RECH-LEACH: A NEW CLUSTER HEAD SELECTION ALGORITHM OF LEACH ON THE BASIS OF RESIDUAL ENERGY FOR WIRELESS SENSOR NETWORK

BY

GULFAM AHMED SAJU
ID: 161-15-6752

MD. MOSHGUL BHUIYAN
ID: 161-15-6912
AND

MD. NAZRUL ISLAM
ID: 161-15-7255

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Supervised By
Narayan Ranjan Chakraborty
Assistant Professor
Department of CSE
Daffodil International University

DAFFODIL INTERNATIONAL UNIVERSITY

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APPROVAL

This Project/internship titled **"RECH-LEACH: A New Cluster Head Selection Algorithm of LEACH on the Basis of Residual Energy for Wireless Sensor Network"**, submitted by Gulfam Ahmed Saju, ID No: 161-15-6752, Md. Moshgul Bhuiyan, ID No: 161-15-6912, Nazrul Islam, ID No: 161-15-7255 to the Department of Computer Science and Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on 07/12/2019.

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Faculty of Science & Information Technology
Daffodil International University

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Assistant Professor
Department of Computer Science and Engineering
Faculty of Science & Information Technology
Daffodil International University

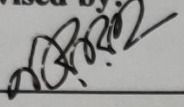
Shaon Bhatta Shuvo — **Internal Examiner**
Senior Lecturer
Department of Computer Science and Engineering
Faculty of Science & Information Technology
Daffodil International University

Dr. Md. Saddam Hossain — **External Examiner**
Assistant Professor
Department of Computer Science and Engineering
United International University

DECLARATION

We hereby declare that, this project has been done by us under the supervision of **Narayan Ranjan Chakraborty, Assistant Professor, Department of CSE** Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

Supervised by:



Narayan Ranjan Chakraborty
Assistant Professor
Department of CSE
Daffodil International University

Submitted by:

Gulfam

(Gulfam Ahmed Saju)
ID: 161-15-6752
Department of CSE
Daffodil International University

Moshgul

(Md. Moshgul Bhuiyan)
ID: 161-15-6912
Department of CSE
Daffodil International University

Nazrul

(Md. Nazrul Islam)
ID: 161-15-7255
Department of CSE
Daffodil International University

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ABSTRACT

Wireless sensor network is constructed of small low power sensor devices. These sensor devices contain small battery capacity and placed in hostile condition. When these sensor nodes are positioned in an area, it is almost impossible to make an alteration of the battery of these devices if they run out of power. If a sensor device dies due to low power, it becomes quite illusive to monitor the condition of that area. Therefore, controlling the energy depletion of the network is a vital task. LEACH protocol is such kind of energy competent protocol which reduces energy dissipation of the network and enhances its lifespan. But it has a few constraints too. The cluster head (CH) election procedure of LEACH is not quite competent. It selects cluster heads randomly without judging the energy or distance of the nodes from the base station. So, to resolve these issues we come up with new CH election algorithm. We named RECH-LEACH (Residual Energy-based Cluster Head selection). RECH-LEACH works almost same as LEACH except the selection procedure of CH after the first round. In RECH-LEACH, CHs are chosen on the basis of remaining energy of the sensor devices. The nodes with the highest energy after each round will become CH based on the probability of being CH. The aim of the RECH-LEACH algorithm is to shrink the energy dissipation of sensor nodes and elongate the lifespan of the network. We run the simulation in MATLAB and after the simulation the result shows that RECH-LEACH surpasses LEACH protocol with a huge margin and attains its goal.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Wireless Sensor Network is recently one of the most emerging potential filed of modern time. It is a branch of the Internet of things (IoT). WSN is a set of a colossal number of autonomous sensor devices. These sensor devices are capable of sensing and monitoring many conditions of nature like temperature, sound, pressure etc. These sensor nodes activities are distinct. Sensor nodes can be placed in a small area or distributed in a massive area for sensing or computing the condition of the environment.

