Study of
Energy and QoS Aware Image Transmission in Wireless Multimedia Sensor Networks

DISSERTATION-II

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MASTER OF TECHNOLOGY

In

Electronics and Communication Engineering

By

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May 4, 2015

Certificate

This is to certify that the Dissertation-II titled "**Study of Energy and QoS Aware Image Transmission in Wireless Multimedia Sensor Networks**" that is being submitted by "**Nithin Joseph Panicker**" in partial fulfillment of the requirements for the award of MASTER OF TECHNOLOGY, is a record of bonafide work done under my guidance. The contents of this Dissertation-II, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Bhaktapriya Mohapatra
(Assistant Professor)
SECE, LPU, Punjab

Objective of the Dissertation-II is satisfactory / unsatisfactory.

Examiner I

Examiner II

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I would like to express my earnest gratitude to my project guide, Asst. Prof. Bhaktapriya Mohapatra for believing in my ability to work on the challenging domain of WSN. His profound insights have enriched my research work. The flexibility of work he has offered, deeply encouraged me in producing the research.

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Last, but not the least, I would like to dedicate this project to my family, for their love, patience and understanding.

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May 4, 2015

CANDIDATE'S DECLARATION

I hereby certify that the work, which is being presented in the report, entitled "**Study of Energy and QoS Aware Image Transmission in Wireless Multimedia Sensor Networks"**, in partial fulfilment of the requirement for the award of the Degree of **Master of Technology** and submitted to the Department of Electronics and communication Engineering of Lovely Professional University, Punjab, institution is an authentic record of my own work carried out during the period *January-2015* to *April-2015* under the supervision of **Mr.Bhaktapriya Mohapatra**. I also cited the reference about the text(s)/figure(s)/table(s) from where they have been taken.

The matter presented in this thesis has not been submitted elsewhere for the award of any other degree of diploma from any Institutions.

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Abstract

Wireless sensor networking continues to evolve as one of the most exciting and challenging research areas of our time. These networks can be useful for a large number of applications, including habitat monitoring, structural health monitoring, pipeline monitoring, transportation, precision agriculture, supply chain management, and many more. In sensor networks where the environment is needed to be remotely monitored, the data from the individual sensor nodes is sent to a central base station (often located far from the network), through which the end-user can access data. Manual replacement or recharging the batteries is not an easy or desirable task. Energy utilization and network life time are key issues in the design of Wireless sensor network. Many algorithms have been proposed for reducing energy consumption and to increase network life time of the WSN.

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.

This project presents a novel architecture and protocol for energy efficient image processing and communication over wireless sensor networks. The nodes discussed in this research are focused on the image acquisition devices. In the image acquisition devices, used for surveillance the camera mote often has a fixed frame of view. The background image represents a static scene of the camera view without any moving objects, so only the updated pixels are needed to be transmitted. Also it is not necessary to transmit all the frames. In this case, to detect moving (updated) objects from the background image is done using an intelligent fore ground extraction algorithm which uses the Gaussian running average method. Then JPEG compression is used to further reduce the power. Based on wavelet compression, a robust and energy efficient scheme called Priority Image Transmission in WSN is proposed by providing various priority levels during image transmission. The information for the significant wavelet coefficients are transmitted, whereas relatively less important coefficients are suppressed. The application of the error detection and correction algorithm will reduce the requirement for retransmissions. Practical results show the effectiveness of these approaches to make image communication over wireless sensor networks feasible, reliable and efficient.

Contents

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List of Abbreviations

WSN- Wireless Sensor Network

WMSN- Wireless Multimedia Sensor Network

DPM- Dynamic Power Management

DFS- Dynamic Frequency Scaling

DVS- Dynamic Voltage Scaling

SNR- Signal to Noise Ratio

GPS- global Positioning System

VLSI- Very large Scale Integration

QoS- Quality of Service

FPGA- Field Programmable Grid Array

PDF- Probability Density function

DWT- Discrete Wavelet Transform

JPEG-Joint Photographers Expert Group

Chapter 1

Introduction

With the advancement in micro-fabrication technology, Wireless Sensor Networks (WSNs) have started to play a vital role in our daily lives. It is because of the reduction in cost of the sensor nodes, leading to increasing deployments of WSNs to a larger extent. Potential applications for wireless sensor networks exist in a variety of fields, including industrial process monitoring and control, environment and habit monitoring, machine health monitoring, home automation, health care applications, nuclear reactor control, fire detection, object tracking and traffic control. Efficient design and implementation of wireless sensor networks have become a hot area of research in recent years, due to the immense capacity of sensor networks to enable applications connecting the physical world with the virtual world.

It is possible to obtain data about physical or environmental phenomena by networking large number of tiny sensor nodes that was difficult or impossible to obtain in more conventional ways.

1.1 Wireless Sensor Network

Wireless sensor network are emerging as both an important new tier in the IT ecosystem and a rich domain of active research involving hardware and system design, networking, distributed algorithms, programming models, data management, security and social factors. WSN, have evolved in the past years from a promising research to a useful technology applicable to real-world scenarios (e.g. industrial monitoring in critical infrastructures). Wireless sensor networks are one of the technologies that are gaining a considerable attention. They have been deployed to monitor the activities of animals and plants whose behavioral patterns or distributions can easily be affected by human presence; to inspect the structural integrity of bridges and buildings as well as of pipelines; to capture the presence and extent of active volcanoes. Likewise, in precision agriculture, they have been used to monitor soil moisture, radiation, pH, and humidity. Other applications include healthcare and supply chain management. Typically, a wireless sensor network consists of a large number of nodes each of which integrates one or more sensors, a processing subsystem and a short range transceiver. The nodes are capable of organizing themselves to establish and maintain a network and carry out reliable sensing. However, when considered individually, each node is a simple device; the components that make up its subsystems are commonplace, off-the-shelf components. A structure of a WSN is shown in Figure 1

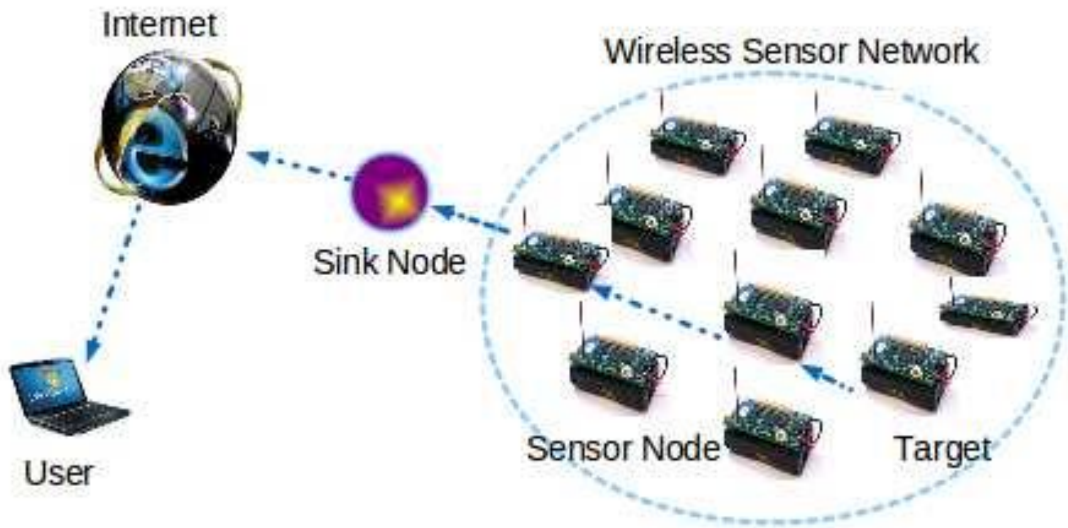


Figure 1: Wireless Sensor Network

In sensor networks where the environment is needed to be remotely monitored, the data from the individual sensor nodes is sent to a central base station (often located far from the network), through which the end-user can access data.

The main characteristics of WSNs include:

- Ease of use
- Ability to cope with node failures
- Communication failures
- Scalability to large scale deployment
- Power consumption constrains for nodes that use batteries or Energy harvesting
- Ability to cooperate with harsh environmental conditions, etc.

Wireless sensor networks represent a recent research area, due to their great capability of performing environment monitoring and information collection. Wireless sensor networks allow deployment of sensing elements close to the phenomena of interest. Sensing close to the signal generation point should lead to improved Signal to Noise Ratio (SNR) in general, and enable detection in otherwise obstructed environments. This fundamental benefit of local sensing, combined with the decreasing cost and increasing availability of low cost micro-sensors/actuators and processors, suggests that effective systems will exploit densely distributed elements. However, dense sensing capability is only scalable if the elements are networked to support collaborative processing near the sensory inputs. Therefore, in many contexts low-power wireless communication is a critical enabler of these systems because it overcomes the logistical infeasibility of deploying wires in remote, dynamic, and mobile-node, contexts.

