# ADAPTIVE IMAGE TRANSFER FOR WIRELESS SENSOR NETWORK

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## *ABSTRACT*

**When using wireless sensor networks for real-time data transmission, some critical points should be considered. Restricted computational power, memory limitations, narrow bandwidth and energy supplied present strong limits in sensor nodes. Therefore, maximizing network lifetime and minimizing energy consumption are always optimization goals. To reduce the energy consumption of the sensor network during image transmission, an energy efficient image compression scheme is proposed. The image compression scheme reduces the required memory. To address the above mentioned concerns, in this paper we describe an approach of image transmission in WSNs, taking advantage of JPEG2000 still image compression standard and using MATLAB and C from Jasper. JPEG2000 provides a practical set of features, not necessarily available in the previous standards. These features were achieved using techniques: the Discrete Wavelet Transform (DWT), and Embedded Block Coding with Optimized Truncation (EBCOT). Performance of the proposed image compression scheme is investigated with respect to image quality and energy consumption. Simulation results are presented and show that the proposed scheme optimizes network lifetime and reduces significantly the amount of required memory by analyzing the functional influence of each parameter of this distributed image compression algorithm.**

**Keywords: WSNs; Image compression; Energy conservation; System lifetime;JPEG2000; Matlab;C**

## I.INTRODUCTION

Recently wireless sensor network (WSN) has become one of the most interesting networking technologies since it can be deployed without communication infrastructures [1]. The WSNs are based on small sensor nodes and a sink (figure1). The main characteristic of such networks is nodes with scarce resources. These nodes consist of sensing, data processing, and communication components. So, sensor nodes are embedded system witch sense their environment, collect sensed data and transmit it to the sink in an autonomous way using multi-hop communication. However, theyare energized by small and irreplaceablebatteries. Under such energy constraint condition, sensor nodes can only transmit a finite number of bits in their lifetime. Consequently, energy consumption and data transmission are always considered together in WSNs. Therefore, approaches to optimize data transmission are a critical issue. For image- based applications, such as still pictures, stream video, voice, animal sounds and monitoring data, one uses a wireless sensor networkwhereby the nodes arecamera-equipped[2].

In this context, image transmission optimization through WSNs is mainly done by the implementation of distributed image compression algorithm embedded in order to reduce the number of transmitted bits, thus reducing the energy consumption. The use of distributed image compression in resource-constrained networks is essential. Even if the necessary total energy for the whole system is increased, the energy needed for every node is reduced, whichprolongs the network lifetime. This technique is based on the fact that an individual node does not have sufficient computational power to completely compress a large volume of data to meet the application requirements; this is not possible unless the node distributes the computational task among other nodes. In this case, a distributed method to share the processing task is necessary. In this paper, we propose an alternative image transmission approach in WSNs, based on JPEG2000 image compression standard. JPEG2000 can provide various new additional functions such as high resolutions image compression, progressive transmission and scalable image coding. This approach is based on discrete wavelet transform (DWT) and Embedded Block Coding with Optimized Truncation (EBCOT) which uses a better order of transmission. This paper is organized as follows: Section III describes general architecture of a wireless sensor node. Image transmission to WSNs is proposed in section IV. Experimental results are shown in Section V. Finally, section VI concludes this work.

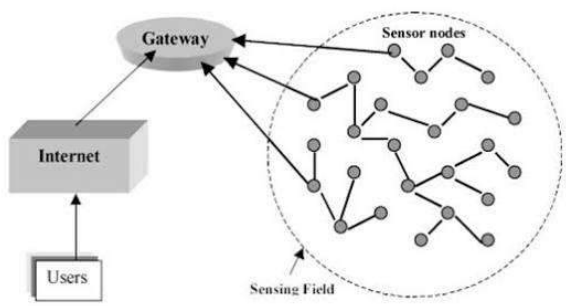


***Fig.1. Sensor network architecture***.

II. RELATEDWORK

Image compression is a well-established research field, but sensor networks present a context in which new design issues have to be addressed. The maincharacteristic of such networks is nodes with scarce resources. In fact, the primary focus on energy, computational power and allocated memory call for new approaches. In the case, a large variety of compression algorithms have been proposed. The image compression techniques and processing algorithms in a wireless sensor networkare classified in two categories:

