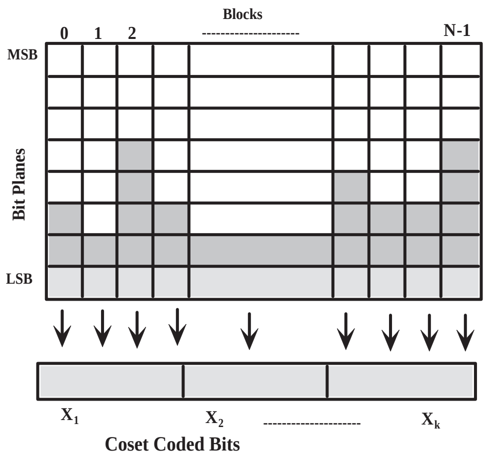


Thus the number of least significant bits that needs to be communicated to decoder is dependent on the correlation noise between the source X and the side information Y. Bit planes marked in gray in Figure 6 are transmitted to the decoder and the bit planes in white can be inferred from the side information. More the correlation noise, more number of bits are to be transmitted to the decoder. This corresponds to Wyner Ziv coding where in the least significant bits that cannot be obtained from the side information are transmitted to the decoder. The unique symbol S_{t_i} obtained from l_i and S_i is then arithmetic coded and transmitted to the decoder.

Coset Channel Coding using Golay code : The bit rate can be further reduced by coding few bitplanes with respect to a channel code. If high complexity of the decoder is acceptable coset channel coding can be considered.

These bits as shown in Figure 6 cannot be generated by side information and hence are transmitted to the decoder. However this may incur higher bitrate. In order to further reduce the bitrate some of the least significant bitplanes are further compressed based on the principle of distributed source coding (Pradhan and Ramachandran, 1999). Distributed video coding in (Aparna et al., 2009) uses

Figure 7 Bitplanes of a single coefficient Band



LDPC codes for coset channel coding. This gives only a marginal gain in the bitrate with reasonable quality, but at the cost of very high complexity at the decoder. It also needs a very long block length n to give a good performance. In this method (23,12,7) Golay code is used where the block length n is 23 and the message bit length k is 12 and the hamming distance d_{min} between the code words is 7. In this method the parity check matrix H of a (23,12,7) Golay code is used to generate the syndrome bits S_i from the input bits X_i. One or two least significant bitplanes of the syndrome bitplanes can be considered for coset channel coding which are formed into a block of n bits each as shown in Figure 7. Each of the n bits X_i data block is transformed into $n-k$ syndrome bits by using the parity check matrix H according to $S_i = HX_i$. Thus n data bits are compressed to $n-k$ syndrome bits giving a compression rate of $n/n-k$.

Side Information: If a less complex encoder as well as decoder is desirable we consider the co located block of the reference frame as side information. Instead we can generate additional CRC bits on the quantized codewords so that motion search for the side information can be incorporated at the decoder. These CRC bits generated at the encoder are also transmitted as the side information to the decoder which will help in the motion search at the decoder to construct the side information frame required to perform syndrome decoding.

3.1.2 Decoder

The Decoder block diagram is shown in the Figure 8.

IntraDecoding: The frames that are intracoded are passed through an entropy decoder, then dequantized and Inverse transformed to get back the intra coded frame.

Syndrome Decoding and coset channel Decoding: The coefficients that are syndrome coded are first passed through the arithmetic decoder to decode the unique symbol S_{t_i}. From this symbol S_{t_i} the number of least significant bits l_i and the syndrome bits S_i are obtained. At the decoder only the syndrome bits S_i and the side information bits Y_i are available. As long as the hamming distance between X_i and Y_i is less than d_{min} of the Golay code, the data X_i can be recovered. The syndrome bits S_i indicates the coset to which X_i belongs to. The coset leader of that coset is chosen as say A_i. We then find Y_i' such that $Y_i' = Y_i \oplus A_i$ where $\oplus$ is bitwise EXOR operation. We then find X_i' a codeword corresponding to the Golay code closest to Y_i'. The required data bits X_i is then obtained from X_i' as $X_i = X_i' \oplus A_i$. These decoded bits X_i are combined with rest of the multilevel coded bits to reconstruct back the current frame. Side information generation unit provide the best side information Y_i for the current frame. Based on the side information Y_i the rest of the MSBs are retrieved and combined together with the LSBs to form the current frame coefficient band for X. The coefficient bands are uniform dequantized based on the bit allocation set chosen. Rest of the coefficient that are intracoded are further combined with syndrome decoded coefficients and then block IDCT is applied to get back the original frame.

