Application Layer Protocol for Image Transmission in Wireless Multimedia Sensor Networks

[I]Meepa Mathew, [II]Dhanya S
[I,II]Federal Institute of Sc. and Tech., Scholar in Dept. of Elec. and Communication, Ernakulam, India

Abstract
A Wireless Multimedia Sensor Network (WMSN) is a network of wirelessly interconnected devices like sensor nodes that are able to retrieve data from environment in the form of audio/video streams, still images and scalar sensor data. Real-time multimedia data such as video are usually loss-tolerant but require timely delivery in order to be useful to the image transmission applications like surveillance, environmental monitoring and person locator services. However, in Wireless Multimedia Sensor Networks (WMSNs), these mechanisms are not enough to provide an acceptable image quality and, thus, more reliable and efficient protocols adapted to these requirements are needed. This paper presents an efficient application layer protocol for energy efficient image processing and communication over wireless sensor networks. Simulation results show the effectiveness of this approach to make image communication over wireless sensor networks feasible, and efficient in terms of Packet error rate and throughput.

Keywords
Background subtraction, Image transmission, Object extraction, Wireless multimedia sensor networks

I. Introduction

The future will witness the next revolution through telecommunications technology to reach the ultimate goal of ubiquitous connectivity at anytime, anywhere, with anyone, and with any media. In recent years, the communications sector was one of the few constantly growing sectors in industry and a wide variety of new services were created. Two of the areas that have experienced a massive growth are multimedia communications and wireless communications. Based on this growth, there is an extensive demand for systems that combine these two areas to provide wireless multimedia communications. With the ever-increasing demand for Wireless Local Area Networks (WLAN), possibilities of transmitting a wide range of data like image with high resolution and videos over the wireless channels are increasing.

In recent years, the growing interest in the wireless sensor network (WSN) area have enabled many civilian and military applications, and several start-up companies and large corporations are investing considerable amounts of resources in this technology to provide wireless multimedia communications. A wireless sensor network consists of low power, low cost, multifunctional sensor nodes (SN) that are powered by small irreplaceable batteries and communicate over short distances. These sensor nodes are densely deployed in the area to be monitored and sense and transmit data towards the base station using data processing and communicating components in it. The data sensors sense physical phenomena such as motion, sound, heat, or light to initially identify and locate the target. In general, the sensor nodes in a WSN sense data and convey them to one or more high power nodes called the sink or the base station (BS) which do most of the complex processing. The sink (or BS) might be the final destination of the data or might act as a hub from where the data is sent to users over the wired network. Sensor networks are designed for data-only delay-tolerant applications with low bandwidth demands.

The integration of low-power wireless networking technologies with inexpensive hardware such as complementary metal–oxide semiconductor (CMOS) cameras and microphones is now enabling the development of distributed networked systems which is also called as wireless multimedia sensor networks (WMSNs), defined as networks of wireless interconnected smart devices that enable retrieving video and audio streams, still images, and scalar sensor data - [1], [2]. WMSNs will enable the retrieval of multimedia streams and will store, process in real-time, correlate, and fuse multimedia content captured by heterogeneous sources. In a wireless multimedia sensor network with both standard data sensors and video sensors, video sensors capture image or video of the target environment and process it either independently or triggered by standard data (e.g., motion, light) sensors. The processed image/video is streamed via aggregator nodes to the base station.

With the fast growing business in wireless access of multimedia information, visual communication over wireless channels has become an important service in multimedia communications. Image transmission services should be supported with a high wireless transmission bit rate within a wider allowable bandwidth. However, due to limited spectrum, it is difficult to achieve this during the direct transmission of raw images. As a result, image data should be processed before transmission in order to efficiently use the channel. The image processing algorithm for the purpose of wireless applications does not only have to provide good processing, but has to also offer robustness, as well as a low complexity. Different techniques used for image processing include background subtraction and object extraction (detection and extraction of moving object in frame) as in [3], etc. WMSNs are applied in different fields like multimedia surveillance sensor networks, traffic avoidance, enforcement and control systems, advanced health care delivery, automated assistance for the elderly and family monitors, environmental monitoring, person locator services and industrial process control for multimedia data transmission especially in the form of images. The main challenges faced for an efficient image transmission through wireless multimedia networks include limited bandwidth of cellular networks, restricted computational power, limited storage capability, battery constraints of the appliances, need of frequent retransmissions, lack of an efficient architecture, limited resources and an inefficient protocol.

