Hybrid Compression Algorithm for Wireless Sensor Network

Amr M. Kishk, Nagy W. Messiha, Nawal A. Elfishawy, Abdelrahman A. Elkafs, and Ahmed H. Madian

***Abstract*—Discrete Wavelet Transform (DWT) was developed to improve the performance of data compression. Hybrid Fast Zonal-DCT with DWT is proposed to enhance the image compression during the transmission in WSN. The reduction in power consumption relies on data distribution in the clusters. The performance of the proposed algorithm is monitored by some metrics. The enhancement in image quality and compression ratio is achieved.**

***Index Terms*—DWT compression, zonal-DCT compression, image quality, processing time.**

I. Introduction

Wireless Sensor Network (WSN) is composed of multiple battery-operated nodes .These nodes consist of a Micro - Electro Mechanical System, a low-power Digital Signal Processor, a radio frequency circuit, and a battery [1]. WSN can be used in multiple fields such as :remote monitoring and object-tracking in military applications, temperature measurement of different environments, radiation detection in the nuclear reactors, and wide range of applications in different fields. There are many constraints that should be considered to design sensor nodes to use them in some applications. One of these constraints is energy consumption which specify the life time of node battery [2]. The energy consumption due to transmitted data should be limited. The reduction in the data size by compression reduces the transmission power. However, it is crucial to select an image compression algorithm, which requires less memory access during execution time.

JPEG is one of the image compression algorithms [3]. It depends on Discrete Cosine Transform (DCT), Quantization, and Entropy Encoding, while its decoder stages are the inverse of the JPEG encoder stages, as in Fig. 1. The N-bits 1-D DCT can be expressed as in (1) [4]. Based on the related works about fast DCT algorithms, Fast Zonal DCT is proposed in [5]. In Fast Zonal coding, the only coefficients within a specified region are encoded. Refer to equation (1), the number of operations is reduced to 9 multiplications and 24 additions, and it allows an efficient turning of the trade-off between energy consumption and image distortion. DCT is replaced by DWT to improve the image compression. So JPEG was under name JPEG2000. The description of JPEG2000 in WSN is shown in next section.

$$F(k) = \frac{C(k)}{2}\sum_{x=0}^{7} f(k)\cos\left(\frac{2x+1}{16}k\pi\right),\ k=0,\dots,3 \quad (1)$$

where: $C(k) = \begin{cases} \sqrt{1/2} & ,k=0 \\ 1 & ,k>0 \end{cases}$

The goal of this study is to enhance the image compression in JPEG2000. The hybrid of fast Zonal-DCT (at k=0,…,3) with DWT in 1-D and 2-D is the main target of this paper. The benefits of hybrid both algorithms is getting higher compression rate with high decompressed image quality is shown in this paper.

This paper is organized as follows :Section II introduces survey on JPEG2000 compression, Section III shows the hybrid algorithm, and Sections IV and Section V give the results and conclusions.

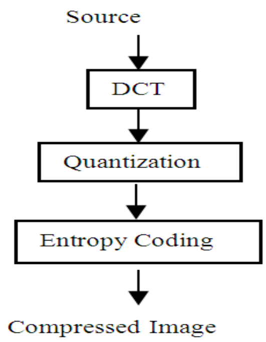

Fig. 1. JPEG encoder.

II. JPEG2000 Compression

JPEG2000 encoder consists of three stages: DWT, Quantization, and Entropy Encoding. The basic idea of the distributed JPEG2000 image compression is the distribution of the DWT workload to several nodes in the same cluster [3]. The data is partitioned into n blocks $R_1,\dots,R_n$ in the cluster centre to select number of nodes from its cluster region, equals to the number of blocks R_i , i=1,2,…,n, to perform 1-D wavelet (1-D DWT) on R_i; one block per node. Once the 1-D DWT is done on rows, the cluster center collects the intermediate results $P_1,\dots,P_n$ to send them to the next cluster centre to apply the same operations but on columns instead of rows to have 2-D DWT as a final result as shown in Fig. 2. The Quantization and the Entropy Encoding are performed at the sink node. In the Quantization Stage, each pixel is divided by a quantization step, Q, as in [3]. Entropy Encoding uses the

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Huffman code to generate codes to send them to the destination instead of the quantized value. The decoding process is the inverse of the encoding one.

