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Image subset communication for resource-constrained applications in wireless sensor networks

Sajid NAZIR[1], **Omar A. ALZUBI**[2,*], **Mohammad KALEEM**[3], **Hassan HAMDOUN**[4]
[1]Glasgow Caledonian University, Glasgow, UK
[2]Al-Balqa Applied University, Al-Salt, Jordan
[3]COMSATS University, Islamabad, Pakistan
[4]Mobile Core End-to-End Solutions, British Telecom (BT), Ipswich, UK

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Abstract: JPEG is the most widely used image compression standard for sensing, medical, and security applications. JPEG provides a high degree of compression but field devices relying on battery power must further economize on data transmissions to prolong deployment duration with particular use cases in wireless sensor networks. Transmitting a subset of image data could potentially enhance the battery life of power-constrained devices and also meet the application requirements to identify the objects within an image. Depending on an application's needs, after the first selected subset is received at the base station, further transmissions of the image data for successive refinements can also be requested. Needs for such progressive refinements exist in applications including tele-medicine, security, and surveillance, where an initial assessment could govern further exploration of only a small region. We propose a scheme for selecting minimum information for a coarser reconstruction by transmitting only the DC coefficients as the first or base layer. This initial layer of information could on request be augmented by transmitting either more data representing an entire image or a selected region of interest. We compare our results with those of other power economization and progressive communications techniques. The proposed scheme offers significant advantages for a range of application scenarios under resource constraints.

Key words: Wireless sensor networks, data transmission, security, progressive image transmission, resource-constrained applications, JPEG, region of interest, image coefficients

1. Introduction

Image and video communications have already surpassed other types of data communication and are the dominant traffic on the Internet [1]. Recently, there has been widespread growth and interest in the deployment and use of visual sensor nodes (VSNs)[2, 3]. With large-scale field deployments of image sensors, the need for image communications for battery-powered wireless devices has become a research challenge. Unlike scalar data (temperature, humidity, etc.), compressed images are larger by many orders of magnitude and the availability of transmission energy determines the sensor node's lifetime [4, 5]. Joint Photographic Experts Group (JPEG) is the predominant image coding standard with large deployment in security, medical, and industrial applications[1] [6]. It is also extensively used for embedded sensing applications. The JPEG algorithm has different coding

*Correspondence: o.zubi@bau.edu.jo

[1]CCITT (1993). Information Technology-Digital Compression and Coding of Continuous-Tone Still Images-Requirements and Guidelines [online]. Website https://www.w3.org/Graphics/JPEG/itu-t81.pdf [accessed 15 02 2020].

modalities such as baseline and progressive. The progressive transmission was designed for low speed networks so that a low quality holistic image could be quickly delivered and then gradually improved. The problems with progressive JPEG compression are that (i) it is not the default configuration for cameras, (ii) the progressive mode needs more CPU time and memory for encoding [7], and (iii) it generates an image of a larger size compared to the baseline configuration. JPEG2000 [8] is based on wavelet technology and can compress the image data more efficiently but requires complex computations that may outweigh the gains in compression efficiency [9, 10] at a sensor node, and also it has not yet been adopted by camera manufacturers. One way for the battery-powered sensor node to increase its lifetime is to extract and transmit an image data subset to the base station, which can realign image data, or request additional data. As shown in Figure 1, a low quality image may satisfy the application decision process requirement, or it may be followed by more data for the entire image or a region of interest (RoI).

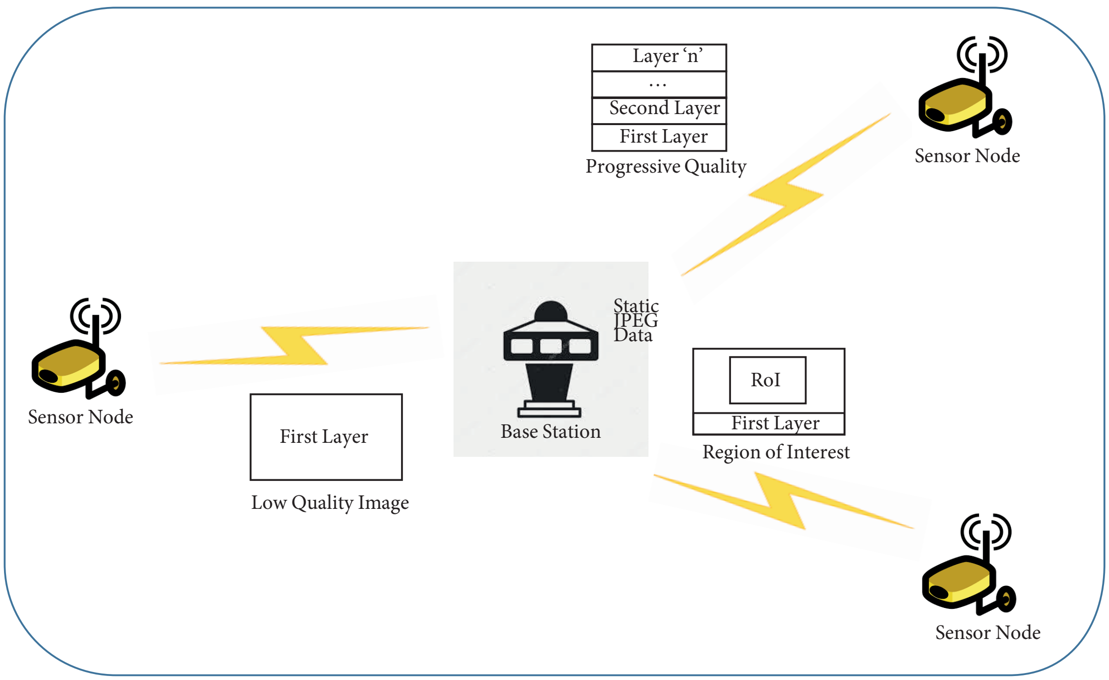

Figure 1. System model showing different cases of progressive image data transmission.

