Image Transmission using DWT Technique Over OFDM System

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Abstract t- **In an OFDM system, due to channel fading, only a subset of carriers is usable for successful data transmission. With the help ofthe channel state information at the transmitter, it is possible to take a pro-active decision of mapping the description optimally onto the good subcarriers and discard it at the transmitter itself.**

In this paper, an image frame is compressed using DWT and the compressed data are mapped onto the OFDM system. Here, we have taken into consideration the one-bit channel state information that is available at the transmitter, informing whether the sub-channels are good or bad. In the case of a good sub-channel, the instantaneous received power should be greater than threshold P_{th}. Otherwise; the lesser data values are discarded. By using MATLAB simulation, we can analysis the performance of our proposed scheme, in terms of energy saving where the received quality is in terms of peak signal to noise ratio.

Key Words: DWT-OFDM System, Fading channel, Energy saving.

I. INTRODUCTION

Wavelet transform has recently emerged as a strong candidate for Digital Communication [1]. DWT is a technique to transform image pixels into wavelets. Using a Wavelet transform, the wavelet compress methods are sufficient for representing transients, such as the percussion sounds in audio or high frequency components into a two-dimensional image. In signal processing, wavelets make it possible to recover weak signal from noise.

In DWT, the most prominent information in the signal appears in high amplitude and the less prominent information appears in low amplitude. Data Compression can be achieved by discarding these low amplitudes. With the help of wavelet transform, high compression ratio with good quality of upgrading is obtained. In recent times, the wavelet transforms have been chosen for the JPEG2000 compression standard.

JPEG2000 [2] is a wavelet-based image compression standard. It was proposed by the ISO JPEG committee in the year 2000 with the intention of replacing their original DCT-based JPEG standard. The preliminary study on discrete wavelet –based image compression (using JPEG 2000) says that the wavelet transform step consumes more than 60% of the CPU time during image compression process. By optimizing algorithmic features of the transform step, performance and energy requirements of the entire image compression process can be significantly improved. For this reason, we target the wavelet transform step to minimize the energy consumption.

Orthogonal Frequency Division Multiplexing (OFDM) [3] is a multi-carrier modulation technique over wireless channels. It is always desired to increase the data rate over wireless channels. But, high data rate communication is significantly limited by Inter Symbol Interference (ISI). Multi-carrier modulation is used for such channels to mitigate the effect of ISI. The OFDM provides an opportunity, where a single data stream is transmitted over a number of lower rate subcarriers. It is used to exploit the diversity in frequency domain by providing a number of subcarriers, which can work as several channels for applications having multiple bit streams. In an OFDM system the sub-channels overlap with each other to a certain extent which leads to the reduced use of bandwidth and since these carriers are orthogonal to each other and the Inter carrier Interference (ICI) is also reduced [4]. The input data sequence is mapped into symbols, which are disseminated and sent over the N parallel sub-channels, one symbols per channel. To permit dense packing and still guarantee that a minimum of interference between the sub-channels is encountered, the carrier frequency must be chosen carefully. In our paper, we generate the four co-efficient using DWT and those are mapped onto OFDM sub-channel versus discarding the ones that are mapped onto the bad channels. Our result shows that, up to 60% energy saving is possible at the low fading margin in the quality PSNR of the received image.

This paper is structured as follows: The system model is given in section II, formulation and analysis is in section III, performance and analysis is in section IV and finally conclusion is in section V.

II. SYSTEM MODEL

The system model will explain about the DWT-OFDM system process in the following four sessions. In our model, an image frame is compressed using DWT and those data are mapped onto the OFDM sub-channels. Using the channel state information, it will check each bit individually either good or bad by assigning the threshold value P_{th}. For a good sub-channel, the P_{th} value should be greater. Otherwise; the less power data will be discarded at the transmitter. Thus the power saving is achieved in image transmission.

A. DWT System

This section discusses the conventional DWT system [5]. Discrete wavelet Transform (DWT) transforms a discrete time signal to a discrete wavelet illustration.