Local algorithms are useful only when the complete processing, including image compression and transmission, is less energy consumming than the single transmission of uncompressed image. Some works have demonstrated that the complexity of certain compression algorithms leads to greater power consumptions than the simple transmission of the uncompressed image. For instance, Ferrigno et al presented in [13] a platform to evaluate the performance of different traditional algorithms for image compression in a single sensor node. They analyzed five algorithms: JPEG2000, SS, DCT, SPITH and JPEG. Results show that SS is the unique algorithm which presents energy savings with respect to the no-compression case, allowing a power reduction of about 29%. The mechanism proposed in [12] uses a scheme based in SPIHT coding of data blocks generated from parent-child relation chips of wavelet coefficients. This parent-child relationship is performed in order to reinforce SPIHT fragilities in bit error transmission cases. The adopted approach in [11] uses a local compression of JPEG2000 standard. In this approach, H.Wu and Abouzeid introduced a power aware technique that incorporates the JPEG2000 standard to compress captured images from wireless camera nodes. They formulated the image transmission problem as an optimization problem and proposed a heuristic algorithm called MTE (Minimize Total Energy).

In [9] a distributed image compression for images captured by sensor nodes having overlapping fields of view is used. The approach uses a technique similar to stereo-image compression to identify overlap in the images of neighboring sensor nodes [10]. This approach of distributed image compression falls within the domain of techniques that apply the concept of network processing, i.e. processing in the network by computing over the data as it flows through the nodes. In [3] a distributed image compression using the JPEG2000 standard is proposed. The basic idea is the distribution of the wavelet transform processing workload between various nodes. Two methods for data exchange have been proposed: Parallel wavelets transform method and tiling method. In [14,15] an exploitation of correlations between data at close-by sensors in order to jointly compress or fuse the correlated information is presented resulting in savings in communication energy. Song et al. [16] presented an algorithm that uses transform coding of distributed sources and the geometric correspondence between sensor nodes of a given neighborhood to reduce the bit- rate required for image transmission. Qin Lu et al. [17]

proposed a distributed implementation scheme of the Lapped Biorthogonal Transform (LBT) based on a clustering architecture. They overcome the computation and energy limitation of individual nodes by sharing the processing of tasks. This Approach aimed to prolong the lifetime of the wireless sensor network under a specific image quality requirement. In this paper, we study the interesting problem of distributed image compression using the JPEG2000 standard in context of a WSN. This paper proposes an original technique to reduce power consumption of the sensor network during image transmission. The flexibility of a distributed image compression algorithm is used to adapt the communication process.

## III. GENERAL ARCHITECTURE OF A WIRELESS SENSOR NODE

Fig. 2 shows the architecture of a typical wireless sensor node, as usually assumed in the literature. It consists of four main components: (i) a sensing unit including one or more sensors and an analog-to-digital converters for data acquisition; (ii) a processing unit including a micro-controller and memory for local data processing; (iii) a radio subsystem for wireless data communication (RF unit); and (iv) a power supply unit. Depending on the specific application, sensor nodes may also include additional components which are optional such as a location finding system to determine their position, a mobilizer to change their location or configuration.

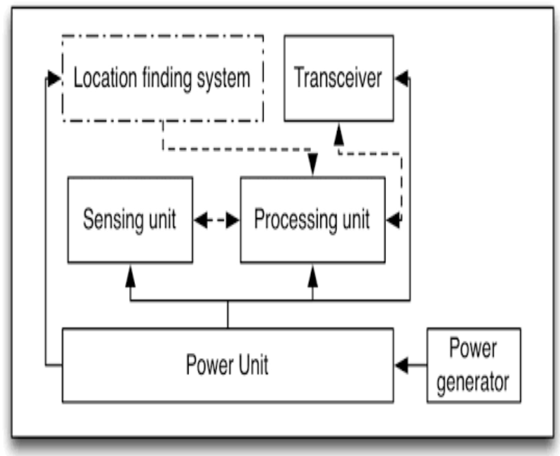


***Fig.2. Architecture of a typical wireless sensor node.***

For wireless multimedia network, sensor nodes are equipped with multimedia devices such as cameras. These devices are smaller, and offer more performances in terms of speed and image quality. Thus such network will have the capability to transmit multimedia data. The most important requirements of image transmission in WSNs are: Image sensing, allocated memory and image processing.