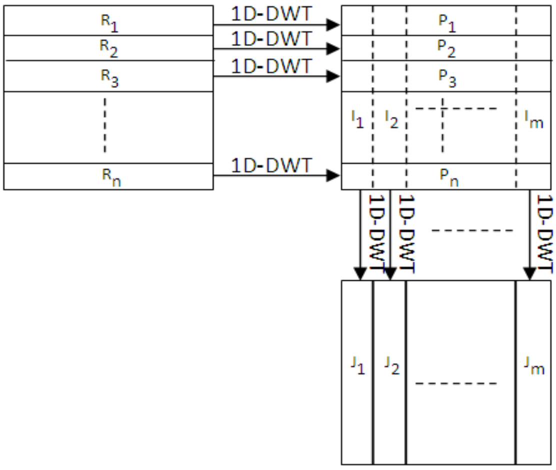

Fig. 2. 2-D DWT processing.

III. Proposed Hybrid Algorithm

The addition of Zonal-DCT (at *k*=0,…,3) between DWT and Quantization stage is the main idea of the proposed hybrid algorithm in 1-D or 2-D as in Fig. 3. 1-D DWT Zonal means the hybrid 1-D DWT with 1-D Zonal (at *k*=0,…,3) while 2-D DWT-Zonal means the hybrid 2-D DWT with 2-D Zonal DCT (at *k*=0,…,3).

Because of the problem of power consumption, the image compression process is partitioned between the sensors. 1-D Zonal DCT is processed in the same cluster. 2-D DWT, 2-D Zonal, and 1-D DWT-Zonal are processed in two adjacent clusters. 2-D DWT-Zonal is processed in four adjacent clusters.

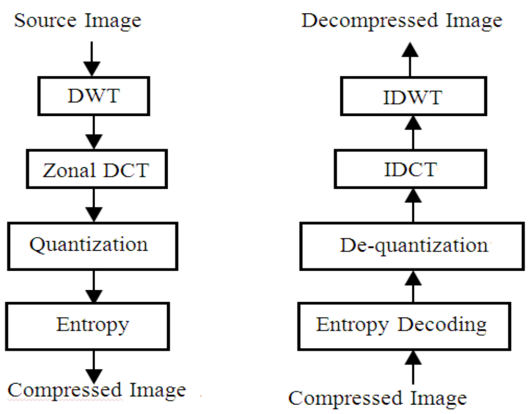

Fig. 3. Block diagram of proposed hybrid algorithm.

IV. Results and Discussions

The proposed hybrid algorithm, Zonal-DCT (at *k*=0,…,3), and JPEG2000 are compared with each other in their performance using MATLAB .Mandrill image of size 512×512 is the original image in bmp format used for comparison purpose. The comparison is applied between

- 2-D DWT

It means applying 1-D DWT on rows followed by applying 1-D DWT on columns.

- 1-D Zonal-DCT (at *k*=4)

It means applying fast zonal algorithm on image rows, and *k*=0,…,3.

- 2-D Zonal-DCT (at *k*=4)

It means applying 1-D Zonal-DCT on rows followed by applying 1-D Zonal-DCT on columns, and *k*=0,…,3.

- Hybrid 1-D DWT-Zonal (at *k*=4)

It means applying 1-D DWT on image rows followed by applying 1-D Zonal-DCT on resulted image rows, and *k*=0,…,3.

- Hybrid 2-D DWT-Zonal (at *k*=4)

It means applying 2-D DWT on the image followed by applying 2-D Zonal-DCT on the resulted image, and *k*=0,…,3.

The benefits of the Zonal DCT (at *k*=4) after DWT are the reduction for the number of multiplications used to compress the image and getting high quality of reconstructed image with high compression rate. Table I shows that the number of multiplications reduced by 50 % and 75 % in the case of 1-D DWT-Zonal and 2-D DWT-Zonal respectively. Table II shows the enhancement in compression rate of hybrid 2-D DWT- Zonal than the others. The compression rate scores 1:16 in the case of Hybrid 2-D DWT-Zonal while 1:4 in the case of 2-D DWT.

