CROSS LAYER OPTIMIZATION IN CLUSTER BASED WIRELESS SENSOR NETWORK

Project report submitted in partial fulfilment of the requirement for the degree of Bachelor of Technology

in

ELECTRONICS AND COMMUNICATION ENGINEERING

By

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DECLARATION BY THE SCHOLAR

I hereby declare that the work reported in the B-Tech dissertation entitled **"CROSS LAYER OPTIMIZATION IN CLUSTER BASED WIRELESS SENSOR NETWORK"** submitted at **Jaypee University of Information Technology, Waknaghat India,** is an authentic record of my work carried out under the supervision of **Dr. Ashwani Sharma**. I have not submitted this work elsewhere for any other degree or diploma.

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Date: 21st May,2018

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CERTIFICATE

This is to certify that the work reported in the B.Tech project report entitled **"Cross Layer Optimization in Cluster based Wireless Sensor Network "**which is being submitted by **Harshul Tandan** and **Parima Goel** in fulfilment for the award of Bachelor of Technology in Electronics and Communication Engineering by the Jaypee University of Information Technology, is the record of candidate's own work carried out by him/her under my supervision. This work is original and has not been submitted partially or fully anywhere else for any other degree or diploma.

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LIST OF FIGURES AND GRAPHS

ABSTRACT

Wireless sensor network is one of the pioneering research topic in academia. Sensor networks are a network of sensing nodes deployed randomly and densely in a sensing area to gather the information about a specific parameter. These sensor nodes are small and have numerous tasks to perform with very limited energy, hence network lifetime is very small and needs to be addressed for network to work for long time.

We tried to exploit redundancy in a sensor network to maximise the network lifetime by proposing different transmission schemes. To do so we simulated two different networks, first being DWT image transmission over Rayleigh fading channel and the second being a cluster-based network with dynamic packet length, based on Gaussian correlation model given by Slepian & Wolf. In our research we proposed energy efficient transmission schemes for these networks to maximize the network lifetime.

CHAPTER 1

OVERVIEW

The use of Wireless Sensor Network (WSN) has proliferated in recent times. With the advancement of digital technology and electronics, the design and development of low-cost, low-power multifunctional sensor nodes have become feasible.

The enhancement capabilities of these sensor nodes, which include sensing, data processing and communication, enables the creation of wireless sensor networks (WSN) in various unrelated fields. Easy to expand, reduced wiring and implementable in un-accessible areas is its main advantages. This is the reason, it is widely used all over the world for different applications. WSN consists of several nodes of sensors powered by batteries. There are several types of sensors that are used for various purposes, such as heat, temperature, image, motion detection.

Using the WSN for real-time broadcasting has many important obstacles, such as limited energy resources and handling latency. There are many other problems encountered during transmission in WSN, such as redundancy, QoS requirements, fault tolerance, mobility, etc. All these problems require some different methods to overcome it.

Further in our discussions we provide an exposition to the DWT image transmission in a Wireless Sensor Network. We will be covering various aspects of the basic principles of the Wireless Sensor Network, advantages, disadvantages, issues faced and Image transmission using DWT in WSN. There already exists an extensive list of work in this field. Systemizing the Literature review, we'll discuss different transmission schemes for image sensing in WSN and propose our alternate approach exploiting redundancy and CSI to get energy efficient transmission of DWT images in a static model. We will further discuss our scheme in simulations and result to prove that our scheme performs better than other schemes in lifetime maximization.

Background of Wireless Sensor Network

Recent advances in technology have advanced to the development of small-sized battery-operated sensors that have the ability to detect environmental conditions such as temperature and sound. These sensor nodes are planted over a region building up a Wireless Sensor Network for the desired application

Typically, there are four basic components for the governing of a WSN:

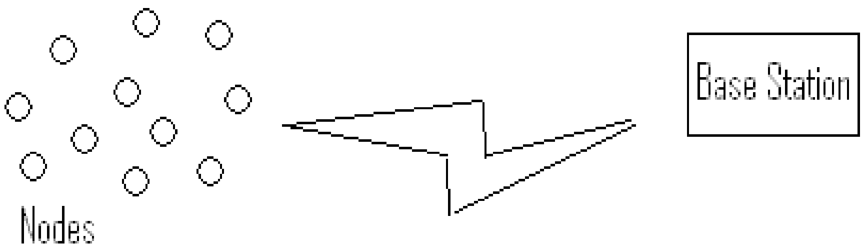
(1) Spatially distributed or localized sensors

(2) A wireless based interconnecting network

(3) A central hub for information clustering (in case of cluster based WSN)

(4) A Sink or a base station

Fig 1.1 Representation of Basic WSN



The sensor nodes communicate each other with the help of the radio Signals receiver or a base station acts as an interface between the network and users. You can get the information you want from the network by establishing queries and collecting the results from the base station. Each node of the wireless sensor network consists of a battery, a radio trans receiver& a CPU with computational abilities. They have limited storage capacity, processing speed and communication bandwidth.

Wireless Sensor network has attained extensive popularity due to their flexibility of deployment in any harsh or unfavorable environment and consequently remaining unattended yet performing their task.

This helps to use it in various applications like:

Military applications and Security Surveillance

Area Monitoring

Transportation

Health Application

Environmental Sensing

The topology of the network is not regular, and the nodes communicate with the base station through single or multi-hop paths. The nodes are deployed in the region randomly, geographically or using other algorithms as per the application.

Design Issues

There are a lot of challenges faced in the deployment of the Wireless Sensor Network. Nodes communicate over wireless channels which usually have interferences and noise and are hence, lossy. The most important is the limitation of resources at the sensor node. Once the energy of a node is consumed, it can no longer participate in the operation of the sensor network. After a significant number of nodes fail, in most cases over 70%, the network is declared dead.

. Therefore, the protocol should be designed initially keeping network lifetime maximization in mind. Let us elaborate the issues faced:

1.2.1 Scalability

Sensor networks vary in scale according to the application they are used in. Furthermore, the deployment density might also be varying. For acquiring high-resolution data, the node density should be distributed such that no single node has the burden of collecting a huge amount of data and eventually dying. Every node should have adequate number of neighbours to spatially transmit the data.

Transmission Media

Usually radio signals are used for transmission of the data across the nodes. This medium turns out to be lossy and thus resulting into loss of data. Although, some wireless networks use infrared or optical communication, the former having the advantage of being virtually interference free and robust.

1.2.3. Power Consumption

Many of the sensor network challenges revolve around power limitation. The size of the nodes limits the size of the battery. The design of the hardware and software must carefully consider the problems of effective energy use [1].

Transmission Collision

When many nodes transmit their data at the same time, the chances of collision of data near the sink due to data aggregation increases, resulting in data loss. This issue is also known as the hotspot problem.

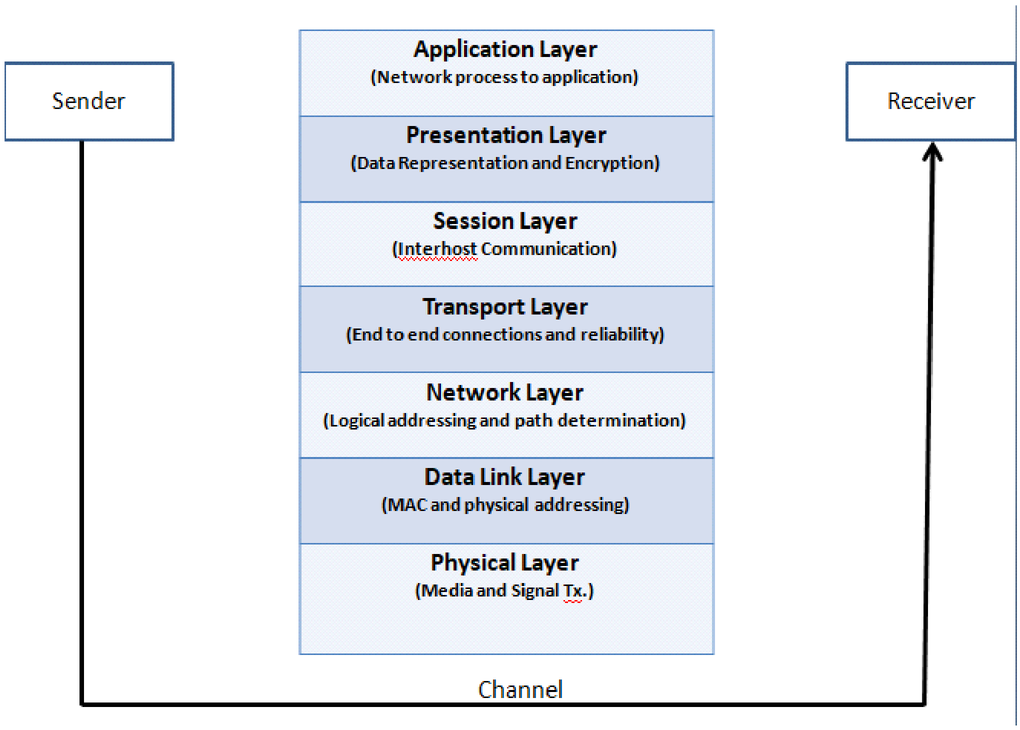
Communication structure of a wireless sensor network

The sensor nodes are usually randomly distributed in a region. Each individual node has the ability to detect data and send data to the base station. The basic protocol stack used by the sink and Sensor nodes is the OSI model or the cross-layer model.

1.3.1 The OSI Model

The Open System Interconnect (OSI) model defines a network Framework for implementing seven-tier protocols. Divides network communication into 7 different levels. The 1-4 levels are considered as the lowest layers and are generally involved in the information movement. Levels 5-7, higher levels, contain application-level information. The function of systems according to a fundamental rule: "pass it Over". Each level takes care of a secure task and then passes the information to the next level. In the OSI architecture, the control is passed by starting with a layer then in the next, starting from the application (layer 7) on a station, moving to the physical layer, traversing the channel, and getting into the physical level of the receiver. From there it goes to the application layer and the information is retrieved. The OSI architecture takes the allocation between system and partition management that even in what is referred to as a vertical stack that consists of the 7 levels that accompany. All these layers have their extended function as shown in the figure. They perform their task individually without interference from any other level. In this way, all seven layers waste a significant amount of energy on the network by performing different functions. In battery powered wireless networks due to energy restriction, working with these protocols produces hinderances and requires a serious review.