## IV. IMAGE TRANSMISSION TO WSNs

Nowadays, more and more multimedia applications integrate wireless transmission functionalities. Due to their ease of deployment, WSN has many applications such as military application, surveillance, localization, and tracking. The main task of a sensor node is to sense the environment and report what happens. Data collected by sensor nodes are usually routed back to a sink node by a multiple-hop [6-

7]. Each sensor node has two roles, data gathering and data relaying. In order to make image transmissions possible via energy preservation and allocated memory based heuristic. Weuse a scenario to request image QoSs parameters:

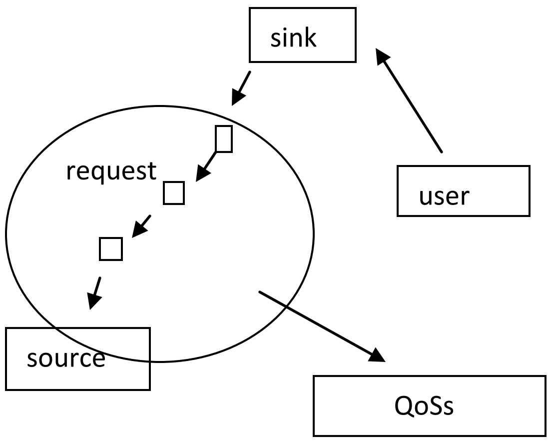


***Fig.3. Scenario used for the image request***

In this scenario a request specifying the necessary constraints of QoSs is required to initiate image transmission scheme with the operation parameters such as: PSNR, compression ratio, rate…. When sending an image request, the monitor specifies the desired parameters. The scenario is based on image compressing system which supports the rich set of features that are not available in other standards, such as excellent low bit-rate performance, both lossy and lossless encoding in one algorithm, random code stream access, precise single-pass rate control, region-of-interest coding and improved error resiliency. In this investigation, the communication environment is assumed to be contention-free and error-free. In this approach we focus on the problem of efficiently compressing and transmitting images in a resource-constrained multi-hop wireless. We propose a distributed image compression scheme where nodes compress an image while forwarding it to the destination subject to a specific image quality requirement and optimize networklifetime.

IV.1IMAGE PROCESSINGIN WSNs

As the radio subsystem is one of the most power consuming parts in sensors node, it is obvious that reducing transmitted data will save energy. However, the most evident solution is the image compression. The purpose of image compression is to reduce the number of bits needed to represent an image by removing the spatial and spectral redundancies as much as possible. In this paper, the proposed image transmission scheme is based on wavelet image transform. The structure of a transform coder is illustrated in Fig.4:

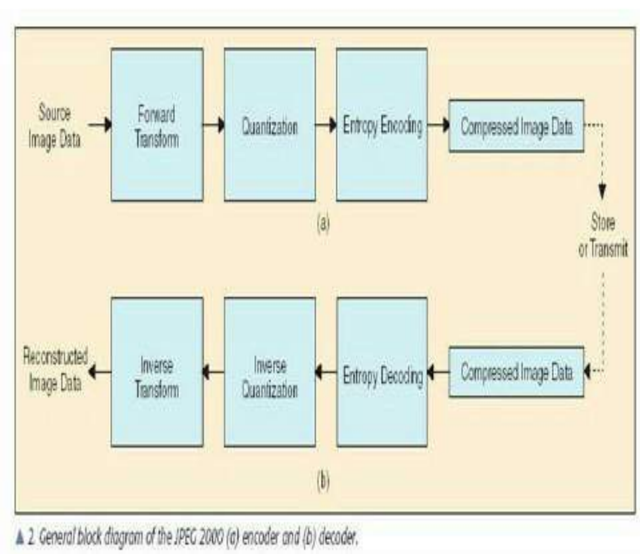


***Fig.4. Functional block diagram of JPEG 2000 encoder***

The main objectives achieved by this image compressing system are: Progressive transmission, progressive quality, reduced allocated memory, minimized energy consumption, and optimized network lifetime. More recently, the wavelet transform has gained widespread acceptance in signal processing in general and in image compression research in particular. Wavelet-based coding (also referred to as lifting scheme (LS)) is more robust under transmission and decoding errors, and also facilitates progressive transmission of images. Wavelet coding schemes are especially suitable for applications where scalability and tolerable degradation are important. Theoretically, DWT is a 2 dimensional separable filtering operation across rows and columns of input image. The DWT based on the concept of multi-resolutions which facilitates progressive transmission of images. This is achieved by first applying the low-pass filter L and a high-pass filter H to the lines of samples, row- by-row, and then re-filtering the output to the columns by the same filters. As a result, the image is divided into 4 sub bands: low-low (LL1), low-high (LH1), high-low (HL1) and high-high (HH1) [5]. The high-pass sub-band represents residual information of the original image, needed for the perfect reconstruction of the original set from the low- resolution version. Specifically, the LL1 sub-band can be transformed again to form LL2, LH2, HL2, and HH2 sub- bands, producing a two-level wavelet transform…and so on.

