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Energy Efficient Image Transmission In Wireless Multimedia Sensor Networks

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ABSTRACT
This paper presents a novel architecture and protocol for energy efficient image processing and communication over wireless sensor networks. The key obstacle to communicating images over wireless sensor networks has been the lack of suitable processing Architecture and communication strategies to deal with the large volume of data. High packet error rates and the need for retransmission make it inefficient in terms of energy and bandwidth Practical results show the effectiveness of these approaches to make image communication over wireless sensor networks feasible, reliable and efficient.
Keywords:- Wireless sensor network, Image communication, ARM7, CMOS Camera, PIR sensor, ZigBee

I. INTRODUCTION

In Wireless Multimedia Sensor Network (WMSN), with the large volume of the multimedia data generated by the sensor nodes, both processing and transmission of data leads to higher levels of energy consumption than is any other types of wireless sensor networks (WSN). This requires the development of energy aware multimedia processing algorithms and energy efficient communication [1] in order to maximize network lifetime while meeting the QoS constraints.

A few protocols have been proposed to achieve image transmission over WSN [2]-[4].Reference [2] aims at providing a reliable, synchronous transport protocol (RSTP), with connection termination similar to TCP, but does not consider the resource limitations of WSN. Reference [3] presents an energy-efficient and reliable transport protocol (ERTP) with hop-by-hop reliability control, which adjusts the maximum number of retransmission of a packet. Reference [4] proposes another reliable asynchronous image transfer (RAIT) protocol. It applies a double sliding window method, whereby network layer packets are checked and stored in a queue, to prevent packet loss. With protocols providing reliability at the transport [3] or network layers [4], erroneous packets at the application layer can still be forwarded to the base station, requiring retransmission and associated energy cost [5]. In [6], the authors stated that multi-hop transmission of JPEG2000 images is not feasible due to interference and packet loss. This statement is also cited by other literature [5], [7]. In this paper, image transmission over multi-hop WSN is proved to be feasible, using a combination of energy efficient processing architecture and a reliable application layer protocol that reduces packet error rate and retransmissions. ARM 7 architecture is used to extract updated objects from the background image. Only the updated objects are transmitted using the proposed protocol, providing energy efficient image transmission in error-prone environments.

II. ARCHITECTURE FOR OBJECT EXTRACTION

The network processor performs some standard operations as well as customized instructions to support the operations of the wireless transceiver. It operates at a low clock frequency to keep the power consumption low. The image processing block runs at a high frequency to process images at a high speed. By default, it is in inactive mode (sleep mode with suppressed clock source), and can be quickly set into the active mode by the network processor whenever an object extraction task needs to be performed.

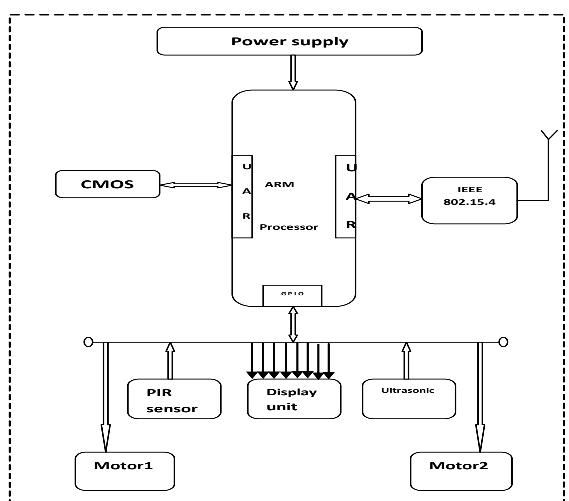

Fig. 1 Block diagram

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 [8]. The basic concept of this is to detect the 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. An algorithm must be applied to keep the background image regularly updated to adapt to the changes in the camera view. For background subtraction, the Running Gaussian Average appears to have the fastest processing speed and lowest memory requirements [9]. It is further optimized for ARM 7 implementation and is incorporated into the proposed WMSN system.

