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An Energy Efficient Protocol Based on Hierarchical Routing Technique for WSN

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ABSTRACT

The area of wireless sensor networks (WSNs) is one of the emerging and fast growing fields in the scientific world. This has brought about developing low cost, low-power and multi-function sensor nodes. However, the major fact that sensor nodes run out of energy quickly has been an issue and many energy efficient routing protocols have been proposed to solve this problem and preserve the longevity of the network. This is the reason why routing techniques in wireless sensor network focus mainly on the accomplishment of power conservation. Most of the recent publications have shown so many protocols mainly designed to minimize energy consumption in sensor networks. This thesis work proposes a hierarchical routing technique which shows energy efficiency. Our technique selects cluster head with highest residual energy in each communication round of transmission and also takes into account, the shortest distance to the base station from the cluster heads. Simulation results show that hierarchical routing technique with different level of hierarchy prolongs the lifetime of the network compared to other clustering scheme and the energy residual mean value after some communication rounds of simulation increases significantly.

Keyword:

Wireless Sensor Network, Hierarchical Routing, Clustering, Energy Efficiency, Network Lifetime

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DEDICATION

To God Almighty for His guidance and mercy over me.

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Definitions

Term	Description
Base station (BS)	It is an information processing center where a high energy node process all its data that are sensed by the sensors in the network. The destinations of all the data sensed by the nodes are aggregation to the BS.
Cluster	It is a bunch of nodes in a network that are grouped together to reduce energy consumption in data transmission.
CH	This acronym is used throughout this thesis to represent a cluster head.
Homogeneous	It means sensor nodes are very alike and they are of the same nature.
Inter-Cluster	It is the data communication or transmission between clusters.
Intra-Cluster	It is the data communication or transmission within cluster.
Residual Energy	This is the energy that is remaining in a node in WSN.
Residual mean energy	It is the sum of all the residual energy of each node divided by the total number of node in the network.
Residual Variance Energy	It is a measure of dispersion or variation in statistical data. It indicates how much variation of the residual energy of each node from the mean value.
Rounds	A round comprises of a set up phase (cluster organization, CH role rotation) and a steady state phase (data collection, data aggregation and data forwarding).
System Lifetime	The lifetime of a system is the active time of the network until the first loss of coverage or quality failure [20]. This refers to the time number of alive nodes at a particular simulation rounds.
WSN	This acronym stands for wireless sensor network. It uses micro-sensor to communicate wirelessly.

Chapter One

Introduction

Wireless Sensor Network (WSN) is an upcoming technology which has a wide range of application including infrastructure protection, industrial sensing and diagnostics, environment monitoring, context-aware computing (for example intelligent home and responsive environment) and so on. This kind of network usually consists of a large number of nodes that bring themselves together to form a wireless network. The components of a WSN are sensor nodes, BS and monitored events (that is, an event that is required to be sensed in the environment) [7]. A typical sensor node is made of four building blocks: power unit, communication unit, processing unit and sensing unit [1]. The sensing component in a node measures certain physical characteristic like temperature or detects soil moisture of a location in which it is placed. The processing component is responsible for collection and processing captured data from its surrounding. The wireless communication component of a sensor node is responsible for transmission or reception of captured data from one sensor node to another node or to an end user through the cluster head to the base station (BS). The sensor node, its processing and communication component requires energy to function as expected, and the power component, which is of limited amount, is solely responsible for provision of energy to the three other components [1]. Based on application, the monitored event can either be dynamic or static in its operation.

WSNs are usually deployed in an environment to monitor static or dynamic events. The measurement of static events (such as temperature, humidity etc) is very easy to carry out. On the other hand, dynamic events are typically non-cooperative event is the movement of an unwanted vehicle in a battle field and the movement of whales in the ocean. They are not easy to monitor and they are not stable as they go up and down. Therefore, it is highly difficult to study energy saving schemes for sensing of dynamic event. For example, a forest monitoring application involves static monitoring approach whereas a target tracking application involves a dynamic monitoring approach [7].

Sensor network requires certain protocol for efficient performance. For instance, protocol can come in form of a specific application with a defined order to aggregate data and optimizing energy consumption. This kind of protocol is referred to as hierarchical routing. Moreover, we

have also a data centric routing protocol which describes a network environment whereby a sensor node also relies on data centric approach which performs sensing application to locate route path from multiple sources to a single destination. With this in mind, data from every node in a network can be describe by a list of attribute value pairs called attribute-based addresses, such that a node can expose its availability to the entire sensor network [2].

It is however essential to improve the energy efficiency for wireless sensor networks as the energy designated for sensor nodes is usually extremely limited. And, due to the fact that there is an increase in societal reliance on wireless sensor network technology, we can foresee the complexity of individual networks as well as huge increment in number of networks.

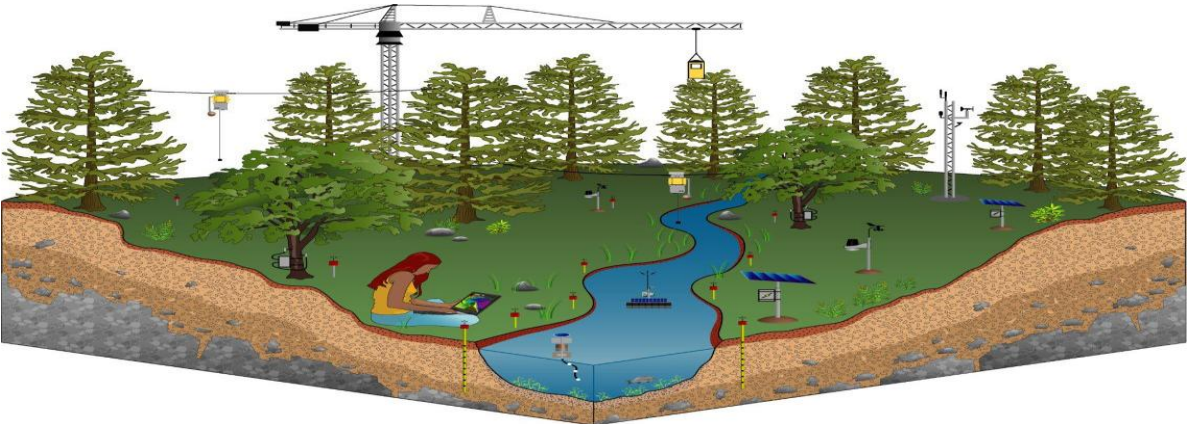


Figure 1.1 Environmental monitoring application of WSN

Due to the nature of the WSN, sensor nodes are normally powered by the use of batteries and thereby having a very constrained budget in terms of energy [1]. To effectively maintain the network sensors to have longer lifetimes, all areas of the network should be carefully designed to be energy efficient. Among many methods, clustering the sensor nodes into groups, so that sensors send information to only the cluster heads (CH) and then the CH communicate the aggregated information to the base stations, may be a good method to minimize energy consumption in WSN. Especially for WSN that has a large number of energy-constrained sensors; it is necessary to organized sensors in cluster form to reduce energy consumed when transmitting information from nodes to the base station.

Having Chapter 1 which introduces the project and its overview, Chapter 2 explains the theoretical background of different routing protocols that could save energy consumption in wireless sensor network. Chapter 3 explains in depth the proposed energy efficient routing

protocols and introduces the energy model employed and analyzes the algorithm of the protocol both in cluster formation and cluster head election. Chapter 4 shows the validation of the proposed technique and how it is being implemented in MATLAB by showing the simulation result of the protocol both in cluster formation and cluster head election. We also went ahead to simulate the mean and variance residual energy of the proposed protocol and see how it have effect on the energy efficient of the WSN. Chapter 5 conclude the report and also defines scope of future enhancements is also emphasized. Appendix- shows the mat lab code for the simulation.

1.1 Related Work

Various methods for minimizing energy consumption in wireless sensor network have been proposed such as by Heinemann et al. [3] who described the LEACH protocol as a hierarchical self organized cluster based approach for monitoring application. The data collection area of the data is randomly divided into clusters. LEACH uses time division multiple access (TDMA), to transmit data from the sensor nodes to the cluster head. Then CH aggregates the data and transmits it to the base station for processing. One of the features of LEACH is localized coordination and control for the formation and operation of clusters. The cluster head rotate randomly.

In [4] Lindsey et al. came about the proposition of PEGASIS which is an extension of LEACH. It eliminates the overhead of dynamic cluster formation created by LEACH. In this protocol, the nodes transmit to the CH and transmission of data is done by the cluster head, which is selected in a rotational manner, to the BS. PEGASIS protocol is found to save more energy and is more robust in node failure when compared to LEACH.

Muruganathan et al. [5] developed a protocol that creates clusters of the similar size and uses multi-hop routing between CH and the BS. The cluster head which forward the last hop is selected randomly from the sets of cluster heads to minimize the load of cluster head which are located nearest to the base station.

In [8], Wei Li proposed a geometric programming model to extend the network lifetime of the sensor network by clustering sensor nodes into groups. He developed an iterative method for solving the geometric programming by choosing the optimal location of cluster heads. The optimum mentioned in his proposition refers to minimizing energy consumption based on to inter-sensor network under specific constrained.

Clustering of approaches is useful in the monitoring of habitat and environs. This however, necessitates the use of continuous stream of sensor data. Xinhua Liu et al. [12] propose DDBC (Directed Diffusion Based on Clustering). DDBC is an energy-efficient directed diffusion routing protocol which is based on the reduction of the network topology and gives suppression to the redundancy message in plain flooding in order to minimize energy consumption in wireless sensor network. Ye, Heidemann and Estrin [13] gave a description of a contention based medium access protocol, S-MAC, which minimizes energy consumption in wireless sensor network by using virtual clusters. They developed the common sleep schedule for the clusters and overhearing is avoided by the use of in-channel signaling.

Wei Cheng et al. [14] proposed a novel adaptive, distributed, energy efficient clustering algorithm, AEEC for wireless sensor network. Their approach selects cluster heads based on the node energy related to that of the whole network which can bring about efficiency in heterogenous networks.

Al-Karaki and Kamal [12] also made a survey of the routing technique in wireless sensor network and mentioned that hierarchical routing technique has the advantages related to scalability and efficient communication.

1.2 Problem Statement, Research Questions, and Main Contribution

More researches done on the features of hierarchical technique have been found to offer better approach to effectively prolong the life time of WSN. In wireless sensor network, the energy is mainly consumed by three processes: data transmission, signal processing and hardware operation. It is proved that 70% of energy consumption is caused during data transmission process [5]. Therefore, the process of data transmission should be optimized in order to maximize the network lifetime. It is known that data transmission in sensor network can be optimized by using efficient routing protocol and an efficient ways of data aggregation.

To improve network lifetime, an efficient data aggregation protocols which help to eliminate redundant data transmission in a wireless sensor network must be in place. Usually, a multi-hop approach is necessary to facilitate data collection by one node which can then forward the received data to a neighbor node that is nearer to the BS. The receptive node aggregates the

data collected and also forwards it on. But the process of aggregation and forwarding of data directly from a source to the BS causes significant energy wastage as each node in the entire network is actively involved in the operation.

There is a situation of clustering where each node sends data to the CH and then the CH performs aggregation on the received raw data and then sends it to the BS. This approach also consumes a substantial amount of energy which needs to be improved upon.

Thus, the research question can be formulated as: How can we improve the lifetime by reducing energy consumption in Wireless Sensor Network using the hierarchical routing technique?

The hypothesis which answers the question can then be set as:

To reduce energy consumption in WSN, we have proposed an approach whose principle of cluster head selection is based on the highest predicted residual energy after the following round and the shortest distance via the closest neighboring cluster head to the base station. Since a hierarchical routing technique offers a better scalability and efficient communication approach [12], its concept can also be effectively used to design energy efficient routing protocol in WSN. In our approach, the cluster formation is done geographically.

The main contribution of the thesis can be summarized as follow:

The thesis proposes the new energy efficient routing protocol to improve the network lifetime of wireless sensor network by applying a hierarchical routing method and by introducing a new of cluster head selection and rotation. We also proposed an algorithm for cluster head selection method and implemented it in MATLAB. And for the validation of the proposed idea, we ran the simulation and the results are analyzed.

Chapter Two

Theoretical Background of Routing Techniques

2.1 Overview of Routing Techniques

Challenges encountered as a result of constrained energy supply and bandwidth in WSN when managing the network necessitates the need for development of energy awareness protocol at all levels of networking protocol stack. To offer efficient power management in WSN, researches have been focus on areas such as system-level power awareness like radio communication hardware, low duty cycle issues and energy-aware MAC protocols [7]. Also, it was observed that the network layer offers a better means through which reliable relaying of data and energy-efficient route setup within a network can help to maximize the network lifetime.