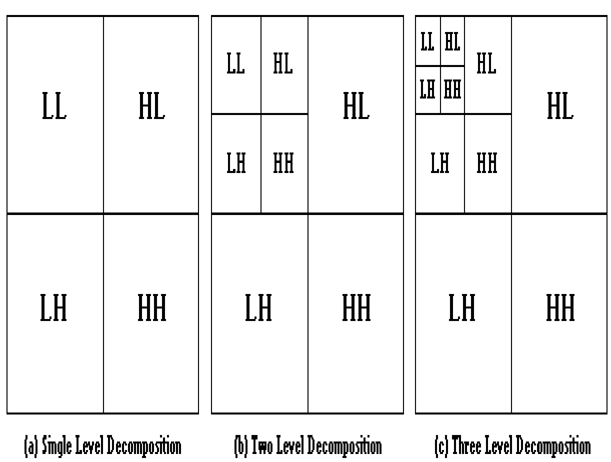


***Fig.5.Illustration of wavelet spectral decomposition***

After the DWT, all the sub-bands are quantized to reduce the precision of the sub-bands and contribute in achieving compression. The quantized DWT coefficients are converted into sign-magnitude represented prior to entropy coding. In the Embedded Block Coding method which is used in JPEG2000 standard, each sub-band (corresponding to LL, LH, HL and HH component at each wavelet decomposition level) is divided into small blocks called ‘code blocks’. And then each code block is coded independently from the other ones thus producing an elementary embedded bit-stream. During the coding phase, each code-block is decomposed into a number of bit-planes: One sign bit-plane and several magnitude bit-planes. The entropy coder for JPEG2000 uses embedded block coding with optimal truncation (EBCOT). EBCOT is divided into two coding steps: Tier-1 and Tier-2 coding. The first is based on tree pass: Significance Propagation Pass (Pass1), Magnitude Refinement Pass (pass2) and Cleanup Pass (pass3); the tier-2 is to organize the portfolio among bit-streams from every block[8].

## IV.2.DISTRIBUTED TASK OF IMAGE COMPRESSION

The basic idea of the proposed distributed image compression is distributing the workload of task to several groups of nodes along the path from the source to the sink. The key issue in the design of distributed task of image compression is data exchange. In this proposition, data is broadcasted to all processors to speed up the execution time which mayoptimize network lifetime and increase the energy consumption. An example of distributed cluster- based compressionusing four nodes in each cluster is shown in Fig.6.

Where applying the scenario proposed in IV and after receiving a query from a source node s, the cluster head c1 selects a set of nodes n1i (i = 1…4) in the cluster which will take part in the distributed tasks then informs source node, the first stage concerns the data partitioning scheme is parallel wavelet transform. The source divides the original image into tile and transmits themto n1i(n11, n12, n13 and n14). Those nodes run 1D-DWT (horizontal decomposition) on their received data then send the intermediate results to c2. After receiving the results, c2 distributes it to the set of nodes n2i (n21, n22, n23 and n24). These nodes process data (vertical decomposition) and send the results (Level 1 data in Fig. 5(a)) to the next cluster head c3.The cluster headc3 chooses apart of the results (corresponding to LL1 in Fig. 5(b)) and distributes it to the set of nodes n3i (n31,n 32, n33 and n34).