The remainder of this paper is organized as follows. In Section II, the existing protocols for image transmission is mentioned and the scope of research is given in Section III. In Section IV, a brief explanation of the proposed image transmission protocol at application layer and image processing technique is given. The network setup and simulation results of the proposed work are shown in Section V. In Section VI, conclusion and future scope of the project are discussed.

II. Related Work

In recent years, with the availability of cheap, small size and low-power CMOS cameras and microphones, there is a strong interest in deploying WSNs for multimedia communication. Such Wireless Multimedia Sensor Networks, with the ability to gather multimedia information from the surrounding environment, is providing the impetus for extending the capabilities of WSNs for many new applications. However, the challenge is how to handle the large volume of multimedia data using sensor nodes that are severely constrained in both processing capability and energy. In addition to developing energy aware multimedia processing algorithms and architectures, it equally important to develop efficient communication strategies protocols to maximize the network lifetime while meeting the application specific Quality of Service (QoS) constraints such as latency, packet loss, bandwidth, and throughput. Several protocols have been put forward to achieve image transmission over WMSN which includes Reliable Synchronous Transport Protocol (RSTP), Energy Efficient and Reliable Transport Protocol (ERTP), Reliable Asynchronous Image Transfer **(**RAIT) as in [4]-[6] respectively.
RSTP aims at the reliable and synchronous transmission of images. To provide synchronization, the higher quality images from certain sensors are transmitted only after the reception of lower quality images from all sensors. Also, only parts of the spectrum are synchronized instead of the whole image. Even though the recovery of lost packets are achieved by retransmission of data using Negative Acknowledgment (NACK) packets packet loss rate is high and it needs a large scale of sensors and wireless links. Also it doesn't consider the resource limitations of network. The ERTP supports the transmission of images to achieve end-to-end reliability and to reduce the energy consumption. It uses a statistical reliability metric which ensures the number of data packets delivered to the sink exceeds the defined threshold. Lost packets are recovered using a Stop-and-Wait Hop-by-Hop Implicit Acknowledgment (SW HBH iACK) and a distributed algorithm is used for retransmission timeout (RTO) estimation, but the improper retransmission timeout estimate results in poor reliability. While the RAITP aims at the reliable transfer of an image using a double sliding window. According to this protocol, each sensor node in the network manages two queues - receiving queue for received packets and sending queue for generated packets and transit packets. One sliding window is used for the receiving queue to prevent packet loss caused by communication failure between nodes and other sliding window is used for the sending queue, which prevents packet loss caused within the node due to network congestion. This protocol is not much supported because of its high energy consumption.

III. Scope of Research

The protocols mentioned in [5] and [6] provides reliability at the transport and network layers respectively, but the lack of an efficient image transmission protocol in the application layer results in the high packet error rates and loss of packets which necessitates the need of frequent retransmissions of packets which in turn results in the high energy consumption and high bandwidth requirement. This paper proposes a new image transmission protocol in the application layer to reduce the packet error rate and energy consumption.