Progressive image transmission (PIT) [11–13] schemes make it possible to curtail transmission to save on storage and transmission and yet make possible intelligent decisions based on the received information, or by requesting further information for example only for a RoI. The PIT mechanisms have been categorized as transform domain, spatial domain, and pyramid structured and a bit plane method (BPM) was proposed, initially sending only the most significant bit (MSB) followed by lower significance bits [13]. An adaptive method is also proposed requiring complex image decomposition and quad-tree structures [13]. A scheme for progressive transmission of the RoI and background information has been proposed [14, 15]. In the present paper we propose a general methodology for power saving in embedded applications for image communications. This is critical for battery-powered systems where the imaging application can work satisfactorily with a low resolution image. We restrict our analysis to system deployments with battery-powered sensor nodes with low power microcontrollers, and assume the base station to have sufficient resources to process the image data received from the sensor nodes.

These assumptions are justified by the majority of sensor network configurations. Thus, simplified operations such as parsing of image data to extract the DC coefficients or RoI can easily be performed on a visual sensor node. This minimal information aids the process of object detection at the base station with the possibility to request further image data, if needed. We also assume the transmission power consumption to be proportional to the number of bytes transmitted. We propose to send only DC coefficients in the first layer to create a coarse quality image at the base station. Subsequent transmissions of image data can take place on request from the base station by sending AC coefficients or RoI data. As an additional saving we propose not to send the headers and tables (quantization, Huffman) of the JPEG compressed file and assume their availability at the base station after receiving the first image. This simple reduction can result in substantial savings in the image data transmitted over the deployment lifetime of VSNs.

This paper has the following contributions: i) Power reduction achieved by not sending fixed information such as tables from the compressed image file. ii) Proposes an initial image subset transmission, that is, only the DC coefficients and sending successive refinements by sending some or all AC coefficients. iii) Introduces methodology to extract and transmit RoI image data based on coordinates provided by the base station.

The remainder of the article is organized as follows: first, an overview of the related literature is presented in section 2. Then theoretical background is described in section 3. In section 4, the methods and models used in the proposed work are explained. Sections 5 and 6 illustrate and discuss the experimental results that are obtained by implementing the proposed work, respectively. Finally, our concluding remarks are presented in section 7.

2. Related work

The transmission of JPEG images over wireless sensor nodes has been an interesting and well-researched problem. Image processing and transmission is often used in remote environmental monitoring, medical, and security applications. While JPEG is a compression standard, JPEG File Interchange Format (JFIF) describes the format for transport of compressed images[2] [16, 17].

The viability of sending a difference object only (rather than transmitting a full image) extracted using a field programmable gate array (FPGA) from a background image over a multihop wireless sensor network has been described but the power consumption for processing and maintaining the background image could be substantial [18]. For reliable communications they propose a custom protocol to overcome transmission errors that only allows communications between sources and sink until the whole image is transmitted. Another scheme proposes object detection in sensor networks to reduce false positives and hence reduce image data transmission [19, 20]. They propose the use of low level computer vision techniques for detecting an object. The node maintains a background model and the image processing after object detection is based on the discrete wavelet transform (DWT). The use of image processing to discard the images with no interesting object is described for a solar-powered satellite-based remote monitoring system [21]. It can balance the image quality against the power budget for continued system operation. The image compression parameters are modified to investigate its effect on energy dissipation, bandwidth required, and quality of image received [22]. This results in the creation of tables for each parameter, from which a particular configuration can be selected.

Wavelet-based compression methods are used to exploit the energy reduction [23, 24]. An interactive quad tree decomposition using peak-signal-to-noise (PSNR)-based rules provided better results than bit plane

[2] Hamilton E. (1992). JPEG File Interchange Format [online]. Website https://www.w3.org/Graphics/JPEG/jfif3.pdf [accessed 15 02 2020].

methods [9]. JPEG and JPEG2000 transmission has been compared for packet losses but no energy model has been described [25]. A low-delay bandwidth-efficient system with an automatic repeat-request (ARQ) scheme has been proposed to transmit the sensitive section of the bit stream. The paper also proposes a relatively simple forward error correction (FEC) scheme to transmit the rest of the image data [26].

Various modes for JPEG transmission like just DC, DC and a subset of selected AC coefficients, or full JPEG have been described [27]. However, the selection of a particular subset does not incorporate any successive refinements over the previously transmitted subset and needs preselection to code only the selected number of coefficients. The implementation is based on very large-scale integration (VLSI) architecture. A scheme is discussed in which only a subset of an 8×8 image block is selected for processing, reducing the energy consumption [2]. However, the selection of coefficients is fixed and independent of application or image characteristics. Some PIT schemes were proposed using discrete wavelet transform (DWT) coding. A method for progressive transmission that transmits the image data using a modified zero tree algorithm can handle the overlapping regions[3] [28]. A comparison of RoI-based schemes is proposed for progressive transmission of images [12]. The progressive transmission could be based on sending the MSBs of each coefficient followed by bits from the least significant bits (LSBs) or by selecting a subset of coefficients. A singular value decomposition (SVD)-based algorithm for RoI selection of images is also proposed. For JPEG2000, although RoI offers a better compression rate, it not possible to choose a RoI after the image has been coded and its position must be known beforehand. A DCT-based method is proposed where after initial data transmission the receiver or base station could request a refined RoI but the reconstruction requires inverse DCT at each step, leading to a high computation cost. An initial coarse image followed by a RoI is proposed but is based on quad tree decompositions [9].

Some schemes were proposed that require computing resources that are either not available at the sensor node or would increase energy consumption. A progressive scheme is proposed by dividing the image into blocks based on smoothness criteria [11]. Similarly quad tree coding based on the JPEG2000 algorithm requiring multiple scans is proposed [9]. An algorithm based on partitioning trees for progressive transmission and RoI extraction similar to JPEG2000 is proposed [29]. The packet size for transmission is 400 bytes but also used 26 bytes of overhead data. MSB to LSB data transmission with error correction coding for uncompressed data has been proposed [30]. The scheme is based on uncompressed data due to increases in wireless link speeds, error prone compressed image data, and easy error recovery with uncompressed data.