WSN has a myriad of sensor nodes, base station (BS) and data center. The sensor nodes transfer data to the BS. Then the BS sends the collected data to the data center. This whole data transmission process is done wirelessly. All these components are connected with each other through a medium. Bluetooth is the most widely used medium for WSN.

Sensor nodes are made of limited sensors which sense a specific condition. A mote also forms a sensor node aggregating with the sensor. A mote contains processor, memory and an analogue to digital (A/D) converter. The purpose of the A/D converter is to connect the mote with the sensor. A mote also has a transceiver of radio for connecting to a network.

Base station (BS) is also acknowledged as sink node, fetches data from the sensor nodes of a network. After successful data gathering and data processing BS sends the data to the control center. The primary purpose of BS is to obtain data from sensor nodes and process those data and then transmit those data to the data center. A base station is built with a processor, antenna, radio board and USB board.

Sensor nodes are often positioned haphazardly in a region and are hoped to do their specific task proficiently. The data collection and monitoring of an area are completely dependent on these sensor nodes. So, if a sensor node faces any defect or issues, it becomes challenging to get flawless data from that sensor node’s area. Sensor nodes are

powered and run on battery energy. These miniature sensor nodes have a limitation of storage and battery power because they cannot hold much power and bigger power capacity battery since they are too little in size.

Nowadays, the use of WSN is augmenting at a promising rate. Therefore, it is very important to ameliorate the lifetime of WSN. Few incentives affect the operation of wireless sensor network, which are power consumption, expense, defect endurance, communication and managing connection. Among these factors, energy limitation is one of the major obstacles of WSN. These nodes are placed in hostile environments, so it is not feasible to change or remove the batteries time and time. Instead, an energy-efficient network where battery depletion will be less can resolve these problems.

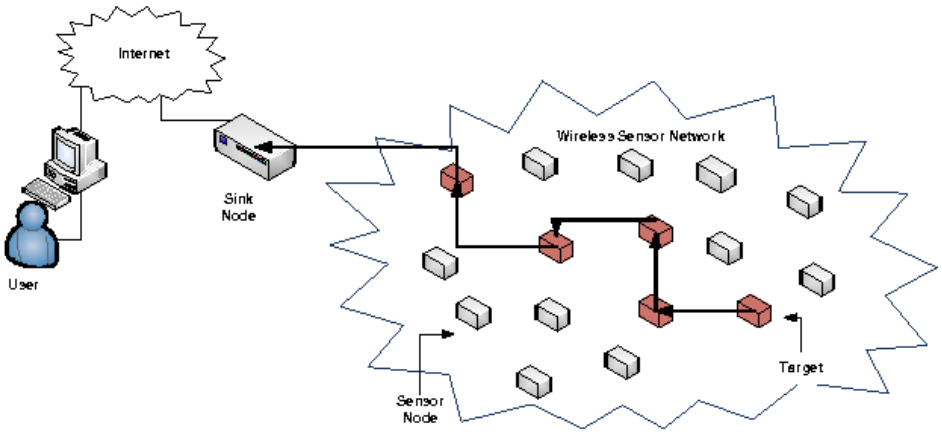


Figure 1.1.1: Wireless Sensor Network

Figure 1.1.1 is an illustration of wireless sensor network. This figure depicts the workflow of WSN.

For reducing energy dissipation, various clustering algorithms are implemented in wireless sensor network. Clustering means dividing sensor nodes into different groups. In every cluster, a particular node is chosen as cluster head (CH). The other nodes transfer data to the CH, which performs data unification function to expunge data redundancy and get pertinent information. By following this process, less data is sent to the BS, which

consumes less energy. *Low Energy Adaptive Clustering Hierarchy* (LEACH) protocol is one of the most energy- competent hierarchical clustering algorithms.

LEACH protocol is one of the most ameliorated routing protocols in WSN. LEACH routing algorithm is mainly based on CH selection among the sensor nodes. After the selection of cluster head, the network is separated into several clusters and the network's runtime is split into many rounds [1]. In LEACH protocol, all the sensing element nodes have a similar chance to be a CH that makes the nodes within the network consume energy in a very comparatively balanced approach [1].