TABLE I: Number of Multiplications and Additions Used by Zonal

	1-D Zonal	2-Zonal
Nº of MUL without hybrid	294912	442368
Nº of MUL with hybrid	147456	110592
Reduction in Nº of MUL(%)	50%	75%
Nº of ADD without hybrid	786432	1179648
Nº of ADD with hybrid	393216	294912
Reduction in Nº of ADD (%)	50%	75%

TABLE II: Compression Rates

Compression Type	2-D DWT	1-D Zonal	2-D Zonal	1-D DWT-Zonal	2-D DWT-Zonal
Compression rate	1:4	1:2	1:4	1:4	1:16

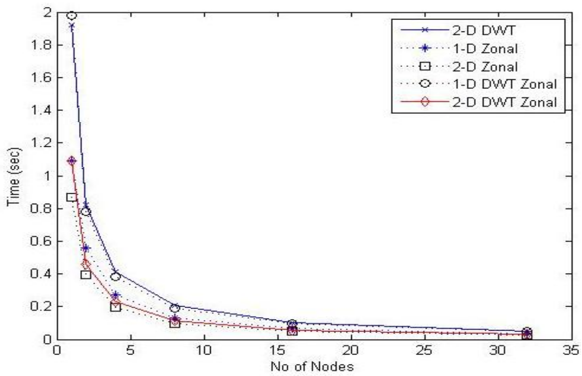

Fig. 4. Processing time.

The distribution of data processing between nodes reduces the power consumption per node. The total processing time is compared with the number of nodes used for processing per cluster as shown in Fig. 4. The comparison shows that 2-D Zonal-DCT takes the minimum processing time while

2-D-DWT-Zonal scores the next one. The other comparison metrics are Peak Signal to Noise (PSNR) [3], Spatial Frequency (SF) [6], and Correlation Coefficient (CC) [7]. The comparison shows that:

- The proposed hybrid 2-D DWT-Zonal gives higher PSNR for high Q while 2-DWT for low Q as shown in Fig. 5.
- The measured CC and SF for the proposed hybrid 2-D DWT-Zonal gives good results between the different algorithms as shown in Fig. 6 and Fig. 7 respectively.
- The previous results ensure the preference of 2-D DWT-Zonal than the others.

The benefit of data compression in WSN is the reduction in power consumption at the transmission. Proposed hybrid 2-D DWT-Zonal DCT enhances the compression rate and PSNR for high *Q*. The distribution of data compression in between sensors reduced the power consumption .The comparisons shows the preference of proposed hybrid 2-D DWT-Zonal than the others.

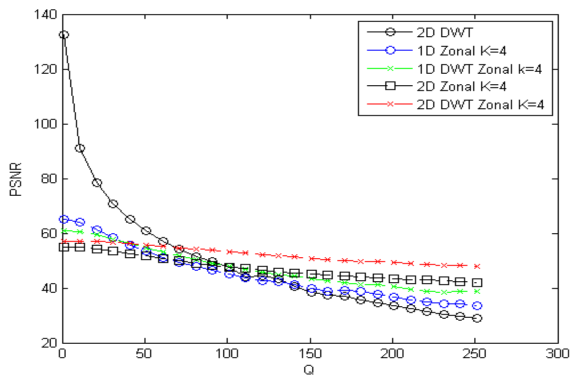

Fig. 5. PSNR comparison.

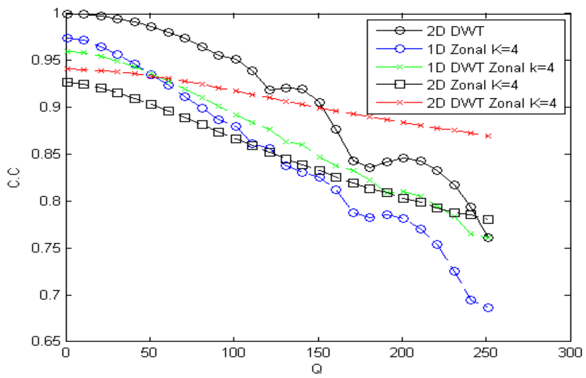

Fig. 6. CC comparison.

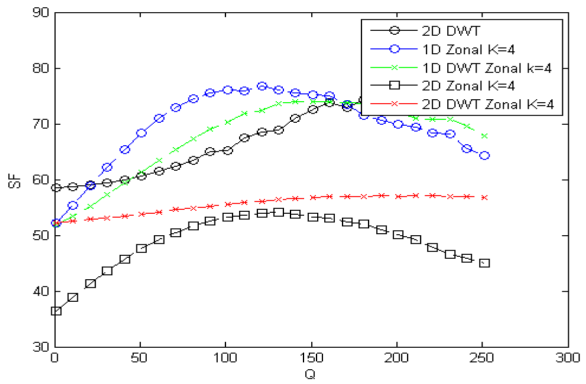

Fig. 7. SF comparison.

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