Wavelet Video with Unequal Error Protection Codes in W-CDMA System and Fading Channels

MINH HUNG LE and RANJITH LIYANA-PATHIRANA
School of Engineering and Industrial Design
College of Science, Technology and Environment
University of Western Sydney
Second Avenue, Kingswood, 2747, N.S.W.
AUSTRALIA

Abstract: - Wavelet-based algorithm for video compression with unequal error protection (UEP) codes in wide-band code division multiple access (W-CDMA) system over additive white Gaussian noise (AWGN) and Rayleigh fading channels are analysed. The utilization of Wavelets has come out to be a powerful method for compress video sequence. The wavelet transform compression technique has shown to be more appropriate to high quality video applications, producing better quality output for the compressed frames of video. A spatially scalable video coding framework of MPEG2 in which motion correspondences between successive video frames are exploited in the wavelet transform domain. The basic motivation for our coder is that motion fields are typically smooth that can be efficiently captured through a multiresolutional framework. Wavelet decomposition is applied to video frames and the coefficients at each level are predicted from the coarser level through backward motion compensation. The proposed algorithms of the embedded zero-tree wavelet (EZW) coder and the 2-D wavelet packet transform (2-D WPT) are evaluated.

Key-Words: - Video sequence, Unequal error protection codes, Embedded zero-tree wavelet transform, 2-D wavelet packet transform, W-CDMA, AWGN, Rayleigh fading channels.

1 Introduction

The wavelet functions are developed for harmonic analysis, signal representation, speech and video bandwidth compression, multiresolution signal processing, and signal design in various coding and communication applications. The wavelets in commercial applications were mainly with efficient compression techniques on signals such as voice and video. This was due to the logarithmic-scale decomposition in frequency, which fits naturally in many of the sound and video sequence reconstruction studies. Wavelet theory covers quite a large area. It treats both the continuous and discrete time cases. The introduction of the embedded zero-tree concept for wavelet-based video compression has generated a significant improvement in performance compared to previous video coding methods. A refinement of the EZW approach, called set partitioning into hierarchical trees (SPIHT) by Said and Pearlman, is the most well known EZW derivative. While SPIHT enjoys a good rate-distortion performance for video sequences with comparatively low complexity, it is quite fragile against bit errors in noisy communication channels. Direct sequence signal acquisition in W-CDMA environment is estimated. A digital matched filter is presented and investigated for direct sequence spread-spectrum systems [1].

The coding scheme presents four levels of error protection for different sets of bits in a transmitted symbol using W-CDMA system over AWGN and Rayleigh fading channels. The proposed scheme accomplishes unequal error protection by encoding the data according to the significance of the information and switching between four codes. The scheme uses the different pseudo-noise codes of digital matched filter synchronizer to make up four levels of unequal error protection codes. It was shown that four levels of different error protections were easily accomplished with the digital matched filter pseudo-noise code synchronizer systems over AWGN and Rayleigh fading channels by providing the coded detection at the receiver. The scheme provides the capability of multi-level error protection without complexity as compared to regular digital matched filter pseudo-noise code schemes. Wavelet video with UEP codes in W-CDMA system obtains smaller PSNR than wavelet video with UEP codes for wideband MC-CDMA and Rake receiver. However, it requires less complex design and less cost of acquisition [2].

2 Wavelet Video Transmission with UEP Codes in W-CDMA System over AWGN and Rayleigh Fading Channels

The four levels of unequal error protection codes with wavelet video transmission in W-CDMA system over AWGN and Rayleigh fading channels are analyzed. Figure 1 illustrates the block diagram of wavelet video transmission with UEP codes in W-CDMA system over AWGN and Rayleigh fading channels Encoder. Figure 2 shows the block diagram of wavelet video transmission with UEP codes in W-CDMA system over AWGN and Rayleigh fading channels Decoder.