Incorporating user interaction to select the image quality and regions has received little attention. An interactive image transmission system for mobile wireless networks has been proposed that can tailor the image data based on the image content and network bandwidth [31]. The reduction in data size is achieved by sending a low quality image except for the RoI. This requires significant processing, which might not be available on a low power sensor node [31, 32].

The idea of not sending the header information (few bytes) is proposed for bilevel compression algorithms such as JBIG2 [3]. Change coding is also proposed using a bilevel image to only transmit the RoI in the change frame. A scheme is proposed for adding a two-byte counter with every data packet to minimize lost packet retransmissions in image sensor networks [33]. This helps to reduce the number of lost, repeated, and out of order packets. Our work differs from the earlier work as we propose to send only the compressed image data

[3]Uwe Rauschenbach (2007). Progressive Image Transmission Using Levels of Detail and Regions of Interest [online]. Website `http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.149.920&rep=rep1&type=pdf` [accessed 15 02 2020].

without the associated headers and JPEG compression tables. We propose to transmit selected elements of compressed JPEG bit-stream (DC and AC) based on requirements from the base station. We contend that in this way only the important information suiting the application gets transmitted, hence saving the premium power at the sensor node. We also propose an algorithm (see Algorithm 1) for RoI extraction based on the restart markers from JPEG compressed data derived from the coordinates transmitted by the base station.

3. Background

In this section we briefly describe the relevant features of JPEG compression standard that are helpful to understand the later sections. For a true color image the red green blue (RGB) values are transformed into YCrCb values, to disassociate luminance component Y from the less important Cr and Cb (chrominance) components.

3.1. JPEG compression

JPEG is a block-based image compression algorithm in which the image is divided into 8×8 image blocks before applying the operations shown in Figure 2. All the process blocks shown highlighted in Figure 2 are lossless except quantization. As a result of discrete cosine transform (DCT), 64 coefficients are obtained. The first coefficient is the DC coefficient (labeled 0 in Figure 3a), whereas the remaining 63 values are AC coefficients (Figure 3a) with the numbers showing their order and importance for image reconstruction. The objects of interest in an image for security and medical applications are often many times larger than an 8×8 pixel block. DC coefficient is the average of the 8×8 block pixel values and represents the coarse or low level details in the image. AC coefficients, on the other hand, represent the fine details in the image and can be up to a maximum of 63 values for an 8×8 block. However, due to the process of quantization and rounding, there are generally far fewer AC coefficients per block. In order to decode a JPEG compressed image, inverse operations (Figure 2) are applied to yield the original image.

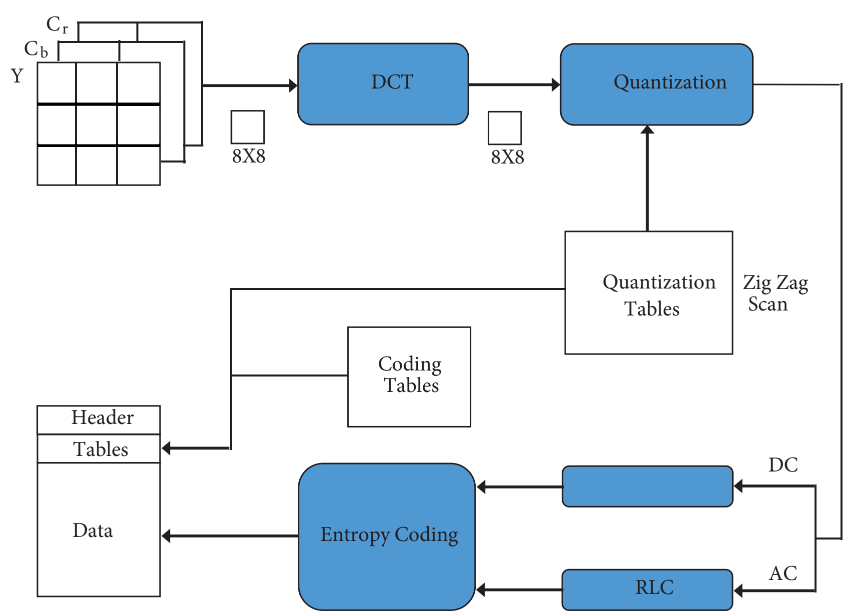

Figure 2. JPEG compression block diagram.

3.2. JPEG restart markers

Restart markers are an error-resilience scheme present in the compressed JPEG stream and allow resynchronization in the case of an error in the image bit stream. These markers occur in the compressed stream with a value from 0xFFD0 to 0xFFD7 (Figure 3b) and then repeat starting at 0xFFD0. Each decoding marker encapsulates a specified number of minimum coding units (MCUs), which is specified by the two bytes following the DRI ($0xFFDD$) marker that defines the restart interval. Thus, for an image, it is possible to relate the MCU to a particular location in the image by interpolation. If the decoder does not find the specified number of MCUs following a restart marker in the compressed image stream, it can discard the data and tries to locate the next marker to synchronize. An additional benefit is that restart markers allow for independent decoding allowing multithreaded JPEG encoders and decoders. A restart marker regulation technique for error robustness is proposed for preprocessing the restart markers at the decoding side [34].

0	1	5	6	14	15	27	28
2	4	7	13	16	26	29	42
3	8	12	17	25	30	41	43
9	11	18	24	31	40	44	53
10	19	23	32	39	45	52	54
20	22	33	38	46	51	55	60
21	34	37	47	50	56	59	61
35	36	48	49	57	58	62	63

(a)

0xFFD0	…..	0xFFD7	0xFFD0	…..	0xFFD7

(b)

Figure 3. (a) Zig-zag coding sequence for DCT coefficients, (b) restart markers.

3.3. Quantization parameter

The quantization parameter (QP) has an important role for compression in that a higher quantization value can truncate a smaller coefficient value to 0. A JPEG image can have a quality value from 0 to 100, with 92 being the default. A common measure of image quality is the mean square error (MSE) and peak-signal-to-noise (PSNR) defined as follows:

$$MSE = \frac{1}{MN} \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} \left[X(i,j) - Y(i,j) \right]^2, \tag{1}$$

where X and Y are image arrays of size $N \times M$.

$$PSNR = 10\log_{10}(maxValue^2/MSE), \tag{2}$$

where $maxValue$ for an $8-bit$ image is 255.

