An End-to-End Video Transmission System over Multimedia Wireless Sensor Networks

Shibi K. John, T. V. U. Kiran Kumar, Alice Abraham

Abstract- Multimedia transmission requires timely delivery for its real time application. Multimedia wireless sensors have special characteristics that make them different from traditional Wireless sensors. In this paper we propose an End-to-End Video streaming system over wireless multimedia sensor networks. First part of this paper explains the video encoding and the second part contains the route discovery along with Low Density Parity Check based forward error correction scheme to ensure error free data delivery The goal of the proposed system is to provide high quality video with maximum signal to noise ratio and minimum mean square error . The system is fully implemented in MATLAB

Index Terms - Wireless multimedia sensor network, video encoding, Peak signal to noise ratio, Low density parity check, Mean square error.

I. INTRODUCTION

Wireless sensor network has emerged as a popular area of research since last decade. A sensor network can be defined as a collection of several sensor nodes, distributed over an area with the motive to monitor physical phenomena such as temperature, pressure, humidity etc. A typical sensor node is comprised of three parts: a data processing unit which is responsible for collection, compression and correlation of data from a series of measurement. Data processing unit is also responsible for communication and power management issues. Transmission of data is guided through a communication interface, normally sensor nodes utilize IEEE 802.15.4 standard for data transmission. Furthermore a battery is primary source of power for sensor nodes. In addition to the conventional sensing applications, some application may also require WSN to collect multimedia data such as images, video or audio data. These data types are usually large and represented as an array or stream and requires complex processing. This requirement led to the development of a new class of wireless sensor networks known as wireless multimedia sensor network(WMSN) [**1**],[**2**].WMSNs require stringent resource requirements such as: wireless link must be reliable as well as capable of transmitting data at high rates. Complex data processing algorithm consumes higher power which is quite challenging to maintain in case of battery powered nodes. WMSNs are strict to Quality of service requirement, hence sensor network must be able to maintain QoS with real time data delivery capabilities.

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In WMSNs, sensor nodes are require to handle extra responsibilities such as data compression, event detection in addition to conventional responsibilities so deployment schemes used for WMSNs must be intelligent in order to prolong network lifetime. Ideal multimedia sensor ought to have a lot of processing power to work with the data, a high speed network to transfer it, a strong power source to keep the system running and it should be carefully deployed. These demands stand in open contrast to the idea of classical WSNs.

II. OVERVIEW OF H.264

H.264/AVC is a next generation video compression standard to support improved coding efficiency and improved network adaptation while maintaining the same quality level [5]. H.264/AVC encoder converts digital video to a format that requires lesser capacity while storing or transmitting. Basic architecture of H.264 video encoder and decoder is depicted in figure-1 below:

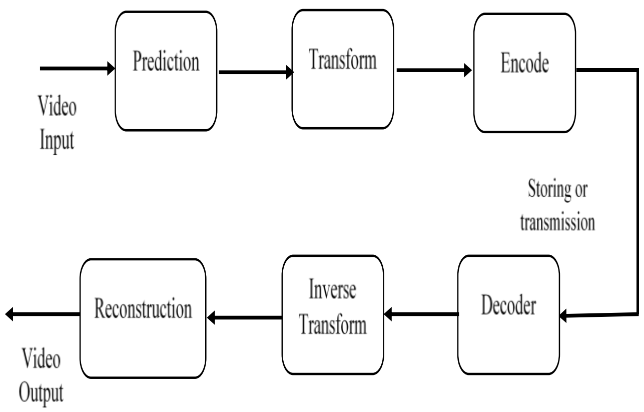

Figure 1. The H.264 video encoding and decoding process [6]

The H.264 encoder carries out prediction, transform, and the encoding process, while the H.264 video decoder follows the reverse processes of decoding, inverse transform and reconstruction to produce a decoded video sequence. The encoder processes a frame of video in units of a macro block. It forms a prediction of the macro block based on previously-coded data, either from the current frame (intra-prediction) or from other frames that have already been coded (inter-prediction). The encoder then subtracts the prediction from the current macro block to form a residual. A block of residual samples is transformed using an approximate form of the Discrete Cosine Transform (DCT), and this is later quantized. Finally, bit stream encoding occurs, which includes a) quantized transform coefficients, b) information about the complete video sequence, and c) other necessary information required by the decoder. The output of this video coding process is a periodic combination of I-frames (Intra frames) as set by the encoding parameters, with P-frames (Predicted frames) and B-frames (Bi-directional

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frames) in between, as shown in Figure 2.