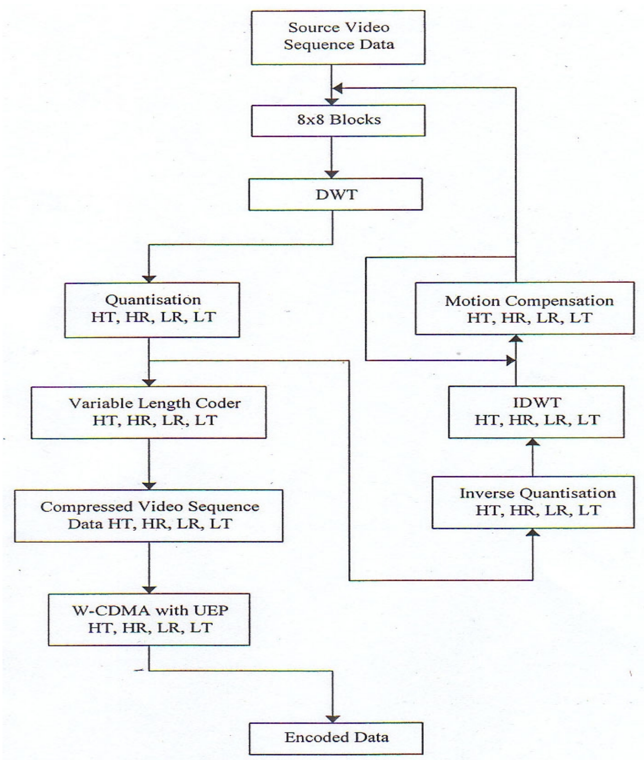


Fig. 1 Block Diagram of Wavelet Video Transmission with UEP Codes in W-CDMA system over AWGN and Rayleigh fading channels Encoder

The discrete wavelet transform is described with the generic signal $g(t)$ that can be represented in terms of translates and dilates typically bandpass of a single prototype wavelet $\beta(t)$.

$$g(t) = \sum_{i,j=-\infty}^{+\infty} \alpha(i,j)\, 2^{-i/2} \beta(2^{-i} t - j) \tag{1}$$

or similarly for some $W>0$

$$g(t) = \sum_{j} \eta(j)\, 2^{-W/2} \theta(2^{-W} t - j) + \sum_{i=-\infty}^{W} \sum_{j} \alpha(i,j)\, 2^{-i/2} \beta(2^{-i} t - j) \tag{2}$$

where

$$\alpha(i,j) = \int_{-\infty}^{+\infty} g(t) 2^{-i/2} \beta(2^{-i} t - j) dt$$

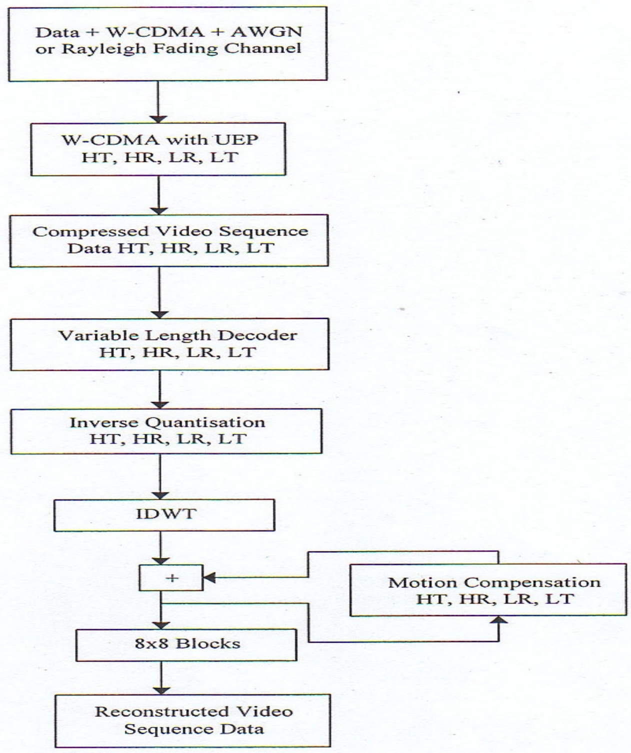


Fig. 2 Block Diagram of Wavelet Video Transmission with UEP Codes in W-CDMA system over AWGN and Rayleigh fading channels Decoder

are detail coefficients of wavelet.

