GECOM: GREEN COMMUNICATION CONCEPTS FOR ENERGY EFFICIENCY IN WIRELESS MULTIMEDIA SENSOR NETWORK

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ABSTRACT

Wireless multimedia sensor network (WMSN) is one of broad wide application for developing a smart city. Each node in the WMSN has some primary components: sensor, microcontroller, wireless radio, and battery. The components of WMSN are used for sensing, computing, communicating between nodes, and flexibility of placement. However, the WMSN technology has some weakness, i.e. enormous power consumption when sending a media with a large size such as image, audio, and video files. Research had been conducted to reduce power consumption, such as file compression or power consumption management, in the process of sending data. We propose Green Communication (GeCom), which combines power control management and file compression methods to reduce the energy consumption. The power control management method controls data transmission. If the current data has high similarity with the previous one, then the data will not be sent. The compression method compresses massive data such as images before sending the data. We used the low energy image compression algorithm to compress the data for its ability to maintain the quality of images while producing a significant compression ratio. This method successfully reduced energy usage by 2% to 17% for each data.

Keywords: Compression, control management, power consumption, wireless multimedia sensor network.

GECOM: KONSEP *GREEN COMMUNICATION* UNTUK EFISIENSI ENERGI DI JARINGAN SENSOR MULTIMEDIA NIRKABEL

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ABSTRAK

Wireless multimedia sensor network (WMSN) merupakan salah satu dari banyak teknologi yang digunakan untuk membangun sebuah kota pintar. Setiap node pada sistem WMSN memiliki komponen utama, yaitu: sensor, mikrokontroler, wireless radio dan baterai. Komponen WMSN tersebut digunakan untuk penginderaan, komputasi, komunikasi antar node dan fleksibitas peletakan setiap node. Namun, teknologi WMSN memiliki kekurangan yaitu besarnya konsumsi daya yang digunakan ketika mengirim media dengan ukuran yang besar seperti file gambar maupun video. Dalam beberapa penelitian terakhir, terdapat beberapa metode yang digunakan untuk mengurangi konsumsi daya yang digunakan, seperti dengan melakukan kompresi pada file hingga metode untuk mengontrol konsumsi daya pada proses pengiriman sebuah data. Kami mendesain sebuah metode yang kami namakan GeCom atau Green Communication dimana metode ini menggabungkan algoritma kompresi dengan kontrol managemen daya pada masing – masing sensor. Untuk control management daya, system akan mengontrol apakah data akan dikirim atau tidak berdasarkan kemiripan data, dimana jika data mirip dengan data yang sebelumnya data tersebut tidak perlu untuk dikirim. Sedangkan untuk metode kompresi gambar, kami menggunakan Low Energy Image Compression Algorithm (LEICA). Metode ini berhasil mereduksi penggunaan energy sebanyak 2% sampai 17% pada tiap data.

Kata kunci: Kompresi, konsumsi energi, manajemen kontrol, wireless multimedia sensor network.

I. INTRODUCTION

WIRELESS multimedia sensor network (WMSN), which connects several sensor node devices and transmits multimedia data information [1], is getting more attention due to its broad-wide applications such as forest fire monitoring [2], real-time video surveillance [3], water quality monitoring [4], indoor po-

sitioning and localization [5], and smart city based applications [6]. Developing a robust WMSN network within real world videos, *i.e.* image processing and human activity recognition [7, 8], can be challenging for some reasons, such as power consumption reduction, memory allocation, inefficient data transmission, and routing of real-time multimedia traffic.

A myriad of methods has been addressed for reducing power consumption in WMSN [9, 10, 11, 12]. For instance, Singh *et al.* [9] utilized image processing method in video-based sensor network to develop an energy-efficient and video transmission architecture. Collotta *et al.* [10] employed fuzzy-logic based approach to control the power management in access point to reduce the power consumption. Banarjee *et al.* [11] proposed a partial discrete wavelet transform in audio data to develop an efficient data compression algorithm. Recently, Sun *et al.* [12] invoked a low energy image compression algorithm based on the interest of region in WMSN to produce low-cost energy consumption. However, this method did not consider time scheduling mechanism and thus the redundant information may be included into the system.