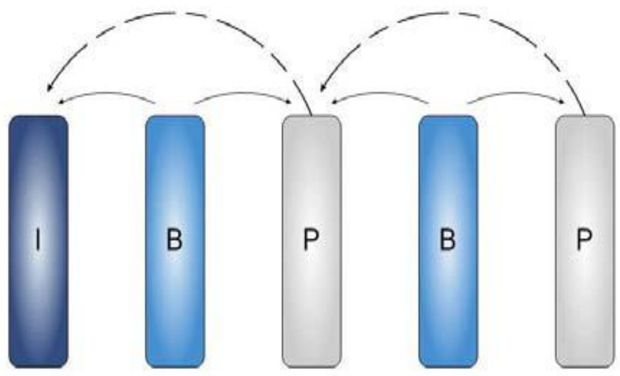

Figure 2. A typical IBP-based video frame.

At the decoder, a reverse process occurs: first, bit stream decoding occurs to extract quantized transform coefficients and prediction information, and then rescaling and inverse-transform are taken. Finally, the residual data obtained is reconstructed [**3**]. The decoding of I-frame is independent of any other frames, the decoding of P-frame depends on the successful decoding of I-frame and/or P-frame, while the decoding of B-frame depends on the decoding both I and P frames and the succeeding P frames [**4**].

III. RELATED WORK

In recent years the field of WMSNs has received much attention in the networking research community and as an interdisciplinary field of interest. Several efforts have been made to achieve important results in various fields related to WMSN, from the research unspecialized hardware to the development of efficient algorithms and protocols for multimedia transmission. Image transmission over low bitrates networks such IEEE 802.15.4 and Zigbee is addressed in [7],where both JPEG and JPEG2000 compression schemes are tested, highlighting limitations of the network and evaluating both Peak Signal to Noise Ratio (PSNR) and byte error rate. The work in [8] describes a simple single hop network architecture based on theFleck3 platform, which enables to acquire, compress and send to abase node QVGA images using a compression technique very similar to JPEG. The system is evaluated in details with experiments focused on the achieved PSNR and energy usage. For what concerns video transmission, [9] investigates issues associated with the transport of multimedia streams across WSNs, introducing a flow-control algorithm based on pipelined transmission to increase network performance. In [10], the authors propose a cross layer approach to dynamically tune the rate of video transmissions to minimize distortion while achieving fairness among multiple concurrent video flows in multi-hop WSNs. Chen et al. in [11] propose a real-time video surveillance system composed of two IP-cameras and sixteen low-cost wireless sensors in a multiple-tier architecture. In this case the sensor network can detect and track an object and wake up the IP cameras to record these events. Other similar multiple-tier architectures can be found in [12], [13] and [14].