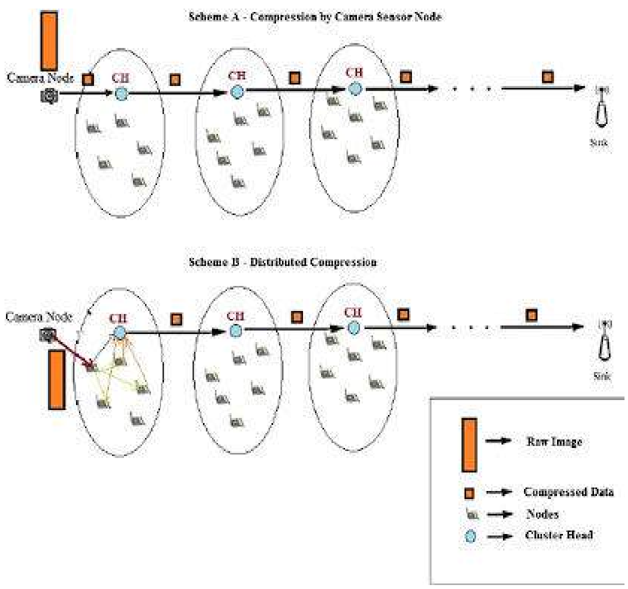


**Fig.6.Data exchange of distributed task for image compression in a multi-hop wireless network. Three levels of wavelet decomposition are used**.

Those nodes run 1D wavelet transform algorithm of LL1sub- band then send the intermediate results to c3. After running the second 1D wavelet transform of LL1sub-band, c3 process data and send the results (Level 2 data in Fig. 5) to the next cluster head c4. To be compatible with experiment results and dependingonthe image quality specified by the query (which is application-dependent), this procedure may continue on c4. The cluster head c4 chooses a part of the results (corresponding to LL2 inFig. 5(c)) and distributes it to the set of nodes n4i (n41, n42, n43 and n44). Those nodes run 1D wavelet transform algorithm on their received data ( LL2sub- band) then send the intermediate results back to c4 witch run 1D wavelet transform twice (corresponding to LL2 sub-band) and code the results (Level 3 data in Fig. 5 (d)). This procedure may continue on c7 and its following nodes until the final compressed image reaches the destination (sink) node. It should be noted that, as shown in Fig. 6, after the DWT, all the sub-bands are quantized by a single node (n5i). The other nods are put awake. Since the quantization represents about 5,5% of the total process time, In spite of resource constraints, an individual node has a sufficient power to realize the quantization block. Given that the Tier-1 coding represents about 43% of the total process time, the tasks partitioning optimize the network lifetime. After receiving the results, c6 divides quantized sub-bands into a number of smaller code-blocks of equal size and send their processed results to set of nodes n6i (n61, n62, n63 and n64). In these nodes each code-block is entropy encoded independentlyto produce compressed bitstreams.

IV.3. SYSTEM MODEL

For this study, we have adopted the 9/7 wavelet transforms implemented via lifting scheme (LS). For each sample pixel, low-pass decomposition requires 8 shifts (S) and 8 adds (A) instructions whereas high-pass decomposition requires 2 shift and 4 add. There are two input lines in the architecture, one with all the even samples (x2i) and the other with all the odd samples(x2i+1).In this case,eachpixel is read and written twice. Assuming that the input image size is of M×N pixels and that the image is decomposed into p resolution level, then 2D-DWT is iteratively applied p-1 levels. Using the fact that the image size decreases by a factor of 4 in each transform level, the total computational energy forthis processcan berepresented as follows:

V. EXPERIMENT RESULTS

In this section, we analyze the functional influence of the parameters initialized in the scenario proposed on Quality-of-Service (QoSs) requirements on WSNs. Then, we study the impact of some parameter on the behavior of the distributed scheme to evaluate energy performance of image transmission. However, the deviation of these parameters to ensure a multi-level processingshould affect other interesting factors which may influence the quality of the communication process such as:

V.1.IMPACTOFDWTONCOMPUTATIONENERGY

The energy concentration in the image by successive decomposition levels will allow decreasing the amount of information to be transferred to the destination.

The computed quantity is divided by 4 at each decomposition level. This is a main objective to be achieved, since the energy consumption in sensor nodes is proportional to the information quantitybeing transmitted.

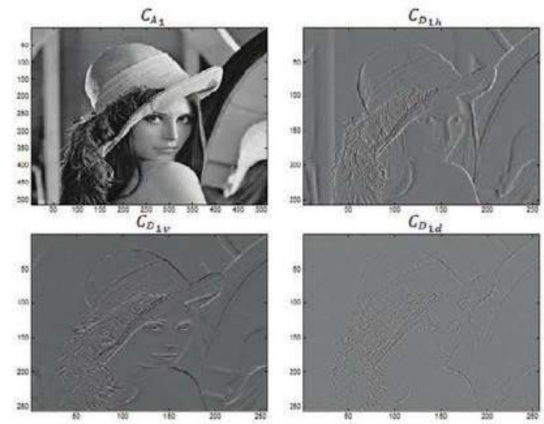

***Fig.7. (a) Original image component, (b) Output image after the first decomposition level, (c) Output image after the second decomposition level and (d) Output image after the third decomposition level.***