In this paper, we develop Green Communication Network (GeCom) for energy efficiency in wireless multimedia sensor network. The essence of GECOM is to combine the power control management method with data file compression algorithm to reduce power consumption in WMSN. As shown in Figure 1, GeCom utilizes power control scheduling mechanism to control the timing of the data transmission, which prevents the redundancies among the sequential transmitted data. It computes the distance between two corresponding data. If the distance is less than a prescribed threshold, the data is considered as a near-duplicate data and removed from the sequence. Next, we employ low energy image compression algorithm [12] to compress the multimedia data prior to transmission. The contribution of this paper includes the following, i) we employ an effective time scheduling algorithm to prevent data redundancy during data transmission; ii) we utilize data compression mechanism to reduce the cost of the energy; iii) simulations show that proposed method can obtain a promising result in image data transmission.

The rest of this paper is organized as follows. Section II gives the overview of the related work following by the introduction of the proposed method in Section III. Extensive experiments are described in Section IV to assess the performance of the proposed method. Section V draws some concluding remarks to summarize our work.

II. RELATED WORKS

In this subsection, we investigate the existing studies, which provide the development of wireless multimedia sensor network and the energy efficient mechanisms.

A. Wireless Multimedia Sensor Network

Wireless multimedia sensor network has been received a considerable among of attention due to its potential in broad wide applications [13, 14, 11, 15]. For example, Azis *et al.* [15] proposed an architecture and protocol for energy efficient image processing and communication over wireless sensor networks. Also, Zhou *et al.* [13] used the advantages of depth map and frame loss concealment to overcome the issue of the loss of the whole frames for multi-view 3-D video transmission over WMSNs. Recently, Koyuncu *et al.* [16] investigated the impact of fusing the audio-visual and scalar data for energy-efficient yet maintained the detection accuracy. Shah *et al.* [17] utilized cross-layer architecture for quality-of-service support in WMSN by maximize the capacity of the network.

B. Energy Efficient

Several energy efficient mechanisms were considered to reduce the consumption of multimedia data transmission [1, 14, 2]. For instance, Singh *et al.* [9] proposed an effective architecture pertaining to video transmission in connection with wireless sensor. Also, Sun *et al.* [12] invoked an efficient image compression scheme based on the interest of region in WMSN to produce low-cost consumption. Wan *et al.* [14] used energy-efficient sleep scheduling schemes, which calculates and clusters the optimum transmission range of each sensor to balance energy consumption and sleep state procedure to reduce energy consumption.