IV. Image Transmission Protocol

A. Image Transmission Protocol

A simple energy efficient image transmission protocol at application layer for WMSN is proposed here. The transmission protocol between the base station and the camera node/server node is illustrated in Fig. 1. The basic idea behind this protocol is dividing the image into a number of packets, embedding the packet ID and error detection mechanism. The protocol allows only one node to transmit packets to the base station at a time. When the base station (BS) wishes to collect image from server node, it will first establish a connection with the server node using its server IP and send a 'camera setup request'. If the server node is idle, then it will initialize it camera and replies with a positive acknowledgement (ACK). The BS then sends an 'image query request' for image capturing. The server node will capture the image and process the image ie; background subtraction. When BS wants to start an image transmission, first it broadcasts a small 'start-of-transmission message' to all nodes in the network. This message will forbid any nodes which are not part of the active image transmission link to send anything until they receive the 'end-of-transmission message'. Upon receiving the 'start-of-transmission message', the server node will send the image packets one-by-one depending on receiving ACK from BS. This is similar to the operation of 'Stop-and-Wait protocol'. After receiving all the packets from the server node, BS will send an 'end-of-transmission message' to stop the transmission. The received packets are combined to reconstruct transmitted image using which the current frame is also reconstructed and moving object is extracted. This mechanism ensures that only one image packet is sent at a time to avoid collision and congestion, and therefore to reduce packet loss and the associated energy cost of retransmission. In this protocol, every data packet is checked for correctness using parity check to reduce the Packet Error Rate (PER).

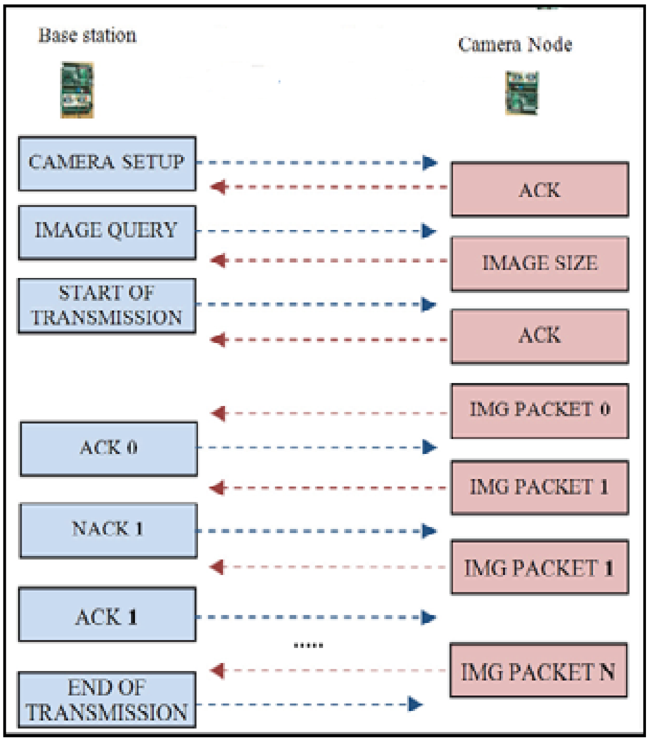

Fig. 1: Image transmission protocol at application layer for WMSN

B. Image processing

During image transmission, the direct transmission of a raw image requires high bandwidth and energy consumption for transmission will be high. To overcome this, the image is processed before transmission using background subtraction and object extraction.

In WMSN applications, the camera mote often has a fixed frame of view. In this case, to detect moving (updated) objects, background subtraction is a commonly used approach which is also known as foreground detection. The basic concept of background subtraction is to detect the moving objects from the difference between the current frame and the background image. The background image represents a static scene of the camera view without any moving objects. The background image must be regularly updated to adapt to the changes in the camera view.

The simplest way to implement this is to take an image as background and take the frames obtained at the time t, denoted by I(t) to compare with the background image denoted by B. Here using simple arithmetic calculations, we can segment out the objects simply by using image subtraction technique for each pixels in I(t). Take the pixel value denoted by P [I(t)] and subtract it with the corresponding pixels at the same position on the background image denoted as P[B]. Mathematically, it is expressed as:

$$P[F(t)] = P[I(t)] - P[B] \quad (1.1)$$

where, P[F(t)] is the difference image.