The spatially dense and temporally continuous monitoring capabilities of wireless sensor networks had transformed the way in which we understand and interact with the physical world: e.g., contaminant flow monitoring in soil, air, and water; precision agriculture; transportation and traffic management; and remote habitat monitoring for bio complexity studies. However, in order for wireless sensor networks to effectively provide dense and continuous monitoring/data collection, they must be able to operate unattended for long periods of time. Long lifetime obviously requires that the individual components be low-power. However, component-level efficiency is not sufficient; the distributed sensor network as a whole must be designed with energy-efficiency as a primary constraint. For example:

- Due to low-lying antennae and uncontrollable environmental settings, long-range communication consumes significant amounts of energy. Consequently these systems should perform in-network processing so that sensory data is processed as near the source as possible and the number of bits communicated over links is reduced significantly.
- In many contexts it may be feasible to deploy many times more elements than are needed to provide coverage at any point in time. To achieve long-lifetime, the network should be designed to exploit redundancy by coordinating duty cycles and coverage across these nodes over time; and by taking advantage of energy-aware load balancing across multiple paths.

• Capabilities such as triggering are critical to allow lower power capabilities to activate higher-power capabilities only when they are needed. For example, sensing techniques with low communication overhead (e.g., vibration defection) can activate ones with higher communication overhead when necessary (e.g., distributed signal for localization and tracking).

There are several component-level capabilities that are needed to support such system-level low-power techniques. For example:

- Low-power wakeup circuitry, as in a paging channel, is needed so that nodes can be wake up other nodes.
- Adjustable-power, short-range radios, and RSSI measurement circuits, so that transmission range and energy expenditure can be adjusted through software and during node operation to support adaptive-density systems and efficient cluster formation.
- Accurate power measurement onboard to support self-adjusting, load balancing coordination for which a node should be able to approximate energy reserves.
- Alternate energy sources and scavenging techniques.

1.2 Key Issues in the Design for WSN Nodes

There are some issues in the design of WSN because of several constraints in the network. WSNs suffer from the limitations of several network resources such as, energy, bandwidth, computation power and storage. The design challenges in sensor networks involve the following key aspects:

Limited energy capacity:

Since the sensor nodes are battery powered having limited energy capacity, energy is a big challenge for the network designers in hostile environments. For example, in a battlefield, it is almost impossible to access the sensors and recharge their batteries. Also, when the energy of a sensor reaches a certain threshold, it may become faulty and may not be able to function properly, which can have a major impact on the network performance. Thus, transmission protocols designed for WSN should be as energy efficient as possible to extend the lifetime of the sensors and hence prolong the network lifetime while guaranteeing decent overall performance.

Sensor locations:

Another challenge that is faced during the design of routing protocols is to manage the locations of the sensors. Most of the protocols assume that the sensors either are equipped with GPS receivers or use some localization technique to learn about their positions.

Limited hardware resources:

The processing and storage capacities of sensors are also limited as the energy capacity. Thus, they can only perform limited computational functionality. These constraints give rise to many challenges in network protocol design for WSN, which must consider not only the energy efficiency of sensor nodes, but also the processing power and storage capacities.

Massive and random node deployment:

Sensor node deployment in WSNs is application dependent and affects its performance. Sensor nodes can be scattered randomly in a specified area or dropped massively over a remote or hostile region in most of the applications.

Network characteristics and dynamic environment:

A sensor network generally operates in a dynamic and unreliable environment. The network topology, defined by the sensors and communication links between them, changes frequently because of sensor addition, deletion, damages, node failures or energy depletion. Furthermore, the sensor nodes are linked by a wireless medium, which is noisy, susceptible to errors and time varying. Therefore, transmission protocols should consider network topology dynamics to maintain particular application requirements in terms of coverage and connectivity.

Data Aggregation:

Sensor nodes may generate significant redundant data. So, similar packets from multiple sensors can be aggregated to reduce number of transmissions. Data aggregation techniques are used to achieve energy efficiency and to optimize data transfer.

Diverse application requirements:

WSNs have a wide range of applications each having different requirements. No network protocol can meet all the requirements of every application. Hence, routing protocols should guarantee data delivery and its accuracy to provide the sink with the required knowledge about the physical and environmental condition on time.

1.3 Motivation of Study

Wireless sensor networks are resource-constrained self-organizing systems that are often deployed in inaccessible and inhospitable environments in order to collect data about some outside world phenomenon. For most sensor network applications, point-to-point reliability is not the main objective; instead, reliable event-of-interest delivery to the server needs to be guaranteed (possibly with a certain probability).

A Wireless Sensor Network (WSN) comprises many sensor nodes each one containing a processing unit, one or more sensor, a radio for data communication and power unit usually equipped with a low capacity battery. All sensors present in wireless sensor network are battery operated devices which have limited battery power. After the deployment of sensor nodes it is not possible to replace each and every battery in the network. Therefore optimal energy consumption for WSN protocol is a necessity. So in this paper we have tried to implement some methods to reduce the power consumption by the sensor nodes and thus to utilize it to the maximum. They are as follows:

- An energy efficient image processing algorithm to handle the large volume of data generated.
- A reliable application layer protocol that reduces packet error rate and retransmissions.
- Energy-efficient image transmission in error-prone environments.
- Selective switching
- Dynamic scaling

1.4 Problem Statement

The objective of this paper is to develop an energy efficient architecture and protocol for energy efficient image processing and communication over wireless sensor networks, improving on the existing communication strategies to deal with the large volume of data to outperform:

- The sensor node life time.
- Consumption of energy in the network.
- Amount of retransmission.
- Reliability in error prone areas.

1.5 Objectives of the Thesis

- To setup the image acquisition device such that t consumes minimum power.
- To implement a fore ground extraction algorithm which can extract the fore ground effectively using minimum power.
- To implement compression techniques to further reduce the power consumption.
- To implement channel encoding schemes to avoid the requirement of the retransmissions and to provide reliability in error prone areas.
- To reconstruct the transmitted data efficiently using the reverse algorithm.
- The robustness of all the techniques used have also be analysed in respective chapters.

1.6 Organisation of the Thesis

The thesis contains six chapters as follows

- **Chapter 1 -** introduces about the Wireless Sensor Networks, its working, setup and the real world applications with examples. It also describes the key issues faced during the design of WSN. It also describes the motivation of the study, problem statement and the objectives of the thesis work.

- **Chapter 2 –** deals with the review of the research papers which are studied for the development and analysis of the thesis work. The summary of the research papers are included in this chapter.
- **Chapter 3 –** includes the research analysis and simulation results which broadly describes the output of the work done, comparison of different schemes used etc. It is divided into different sub parts in which each technique is briefly described and the simulation results added to support the description.
- **Chapter 4 -** Draws conclusions on the various works presented and aptly suggests the scope of future work.

Chapter 2

Literature Review

Battery-operated portable appliances impose tight constraints on the power dissipation of their components. Such constraints are becoming tighter as complexity and performance requirements are pushed forward by user demand. Reducing power dissipation is a design objective also for stationary equipment, because excessive power dissipation implies increased cost and noise for complex cooling systems.

Numerous computer-aided design techniques for low power have been proposed targeting digital very large scale integration (VLSI) circuits, i.e., chip-level designs. Almost every portable electronic appliance is far more complex than a single chip. Portable devices such as cellular telephones and laptop computers contain tens or even hundreds of components. To further complicate the picture, in most electronic products, digital components are responsible for only a fraction of the total power consumed. Analog, electro- mechanical and optical components are often responsible for the largest contributions to the power budget. For example, the power breakdown for a well-known laptop computer shows that, on average, 36% of the total power is consumed by the display, 18% by the hard drive, 18% by the wireless LAN interface, 7% by noncritical components (keyboard, mouse, etc.), and only 21% by digital VLSI circuitry (mainly memory and CPU). Reducing the power in the digital logic portion of this laptop by 10X would reduce the overall power consumption by less than 19%. Laptop computers are not an isolated case. Many others electronic appliances are complex and heterogeneous systems containing a wide variety of devices that do not fall within the scope of the available computer-aided power optimization techniques. Designers have reacted to the new challenges posed by power-constrained design by mixing technological innovation and power-conscious architectural design and optimization. The power consumption of a wireless sensor network (WSN) is of crucial concern because of the scarcity of energy. Energy is a limited resource in wireless sensor networks. In fact, the reduction of power consumption is crucial to increase the lifetime of low power sensor networks. A sensor node has limited resources such as processing and storage capacity. Furthermore, a sensor node is typically battery operated, which means that it is also energy constrained. Hence, it is critical to use different power management techniques for a wireless sensor network to utilize and efficiently complete the tasks allotted to the nodes with the minimum utilization of resources. Power management is the efficient direction of power to different components of a system. Power management is especially important for portable devices that rely on battery power. By reducing power to components that aren't being used, a good power management system can double or triple the lifetime of a battery. It involves efficiently converting unregulated voltages derived from the AC line, batteries, or other sources to regulated, precise and protected levels. Power management ICs manage transitions between standby, sleep and high power modes effectively. As systems become more complex, Power management ICs often include auxiliary functions such as Audio, Li-Ion Charging, LED drivers to reduce overall cost and size. Power Management devices help to extend battery life in portable products. These solutions support products that are popular in consumer (hand held/portable), networking and computing, wireless, automotive and motor control applications - especially for extremely specialized, high performance products.