$$\eta(j) = \int_{-\infty}^{+\infty} g(t) 2^{-W/2} \theta(2^{-W} t - j) dt$$

are approximation coefficients or scaling coefficients, and $\theta(t)$ is a low-pass scaling function. The significance is the interpretation of equation (2) as a multiresolution analysis of $g(t)$: i indexes the *scale* or *resolution*, the smaller i the higher the resolution, while j indexes the *spatial* location of analysis. If the mother wavelet is centred at time 0 and frequency f_c, $\alpha(i,j)$ measures the content of around time $2^i j$ and frequency $2^{-i} f_c$, while $\eta(j)$ represents the local mean around time $2^W j$. In this framework, we can think of $g(t)$ as the finest scale (W=0) representation of $g(t)$ itself. The function $\beta(t)$ has to satisfy some critical conditions to ensure that equation (2) holds for any square integrable function $g(t)$. In particular, $\beta(t)$ has to satisfy the two scale equations:

$$\theta(t) = \sqrt{2} \sum_{n} c_o(n) \theta(2t - n) \tag{3}$$

$$\beta(t) = \sqrt{2} \sum_{n} c_1(n) \theta(2t - n) \tag{4}$$

where the coefficients $c_i(n)$ can be nonzero only over a finite number of consecutive values of n. Hence,

$$\beta_{i,j}(t) = 2^{-i/2} \beta(2^{-i} t - j)\,;\; \theta_{i,j}(t) = 2^{-i/2} \theta(2^{-i} t - j)$$

The three orthogonalities constraints require

$$\int \theta_{i,j}(t) \theta_{i,j'}(t)^* dt = \delta(j - j')$$

$$\int \beta_{i,j}(t) \beta_{i',j'}(t)^* dt = \delta(j - j') = \delta(i - i')$$

$$\int \beta_{i,j}(t)\theta_{i',j'}(t)^{*}\,dt = \delta(j-j') = 0$$

The three orthogonalities are satisfied by coefficients $c_i(n)$ those have the following properties:

$$\sum_{n} c_o(n)c_o(n+2k) = \delta(k)$$

$$c_1(n) = (-1)^n c_o(n)$$

where $c_i(n)$ are the coefficients of a perfect reconstruction two-band or dyadic filter bank with the quadrature mirror reconstruction property. Therefore, the design of wavelets is equivalent to the design of filter banks. Observe that the conditions imposed up until now are not sufficient to construct in practice useful wavelets. Certainly, they can lead to decompositions with not enough regularity. Regularity is imposed requiring a large number of vanishing moments. In practice, $\eta(j)$ and $\alpha(i,j)$ can be computed recursively from $\alpha(i+1,j)$ using the efficient pyramid algorithm proposed by Mallat [3]. It is not necessary to explicitly compute the shape of $\theta(t)$ and $\beta(t)$. The basic applications of wavelets in this paper stems from a multiresolution decomposition of a time-varying multipath response of the form $\tilde{h}(t,\tau)$ at any τ with respect to t are:

$$\tilde{h}(t,\tau) = \sum_{j} \eta(j,\tau)2^{-W/2}\theta(2^{-W}t-j) + \sum_{i=-\infty}^{W}\sum_{j} \alpha(i,j,\tau)2^{-i/2}\beta(2^{-i}t-j) \qquad (5)$$

where $\alpha(i,j,\tau)$ are wavelet coefficients and $\eta(j,\tau)$ are scaling coefficients. If the channel is modelled as deterministic, wavelet and scaling coefficients are considered deterministic, and if the channel is modelled as random, wavelet and scaling coefficients are considered random parameters. The wavelet-based representation will exhibit *global* characteristics of the channel dynamics in the low-resolution coefficients, while retaining *local* rapid transitions in just a few coefficients at higher resolutions. A practical advantage is that the decomposition decouples the variations in time and relegates them in $\beta(t)$ and $\theta(t)$, so that the wavelets coefficients are indeed time invariant for any τ. Subsequently, we will assume discretized responses with resolvable multipath components of the form $\tilde{h}(t,\tau) = \sum_{i=1}^{Q} g_i(t)\delta(\tau-\tau_i)$ [3].