It should be noted that routing in WSN has much distinguishable features compare to contemporary communication and ad hoc networks [7]. These features are as follows:

- I. WSN cannot be built with global addressing (internet protocol address) scheme due to the enormous number of sensor nodes;
- II. There is significant redundancy in generated data because several sensors may gather the same data within a particular field. These redundancy needs to be removed to increase the bandwidth utilization and also reduce energy consumption in the network;
- III. Transmission power, processing capacity and storage are constraint factors to be considered when managing a WSN.

Due to these differences, new protocols are being researched and fashioned to eliminate the problem faced in WSN. These routing protocols have been fashion on sensor nodes characteristics alongside it application and architectural requirement. The various protocols can be classified as location-based, data-centric or hierarchical. Although there are other ones developed based on flow quality.

2.1.1 Location–Base Protocol

Most routing technique for WSN depends on location information of sensor nodes for estimation of distance between two specific nodes to deduce energy consumption. For example, to sense a known region, through the use of location sensor, a specified query can be sent to that known region and this will significantly reduce transmitted data compare to a broadcast request being sent to the entire network [7]. In other words, the location-based protocol utilizes the position information to relay the data to the desired regions rather than the whole network. An example of a protocol that uses this technology is MECN (minimum energy communication network). MECN sets up and also maintains a low energy in a WSN by using low power global power positioning system (GPS).

2.1.2 Data-Centric Protocol

Since assigning global identifiers to every sensor nodes in a WSN may appear not visible (due to sheer number) in some randomly deployed application, data transmitted by every sensor node within a particular region has significant redundancy with it. To reduce this redundancy, data centric protocols were developed to select a set of sensor nodes and also utilize data aggregation during relaying of data. An example of data centric is a sensor protocol for information via negotiation (SPIN) [6]. SPIN's data are named using meta-data that highly describes the characteristics of the data which is the key feature of SPIN.

Flooding is another type of routing protocol in which each sensor node receives data and then sends them to the neighbors by broadcasting, unless a maximum number of hops for the packet are reached or the destination of packet is achieved.

The advantage of SPIN is that the topological changes are localized since each of the sensor node needs to know only its single-hop neighbors. However, it has a disadvantages of scalability (not scalable) and also, the nodes around the base station could deplete their energy if the BS is interested in too many event. Moreover, SPIN's data advertisement mechanism can not guarantee the delivery of data. For instance, if the sensor nodes which are interested in the data are far away from the source node and the nodes between source and destination are not interested in that data, such a data will not be transmitted to the destination at all.

2.1.3 Hierarchical Routing

Hierarchical routing in WSN involves the arrangement of clusters in form of hierarchy when sending information from the sensor nodes to the base station. Hierarchical routing efficiently reduces energy consumption by employing multi-hop communication for a specific cluster and thus performing aggregation of data and fusion in a way that decreases the number of data carried across the network to the sink. Cluster formation is based on residual energy in the sensor nodes and election of a CH [7]. A very good example of an hierarchical routing protocol is low-energy adaptive clustering hierarchy (LEACH). The LEACH approach involves formation of clusters of sensor nodes centered on the received signal quality and the use of a local CH as a router to the BS. Reduction in energy consumption in data transmission is achieved since the CH is involved in transmission to the BS rather than individual sensor nodes. The disadvantage about LEACH is its inability to be deployed in large network.

The table 2.1 shows the comparison [17] of the different routing protocols in terms of scalability, lifetime, data diffusion and power required in WSN. From table 2.1, we understand that hierarchical technique offers an approach to energy minimization and scalability features in a WSN.

TABLE 2.1: Comparison of routing technique

	Data-centric Technique	Hierarchical Technique	Location-based Technique
Scalability	Limited	Good	No
Lifetime	Long	Long	Long
Data Diffusion	No	Yes	No
Power Required	Limited	High	Limited

2.2 Clustering in Wireless Sensor Network

Clustering is a method by which sensor nodes are hierarchically organized on the basis of their relative proximity to each other. Hierarchical (sensor nodes clustering) energy consumption creates an effective and reliable means of routing collected data from the physical environment, through the sensor nodes to the BS. Clustering of sensor nodes helps to compress the routing table such that the discovery mode between sensor nodes is done more easily. Clustering can also conserve communication bandwidth because it limits the scope of inter-cluster interactions to CHs and avoids redundant exchange of messages among sensor nodes. Each sensor node performs a route table look up for the CH in its region and then routes its collected data to the CH. The CH performs a route discovery estimation based on

shortest distance to a recipient CH closer to the BS or directly to the BS. In order to maintain the routing table, link information is exchanged from time to time between sensor nodes to adapt to the change in energy requirement for data transmission by all nodes.

2.3 Energy Saving Schemes in Clustering Technology

2.3.1 Cluster Formation and Rotation

With the evolving trend in application and management of WSN, clustering provides an efficient means of managing sensor nodes in order to prolong its lifetime. Several clustering formation technique have been develop in the past such as random competition based clustering (RCC) [18]. RCC algorithm uses random timer and node identification for cluster formation is based on First Declaration Wins Rule. This rule assigns governorship position to any node which declares itself first as being a CH to other nodes in its radio network.

Furthermore, there are other approaches to cluster formation and an example of that is the broadcasting technique. Broadcasting can simply be described as when one sensor node is sending a packet to all other sensor node in wireless sensor network. It should be noted that not all broadcast messages are useful and also some of the messages sent by the sensor node are dropped because a sensor nodes status has already been assigned and cannot be changed.

In direct broadcasting technique, cluster advertisement message is sent to all sensors within a selected region. For instance, two clusters formation requires two random nodes are selected for broadcasting. This randomly selected node is known as an initiator. All initiators broadcast a cluster advertisement message to all sensor nodes in the network. If any node in the network that is not an initiator receives an advertisement message within the cluster, it sends a message to the initiator from which the message was received. It will not only send a reply but also refrain from accepting any other cluster advertisement message for that simulation round. Such a sensor node will however become a part of this initiator's cluster [13, 14].

The technique of direct broadcasting is very simple when it comes to its implementation but it is not cost effective in terms of energy consumption. This is due to the fact that all sensor nodes receive a broadcast from the CH. The sensor nodes that are very far to the CH will still need to receive broadcast but it does not mean that the sensor will respond to the message. But, in a situation where a sensor node receives a broadcast from an initiator, the subsequent broadcast message will be dropped, and energy which is used in transmission will be underutilized.

Multi-hop broadcasting on the other hand uses specific transmission range to transmit a cluster advertisement message to the sensor nodes. It is the duty of the receiving node to proceed in sending the cluster advertised message to all the sensor nodes in its transmission range. This technique works very closely to direct broadcasting technique for the fact that it also selects an initiator node that sends cluster advertisement messages at the start of cluster formation. These techniques use a concept which is known as minimum communication energy which means that the sensor node that is easiest to reach will form part of the initiator cluster [4]. Also, when cluster are formed dynamically, the reorganization is done on a periodic basis. The initiator is selected at the beginning of every period and broadcasted messages are sent out using one of the above-mentioned methods for cluster organization.

The multi-hop broadcasting minimizes the problem of energy usage. This is due to the fact that there is a limit for transmission because the highest amount of energy that can be wasted is the minimum transmission energy of neighboring sensor nodes. This will create no need for the sensor nodes which are far away from each other to transmit directly. It has a disadvantage in the sense that it has more delay when compared to the former technique of broadcasting. This is because, in multi-hop broadcasting, the data are required to be processed by each sensor node along the multi-hop path, which creates delay in the formation of cluster. However, the multi-hop is much better than the direct broadcast if the problem of delay is taken care of.

2.3.2 Cluster Head Election and Rotation

After cluster formation, CHs are designated which act as a leader in each clusters. Cluster heads are saddled with the responsibility for data aggregation and performing routing for its cluster member's information to the base station. Also, the clusters that consist of many nodes have a higher burden than clusters with fewer nodes as the CHs for those large-sized clusters have to receive, aggregate and transmit more data.

A CH can be elected randomly or pre-assigned by the designer of the network. A CH can also be elected by taking into consideration the residual energy of nodes in the cluster. The CHs are known to have higher burdens than member nodes; therefore, the role of CH is rotated to share the burden and thus improving the useful lifetime of those clusters.

In random selection, a node is selected randomly as CH, based on the probability that it has never being selected during the entire lifetime of the network. This reduces the traffic burden on a CH since the role of CH is spread throughout the sensor nodes. The rotation is done at a periodic interval.

Whereas, in the residual energy selection, the sensor node that has the highest amount of energy in the cluster is selected as the cluster head. It will continue to remain the CH until the energy drops below the average energy of the entire cluster. So, rotation of CH is done at every instance when its energy level drops below the average cluster energy. This rotation of CHs will lead to the overall energy of the sensor network being evenly distributed. This technique eventually improves the lifetime of the network.

Another approach to cluster head selection is based on minimizing the distance to cluster nodes as this offers reduction in energy usage during data transmission to the BS. With this method of minimizing sum of distances to CH, the cluster formation is better enhance to reduce energy usage as transmission takes place. It helps in reducing the unnecessary energy which the sensor node uses in communicating with the CH by minimizing the transmission distances from sensor node to any CH [15].

Since communication energy is an important concept to consider in wireless transmission, it is known that energy greatly depends on distance [7]. Therefore, it is very good idea to minimize the distance in transmitting data from sensor nodes to base station via the CH, as this helps to reduce the communication energy in wireless sensor network.

2.3.3 Cluster Optimization by using K -hops

When addressing the problem of energy consumption in wireless sensor network, the size of a cluster is an important factor subject to analysis in hierarchical network. Clusters of small size save power in intra-cluster communication but it will also increase the complexity of the backbone network. Also, smaller cluster size means less load in the backbone and thus a less complicated communication, but the intra-cluster communication consumes more power and reduces the lifetime of the sensor network. These necessitate a tradeoff in clusters formation [15].

One of the trade-off is mentioned in [16] where a method of limiting the number of hops which a sensor node takes in communicating with its CH. Bandyopadhyay's and Coyle's

approach makes a use of the K -tree cluster framework and optimize the framework and optimize the value K to minimize power consumption within a cluster. The K -tree clustering algorithm can be described as a technique that ensures that every sensors node within a cluster can carry out communication with its corresponding cluster head by using a maximum of K -hops. Therefore, a sensor node needs to use other sensor nodes to relay its transmission to the base station via its routing table. And, the data of any sensor node will not be relayed within a cluster for more than K times.

Moreover, in [16], Bandyopadhyay and Coyle utilize a method of selecting cluster head with the probability P . The message will then be forwarded to all nodes which are K -hops away. The optimal K value is a predetermined number that is set according to the size of the network. Any sensors that receive the advertisement message from the elected CH are considered a cluster member of the cluster from which it received this message. The message sent by the sensor node would be ignored if it is received by another volunteer cluster head. Also, a node can be mandated to become a cluster head if it does not receive a CHs advertisement in a specific time t which is defined as the time required to send K hops data away [15, 16].

With the K -hops approach, communication in wireless sensor network can be either of the single-hop or multi-hop. Single-hop simply refers to direct communication from sensor node to cluster head while multi-hop does not require direct communication from all sensors to the base station. But, it can send data to the next cluster head which is closer to the base station. Therefore, multi-hop communication has higher energy efficiency than the single hop within the clusters. When the sensor node is at a far distance from the CH, much energy is expended thereby reducing the lifetime of sensor network.

For instance, when two sensor nodes are placed at a far distance away from each other in the same cluster but one of them is closer to the base station, it is observed that the energy consumed by the node closer to the base station is lower compared to that which is far away. And with the help of multi-hop communication, an intermediary node is used between a source environment and BS to relay the data, a great deal of energy is conserved in the network. Figures 2.2a and 2.2b illustrate the concept of single-hop and multi-hop respectively.