Local Power Management strategy is developed by the understanding of how power is consumed by the different subsystems of a wireless sensor node. This knowledge enables wasteful activities to be avoided and to frugally budget power. Furthermore, it enables one to estimate the overall power dissipation rate in a node and how this rate affects the lifetime of the entire network.

2.1 Energy Efficient Image Transmission In Wireless Sensor Networks

By Syed Mahfuzul Aziz, Senior Member, IEEE, and Duc Minh Pham, Student Member, IEEE.

In Wireless Multimedia Sensor Networks (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 in any other types of wireless sensor networks (WSN). This requires the development of energy aware multimedia processing algorithms and energy efficient communication in order to maximize network lifetime while meeting the QoS constraints.

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. This project presents a novel architecture and protocol for energy efficient image processing and communication over wireless sensor networks. Practical results show the effectiveness of these approaches to make image communication over wireless sensor networks feasible, reliable and efficient.

In this project, 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. A novel FPGA 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.

2.1.1 Architecture for 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. 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. It is further optimized for FPGA implementation and is incorporated into the proposed WMSN system.

Background Subtraction

The Running Gaussian Average model 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).

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

where, B_n is the updated background average,

F_n is the current frame intensity

B_{n-1} is the previous background average

α is an updating constant.

The value of α is chosen in the form of $\frac{1}{2^k}$ because multiplication by $\frac{1}{2^k}$ can be easily implemented by a simple bit shifting circuit, thereby greatly reducing hardware complexity. So, (1) is written as:

$$B_n = B_{n-1} + \frac{1}{2^k}(F_n - B_{n-1}) \quad (2)$$

At each new frame, the pixel is classified as foreground (i.e. belongs to an updated object) if the condition below is true.

$$| F_n - B_{n-1} | > T \quad (3)$$

where, T is the *updating threshold*.

The result of the calculation $| F_n - B_{n-1}|$ in (2) is reused in (3). This, along with a multiplier free implementation, leads to an optimized hardware architecture. The results in (3) can be used to decide whether a background image needs to be updated or not. The hardware implementation of (2) and (3) is shown in Fig. 2.

By default, B_n is calculated for every pixel in each frame; however the decision to update the previous average (B_{n-1}) depends on the value of the *update* signal *U*, which is a 1-bit signal. This signal is saved in an external RAM to provide the information required to calculate the location of the updated objects to be extracted.

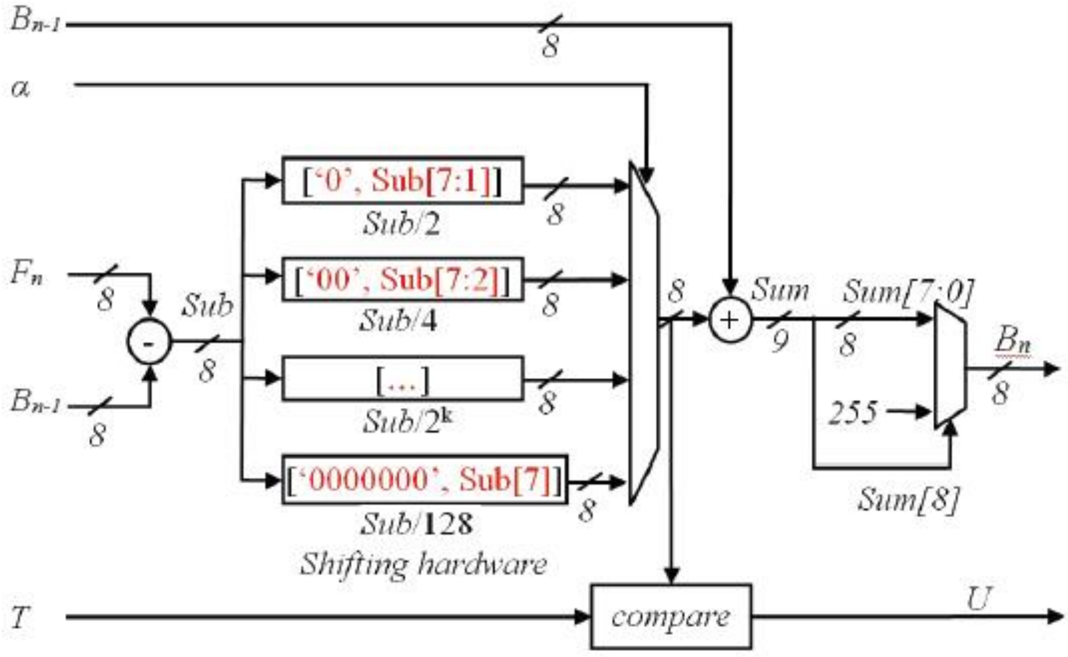


Fig. 2. Optimized hardware architecture for background subtraction.

Object Extraction

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 determine if the number of consecutive differences (1s) is greater than a pre-determined *difference threshold.*

2.1.2 Image Transmission Protocol

The first challenge in image transmission is that compressed images are sensitive to packet errors. For this reason, a reliable transmission protocol is needed at the application layer to ensure that all image packets are sent and received correctly and in the right order. We have implemented a transmission protocol at the application layer as depicted in Fig. 3. The basic idea behind this protocol is dividing the image into a number of packets, assigning packet ID, packet control and error detection.

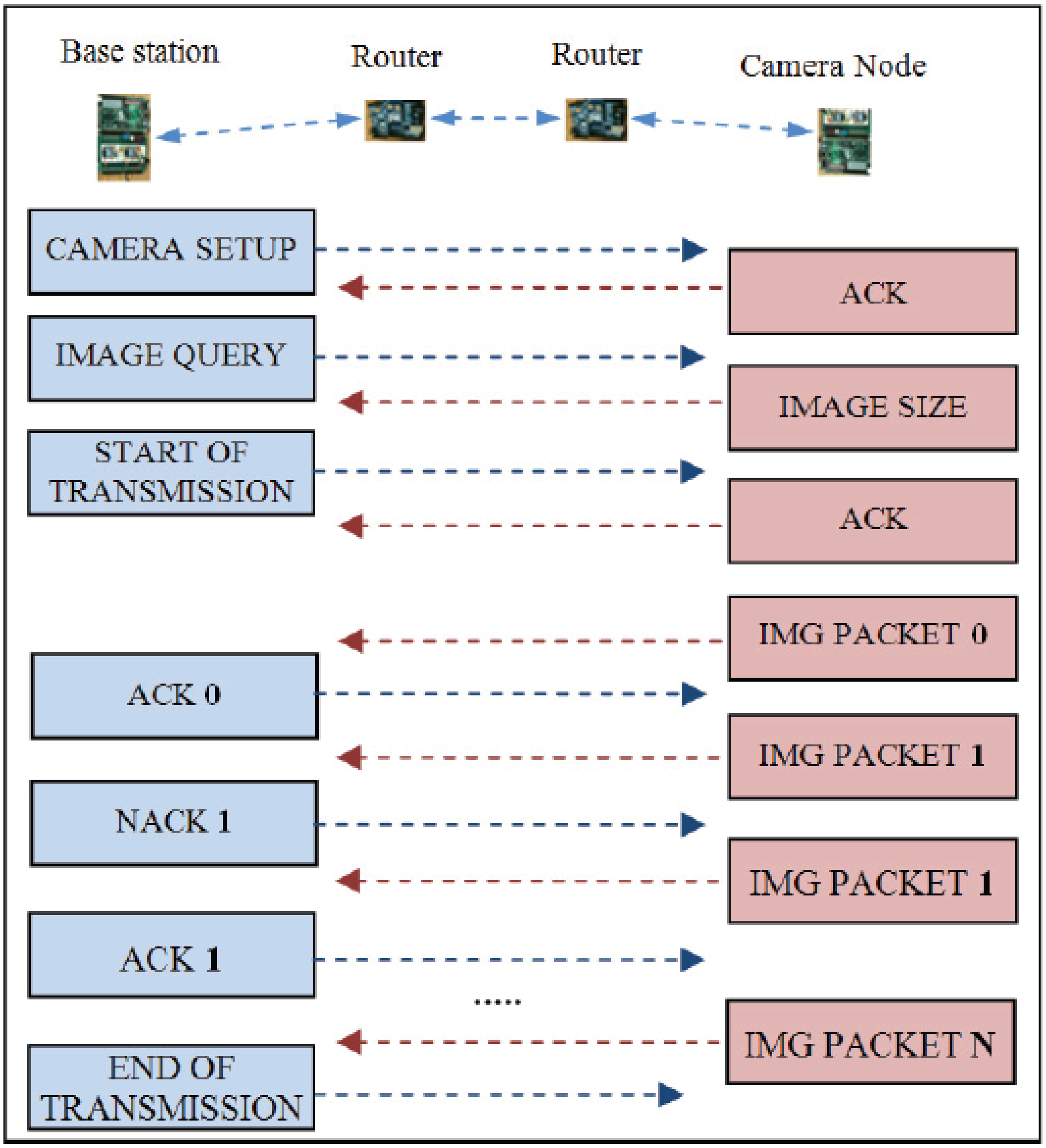


Fig. 3. Efficient image transmission protocol for WMSN.