C. Data Compression

Some notable frameworks have been developed for data compression in many areas [18, 12, 19, 20]. Singh *et al.* [19] investigated various schemes of data compression techniques such as lossy and lossless application. Purwanto *et al.* [18] employed multi streams network to effectively learn the pattern of human activities on low-resolution video classification. In Hua *et al.* [21], a context-constrained demosaicking algorithm via sparse-representation based joint dictionary learning was proposed for predicting the missing color information in low-resolution image. Also, Barannik *et al.* [22] reduced the structural redundancy under limited loss of visualization quality to develop an effective video data compression.
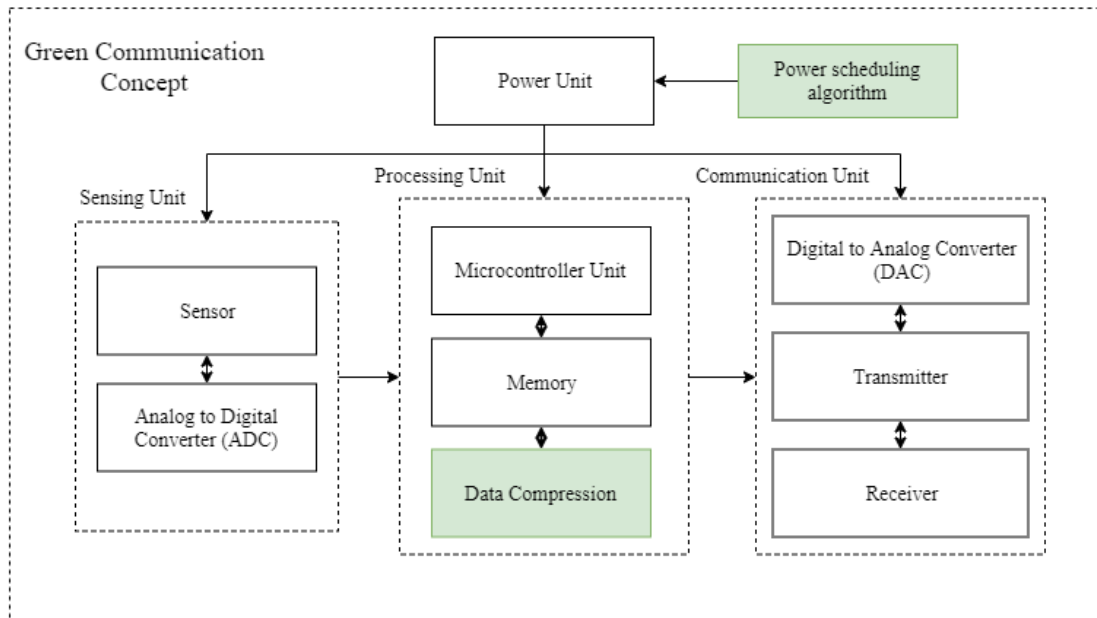
Fig. 1. The pipeline of the proposed architecture.

III. METHODOLOGY

In this section, we introduce the pipeline of the architecture, as shown in Section III-A. Next, we describe the proposed power scheduling algorithm in Section III-B following by the image compression algorithm in Section III-C.

A. Overall Architecture

In this section, we begin with a brief introduction of the power scheduling algorithm in Section 3-A. Our focus in then on three main parts. First, sensor node model, energy consumption model and system model. Next, we explain the image compression algorithm in Section 3-B, which composed of discrete coefficient matrix, a low energy image compression scheme, and energy consumption model. For easy reference, the overall pipeline is shown in Figure 1.

B. Power Scheduling Algorithm

In this subsection, we describe the power scheduling algorithm, which composed of three main structures: sensor node model, energy consumption model, and system model.

1) Sensor Node Model

In this subsection, we describe the sensor node model, in which each sensor node has three essential parts, such as micro controller unit (MCU), transceiver, and sensor sensing. The first component, MCU, is employed to process, manage, and change the state of in each sensor node into several conditions, such as sleep, idle, sensing, transition, receiving, and transmitting [14]. Each state has different power consumption that runs parallelly at different intervals of time. Note that the setting of each state can substantially affect the power consumption. Next, transceiver, which uses for data transmission, is employed and integrated with sensor node. Thereafter, sensor sensing is utilized to read the observed condition values. For easy reference, the sensor node model is illustrated in Figure 2.
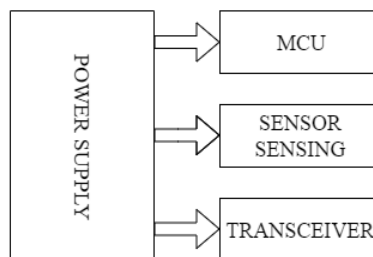

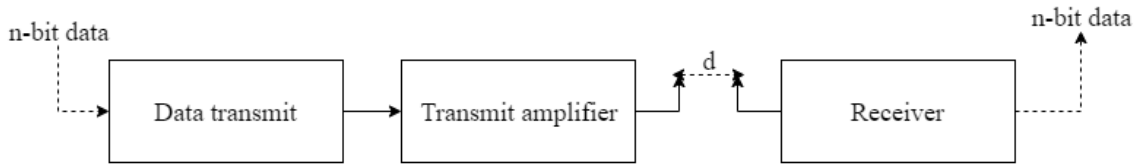Fig. 2. The architecture of sensor node model.