As a result, reducing the quantity of transmitted data will extend the topological lifetime of WSNs. From the experiment, a Lena image of 256*256 pixels is used as a test image. We first apply the decomposition in the horizontal direction. Since all even-positioned image pixels are decomposed into the low-pass coefficients and odd- positioned image pixels are decomposed into the high-pass coefficients, the total computational energy involved in horizontal decomposition is

The average energy dissipated by every node is provided in Fig.8. The energy consumed by the nodes n1i and n2i(i=1….4) to run 1D-DWT is of about 301mJ (by component) and 75mJ to run 1D wavelet transform algorithm of LL1 sub-band (n3i) corresponding to a 75% drop off. While the energy dissipated by every node n4i is of about 18mJ.

***Fig.8. Computationalenergy dissipatedby every node***

In this case, we were interested by analyzing the impact of the decomposition levels on theenhancementof the execution time. In Fig. 9, it's represented the execution time till five decomposition levels using the LS 9/7.

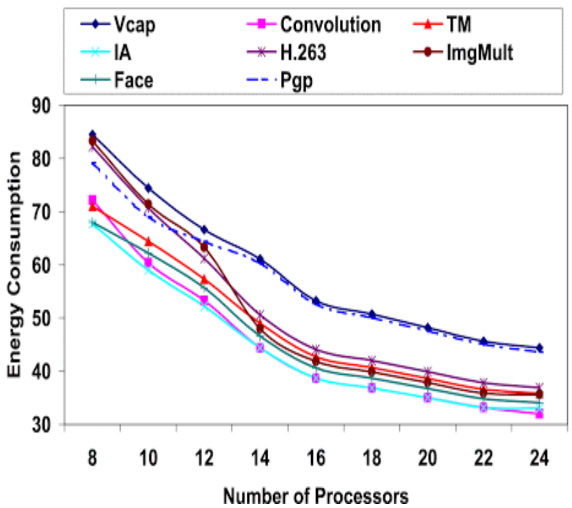


***Fig.9. Process time for 5 decomposition levels of LS 9/7.***

We have considered Lena image with different dimensions. The process time vary over decomposition levels and then reduced and become almost constant from the third decomposition level. Thus, the most of the image energy is located in LL sub-band. Therefore, an additional decomposition is useless and will waste energy without extracting more details.

Fig. 10 illustrates the distribution of high-pass coefficients after applying tow levels wavelet transform to the 256*256 image. We notice that the high-pass coefficients values are very small. Indeed, 75% of the high- pass coefficients for level 1 are less than 5. Since the images have a low pass spectrum, the sub-bands transmission from cluster head c4 to the sink must be transmitted with priority in order to save more energy.

V.2. IMPACT OFENTROPYENCODING

Coding a 32*32 LL sub-band with 4 magnitude bit planes, the energy dissipated is of about 5µJ (pass1) and 15µJ (pass2), whereas energy dissipated by pass3 is inconsiderable. For a 32*32 LL sub-band with 5 magnitude bit planes, the average energy dissipated to run pass1 and pass2 is estimated to be 10µJ each and the energy spent in pass3 is of about 2µJ. So decrease in magnitude bit planes leads to lower image quality (table1) and less computation energy.

We have also studied the image transfer adaptability to WSNs through the analysis of some image compression parameters. This study has been achieved by analyzing the dependence between system lifetime and allocated memory, and helped to select the better compression rate as well as better image quality. Themost important data are provided in the table1.

VI.CONCLUSION

In this paper, we have studied the problems of distributed image compression algorithm and its application in WSNs. The distributed image compression algorithm presented in this paper offers much flexibility at different process levels. These flexibilities are considered as dynamic parameters during the system to adapt the communication process. We have focused our study on the design and evaluation of distributed scheme depending on the operating parameters atdifferent process levels.

We have explained the impact of these parameters on the WSNs operations. Adopting the proposed technique, should reduce required memory, minimize energy consumption and optimize network lifetime.

In this work the base idea of this approach is the communication cost of the nodes closer to the destination (more compressed) is smaller than the communication cost of its previous nodes on the path. In the future, further research must be focused on multipath routing which may enhance the performance of distributed image compression

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