Energy Efficient Image Compression in Wireless Sensor Networks

S.A. Hussain\(^1\), M.I. Razzak\(^2\), A. A. Minhas\(^3\), M. Sher\(^2\), G.R Tahir\(^2\)

\(^1\)Air University, Islamabad, Pakistan
Email: nfaq.hussain@mail.au.edu
\(^2\)International Islamic University, Islamabad, Pakistan
Email: imran.mian@yahoo.com, m.sher@iiu.edu.pk, grtpak@gmail.com
\(^3\)Bahria University, Islamabad, Pakistan.
Email: abid_researcher@gmail.com

Abstract—Wireless Sensor networks are powered by battery due to which their lifetime is very limited. In camera an equipped wireless sensor node, life time of sensor network is decreased quickly due to battery and processing power constraints when image is processed and is transferred to the destination. The image compression not only helps to reduce the communication latency but also gives energy efficiency in wireless sensor networks. In this paper, we present a novel technique, Image Subtraction with Quantization of image (ISQ). We have shown that ISQ improves the energy efficiency of each node of the sensor networks consequently the lifetime of the sensor network is increased.

Index Terms—Wireless Sensor network, image compression, energy efficiency, lifetime of network,

I. INTRODUCTION

Sensor networks are comprised of low cost, and battery operated nodes which are used for remote monitoring and object-tracking for wide range of applications in different environments. Typically, a sensor consists of a Micro- Electro Mechanical System (MEMS), a low-power Digital Signal Processor (DSP), a radio frequency circuit, and a battery. Due to their low-cost and low-complexity nature, sensors are characterized by several constraints, such as a short transmission range, poor computation and processing capabilities, low reliability and data transmission rates, and a limited available energy [1]. Networks composed of multiple sensors should be designed with the aim to overcome these limitations by exploiting the energy between distributed nodes.

Although computer is much faster than human yet fails in image processing because heavy processing requires for images. As sensor nodes have limited battery, so to overcome the drawback of processing the image at sensor node it is better to send the image to the base station. As image is a large data, thus to transfer the image communication overhead is increased. To decrease this overhead compression is required. Transmission of data especially image is one of the most energy expensive tasks for a node. It is clear that communication of an image that is based on compression followed by transmission is generally more energy efficient than direct transmission of image without compression. Using data compression, energy can be reduced by reducing the number of bits that will be sent to the other end. While compression at a single node is not possible due to low power of node, thus distributed image compression requires. Min Wu and Chang Wen Chen discussed a novel technique for collaborative image compression in wireless sensor networks [2]. A shape matching method is applied to collaborative image coding to reduce energy consumption. Background from each camera node is segmented using light weight image subtraction method due to the nodes are stationary with respect to position. The background is send only once. Only the changes are sent from each camera node. The image is then reconstructed by fusing the background and changes sent.

Huaming Wu Abouzeid, presented two methods in order to to reduce energy consumption during image compression. In the he first method image is partitioned in to n number of blocks along the rows to perform 1-D wavelet. In the second phase image is portioned into m number of block to perform 1 D wavelet on column. The second method, image tiling technique is used with wavelet compression. Full captured image is sent to the nearest nodes that take part in compression in both methods [3]. Thus the camera equipped node life time is decreased due to sending the complete image to the nearest node and life time may also decrease due to communication required in distributed computation. As per our literature review, image compression in sensor network with respect to static position has not been studied in the literature. However, work done on image processing revolves around distributed image compression [1-11]. This paper presents a novel technique that compresses the images on camera equipped node by considering static node by position. The previous work is focused on node collaboration where as the presented a novel technique, Video Subtraction with Quantization (VSQ) of each frame. This approach saves lot of energy of camera equipped node as well as reduces the network communication overhead in collaborative image compression.
II. PROPOSED SYSTEM

Energy consumption is one of the most important factor to determine the sensor network life. Energy optimization is most complicated task because it involves not only reduce the energy consumption but it also distribute the data in network. Energy efficient data communication is one of the most important goal for wireless sensor network. The camera equipped nodes are fixed by position like security camera fixed in a room. Every camera-equipped node can respond to an image query by generating a raw image (e.g. sensing are snapshot in the case of a static wireless sensor network) and transmitting this compressed image to the sink (destination).

In this paper compressing and transmitting images in a wireless sensor network is considered and also new technique ISQ is discussed. The benefit discussed image compression technique in sensor networks can be illustrated in the following two cases. In the first case, nodes have extremely constrained computation power. Hence, a wireless node does not have enough computational power to completely compress a image. In the second case, even if nodes are not extremely computation powers constrained, but are battery operated. To overcome these issues a new approach is introduced when the sensors are fixed [3].

ISQ is proposed in this paper in which only the changes in the image are sent back instead of sending back whole image. The small changes are extracted from the image that are greater than threshold value 0. These small images are quantized before sending, and then resultant (small quantized images and their coordinates value) are sent towards the destination where the image is recomputed by using the image at destination (Previously save at the destination when the node is equipped in the environment) and small images with their coordinates values that are sent from the sensor node. This scheme is very simple and easy to implement while still satisfying image quality requirement. Simulation results show that our scheme increases the system lifetime by up to ten times and has total energy consumption comparable to the sending image without ISQ.