A. Background Subtraction

The Running Gaussian Average model [8] is based on ideally fitting a Gaussian probability density function on the last n values of a pixel. The background pixel value at frame n is updated by the running average calculation shown in (1).

$$B_n = (1 - \alpha)B_{n-1} + \alpha F_n$$

B. Object Extraction

The ARM7TDMI-S is a general purpose 32-bit microprocessor, offers high performance and very low power consumption. ARM architecture is based on RISC principles, instruction set and related decode mechanism are simpler than CISC Pipeline techniques employed ARM Processor supports both 32-bit and 16-bit instructions via the ARM and Thumb instruction sets.

The 3 parameters to be monitored are sensed using respective sensor and data is feed to ARM7 .Traditionally, embedded devices include two types of processors: a Microcontroller and a DSP to process signals. However, with the development of ARM processors, last two can be replaced by one single processor. This unit is the heart of the complete system.

It is actually responsible for all the process being executed. It will monitor & control all the peripheral devices or components connected in the system. In short we can say that the complete intelligence of the project resides in the software code embedded in the ARM 7.

The code will be written in Embedded C and will be burned or programmed into the code memory using a programmer.

An efficient object extraction algorithm has been implemented to detect portions of the current frame that is significantly different from the background image. It involves row and column scanning of the update signals (*U*) to deter- mine if the number of consecutive differences (1s) is greater than a pre-determined difference threshold. The proposed object extraction scheme, consisting of background subtraction, row/column scanning and threshold comparison blocks, was implemented and tested on ARM7. Table I compares the proposed architecture with [10] and [11], which have reported results for similar object extraction functions.

III. IMAGE TRANSMISSION PROTOCOL

A CMOS imaging chip is a type of active pixel sensor made using the CMOS semiconductor process. Fig 2 represents the CMOS camera Extra circuitry next to each photo sensor converts the light energy to a voltage. Additional circuitry on the chip may be included to convert the voltage to digital data. Neither technology has a clear advantage in image quality. On one hand, CCD sensors are more susceptible to vertical smear from bright light sources when the sensor is overloaded; high end CMOS sensors in turn do not suffer from this problem. On the other hand, cheaper CMOS sensors are susceptible to undesired effects that come as a result of rolling shutter.

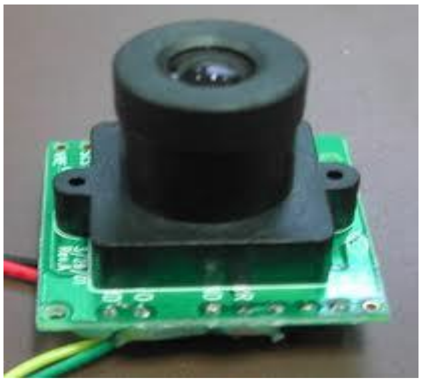

Fig.2 CMOS CAMERA

Transmitting image packets through multi-hop, the high packet error rate necessitates frequent retransmission, which is inefficient in terms of energy and bandwidth. The high packet error rate arises due to the following reasons.

1) Unpredictable data throughput of the wireless channels due to variations in noise levels.

2) Limitation of the size of packet queue in routers, because the sensor nodes have limited memory.

3) Inability to adjust image packet size based on link conditions to minimize packet error rate.

In contrast with other image transmission protocols [2]–[4] where multiple nodes can start data transmission at the same time, the proposed protocol allows only one node to transmit packets to the base station. In Fig. 3, when the base station starts an image transmission, first it broadcasts a small START-OF-TRANSMISSION message to all nodes in the network. This message will also pre-define the size of the image packet and forbid any nodes which are not part of the image transmission link to send anything until they receive the END-OF-

TRANSMISSION message. 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.