Politis et al. in [15] propose a scheduling algorithm for transmitting video packets over multi-paths according to their importance (high priority packets over high bandwidth paths), including a power aware packet scheduling mechanism that selectively drops the least significant video packets prior to transmission in order to save energy. Guo and Little in [16] propose a QoS-enabled dynamic path formation algorithm to yield throughput-aware video delivery over WSNs by distributing a limited number of mobile sinks to the bottleneck location for each video stream. A multi-path multi-stream video delivery architecture for WMSNs is proposed in [17] the video sequence is encoded in multiple streams and each of these is assigned to a different path for ensuring load balancing and error resilience. As the packets traverse the multi-hop network, they are partially and progressively decoded through a distributed error recovery frame work to recover from channel-induced errors. The work in [18] describes a multi-channel approach for video forwarding in WSN, providing the rationale for employing multiple channels in the transmission of constrained video feeds and describing the practical implementation of the proposed approach in commercially-available sensor network hardware. This research work is focused towards the development of end-to-end video transmission system over multimedia wireless sensor networks. The proposed video transmission system utilizes H.264 AVC encoder for video compression and AODV based route discovery along with LDPC based forward error correction scheme to ensure error free data delivery. The process of video transmission starts with H.264 video encoder part where the input video stream is converted into frames, then each frame is processed through Inter prediction/Construction or Intra prediction/Construction unit for removal for temporal and spatial redundancy respectively. Inter prediction/construction block requires current frame with reference frame to calculate temporal redundancy with the help of motion vector of current block. The search space is taken to be double of block size N. Sum of absolute difference (SAD) algorithm is used for motion vector calculation. Finally the prediction error is calculated by the difference of current frame and predicted frame pointed by the motion vector. Inter prediction /reconstruction unit adds the motion vector to current frame and reconstructs new frame. Inter error calculation unit calculates error between current frame and reconstructed frame. If this mean error is less than the predefined threshold value than the reconstructed image is considered to be correct else Intra frame prediction is done. Intra frame prediction module does not requires reference frame for redundancy calculation. It has nine modes of operation in case of block size 4×4 and four modes in case of block size either 8×8 or 16×16. The mode of operation selected by intra frame prediction block is also conveyed to intra frame reconstruction module known as spatial redundancy prediction module. Again mean error is calculated through intra error calculation unit and prediction error between current frame and reconstructed frame is compared with threshold value. If the prediction error is less than the predefined threshold than only intra frame prediction is found to be correct else if the threshold error is greater than inter frame prediction error and intra frame prediction error than data is sent directly without any compression. Finally the encoded frame is ready to be transmitted and given to wireless sensor network for data transmission. Wireless multimedia sensor network considered for this research study contains 10 nodes located randomly over an area of 10x10 square meters and follows AODV based route discovery mechanism. Each node in the network is associated with random link state and trust value. These parameters are used to discover a path between source and destination. Each encoded frame is first converted to serial stream of data, zero padded and packetized. These data packets are now encoded by LDPC based forward error correction scheme, modulated by BPSK modulator and transmitted over AWGN channel with link states associated with the nodes present in the route. At the receiver end, the received data packet is decoded through bit-flip algorithm. After successful decoding, data packet is demodulated, reconstructed as image frame and applied to standard H.264 decoder for decompression. H.264 decoder block uses encoded information saved at encoder as per the encoder information, decoder performs inter frame prediction, intra frame prediction or direct data transmission modes to reconstruct the decompressed frame. Finally decompressed frame is now compared with transmitted frame to calculate mean square error (MSE) and PSNR. Block diagram of the proposed work is shown in figure below:

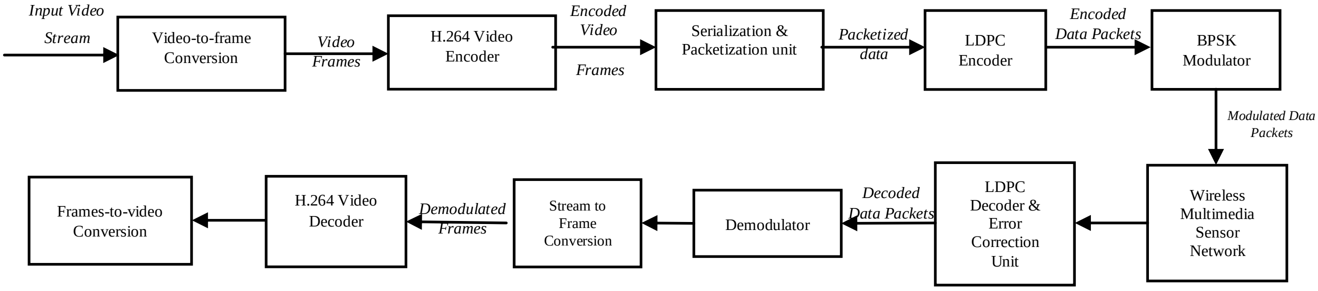

Figure 3. Proposed end-to-end video transmission system

IV. EXPERIMENTAL SETUP

This research work proposes novel end-to-end video transmission system over multimedia wireless sensor networks. To evaluate the performance of our proposed system MATLAB based framework is considered and 10 frames from given video stream were transmitted over sensor network and compared for mean square error and peak signal to noise ratio.