A plot showing the relationship between the quality values and corresponding (PSNR) values for the images in Figure 4 is shown in Figure 5. The rise in PSNR is much steeper for values beyond 92% as at that point the quantization step, which is the main lossless step in JPEG compression, loses its significance. JPEG images were converted to bitmap (BMP) images for the purposes of calculating the PSNR using equation 2.

4. Methods and models

In this section, we provide details of the methods used to reduce the amount of image data to be communicated to the base station from a sensor node. The JPEG compressed image after its capture is available at the sensor node for further processing. We propose simple processing comprising parsing of the compressed JPEG data to identify and discard the static meta data, extract the DC and AC coefficients, and extract the RoI given the pixel coordinates. The energy saving is obtained by transmitting only the DC coefficients so that additional image data are only transmitted if required by the base station. The selected images are shown in Figure 4 and represent a range of resolutions and image complexities. All images were encoded in JPEG by using a quality value of 75.

4.1. JPEG headers and tables

The JPEG image headers and compression tables do not change from one image to another; thus it helps to transmit only the compressed image data and not this fixed information. As shown in Table 1, the JPEG markers SOS and EOI mark the image data. The information preceding the SOS marker comprises headers and tables. We propose not to send the compressed data from the beginning to the SOS due to its significant size and because it becomes available at the base station after the first image is received.

Table 1. JPEG markers.

Marker	Representation	Description	Size(bytes)
SOI	0xFFD8	Start of Image	2
APP0	0xFFE0	Application Marker	16
DQT	0xFFDB	Define a Quantization Table	132
S0F0	0xFFC0		17
DHT	0xFFC4	Define Huffman Table	418
SOS	0xFFDA	Start of Scan	12
EOI	0xFFD9	End of Image	2

4.2. Progressive transmission

For progressive transmission of a JPEG image over a power-constrained device, there is a trade-off between the power consumed for image transmission and the corresponding image quality achieved at the base station. The DC coefficient is the most important subset of the compressed image data and it can be used to generate an image of sufficient quality to determine the presence of an object of interest. The image may need additional

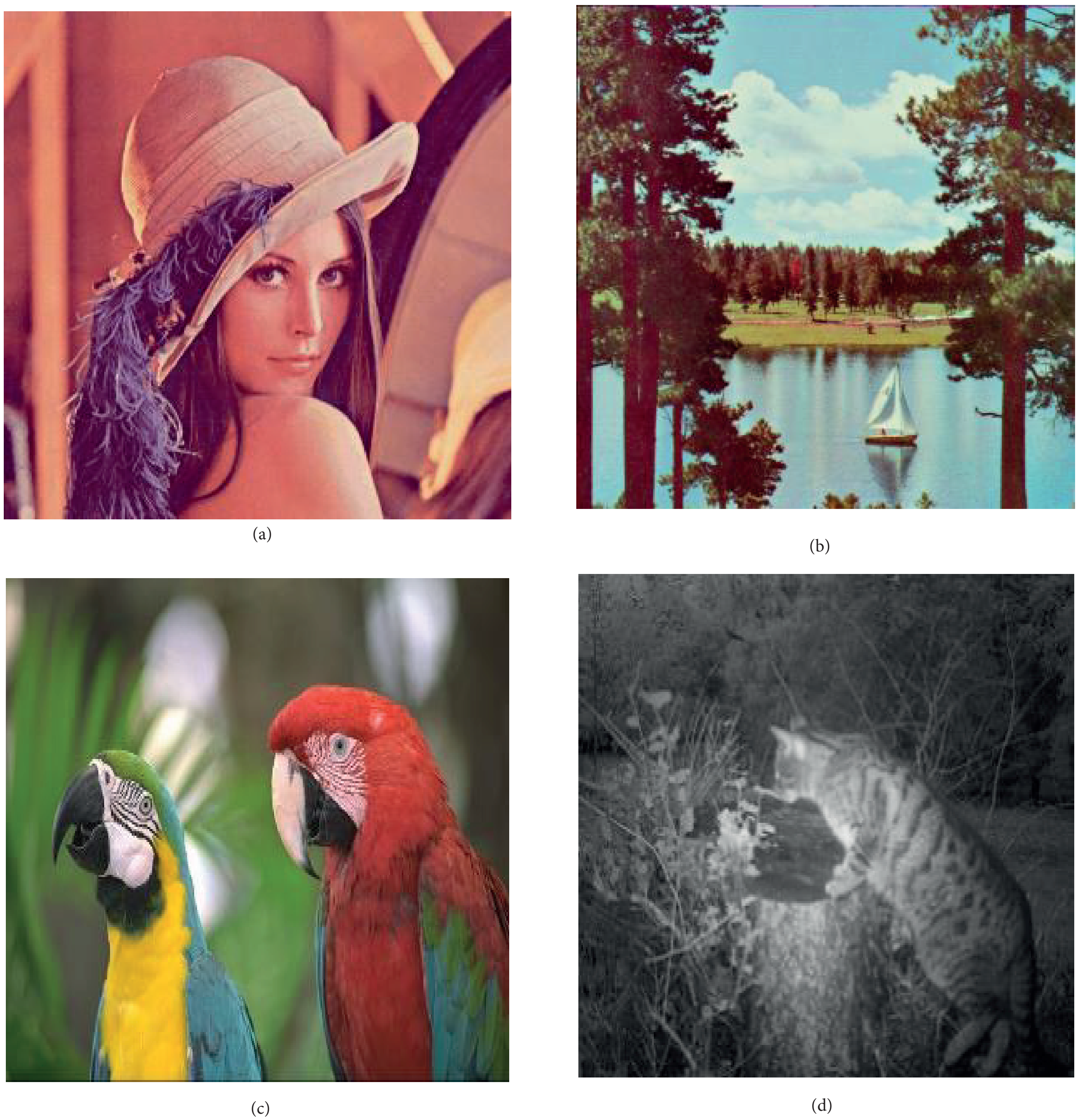

Figure 4. Selected images (a) Lena, (b) Lake, (c) Parrots, (d) Cat.