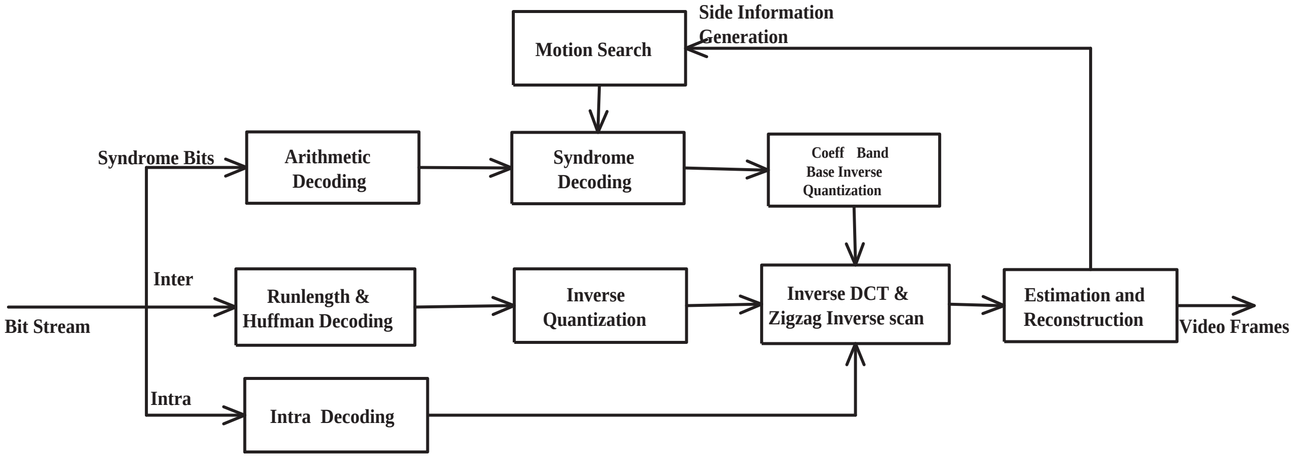
Side information Generation : In case of complex decoder side information is generated by performing the motion search and quantizing the candidate block and computing the CRC. If the CRC generated matches with that transmitted from encoder, that block is considered as side information. These blocks are used as the side information for syndrome decoding.

By using a (n, k) linear channel code, the encoding rate achieved is $(n-k)/n$. In the work (Aparna et al., 2009) the syndrome coding of the inter coefficients was done using $3/4$ or $1/2$ rate LDPC code. It is observed that for a $1/2$ rate LDPC code, the correlation of the sources with the side information should be very high, which other wise would result in high distortion. On the other hand the use of $3/4$ rate LDPC encoder results in less distortion, but the compression achieved is quite low. The other issues with the LDPC code is the parity check matrix H which needs to be generated in real-time or stored at the encoder. This would increase the complexity of the encoder as storing increases the resource requirement and power consumption. Also LDPC codes require long block lengths and high decoding complexity. As we have small block length of data to be coset channel coded, LDPC code seems to be unsuitable for the current implementation. Hence in this work we have considered Golay codes for coset channel coding. The encoder of this method is simple, satisfying the main objective of this work. However decoding the Golay coded bits increases the complexity of the decoder but is much less than that of LDPC codes. Also quality of the reconstructed sequence is quite well with Golay codes for a $1/2$ rate encoder.

3.2 Syndrome Generation with multilevel coding with coarse motion search for side information(DVC Method 2)

In this method an improvement to the above explained method is proposed. In this method a coarse motion search is performed at the encoder, position of which will be transmitted to the decoder as an additional helper information. In conventional motion-compensated video coding system, every block X at the encoder is encoded with reference to a best matching block Y in the reference frame. This best predictor block Y serves as the side information for X. The best predictor Y is found by performing an exhaustive motion search at the encoder. In distributed video coding,