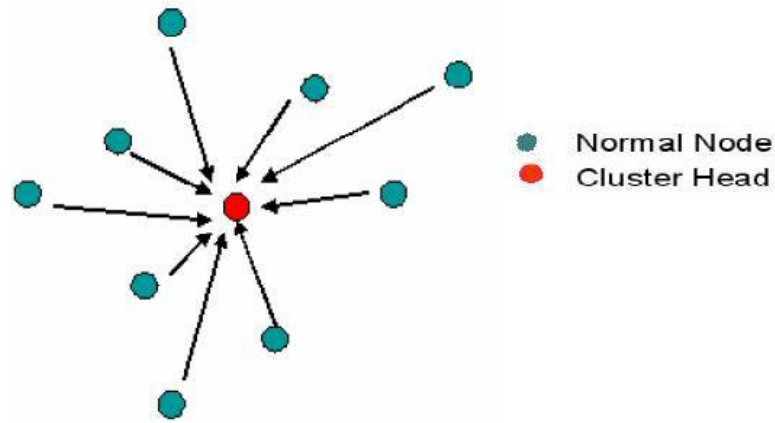


Figure 2.1a Direct transmission between sensor nodes and cluster head

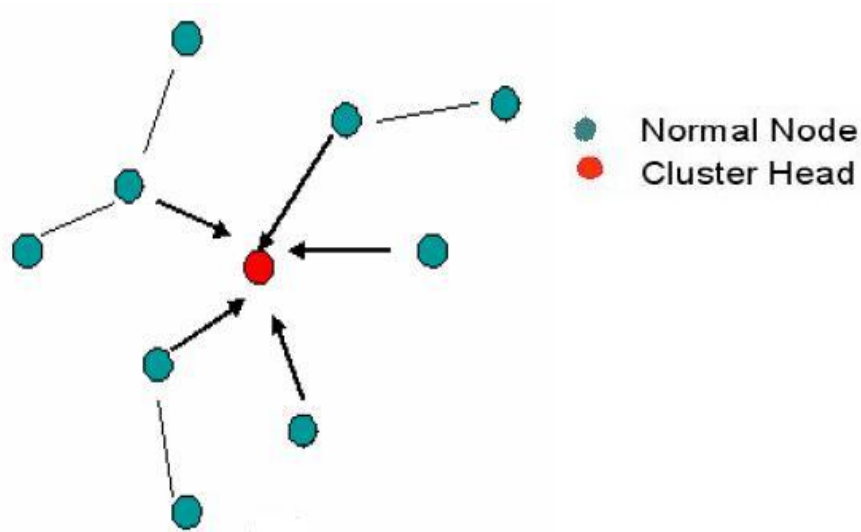


Figure 2.1b Multi-hop transmission between sensor nodes and cluster head

Furthermore, taking *computational complexity* into consideration when designing cluster with *uneven data traffic* in each clusters when data are being transmitted, the size of clusters seem to be random at the time of formation. Although, in some circumstances, the cluster sizes are equal which denotes equal number of nodes, and in other scenario, the size is randomly sized.

When the cluster sizes are approximately equal, the clusters very close to the base station will consume more energy and die quicker than the cluster that is far away from the base station. This is because the cluster head closer to the base station collects all data from other cluster heads in the network and thereby having much data to relay to the base station. Therefore, the communication traffic between clusters is uneven. The Figure 2.1 shows an example of this. In Figure 2.1, the communication between clusters is clearly uneven since the cluster head 1 relays more data to the base station (due to its closeness) than all other cluster heads.

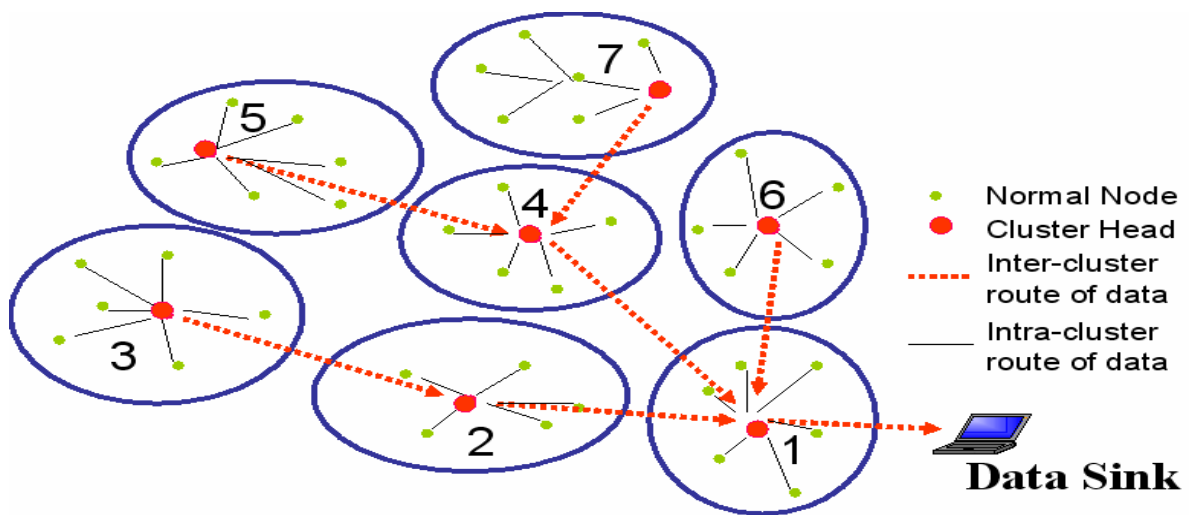


Figure 2.2 Network illustration of inter and intra cluster data routings in WSN

To improve the energy efficiency by clustering, there should be a method of cluster optimization that considers the uneven data traffic of the communication between cluster and within clusters. Having relevant understanding about the various concepts to be consider when designing a clustering algorithm, we proposed a new routing algorithm that efficiently manages the energy usage in a network and this is discussed better in chapter three.

Chapter Three

Proposed Hierarchical Routing Technique

Various techniques can be found in hierarchical routing protocol. The basic idea of the techniques is a situation whereby nodes are clustered so that cluster heads can do some aggregation and a compression of data in order to save energy thereby prolonging the lifetime of WSN.

3.1 System Energy Model of a Sensor Node

Having an understanding that the wireless communication component of a sensor node is responsible for the energy draining activities, we use the radio model shown in Figure 3.1 [19]. The first order radio model offers an evaluation of energy consumed when transmission or reception is made by a sensor node at each cycle. The radio has a power control to expend minimum energy required to reach the intended recipients.

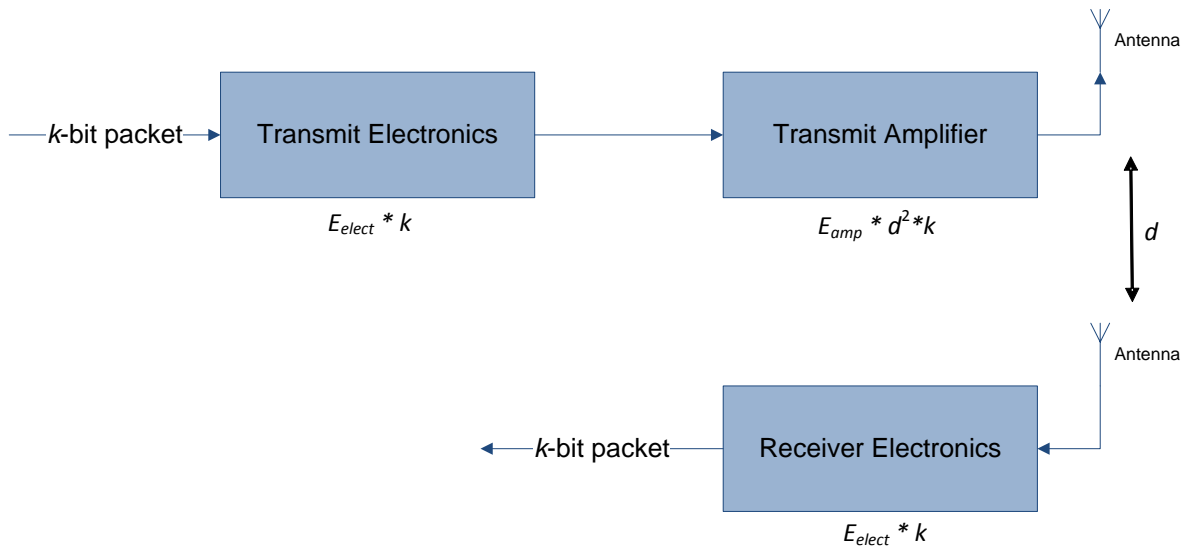


Figure 3.1 Schematic diagram of the first order radio model equation

Mathematically, when a k -bit message is transmitted through a distance, d , required energy can be expressed as stated in the equation:

$$E_{Tx} = E_{elect} \cdot k + E_{amp} \cdot d^2 \cdot k \quad (1)$$

Likewise, the energy consumed at the reception is illustrated as shown in the equation:

$$E_{Rx} = E_{elect} \cdot k \quad (2)$$

Where

$E_{Tx-elect}$ - energy dissipated per bit at transmitter

$E_{Rx-elect}$ - energy dissipated per bit at receiver

E_{amp} - amplification factor

E_{elect} - cost of circuit energy when transmitting or receiving one bit of data

E_{amp} - amplifier coefficient

K - a number of transmitted data bits

d - distance between a sensor node and its respective cluster head or between a CH to another cluster head nearer to the BS or between CH and BS.

The first order radio equation was used to verify the operation of our proposed protocol, assuming that the radio channel being symmetric such that equal energy is used up when a node A transmits to node B and when a node B transmits to node A with a given signal to noise ratio.

3.2 The Proposed Routing Protocol Algorithm

Our proposed hierarchical routing protocol is based on the principle of clustering algorithm. With data transmission at the network layer being the core area of interest, we have modified the LEACH protocol in terms of hierarchical data transfer with the employment of energy prediction technique for selection of CH via any shortest path to the BS.

In the proposed model, clusters are formed geographically. Geographical formation of cluster sizes is based on equal segmentation of area space, depending on the case being considered. Apart from the one cluster formation which makes use of the entire sensors area space, other formation such as two clusters formation and three clusters formation involves equal segregation of area space. The two clusters formation and the three clusters formation are otherwise known as first level and second level hierarchy respectively.

The CH election phase proceeds after the cluster formation phase. The selection of CH(s) within each cluster formed is carried out by electing a node that require less transmission energy (to BS or to the next hop CH nearer to the BS) to be the CH for a particular

transmission round. Due to draining activities being constraint on a cluster head during data aggregation and transfer phase, the cluster head is rotated among the sensor nodes of each cluster at every transmission round. A completely new estimation of energy is carried out at the beginning of every transmission round to elect a new CH for the cluster and thereby energy wastage is being reduce to its minimum, and utilization of each nodes energy is being maximized to ensure a prolong network lifetime.

Figures 3.2 and 3.3 illustrate the proposed hierarchical routing technique and the cluster head selection of the protocol respectively.

The algorithm in Figure 3.2 consists of four main stages

- i. Geographical formation of cluster.
- ii. Selection of cluster heads in each cluster formed.
- iii. Data aggregation phase which involves the gathering of collected data by the cluster head from the sensor nodes within its cluster.
- iv. Data transmission phase which involves the transfer of all data from the nearest cluster head(s) to the BS.

Also, the Figure 3.3 illustrates the CH selection in the proposed hierarchical routing technique. The CH selection flowchart can be explained also in four main stages:-

- i. The initial energy $E_{in}(n)$ of node is measured
- ii. Also, the distance $d(n)$ from each node to the base station or to the corresponding higher level cluster head is measured.
- iii. Estimation of the energy required by each node for transmission within the cluster not to BS or to higher level CH for two and three cluster formation within a cluster is carried out using the formula: $(E_{amp} * k * d^2)$.
- iv. The maximum energy after the subsequent transmission round for each node is estimated and selection of CH is done using the formula: $\max (E_{in}(n) - E_{amp} * k * d^2)$, then after the CH selection is carried out, the next cluster head selection will take place after the current round is completed.

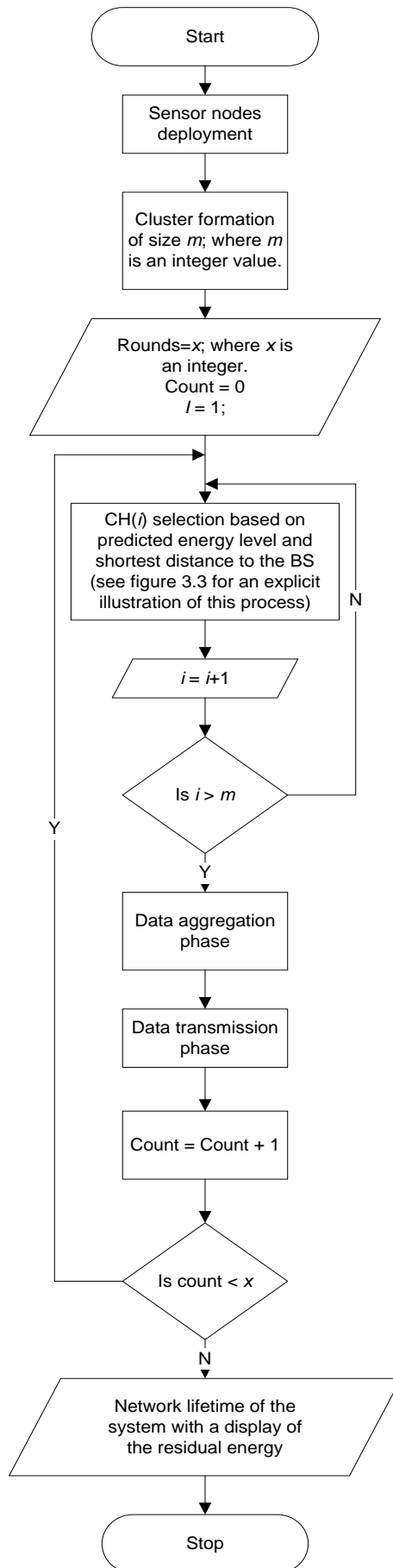


Figure 3.2 Flowchart of the proposed hierarchical routing technique.