Fig. 3. Energy consumption model.

2) Energy Consumption Model

Next, we describe the energy consumption model in WMSN network in which the power consumption can be categorized into three major components: MCU, sensor sensing, and communication. It is noteworthy that the cost-energy for communication is larger than the other two components as this part requires several processes such as transmission, receive, and transition from normal/active to idle, or from idle to normal/active. For easy understanding, this energy consumption model is shown in Figure 3.

More specifically, the energy consumption model and the energy consumption can be calculated with the following formula:

$$E_{Transmitter} = (E_{Tx} + E_{amp} * d) * n, \tag{1}$$
$$E_{Receiver} = E_{Rx} * n, \tag{2}$$

where E_{Tx} is the energy used for data transmission, E_{amp} is the energy used to send data to other devices on the network, and E_{Rx} is the energy used by the sensor to receive information or data from other sensor devices. Note that the energy is influenced by the distance between the sensor node and the receiver.

3) System Model

Next, we describe the system model, which composed of three states: active/normal, sleep, and idle condition, as described in Table I. For active/normal condition, the sensor reads the data and send the data to other devices. For sleep condition, the sensor unread the data until the sensor data is sent. For the idle state, the sensor reads the data without sending any information. The idle state is used in green communication systems to preserve the power consumption. The changing of each condition in WMSN network is performed manually. For instance, the use of a time/timer where the system will change every state following a predetermined time. The use of timers for setting conditions enables the system to run periodically, and a constant estimation of the power used can also be calculated. However, setting the state by using a timer can cause the level of accuracy of each sensor to decrease because the sensor does not turn on continuously that could miss recording an event at a time when the sensor is off.

Inspiring by the effectiveness of the green communication concepts in diverse applications [23], here, we proposed an efficacious method to save the power consumption in WMSN with this scheme in which the condition control system is manually changed using an automated system. The condition settings on each system is determined by the value obtained by each sensor on the WMSN network. Here, the data matching process checks the value generated by each sensor, where the value is constant or less than prescribed threshold will be considered as near duplicate information and thus the sensor node does not need to transmit any data to the other sensor node. The pipeline of this procedure is depicted in Figure 4.

- **Read Sensor Data.** WMSN contains several multimedia data types such as text data, audio data, and video data, which captured from various sensors. Note that every process is done in real-time fashion.
- **Data Collection.** Each sensor node is designed to have single MCU in which the limited internal memory is used for data storing.
- **Data Sampling.** The sensor value on WMSN moves dynamically over a specified period. The data sampling method is invoked to sample specific data at specific time by Slovin formula. This operator is defined as follows:

$$n = \frac{N}{1 + N(e)^2}, \tag{3}$$

  where n is sample size, N is population size, and e is error tolerance.
- **Data Matching.** We utilize data matching scheme, which a finding records tasks that refer to the same entities, to control the state of the WSN node. There is two type of data: text data and image data. Specifically, we use the K-means algorithm, as shown in Algorithm 1, to cluster the data for each state.

C. Image Compression Algorithm

Inspired by the effectiveness of data compression for data efficiency [18, 13], here, we employ JPEG compression method and a low energy image compression algorithm [12] to transform the Discrete Cosine Transform (DCT) [9]. It first selects parts of DCT coefficient matrix, transforming high-frequency regions, and keep the in-

formation of low to middle frequencies. This DCT then passed for quantization to reduce the redundant data before the encoding procedure. For easy understanding, this process is illustrated in Figure 5.