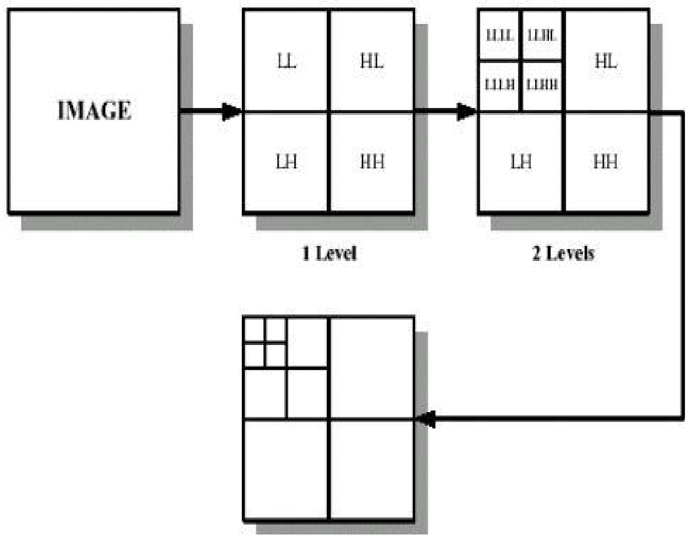

Fig.1 Flow of Discrete Wavelet Transform Process

It transforms an input series x_0, x_1, x_m into one high-pass wavelet co-efficient series and one low-pass wavelet co-efficient series (of length n/2 each) is given by:

$$H_i = \sum_{m=0}^{k-1} X_{2i-m} \cdot s_m(z)$$

$$L_i = \sum_{m=0}^{k-1} X_{2i-m} \cdot t_m(z)$$

Where, $s_m(z)$, $t_m(z)$ are wavelet filter, k:the length of mesh and i=0….[N/2]-1.

A step of wavelet transform decomposes an image into four parts: HH, HL, LH and LL as shown in Fig(1). LL is low frequency coefficient; LH is high frequency coefficient horizontally; HL is high frequency coefficient vertically and HH is high frequency coefficient diagonally.

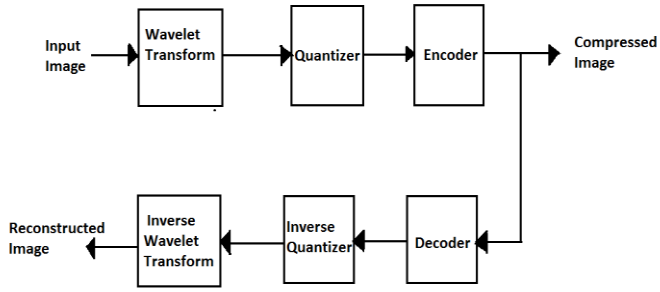

Fig (2) The structure of wavelet transform based compression

The DWT technique [6] first decomposes an image into co-efficient called sub-bands and then the resulting co-efficient are compared with threshold. Co-efficient below the threshold is set to zero. Finally, the co-efficient above the threshold value are encoded with the compression technique.

The steps of the compression algorithm based on DWT for the Fig (2) are described below:

i. Decompose:
Choose a wavelet; choose a level N; compute the wavelet. Decompose the signal at level N.

ii. Threshold detail coefficient:
Designed for each level from 1 to N, a threshold is designated and hard thresholding is applied to the detail coefficient.

iii. Reconstruct:
Compute wavelet re-establishment using the unique approximation co-efficient of level N and the modified detail co-efficient of levels from 1 to N.

B. OFDM System

The data coefficient received from the DWT technique is entered into the OFDM system. The upcoming points will explain about the OFDM system generally as shown in the Fig (3).