coefficients to be transmitted after the initial DC transmission. We divide the total image data into two groups. The first group comprises the DC coefficients only, whereas the second group contains the remaining image details. The second group or class of data will only need to comprise the AC coefficients as the DC coefficients (and other supporting information, tables, etc.) are already available at the base station. Although

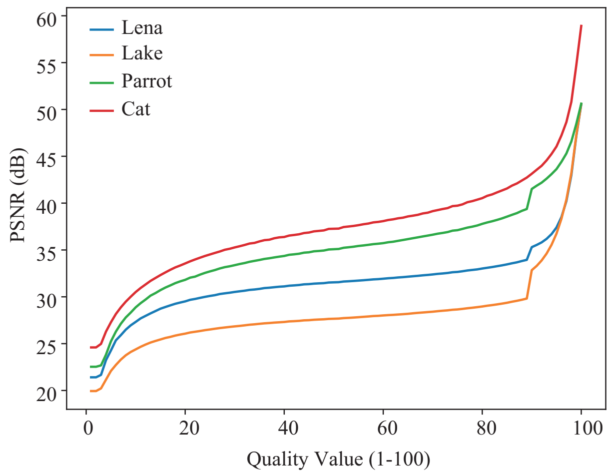

Figure 5. Quality value vs. PSNR plot for the selected images.

the progressive refinement of an image could take place by transmitting AC coefficients one by one in their order of importance from the image macro blocks, for simplicity we consider sending AC coefficients in larger groups in the zig-zag ordering sequence shown in Figure **??**. These coefficients can easily be extracted from the compressed JPEG image through parsing the image data. Comparative sizes of the DC and AC coefficients for the images are given in Table 2.

Table 2. Relative sizes of DC and AC coefficients.

Image	Resolution	Size (bytes)	DC coefficient (bytes)	AC coefficient (bytes)
Lena	512x512	51,008	4096	38312
Lake	512x512	70,350	4096	57440
Parrot	768x512	53,684	6144	33204
Cat	1152x864	152,494	15552	116366

4.3. ROI extraction

Many imaging applications can work well using a coarser image but may require finer details for only a specific region. We propose to define RoI extraction such that most of the processing is performed at the base station so that the sensor node only parses and returns the required RoI data. The overall process has the following three steps: i) an image containing only the DC coefficients is sent to the base station; ii) the image is analyzed at the base station and coordinates for the required RoI data are sent to the sensor node; iii) the sensor node extracts and sends the RoI data to the base station.

The process for determining the coordinates of the required RoI in step ii is explained below with reference to Figure 6. The image has a size of 512×512 pixels and thus it comprises 4096 MCUs (64×64 of size 8×8). The DRI marker has value 16 and that means a restart marker after every 16 MCUs. We will determine the position of the RoI in terms of the restart markers that can be then be communicated to the sensor node from the base station. Let the width and height of image be $width_{img}$ and $height_{img}$, and the left-top and bottom-right coordinates for the rectangular area representing the RoI as shown in Figure 6 to be (x_{p1}, y_{p1})

and (x_{p2}, y_{p2}), respectively. The coordinates for the nearest MCU boundaries enclosing the RoI can be defined based on equations 3, 4, 5, and 6:

i) Coordinates in terms of MCUs:

$$(x_{m1}, y_{m1}) = \left(\left\lfloor \frac{x_{p1}}{8} \right\rfloor\right), \left(\left\lfloor \frac{y_{p1}}{8} \right\rfloor\right) \tag{3}$$

$$(x_{m2}, y_{m2}) = \left(\left\lfloor \frac{x_{p2}}{8} \right\rfloor\right), \left(\left\lfloor \frac{y_{p2}}{8} \right\rfloor\right) \tag{4}$$

ii) Size of the RoI in terms of MCUs:

$$width_{RoI} = (x_{m2} - x_{m1}) \tag{5}$$

$$height_{RoI} = (y_{m2} - y_{m1}) \tag{6}$$

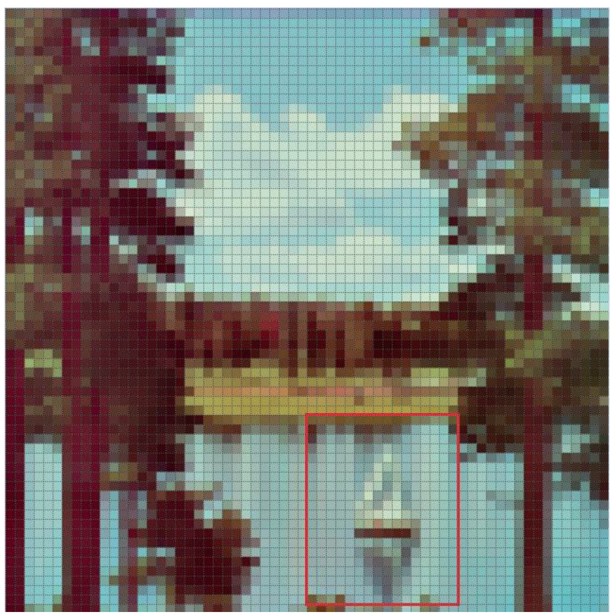

Figure 6. 'Lake' image with DC coefficients only. The 8×8 MCUs are marked by the grid and the RoI (enclosing a boat) is marked with red lines.

The image data can then be extracted starting at (x_{m1}, y_{m1}), in terms of the restart markers based on Algorithm 1.

5. Results

5.1. JPEG metadata

The fixed data such as encoding tables were transmitted only for the first transmission from the sensor node to the base station. Subsequent image transmissions could remove this information before transmission. A saving of around 1% can be obtained for the Lena and Lake images as shown in Table 3. The saving in total data to be transmitted depends to a large extent on the image resolution and the frequency of image transmissions. The savings are higher for small image resolutions and increase with the frequency of image transmissions.