Even with the above application layer protocol incorporated within 802.15.4, practical experiments show that when 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 –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 predefine 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.

2.1.3 Network Set-up

The WMSN processing architecture presented in this paper, including a networking processor and the object extraction block. To further reduce the size of the updated object and consequently the transmission energy, an efficient JPEG2000 Discrete Wavelet Transform (DWT) processor was used. Only the low frequency sub-band of the transformed object is transmitted. The background image and the extracted objects can be received and reconstructed by software running on the PC.

2.2 Priority Image Transmission in Wireless Sensor Networks

By Mohsen Nasri, Abdelhamid Helali, Halim Sghaier & Hassen Maaref.

Digital image transmissions are a significant challenge for image sensor based Wireless Sensor Networks (WSNs). Based on a wavelet image compression, we propose a novel, robust and energy-efficient scheme, called Priority Image Transmission (PIT) in WSN by providing various priority levels during image transmissions. Different priorities in the compressed image are considered. The information for the significant wavelet coefficients are transmitted with higher quality assurance, whereas relatively less important coefficients are transmitted with lower overhead.

We consider compressing and transmitting images in a multi-hop wireless network. We focus on the design and performance evaluation of priority image transmission. Our approach can be expressed in two aspects, i.e., (i) Identification of the essential and important sub-band coefficients, and (ii) Efficient transmission of these coefficients. In the first step, wavelet coefficients are produced after Discrete Wavelet Transform (DWT) on the original image as in the main-stream compression algorithms. After the DWT, multiple parts according to the magnitude of wavelet coefficients are identified, marked and associated with their importance levels. In the second step, unequally important transmissions are applied to different sub-bands in the compressed image. More reliable transmission of the important parts enhances image quality, while less effort is put on unimportant sub-band coefficients, leading to energy efficiency. Our proposed Priority Image Transmission (PIT) approach achieves high energy efficiency with an acceptable compromise on the image quality.

The basic idea of the proposed technique is transmitting the image wavelet coefficients by priority. This technique attempts to conserve energy using progressive image transmission. The wavelet image compression provides at the source the means to arrange data packages of various priorities. Assuming that the input image size is of MxN pixels and that the image is decomposed into r resolution level, then the 2D-DWT is iteratively applied r-l levels. In this way, data packet priority can be performed. In each transform level the priority level is defined as follow:

$$P_L = 3r - 2$$

Theoretically, DWT is a 2 dimensional separable filtering operation across rows and columns of input image. The DWT based on the concept of multi-resolutions facilitates progressive transmission of images. This is achieved by first applying the low-pass filter L and a high-pass filter H to the lines of samples, row by-row, and then re-filtering the output to the columns by the same filters. As a result, the image is divided into 4 sub bands: low-low (LL), low-high (LH), high-low (HL) and high-high (HH).

The smallest resolution, which is represented by the sub-band LL is the most significant. The priority assigned to HL, LH and HH sub-bands are defined according to the importance of their output streams consisting of pixel position.

Figure 4 illustrates the distribution of wavelet coefficients after applying 2-D wavelet transform to the 256*256 Lena image.

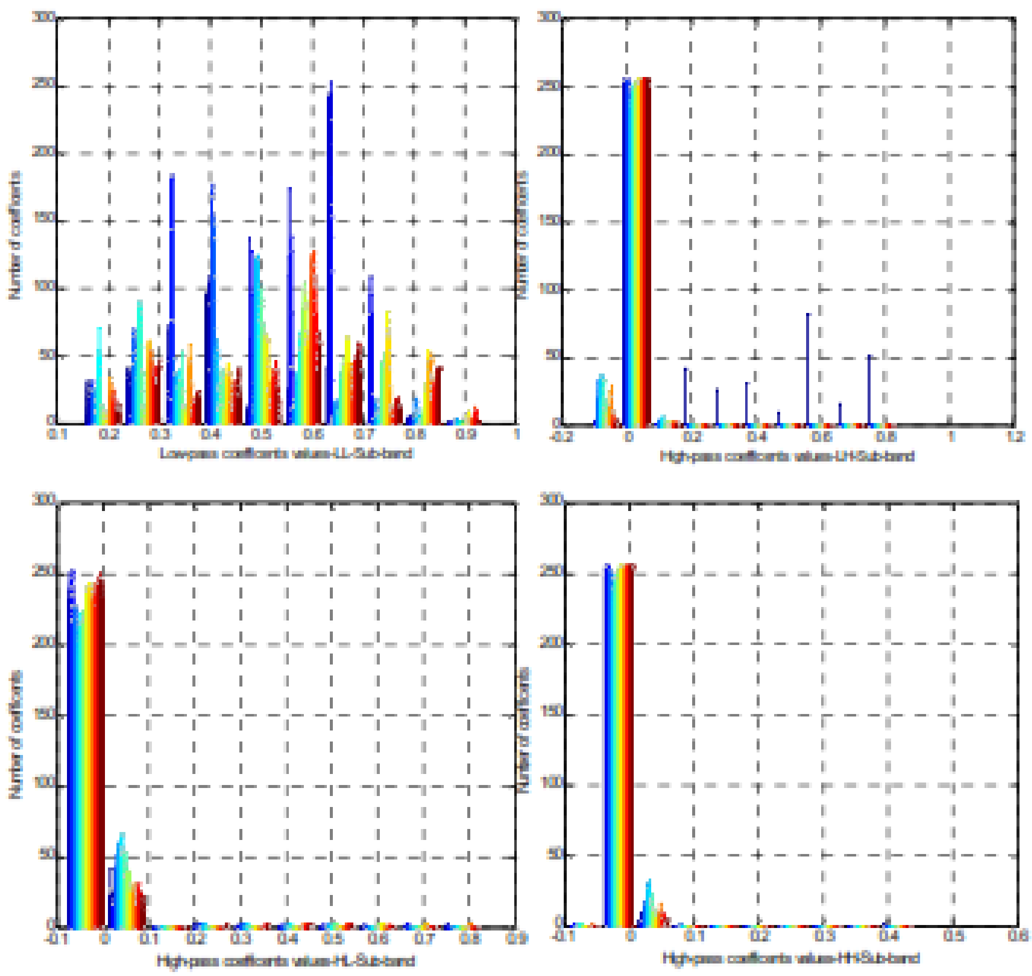


Figure 4 : The distribution of LL, LH, HL and HH sub-bands coefficients respectively after wavelet transform through 2D-DWT

We notice that, the lowest image resolution (represented by the LL sub-band) is the most important, thus it's assigned to priority 0. Since, the LH sub-bands coefficients are more important than the HL and HH sub-bands coefficients and because of the numerical distribution have decreasing importance from the LL sub-band to HH sub-band, the sub-band LH have priority P=1, the sub-band HL have priority P=2 and the sub-band HH have priority P=3.
So according to the proposed energy efficient scheme called Priority Image Transmission, the information for the significant wavelet coefficients are transmitted, whereas relatively less important coefficients are transmitted with less overhead.