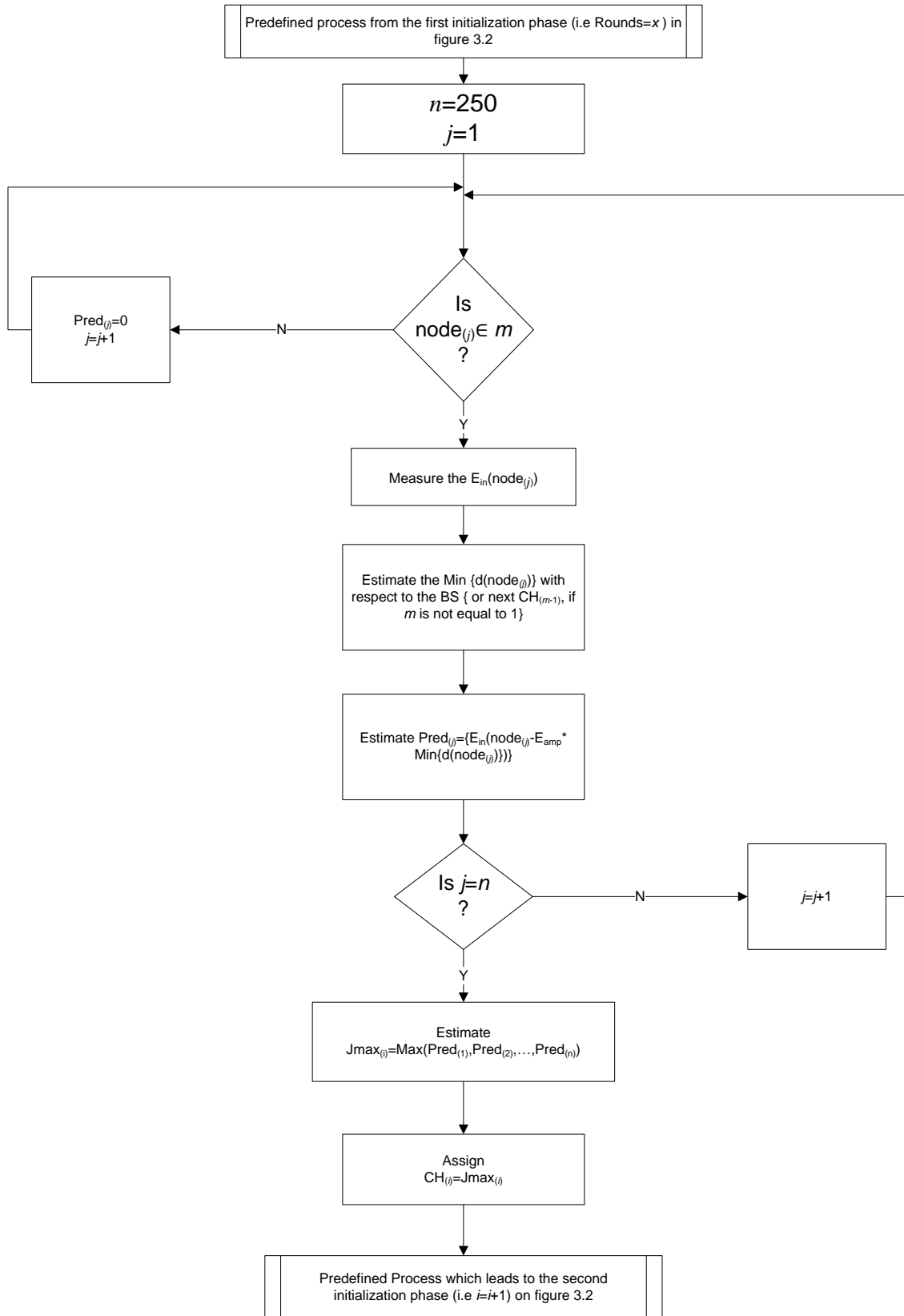


Figure 3.3 Flowchart of CH selections in the proposed hierarchical routing technique

Chapter Four

Validation

In Chapter 3, we proposed a hierarchical-based routing protocol that improves the network lifetime of the system. In this chapter, we show how the protocol performs better in terms of energy efficiency by improving the lifetime of WSN.

There are several simulation tools available for validating the behavioral pattern of a wireless network environment such as NS-2, J-Sim, OMENT++, MATLAB, GloMoSim. We have chosen MATLAB (an abbreviation for Matrix Laboratory) as our tool in simulating the proposed protocol.

4.1 Simulation Setup and Scenarios

In this simulation, a total number of 250 nodes were randomly deployed within a space region on 300 m x 300 m. The figure 4.1 illustrates the simulated environment of the 250 nodes we deployed. The coordinates of X and Y are measured in meters.

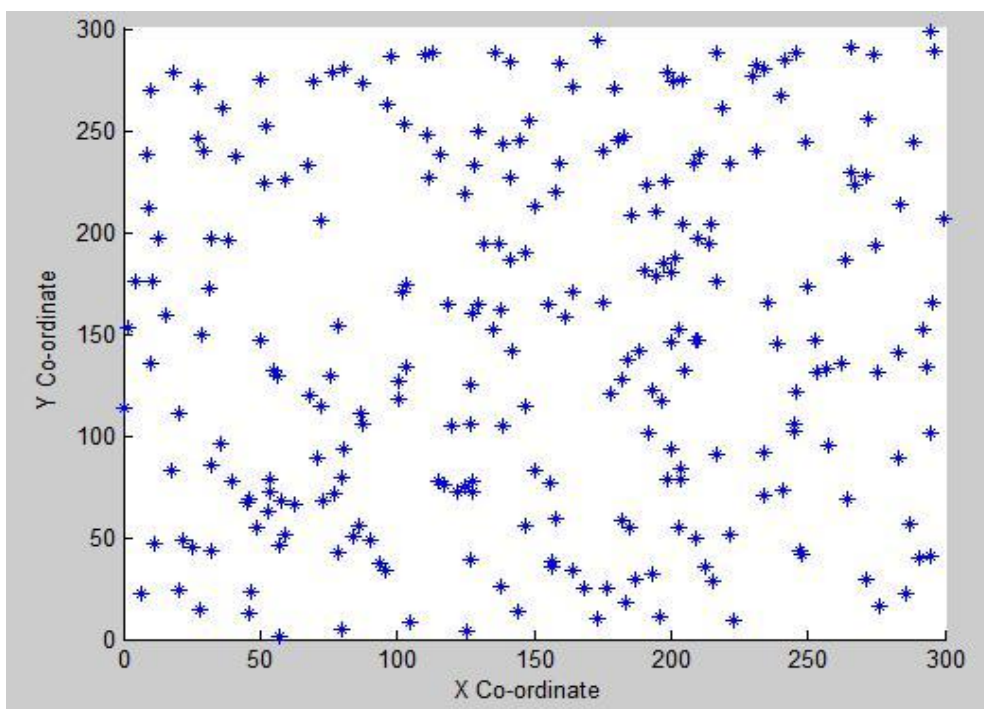


Figure 4.1 250 nodes deployed randomly in a geographical location of X and Y coordinates measured in meters

With the nodes being deployed, some assumptions were made concerning the node features and these are as follows:

- All nodes are homogeneous in nature;
- All nodes starts with the same initial energy;
- The base station is situated at the (0,0) origin of the area space;
- Clusters and nodes are static;
- Normal nodes transmit directly to their respective cluster heads within a particular cluster;
- Cluster heads use multi-hop routing to relay data to the data sink;

The parameters used in the simulation are listed in Table 4.1:

Table 4.1: The initial parameters of our implementation

Parameter	Quantity
Total number of nodes, (N)	250
Initial energy of each node (Joules), ($E_{in}(n)$)	200
Packet size (k) in bytes	100
Energy circuitry cost at transmission and reception of a bit of data (E_{elec}) in nano Joule per byte	50
Amplifier coefficient(E_{amp}) in pico Joule per bit	100
Coordinate of base station	(0,0)

The sensor nodes in the network are formed into clusters of different sizes of one, two and three. One indicates a non-hierarchy formation of cluster and, two and three indicate different level of hierarchy one and two respectively for data transmission. Figure 4.2 indicates the non-hierarchical structure of our routing technique. Likewise, Figure 4.3 and 4.4 shows the simulation result of the cluster formation in the proposed technique.

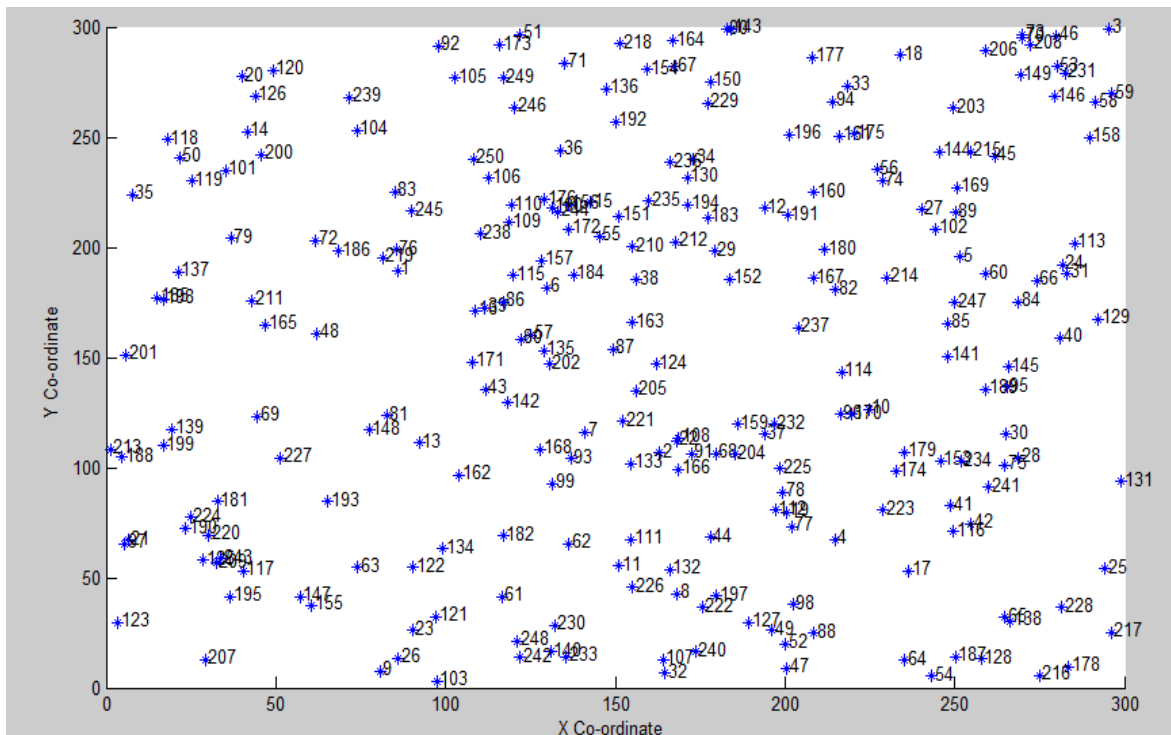


Figure 4.2 Non hierarchical formation

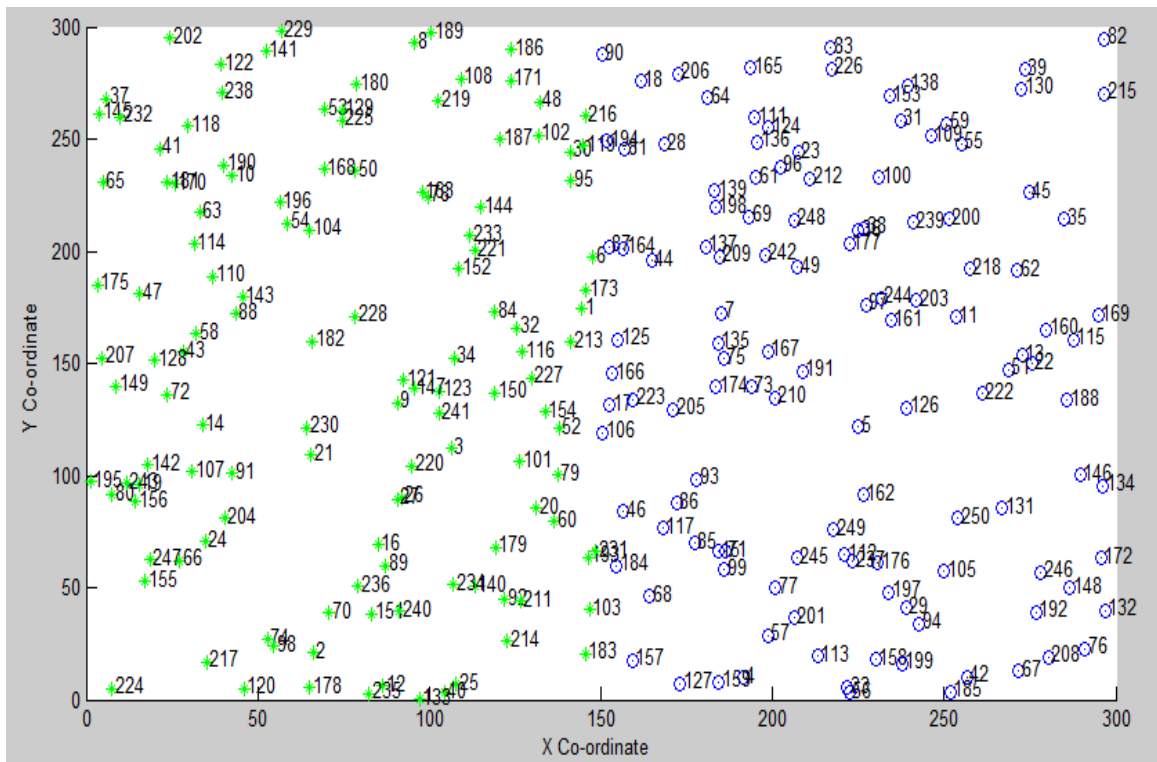


Figure 4.3 First level hierarchical formation with differentiated colors indicating difference in two clusters.