Our work will be on LEACH protocol where we ameliorate the functioning of LEACH protocol by a few changes in the conventional LEACH. LEACH protocol selects cluster heads randomly without considering the residual energy in the sensor node. In our new proposed method CH will be elected based on the energy left on the node. Applying this algorithm, power dissipation will be lessened and the lifespan of the network will increase drastically. Therefore, getting flawless data from a network will be much easier.

1.2 Motivation

Wireless sensor network implementation is mounting at a promising rate. As it works with numerous sensor nodes which are diminutive in size, so it requires an energy competent routing protocol to augment the performance of WSN. LEACH protocol is implemented to lessen the energy attenuation of sensor nodes. The main motto of implementing LEACH protocol was to enhance the network lifespan of WSN, and it successfully fulfilled its motto. It is one of the most efficacious routing protocols for reducing energy dissipation in WSN. But it has a few issues which must be solved to decrease energy consumption completely. In every round, some extra energy is wasted because of new CH and cluster formation. CHs chosen arbitrarily without considering their distance from the BS and their residual energy. So, there is a chance that a low power node may get selected as CH in any round. If a low power node becomes CH, it may die at any time. Because CHs requires more energy than normal nodes as they fetch data from all sensor nodes of a cluster and transmits all of the data to the sink node. Therefore, it is obligatory to select a

high-power node as a CH. So, an amendment is indispensable in the existing LEACH protocol. Many researchers had worked and still working on the improvement of LEACH protocol. They have made a few changes in the working algorithm of LEACH protocol and proposed new LEACH better performed LEACH. Still, there are opportunities of betterment in the LEACH protocol and newly developed LEACH protocols which are proposed by many researchers. That is the motivation of our thesis to resolve the existing problems in the LEACH protocol and make it the most energy competent routing protocol of wireless sensor network.

1.3 Objectives

To develop our improved LEACH named as RECH-LEACH (Residual Energy base CH selection) our key objectives of this thesis are abridged as follows:

- To construct an environment for WSN in an approach that the lifespan of the network increases drastically.
- To make sure that data transmission between the sensor nodes and the BS of a network is running flawlessly.
- To study the preceding protocols of WSN and their structures.
- Detect the most common existing issues of the wireless sensor network.
- To construct a better performed LEACH clustering algorithm which will prolong the lifecycle of the network.
- Simulate the new improved LEACH using MATLAB.
- Make a comparison of performance, lifetime and energy dissipation between the newly developed LEACH and the existing LEACH.

1.4 The Rationale of the Research

After the invention of LEACH protocol, it has been implemented in a wide range in WSN. It has made a massive impact in expanding the lifespan of WSN. LEACH protocol is known for its low energy dissipation of sensor nodes. But still, there is a scope of betterment in the LEACH protocol. It has a few issues which encumber the performance

of the protocol. The primary issue is the CH election procedure. The cluster head picking process occurs randomly considering the arbitrarily selected number by the sensor node and the calculated threshold value. But following this process, cluster heads get selected without considering a sensor nodes energy and robustness, which may lead the sensor node to die. If a cluster head dies the communication and data transmission with the base station will be stopped. Data aggregation from that cluster's area will be impossible. Therefore, the monitoring system of that area will be thwarted. So, there comes the need for a new improved LEACH protocol which will solve these problems. Therefore, we come up with our new idea of an improved CH selection procedure on the basis of the sensor nodes remaining energy. In our proposed method, CHs will be elected determining the energy remained in a sensor node. The top nodes with the highest residual energy will be nominated as CHs in each round. So, to extend the network lifespan, improvement in the LEACH was obligatory.

1.5 Research Questions

- What is the purpose of reducing power consumption in wireless sensor network?
- Why cluster head selection of LEACH protocol is important for wireless sensor network?
- What is the constraints of LEACH protocol in cluster head selection procedure?
- Why a modified cluster head selection algorithm is required for LEACH protocol?