This difference image would only show some intensity for the pixel locations which have changed in the two frames. A threshold is put on this difference image to improve the subtraction.

$$| P [F (t)] - P [F (T+1)] | > \text{Threshold} \quad (1.2)$$

The difference image's pixels' intensities are 'thresholded' on the basis of value of Threshold. The accuracy of this approach is dependent on speed of movement in the scene. Faster movements may require higher thresholds.

Object extraction is a technique used for extracting foreground objects from background subtracted images. Initially, the region of interest is specified which contain all foreground objects to extract and as few background as possible. The pixels outside the region of interest form the sure background while the inner region define a super set of the foreground. Find the connected components in the super set of foreground to define a selection mask. This selection mask is used to extract the moving object from the background subtracted image.

C. Packet division and image reconstruction

The processed image is split into its RGB components and stacked horizontally and then it is divided into several packets with a unique packet id for transmission. Packets are delivered strictly in order at the BS. The BS collect all the packets and reconstruct the transmitted image by vertically stacking the RGB components of image. After reconstructing the background image and current frame, moving object is extracted out at the BS.

V. Experimental Setup

A wireless multimedia sensor network with a BS and a server node is created using Matlab software. Server node is equipped with a camera to collect multimedia data ie; image and it is then transmitted to the BS. The protocol implementation and its functioning are shown as in Fig. 2 to Fig. 6 using Matlab GUI at BS. Axes is defined in the GUI to show the reconstructed image and a system log is implemented to display the activities like 'connection established', 'request send', 'waiting for ACK', 'transmission stops', etc.

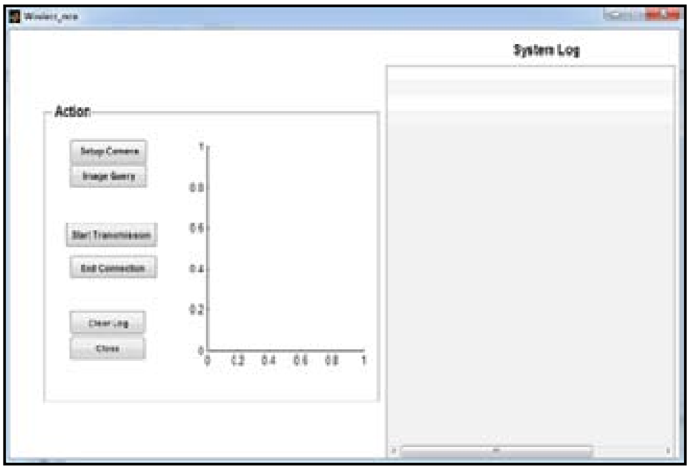

Fig. 2: GUI showing protocol setup

Fig. 3: Background frame and current frame displayed at server node

Fig. 4: Background subtracted image at server node

ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

Fig. 5: Reconstructed background frame and current frame displayed at BS

Fig. 6: Moving object extracted at BS

VI. Results

The characteristics of the control messages used in the protocol are shown in Table 1. The efficiency of proposed protocol is analyzed based on the following parameters – Packet Error Rate (PER), Throughput, transmission delay, round trip delay. Table 2 summarizes the results of image transmission protocol.

A. Packet Error rate (PER)

Packet Error Rate (PER) is used to test the performance of the propose image transmission protocol. PER is the ratio, in percent, of the number of image packets not successfully received by client node to the number of image packets sent to the client node from the server node ie; PER = no. of error packets / total no. of packets received. A PER of 21.2% is detected for the current proposed application layer protocol.

Table 1: Characteristics of Application Layer Control Messages

Message	Features		
Image packet	Packet ID (1 byte)	Image data (N bytes)	Error check (2 bytes)
SC	Setup Camera (2 bytes)		
IQ	Image query (2 bytes)		
Image size	Image size (3 bytes)		
ST	Start-of-transmission (2 bytes)		
TS	Transmission Stop (2 bytes)		
CUT	End connection (2 bytes)		
ACK	Positive acknowledgement (2 bytes)		
NACK	Negative acknowledgement (2 bytes)		

B. Throughput

Throughput refers to the amount of data transferred from one sender to receiver or processed in a specified amount of time in a network. Data transfer rates for networks are measured in terms of throughput. Typically, throughputs are measured in kbps, Mbps and Gbps. The image transmission protocol used here provides a throughput of 26kbps for a packet size of 194.