Chapter 3

Research Analysis and Simulation Results

3.1 Block Diagram of the system

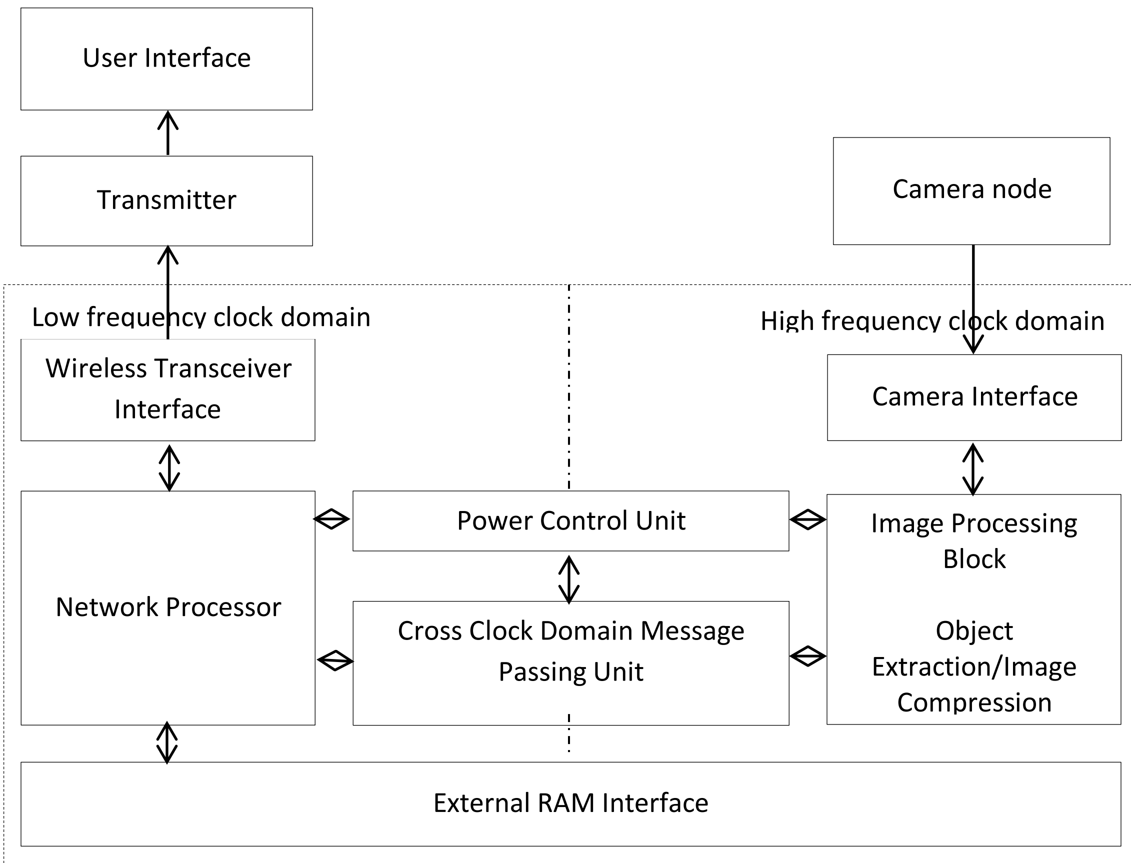


Fig.5 Architecture of the WMSN system

Fig. 4 presents the architecture of the proposed WMSN processing system. 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.

Block diagram of Image processing block

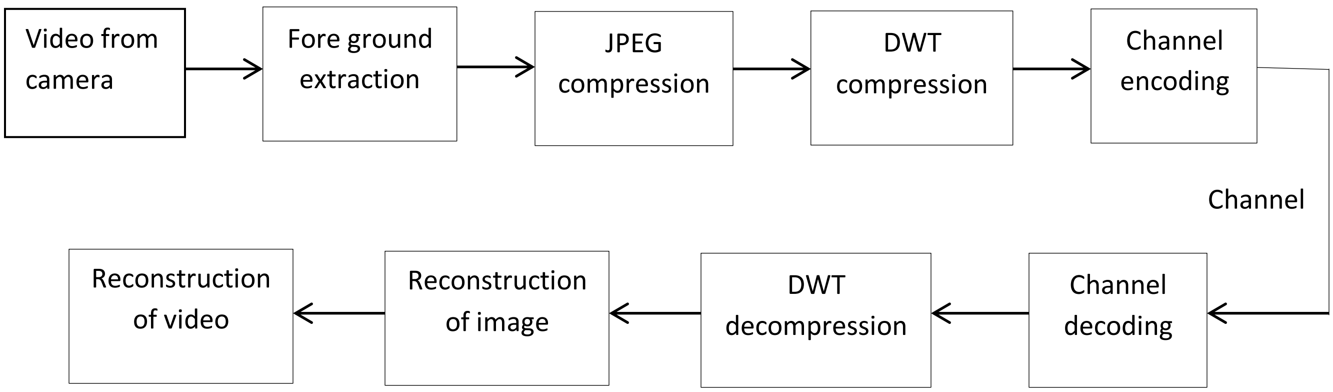


Fig.6 Block diagram of Image processing block

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. 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. It is further optimised for FPGA implementation and is incorporated into the proposed WMSN system.

Then JPEG compression is used to further reduce the power. Based on wavelet compression, a robust and energy efficient scheme called Priority Image Transmission in WSN is proposed by providing various priority levels during image transmission. The information for the significant wavelet coefficients are transmitted, whereas relatively less important coefficients are suppressed. The application of the error detection and correction algorithm will reduce the requirement for retransmissions.

3.2 Foreground extraction

Algorithm for foreground image extraction

1. Start
2. Initialize the object for video
3. Take the first frame and set as the background image
4. Convert the background image into gray scale
5. Calculate the mean value for the pixels in the background image

   $$Mean = \frac{\sum \text{Pixel value}}{Total\ no.of\ pixels}$$

6. Calculate the variance for the pixels in the background image

   $$Variance = \frac{\sum(Pixel\ value - mean)}{Total\ no.of\ pixels}$$

7. Calculate the Gaussian PDF for each pixel.

   $$B_n = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma}}$$

8. Take the second frame and set as the foreground
9. Calculate (Frame intensity of foreground-Gaussian PDF of background) for each pixel
10. Calculate the Gaussian PDF for foreground by (Gaussian PDF of background+0.5*(Frame intensity of foreground-Gaussian PDF of background))

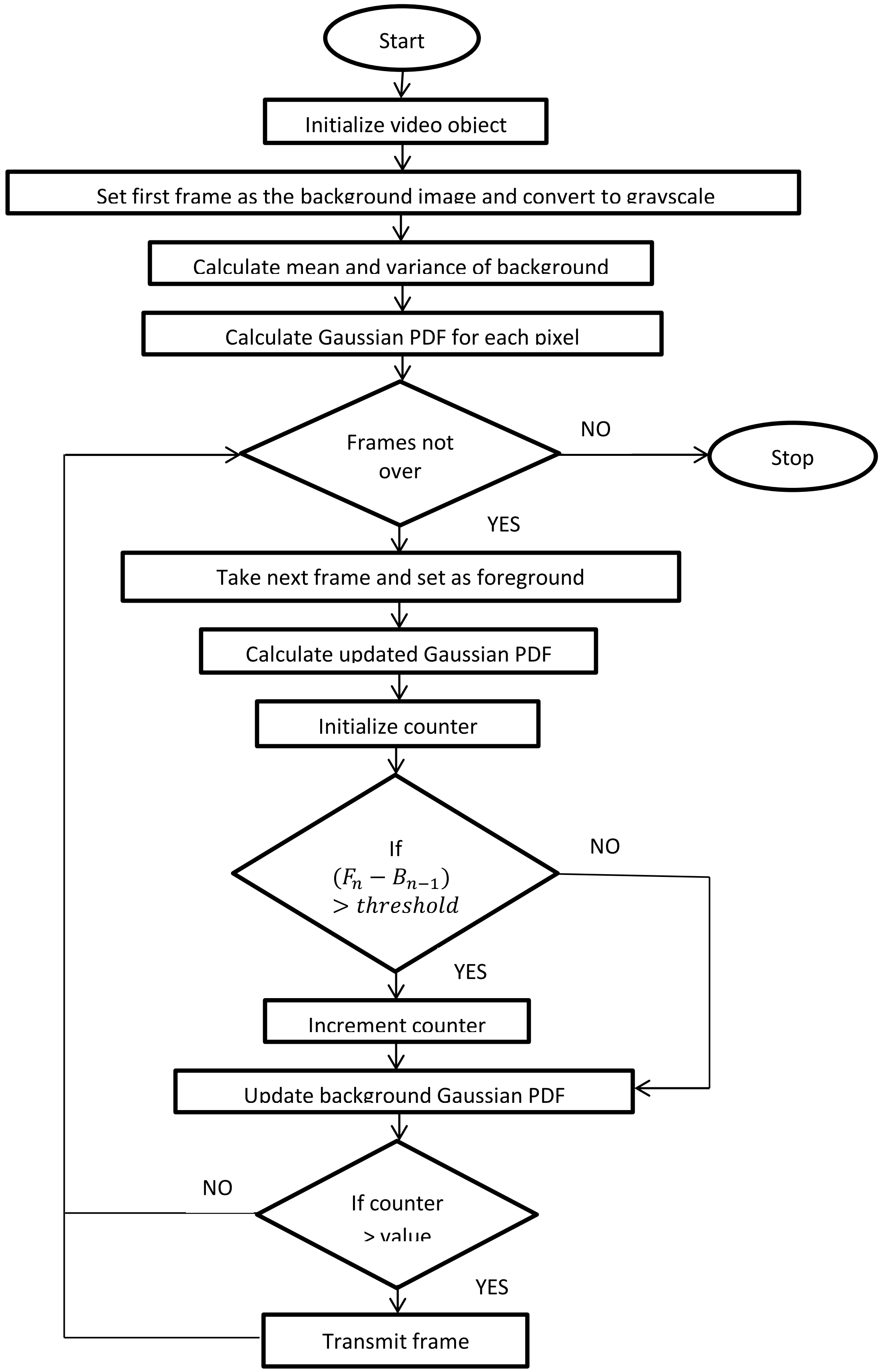
    $$B_n = B_{n-1} + \frac{1}{2^k} (F_n - B_{n-1})$$

11. Initialize counter
12. Check if each value of (Frame intensity of foreground-Gaussian PDF of background) greater than the threshold value then increment counter

    $$|F_n - B_{n-1}| > Threshold$$

13. Continue the above step for all pixels
14. Update the background Gaussian PDF
15. –Checks whether the value of counter is greater than a pre-defined value, if yes then transmit the frame
16. Check whether all the frames are over, if no go to step 8 else STOP

Flow Chart


Start
Initialize video object
Set first frame as the background image and convert to grayscale
Calculate mean and variance of background
Calculate Gaussian PDF for each pixel
Frames not over
NO
Stop
YES
Take next frame and set as foreground
Calculate updated Gaussian PDF
Initialize counter
If $(F_n - B_{n-1}) > threshold$
NO
YES
Increment counter
Update background Gaussian PDF
NO
If counter > value
YES
Transmit frame

Simulation Results of foreground extraction

Background image

Fig.7 Background image

The first frame is set as the background image and then it is converted to gray scale. It is only necessary to transmit the frames that have any movement, instead of transmitting the same image over and over again. If there is no change then that frames are discarded.