Figure 8 Video Decoder

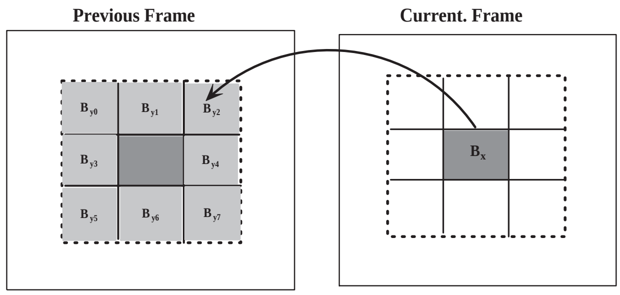


the encoder encodes the current block X using the syndrome coding method assuming that the best side information or the best predictor Y is available at the decoder. Side information has a significant influence on the rate-distortion performance of the system. Better the side information, better is the quality of the reconstructed signal for a fixed bitrate. In DVC environment, side information is obtained by performing an extensive motion search at the decoder. However the only data available at the decoder is the reference frame and wyner-ziv coded bits, using which side information should be constructed. In order to assist the decoder in finding the best side information, additional helper information is transmitted. In the previous method explained in section 3.1, CRC bits of sufficient strength are generated and transmitted to the decoder. At the decoder, for every candidate predictor block, the CRC bits are generated and compared with that of transmitted bits. If this matches, corresponding block will be considered as the side information. However this increases the complexity of the decoder as an exhaustive search has to be performed till the CRC matched block is found. In order to reduce this complexity at the decoder, a coarse motion search is performed at the encoder on few fixed number of blocks. This serves as an additional helper information that implies the direction in which the motion search is to be performed at the decoder. Experimentally it has been observed that, with this additional information, the best predictor block can be found quickly.

3.2.1 Encoder

Most of the basic blocks are similar to that explained in section 3.1.1. An additional coarse motion search block is included at the encoder. This considers a block Bx_i in the current frame which has to be coded with reference to the side information in the reference frame as shown in the Figure 9. Instead of considering the co-located block in the previous frame, this method performs a very coarse motion search. For a block Bx_i of size 8x8 a window of size 16x16 is considered in the reference frame. Within this window, p

Figure 9 Reference Frame and the Current Frame



blocks (8 in our case) at different fixed locations as shown in Figure 9 are considered and compared with the block Bx_i in terms of maximum absolute difference (MAD). The block which results in least MAD is considered as the side information block By_i The position of the side information block is encoded with additional $\log_2 p$ bits for every block Bx_i. Further coding of the block Bx_i is done as in previous method. Increasing the number of reference blocks improves the efficiency but also increases the complexity. Also more bits have to transmitted to code its position. Hence an ideal number of reference blocks is to be considered in order to maintain an complexity-performance tradeoff.

3.2.2 Decoder

Most of the basic blocks of the decoder are similar to that explained in section 3.1.2. The only change seen is in the side information generation unit, which in this case considers the additional bits transmitted at the encoder. Using these bits, the direction of motion search is fixed and the candidate predictors around that block are considered. For each of the candidate predictor block, DCT is applied and quantized and the CRC bits are generated. This is compared with the transmitted bits and if it matches, the corresponding block is considered as the side information block By_i. This block By_i is further considered for syndrome decoding Bx_i as explained in section 3.1.2.

In this method, coarse motion estimation is performed at the encoder which don't increase the complexity considerably. But by performing a search for better side information the correlation noise N_i between Bx_i and By_i is reduced considerably thus improving the bitrate without compromising on the quality. This method can be combined with coset channel coding further improving the bitrate but at the expense of increased complexity.