1) Discrete Coefficient Matrix

In this subsection, we describe the mechanism to calculate the regions based on the frequency domain. We utilize two-dimensional discrete cosine transform (2D DCT-V) to transform the modality, which can be defined as follow:
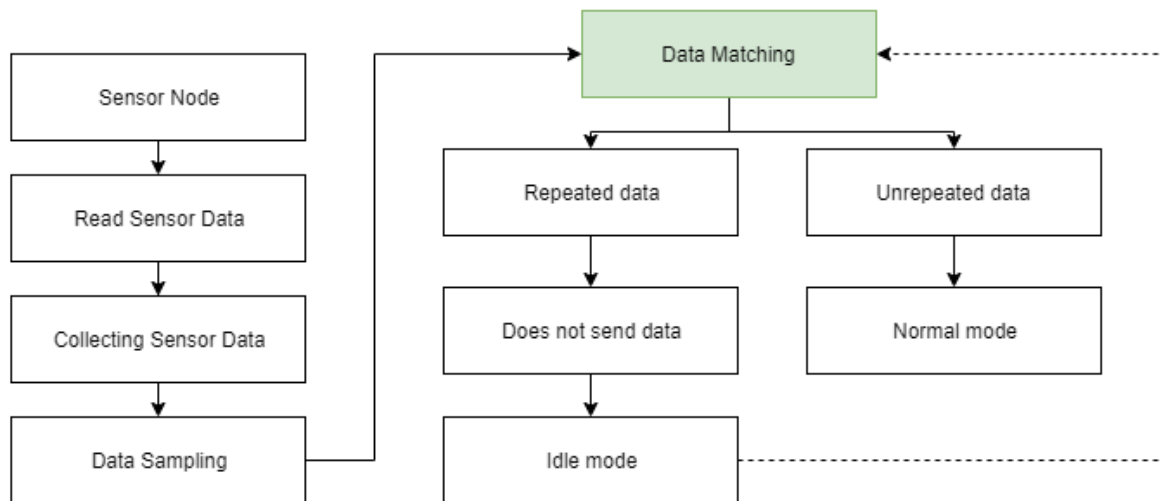
Fig. 4. Power scheduling algorithm.

Fig. 5. Image compression algorithm.

TABLE I
SENSOR NODE MODE.

Mode	Sensor Sensing	MCU	Transceiver
Active / normal	On	On	On
Idle	On	On	Off
Sleep	Off	Off	Off

| **K-means clustering algorithm**	
1.	Specify the number of clusters K
2.	Initialize centroids by first shuffling the dataset
3.	Randomly selecting K for the centroids
4.	Keep iterating until there is no change in the centroid
4.1	Compute the sum squared distance between data points to all centroid
4.2	Assigned each data point
4.3	Compute the centroids for the clusters by taking the average of all data points that belong to each cluster.

Algorithm 1. Data matching mechanism.
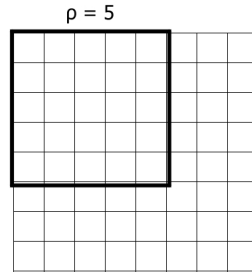
Fig. 4. Sub region of DCT.

$$X_{k,l} = \sum_{n=0}^{M-1} \sum_{m=0}^{M-1} x_{n,m} \cos \frac{(2m+1)(2k+1)\pi}{4M})\cos \left(\frac{(2n+1)(2l+1)\pi}{4M}\right) \quad \begin{matrix} k=0,1,2,...N-1 \\ l=0,1,2,...M-1 \end{matrix} \tag{4}$$

where X is the values of the coefficient matrix and x is the pixel values of an image. Then, the orthogonal normalization is used to multiply X, which resulting a new DCT coefficient matrix F. This operator is defined as follows:

$$F_{k,k} = \frac{1}{2}\sqrt{\frac{2}{N}} X_{k,k}. \tag{5}$$

Thereafter, having the DCT coefficient matrix, which can be expressed as

$$F_{(k \times l)} = A_{(k \times l)} P_{(k \times l)} A^T{}_{(k \times l)}, \tag{6}$$

we then compute the matrix values of each sub-region with the size ρ, which can be defined as follow:

$$F_{(\rho \times \rho)} = A_{(\rho \times l)} P_{(k \times l)} A^T{}_{(k \times \rho)}, \tag{7}$$

where F is the coefficient matrix, P is the pixel matrix, and A is the discrete coefficient matrix.