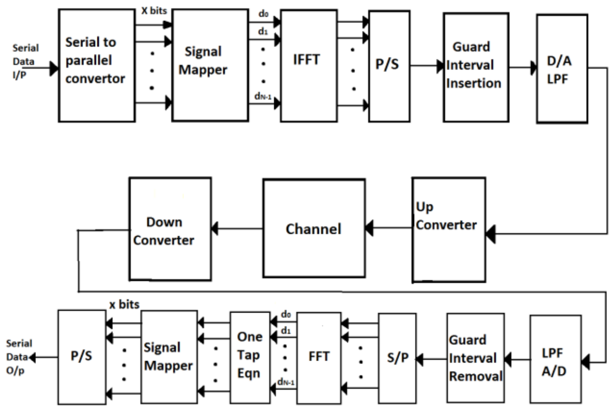

Fig (3) Orthogonal Frequency Division Modulation system

- The inward serial data is first transformed from serial to parallel and assembled into x bits to form a complex number.
- In the top part, those x bits use a digital modulator (i.e. 16 QAM) which is used to map the serial bits named as the signal mapper.
- The complex numbers are modulated in the baseband fashion by the IFFT.
- Then, the signal is up sampled and filtered by LPF coefficient. Since our aim is to have low frequency signals, the modulated signals perform circular convolution with LPF filters whereas the HPF filters also perform the convolution with zero padding signals.
- A guard interval is introducedin the middle of symbols to avoid the ISI caused by multipath distortion.
- To send those data through the channel, the DAC and Up convertor are used in the Fig (3).
- The receiver performs the inverse process of the transmitter. One tap equalizer is used to correct the channel distortion. The blow coefficients of the mesh are considered based on channel information.

C. Mapping on to the OFDM System

The bit streams are packetized by chopping them into vectors of size N-bits, each packet containing four vectors. For each vector, have to add one training bit to estimate the sub-channel at the receiver [7]. For this paper, taking an example of OFDM with IFFT size 128, system has 32 packets are arranged in parallel to get 128 bit streams as shown in Fig (4). Each bit vector in a packet is m-ary modulated, and 32 packets are simultaneously transmitted through different sub-channels set.

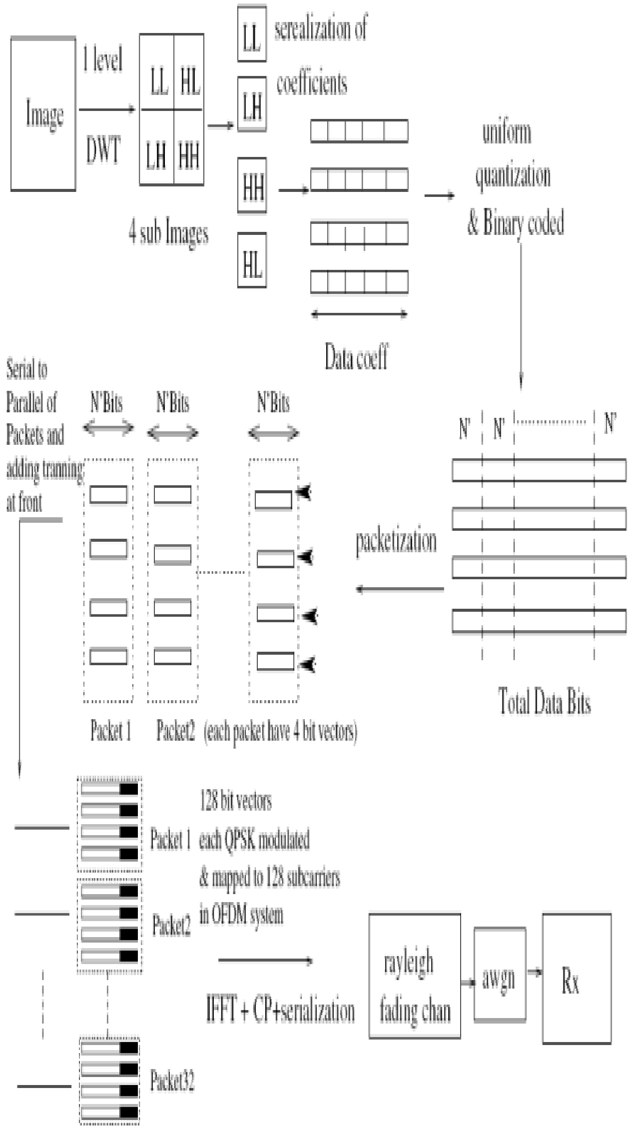

Fig (4) Discrete Wavelet Transform – Orthogonal Frequency Division Modulation system

By the feedback from system decides the sub-channel condition either it is good or bad, and accordingly rearrange the data vectors to map them to the IFFT module. For quality reception and energy saving implement a new mapping scheme. The reverse process is done at the receiver with suitable treatments due to the discarded or lost data vectors.