Algorithm 1

begin:
- Initialize $x_m = x_{m1}$
- Initialize $y_m = y_{m1}$

while (MCU at (x_{m2}, y_{m2})not included) **do**
find restart marker at or before (x_m, y_m) for current row
do
copy restart marker
copy MCUs between current and next restart marker
while (not all MCUs in RoI's current row included)

$$x_m = x_m + \frac{width_{img}}{8} \tag{7}$$

$$y_m = y_m + 1$$

endwhile
end

Table 3. Relative sizes of redundant data.

Image	Resolution	Redundant data	Image data
Lena	512 x 512	593	50415
Lake	512 x 512	593	69757
Parrot	768x512	593	53091
Cat	1152x864	593	151901

5.2. Progressive transmission

The resulting images obtained from sending DC coefficients and adding AC coefficients in increments are shown in Figure 7 for the four images. The energy conservation through sending only the DC coefficients is directly proportional to the image size. Figure 8 shows a graph depicting the change in file size with an increase in the number of coefficients being transmitted. As can be seen for all images, there is a large contribution to the file size up to 20 coefficients, after which it levels off. The reason is that the AC coefficients occurring earlier in the zig-zag sequence are larger and have significant contribution to image reconstruction quality.

It seems reasonable considering the size increase by the first 5 AC coefficients that it is better to send only DC coefficients in the first layer and then wait for further data requests from the base station for additional AC coefficients or RoI.

5.3. ROI extraction

As a result of running the steps in Section 4.3 for Figure 6, the information request that gets passed to the sensor node is: (a) data following the 23^{rd} to 32^{nd} occurrences of $0xFFD1$, (b) data following the 22^{nd} to 31^{st} occurrences of $0xFFD5$. The result of embedding the full image data for the selected RoI for image in Figure 6 is shown in Figure 9. This makes better decision making possible at the base station regarding object detection within the selected RoI at a much lower cost.

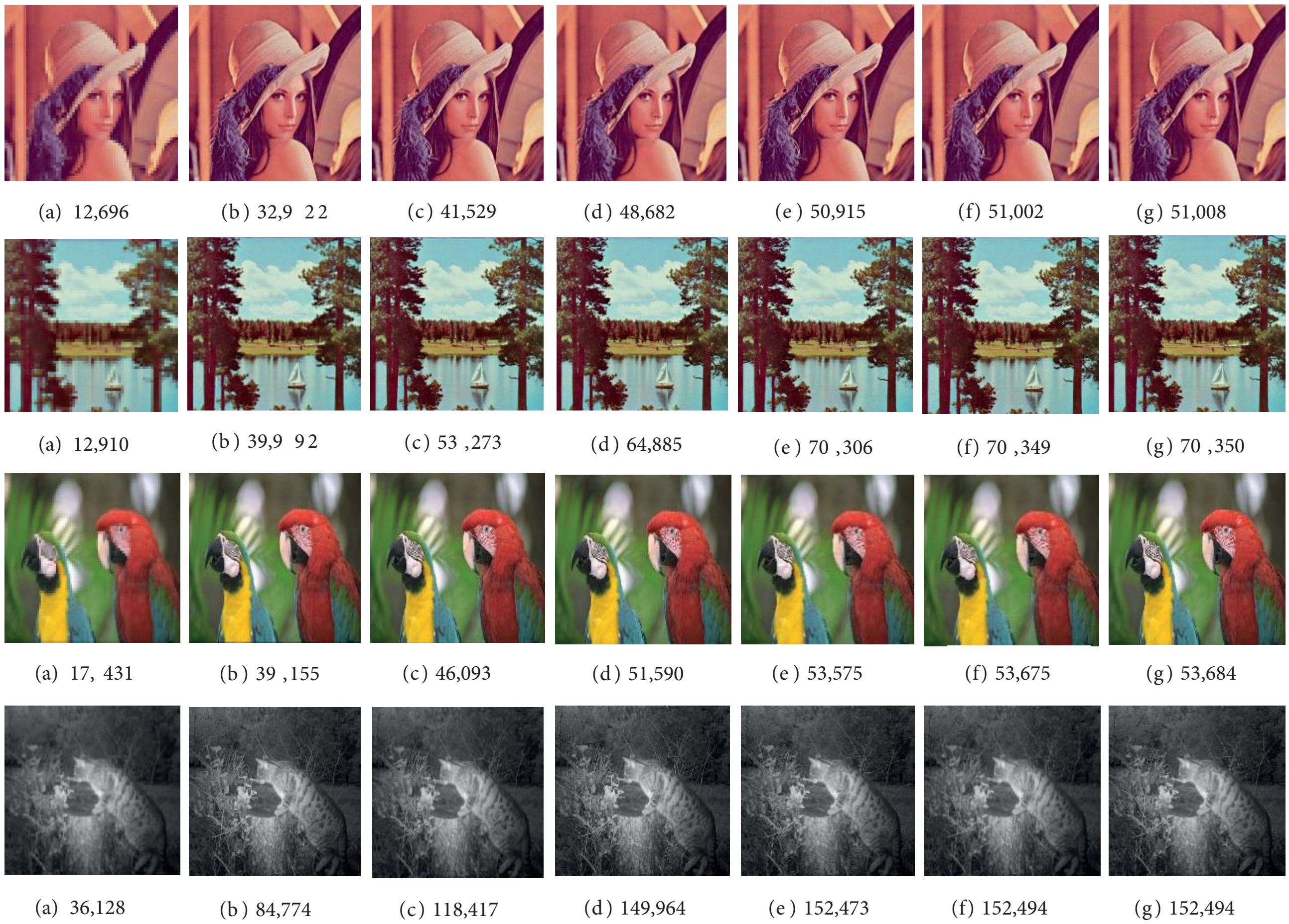

Figure 7. Images from left to right show (a) only DC, (b) DC+5AC, (c) DC +10AC, (d) DC +20AC, (e) DC +40AC, (f) DC +50AC, (g) DC+All AC. The values below each image shows file size (bytes).