1.6 Expected Output

We propose new LEACH to enhance the functioning of the existing LEACH. When this algorithm will be applied in a network, the energy consumption of the entire network will reduce. As the sensor nodes are costly and it is difficult to justify the new LEACH in a real wireless sensor network. So, we do the whole simulation in MATLAB and then compare it with the existing LEACH. The simulation is done among 100 nodes network. The expected outcomes after the simulation are:

- Simulate the existing LEACH protocol and newly developed residual energy-based cluster head election algorithm based RECH-LEACH.
- The simulation process to run until all sensor nodes are dead.
- Simulate the new RECH-LEACH in MATLAB and after the simulation gets the energy dissipation graph and lifetime graph of the WSN.
- Get better result than the existing LEACH.
- After implementing RECH-LEACH acquire low energy dissipation and higher lifetime than the existing LEACH.

1.7 Report Layout

Our work comprises three portions. In the first part, a literature survey is done. In the literature review, we try to review the papers based on the LEACH protocol. Many authors proposed a variety of LEACH protocol for its performance improvement. A brief overview of LEACH protocol and amended LEACH protocols are described in this portion. In this portion, we also try to find the challenges faced by other researchers.

In the second portion, we describe the methodology of the new RECH-LEACH protocol which is proposed by us. We try to describe the whole algorithm and its working procedure.

The final part is the implementation, result and outcome part. In this part, we simulate the RECH-LEACH in MATLAB and get the result of the simulation.

Chapter 1 gives a summary of the thesis and the goal. Chapter 2 gives an outline of WSN, a literature survey on the basis of LEACH protocol and challenges of the research. Chapter 3 describes the methodology of the newly proposed RECH-LEACH. Chapter 4 portraits the result of the simulation. Chapter 5 is the conclusion.

CHAPTER 2

BACKGROUND

2.1 Wireless Sensor Network

Wireless Sensor Network (WSN) is a popular research topic in the field of Networking. WSN is a network that comprises of sensor nodes and the base station (BS) to observe environmental and physical circumstances such as temperature, humidity, sound, pressure, vibration, and motion. It is a self-organized wireless network. WSN has two main parts such as sensor nodes, sink nodes and base stations. A WSN has a huge number of sensor nodes that are autonomous and small. Nodes communicate with each other and with sink node via radio frequency wave. Sensor nodes collect information from the environment. Sensor nodes pass their information through the network to the main location called sink node where information or data can be observed and analyzed. WSN also has a sink node or base station which gathers data from the sensor nodes and propels data to the end-user via the internet.

The main constraints of a sensor node in the WSN are battery power, computation capacity, low memory storage, and communication range.

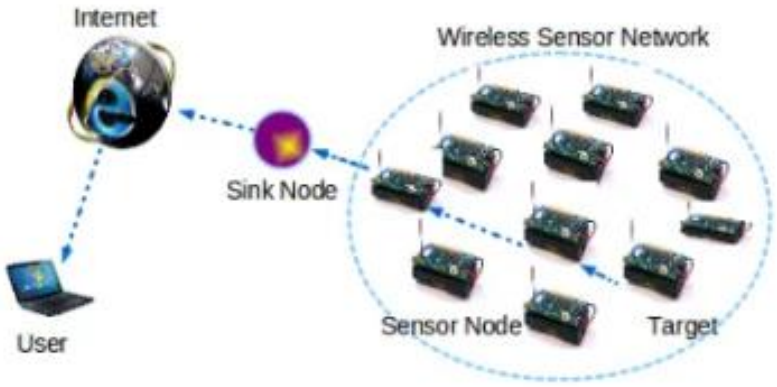


Figure 2.1.1: Wireless Sensor Network

The sensor node supplied with transceivers to accrue data from its around environment and transmit data to the BS, where the measured factors can be kept data and obtainable for the end-users. The sensor node senses the physical state of an environment and if there is any variation in then it produces electrical signals. Then signals go to the microprocessor for calculating the signal. A chief computer sends commands to the transceivers and then the sensor node mails data to the computer.