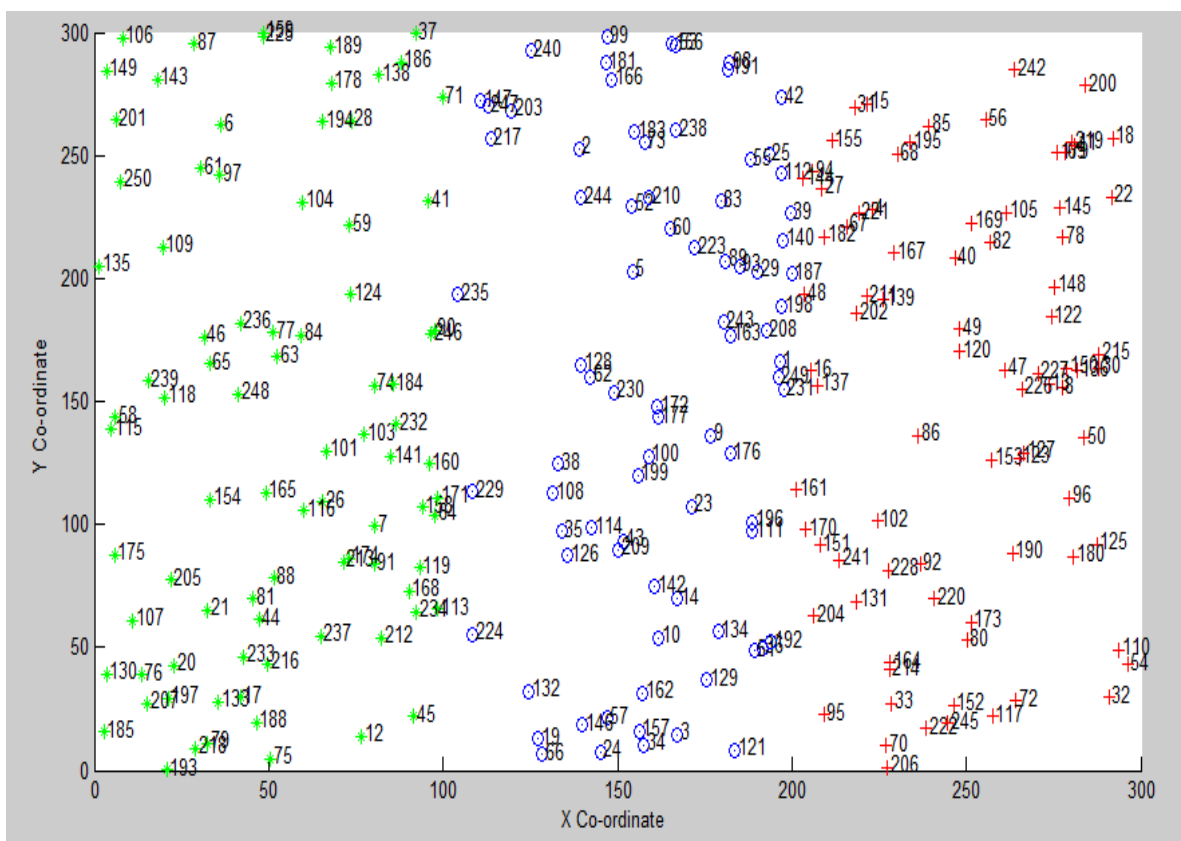


Figure 4.4 Second level hierarchical formations with differentiated colors indicating three clusters.

Using MATLAB, all 250 nodes were randomly distributed as shown in Fig. 4.1 with the origin plane (0, 0), being the location where BS was situated. With the initial energy level of all nodes being set at 200 J, E_{elec} set to 50 nJ/bit, E_{amp} set to 100 pJ/bit/m², and the size of the sensor data set to 1024 bits, we used the radio model equation in predicting minimal transmission energy level for cluster head selection, data aggregation and transmission phase for 400 rounds for non hierarchical formation scenario, first level hierarchical formation scenario and second level hierarchical formation scenario. The cluster head(s) of m -th cluster formed aggregates the data received from other sensor nodes with its own data and transmits it to the next hop cluster head closer to the base station or to the base station depending on the cluster formation and the shortest distance between the cluster head and the BS. At every transmission or reception made, energy reduction occurs for every node, thereby cluster head rotation was utilized to help prolong the lifetime of the WSN.

4.2 Simulation Results

It can be proved that the proposed hierarchical routing technique offers when compared to the non-hierarchical routing. We investigated the advantage of the proposed technique by comparing the time in which the first node dies during the 400 rounds of simulation (network lifetime) to that of the non-hierarchical routing technique.

The network lifetime is shown in Figure 4.5. We observed that the first node dies faster in the non-hierarchical formation since all nodes tend to send captured data via one randomly selected cluster head per round to the base station. The constrained load on the elected cluster heads during the 400 round of simulation drastically reduced the CHs' energy over a short period. Unlike the non-hierarchical formation, the proposed hierarchical routing technique in which cluster hierarchy takes precedence in cluster formation and prediction of minimal transmission energy for selection of cluster head, we observed that this technique offers a better life span for individual nodes and even the entire network. With optimization in energy usage, we observed that the lifetime in our proposed hierarchical technique extends to an impressive range when compared to non-hierarchical technique. The impressive increment in life span of the network from our proposed hierarchical technique is seen as a result of efficient routing decision and optimization of energy in cluster head selection of each cluster formed. Since the sensor nodes in each cluster send data to the cluster head within its cluster range and then the aggregated data is sent to the cluster head closer to the base station, which further aggregates data of its own cluster and that of the incoming data, from cluster head whose distance is farther to the BS, before sending the data to the base station. Thus, a

considerable amount of energy is saved which indicate improved network lifetime in the case of first level hierarchy when compared to non hierarchical technique.

From Fig.4.5, we observed that the Non-hierarchical technique had an estimated lifetime of 10 rounds, First level hierarchical technique had an estimated lifetime of 110 rounds and Second level hierarchical technique had an estimated lifetime of 130 rounds. The progressive increase of network lifetime employed by our proposed technique offers efficient energy usage for each node in the entire network.

Also, it was observed that the Non-hierarchical technique network completely stopped functioning at an earlier simulation rounds compared to our proposed technique. We saw that the functional capacity for Non-hierarchical network lasted till an estimated value of 120 rounds of simulation, while the functional capacity of the First level Hierarchical approach and Second level hierarchical approach lasted till an estimated value of 180 rounds and 330 rounds of simulation.

Furthermore, we also observed in Fig. 4.5 that the network lifetime increased to a certain length in the three cluster formation scenario (second level hierarchy). With this increase, the WSN’s lifetime was further prolonged when compare to the two cluster formation and the non hierarchical technique.

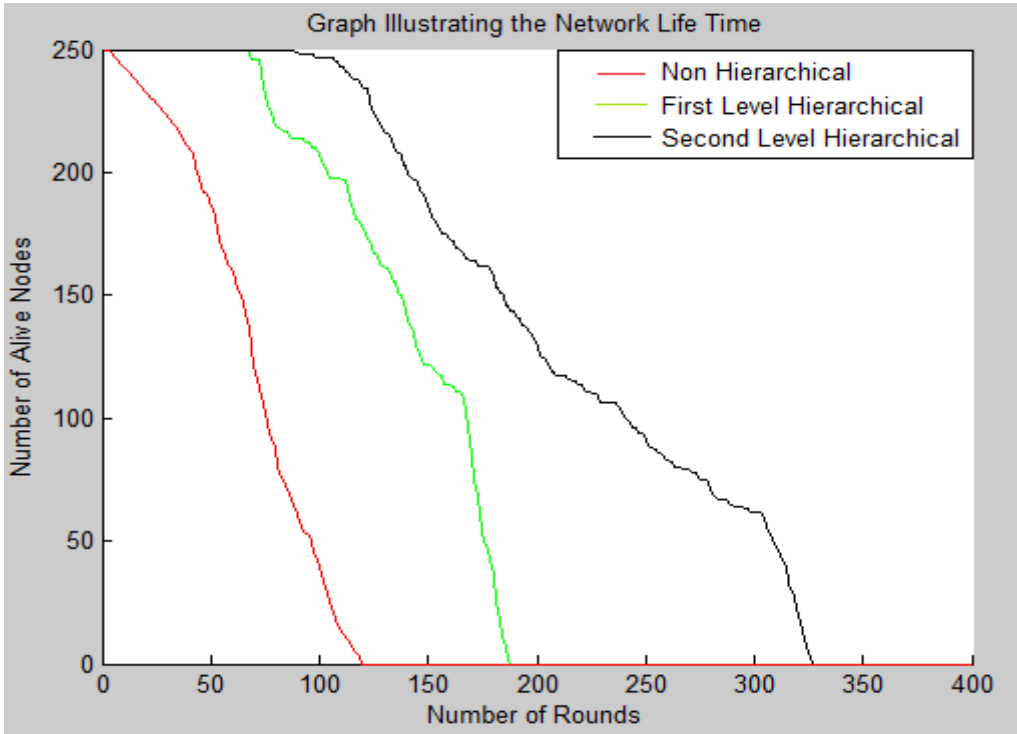


Figure 4.5 Network lifetime graph (number of alive nodes for a particular round of simulation)

Our proposed protocol is also proved by evaluating the residual energy in each node for a particular rounds of simulation. The results in Figure 4.6, 4.7 and 4.8 show that the mean residual energy value of all the sensor nodes of our proposed method is higher than the non hierarchical method which is a further indication of an improved network lifetime when our proposed technique is being implimented.

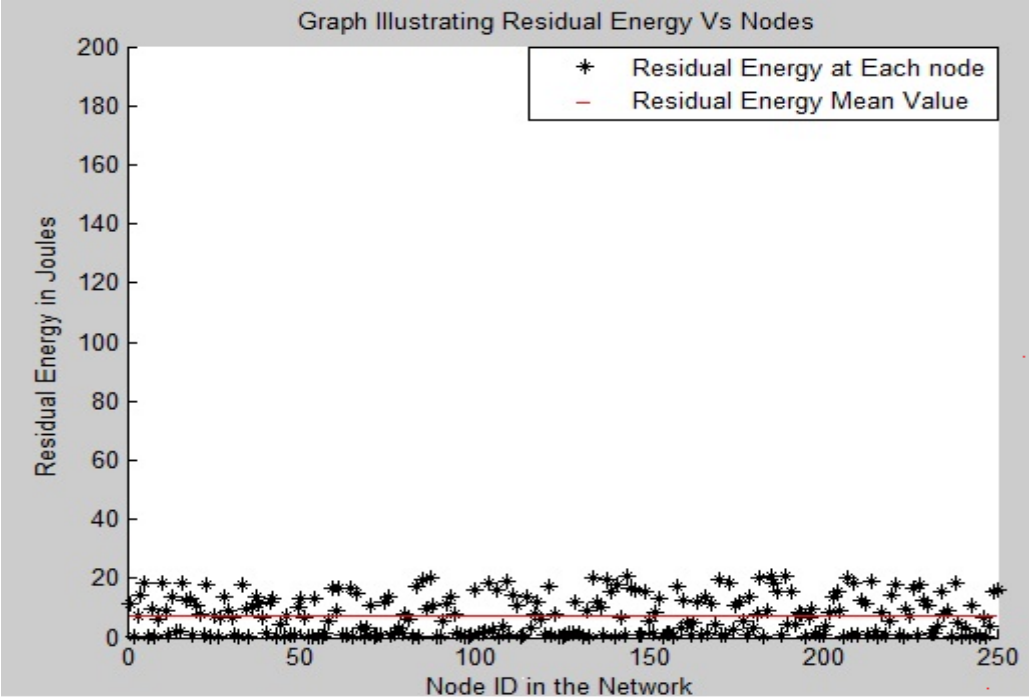


Figure 4.6 Nodes energy residue in non hierarchical technique after 400 rounds simulation