C. Transmission Delay

In a network, transmission delay or packetization delay is the amount of time required to push all of the packet's bits into the wire. It is a function of the packet's length and has nothing to do with the distance between the two nodes. This delay is proportional to the packet's length in bits. The ratio of packet's length in bits to the rate of transmission will give the transmission delay. Transmission delay of the proposed image transmission protocol is measured to be 53.03µs.

D. Round trip delay

Round-trip time (RTT), also called round-trip delay, is the time required for a signal pulse or packet to travel from a specific source to a specific destination and back again. The image transmission protocol provides a round trip delay of 0.285s.

Table 2 : Results for Protocol Simulation

Parameters	Values
Packet Error Rate	21.2%
Throughput	26kbps
Transmission delay	53.03µs
Round trip delay	28.5ms

VII. Conclusion

The lack of an image transmission protocol at application layer in WMSN results in high packet loss, need for more number of retransmissions and thereby high energy consumption. To overcome this, an image transmission protocol at application layer was proposed for transmitting images between nodes in a WMSN. The protocol defines a specified structure for the capturing, processing and transmission of images. It divides the images into packets before transmission and it allows only one node to transmit at a time to avoid congestion and thereby packet losses. The amount of retransmissions are also controlled to save energy consumption. The evaluation of packet error rate using parity based error check mechanism and throughput shows that the protocol is energy efficient.

The future works include the implementation of image transmission protocol at application layer with image processing techniques based on FPGA.

VIII. Acknowledgement

I invoke my overwhelming indebtedness to Almighty God for the successful completion of this paper. I express my deep sense of gratitude to my research guide Ms. Dhanya S, Assistant Professor in Department of Electronics and Communication Engineering, Federal Institute of Science and Technology (FISAT), India for being a source of inspiration and constantly encouraging me to pursue new ideas.

References

[1] *I. F. Akyildiz, T. Melodia, and K. R. Chowdhury, "A survey on wireless multimedia sensor networks," Computer Networks, vol. 51, no. 4, pp. 921–960, 2007.*

[2] *S. Misra, M. Reisslein, and X. Guoliang, "A survey of multimedia streaming in wireless sensor networks," IEEE Commun. Surveys &Tutorials, vol. 10, pp. 18–39, 2008.*

[3] *Syed Mahfuzul Aziz and Duc Minh Pham, "Energy Efficient Image Transmission in Wireless Multimedia Sensor Networks", IEEE communications letters, vol. 17, No. 6, June2013.*

[4] *A. Boukerche, D. Yan, F. Jing, and R. Pazzi, "A reliable synchronous transport protocol for wireless image sensor networks," in Proc. 2008IEEE Symposium on Computers and Communications, pp. 1083–1089.*

[5] *T. Le, W. Hu, P. Corke, and S. Jha, "ERTP: energy-efficient and reliable transport protocol for data streaming in wireless sensor networks," Computer Commun., vol. 32, pp. 1154–1171, 2009*

[6] *J. H. Lee and I. B. Jung, "Reliable asynchronous image transfer protocol in wireless multimedia sensor networks," Sensors, vol. 10, pp. 1486–1510, 2010.*

Author's Profile

Meepa Mathew received the B.Tech degree in Electronics and Communication Engineering from Mahatma Gandhi University, Kerala, India, in 2011. Currently, she is doing her post graduation in Communication Engineering, Federal Institute of Science and Technology (FISAT), Kerala, India. Her current research area includes wireless communication.

Dhanya S received the Bachelor's degree in Electronics and Communication Engineering and her post graduation in Communication Engineering in Federal Institute of Science and Technology (FISAT), Kerala, India. Since 2013, she has been working as an Assistant Professor in Federal Institute of Science and Technology (FISAT), Kerala, India.