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# Collaborative Image Compression Algorithm In Wireless Multimedia Sensor Networks

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Abstract. *In order to meet the limited power and processing ability of WMSNs, and also must weigh up the relationship among energy consumption, calculation and image quality. Combining the idea of "in network processing" and compression process of JPEG-XR, an image compression method of multi-node cooperation is proposed. Firstly, a cluster-head centric dynamically partition non-uniform (DPNU) structure is established in order to get WMSNs load balance; then the image is divided into many parts and every segment is sent to neighbor clusters, the cooperation nodes implement the compression mission. Simulation results show that the PSNR of this method is about 3db higher than the PSNR of JPEG under the condition of low bit rate; and the proposed method more effectively reduces energy consumption than JPEG2000 and centralized processing method.*
**Keywords:** WMSNs; Cooperative processing; JPEG-XR; Image compression

1. **Introduction.** Wireless Multimedia Sensor Networks (WMSNs) has wide application prospect in industrial production, environmental monitoring and daily life because of its intuitive and convenient information presentation characteristics [1]. On account of the data processing and energy consumption of wireless transceiver are "uniform distribution", WMSNs is different from traditional WSNs [2]. The application of WMSNs faces the following problems: on the one hand, the computing and storage capacity of sensor nodes are limited, it is difficult to process large amounts of data separately [3]. On the other hand, the limited energy of sensor nodes is also a fatal flaw. So how to use the limited energy of sensor nodes to complete image compression transmission accurately becomes a hot topic.

For the above problems, many scholars at home and abroad to do a lot of research work in the collaboration among the nodes of network and the transmission of the compressed image. In order to make up for the shortcoming of wireless sensor nodes limited computing capability, a scheme of the low complexity of image coding based on change detection and improved JPEG algorithm was proposed in [4], which detected the area of interest of the target image to reduce the data transmission observably and improved DCT and quantization process of JPEG algorithm to reduce the computational complexity. A multi-node cooperative mechanism of image compression based on singular value decomposition and block adaptive image compression algorithm of SVD was explored in [5], so as to balance the energy consumption of network nodes effectively, the camera nodes and ordinary nodes worked together to accomplish collection, compression and transmission of the image. A method based on collaborative compressive sensing theory was presented in [6], which took advantage of the image block and collaboration of nodes to reduce the dimension of the matrix measurement and the computational complexity of compressive sensing. In [7–10], network structure of cooperation nodes and load balancing was built separately, then the block image was assigned to each node to accomplish the task so that it can balance the network load and prolong the network life in this way. In [11], a method for using the technology of vMIMO and cooperative communication to complete compressed data transmission was proposed, which can access to send and receive diversity gain and array gain, reduce link error rate, thus improve the signal-to-noise ratio. All methods of WMSNs image compression transmission above only take the key steps in a separate implementation into account, lacking of giving consideration to both energy consumption and image quality.

In view of the advantages and disadvantages of the existing related studies, in this work, we propose a method for WMSNs based on collaborative image compression algorithm of JPEG-XR. So it is more suitable for practical condition. This method has better effectiveness as well as higher accuracy, which provides a reliable method for image compression transmission. Main contributions of our work are briefly introduced as follows:

(1) Build the network structure, which have camera nodes, neighboring sensor nodes and cluster head nodes.

(2) Image compression transmission is distributed in collaborative cluster.

(3) Complete image compression process through cooperation of multi-node.

The remainder of this paper is organized as follows. In section 2, we briefly describe the analysis of JPEG-XR compression algorithm. In section 3, we introduce procedures of our algorithm in detail. In section 4, the simulation performance analysis is presented. Finally, in section 5, we summarize our main works.

## 2. Analysis of JPEG-XR Compression Algorithm.

Low computational complexity, low storage requirements and good quality of reconstructed image are the targets of WMSNs image processing [12]. A new generation of JPEG-XR image compression algorithm not only overcomes the block effect under low bit rate, but also has much lower computational complexity than that of JPEG2000 [13].

### 2.1. Computational complexity analysis.

JPEG-XR uses LBT transform as a core. In order to simplify the computational complexity of transformation phase, Microsoft team introduces Kronecker to JPEG-XR transformation algorithm [14]. The basic expression is described as follows:

$$Y = T_c X T_r' \xrightarrow{Kronecker} \begin{array}{l} y = Tx \\ T = T_c \otimes T_r \end{array} \tag{1}$$

Where $T_c$ is column transformation matrix of matrix $X$. $T_r$ is line transformation matrix of matrix $X$. After Kronecker algorithm, the two-dimensional transformation of matrix can be turned into as shown on the right side. $x$ and $y$ are rearrangement matrices of $X$ and $Y$ respectively. A new transformation matrix $T$ stands for Kronecker algorithm of $T_c$ and $T_r$.