There are two main components of Wireless Sensor Network:

- Sensor Node and
- Base Station (BS)

2.1.1 Sensors Node

A sensor node is a basic and notable part of a WSN that is able to perform some processing, fetching information and connecting with other linked nodes in a network. It is a device, also known as a mote. We use it to make a wireless sensor network. A sensor node senses information from its environment and sends it to the sink node to process this information. Sensors are naturally used to compute the changes in the physical environmental factors such as humidity, temperature, pressure, vibration, and sound. It also senses the changes in the health of a person like a heartbeat and blood pressure. There are many parts of a sensor node such as battery, processor, memory, A/D converter. A/D converter is used to connect a sensor and a radio transceiver used to form an ad hoc network. A sensor node and all its components make an ad-hoc wireless sensor network. Each sensor node follows the multi-hop routing algorithm and it also follows the routing protocol for sending data packets to the BS.

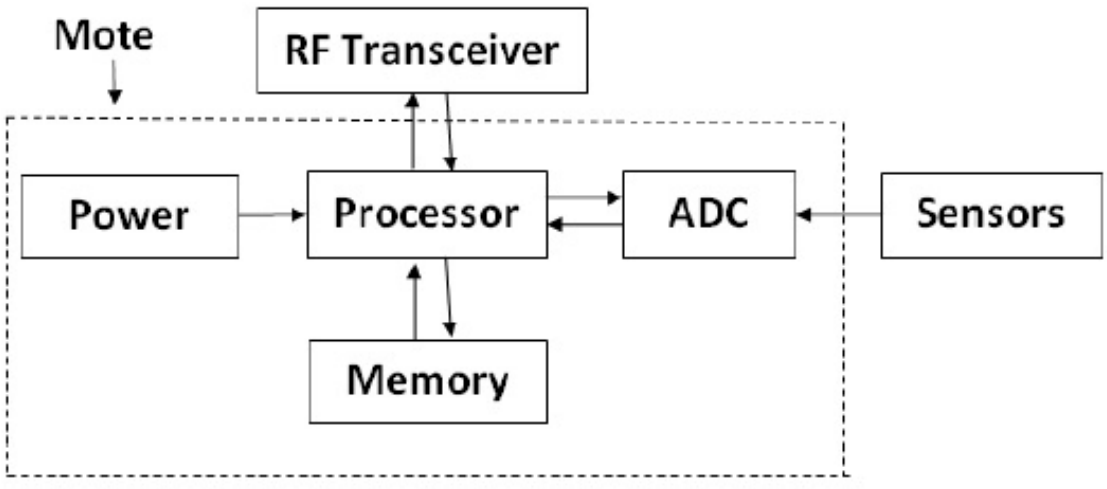


Figure 2.1.1.1: Block Diagram of Sensor Node [16]

2.1.2 Base Station

Base station is one kind of node which is used to collect data from the cluster head (CH). It is known as the sink node also. The CH is a node which is to assemble data from the sensor node and transfer the data to the BS. A BS or sink node helps to connect one sensor network to other networks. It contains a radio board, processor, antenna and USB interface board. A BS is programmed which is used low power mesh network software. This programming is used to build communication with wireless sensor nodes. The deployment of a sink node or BS is very significant in WSN as sensor nodes pass data to the BS for processing and decision making.

Figure 2.1.2.1: A Base Station Node [16]

2.1.3 Radio Model

A radio model is used to transfer data node to node and node to base station. We have described the radio model which is used in previous research or project works. In the radio model, the energy of the transmitter is used to run the transmitter radio electronics and the power amplifier. The energy of the receiver is used to run receive radio electronics as shown in figure 1.4. The radio model describes both the free space and the multipath fading channel model. Based on the distance between the transmitter and the receiver, the radio model is used. The distance is compared to the threshold to take the right decision. If the distance is less than the threshold, the free space model is utilized, otherwise, the multipath model is used. The sensor node transfer data used the radio frequency wave with other sensor nodes and also transfer data to the BS properly and accurately.