Fig 1.2 Functions of OSI layers



1.3.2 The Cross-Layer Model

Wireless sensor networks (WSN) can be used for various applications and require unconventional paradigms for protocol design due to several limitations. Managing a less complex design together with energy restriction management requires an adequate balance between signal / data processing capabilities and communication. This is when the design of the cross layer comes into picture.

The cross-layer design is called, "the breakdown of the OSI hierarchical levels in communication networks " [3]. The reason for cross-layer configuration is simply to use multi-layered OSI/TCP model data and to advance each other's execution of these levels to improve QoS of remote systems. In two distinctive ways we can select the cross-layer approach i.e. the static cross-layer approach in which we can use the known qualities of layers and together rationalize exposures or Co-adjust these layers by making new interfaces or Cooperation between levels. Secondly, by updating the dynamic transverse layer, it can react and adapt to the dynamic conditions, revealing the internal layers data to build new interfaces.

The immense challenge behind executing cross-layer configuration lies in the fact that occasionally the formation of new interfaces may prompt startling conditions which generally can't be anticipated at reproduction or testing level. Besides in communication systems, numerous irregular ambiguity may happen at top (application layer) and base (physical) layers.

1.4Cluster based WSN

1.4.1 Need for cluster based WSN

The most critical challenge in WSNs is to maximize the network lifetime because of the constrained energy resources. Another real challenge in WSNs is the hotspot issue that develops in the region with heavy traffic load. Nodes in such regions rapidly deplete energy, hence dying out early. In such a situation, cluster based WSN can help to increase the network lifetime and energy.

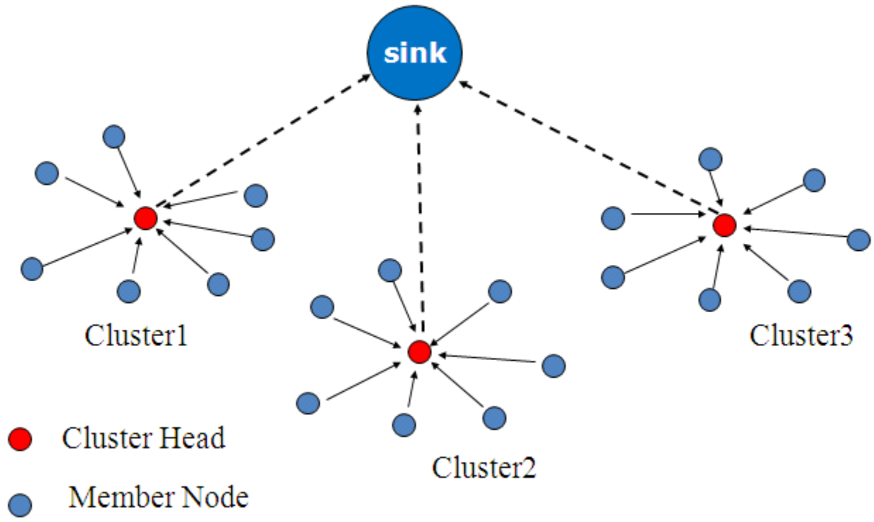


Fig 1.2 Layout of a Cluster based WSN

1.4.2 Overview

Cluster-based WSN is based on clustering nodes in different, equal, or unequal structures. A cluster consists of a cluster Head (CH) and a cluster members (CMS). The cluster header can be selected by sensors in a cluster or pre-assigned by Network Designer. A CH can also be just one of the sensors or a node that is richer in resources. To balance the power consumption and traffic load on the network, CHS is rotated across all CMS. In addition, the CH assigns slots to the CMS based on its residual energy to increase the rest time, i.e., which remain dysfunctional when not transmitting. Furthermore, the energy consumption of CH can be further reduced by aggregating the data.

Redundancy

Redundancy is an important feature of the sensor networks that must be carefully handled to improve the energy efficiency of sensor networks. The amount of required redundancy is one of the major parameter that affects almost all of the protocols designed for WSN. It must be used to increase the accuracy of the data, reliability of detection, network lifetime and security, routing of data and the time when the planned measures are ready to be used, there are two types of redundancy in WSN: spatial and temporal redundancy. Spatial redundancy describes the ability to obtain information for a specific location from various sources. This type of redundancy is almost inherent and very common in wireless sensor networks because, in general the nodes are densely distributed, providing a lot of redundancy in the network both spatially and temporally. There are two possibilities to involve spatial redundancy in the transmission process by a specific sensor: physical redundancy and analytical redundancy (functional). Physical redundancy is an attribute of a WSN that can measure a variable in a specific location using more than one sensor. Physical redundancy involves the same data being measured by different sensors which are physically close to each other.

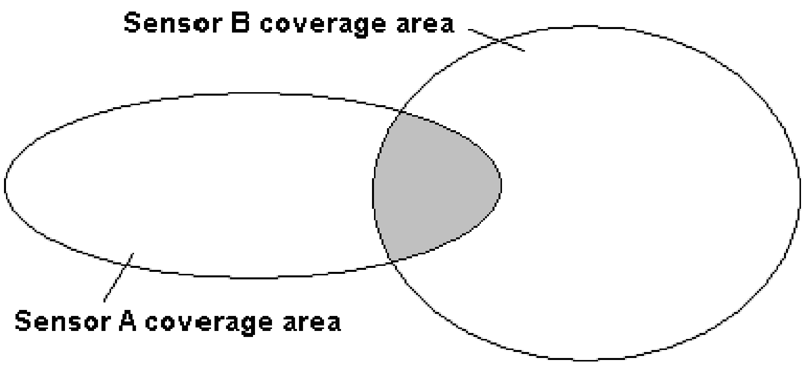


Fig 1.3 Physical redundancy

Analytic redundancy is an attribute of a WSN which estimates data of different nodes using mathematical models based on actual detection data provided by nearby sensors. The analytical redundancy allows a comparison process between the real value of the sensor and the expected/estimated value of the sensor which leads to improvements in the function and detection of bad/harmful sensors. This approach is based on a mathematical model capable of estimating the value of sensed data from different sensor, taking into account the past and current values of the nearby sensors.

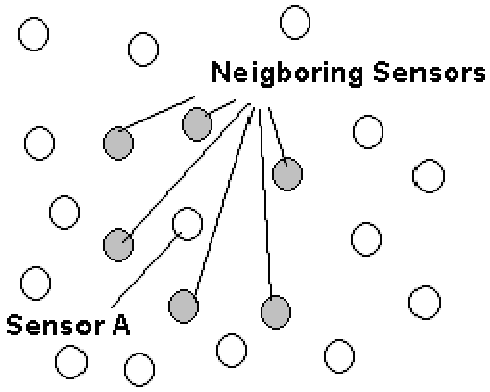


Fig 1.4 Analytical Redundancy

Methods are often needed to reduce or even eliminate spatial redundancy in order to find a balance between the pros and cons of a specific WSN application. This process is done by adding data to a specific node, this process is called data aggregation.

Temporal redundancy also known as time redundancy can be related to detection, communication, or both. The temporal redundancy of detection is defined as obtaining different measurements from the same point of the sensor, over different time. This type of redundancy is often used in video surveillance and represents support for multiple codecs based on special data compression techniques. The redundancy of temporary communication is defined as sending the same data packet more than once, distorted over time. The Auto-repeat request (ARQ) is an example of temporary communications redundancy.

The redundancy of the information is defined as the use of redundant data, additional p. bits, to rebuild the lost information. Redundancy can be used to improve fault tolerance, increase energy efficiency and even improve the security of wireless sensor networks. The redundancy property can be used in all types of sensor network applications.

In this chapter we tried to provide an overview of what wireless sensor network is all about and how it can be used in wide range of applications. Also, we looked at some of the shortcomings related to it and some methods that can be exploited to overcome those shortcomings. In the next chapter we would present a review of preexisting work that had been done in WSN. More precisely we would look at image sensing and how transmission protocols are designed for Wireless multimedia sensor network

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Fig1.1

https://www.google.nl/search?biw=1366&bih=637&tbm=isch&sa=1&ei=3jMhWpGtOYfUwQKvmYaYDQ&q=wireless+sensor+networks+images&oq=wireless+sensor+networks+&gs_l=psy-ab.1.2.0i19k1l10.29982.29982.0.32330.1.1.0.0.0.0.220.220.2-1.1.0....0...1c.1.64.psy-ab..0.1.216....0.mlnw2JUoNCE#imgrc=ZyXRwGaRn6dO0M:

Fig1.2

https://www.google.nl/search?q=cluster+based+wsn&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiPu_TazebXAhWFZVAKHdnqCcAQ_AUICigB&biw=1366&bih=637#imgrc=zv3Hy2R-90WbDM

CHAPTER 2

LITERATURE REVIEW

In our research pertaining to wireless sensor networks we came across a vast array of applications related to it, here are some of the works that had been done in academia.

To address the issue of redundancy in image transmission for a WSN,

In [1] the authors exploited spatial and temporal redundancy to propose a distributive image coding and transmission scheme. The spatial redundancy among neighbouring image sensors was exploited using image subtraction method. The authors first applied shape matching methods to find the maximum overlap between the sensed images of neighbouring nodes and then used it to transmit the background image once to the sink. The difference between the background image and sensed image of each node is coded separately and transmitted to sink. Temporal redundancy of each node is used to transmit the difference between two successive images to the sink. When an event is triggered one of the sensor nodes among redundant nodes transmits the background image and rest of the sensors only transmit the difference between this background image and their sensed image.

At sink the background image is fused with the difference images during any triggered event and whole image is reconstructed for each sensor node.

In this extensive survey [2] the authors reviewed existing protocols in multimedia WSN for each layer in TCP/IP model. Then they emphasized the fact that cross layer approaches for multimedia WSN are fairly non-present and the existing cross layer protocols in the literature do not provide full scalability. The authors concluded that for minimizing power consumption, coding of the raw data and communication from nodes to other nodes or sink should be jointly optimized. In a densely deployed WSN, multilayer scheme at application layer, multipath routing at network layer and hybrid MAC protocols give better solution than existing schemes.

The revelations made by the authors about the value of energy required for compressing 1 bit of image using a transform level of L=2 (0.278 micro Joules) & energy required for transmitting and receiving 1 bit of image over a single hop of 30 m (0.19 micro Joules). These values were used by us in modelling of our system.

In [3] the authors proposed a joint optimization problem based on correlated data (redundancy). They used distributive source coding along with a power allocation scheme to reduce overall distortion & power consumption. The main contribution of this paper is to use source coding for information from a vector source.