LBT consists of image core transform (PCT) and image overlap transform (POT). According to the above calculation method, the basic operation $T_H$, $T_{HH}$, $T_R$, $T_{HR}$ and $T_{RR}$ of PCT and POT can be equivalent to a few basic cascade forms of rotation operation $R(\alpha)$. The equation is defined as follows:

$$\begin{cases} T_H = R(\pi/4) \\ T_{HH} = R(\pi/4) \otimes R(\pi/4) \\ T_R = R(\pi/8) \\ T_{HR} = R(\pi/4) \otimes R(\pi/8) \\ T_{RR} = R(\pi/8) \otimes R(\pi/8) \end{cases} \tag{2}$$

Rotation operation $R(\alpha)$ with lifting scheme which can convert multiplication to addition and shift operation. So that it can reduce the computational complexity greatly.

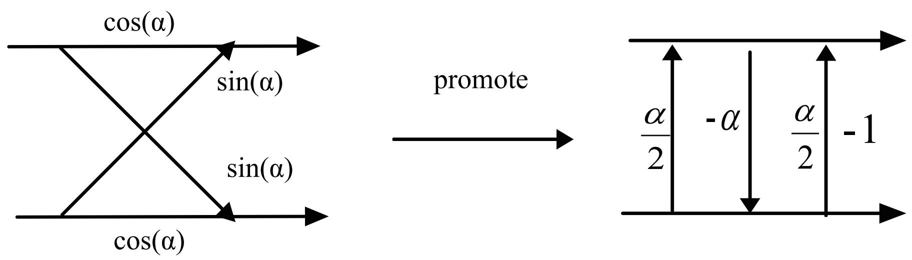


Figure 1. Lifting scheme of rotation operation

Computational complexity of different transform arithmetic is exhibited in Table 1. It can be seen that the LBT transform has higher computational complexity than DCT transform, but much lower than CDF9/7 wavelet transform.

Table 1. Average calculation cost of one bit

| | floating point DCT | floating point CDF9/7 | binDCT | binCDF9/7 | LBT |
|---|---|---|---|---|---|
| floating point+ | 0 | 0 | 7.79 | 34.1 | 13 |
| floating point× | 0 | 0 | 3.5 | 23.6 | 6.7 |
| integer+ | 7.25 | 10.5 | 0 | 0 | 0 |
| shifting | 3.25 | 7.9 | 0 | 0 | 0 |

2.2. **Decomposition of compression algorithm.** WMSNs nodes processing and energy consumption of transmission present "uniform distribution" [15]. So that it is a kind of promising idea that compression process is assigned to each node to balance energy consumption.

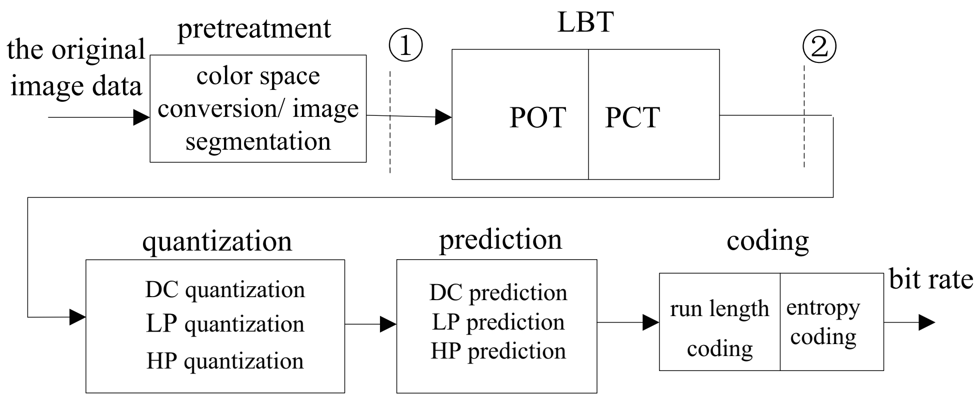


Figure 2. Encoding process of JPEG-XR

Fig.2 shows encoding process of JPEG-XR. It can be seen that color space conversion and image segmentation will be finished in the image pretreatment part. The data is divided into DC, LP, HP three subbands after LBT transformation, then quantization, prediction and coding will be executed aim at these three subbands respectively. As a result, compression task can be broken up at two stages: Original image will be divided into tiles which are not intersect each other if it breaks up at ①. The data of different subbands will be assigned to collaboration nodes to realize their quantization coding if it breaks up at ②.