First the Gaussian Probability Function of every pixel of the background image is calculated using the equation

$$B_n = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma}}$$

The decision for whether the pixels in the foreground is to be updated is taken according to the condition,

$$| F_n - B_{n-1}| \ > Threshold$$

This threshold value can be varied for reducing the power consumed even more or to increase the clarity of the transmitted frame.

After processing a frame, the updated pixels are only transmitted which carry the information about the movement in the frame. Decision has to be made whether the frame to be transmitted is according to the number of updated pixels. If there is a considerable amount of variation or the updated pixels, then only the frame is transmitted. The number of updated pixels for transmitting the frame can be varied accordingly for reducing the power consumed even more or to increase the clarity of the transmitted frame. Since only the updated pixels are transmitted all the other pixels will be black so that an efficient source encoding technique like Huffman coding can compress the data to be transmitted even more thus saving more power.

Again the Gaussian PDF of the foreground image is updated using the equation,

$$B_n = \ B_{n-1} + \frac{1}{2^k} \ (F_n - B_{n-1})$$

Updated foreground images

Fig. 8 Extracted foreground frame no.1

The number of updated pixels or the pixels to be transmitted is 153883. The above image is the updated image from the background. When there is a movement in the frame then that frame will be transmitted instead of transmitting all the frames. In this example I have made movements (placed the hand) in the last 2 seconds and removed it immediately. In that 2 seconds 5 frames were transmitted but before that there wasn't any change in the background so all that frames were discarded. The rest of the updated images are shown below.

Fig. 9 Extracted foreground image no.2

The number of updated pixels or the pixels to be transmitted is 199067. When there is a movement in the frame then more number of frames is transmitted than the number of frames transmitted at the time when there were no movements.

Fig. 10 Extracted foreground image no.3

The number of updated pixels or the pixels to be transmitted is 183709. This number of pixels holds the information about the movement and all the others are black pixels.

Fig. 11 Extracted foreground image no.4

The number of updated pixels or the pixels to be transmitted is 225888. The total number of pixels is 640*480=307200. In which the updated number of pixels are as above said. The rest 81312 pixels are black which can be efficiently compressed to a very small size using any source coding technique.

Fig. 12 Extracted foreground image no.5

The number of the pixels to be transmitted is 218025. If there is less movement the number of updated pixels will get reduced correspondingly and will not transmit the frames which have the number of updated pixels less than a predefine value by considering the clarity and power utilizations.

Fig. 13 Extracted foreground image no.6

The number of updated pixels or the pixels to be transmitted is 166109. The above shown figures are the updated frames that we have to send. In a 9 second video of 24 frames per second, we have to transmit only 6 frames according to the algorithm. The frames having any changes are only needed to be transmitted. Thus we can save a huge amount of energy than the previous technologies used.

3.3 Image Compression and Channel Encoding

JPEG Compression

JPEG is an image compression standard used for storing images in a compressed format. It stands for Joint Photographic Experts Group. The remarkable quality of JPEG is that it achieves high compression ratios with little loss in quality. JPEG format is quite popular and is used in a number of devices such as digital cameras and is also the format of choice when exchanging large sized images in a bandwidth constrained environment such as the Internet.

The JPEG algorithm is best suited for photographs and paintings of realistic scenes with smooth variations of tone and color. JPEG is not suited for images with many edges and sharp variations as this can lead to many artifacts in the resultant image. In these situations it is best to use lossless formats such as PNG, TIFF or GIF. It is for this reason that JPEG is not used in medical and scientific applications where the image needs to reproduce the exact data as captured and the slightest of errors may snowball into bigger ones.

A JPEG image may undergo further losses if it is frequently edited and then saved. The operation of decompression and recompression may further degrade the quality of the image. To remedy this, the image should be edited and saved in a lossless format and only converted to JPEG format just before final transmittal to the desired medium. This ensures minimum losses due to frequent saving. Image files saved in the JPEG format commonly have the extensions such as .jpg, .jpeg or .jpe.

Block diagram

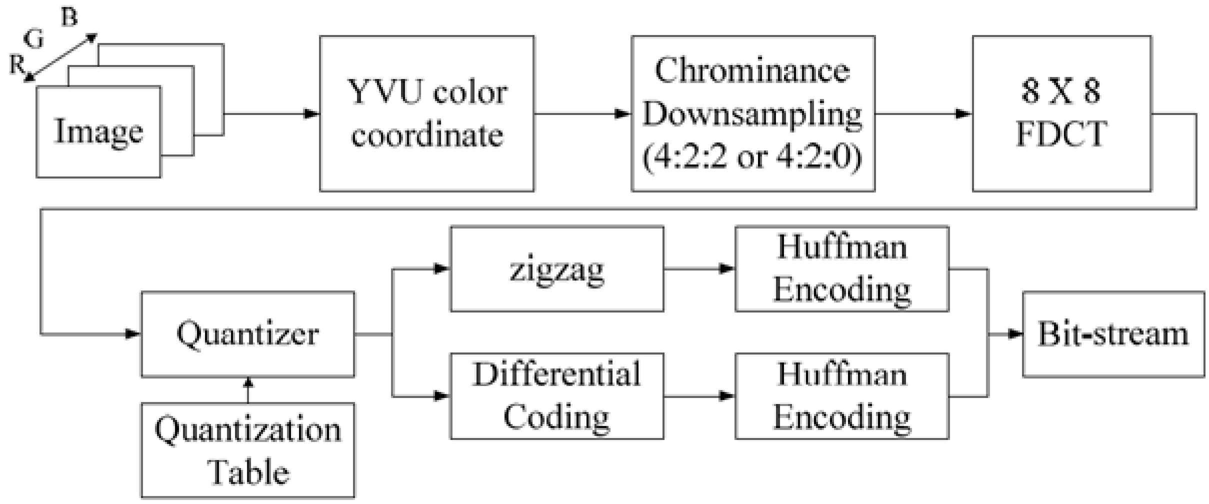


Fig.14 Encoder model of JPEG compression standard

Algorithm

Image is transformed into a suitable color space. This is a no-op for grayscale, but for color images we generally want to transform RGB into a luminance or chrominance color space (YCbCr, YUV, etc). The luminance component is grayscale and the other two axes are color information. The reason for doing this is that we can afford to lose a lot more information in the chrominance components than we can in the luminance component. The human eye is not as sensitive to high frequency chroma info as it is to high frequency luminance. However, compression will be less since we will have to code all the components at luminance quality. The color-space transformation s slightly lossy due to round off error, but the amount of error is much smaller than what we typically introduce later on.

The next step of the JPEG algorithm is to partition each of the color planes into 8x8 blocks. Each of these blocks is then coded separately. The first step in coding a block is to apply a cosine transform across both dimensions. This returns an 8x8 block of 8-bit frequency terms. So far this does not introduce any loss, or compression. The block-size is motivated by wanting it to be large enough to capture some frequency components but not so large that it causes “frequency spilling”. In particular if we cosine-transformed the whole image, a sharp boundary anywhere in a line would cause high values across all frequency components in that line.

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Table.1 JPEG default quantization table

After the cosine transform, the next step applied to the blocks is to use uniform scalar quantization on each of the frequency terms. This quantization is controllable based on user parameters and is the main source of information loss in JPEG compression. Since the human eye is more perceptive to certain frequency components than to others, JPEG allows the quantization scaling factor to be different for each frequency component. The scaling factors are specified using an 8x8 table that simply is used to element-wise divide the 8x8 table of frequency components. JPEG defines standard quantization tables for both the Y and I-Q components. The table for Y is shown in Table 1. In this table the largest components are in the lower-right corner. This is because these are the highest frequency components which humans are less sensitive to than the lower-frequency components in the upper-left corner. The selection of the particular numbers in the table seems magic, for example the table is not even symmetric, but it is based on studies of human perception.