In [4] the authors proposed an energy saving scheme where they encoded the image using DWT layered scheme & then transmitted the sub images over OFDM sub-channels according to 1bit channel state information (CSI). They exploited the scalability of layered coding scheme, where fewer layers are needed at the receiver to reconstruct the complete image while maintaining quality. The sub images are mapped onto sub channels according to decreasing priority. The most important sub image is transmitted through the good sub channel & unimportant sub images are mapped onto bad ones. The mapped sub channel having SNR below a threshold values were dropped at the transmitter itself hence saving more energy. This approach reduced latency in image surveillance as important sub images almost always reaches at the receiver which can be used to construct image without the need of other layers. We tried to make use of this multilayer multichannel approach to send DWT images in a densely deployed redundant WSN.

In [5] the authors proposed a scheme based on reliable transmission of important and semi reliable transmission of unimportant sub images. The authors used DWT coding scheme to make four sub images of unequal importance. The lowest resolution sub image is transmitted reliably i.e. this packet is given highest priority by all nodes between the source and sink. The rest of the sub images are transmitted semi reliably i.e. packets can be dropped by the nodes according to their battery's energy level. This scheme results in overall saving of energy of nodes, maximizing the Network Lifetime while maintaining monitoring quality.

In [6] the authors proposed a retransmission scheme based on sensing relevancy and most important packets. They used DWT to encode the image and then the resulting sub images are transmitted through multi hop. The sensing areas with high relevancy have packets of high priority and if they are corrupted during transmission all the packets are retransmitted. The highest priority packets from low relevancy sensing area are retransmitted and rest if corrupted are not retransmitted.

In [7] the authors used distributive image coding to minimize the computational power required by one node. They proposed a scheme where high pass sub image coefficients were not computed hence saving the energy for little trade off in quality.

In [8] The authors investigated the problem of maximizing life in wireless sensor networks under the limitation of the likelihood of success of end-to-end transmission, adopting a cross-layered strategy that considers the physical layer, Mac sheet and finish. of the network together. Power control in the physical layer, the ARQ control in the MAC layer, the routing protocol in the network layer balances the balance between the network life and the reliability restriction and provides the means to control the reliability Quantitatively minimizing energy consumption.

In [9] the authors proposed a redundancy removal technique using support vector machine (SVM) to eliminate the identical sensed data from different sensors. In this approach all sensor nodes send their sensed data to a cluster head or aggregation supervisor node which directs one of the sensor node among nodes having the same data to transmit the data to sink and rest of the nodes remain dormant. This data aggregation technique helps in removing redundant data conserving the limited energy of nodes hence maximizing the network lifetime.

In [10], the authors proposed a pattern of transmission of the grouped images of two leaching based jumps. In the proposed scheme, the node with a camera acts as a cluster head and forms its own cluster of cameras. Nearby normal sensors unite the camera cluster, share image compression activities, and assume responsibility for transmitting compressed data to the normal cluster header. By adjusting the transmission radius of the camera-equipped node and assigning image compression tasks based on the irregular distribution of residual energy from the sensor nodes, the network's useful life is maximized. The main drawback of this scheme for WMSN is that the nodes must be densely distributed to conserve total energy and maximize lifetime.

In [11], the authors proposed an efficient image transmission strategy that exploits DWT's multiple resolution functionality. They considered the SDF cooperative transmission scheme (decoding and selective forwarding), Where the relay sends a lower resolution version (LL) of the image originally transmitted from the source to the destination node. So even if the destination does not receive the source image, it is likely to receive it from the relay. This scheme reduces energy consumption by avoiding retransmission while maintaining the average quality of the monitoring.

The majority transmission protocol presented in this review use source coding techniques, such as DWT to encode the image and then exploiting the cluster-based property of WSN came up with energy efficient protocols to prolong the network lifetime. Our inspiration for designing a protocol for WSN came from extensive reviews of literature pertaining to image sensing and transmission. We tried to implement this source coding technique DWT in our model and manipulate the sub images to come up with an energy efficient protocol. In the next chapter we present a detailed view of the transmission protocol that we designed for WSNs.

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CHAPTER 3

Energy Efficient Handling of DWT-Image Transmission over Wireless Sensor Network

3.1 INTRODUCTION

In the previous chapter the reader was made aware of the preexisting work that had been done in designing of the protocols for WSN. To maximize the network lifetime the focus was on removing redundancy in the sensed data so as to save the amount of data being transmitted by each sensor nodes, saving the energy in the process. But due to bad channel conditions, congestion, packet dropping and collision all the data is not transmitted successfully to the sink from sensor nodes the very first time and requires retransmission of packets which again requires energy and hence network lifetime is reduced. Another problem that arises due to redundancy removal is that the monitoring quality reduces significantly as only one packet of each type is transmitted and if it is corrupted during the sensing period or during the transmission period there is no other way to retrieve that data once it is removed.

To overcome these shortcomings, we tried to exploit the redundancy in data transmission for image sensing, instead of removing it. To do so we used an image coding technique DWT (Discrete Wavelet Transform) to encode the sensed image at the sensor node and then transmit the data to sink via cluster head.

We explored the possibility of a collaborative image-transmission approach to increase network life by leveraging data priorities along with channel state information (CSI) between the sensor nodes and CH. The proposed scheme implies a reduction in redundancy and a more efficient use of the power of the network to achieve an acceptable quality of the image detected in the CH. We simulate this scheme to support our hypothesis. We also compared this pattern with two other patterns: Scheme I in which all nodes transmit detected images that result in a good quality reception but a shorter network lifetime and Scheme II in which only one packet is transmitted between the nodes related to the maximum residual energy, which increases the network lifetime.

We simulate the model for three different transmission schemes for transmission from sensor nodes to Cluster head and then compare those schemes for network lifetime and quality of reception. In the next section we provide a detailed overview of DWT. Section 3.3 provides the system model used in our simulations and section 3.4 gives the simulation results for the different schemes.

3.2 Discrete Wavelet Transform

The most important challenge in WSNs are network lifetime and area coverage. Network lifetime is reduced due to limited battery life. Common method to reduce energy consumption are data coding at the source based on relevancy of data and turning off redundant nodes.

Priority based algorithms optimizes energy usage by giving the data and/or sensors a set of relevancies. Priority level optimization can be performed using two ways: local level prioritization and global level prioritization. Global level prioritization is not associated with network topology or sensor positioning, it gives priority to sensors and/or data on global level depending upon application. Priority at the local level gives priority to data based on relevance in quality and reconstruction at the receiver. One of the local prioritization techniques is DWT (discrete wavelet transformation) which provides the decomposition of data at multiple resolution levels that can be used to send more relevant data reliably and less relevant data in a semi-reliable manner.

DWT decomposes a signal (a series of digital samples) by passing it through two filters: a low-pass filter L and a high-pass filter H. The low-pass sub-image represents a low-resolution version of the original sample signal, while the high-level secondary image contains information about the residual signal. For a perfect reconstruction of the original signal on the receiver side, all information on the low-pass and high-pass filters is required.

A 2D DWT is a process of a layering where the original image, taking rows and columns, generates four sub-images based on the filter considered (low and high) in LL, HL, LH, and HH. The Sub image LL represents the lowest resolution and a version of a quarter of the original image. In fact, it is the most important information for the decoding process (without it, the image cannot be recompiled), while the remaining subpictures contain the vertical, horizontal, and diagonal details for the decoding process that They add quality to the image reconstruction. Figure 3.1 shows a Lenna image that is decomposed using 1 level DWT into four sub images, as you can see that the sub LL image represents the most important part and rest of the sub images just add depth to the image. This property of DWT to decompose an image into four sub images reduces the size of images to be transmitted by one fourth and hence reduces the required transmitted energy. This is a lot of energy saved for a small sensor with limited battery life. So, this type of layered coding scheme is an indispensable tool in WMSN and DWT is one of them which we used in our model.

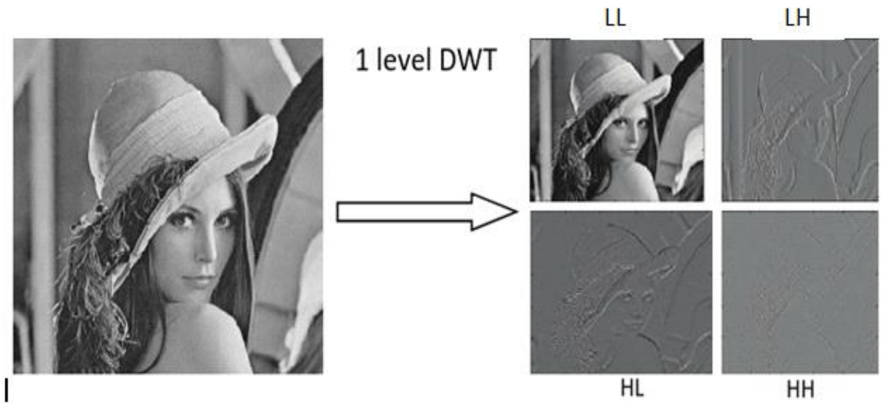

Fig 3.1 Decomposition of an image into four sub images

3.3 System Model

Consider a general cluster-based WSN model in which nodes are randomly and densely deployed to detect images in a tracking environment. The nodes of the sensor detect the images in the target areas and communicate with their respective CH, which then transmits the data to the receiver. Each group consists of N-nodes of the sensor and a CH as shown in Fig. 3.2.