## 3. Multi-node Cooperative Image Compression Algorithm.

3.1. **Network construction.** Camera nodes and ordinary nodes are two category nodes in the network where ordinary nodes are isomorphic and have same position and function, besides have a certain ability to calculate. At present there are mainly flat network structure and cluster stratified structure about network structure. In cluster stratified structure, it is so easy to organize MAC access and routing, and can execute data fusion in the cluster head [16]. So that cluster stratified structure is the most popular network structure.

There are two ways to construct cluster network which has camera nodes and ordinary nodes: structure for the center with the camera node and structure for the center with the cluster head node. On account of the network structure based on cluster needs a node which is responsible for the coordinated dispatching and completes the task allocation and other administrative tasks of multi-node cooperation. If structure for the center with the camera node is adopted, camera node will not only completes the image acquisition and distribution, but also finishes scheduling of each collaborative node. So that too much task will run out of the camera node energy quickly. Therefor structure for the center with the cluster head node will be the first choice to build network structure, and specific forming process is as follows:

Step 1: SINK node spreads message which includes a set of distance $D = \{d_1, d_2, d_3, \ldots d_i \ldots\}$ information to other nodes. In the network, ordinary node estimates the distance $d$ from SINK node based on RSSI, then calculates $\Delta d = |d - d_i|$ and combines energy information $E_i$, finally according to a certain probability $P(\Delta d, E_i)$ to decide whether it can become a candidate member of distance near $d_i$ or not.

Step 2: Candidate nodes which belong to the same candidate set compete the cluster head of candidate set according to their residual energy and energy consumption.

Step 3: Cluster head node broadcasts information about it becomes a cluster head. Ordinary nodes that receive information from cluster head according to the given probability algorithm add to the cluster. Camera node chooses add to the nearest cluster based on the distance from cluster head.

Step 4: Cluster head according to the join request message, sets up a member id list, and completes time slot allocation.

Step 5: Above step repeated regular.

From each round is over, the adjacent two clusters of $\mathrm{CH}_i$, $\mathrm{CH}_{i+1}$ form a integrated compression process, respectively take on image transformation, quantization, coding and prediction. The structure is shown in Fig.3.

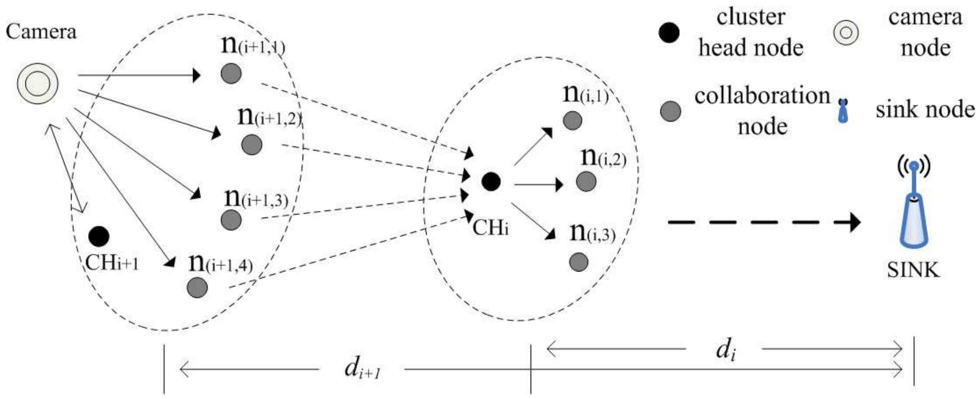


FIGURE 3. Distributed compression algorithm

3.2. **Algorithm implementation.** Distributed compression algorithm reaches the purpose that large energy consumption part in the compression process is distributed to various collaboration nodes to complete together. Camera node will send the request signal after it collects images. As soon as cluster node receives signal, it will organize the members of the collaboration nodes to complete image compression task. In order to prevent signal interference, intra-cluster communication makes use of the f1 frequency, and communication among cluster uses f2 frequency. Overall segmentation scheme is described as follows:

Step 1: Camera nodes collect image and complete block. Then send distributed information request to $\mathrm{CH}_{i+1}$. Collaboration node $n_{(i+1,j)}$ will receive acknowledgment message after $\mathrm{CH}_{i+1}$ receives the camera node request.