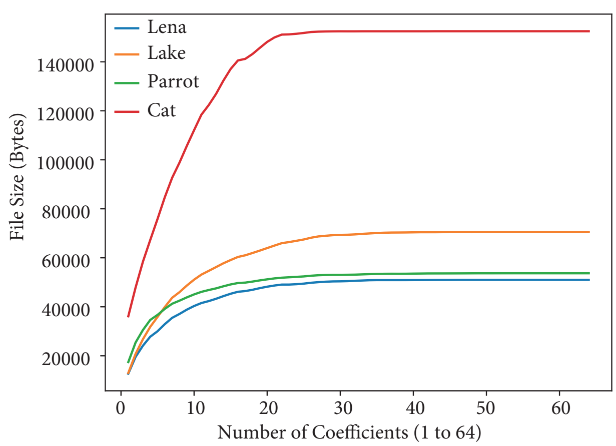

Figure 8. File size vs. number of coefficients for the selected images.

Figure 9. Lake image with the RoI filled with AC coefficients.

5.4. Energy consumption

The energy consumption for data communication is proportional to the number of bytes. Thus, instead of providing absolute measures for energy consumption for a full JPEG image versus our proposed data reduction, we assume it to be proportional to the data size to be transmitted.

5.5. Comparison with other methods

In this section we provide a comparison of our results with those of two other methods reported in the literature. The authors proposed sending a selection of the important AC coefficients [2]; however, depending on the requirements and image complexity it may not always yield the requisite results. The methods in previous studies [2, 27] propose to send DC coefficients only later supplanted by AC coefficients but only in fixed configurations. In comparison to sending a triangle of AC coefficients, our method of progressive refinement has the following advantages:

- The initial transmission comprising just the DC coefficients reduces the power consumption to minimal.
- We have proposed a dynamic system that can adjust to changes in lighting conditions and image complexity where more or less details need to be sent. The requested data can progressively add to the data already received and this additional information can be terminated at any stage. Moreover, it gives an opportunity to the observer to request additional refinement data in case a better quality image is required.
- The size increase by sending even a few additional (say first 5) coefficients is many times that of a DC image; therefore, it is better to request the RoI rather than a refinement (with 5 coefficients overall) of the full image.

The refinement of sending RoI data also has its merits. The scheme provides a much higher resolution image quality for the selected RoI, resulting in better decision management at the base station. Correspondingly, much less overall data needs to be transmitted for example compared to additional AC coefficients.

6. Discussion

The wireless channels for embedded applications need to conserve the limited battery energy to provide sensing over a longer duration. The transmission of only the DC coefficients from compressed JPEG images not only optimizes the low bandwidth channel but also enables identification of the objects of interest as determined by the application. It is a much better scheme compared to bit plane coding because that requires bit extraction (a costly process at the sensor node). Some schemes [2] only preselect a subset of coefficients, which might not be suitable for the application. Instead we propose a dynamic system where after a first coarser DC image the base station can request further information. This additional information could relate to the whole image as additional AC coefficients or may be restricted to a particular RoI. The proposed scheme for RoI extraction based on the restart markers provides an energy efficient method to send additional information just by parsing the JPEG compressed stream. This is preferable to other processes for RoI data extraction that would need decoding and encoding of image data. Our implementation does not rely on complex computations [9, 12] or specialized hardware [27] but relies only on the JPEG generated by the camera and simple parsing operations that can be performed by a low power sensor node. Most cameras for embedded applications provide a JPEG encoded stream by default and thus the sensor node only needs to process the encoded stream to extract the relevant information. The cameras firmware may differ in terms of the uses of DC and AC tables and Huffman tables, but these parameters remain constant from one image capture to the next. These comprise a substantial portion of the image data that is transmitted with every picture although they are constant data. We contend that these redundant data can easily be recreated at the receiver or base station, which invariably is equipped with more powerful processing resources unhindered by battery power. The proposed scheme can be used advantageously for security applications where cameras are deployed in static configurations and the only change is the periodic change in the natural or artificial lighting conditions. This can save bandwidth for power critical applications. The potential applications for RoI extraction are in medical and security fields where the human operator may require a better image resolution fulfilled by requesting full image data for a particular RoI in order to make critical decisions.

7. Conclusions and future work

We have proposed a simple and efficient method for transmitting the salient image data subset of a JPEG image by initially sending the DC coefficients only that can later be supplemented by AC coefficients or selected RoI data as required for image refinement. We propose that it is sufficient to transmit the headers and tables only once with the first image, and later save on image transmissions by sending the actual image data only. The proposed schemes not only aid in meeting the imaging application needs but also enable transmission of an image data subset, hence prolonging the deployment time of the resource-constrained embedded device. In future work, we intend to apply the proposed method to IoT devices and measure its efficiency.

References

[1] Al-Najdawi N, Tedmori S, Alzubi OA, Dorgham O, Alzubi JA. A frequency based hierarchical fast search block matching algorithm for fast video communication. International Journal of Advanced Computer Science and Applications 2016; 7 (4): 447-455.

[2] Mammeri A, Khoumsi A, Ziou D, Hadjou B. Energy-efficient transmission scheme of JPEG images over visual sensor networks. In: 2008 33rd IEEE Conference on Local Computer Networks (LCN); Montreal, QC, Canada; 2008. pp. 639-647.

[3] Khursheed K, Imran M, Ahmad N, O'Nils M. Efficient data reduction techniques for remote applications of a wireless visual sensor network. International Journal of Advanced Robotic Systems 2013; 10 (5): 240-249.

[4] Göse E. Adaptive Wiener-turbo systems with JPEG & bit plane compressions in image transmission. Turkish Journal of Electrical Engineering & Computer Science 2011; 19: 141-155.

[5] Saida R, Kacem YH, Bensaleh MS, Abid M. A model-based transformation framework for designing and analyzing wireless sensor networks. Turkish Journal of Electrical Engineering & Computer Science 2018; 26: 3274-3286.

[6] Alzubi JA, Manikandan R, Alzubi OA, Qiqieh I, Rahim R et al. Hashed Needham Schroeder industrial IoT based cost optimized deep secured data transmission in cloud. Measurement 2020; 150: 107077-107100.