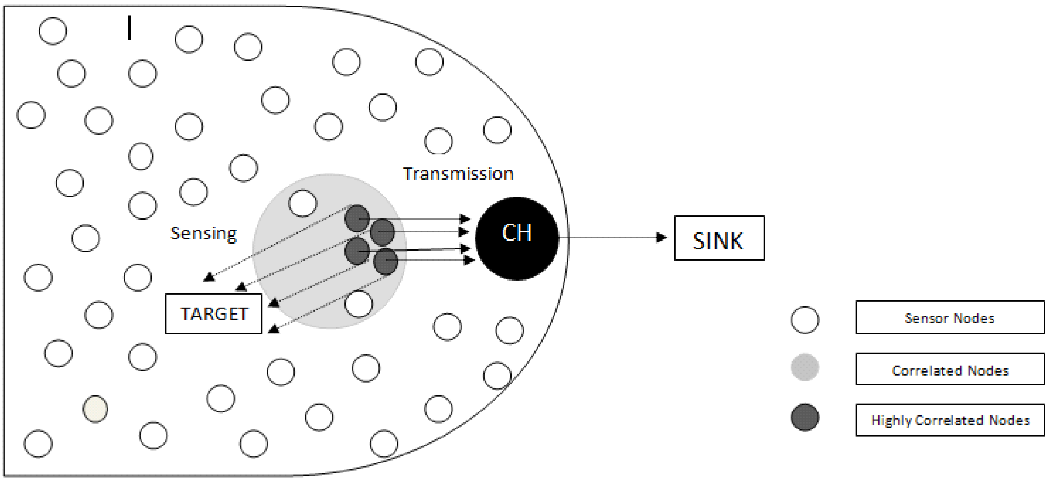

Fig. 3.2 Cluster based WSN model with redundant nodes

Priority based algorithms optimizes energy usage by giving the data and/or sensors a set of relevancy. Priority level optimization can be performed using two ways: local level prioritization and global level prioritization. Global level prioritization is not associated with network topology or sensor positioning, it gives priority to sensors and/or data on global level depending upon application [3]. Local level prioritization prioritizes data based on relevance in monitoring quality and reconstruction at the sink. One of the local level prioritization technique is DWT (discrete wavelet transforms) that provides data decomposition in multiple level of resolution which can be exploited to send more relevant data reliably and less relevant data semi-reliably [4].

We consider N nodes deployed randomly and densely in a sensing environment. This part of the network as shown in fig.1 consists of sensing nodes, a cluster head and a sink. The nodes are deployed to sense images for monitoring applications. These nodes sense images from the surrounding environment and send the data in the form of packets to the cluster head which then transmits the data to the sink. Out of these N nodes, k nodes have the same sensing radii [4] and hence have highly correlated data. These k nodes having the most redundant data, have four nodes with entirely same data. This redundancy can be exploited to save energy hence maximizing the Network Lifetime. We assume single hop transmission between the sensor nodes and CH. The channel between the nodes and CH is a slowly fading, Rayleigh fading channel with Additive White Gaussian noise (AWGN). The fading coefficient remains the same between two consecutive image transmissions i.e. fading decorrelates after each image transmission. The channel characteristic is a measure of average SNR. We say SNR_{avg} as the nodes adjust their transmission power according to the distance between them and CH thereby averaging out the SNR for the whole network.

Threshold SNR (SNR_{th}) is the minimum SNR required for the transmission of a packet without complete loss of information.If SNR of a channel is below SNR_{th}, then the node does not transmits the image to the CH thereby conserving the energy. Each sensor node in the network senses the image using its sensors and then in the microprocessor, image is decomposed into four sub-images using DWT (discrete wavelet transform). DWT provides data decomposition into multiple level of resolution which can be sent through the sensor nodes channel.

DWT decomposes a signal (a series of digital samples) by passing it through two filters: a low pass filter L and a high pass filter H. The low pass sub-image represents a down-sampled low resolution version of the original signal, while the high pass sub-image contains residual information of the signal. For the perfect reconstruction of the original signal at the sink, all information from low pass and high pass filters are necessary. A one level 2D DWT processes original image considering rows and columns generating four sub-images according to the considered filter (low & high) into LL, HL, LH & HH. The LL sub-image represents the lowest resolution and a half-sized version of the original image. In fact, it is the most significant information for the decoding process (without it, the image cannot be rebuilt), while the remaining sub-images contain vertical, horizontal and diagonal details for the decoding process which add quality in reconstruction of image.[3] In our system model we consider an image of size 256 X 256 X 8 bits sensed by a sensor node which is compressed using DWT into priority based sub-images with each sub-image of size 128 X 128 X 8 bits .The main energy consumption of the nodes takes place in the transmission of image. The transmission of one image from a sensor node to the cluster head requires an energy of .25 micro joules. In our model we use three different schemes to transmit the image from a node to the cluster head. Each scheme will have different energy consumption according to the transmission model and different quality of reception. The channel quality is measured using average SNR and the quality of reception using PSNR. The channel with high SNR will transmit image with less distortion and noise thereby increasing PSNR for the received image at the cluster head.

3.3.1 Scheme 1

In first scheme, the transmission of k identical images takes place through each of their channels. This transmission scheme sends the identical data from k nodes to the cluster head through four different channels. Each channel will have different values of SNR for any given time. This scheme has high quality of reception due to the same image being transmitted through four different channels hence increasing the PSNR of the received image at the cluster head. However this scheme requires four times the energy required to send one image which results in frequent depletion of energy of the nodes. This results in a short Network Lifetime as nodes die out very fast.

3.3.2 Scheme 2

In second scheme, sensor nodes transmit data based on residual energy. The node with more residual energy transmits the data while the rest of nodes remain inactive during that time hence saving the energy of the network. The residual energy of the node is the amount of energy left in a sensor node at any given time. Cluster head has the information of all the sensor nodes' residual energy. Cluster head assigns the task of transmission of image to the node with highest residual energy among the four nodes. This scheme consumes less energy than the first scheme as only one node's energy is depleted in transmitting the image. But the node with the highest residual energy may not have the channel with good SNR. This results in distortion of the image and bad quality of reception at the cluster head. This bad quality is due to less PSNR of the received image which results in low monitoring quality. Although this scheme maximizes the Network Lifetime it does so with degraded Quality of Service.

3.3.3 Scheme 1 & Scheme 2 with 1-bit CSI at the transmitter

In the event that the CSI available at the receiver side can be returned to the transmission nodes of the sensor, the network lifetime can be further improved as shown in diagram 1 and Diagram 2, abstaining from transmissions when the channel is in deep fade. Assuming that the 1-bit CSI is available on each node of the sensor, which means that the channel condition is good or bad (the instant SNRth channel is less than SNRth), the sensor nodes do not transmit the data during a detection period. The power schemes are simulated with and without CSI for comparison purposes.

3.3.4 Proposed Scheme

The proposed scheme uses local level prioritization DWT in synchronization with global level prioritization, channel state information (CSI). The four nodes having the same four images can exploit the redundancy of data and residual energy. These nodes can transmit four different sub-images according to relevance. The node with highest SNR transmits the most relevant sub-image LL. Remaining channels with less SNR are used to transmit sub-images of decreasing priority (LH>HL>HH) as shown in fig. 2. As the LL sub-band is send through the best channel, the PSNR of the received sub-image LL is highest at the cluster head. The sending of one sub-image through a node results in a quarter of energy consumption by each node is different from the other two schemes. This distributed energy consumption among the nodes with same data prolongs the Network Lifetime while maintaining a good quality of reception. This scheme results in less energy consumption than the first scheme while maintaining a good PSNR than the second scheme. Our scheme consumes optimal energy and has the highest residual energy per node .This prolong the network lifetime giving good monitoring quality as well.

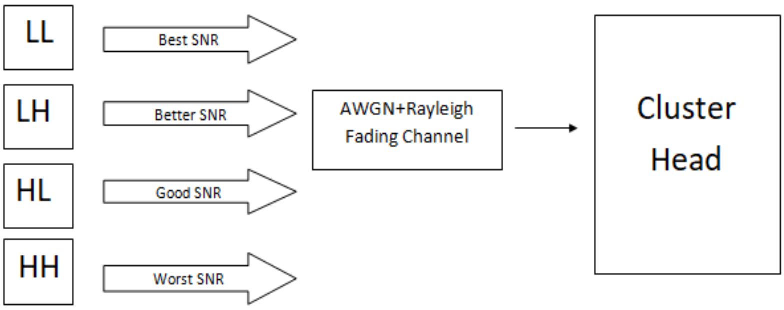

Fig 3.3 Sub images mapped in proposed scheme

The schemes above are simulated and the results are compared in the next section. For a comparison of the rates, the proposed scheme is simulated even without CSI and with the CSI cases of 1 bit. In both cases, the proposed schema cannot use priority in the transmission channel due to the lack of full availability of CSI in the sensor nodes, so subpictures LL, LH, HL, and HH are transmitted respectively from the nodes in the Sensor to decrease the residual energy. In addition, the 1-bit schematic proposed CSI adopts the limited approach of sub-image transmission that corresponds to widely used channels, as the sensor nodes know the good or bad status of the channel.

3.4 Simulation Results

The simulation and analysis results of the existing 2 Schemes and the proposed Scheme are presented here. We have obtained results by simulating a standard 'Lenna' image of dimension '256*256*8' pixels in a Wireless Sensor Network with Rayleigh fading in MATLAB. We have plotted the 3 System models and obtained the results. The first and second schemes are implemented with No Channel State Information (CSI) and the proposed scheme with CSI.

We have simulated results in 2 contexts. 1st shows the change of Peak Signal to Noise Ratio (PSNR) of the image, that determines the quality of the image with the Change in the Signal to Noise Ratio (SNR) of channel, i.e. the quality of the Channel (Figure 3.4).

If the received image's quality is less than the Threshold PSNR (here, 4dB), we declare that the image can't be reconstructed. 2nd result portrays our main Objective, i.e. Change in the Network Lifetime Maximization of the three schemes with respect to the SNR of the channel (Figure 3.5). The results are the averages of many simulations for the 3 Schemes.

Figure 3.6 shows the received Lena image on simulation of the Schemes. Scheme I results in the best image quality upon transmission. The quality has a very less deviation from the original image, i.e. all the DWT priority levelled images are received and have been reconstructed together. Scheme II image's PSNR is less than that of Scheme I, but is above the Threshold PSNR. It has a significant deviation with the original image i.e. some DWT priority packets must have been dropped due to bad Channel. The proposed Scheme's image PSNR has little deviation when compared to Scheme II.