For intelligent mapping of the data vectors, the sub-channel state considered the good data as '1' and the bad data as '0' by involving comparison with the predefined threshold P_{th}. In our energy saving transmission policy, those data are mapped onto the bad sub-channels and are discarded at the transmitter. At the receiver, to discard a data vector, the receiver should checks if the received power of a data vector is an acceptable threshold P_{th}.

D. Channel model

In this case, we use fading channel model as in [8]. The channel model is illustrated in Fig (5), where M is the coherence bandwidth in terms of number of sub channels. In a block fading environment, M consecutive sub-channels will simultaneously be either good or bad. Each such set consisting M subchannels is called a sub-band. We denote total number of such sub-bands in the OFDM system as N. Thus, the no of sub-channels in the system is N×M. All sub-bands are independently faded with Rayleigh-distributed envelop, which corresponds to the block fading approximation in frequency domain [9]&[10]. Our proposed mapping scheme generates a situation of subcarrier assignment for each data vector in a packet. Exploration of this location is presented in section.

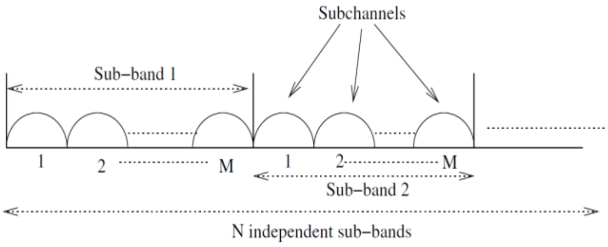

Fig (5) The concept of Block Fading Channel in OFDM system

III. FORMULATION AND ANALYSIS

We now formulate the average distortion and energy savings in our proposed transmission scheme. We measure the system performance by probabilistic analysis of the average distortion in a block fading environment.

A. Distortion involved for various loss events

Let x_1, x_2, x_3, and $x_4$are the data vectors corresponding to the four sub-images from original frame using DWT compression. Also, let $\sigma_{x_1}^2 \sigma_{x_2}^2 \sigma_{x_3}^2$ and $\sigma_{x_4}^2$ are the respective variences. Without any loss of generality, assume that the variance $\sigma_{x_1}^2$ to $\sigma_{x_4}^2$ are in descending order of magnitude.Thus, the corresponding importance levels are also in descending order. These data vectors are mapped over different sub-channels in such a way that only a few specific loss events are possible. The corresponding likelihood of loss events would be: only x_4 is lost; x_3 and x_4 are lost; x_2,x_3, and x_4 are lost; and all x_1,x_2,x_3 and x_4 are lost. Thus, according to our mapping strategy only four combinations of the loss events are possible. The respective distortion associated would be as follows.

The distortion when no data coefficients are lost or discarded is given by:

$$D_{1111} \equiv D_4 = \frac{4\Delta^2}{12},$$

Where Δ is a step size of the quantizer and $\frac{4\Delta^2}{12}$ is the total quantization noise. The distortion when only x_4 is lost or discarded is given by:

$$D_{1110} \equiv D_3 = \sigma_{x_4}^2 + \frac{3\Delta^2}{12}$$

Similarly, the distortion when x_3 and x_4 are lost or discarded is given by:

$$D_{1100} \equiv D_2 = \sigma_{x_3}^2 + \sigma_{x_4}^2 + \frac{2\Delta^2}{12},$$

The distortion when x_2, x_3 and x_4 are lost or discarded is given by:

$$D_{1000} \equiv D_1 = \sigma_{x_2}^2 + \sigma_{x_3}^2 + \sigma_{x_4}^2 + \frac{\Delta^2}{12},$$

And the distortion when x_1,x_2,x_3 and x_4 are lost or discarded is given by:

$$D_{0000} \equiv D_0 = \sigma_{x_1}^2 + \sigma_{x_2}^2 + \sigma_{x_3}^2 + \sigma_{x_4}^2$$

Where D_i = distortion when only i number of data vectors out of the four are received in a packet (i=0, 1, 2, 3, 4). In general, we can write:

$$D_i = \begin{cases} \sum_{i+1}^{\frac{i\Delta^2}{12}\,4} \sigma_x^2 + \frac{i\Delta^2}{12}, \\ if\ i = 4 \qquad b \end{cases} \qquad (1)$$