Camera equipped node contains memory (used to store image) and first time when node is fixed, image shown in figure 1 is stored in the memory of camera equipped node for next time processing and also sent back to the destination after distributed compression discussed in[3]. Image shown in figure 2 is captured after generating the query from destination. Changes are computed from the stored image at camera equipped node and captured image. As the node is fixed by position thus whole picture is same to the previous stored image, expect only few changes in the new picture shown in figure 2. These changes are computed shown in figure 3.

The system structure shown in figure 2 is divided into three phases, source image side, where a image is generated after query from the destination, and compressed by using the proposed method (ISQ), medium where the compressed image node by node moved towards destination node, and destination side, where decompression is applied according to the proposed method.

Figure. 1 Image capture when the node is fixed first time
As the node is fixed, thus there is no change in new image except the new body is introduced as shown in figure 3. So instead of sending the whole image, only changes are sent back. The picture in figure 4 is the resultant picture of after computing changes from figure 1 and figure 2.

Figure 2. System Structure
As there is only one change (monkey is shouted) in the computed picture as shown in figure 4. Thus the final image obtained at node with equipped with camera is shown in figure 5 after cropping the 50 by 50 area of the image. Image compression addresses the problem of reducing the amount of data required to represent a image. As wavelet based compression require much more processing power and battery time, to compress an image, which is mostly done by distributed compression thus to avoided wavelet based compression to save battery time a new compression technique is proposed in this paper, the difference of two image is calculated from the query generated captured image and stored image at sensor node, as the difference contain most of its parts black, thus from the difference of captured image, black pixel are discarded, by defining a 50/ by 50 size image crop from the image, and now apply the compression technique on it, quantize this small image to 4 bit, will also reduce the size of the image.

Compress the resultant image discussed above and sent back to destination. As most of the image consists of black pixel shown in fig 4 thus the compression ratio is increased more than ninety times depends upon the changes.
On the destination final image is recomputed by using the compress image after de-quantizing shown in figure 7 and stored image at destination as shown in figure 8.

III. SIMULATION AND RESULTS

The performance parameter is lifetime of sensor network, which is the time length (the time when the network starts communication until the time when the first node in the network fails due to insufficient energy). Transceiver energy dissipation model [3] is used. The energy consumed in reception per bit is

$$E_{RX} = \varepsilon_e$$

The energy consumed in transmission one bit is

$$E_{TX} = \varepsilon_e + \varepsilon_a d^\alpha$$

where $\varepsilon_e$ is energy consumed by the circuit per bit, $\varepsilon_a$ is the energy dissipated per bit per $m^2$, $d$ is the distance between a wireless transmitter and a receiver, and $2 \leq \alpha \leq 4$ is the path loss parameter [3]. The energy consumed to perform ISQ is

$$E_{ISQ} = \phi$$

Where $\phi$ is the energy consumed for image segmentation and quantization.

The quality of the image is measured by using the peak signal to noise ratio (PSNR), where $x(i,j)$ is the pixel value of the original image, $x'(i,j)$ is of the pixel value of the reconstructed image while $B$ is the no of bits per pixel of the original image [3]. The parameter values for wireless communication energy model (1) and (2) are the typical values $\varepsilon_e = 100 \times 10^{-12}$ and $\varepsilon_a = 50 \times 10^{-9}$ as for example in [3]. The communication range of node $d$ is chosen from 4 to 30 meters while $a$ is chosen 2.

Captured image is of 599 kb of size in jpeg format and 2048x1536 as shown in figure 1, this will reduce to 37 kb, after computation of changes as discussed above and shown in figure 3. As there is only one small change thus the cropped image is reduced to 1kb and after applying quantization this reduced to 558 bytes thus compression ratio is more than 1000 times. As wavelet based compression require much more processing power and battery time, to compress an image, which is mostly done by distributed compression thus to wavelet based compression avoided.

Simulation is done is MATLAB 7, Figure 9 shows the relation ships of energy consumption of compressed image using ISQ and without ISQ while distance vary from 4 to 30 meters. The energy consumed by without ISQ is .03uj while energy consumed by using ISQ is .00003 uj. Thus more than 100 time network life time is increased.

IV. CONCLUSION

In this paper, we have presented a novel technique, Image Subtraction Method with Quantization of image (ISQ). The whole computation of compression is done on the camera equipped node that has more work load of image processing. Increasing the lifetime of camera equipped node(s) increases the life time of the sensor network. Thus there is no needs of distributed Image Compression, because a very low processing power and very low battery is consumed in this system. Five different cases are discussed with different changes in the images, and the compression ratio is shown in figure 10. We have shown through simulation that ISQ improves the energy efficiency of camera equipped node of the sensor networks. The proposed technique is very simple, and easy to implement and gives the better results with respect to processing power. Performance evaluation has shown that ISQ has increased the life time of camera equipped node about ten times.

REFERENCES