The value of ρ is directly proportional to image quality and inversely proportional to its computational process. With the heavier computational process, the device will consume more energy. Thus, the energy consumption is in line with the size of the DCT coefficient.

2) A Low Energy Image Compression Algorithm

Inspired by the effectiveness of low energy image compression for image compression [12], here, we use this concept to maintain the quality of the region of interest (ROI) and reduces the quality outside of the ROI. To do that, we will set ρ value at maximum for ROI and set ρ value at minimum for outside of ROI using Equation (8) as follow:

$$D_{m,n} = \frac{1}{(x*y)} \sum_{i=1}^{x} \sum_{j=1}^{y} |f(xm + i, yn + j) - b(xm + i, yn + j)|, \tag{8}$$

where D is the difference, m and n are DCT coordinate, x is image pixel width, and y is image pixel height.

Note that ρ is chosen with the Equation (9) as follow:

$$\rho = \begin{cases} \rho_{max} & if\ (D_{(m,n)} > D_0 \\ \rho_{min} & else \end{cases}, \tag{9}$$

3) Energy Consumption Model

We use a linear regression model to simulate the energy consumption. Regression linear is a method that able to predict the output given by previous data. This function is defined as follows:

$$y = a + bx, \tag{10}$$

where y is the prediction value, a is input value, x is intercept, and b is coefficient beta.

Note that b is computed with this equation:

$$b = \frac{\sum_{i=1}^{n}(x_i - `x)(y_i - `y)}{\sum_{i=1}^{n}(x_i - `x)^2}. \tag{12}$$

IV. EXPERIMENT RESULT

In this section, we explain the details of the implementation and evaluation protocols in Section IV-A. Finally, Section IV-B assesses the performance comparison of the proposed method.

A. Evaluation Protocols and Experimental Setup

We use 10 sample images vary from 100 Kb to 1000 Kb to assess the performance of the proposed method. We use the size and power consumption as the evaluation metrics.
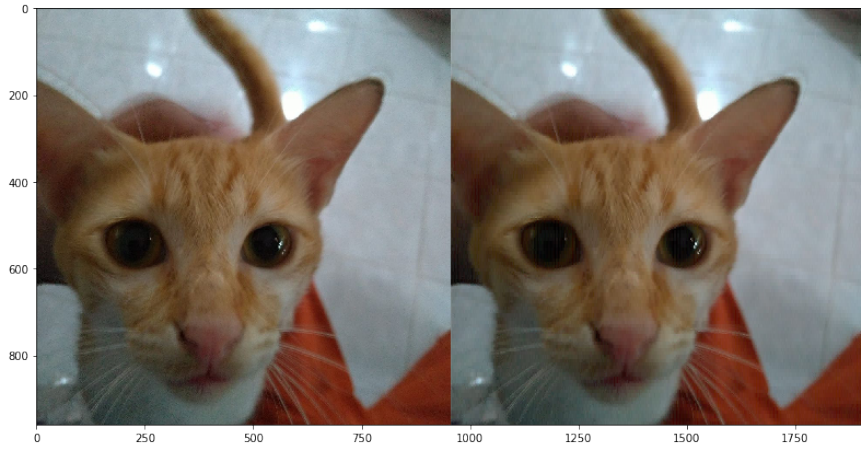
Fig. 5. Comparison result between uncompressed (left) and compressed (right) image.
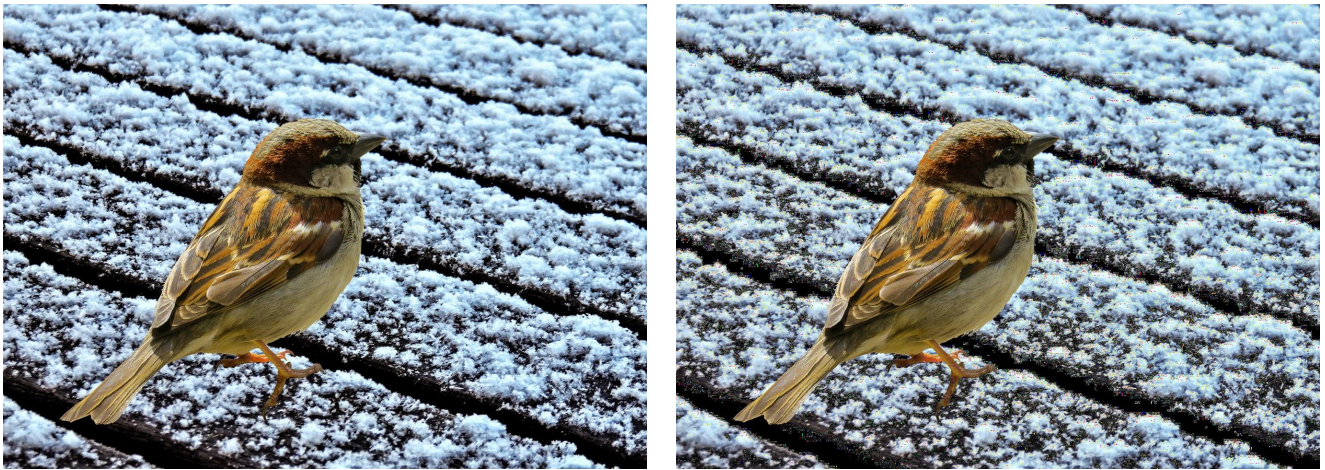