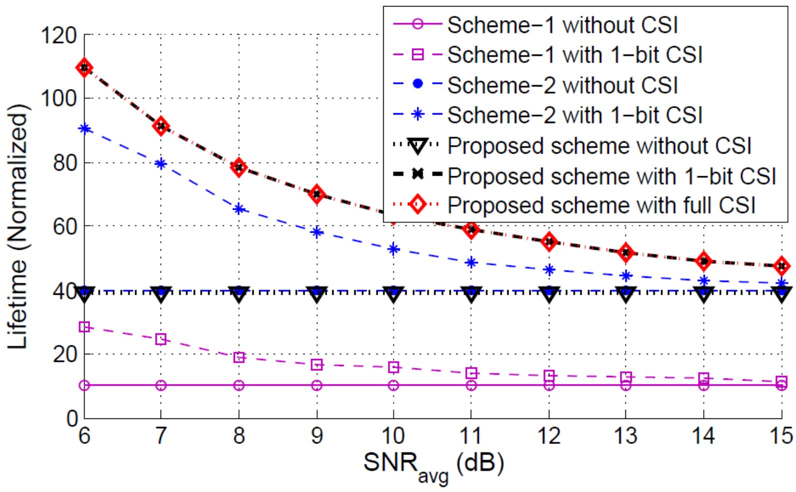

Fig 3.4 Network lifetime vs Fading channel quality

The normalized network lifetime is defined as the total number of images detected and sent that correspond to a target area before all the nodes of the sensor drain the energy. The change in the life of the network with the quality of the SNR_{AVG} channel of all the schemes considered is shown in Fig. 3.4. As is evident in the plots, scheme-1 shows less life, so it is a scheme of energy inefficiency. However, the system-2 improved the life of the network that scheme-1, the proposed system with CSI of 1-bit or full shows the best useful life and therefore turned out to be the energy efficiency regime. For example, in SNRavg = 11 dB, the network duration of the scheme proposed with CSI is greater in about 500%, 50% and 20% compared to that of the scheme-1 with and without CSI, scheme-2 without CSI, and scheme-2 with 1-bit CSI, respectively. In addition, this improvement from the proposed scheme in the network lifetime rises with the decrease of the channel quality as shown in the fig. 3. Therefore, the results confirm the assertion of increasing energy efficiency through the use of collaborative transmission to exploit redundancy along with the priority of the sensor nodes, as well as the data set and channels. To evaluate the performance of the image quality received in the Fading Channel, the variation of PSNR with SNR_{AVG} is plotted in Fig. 3.5 for all schemes. The results show that scheme-1 has the highest PSNR which is obvious because in this scheme the CH selects the best quality image from the multiple received copies of the same image

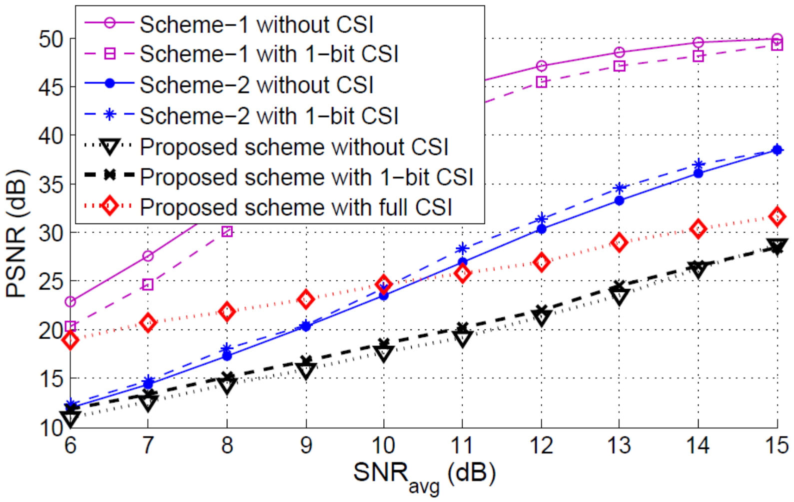

Fig 3.5 Received image quality vs Fading channel quality

The above images are the simulated results in MATLAB and received images are compared at the Cluster Head and it selects the best quality image from several copies received of the same image. In addition, the incorporation of scheme II priorities to eliminate redundancy and enhance the results of network life in a compromised PSNR. Diagram II shows approximately 15 dB of PSNR lower than the I-scheme for SNRavg = 11 dB. However the CSI 1-bit proposal shows the prolonged network life in Fig. 3.4, the PSNR of the image received in the diagram is the lowest, therefore, the energy conservation with degradation in the quality of the image received in relation to the scheme II. However, the proposed scheme with the complete CSI not only provides the maximum network lifetime, the corresponding PSNR is increased compared with the proposed program with 1-bit CSI and is even higher than that of the scheme II under faulty channel conditions. For example, an improvement of 5 dB in PSNR is noted for the proposed diagram with the complete CSI in comparison to the diagram II for SNRavg = 8 dB. However, in better channel conditions for greater SNRavg, the quality received by the proposed regime with the complete CSI is lower than that of the scheme-2 because the transmissions of some sub-images with low priority are retained in the proposed system To save energy that is about 25% for SNRavg = 15 dB as calculated from Fig. 3.5 For visual elements, the received images extracted in several phases of the simulations for diagram-2 and the proposed scheme diagram are shown in Fig.3.6 with PSNR = 18, 25, 33, 38 dB including the original images.

Fig 3.6 Received image with PSNR values for Scheme 2 and Proposed scheme

The effect of the noise in the channel is significant in all the images received mainly by low PSNR for both schemes. Moreover, the resulting images of the proposed scheme are distorted due to loss of low-priority sub images; Therefore, for the same PNSR proposed scheme images contains lesser noise than the respective images of the scheme-2. For PSNR = 33 dB and more, visually received images have much less change from the original image. In short, the results show that scheme-1 provides the best PSNR of the image, but the duration of the network is the lowest. The second scheme translates to a longer duration than the first, but significant degradation is observed in the PSNR quality of the image. While, the proposed scheme with the complete CSI shows the improved PSNR than that of the scheme-2 in the harsh channel condition along with a significantly improved network lifetime in comparison to other two schemes. Therefore, managing redundancy in WSN by the usage of collaborative transmissions and channel conditions results in prolonged network lifetime.

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Chapter 4

Conclusion

Our final year project is to research the possibilty of generating a transmission protocol for cluster based wireless sensor network.In this semester we tried to implement a tranmission protocol for a single cluster in a WMSN.To do these we made a model and proposed a scheme for the model for transmission of still image between sensor nodes and cluster head. The sensed images are encoded using 1-level discrete wavelength transform generating four priority based sub images. The channel state information is assumed available to the CH and can be fed to the sensor nodes. Three schemes for the transmission of prioritized sub images from sensor nodes to the cluster head are considered by exploiting redundancy in the sensed data. In Scheme I, all the sensing nodes transmit the data to the cluster head oblivious to redundancy. This ensures a best PSNR of the received image, however, results in a least network lifetime due to redundant transmissions. In Scheme II, priority of the nodes is explored to allow transmission by a single node having maximum residual energy to improve network lifetime. In the proposed scheme, all the nodes having redundant information participate in collaborative data transmission by exploiting priority of sub-images as well as the channel state information to judiciously utilize node's energy and improve network lifetime. The participating nodes transmit priority based sub-images by mapping more important data to a better quality and less important data to relatively low quality channel. Simulation results show that the proposed scheme outperforms the other two schemes in energy utilization and hence improves the network lifetime. Though, a trade-off between network lifetime and received image quality is present, the proposed scheme provides better quality of reception in harsh channel condition as compared to the Scheme II which addresses redundancy at the local level.

Chapter 5

Handling of Correlation in a cluster based WSN

5.1 INTRODUCTION

In our previous work we exploited redundancy in image sensing by decreasing the transmission energy required to send the image hence maximizing the network lifetime. To do so we used DWT image coding technique to divide the image into multi resolution priority-based sub images for transmission. The four different sub images are mapped onto the channels based on their channel state information to transmit the highest priority image with the best channel. We ran simulations for three different transmission schemes and found out that our proposed scheme performed significantly better than other two schemes in maximizing the network lifetime.

For our new contribution we tried to incorporate redundancy further in our transmission scheme for any sensed parameter in a dense wireless sensor network by using cross layer approach between Physical layer, MAC layer and Network layer. We deployed the sensor network to sense any parameter and then all the sensed data from all the nodes is transmitted to sink. To exploit redundancy in this scheme, we first divided the network into square shaped cluster of equal length and width to accommodate all the nodes present in the network. CH selection is done based on the maximum residual energy. Then Gaussian function is used to find the correlation among nodes. Once we find correlation among nodes using average distance of all the redundant nodes, we can find the packet length for each node for transmission to CH. We used two different schemes for making packets: in the first scheme, packets are transmitted as it is without any redundancy taken into account, for second scheme average distance is calculated between all the redundant nodes and is put into Gaussian function to find correlation. Once we find the correlation the packet length is calculated, for maximum correlation I.e. zero average distance the packet length is minimum and for no correlation I.e. average distance is more than the specified threshold value then the packet length is maximum.

We used cross layer approach in our model by using power control in physical layer, finding dynamic packet length in the MAC layer using distance obtained from physical layer and the data link layer is used to find the best possible route based on minimum distance for inter cluster transmission.

Our scheme of using redundancy to find the packet length saves significant amount of energy for each node in transmission hence maximizing the network lifetime. Our scheme performs better than first scheme, where no dynamic packet is made based on redundancy and all the packets are transmitted as it is.

5.2 System Model

The network consists of n nodes deployed randomly and densely in a sensing area to sense a parameter and send it to the sink located outside the network area as shown in fig 5.1.

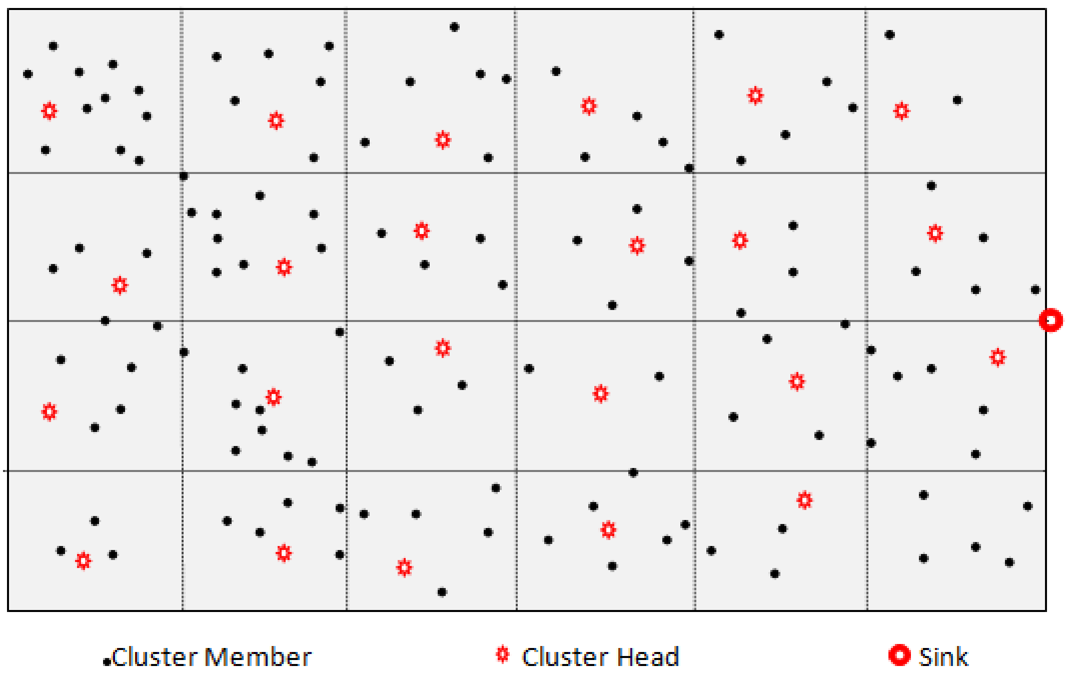

Fig 5.1 Clustered Wireless Sensor Network

Clustering is done spatially, so the nodes lying in a specific area are assigned to a particular cluster. Number of clusters in the network are calculated by dividing the network area with cluster width.