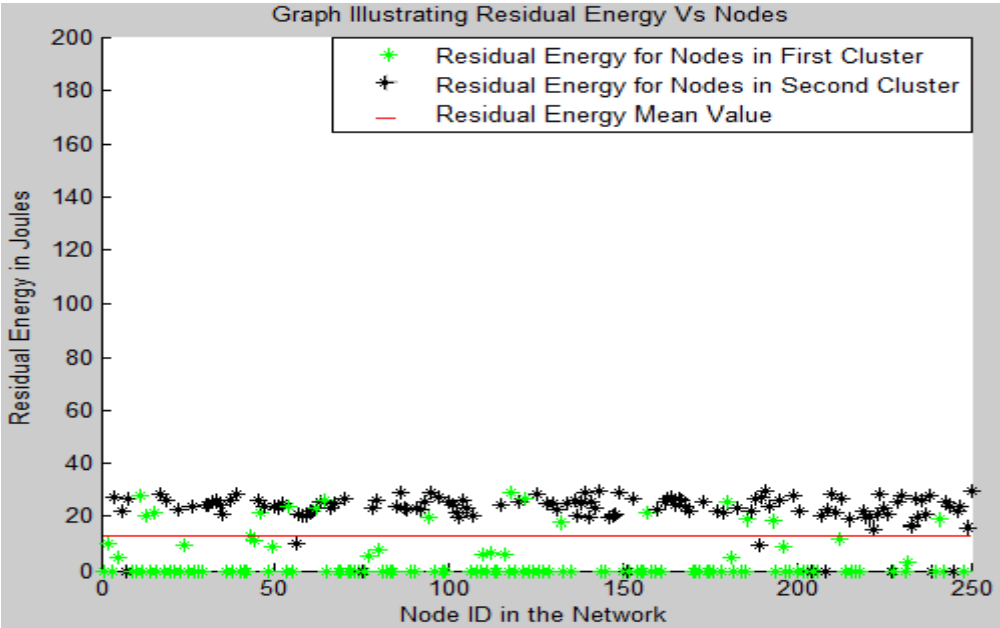


Figure 4.7 Nodes energy residue in first level hierarchical technique for 400 rounds simulation

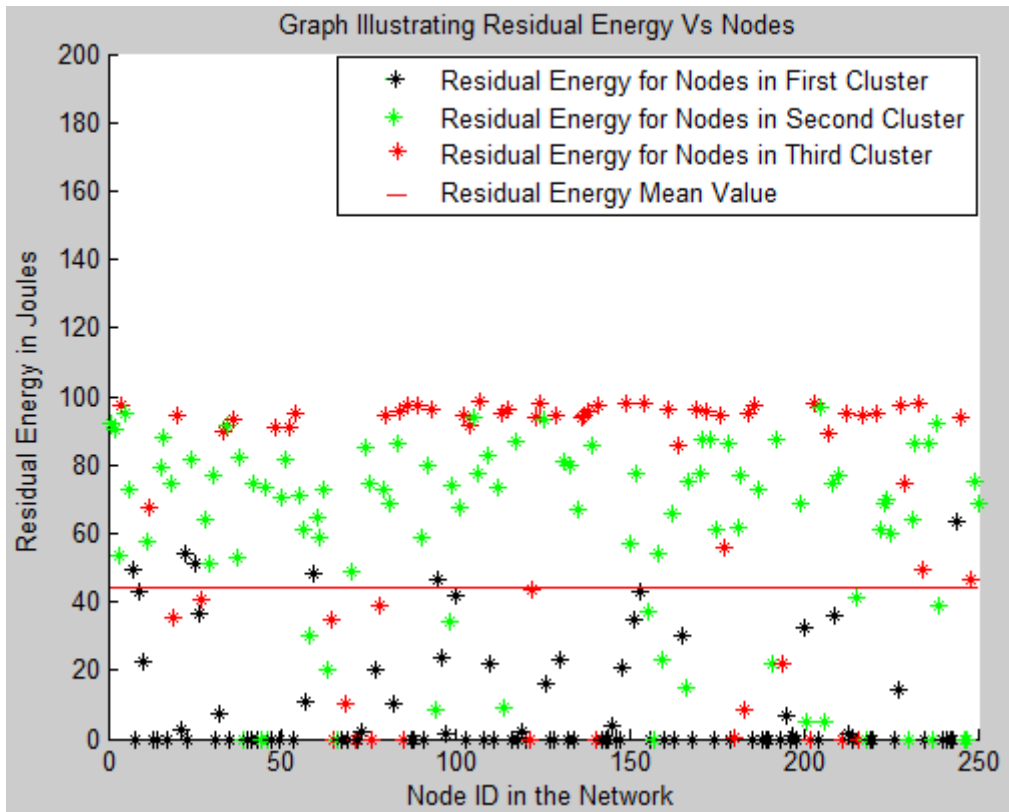


Figure 4.8: Nodes energy residue in second level hierarchical technique for 400 rounds simulation

The Table 4.2 shows the range, mean and variances of the residual energy after 400 rounds simulations for the hierarchical routing technique employed. The mean value of the residual energy increases in each round of simulation as the hierarchical structure increases. This implies better network performance since the nodes has more energy in the latter level of hierarchy.

Table 4.2: Mean value and variance of the residual energy in Figure 4.6, 4.7 and 4.8

	Range (J)	Mean residual energy (J)	Variance residual energy (J)
Non-hierarchical Technique	21.7008	8.1270	7.4039
First level hierarchy	29.7538	13.1419	11.7406
Second level hierarchy	98.5569	43.9161	38.5569

It is also observed in the Table 4.2 that non-hierarchical technique has the lowest variance and the second level hierarchy has highest standard deviation value. The highest value implies the residual energy values after those rounds of simulation are spread out over a large range. Likewise, a lower variance value indicates that the residual energy of each node after the entire

simulation rounds tends to the mean residual energy value. It is also observed that a larger variance value indicate how dispersed the residual energy of all node is from the mean value after the entire simulation rounds. It is also noticed that as the value of the variance gets closer to the mean value, it implies a better performance of network since most of the node will die almost at the same time in the end of the simulation. The Figure 4.9, Figure 4.10 and Figure 4.11 show the plot of the histogram of the residual energy after 400 rounds of simulation.

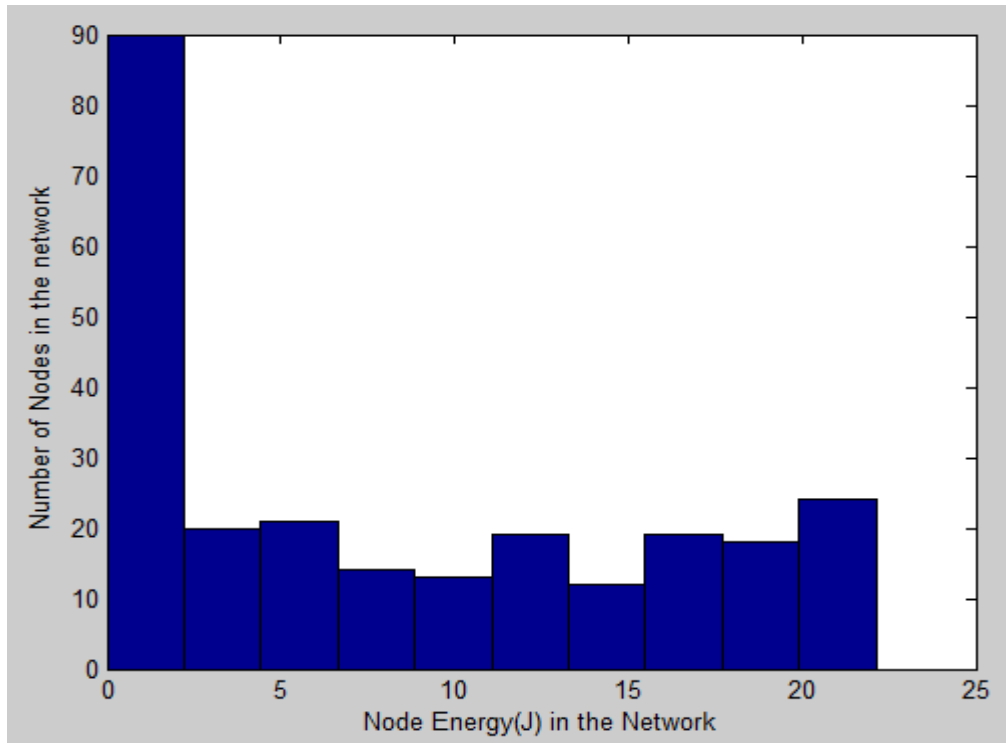


Figure 4.9: Histogram of residual energy for non-hierarchical technique

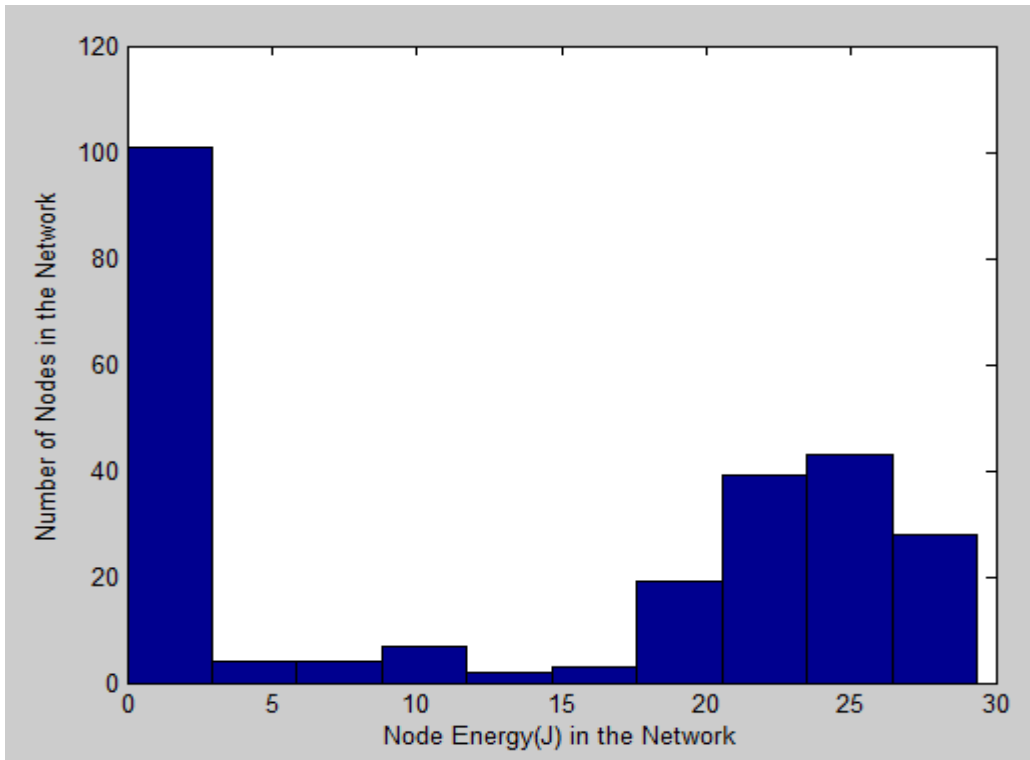


Figure 4.10 Histogram of residual energy for first level hierarchy technique

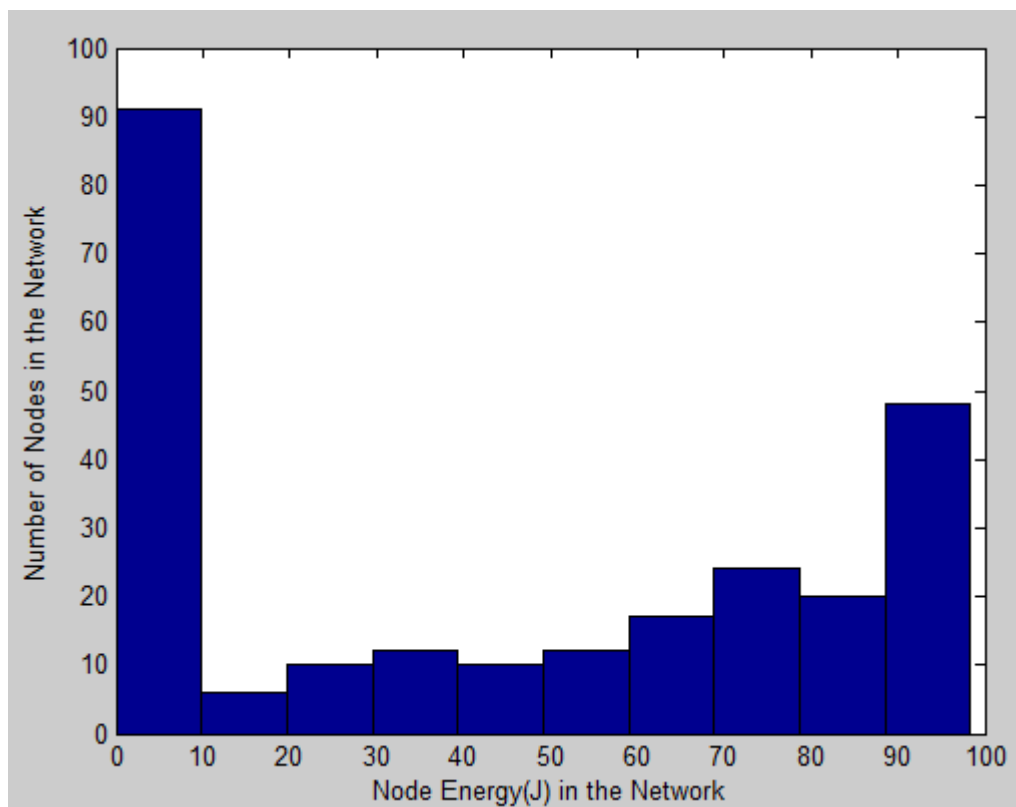


Figure 4.11 Histogram of residual energy for second level hierarchy technique

Chapter Five

Conclusion

5.1 Conclusion and Future Work

In this thesis, we propose an energy efficient hierarchical routing technique in which cluster heads are elected based on the prediction of transmission energy via a shortest distance to the base station. Our approach applies a geographical formation of sensor nodes into clusters, rotating the role of CH, and optimizing the CH selection by prediction of energy transmission energy in every rounds of simulation, and aggregating data before transmission to the BS. The important features which includes cluster formation and rotation, cluster head election and rotation, and cluster optimization of our proposed hierarchical routing technique in transmitting data to the base station was analyzed and emphasized.