B. Block Fading Channel Behavior

For Rayleigh fading channel, the received power P is exponentially distributed with probability density function (pdf) given by:

$$f_p(a) = \frac{1}{\bar{P}} \exp\left(-\frac{a}{\bar{P}}\right), \qquad (2)$$

Where $\bar{P}$ the average is received power. If F is the Fading Margin, it is related to the received threshold voltage P_{th} as:

$$F = \frac{\bar{P}}{P_{th}} \qquad (3)$$

Let p be the probability that a sub-band is in deep fade. Using (2), p can be expressed as:

$$p = \int_0^{P_{th}} f_{p(a)}\, da = 1 - \exp\left(-\frac{1}{F}\right) \qquad (4)$$

In our interleaved coefficient mapping scheme all the four sub channels per group of four coefficients are from different sub-bands. Thus, p will also be the probability of the sub channel to be bad. Let P_i=probability associated with the loss event i, for i=0, 1,2,3,4, which produces distortion D_i. Thus, for an arbitrary received packet we can write:

$$P_i = \binom{4}{i} p^{4-i}(1-p)^i \quad (5)$$

Then, the average distortion of the proposed scheme can be written as:

$$\bar{D} = \sum_{i=0}^{4} D_i P_i, \quad (6)$$

where D_i and P_i can be obtained from (1) and (5), respectively.

C. Energy saving measure

In the proposed scheme the less important data vectors are discarded at the transmitter to save power if corresponding sub channel is in fading state. Using (5), we can write energy saving expression as:

$$\%\ energy\ saved = 100 \times \sum_{i=0}^{4} \frac{iP_i}{4} \quad (7)$$

IV. PERFORMANCE ANALYSIS

For simulation performance, we transmitted standard “Lena” image of size 256×256 pixels. By simulating the OFDM system with N×M=128 subcarriers. By using 128 subcarriers, the 32 packets are transmitted simultaneously through the OFDM system. Those 32 packets are distributed in time and frequency domain as described before, but the 4 sub-channels may be in the occurrence of fading. We can simulate the fading channel with number of sub-bands N=4 and the coherence bandwidth equivalent to 32 subcarriers (M=32). The QAM modulation technique is used here. Then, 128×2 bits are passed over to the OFDM channel.

The Conditional distortion is plotted against the loss events given in Fig (6). We can observe the distortion according to the data rate level. Analytically, the obtained distortion measure and percentage of energy saving is given by 6th and 7th equations respectively are plotted against P_{th} in Fig (7), where the analyzed results are supported by simulated values. We can know that, from the figure that the energy saving is also increasing by restricting less important data from transmission through bad sub-channels. It follows that; we can save up to more than 60 percent power.