2.1 Embedded Zero-Tree Wavelet Coding

Embedded zero-tree wavelet algorithm exploits the important hypothesis. After the embedded zero-tree wavelet transform of a video sequence, the important data is concentrated in the upper left corner that corresponds to the low frequency range of the wavelet coefficients. The remaining data in the high frequency domain is not as significant. A wavelet coefficient tree is defined as the set of coefficients from different bands that represent the same spatial region in the video sequence. A wavelet video sequence representation can be thought as a tree structured spatial set of coefficients [1]. Figure 3 illustrates three levels wavelet decomposition of the video sequence. The lowest frequency band of the decomposition is represented by the root nodes (top left) of the tree (LL_3), the highest frequency bands by the leaf nodes (bottom right) of the tree, and each parent node represents a lower frequency component than its children. Except for a root node, which has only three children nodes, each parent node has four children nodes, the 2x2 region of the same spatial location in the immediately higher frequency band [4].

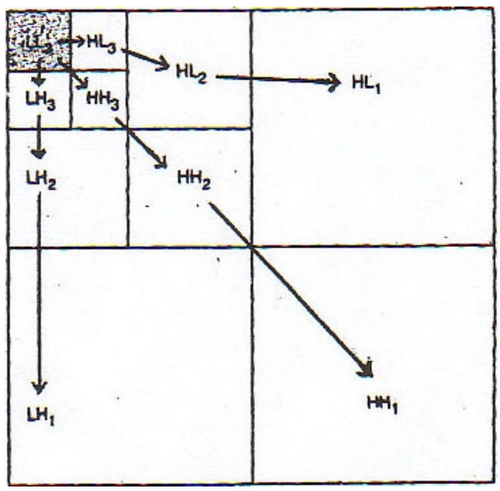


Fig. 3 Three Levels Wavelet Decomposition

2.2 Two-Dimensional Wavelet Packet Transform

Two-dimensional wavelet packet transform of video sequence is composed of low frequency components and high frequency components. Low frequency components give a video sequence its foundation, or character, while high frequency components give a video sequence it is fine details or nuances. Figure 4 illustrates the wavelet decomposition of the two-dimensional wavelet packet transform for the video sequence. The output from the low pass filter produces and approximation of the signal based on the low frequency detail coefficients. The output from the high pass filter produces the fine details of the video sequence, that when put together will form the original video sequence. However, these values are down-sampled. This means that the output of either filter has every second coefficient dropped. This effectively halves the number of coefficients from each filter. Nevertheless, at the reconstruction side, this can produce some distortion, but if the filters are chosen carefully then perfect reconstruction can occur. One of the aspects that make wavelets so suited to video coding is that the filtering process can be iterated repeatedly, allowing us to break up a video sequence into various lower resolution versions or multilevel decomposition. Typically, the way in which this is conducted is by filtering the output of the Low Frequency Decomposing Filter with the same wavelet function. The low frequency coefficients of this output may again be filtered, extracting more information and so on. Now, because there is a down sampling routine done after each filtering process, the theoretical limit that stops us from iterating is until we reach one discrete wavelet transform coefficient. In general, the more levels of decomposition we have, the better the compression, although loss of quality [2].

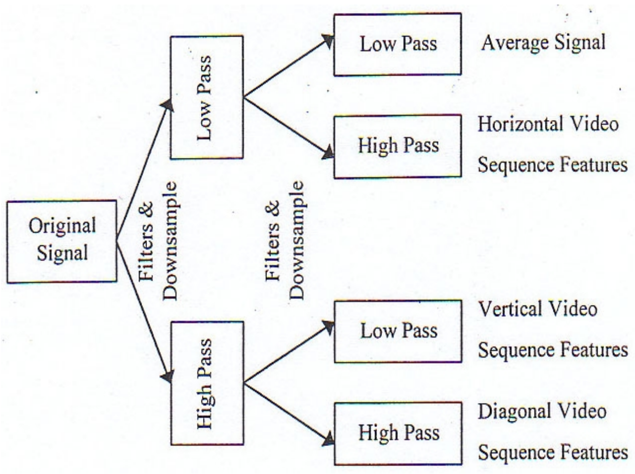


Fig. 4 Wavelet Decomposition of the 2-D Wavelet Packet Transform for the Video Sequence