Our analysis shows that energy efficiency of WSNs can be further improved by using the hierarchical routing technique. The concept of hierarchical routing technique can be effectively used to designed energy efficient routing protocol in WSN. In our approach, the clusters are formed geographically into different sizes to see how it could affect the network lifetime of WSN.

With energy awareness protocol being our core interest in this thesis work, our proposed hierarchical technique, which uses the predict of smallest transmission energy via the shortest path possible to send data to the BS proof to offer more reduced energy consumption and also increase the lifetime of the WSN. From the analysis of our simulation results, we found out that our proposed protocol offers a better solution to energy efficiency usage in a WSN when compared to other technique such as LEACH and non hierarchical technique.

We also extend the validation of our technique by further evaluating the second level hierarchy in which three cluster were formed in the network, and observed an improved network lifetime which indicate a better energy efficiency in the WSN.

In future work, the optimal level of hierarchy, that is, if we increase the number of clusters to four, five, six and so on, can be investigated. Therefore, we can see how the lifetime in the

network would be affected and the optimal cluster size would also be known in case the lifetime is reduced at a certain level of hierarchy. This work can also be extended to the optimization of the number of sensor nodes in each cluster such that they could be organized into cluster equally such as the method of base-station controlled clustering protocol proposed by Muruganathan [21] to solve the problem of uneven data traffic in sensor network. The validation of our proposed technique can also be done in NS2 to have a better view and understanding of the result analysis. Furthermore, in routing of packets in wireless sensor networks, some sensor node energy is wasted on relaying others data instead of using its energy own data. Therefore, limiting the energy of the nodes that has little or no energy is another area of future research. One can also take account the communication cost and its impact on network lifetime.

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Appendix

Appendices A

```
% Wireless Sensor Network MATLAB simulation code
%Author: Simeon A. Soetan and Ismail O. Eleburike
%Final Thesis for Msc in Telecommunication,BTH -Sweden
%Date:24 January,2010
% clc
% clear all
% close all

%%%Deployment of Sensor nodes

non=250;
threshold=120;
linput=300;
rounds=400;
M=input('input M=')
nodey=linput*rand(1,non);
nodex=linput*rand(1,non);
fid = fopen('AliveNodes.txt','w');
nodeEN=[];
for i=1:length(nodey)
nodeEN(i) = 200;
end
length(nodey);
length(nodex);
length(nodeEN);
%plot(nodex,nodey,'b*')

E_elec=50e-9;
E_amp=100e-12;
k_nns=100*1024*8;
k_chs=500*1024*8;
node=[];
hold on

c=['gbrkcmyr'];
s=['*o+x.^*o'];

%%%Cluster Fomration
for i=1:non
figure (1)
node(i,1)=nodeEN(i);%assignment of node energy
node(i,2)=nodex(i);%node x_coordinate
node(i,3)=nodey(i);%node y_coordinate
switch M
case 1
for k=1:M

node(i,4) = k;
xlabel ('X Co-ordinate ')
ylabel ('Y Co-ordinate ')
plot(nodex(i),nodey(i),'b*')
m=int2str(i);
text(nodex(i)+1,nodey(i)+1,m)
end
case 2
```

```

for k=1:M
    if (node(i,2)>((k-1)*linput/2) && (node(i,2)<=(k*linput/2)))
        node(i,4) = k;
        xlabel ('X Co-ordinate ')
        ylabel ('Y Co-ordinate ')
        plot(nodex(i),nodey(i), 'color',c(k), 'marker',s(k))
        m=int2str(i);
        text(nodex(i)+1,nodey(i)+1,m)
    end
end
case 3
for k=1:M
    if (node(i,2)>((k-1)*linput/3) && (node(i,2)<=(k*linput/3)))
        node(i,4) = k;
        xlabel ('X Co-ordinate ')
        ylabel ('Y Co-ordinate ')
        plot(nodex(i),nodey(i), 'color',c(k), 'marker',s(k))
        m=int2str(i);
        text(nodex(i)+1,nodey(i)+1,m)
    end
end
case 4
for k=1:M
    if k==1 || k==2

if node(i,2)>(k-1)*linput/2 && node(i,2)<=k*linput/2 && node(i,3)>0 &&
node(i,3)<=90/2
        node(i,4) = k;
        xlabel ('X Co-ordinate ')
        ylabel ('Y Co-ordinate ')
        plot(nodex(i),nodey(i), 'color',c(k), 'marker',s(k))
        m=int2str(i);
        text(nodex(i)+1,nodey(i)+1,m)
    end
end
    if k==3 || k==4

        if node(i,2)>(k-3)*linput/2 && node(i,2)<=(k-
2)*linput/2 && node(i,3)>45 && node(i,3)<=90
            node(i,4) = k;
            xlabel ('X Co-ordinate ')
            ylabel ('Y Co-ordinate ')
            plot(nodex(i),nodey(i), 'color',c(k), 'marker',s(k))
            m=int2str(i);
            text(nodex(i)+1,nodey(i)+1,m)
        end
    end
end
end

    otherwise error('Clusters should be 1,2,3,4,6 or 8');
end

end

E_amp=E_amp/6;
count=zeros(1,8);

for i=1:non
    switch node(i,4)
        case 1; count(1)=count(1)+1;
    end
end

```

```

        case 2; count(2)=count(2)+1;
        case 3; count(3)=count(3)+1;
        case 4; count(4)=count(4)+1;
        case 5; count(5)=count(5)+1;
        case 6; count(6)=count(6)+1;
        case 7; count(7)=count(7)+1;
        case 8; count(8)=count(8)+1;
    end
end

%%%Estimation of Energy Comsuption per Instances

countlife=zeros(1,rounds);
if M==1
    [CHX,CHY,CheadD,k,CheadE]=Cheader(M,node,non);
else
    [CHX,CHY,CheadD,k,CheadE,Dist21,D]=Cheader(M,node,non);
end
index=[];
for G=1:rounds
    for g=1:1
        EV=[];
        CHXX=[];CHYY=[];
    switch M

        case 1

            for k=1:M
                for i=1:non
                    EV=[EV;CheadE(k)];
                    CHXX=[CHXX;CHX];
                    CHYY=[CHYY;CHY];
                    Enod(G,i)=node(i,1);
                    if node(i,2)~=CHX(k) && node(i,3)~=CHY(k)
                        distan=sqrt((CHX(k)-node(i,2))^2 + (CHY(k)-
node(i,3))^2);
                        node(i,1)=abs(node(i,1)-
(E_elec*k_nns+(E_amp*k_nns*distan^2)));
                    else
                        k_nnsch(k)=k_nns*(count(k)-1);
                    Endtx(k)=(E_elec*k_nnsch(k)+(E_amp*k_nnsch(k)*CheadD(k)^2));
                    Erx(k)=E_elec*k_nnsch(k);
                    node(i,1)=abs(node(i,1)-Entx(k)-Erx(k));
                    CheadE(k)=node(i,1);

                    end

                    if node(i,1)>=threshold
                        countlife(G)=countlife(G)+1;
                    end
                    if node(i,1)<0
                        node(i,1)=0
                    end
                end
            end
            for i=1:non
                distnod(i)=sqrt(node(i,2)^2+node(i,3)^2);
                ET(i)=E_amp*k_nns*(non-1)*distnod(i);
            end
            Est=node(:,1)-ET';

```

```

[C,I]=max(Est);
% CHX(1)=node(I,2);CHY(1)=node(I,3);
node(I,2)=CHX(1); ,node(I,3)=CHY(1);
case 2
k=1;
for i=1:non
EV=[EV;CheadE(k)];
CHXX=[CHXX;CHX];
CHYY=[CHYY;CHY];
Enod(G,i)=node(i,1);
for J=1:non
distnod(J)=sqrt(node(J,2)^2+node(J,3)^2);
ET(J)=E_amp*k_nns*(non-1)*distnod(J);
end
Est=node(:,1)-ET';
[C,I]=max(Est);
CHX(k)=node(I,2);CHY(k)=node(I,3);
if node(i,4)==k
if node(i,2)~=CHX(k) && node(i,3)~=CHY(k)
distan=sqrt((CHX(k)-node(i,2))^2 + (CHY(k)-
node(i,3))^2);
node(i,1)=node(i,1)-
(E_elec*k_nns+(E_amp*k_nns*distan^2));
else
if CheadD(2)==Dist21
k_nnsch(k)=k_nns*(count(k)-1)+k_nns*(count(2));
else
k_nnsch(k)=k_nns*(count(k)-1);
end
Erx(k)=E_elec*k_nnsch(k);
Entx(k)=(E_elec*k_nnsch(k)+(E_amp*k_nnsch(k)*CheadD(k)^2));
node(i,1)=node(i,1)-Entx(k)-Erx(k);
CheadE(k)=node(i,1);
end
end
end
k=2;
for i=1:non
for P=1:non
distnod(P)=sqrt(node(P,2)^2+node(P,3)^2);
ET(P)=E_amp*k_nns*(non-1)*distnod(P);
Dist2_1(P)=sqrt((node(P,2)-CHX(1))^2 + ((node(P,3)-
CHY(1))^2);
ET2_1(P)=E_amp*k_nns*(non-1)*Dist2_1(P);
Est(i)=node(P,1)-ET(P);
Est2_1(P)=node(P,1)-ET2_1(P);
if Est(P)<Est2_1(P)
Est(P)=Est2_1(P);
end
end
if node(i,4)==k
if node(i,2)~=CHX(k) && node(i,3)~=CHY(k)
distan=sqrt((CHX(k)-node(i,2))^2 + (CHY(k)-
node(i,3))^2);
node(i,1)=node(i,1)-
(E_elec*k_nns+(E_amp*k_nns*distan^2));
else
k_nnsch(k)=k_nns*(count(k)-1);
Entx(k)=(.8*E_elec*k_nnsch(k)+(E_amp*k_nnsch(k)*CheadD(k)^2));
Erx(k)=E_elec*k_nnsch(k);
node(i,1)=node(i,1)-Entx(k)-Erx(k);
CheadE(k)=node(i,1);

```

```

        end

        [C, I]=max(Est);
        CHX(2)=node(I, 2) ;CHY(2)=node(I, 3);

    end
end

for i=1:non
    if node(i,1)>=threshold
        countlife(G)=countlife(G)+1;
    end
    if node(i,1)<0
        node(i,1)=0;
    end
end

%
%      %%%%%%%%%%%Estimation For THREE CLUSTERS
case 3
%      [CHX,CHY,CheadD,k,CheadE,Dist21,D]=Chheader(M,node,non);

k=1;
    for i=1:non
        EV=[EV;CheadE(k)];
        CHXX=[CHXX;CHX];
        CHYY=[CHYY;CHY];
        Enod(G,i)=node(i,1);
        if node(i,4)==k
            if node(i,2)~=CHX(k) && node(i,3)~=CHY(k)
                distan=sqrt((CHX(k)-node(i,2))^2 + (CHY(k)-
node(i,3))^2);
                node(i,1)=node(i,1)-
(E_elec*k_nns+(E_amp*k_nns*distan^2));
                else
                    if CheadD(2)==Dist21
                        k_nnsch(k)=k_nns*(count(k)-1)+k_chs;
                    else
                        k_nnsch(k)=k_nns*(count(k)-1);
                    end
                    Erx(k)=E_elec*k_nnsch(k);

Entx(k)=(E_elec*k_nnsch(k)+(E_amp*k_nnsch(k)*CheadD(k)^2));
                    node(i,1)=node(i,1)-Entx(k)-Erx(k);
                    CheadE(k)=node(i,1);
                end

                for i=1:non
                    distnod(i)=sqrt(node(i,2)^2+node(i,3)^2);
                    ET(i)=E_amp*k_nns*(non-1)*distnod(i);
                end
                Est=node(:,1)-ET';
                [C, I]=max(Est);
                CHX(k)=node(I, 2); CHY(k)=node(I, 3);
            end
        end

k=2;
    for i=1:non
        if node(i,4)==k
            if node(i,2)~=CHX(k) && node(i,3)~=CHY(k)