From our practical experiment with a multi-hop WMSN of the proposed ARM7, we can confirm that a JPEG2000 image couldn't be reconstructed at the base station when the standard 802.15.4 protocol was used. The test results in Table 2 show that the proposed queue control strategy significantly reduces Packet-Error-Rate (PER) and increases data throughput for multi-hop communications. Clearly, small sized packets exhibit better performance (throughput) than large sized packets. However, this may not be the case in other environments, for example where the SNR is lower. Without queue control, the image data flow is transparent to the intermediate nodes and this increases the probability of introduction of packet errors at the intermediate nodes. With queue control, the data packets are always checked for correctness using Cyclic Redundancy Checks (CRC) before forwarding. This reduces PER at the base station.

IV. NETWORK SET UP, TESTING AND RESULTS

The WMSN processing architecture presented in this paper, including a networking processor and the object extraction block, was implemented on a ARM7. To further reduce the size of the updated object and consequently the transmission energy, an efficient Discrete Wavelet Transform (DWT) processor [12] was used. Only the low-frequency sub-band [12] of the transformed object is trans-mitted. ARM7 prototypes were developed and connected to ZigBee. Each camera node includes a CMOS camera and a battery. The CMOS camera is a small size, low cost and low power Omni Vision OV7670/8 CMOS colour sensor.

A. Power Analysis

Table 2 presents data on power consumption of the image processing and the power consumption of this block reduces to only 0.3mW. The results reveal that the proposed architecture is suitable for use in low power applications. the proposed object extraction scheme has significantly reduced the energy required for image transmission. Experiments have confirmed that the total power used to process an image and to transmit. an updated (i.e. extracted) object of size 160x100 is ~20 times less than the power required to only transmit the original image of size 640x480. thereby reducing the possibility of collision and congestion.

B. Comparison with COTS based WSN

Software was developed to run the background subtraction and object extraction functions on an ATmega328p micro- controller based WSN node. In the active mode, the power consumption of the ATmega328p node at 16MHz, 3.3V, 25OC is about 11mW, while that of the proposed architecture on LPC 2148 at 12 MHz is 21.96mW (from Table 2). However, the ATmega328p system requires more than 2 seconds to complete the image processing task, while the proposed processing system completes the same task in only 49.15ms, i.e. more than 40 times faster. Consequently, the total energy consumption of the ATmega328p node is 22.8Mj

System	ATmega328p @16Mhz	LPC 2148 @12Mhz
Number of clock cycles	33,177,600	2,457,600
Time (ms)	2073.6	49.15
Total energy consumption (mJ)	22.8	1.08

Table. 2 Power analysis

Which is ~20 times higher than that of the proposed system. The results on processing time and energy consumption are summarized in Table 2. These results show that the proposed WMSN processing system is highly energy efficient and much faster than COTS processor based systems. In addition, the proposed system works effectively in detecting any updating objects in the camera view.

C. Results

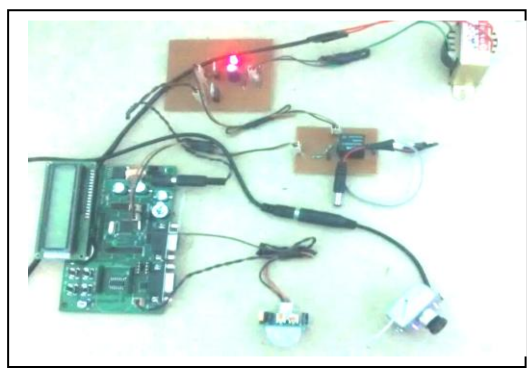

Fig .5 Person detected

V. CONCLUSION

The object extraction architecture coupled with the DWT processor helps significantly reduce the energy cost of image transmission. The application layer protocol proposed in this paper incorporates an effective queue control strategy to reduce packet error rate. In addition, the protocol employs a strategy to allow only one node to transmit at a time, thereby reducing collision and congestion, and consequently the number of retransmissions. The practical results presented in the paper clearly demonstrate the effectiveness of the proposed techniques, namely significant reduction in energy cost of image communication. In contrast with the predictions made in available literature, the proposed strategies make image communication over wireless sensor networks feasible.

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