3 Experimental Results

The QCIF video sequences with compression rate of 0.312 bits/pixel are examined. The W-CDMA system obtains a bandwidth of 5MHz and will also be in many indoor achievements. The various sections of a compressed video sequence obtain different importance and error sensitivity. The W-CDMA system over AWGN and Rayleigh fading channels with unequal error protection codes are considered with four levels of significance for operating with data stream of information. The proposed scheme accomplishes unequal error protection by encoding the data according to the significance of the information and dividing into four codes. The coding scheme introduces four levels of error protection for different sets of bits in a transmitted symbol functioning W-CDMA system over AWGN and Rayleigh fading channels. The proposed scheme applies the different pseudo-noise codes of digital matched filter synchronizer to construct four levels of unequal error protection codes. The functioning estimation of four unequal error protection codes with W-CDMA system over AWGN and Rayleigh fading channels are evaluated.

For the Embedded Zero-Tree Wavelet Coding, the four levels of unequal error protection codes with four significant levels of unequal error protection codes are proposed for this digital matched filter pseudo-noise code synchronizer scheme. From figure 3, the first level or the LL_3 is the lowest error protection level with no encoding. The second level or the HL_3, LH_3, HH_3 is the lower error protection level with easiest level of digital matched filter pseudo-noise code synchronizer. The third level or the HL_2, LH_2, HH_2 is the higher error protection level with easier level of digital matched filter pseudo-noise code synchronizer. The fourth level or the HL_1, LH_1, HH_1 is the highest error protection level with harder level of digital matched filter pseudo-noise code synchronizer.

For the 2-D Wavelet Packet Transform, the four levels of unequal error protection codes with four different levels of unequal error protection codes are designed for this digital matched filter pseudo-noise code synchronizer scheme. Figure 4 illustrates the Wavelet Decomposition of the 2-D Wavelet Packet Transform for the video sequence. The first level or the average signal is the lowest error protection level with easiest level of digital matched filter pseudo-noise code synchronizer. The second level or the horizontal video sequence features is the lower error protection level with easier level of digital matched filter pseudo-noise code synchronizer. The third level or the vertical video sequence features is the higher error protection level with harder level of digital matched filter pseudo-noise code synchronizer. The fourth level or the diagonal video sequence features is the highest error protection level with hardest level of digital matched filter pseudo-noise code synchronizer.

Matlab programs are written to simulate the outcomes of the four levels of UEP codes with wavelet video compression in W-CDMA system over AWGN and Rayleigh fading channels. The peak signal to noise ratio is calculated. The objective video sequence quality has been evaluated using peak signal to noise ratio, which is defined as follows:

$$PSNR = 10 \times \log_{10}\left(\frac{(PeakSignal\ Value)^2}{MeanSquare\ Error}\right) \qquad (6)$$

where, *Peak Signal Value=255 for an 8 bits/pixel video sequence.*

$$MeanSquareError = \frac{1}{(N \times N)}\sum_{ij}(x_{ij} - y_{ij})^2 \qquad (7)$$

x_{ij}-y_{ij}=*value of pixel (i,j) in the original and reconstructed video sequences respectively.*
NxN=number of pixels in the video sequence.

The table of outcomes of tested Miss America sequences is tabulated in the table 1.

Miss America Sequences in QCIF with Compression rate of 0.312 (bits/pixel)	PSNR (dB) of Four levels UEP for EZWT	PSNR (dB) of Four levels UEP for 2-D WPT
W-CDMA System over AWGN channels	11	10
W-CDMA System over Rayleigh fading channels	32	31

Table 1: Outcomes of tested Miss America sequences

The original tested video sequences of Miss America in QCIF (176x144) are illustrated in figure 5.