[7] Yan E, Zhang K, Wang X, Strauss K, Ceze L. Customizing progressive JPEG for efficient image storage. In: 9th USENIX Workshop on Hot Topics in Storage and File Systems (HotStorage 17); Santa Clara, CA, USA; 2017. pp. 26-32.

[8] Marcellin MW, Gormish MJ, Bilgin A, Boliek MP. An overview of JPEG-2000. In: 9th USENIX Workshop on Hot Topics in Storage and File Systems (HotStorage 17); Santa Clara, CA, USA; 2017. pp. 523-541.

[9] Lim N, Kim D, Lee H. Interactive progressive image transmission for realtime applications. IEEE Transactions on Consumer Electronics 2010; 56 (4): 2438-2444.

[10] Santa-cruz D, Grosbois R, Ebrahimi T. JPEG 2000 performance evaluation and assessment. Signal Processing: Image Communication 2002; 17 (1): 113-130.

[11] Dhara BC, Chanda B. A fast progressive image transmission scheme using block truncation coding by pattern fitting. Journal of Visual Communication and Image Representation 2012; 23 (2): 313-322.

[12] Baeza I, Verdoy JA, Villanueva-Oller J, Villanueva RJ. ROI-based procedures for progressive transmission of digital images: a comparison. Mathematical and Computer Modelling 2009; 50 (5): 849-859.

[13] Chang RC, Shih TK. Innovative decomposition for progressive image transmission. Asian Journal of Health and Information Sciences 2006; 1 (2): 204-227.

[14] Han C, Sun L, Du Q. Securing image transmissions via fountain coding and adaptive resource allocation. In: 2016 IEEE 83rd Vehicular Technology Conference (VTC Spring); Nanjing, China; 2016. pp. 2404-2408.

[15] Zhu F. Estimating left ventricular volume with ROI-based convolutional neural network. Turkish Journal of Electrical Engineering & Computer Science 2018; 26: 23-34.

[16] Alzubi OA, Chen TM, Alzubi JA, Rashaideh H, Al-Najdawi N. Secure channel coding schemes based on algebraic-geometric codes over Hermitian curves. Journal of Universal Computer Science 2016; 22 (4): 552-566.

[17] Alzubi OA, Alzubi JA, Dorgham O, Alsayyed M. Cryptosystem design based on Hermitian curves for IoT security. The Journal of Supercomputing 2020: 1-24.

[18] Aziz SM, Pham DM. Energy efficient image transmission in wireless multimedia sensor networks. IEEE communications letters 2013; 17 (6): 1084-1087.

[19] Ur Rehman YA, Tariq M, Sato T. A novel energy efficient object detection and image transmission approach for wireless multimedia sensor networks. IEEE Sensors Journal 2016; 16 (15): 5942-5949.

[20] Alzubi OA. An empirical study of irregular AG block turbo codes over fading channels. Research Journal of Applied science, Engineering, and Technology 2015; 11 (12): 1329-1335.

[21] Nazir S, Fairhurst G, Verdicchio F. WiSE – a satellite-based system for remote monitoring. International Journal of Satellite Communications and Networking 2017; 35 (3): 201-214.

[22] Taylor CN, Dey S. Adaptive image compression for wireless multimedia communication. In: IEEE International Conference on Communications (ICC 2001); Helsinki, Finland; 2001. pp. 1925-1929.

[23] Aziz SM, Pham DM. Energy efficient image transmission in wireless multimedia sensor networks. IEEE Communications Letters 2013; 17 (6): 1084-1087.

[24] Manhas EB, Brante G, Souza RD, Pellenz ME. Energy-efficient cooperative image transmission over wireless sensor networks. In: 2012 IEEE Wireless Communications and Networking Conference (WCNC 2012); Paris, France; 2012. pp. 2014-2019.

[25] Pekhteryev G, Sahinoglu Z, Orlik P, Bhatti G. Image transmission over IEEE 802.15. 4 and ZigBee networks. In: 2005 IEEE International Symposium on Circuits and Systems (ISCAS 2005); Kobe, Japan; 2005. pp. 3539-3542.

[26] Weerackody V, Podilchuk C, Estrella A. Transmission of JPEG-coded images over wireless channels. Bell Labs Technical Journal 1996; 1 (2): 111-126.

[27] Bracamonte J, Ansorge M, Pellandini F. VLSI systems for image compression: a power-consumption/image-resolution trade-off approach. In: SPIE - The International Society for Optical Engineering; Denver, CO, USA; 1996. pp. 591-596.

[28] Sholiyi A, Alzubi JA, Alzubi OA, Almomani O, O'Farrell T. Near capacity irregular turbo code. Indian Journal of Science and Technology 2016; 8 (23): 1-9.

[29] Rubino EM, Centelles D, Sales J, Marti JV, Marin R et al. Progressive image compression and transmission with region of interest in underwater robotics. In: OCEANS; Aberdeen, UK; 2017. pp. 1-9.

[30] Yoon H, Jung Y, Lee S. An image sequence transmission method in wireless video surveillance systems. Wireless Personal Communications 2015; 82 (3): 1225-1238.

[31] Zhuang Y, Jiang N, Hu H, Chiu DKW, Li Q. Interactive transmission processing for large images in a resource-constraint mobile wireless network. Multimedia Tools and Applications 2017; 76 (22): 23539-23565.

[32] Mudeng V, Priyanto Y, Giyantara A. Image reconstruction for frequency-domain diffuse optical tomography. Turkish Journal of Electrical Engineering & Computer Science 2018; 26: 2287-2300.

[33] Tao D, Yang G, Chen H, Wu H, Liu P. Efficient image transmission schemes over Zigbee-based image sensor networks. Chinese Journal of Electronics 2016; 25 (2): 284-289.

[34] Tien-Hsu L, Hsiu-Hua H, Pao-Chi C. Restart marker regulation technique for progressive JPEG image coding in mobile communications. IEEE Communications Letters 2000; 4 (12): 411-413.