Energy is assigned equally to all the nodes of the network. A node randomly becomes the cluster head as all nodes have equal energy for that iteration. The transmission process of a packet involves two steps:

1. Intra cluster transmission
2. Inter cluster transmission

In Intra cluster transmission all the nodes in a particular cluster sense the data and transmit the entire packet to the cluster head. The energy of all the nodes is depleted according to power control which is implemented according to its distance with the cluster head. Further, the cluster head transmits the collected data from all the node to the next cluster head. This is done using shortest path algorithm where the distance between all the CHs is calculated and each CH transmits its data to the sink using multi hop routing. The CH finds its route dynamically by sending the packet to the CH which is nearest from the sink and eventually the packets reach at the sink. For inter cluster communication CH loses energy while transmitting the data and all other CH which lie on the route lose energy for receiving and transmitting it further. Once all the packets from all the clusters reach the sink one complete iteration takes place. The energy of the cluster is also depleted as per the power control and number of packets aggregated. This process is repeated for all the clusters completing one iteration i.e. transmission of one packet from all the clusters to the sink.

Again, the transmission process is repeated, Cluster heads are assigned and packets are sent. There is a threshold set for both the cluster head and members. If their energy gets depleted beyond the threshold, the specified nodes do not take part in further transmission. If more than thirty percent of nodes in the network have energy below threshold energy, the network is declared dead.

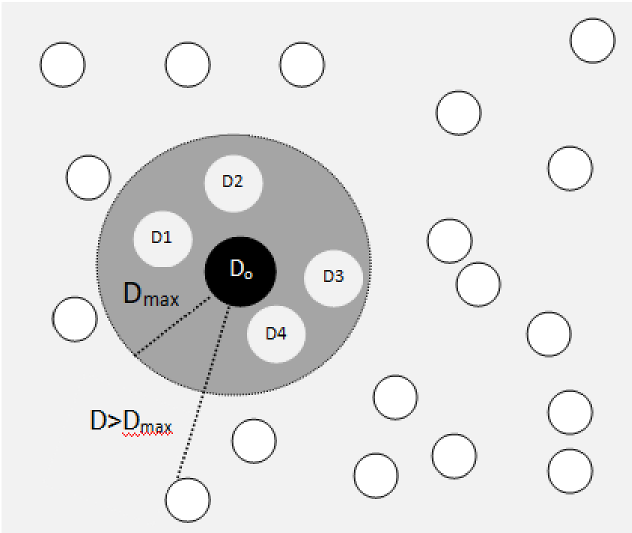

Fig. 5.2 Redundant nodes with correlated data with respect to node D_o

The case mentioned above is the ideal case, where if m number of cluster members are present in the cluster, the cluster head would have to transmit m+1 packets ahead. This would exhaust a lot of energy. To reduce this overhead, we try to exploit redundancy by considering the correlation of data as the handling parameter. The nodes that are situated near each other within a specific range are said to be correlated. In order to exploit redundancy in the network, we tend to change the packet length that needs to be transmitted according to the correlation between nodes. We assume that if 2 or more nodes are present at the same position, that is the difference between their positions is zero, the amount of correlation is the maximum. In this case, the packet size that the nodes would be transmitting will be half of the actual length. There is a threshold distance considered in order to calculate the correlation among nodes. If a node lies beyond the threshold distance, its packet size is considered 1. We have assumed correlation among the nodes to be of Gaussian in nature with distance as the parameter deciding correlation. Once the redundant groups have been decided the average distance is calculated by taking into account all of the nodes in the group. This average distance is used to correlation among the nodes. This correlation is used to find the packet length accordingly. All the nodes lying in a redundant group have same packet length.

For smaller distance among the nodes the correlation is high & packet length is small. Similarly, when there is greater distance the correlation is small & we get bigger packets. For no correlation packet length is same as the first case.

After finding the packet length for each node in the cluster, intracluster transmission takes place. In this phase, as discussed earlier each node transmits its packet to the respective cluster head using power control. As the packet length of the nodes would have reduced if they were in correlation with any other node, the energy required to transmit the packet would have reduced.

Once the intra cluster communication takes place & all the packets arrive at CH, next phase is initiated called inter cluster transmission. In this phase, all the CHs of the network form a network to send the sensed packets to the sink. As the total number of packets collected by the cluster head would be lesser now, the energy consumed would be reduced.

We evaluated two cases for the transmission of packets:

1) First case: When the correlation is not taken into account while calculating packet length I.e. all the nodes have same packet length.

2)Proposed case: When correlation is considered, and packet length is calculated accordingly. In our simulations we find out that lifetime of the network transmitting correlated packets is greater than the lifetime of network transmitting uncorrelated packets.

5.3 Correlation model

5.3.1 Variation of correlation with distance

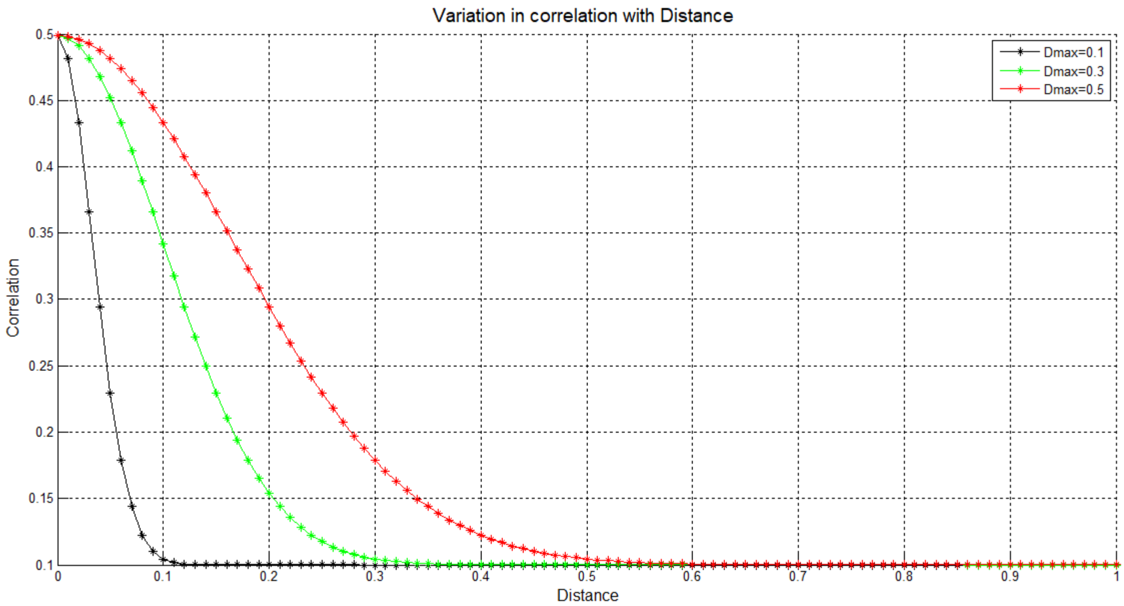

Fig 5.3 Change in correlation w.r.t. Distance between Nodes

In the following plot, the relation between the dependencies of correlation with respect to the distance between 2 nodes is shown. As discussed earlier if the distance between 2 nodes is minimum i.e. zero, the correlation between the two nodes will be maximum. In our case, the correlation would be 0.5. If the distance between any 2 nodes is beyond the stated threshold, the correlation between them becomes zero. The correlation between the nodes is considered a Gaussian function.

To plot this graph, we have considered three test cases with threshold values- 0.1, 0.3 and 0.5. We can see from the graph that beyond the threshold D_{max} for any test case, the correlation between nodes becomes zero along the Gaussian curve.

5.3.2 Packet length

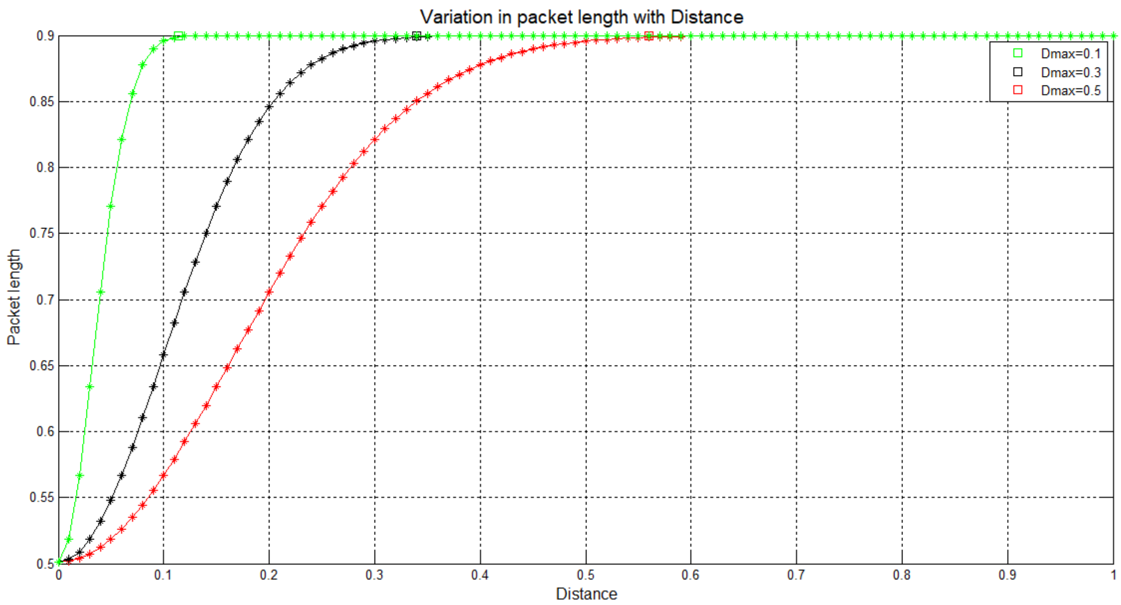

Fig 5.4 variation of packet length with distance

In fig 5.4, packet length is plotted against distance with different values of D_{max}.