Step 2: $\mathrm{CH}_{i+1}$ returns acknowledgment message to camera nodes to verify the result. Tiles will be distributed to collaboration nodes by camera nodes.

Step 3: $n_{(i+1,j)}$ completes LBT transformation, then sends DC, LP and HP subbands to the next cluster head in f2 frequency, finally sends acknowledgment message to $\mathrm{CH}_{i+1}$ in f1 frequency. Return step 2.

Step 4: Each subband will be assigned to collaboration nodes after $\mathrm{CH}_i$ receives the data and completes quantization, prediction and coding. Then sends code stream to SINK node in the way of multi-hop.

4. **Experimental Performance Analysis.** The goal of image compression is high Qos based on low energy consumption in WMSNs. In order to verify the validity of this method, reconstruction image quality and the network life simulation analysis will be given in this section.

4.1. **Reconstruction image quality.** Image compression algorithm based on JPEG-XR not only has low computational complexity and low storage requirements, but also has higher image quality than JPEG in low bit rate case, which is the most important characteristic. WMSNs is limited in hardware node computing power and energy so that it generally chooses image format of less code and low computational complexity. The image format of JPEG-XR has obvious advantages. Image quality comparison under the bit rate 0.2bpp to 0.36bpp is shown in Fig.4. In Fig.5, the simulation results show the image peak signal-to-noise ratio of lena and baboon with $256*256*8$ bit. It can be seen that image peak signal-to-noise ratio of JPEG-XR is higher than that of JPEG under low bit rate, and the average peak signal-to-noise ratio increases by about 3db.