4 Simulation Results

Video Codec is designed for a single camera scenario which is an application to wireless network of video camera equipped with cell phones. Encoder allows the storage of one previous frame. Objective performance evaluation of the system is done by comparing the bit rate and the Peak Signal to Noise Ratio (PSNR) between the original and the reconstructed video sequence. The DVC method 1 performs syndrome coding with Golay codes and DVC method 2 has an additional hash information transmitted that improves the quality of side information. These two methods are implemented and some preliminary simulation results are presented in this paper. Four test video QCIF sequences with a resolution of 176x144 are considered for evaluating the rate distortion. These video files are considered based on their motion content. It is seen that *container.qcif* has least motion content when compared to all the other files where as *football.qcif* has highest motion content, *foreman.qcif* and *news.qcif* have moderate motion content. The Luma PSNR is computed for various bit rates for all the files as shown in the Table 1. The performance of the two Distributed video coding methods discussed in this paper are compared with the H.263 + Intra (Cote et al., 1998), H.264/AVC Intra (Wiegand et al., 2003), syndrome coding with LDPC codes (Aparna et al., 2009) and H.263 + Inter coding standards (Cote et al., 1998) at frame rate of 30fps. The H.264/AVC Intra coder is the H.264/AVC coder (JM 16.0 reference software (JMCoder, 2009)) in the intra mode of operation without exploiting temporal redundancies, but with a very efficient spatial redundancy reduction technique. For a specific condition it is observed from Table 1, that H.263 + Inter gives good rate distortion performance for all the files except *football* and *foreman*. This is because *football* video sequence has high motion content (less correlation) which the predictive coder cannot efficiently code. From the simulation results we can see that both the DVC implementations perform considerably well for video sequences with higher motion content i.e foreman and football. For video sequences with less motion content (i.e more correlation between adjacent frames) H.263 + Inter coder performs better than DVC implementations. However the results of DVC implementations discussed in this paper are consistently better than H.263 + Intracoder and H.264 Intra coder. Also we can see that the DVC method 2 discussed above have at least 1 dB improvement in Luma PSNR than the first method or we can say that the second method gives better compression in terms of bitrate for the same quality. This is due to less correlation noise between the side information and the reference frame to be decoded. Also an improvement of atleast 3dB is seen in the current implementations when compared to the syndrome coding with LDPC codes (Aparna et al., 2009). Encoder complexity for different methods is also compared in this paper in terms of encoding time in seconds. The encoding time is highly dependent on hardware and software platforms used. For the results presented, simulation is carried out on a x86 machine with Intel core 2 Duo processor at 3 GHz with 2GB of RAM. As seen from the Table 4, DVC methods have considerably low encoding time when compared to H.263+ Inter coder (Cote et al., 1998) and H.264/AVC Intra coder. However the encoding time of DVC 1 is close to that of H.263+ Intra and that of DVC 2 is slightly higher than H.263+ Intra. But the rate distortion performance of H.263+ Intra coder is inferior to the DVC coder which is also to be considered.

5 Conclusion

Distributed Video coding is a new coding paradigm that exploits the source statistics at the decoder thus making encoder simple. Video codec so developed introduces the concept of channel coding in to the problem of source coding with side information. Distributed codec is more robust due to the absence of prediction loop in the encoder. Currently the distributed video coder performs better than H.263+ and H.264 Intra coders. By proper modeling of correlation structure of source and the side information for video we can achieve better compression performance with better quality of reconstructed video sequence. However the main aim of distributed video coding scheme is to reduce encoder complexity to conform uplink friendly applications, which seems to be satisfied. Distributed codec is more robust to packet loss due to the absence of prediction loop in the encoder. Use of simple block codes such as Golay code will improve the rate-distortion performance further without increasing the encoder complexity. Use of LDPC codes for coset channel coding as in (Aparna et al., 2009) is eliminated as it increases decoder complexity and the requirement of resources at the encoder without contributing much to the rate distortion performance. Second method improves the correlation between the reference data and the side information thus improving the bitrate for the same quality. The extension to lower bit rates without any compromise in the quality without increasing the complexity can be further considered so that it is comparable with the conventional codecs.

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Table 1 Comparison of rate-distortion performance of all the QCIF files with the resolution of 176x144 for a frame rate of 30fps

File	Bitrate (Kbps)	Luma PSNR (dB) for different Methods					
		H.263+ Intra	H.264 Intra	Syndrome coding with LDPC codes	DVC Method 1	DVC Method 2	H.263+ Inter
container	220	28.72	29.47	29.03	34.47	34.91	37.83
	280	30.16	30.94	30.41	35.92	36.20	39.06
News	250	28.44	29.93	30.04	32.29	34.10	36.89
	320	29.06	30.68	30.95	33.91	35.72	39.47
Foreman	290	29.56	30.98	31.16	33.14	35.05	34.65
	360	30.65	32.37	32.84	35.30	36.91	35.51
Football	380	26.07	26.22	28.09	29.52	30.64	25.24
	480	26.81	27.33	28.76	30.93	31.29	25.60

Table 2 Encoding Complexity measured in terms of encoding time for all the QCIF files, for 60 frames with the resolution of 176x144 for a frame rate of 30fps

File	Encoding Time (sec) for different Methods					
	H.263+ Intra	H.264 Intra	Syndrome coding with LDPC codes	DVC Method 1	DVC Method 2	H.263+ Inter
container	3	76	4	3	5	17
News	3	80	4	2	5	18
Foreman	2	76	3	2	5	18
Football	2	91	4	3	6	46

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