D_{max} is the maximum average distance among nodes for correlation to be considered and reducing packet length accordingly. As we can see from the figure smaller value of D_{max} gives greater packet length for small distances and as we increase D_{max} the range of correlation increases, and we get smaller packet length for even greater distances.

Fig 5.5 shows the variation in packet length with correlation. As the correlation among nodes increases packet length decreases as less data needs to be transmitted from a specific location by each node which results in less energy consumption for transmission of one packet from each node. This dynamic approach for construction of packets results in good network lifetime in a dense network.

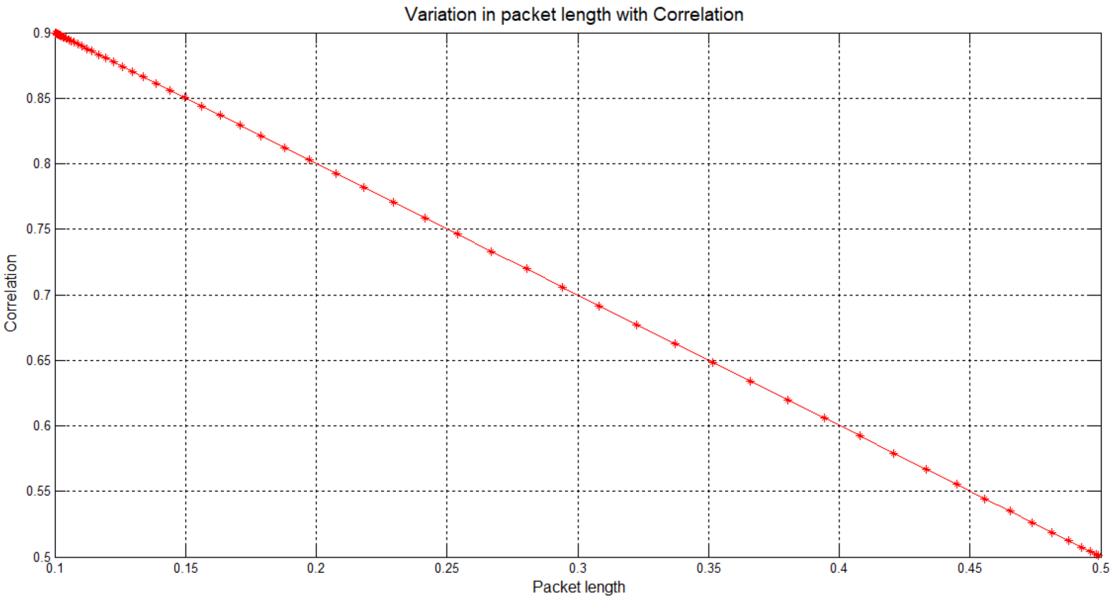

Fig 5.5 Variation of packet length with correlation

5.4Simulation and Results

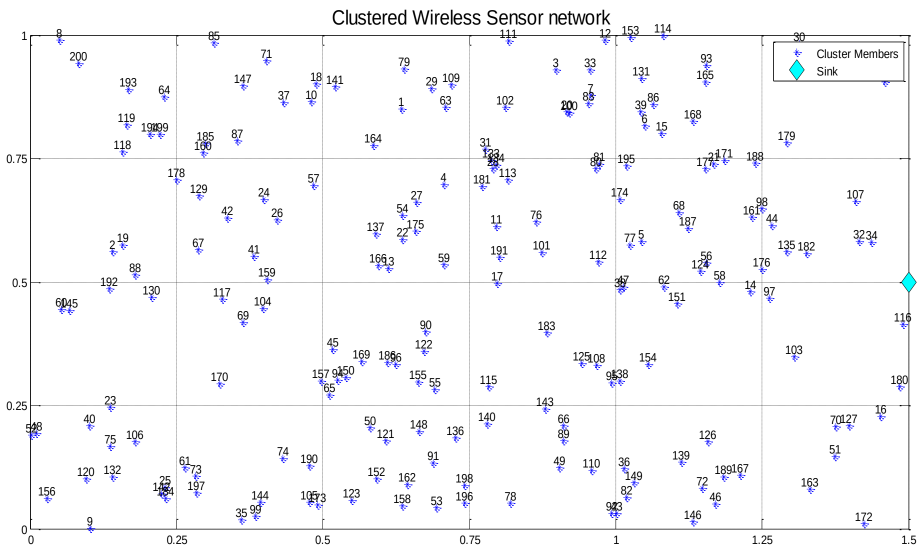

Fig 5.6 Clustered Wireless Sensor Network

Fig 5.6 shows a simulated depiction of the Cluster based Wireless Sensor Network in MATLAB. The nodes are randomly deployed over the network.

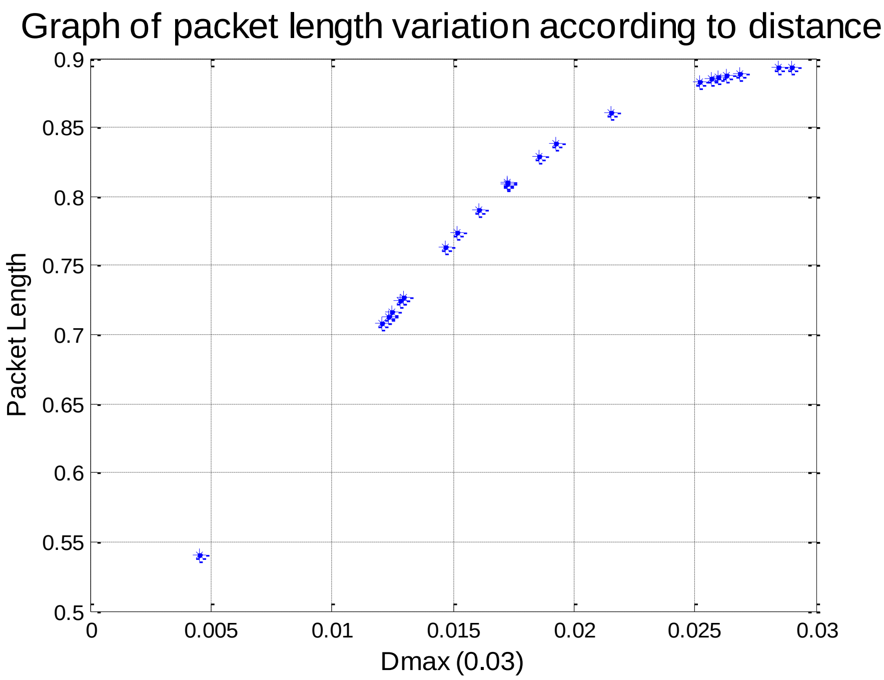

Fig 5.7 Packet Length variation at D_{max}= 0.03

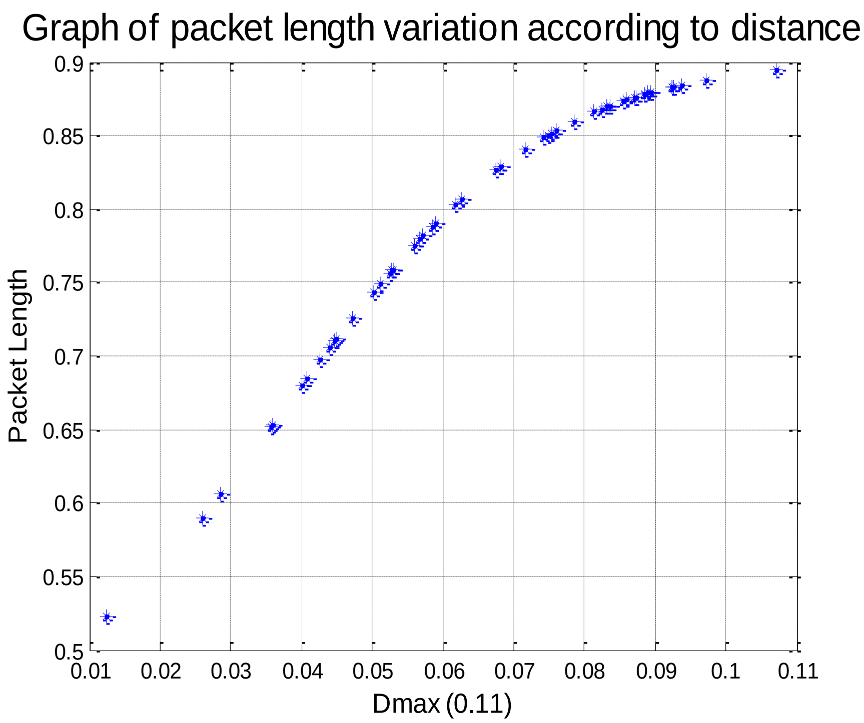

Fig 5.8Packet Length variation at D_{max}= 0.11

Figure 5.7 and 5.8 depicts the variation in packet length of nodes as we vary the threshold distance. At D_{max}=0.03, lesser nodes are in the radius. Hence, the packet length of lesser nodes is varied. Whereas at D_{max}=0.11, more nodes are correlated within that radius. Hence, the packet length of more number of nodes is altered.