These quantized 8X8 blocks are scanned in a zigzag passion. While scanning only those frequency components, which are of interest, are selected and remaining are neglected. Basically zigzag scan is performed to retain DC and Low frequency information and neglect high frequency information.

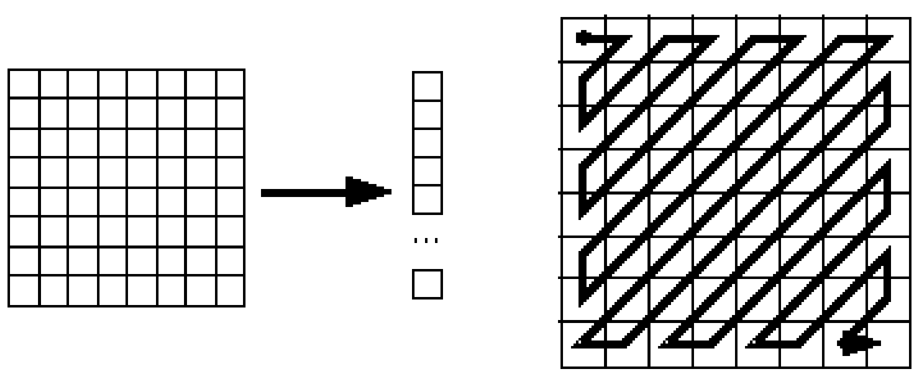


Fig.15 Zig-zag scanning of JPEG blocks

JPEG compression then compresses the DC component (upper-leftmost) separately from the other components. In particular it uses a difference coding by subtracting the value given by the DC component of the previous block from the DC component of this block. It then Huffman or arithmetic codes this difference. The motivation for this method is that the DC component is often similar from block-to-block so that difference coding it will give better compression.

The other components (the AC components) are now compressed. They are first converted into a linear order by traversing the frequency table in a zig-zag order (see Figure 15). The motivation for this order is that it keeps frequencies of approximately equal length close to each other in the linear-order. In particular most of the zeros will appear as one large contiguous block at the end of the order. A form of run-length coding is used to compress the linear-order. It is coded as a sequence of (skip,value) pairs, where skip is the number of zeros before a value, and value is the value. The special pair (0,0) specifies the end of block. For example, the sequence [4,3,0,0,1,0,0,0,1,0,0,0,...] is represented as [(0,4),(0,3),(2,1),(3,1),(0,0)]. This sequence is then compressed using either arithmetic or Huffman coding. Which of the two coding schemes used is specified on a per-image basis in the header.

Since only the updated pixels are transmitted all the other pixels will be black and the implementation of JPEG compression which employs the efficient source encoding technique like Huffman coding can compress the data to be transmitted even more thus saving more power.

DWT compression

More reliable transmission of the important parts enhances image quality, while suppressing unimportant sub-band coefficients, leading to energy efficiency. Our proposed Priority Image Transmission (*PIT*) approach achieves high energy efficiency with an acceptable compromise on the image quality.

The output after applying 2-D wavelet transform to the 256*256 Lena image is shown in Figure-16.

Original image

LL

LH

HL

HH

Fig.16 LL, LH, HL and HH sub-bands respectively after wavelet transform through 2D-DWT

The wavelet coefficients having significant information are LL and LH sub-bands. The information for the significant wavelet coefficients are transmitted with higher quality assurance, whereas relatively less important coefficients are suppressed. So it is only needed to transmit these two sub-bands thus saving 50% of the total energy consumed.

Channel Encoding

The first challenge in image transmission is that compressed images are sensitive to packet errors. For this reason, a reliable channel encoding scheme is needed to ensure that all image packets are sent and received correctly. We have implemented a concatenated channel encoding scheme which uses the (3,1) repetition codes and the (7,4) Hamming codes.

Repetition Code :

In coding theory, the repetition code is one of the most basic error-correcting codes. In order to transmit a message over a noisy channel that may corrupt the transmission in a few places, the idea of the repetition code is to just repeat the message several times. The hope is that the channel corrupts only a minority of these repetitions. This way the receiver will notice that a transmission error occurred since the received data stream is not the repetition of a single message, and moreover, the receiver can recover the original message by looking at the received message in the data stream that occurs most often.

The encoder is a simple device that repeats, r times, a particular bit to the waveform modulator when the bit is received from the source stream. For example, if we have a (3,1) repetition code, then encoding the signal M=1 0 1 0 0 1 yields a code C=111 000 111 000 000 111.

Repetition decoding is usually done using Majority logic detection. To determine the value of a particular bit, we look at the received copies of the bit in the stream and choose the value that occurs more frequently. For example, suppose we have a (3,1) repetition code and we are decoding the signal c= 110 001 111. The decoded message is m=1 0 1, as we have most occurrence of 1's (two to one), 0's (two to one), and 1's (three to zero) in the first, second, and third code sequences, respectively. This approach discards any 'soft' probability information obtained when decoding each received bit, and the performance of the code can be improved by retaining this probability information and using it to derive a joint probability across all n bits of the actual information bit value.

Hamming Codes :

In coding theory, Hamming(7,4) is a linear error-correcting code that encodes 4 bits of data into 7 bits by adding 3 parity bits. The Hamming code adds three additional check bits to every four data bits of the message. Hamming's (7,4) algorithm can correct any single-bit error, or detect all single-bit and two-bit errors. In other words, the minimal Hamming distance between any two correct codewords is 3, and received words can be correctly decoded if they are at a distance of at most one from the codeword that was transmitted by the sender.

Suppose we want to transmit this data (1011) over a noisy communications channel.

Hamming codes can be computed in linear algebra terms through matrices because Hamming codes are linear codes. For the purposes of Hamming codes, two Hamming matrices can be defined: the code generator matrix G and the parity-check matrix H:

$$\mathbf{G} := \begin{pmatrix} 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \qquad \mathbf{H} := \begin{pmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix}.$$

Channel coding:

Specifically, a binary symmetric channel meaning that error corruption does not favor either zero or one (it is symmetric in causing errors). Furthermore, all source vectors are assumed to be equiprobable. We take the product of G and p, with entries modulo 2, to determine the transmitted codeword x:

$$\mathbf{x} = \mathbf{G}\mathbf{p} = \begin{pmatrix} 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 2 \\ 3 \\ 1 \\ 2 \\ 0 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix}$$

This means that 0110011 would be transmitted instead of transmitting 1011.

Parity check:

If no error occurs during transmission, then the received codeword r is identical to the transmitted codeword x. The receiver multiplies H and r to obtain the syndrome vector z, which indicates whether an error has occurred, and if so, for which codeword bit. Performing this multiplication (again, entries modulo 2):

$$\mathbf{z} = \mathbf{Hr} = \begin{pmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 2 \\ 4 \\ 2 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

Since the syndrome z is the null vector, the receiver can conclude that no error has occurred. This conclusion is based on the observation that when the data vector is multiplied by G, a change of basis occurs into a vector subspace that is the kernel of H. As long as nothing happens during transmission, r will remain in the kernel of H and the multiplication will yield the null vector.

Error correction:

Otherwise, suppose a single bit error has occurred. Mathematically, we can write:

$$r = x + e_i$$

For example, if there is an error:

$$\mathbf{z} = \mathbf{Hr} = \begin{pmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 1 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 3 \\ 4 \\ 3 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$$

which corresponds to the fifth column of H. Furthermore, the general algorithm used was intentional in its construction so that the syndrome of 101 corresponds to the binary value of 5, which indicates the fifth bit was corrupted. Thus, an error has been detected in bit 5, and can be corrected (simply flip or negate its value):

$$\mathbf{r}_{\text{corrected}} = \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ \overline{1} \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix}$$

This corrected received value indeed, now, matches the transmitted value x from above.

Decoding:

Once the received vector has been determined to be error-free or corrected if an error occurred (assuming only zero or one bit errors are possible) then the received data needs to be decoded back into the original 4 bits.

First, define a matrix R:

$$\mathbf{R} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

Then the received value, pr, is equal to Rr. Using the running example from above:

$$\mathbf{p_r} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 1 \\ 1 \end{pmatrix}$$

In the proposed image processing system concatenated channel encoding technique is used which is a combination of both repetition codes and Hamming codes. First the image is encoded using repetition code scheme and then the encoded message is again encoded using Hamming code scheme. Even though redundancy is there the combination of the two encoding scheme will reduce the error rate and thus retransmission rate even in high error prone areas. Figure—

shows the Bit Error Rate (BER) Vs Signal to Noise Ratio (SNR in dB) plot of image which is encoded using concatenation encoding scheme.