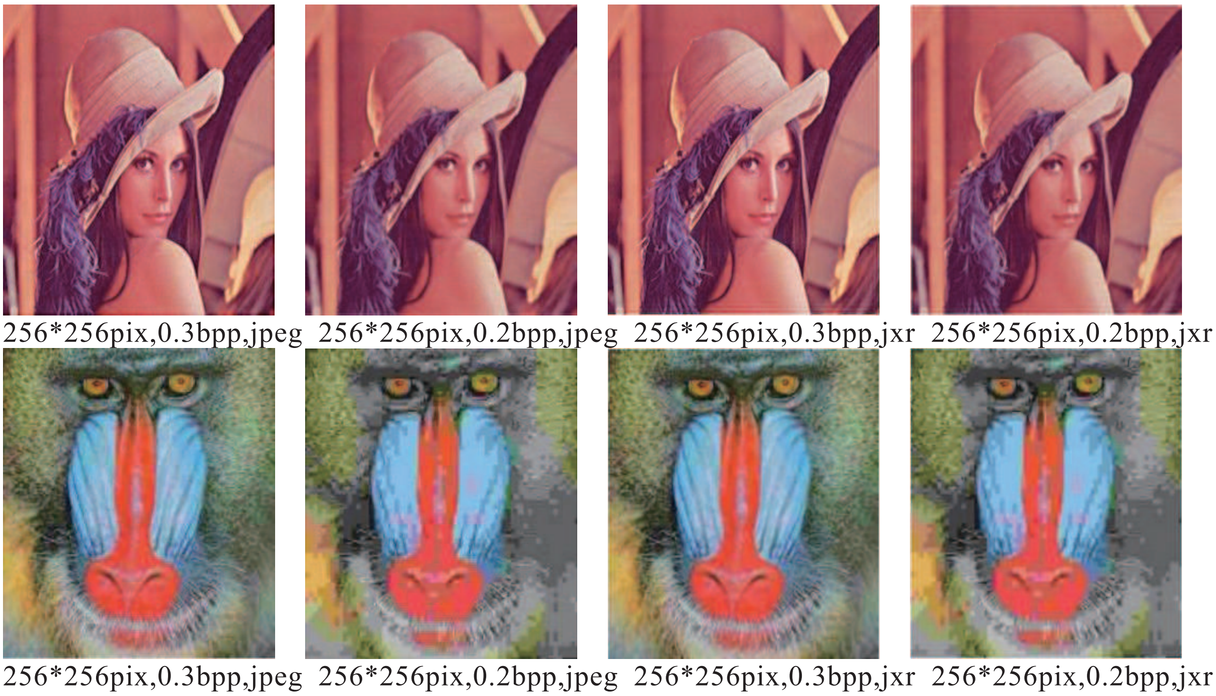


FIGURE 4. Images under different bit rate of lena and baboon

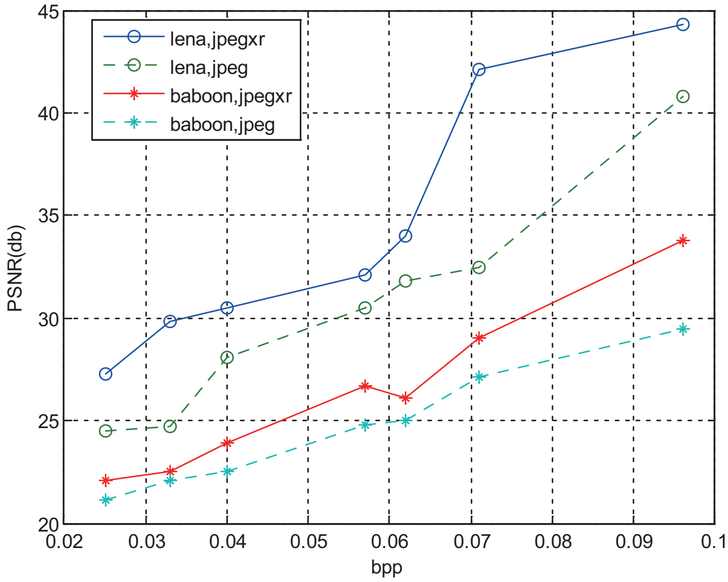


FIGURE 5. Image peak signal-to-noise ratio under low bit rate

4.2. **The network life.** It is assumed that the number of compressed image is unlimited in simulation process, the image size is $256 * 256 * 8$ bit. Each image is divided into blocks of $128 * 128$, then assigned to four adjacent collaboration nodes. Each node energy initializes 10 j, and compression ratio is 8. On the basis of the number of compressed images at the end of the network life to decide which method is best among various methods. When there is a node death, we will draw a conclusion that network life towards the end. The energy consumption model in reference [7] is adopted. Compared with conventional single node compression method, method of this paper and collaboration JPEG2000 compression method in reference [7], it can be seen from Fig.6 that method of this paper has obvious advantages. The reason is that the traditional method uses a single node to compress images so the node energy run out quickly. The method in reference [7] also uses collaborative approach, however, the computational complexity of JPEG2000 compression algorithm lead to large energy consumption. The collaborative JPEG-XR compression algorithm of this paper not only has the same image quality as JPEG2000, but also assigns compression process to multi-node cooperative implementation. In this way it greatly reduces the single node load and prolongs the network life.

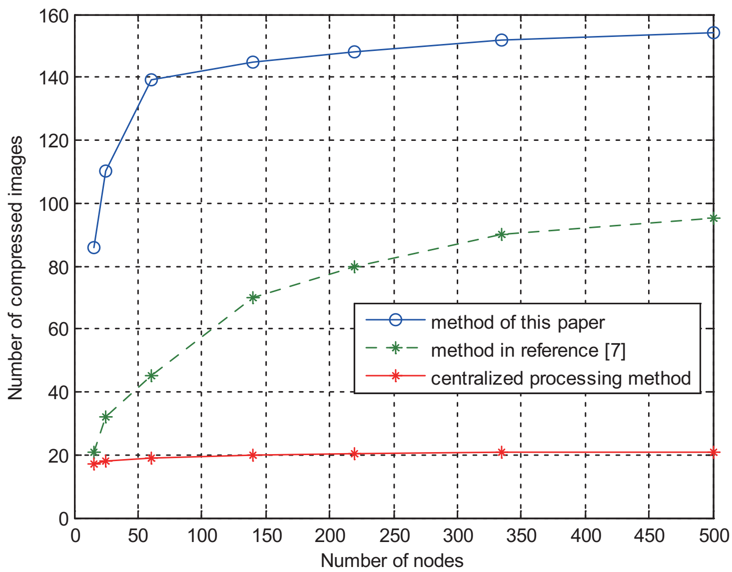


Figure 6. The network life

5. **Conclusions.** In this paper, we have proposed a JPEG-XR image compression algorithm of multi-node cooperation. This algorithm takes Qos and energy consumption of WMSNs into account and combines the structure of JPEG-XR and network structure of WMSNs. This method considers energy consumption of transformation and coding particularly, and assigns tiles to the first cluster nodes to complete LBT transformation. Then coding tasks of three subbands which are the derivatives of LBT transformation are assigned to collaboration nodes of the second cluster. Finally the code stream is sent to SINK node. Simulation results show that the method can achieve higher reconstruction image quality and balance the network load. So that network life prolongs more than three times than the other methods.

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