Fig. 6. Compression result generate noise.

TABLE II
COMPRESSION COMPARISON.

No	Raw Image Size (Kb)	Without Compression (mJ)	Compressed Image Size (Kb)	With Compression (mJ)	File Size Reduction (%)	Power Consumption Reduction (%)
1	237	336	31	288	86%	14%
2	240	336	20	286	**91%**	14%
3	303	351	33	289	89%	**17%**
4	922	493	879	483	**4%**	**2%**
5	432	380	294	349	31%	8%
6	276	345	216	331	21%	4%
7	496	395	211	330	57%	16%
8	305	351	204	328	33%	6%
9	215	331	185	324	13%	2%
10	101	304	58	294	42%	3%

B. Assessment of the Proposed Method

1) Power Consumption

We inspect the performance in terms of the power consumption reduction as shown in Table II, from which we can note that the proposed method can achieve a promising result with the reduction of the cost up to 17%. We can note that the reduced power consumption is linear with the size of the input image. The biggest power consumption reduction is image number 3 with 17% and the lower power consumption reduction is image number 4 with 2%.

2) Output Size

We also evaluate the proposed method in terms of the output size, as shown in Table II, from which we can see that the biggest file size reduction is on image number 2 with a 91% reduction, and the lowest file size reduction is image number 4 with a 4% reduction.

3) Visualization

To demonstrate the effectiveness of the proposed method, we compare the input and the output of our work as shown in Figure 7, from which we can see that low energy image compression algorithm can maintain the quality of the image yet obtain 42% file reduction. The trade-off of this compression is the background image becomes blurry and noisy since the quality is reduced.

We also demonstrate the lowest image reduction, refer to image number 4, as shown in Figure 8, from which we can see that GeCom can maintain the image quality. The low reduction is because in some cases compression, JPEG using DCT-IV will generate some noises, which resulting the larger file size output.

V. Conclusion

This paper has developed a Green Communication Network for energy efficiency in wireless multimedia sensor network, which combines the power control management method with data file compression algorithm to reduce power consumption in WMSN. It first utilizes power control scheduling mechanism to control the timing of the data transmission, which prevents the redundancies among the transmitted data. Next, we employ low energy image compression algorithm to compress the multimedia data prior to transmission. Simulations show that proposed method can achieve a promising result.

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