Fig. 5 (a)

Fig. 5 (b)

Fig. 5 (c)

Fig. 5 (d)

Fig. 5 The original Miss America sequence in QCIF (a) Frame number 0 (b) Frame number 20 (c) Frame number 45 (d) Frame number 80

The results of Miss America sequences in QCIF (176x144) are illustrated in figure 6, figure 7, figure 8 and figure 9.

Fig. 6 (a)

Fig. 6 (b)

Fig. 6 (c)

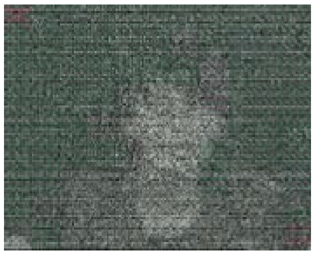


Fig. 6 (d)

Fig. 6 The reconstructed Miss America sequence with Four levels of Embedded Zerotree Wavelet transform in W-CDMA system over AWGN channels; PSNR=11 dB (a) Frame number 0 (b) Frame number 20 (c) Frame number 45 (d) Frame number 80

Fig. 7 (a)

Fig. 7 (b)

Fig. 7 (c)

Fig. 7 (d)

Fig. 7 The reconstructed Miss America sequence with Four levels of Embedded Zerotree Wavelet transform in W-CDMA system over Rayleigh fading channels; PSNR=32 dB (a) Frame number 0 (b) Frame number 20 (c) Frame number 45 (d) Frame number 80

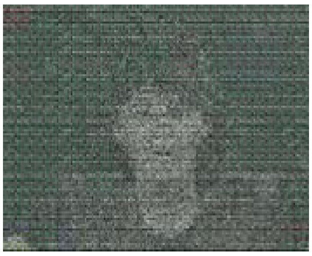
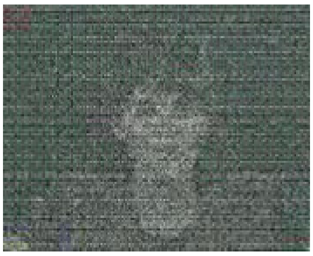


Fig. 8 (a) Fig. 8 (b)



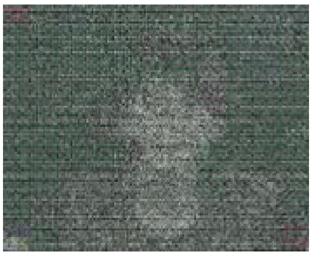


Fig. 8 (c) Fig. 8 (d)

Fig. 8 The reconstructed Miss America sequence with Four levels of 2-D Wavelet Packet Transform in W-CDMA system over AWGN channels; PSNR=10 dB (a) Frame number 0 (b) Frame number 20 (c) Frame number 45 (d) Frame number 80

Fig. 9 (a) Fig. 9 (b)

Fig. 9 (c) Fig. 9 (d)

Fig. 9 The reconstructed Miss America sequence with Four levels of 2-D Wavelet Packet Transform in W-CDMA system over Rayleigh fading channels; PSNR=31 dB (a) Frame number 0 (b) Frame number 20 (c) Frame number 45 (d) Frame number 80

4 Conclusion

Wavelet video compression with four levels of UEP codes in W-CDMA system over AWGN and Rayleigh fading channels are performed and evaluated. The proposed scheme achieves unequal error protection by encoding the data according to the importance of the information and dividing into four codes. The coding scheme establishes four levels of error protection for various sets of bits in a transmitted symbol with W-CDMA system over AWGN and Rayleigh fading channels. The scheme operates the different pseudo-noise codes of digital matched filter synchronizer to create four levels of unequal error protection codes. Wavelet video compression with four levels of UEP codes in W-CDMA system over AWGN and Rayleigh fading channels are functioned to increase the video sequences pre-eminence. EZW transform coding in four levels of UEP codes with W-CDMA system over AWGN and Rayleigh fading channels has advantages compared to 2-D WPT coding in four levels of UEP codes with W-CDMA system over AWGN and Rayleigh fading channels. The Rayleigh fading channels achieve higher PSNR than the AWGN channels. The qualities of QCIF video sequences improve with the progressive increase of the PSNR. The scheme demonstrates design flexibility so that it is easily modified to accommodate different needs for error protection in various data transmission systems.

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