V. RESULTS AND DISCUSSION

Step by step simulation results for our research work are given in figures below, image frame to be transmitted is shown in fig-4, fig-5 represents encoded image frame by H.264 encoder. AODV based route is shown in fig-6 whereas the frames received at receiver end and decompressed by H.264 decoder are given in fig-7 and fig-8 respectively. Calculated MSE and PSNR values for 10 frames are given in table-1.

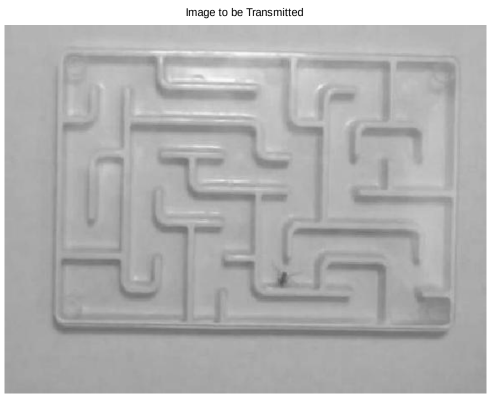

Figure 4. Image Frame to be transmitted

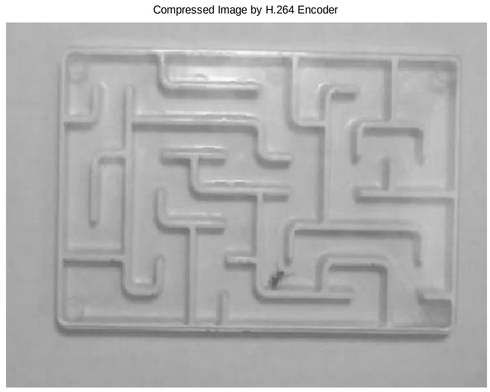

Figure 5. Compressed Image by H.264 encoder

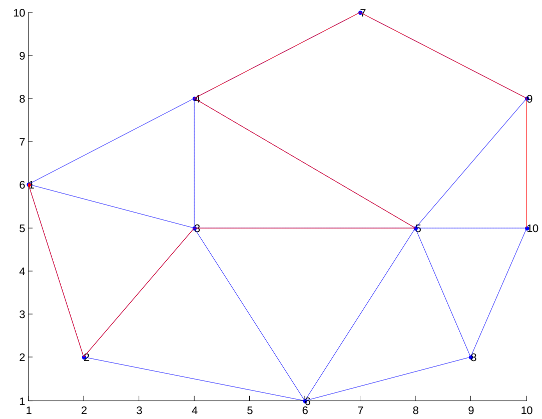

Figure 6. Wireless Sensor Network Route Discovery

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Figure 7. Reconstructed image at receiver's end

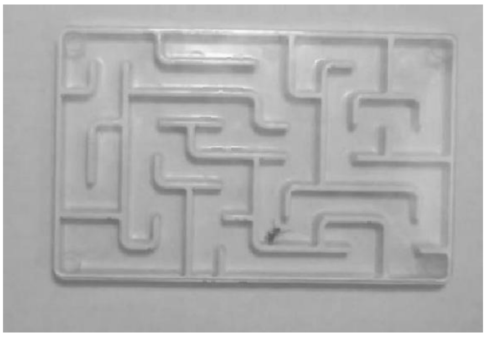

Figure 8. Decompressed image at H.264 decoder

Table1. Calculated MSE and PSNR values for various frames

Frame	MSE	PSNR (in dB)
1	0.0193	25.34
2	0.0190	25.41
3	0.0265	25.44
4	0.0192	25.20
5	0.0210	25.35
6	0.0189	25.19
7	0.0173	25.62
8	0.0197	25.48
9	0.0264	25.46
10	0.0198	25.37

VI. CONCLUSION

MATLAB based framework for end-to-end video transmission over wireless multimedia sensor network is developed in this research. H.264 AVC encoder/decoder is used for data compression followed by Low density Parity Check (LDPC) based forward error correction scheme to ensure error free transmission. Wireless multimedia sensor network with 10 randomly situated nodes and different link states are considered as source and destination of our transmission system. To discover the route between source-destination pair AODV based route discovery mechanism is utilized. To evaluate the performance of our proposed scheme MSE and PSNR are taken as reference parameters. Simulation results shows that our proposed scheme achieves maximum PSNR of 27.62 dB for seventh frame and minimum MSE achieved is 0.0173.

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