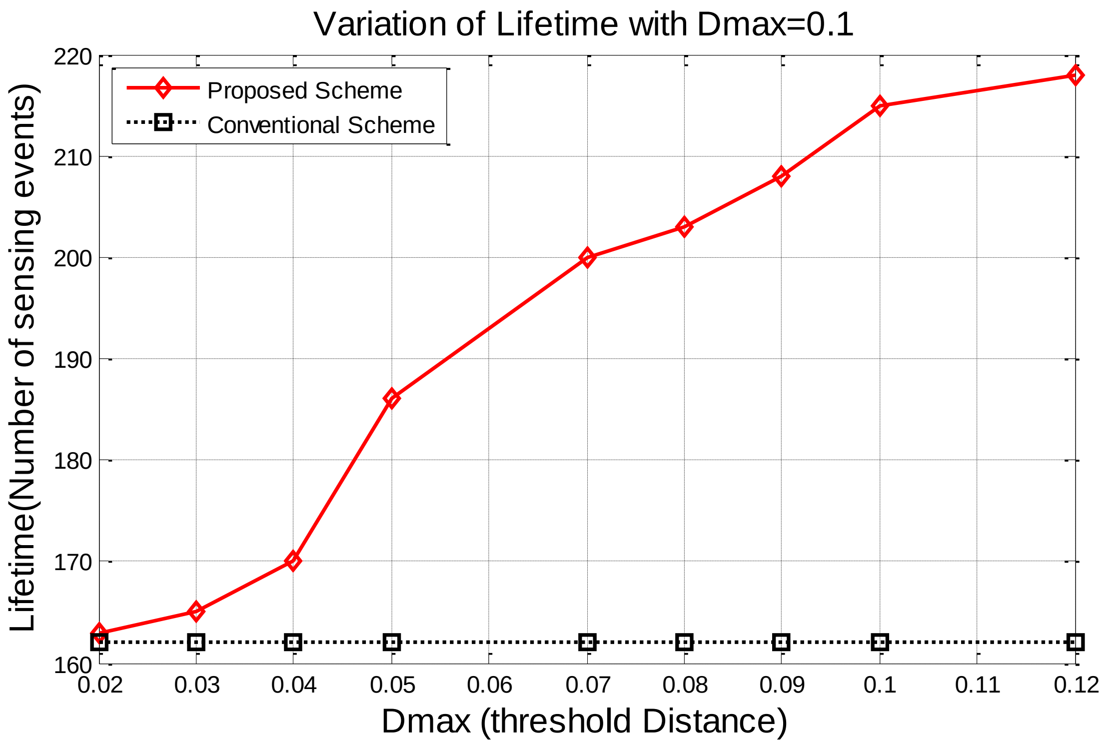

Fig 5.9 Lifetime vs D_{max}

In our output plot 5.7, we can see the variation between the lifetime if the 2 schemes with the variation in D_{max} i.e. the threshold distance of the node within whose vicinity the correlation among nodes is considered. We can see that as we increase the threshold distance D_{max}, there is no change in the lifetime of the conventional scheme. Although, the lifetime with the proposed scheme keeps on increasing as we increase the D_{max}. This is due to the reduction in the packet length that needs to be transmitted. Hence, conserving energy and maximizing lifetime

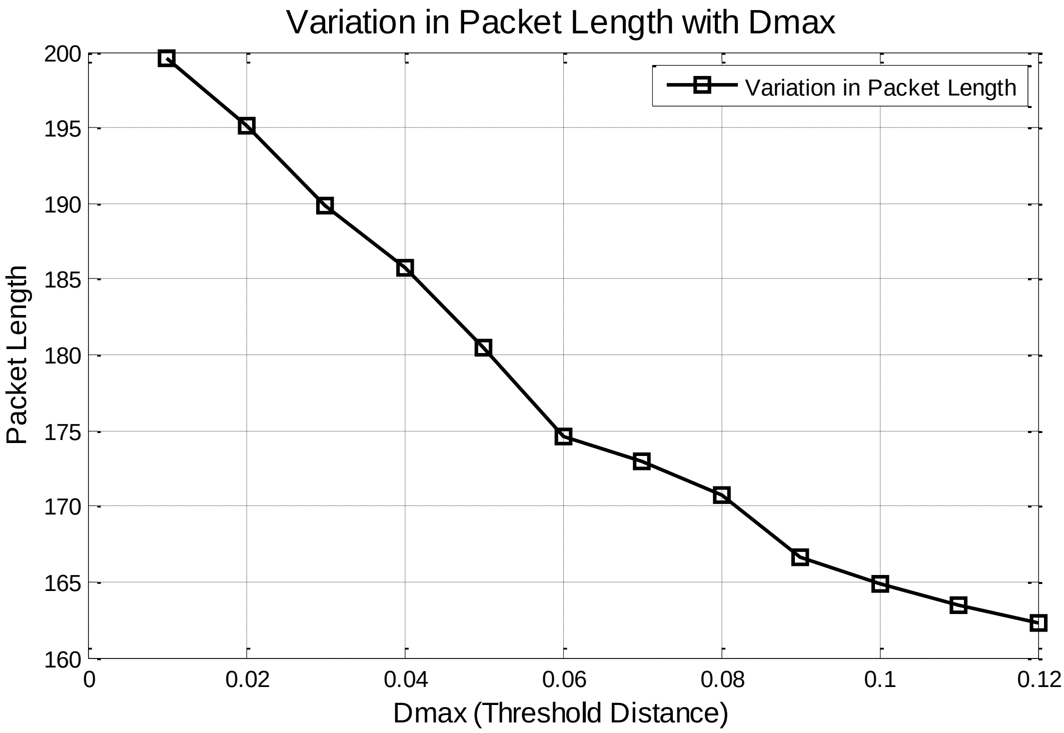

Fig 5.10 Packet Length vs D_{max}

In this figure, we can see the variation between the Packet Length with D_{max}. The relation in inversely proportional i.e. as we increase the D_{max}, the packet length of the entire network reduces. When the value of D_{max} is low, there are very less nodes that are in the vicinity, hence the correlation is less. Resulting in less reduction in packet length as well. When we increase D_{max}, more nodes come under the vicinity of D_{max}, hence the packet length of more nodes is reduced. As the packet length reduces, so is the energy needed to transmit, hence maximizing lifetime.

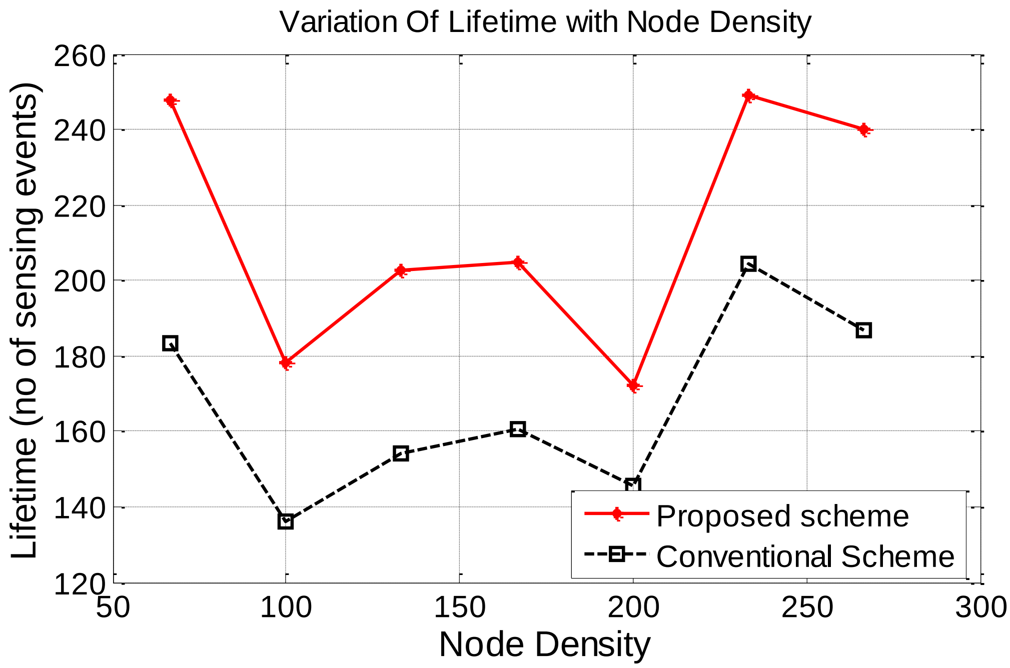

Fig 5.11 Lifetime vs Node Density

In this figure, we are plotting the variation of lifetimes of the 2 Schemes with the node density of the network. We can see that the network lifetime of the proposed scheme is always greater than conventional scheme for all the densities.

Chapter 6

Conclusionand Future Work

6.1 Conclusion

In our extensive research of wireless sensor network, we came across numerous protocols and transmission schemes for transfer of sensing data from sensor nodes to base station. The main goal of all transmission protocols is to make them as energy efficient as possible and maximize the network lifetime. There exists a lot of work in literature related to energy efficient transmission protocols which is done by reducing redundancy in sensing data or removing it all together with data aggregation. We tried different approach to handle redundancy in sensor networks, by exploiting it and maintaining it enough to get good QoS and at the same time reducing it to level such that lots of energy is saved. There exists a tradeoff between the quality of reception and amount of energy required for the transmission, we tried to find just the right balance in different sensing networks.

For our first model, we simulated n nodes deployed in an image sensing area who then transmit the data to their respective CH. In this model, due to dense deployment of nodes we assumed that identical image was being sensed by four different nodes. To exploit redundancy DWT image coding technique was used, then the resulting sub images were transmitted to the CH using three different transmission schemes: two existing and one new proposed scheme. We saw our proposed scheme outperforming other schemes in maximizing network lifetime. The second scheme which also exploited redundancy by transmitting one image out the four gave good network lifetime. From these simulations we observed that redundancy can be exploited on a large scale in the cluster-based network so in our next model we tried to do just that.

To exploit the redundancy in a big sensor network we deployed n number of nodes, n being greater than hundred and divided the whole network into clusters of equal size with maximum energy node in each cluster being the CH. The nodes were assigned to any cluster based on its geographical location. Our proposed scheme was to exploit redundancy in source coding (Slepian Wolf coding)and get the correlation model among nodes to make the packet length dynamic based on the degree of correlation among nodes. In the end we found that the Slepian Wolf coding gives Gaussian correlation among nodes with average distance as the deciding parameter of it. If the correlation was high among nodes their packet lengths were small and vice versa. To compare our scheme with the existing one, where the packet size was not dynamic and all the packets had same packet length, inter and intra cluster transmission of data to the sink took place. In our simulations of the same we find out that our scheme performs better in overall energy consumption and lifetime maximization than the existing scheme. Also, when the density of the network was increased significantly with redundancy increasing with it, our scheme outshone the existing scheme in every aspect. So, in conclusion we can say that wireless sensor networks are very dynamic and protocols are application dependent but exploiting redundancy for any sensed data can help in minimizing energy consumption and maximizing network lifetime.

6.2 Future Work

Till now we have explored the possibility of generating a transmission protocol for single cluster in a wireless multimedia sensor network and finding packet length based on correlation in a dense multi cluster WSN using local level prioritization. In our future research we will try to implement cross layer optimization in a cluster based WSN. Our hope is not only to generate an optimum protocol for cluster based WSN but also for other types of sensed data such as humidity, Temperature, motion etc. We will try to exploit redundancy along with global level prioritization using cross layer approach.