```

```

                                distan=sqrt((CHX(k)-node(i,2))^2 + (CHY(k)-
node(i,3))^2);
                                node(i,1)=node(i,1)-
(E_elec*k_nns+(E_amp*k_nns*distan^2));
                                else
                                    k_nnsch(k)=k_nns*(count(k)-1)+k_chs;
Entx(k)=(E_elec*k_nnsch(k)+(E_amp*k_nnsch(k)*CheadD(k)^2));
Erx(k)=E_elec*k_nnsch(k);
node(i,1)=node(i,1)-Entx(k)-Erx(k);
CheadE(k)=node(i,1);
                                end

                                for i=1:non
                                    distnod(i)=sqrt(node(i,2)^2+node(i,3)^2);
                                    ET(i)=E_amp*k_nns*(non-1)*distnod(i);
                                    Dist2_1(i)=sqrt((node(i,2)-CHX(1))^2 + ((node(i,3)-
CHY(1))^2);
                                    ET2_1(i)=E_amp*k_nns*(non-1)*Dist2_1(i);
                                    Est(i)=node(i,1)-ET(i);
                                    Est2_1(i)=node(i,1)-ET2_1(i);
                                    if Est(i)<Est2_1(i)
                                        Est(i)=Est2_1(i);
                                    end
                                end
                                [C,T]=max(Est);
                                CHX(k)=node(I,2); CHY(k)=node(I,3);
                                end
                                end
                                k=3;
                                for i=1:non
                                    if node(i,4)==k
                                        if node(i,2)~=CHX(k) && node(i,3)~=CHY(k)
                                            distan=sqrt((CHX(k)-node(i,2))^2 + (CHY(k)-
node(i,3))^2);
                                            node(i,1)=node(i,1)-
(E_elec*k_nns+(E_amp*k_nns*distan^2));
                                            else
                                                k_nnsch(k)=k_nns*(count(k)-1)+k_chs*5;
                                                Entx(k)=(E_elec*k_chs+(E_amp*k_chs*CheadD(k)^2));
                                                Erx(k)=E_elec*k_nnsch(k);
                                                node(i,1)=node(i,1)-Entx(k)-Erx(k);
                                                CheadE(k)=node(i,1);
                                            end
                                        end
                                        for i=1:non
                                            distnod(i)=sqrt(node(i,2)^2+node(i,3)^2);
                                            ET(i)=E_amp*k_nns*(non-1)*distnod(i);
                                            Est(i)=node(i,1)-ET(i);
                                            Dist3_2(i)=sqrt((node(i,2)-CHX(2))^2 + (node(i,3)-
CHY(2))^2);
                                            ET3_2(i)=E_amp*k_nns*(non-1)*Dist3_2(i);
                                            Est3_2(i)=node(i,1)-ET3_2(i);
                                            Dist3_1(i)=sqrt((node(i,2)-CHX(1))^2 + ((node(i,3)-
CHY(1))^2);
                                            ET3_1(i)=E_amp*k_nns*(non-1)*Dist3_1(i);
                                            Est3_1(i)=node(i,1)-ET3_1(i);
                                            if Est(i)<Est3_1(i) && Est3_2(i)<Est3_1(i)
                                                Est(i)=Est3_1(i);
                                            elseif Est(i)<Est3_2(i) && Est3_2(i)>Est3_1(i)
                                                Est(i)=Est3_2(i);
                                            end
                                        end
                                    end
                                [C,T]=max(Est);
                                % node(T,2)=CHX(3) ;node(T,3)=CHY(3);

```

```

        CHX(k)=node(I,2); CHY(k)=node(I,3);
    end
end

for i=1:non
    if node(i,1)>=threshold
        countlife(G)=countlife(G)+1;
    end
    if node(i,1)<0
        node(i,1)=0;
    end
end
end

end
end

end

m=0;
for i=1:non
    m = m+node(i,1);
end;

%%% Estimation of Mean Value and Standard Deviation.
Smean=m/non;
Smean
standarddiv=std(node(:,1))

%%% Plot for Network Life time graph
figure (2)
hold on
title ('Graph Illustrating the Network Life Time')
xlabel ('Number of Rounds')
ylabel('Number of Alive Nodes')
% grid on
plot(countlife,'r')

%%%Plot for Sensor node's Residual Energy

figure (3)
hold
xlabel ('Node ID in the Network')
ylabel('Residual Energy in Joules ')
axis([0 non 0 200])
% figure;
for i=1:non
title ('Graph Illustrating Residual Energy Vs Nodes ')

plot(i, node(i,1),'*k');
% text(nodex(i)+1,nodey(i)+1,m)
hold on
end
hold on
y=zeros(non);
y(:)=Smean;
plot (y, '-r')
legend ('Residual Energy at Each node','Residual Energy Mean Value',2)

```

```

Enod;
% figure(4)
% plot(Enod(:,150))

```

Appendix -B

%M-file for Cluster head election

```

function
[CHX,CHY,CheadD,k,CheadE,Dist21,D,Dist31,Dist41,Dist43,Dist42,Dist51,Dist52
,Dist54,Dist62,Dist63,Dist65]=Cheader(M,node,non);
CheadE=zeros(M,1);
CheadD=170*ones(M,1);
switch M
case 1
for i=1:non
D(i)=sqrt(node(i,2)^2+node(i,3)^2);
for k=1:M
if node(i,4)==k
if node(i,1)>CheadE(k)
CheadE(k)=node(i,1);
CHX(k)=node(i,2);
CHY(k)=node(i,3);
CheadD(k)=D(i);
else
if node(i,1) == CheadE(k)
if D(i)<CheadD(k)
CheadE(k)=node(i,1);
CHX(k)=node(i,2);
CHY(k)=node(i,3);
CheadD(k)=D(i);
end
end
end
end
end
end
case 2
for i=1:non
k=1;
if node(i,4)==k
D(i)=sqrt(node(i,2)^2+node(i,3)^2);
if node(i,1)>CheadE(k)
CheadE(k)=node(i,1);
CHX(1)=node(i,2);
CHY(1)=node(i,3);
CheadD(k)=D(i);
else
if node(i,1) == CheadE(k)
if D(i)<CheadD(k)
CheadE(k)=node(i,1);
CHX(k)=node(i,2);
CHY(k)=node(i,3);
CheadD(k)=D(i);
end
end
end
end
end
end

```

```

        end

    end
    for i=1:non
        k=2;
        if node(i,4)==k
            Dist21=sqrt((node(i,2)-CHX(1))^2 + ((node(i,3)-
CHY(1))^2);
            D(i)=sqrt(node(i,2)^2+node(i,3)^2);
            if node(i,1)>CheadE(k)
                CheadE(k)=node(i,1);
                CHX(k)=node(i,2);
                CHY(k)=node(i,3);
                if Dist21<D(i)
                    CheadD(k)= Dist21;
                else
                    CheadD(k)=D(i);
                end
            end
        else
            if node(i,1) == CheadE(k)
                if D(i)<=Dist21;
                    if D(i)<CheadD(k)
                        CheadE(k)=node(i,1);
                        CHX(k)=node(i,2);
                        CHY(k)=node(i,3);
                        CheadD(k)=D(i);
                    end
                else
                    if Dist21<CheadD(k)
                        CheadE(k)=node(i,1);
                        CHX(k)=node(i,2);
                        CHY(k)=node(i,3);
                        CheadD(k)=Dist21;
                    end
                end
            end
        end
    end
end
case 3
    for i=1:non
        k=1;
        if node(i,4)==k
            D(i)=sqrt(node(i,2)^2+node(i,3)^2);
            if node(i,1)>CheadE(k)
                CheadE(k)=node(i,1);
                CHX(1)=node(i,2);
                CHY(1)=node(i,3);
                CheadD(k)= D(i);
            else
                if node(i,1) == CheadE(k)
                    if D(i)<CheadD(k)
                        CheadE(k)=node(i,1);
                        CHX(k)=node(i,2);
                        CHY(k)=node(i,3);
                        CheadD(k)=D(i);
                    end
                end
            end
        end
    end
end
    for i=1:non

```

```

k=2;
    if node(i,4)==k
        Dist21=sqrt((node(i,2)-CHX(1))^2 + ((node(i,3)-
CHY(1))^2);

        D(i)=sqrt((node(i,2)^2+node(i,3)^2);
        if node(i,1)>CheadE(k)
            CheadE(k)=node(i,1);
            CHX(k)=node(i,2);
            CHY(k)=node(i,3);
            if Dist21<D(i)
                CheadD(k)= Dist21;
            else
                CheadD(k)=D(i);
            end
        else
            if node(i,1) == CheadE(k)
                if D(i)<=Dist21;
                    if D(i)<CheadD(k)
                        CheadE(k)=node(i,1);
                        CHX(k)=node(i,2);
                        CHY(k)=node(i,3);
                        CheadD(k)=D(i);
                    end
                    else
                        if Dist21<CheadD(k)
                            CheadE(k)=node(i,1);
                            CHX(k)=node(i,2);
                            CHY(k)=node(i,3);
                            CheadD(k)=Dist21;
                        end
                    end
                end
            end
        end
    end
end
for i=1:non
    k=3;
    if node(i,4)==k
        Dist32=sqrt((node(i,2)-CHX(2))^2 + (node(i,3)-
CHY(2))^2);

        if node(i,1)>CheadE(k)
            CheadE(k)=node(i,1);
            CHX(k)=node(i,2);
            CHY(k)=node(i,3);
            CheadD(k)= Dist32;
        else
            if node(i,1) == CheadE(k)
                if Dist32<CheadD(k)
                    CheadE(k)=node(i,1);
                    CHX(k)=node(i,2);
                    CHY(k)=node(i,3);
                    CheadD(k)=Dist32;
                end
            end
        end
    end
end
end
end

case 4

for i=1:non
    k=1;
    if node(i,4)==k

```



```

        CheadE(k)=node(i,1);
        CHX(k)=node(i,2);
        CHY(k)=node(i,3);
        if Dist31<D(i)
            CheadD(k)= Dist31;
        else
            CheadD(k)=D(i);
        end
    else
        if node(i,1) == CheadE(k)
            if D(i)<=Dist31;
                if D(i)<CheadD(k)
                    CheadE(k)=node(i,1);
                    CHX(k)=node(i,2);
                    CHY(k)=node(i,3);
                    CheadD(k)=D(i);
                end
            else
                if Dist31<CheadD(k)
                    CheadE(k)=node(i,1);
                    CHX(k)=node(i,2);
                    CHY(k)=node(i,3);
                    CheadD(k)=Dist31;
                end
            end
        end
    end
end
end
end
end
for i=1:non
    k=4;
    if node(i,4)==k
        Dist41=sqrt((node(i,2)-CHX(1))^2 + ((node(i,3)-
        CHY(1))^2);
        Dist42=sqrt((node(i,2)-CHX(2))^2 + (node(i,3)-
        CHY(2))^2);
        Dist43=sqrt((node(i,2)-CHX(3))^2 + (node(i,3)-
        CHY(3))^2);
        %
        D(i)=sqrt(node(i,2)^2+node(i,3)^2);
        if node(i,1)>CheadE(k)
            CheadE(k)=node(i,1);
            CHX(k)=node(i,2);
            CHY(k)=node(i,3);
            if Dist41<Dist42 && Dist41<Dist43
                CheadD(k)= Dist41;
            else
                if Dist42<Dist41 && Dist42<Dist43
                    CheadD(k)=Dist42;
                else
                    CheadD(k)=Dist43;
                end
            end
        end
    else
        if node(i,1) == CheadE(k)
            if Dist41<=Dist42 && Dist41<Dist43;
                if Dist41<CheadD(k)
                    CheadE(k)=node(i,1);
                    CHX(k)=node(i,2);
                    CHY(k)=node(i,3);
                    CheadD(k)=Dist41;
                end
            end
            if Dist42<=Dist41 && Dist42<Dist43;
                if Dist42<CheadD(k)

```