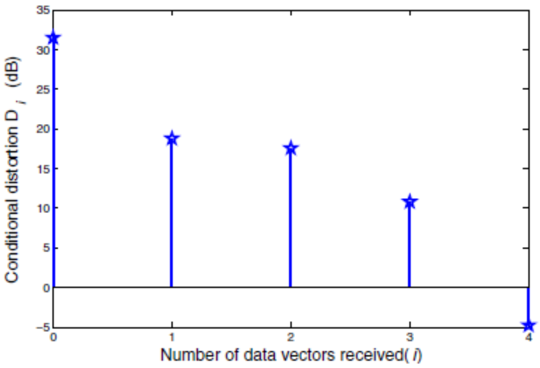

Fig (6) Conditional Distortion for Lena Image

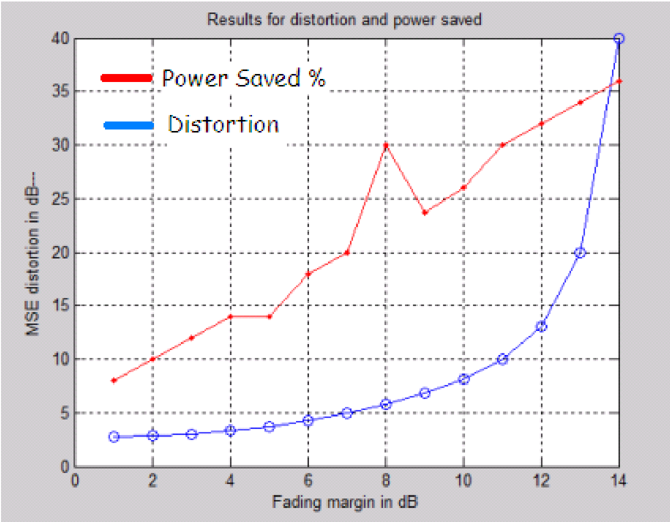

Fig (7).Result for Distortion and power saved.

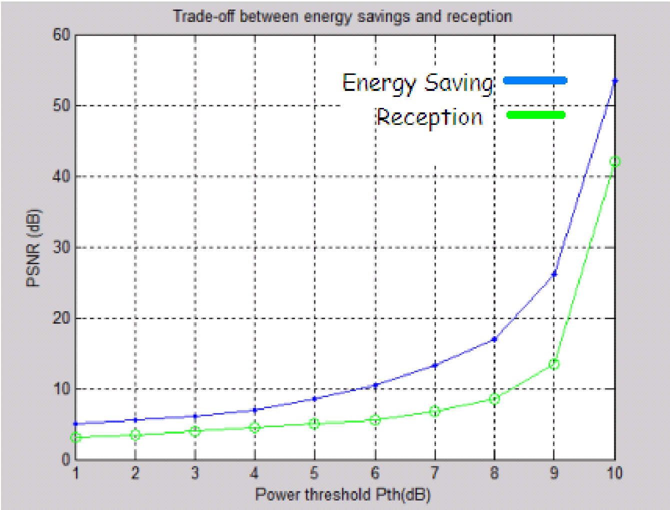

Fig (8) Trade off energy saving and reception

From the Fig (8), the transmission of Lena image through the OFDM provides simulation data in accordance with the PSNR and threshold variation in energy saving level. The receiver rejects a coefficient for which the instantaneous SNR is below an acceptable threshold. As more sub-channels are considered in fading state the quality suffers while providing a higher energy saving. It can be noted that, we restrict the transmission depending upon the instantaneous received power of the sub-channels and a decision is made based on the value P_{th}. Thus, the amount of power saved in between the reception quality and energy saving, as controlled by the parameter P_{th}.

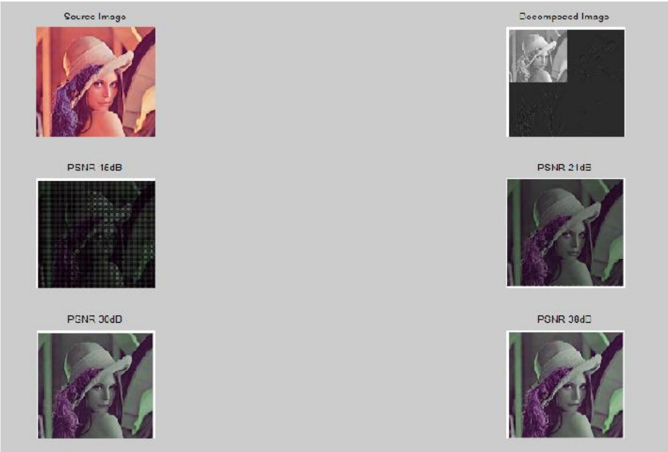

Fig (9) Lena image with different PSNR ratio

The Fig (9) shows the Lena image with different PSNR. Note that, PSNR=15 dB corresponds to the poor image quality. If the PSNR values should increase means, then the image quality will also increase. Consider, PSNR=38 dB, then the image quality will become improves.

V. CONCLUSION

To conclude, this paper presents an energy saving approach in the transmission of the compressed image using the discrete wavelet transformation over the OFDM channel. By assigning the threshold P_{th} voltage levels, the good ones are identified at the transmitter side and those are successfully mapped onto the OFDM system. The coefficient with lower importance levels are discarded at the transmitter level. Our analytic observations on the energy saving performance are seen in the MATLAB simulations in terms of the Peak signal to Noise ratio.

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