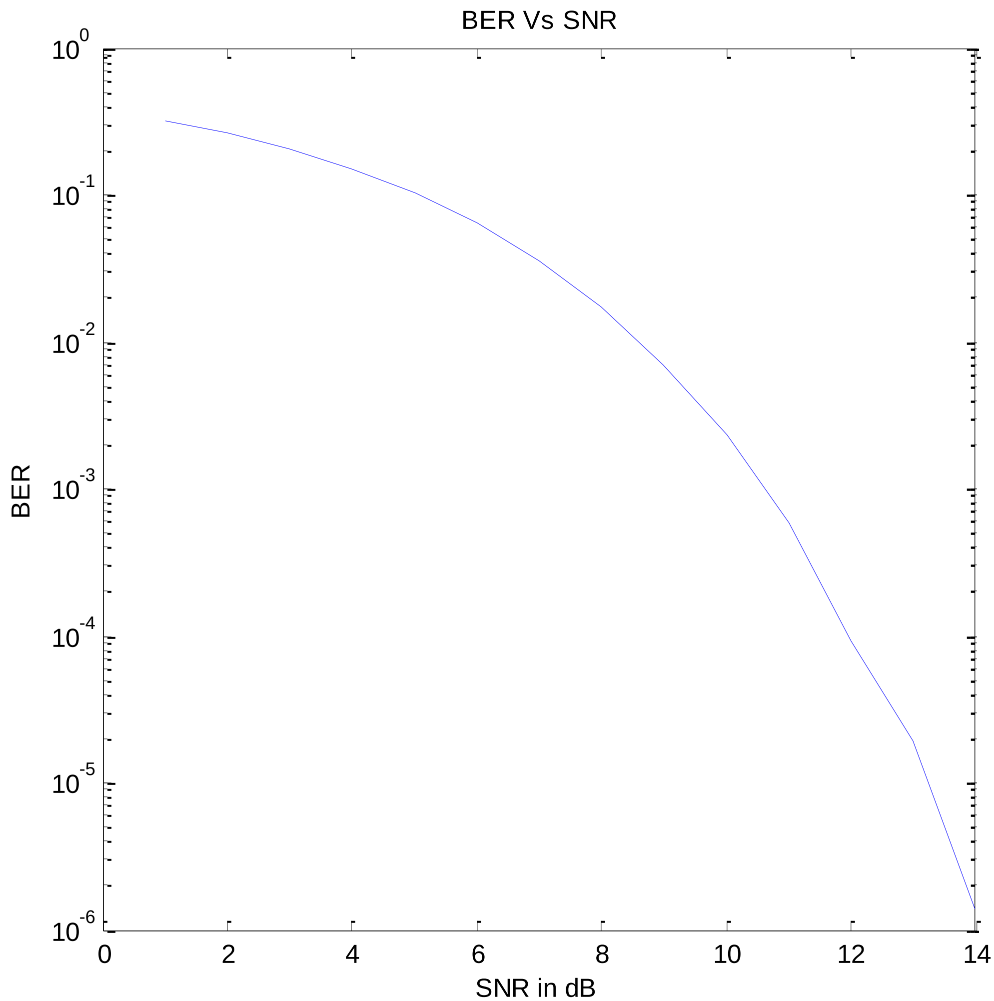


Fig 17: Graph of BER Vs SNR after applying concatenation encoding scheme

From the graph, the Bit Error Rate for an SNR of 10dB is 0.0023 while that without using channel encoding is 0.0377, which proves that the proposed technique will work efficiently in high noisy areas.

3.4 Reconstruction of Image

The extracted image is reconstructed at the receiver using the reverse procedure. The channel encoded data is first decoded into information bits transmitted. Then the decoded data is decompressed and the image is then overlapped with the back ground image to get the original image back.

Steps for reconstruction of the Image received:

- Channel decoding is done.
  - Hamming decoding is carried out first and then for the repetition codes.
- DWT decompression.
  - The reconstruction of the fore ground image using the received co efficients.
- Image overlapping
  - The reconstructed fore ground image is then overlapped with the back ground image.

Reconstructed images

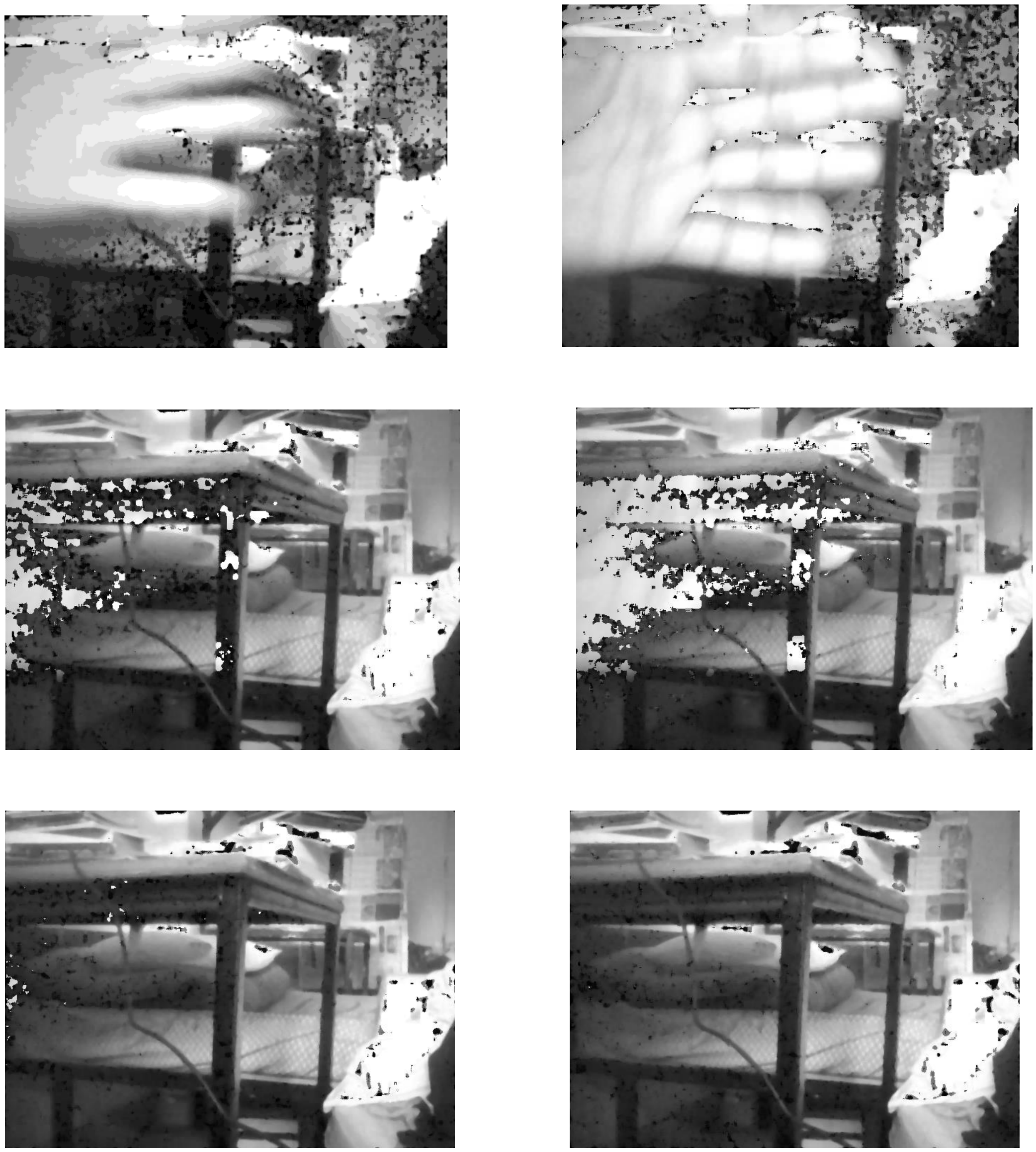


Fig.18 Reconstructed images

Chapter 4

Conclusion and Future works

4.1 Conclusion

An efficient use of energy is a crucial concern in wireless sensor networks. So far, the research community has tried to address the problem of power dissipation in two ways:

(1) Developing energy-efficient communication protocols and data processing algorithms

(2) Implementing and executing power management policies.

Whereas the former approach has usually a global scope (at any rate, a scope that goes beyond a single node), the latter has usually a local scope, limited to a single node.

The fore ground extraction algorithm reduces the huge volume of data generated into a limited number of images. The extracted fore ground images are then JPEG compressed. The fore ground extraction and JPEG compression techniques save a way lot of energy. Based on wavelet compression, a robust and energy efficient scheme called Priority Image Transmission in WSN is proposed by providing various priority levels during image transmission. The information for the significant wavelet coefficients are transmitted, whereas relatively less important coefficients are suppressed thus saving about 50% of the energy required. The object extraction architecture coupled with the DWT processor helps significantly reduce the energy cost of image transmission. The channel encoding scheme proposed in this paper incorporates an effective strategy to reduce packet error rate thus enables the sensor to work at even nosy environments. 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.

4.2 Future work

- A better channel encoding technique can be applied to increase the reliability of the system in error prone situations.
- An encryption algorithm can be implemented to secure the transmission and to make the system more reliable.
- A selective switching algorithm can be implemented to put the system in sleep mode if the system is idle for some time.
- The use of solar power as a secondary energy source will also increase the life of the nodes.

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