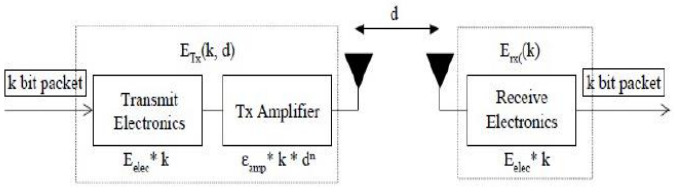


Figure 2.1.3.1: Radio Model [16]

2.2 Literature Survey

This chapter describes the need for a comprehensive literature review to obtain preliminary information and search investment scope, to incorporate LEACH. This document discusses research studies in different energy and routing algorithms and their general aim.

2.2.1 LEACH Protocol

LEACH protocol (*Low Energy Adaptive Clustering Hierarchy*) was suggested by *W.* Heinzelman, Chandrakasan and Balakrishnan for WSN [3]. A LEACH is an algorithm that organizes the network nodes into small clusters and chooses a CH from each cluster. At first, the node senses its destination and then transmits the pertinent information to the CH. Then the CH transmits the gathered information to the BS. LEACH protocol's main objective is to enhance energy efficiency by using a random number to implement a rotation-based CH selection technique. LEACH protocols work in many rounds. Each round comprises two phases. The operation of the LEACH protocol is described in section 2.2.2

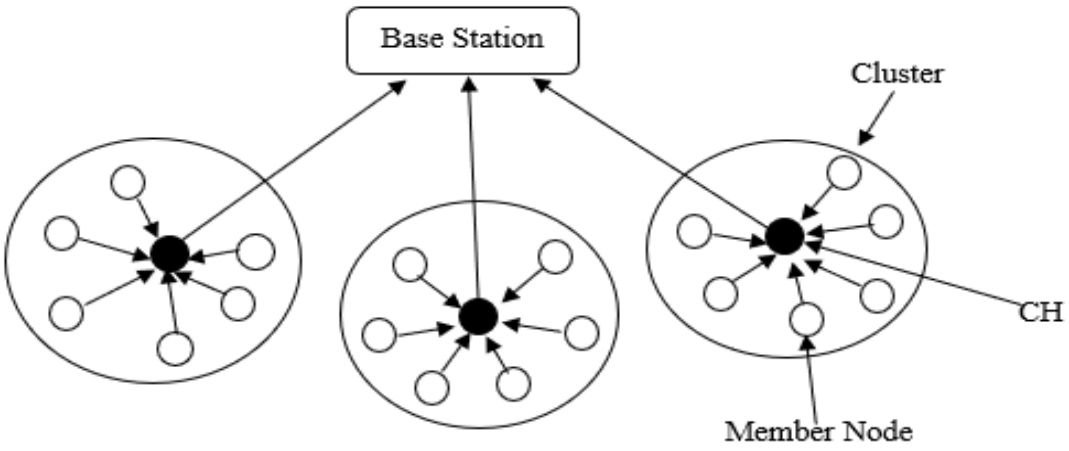


Figure 2.2.1.1: Clustering in LEACH Protocol

2.2.2 Operation of LEACH Protocol

LEACH operation can be isolated into two stages:

- Setup-stage
- Steady stage

The clusters are created and a CH is chosen for each cluster in setup-stage. And in steady-stage data is perceived by the nodes and data is transmitted to the BS.

Setup-stage: During this stage, every node determines whether or not to be CH for the current round. This assessment is based on the choice of a random number between 0 and 1, if random number < the threshold T(s), the node will become the CH for the current round [3].

$$T(n) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Here, P is meant to be the percentage of CHs in the current network, r is defined as the immediate round number, n is the number of nodes exist in the network, G is the set of nodes which have not been picked in the last *1/P* rounds as cluster head. The nodes, which do not CH in the present round, receives a broadcasted advertisement message by the cluster heads. Then the non-CH nodes ascertain which cluster it will associate for that round. The nodes make this decision considering the strength of the advertisement message signal. After that, CH makes a TDMA schedule for each node and set a time for transmitting data. Nodes can transmit data during its assigned time.

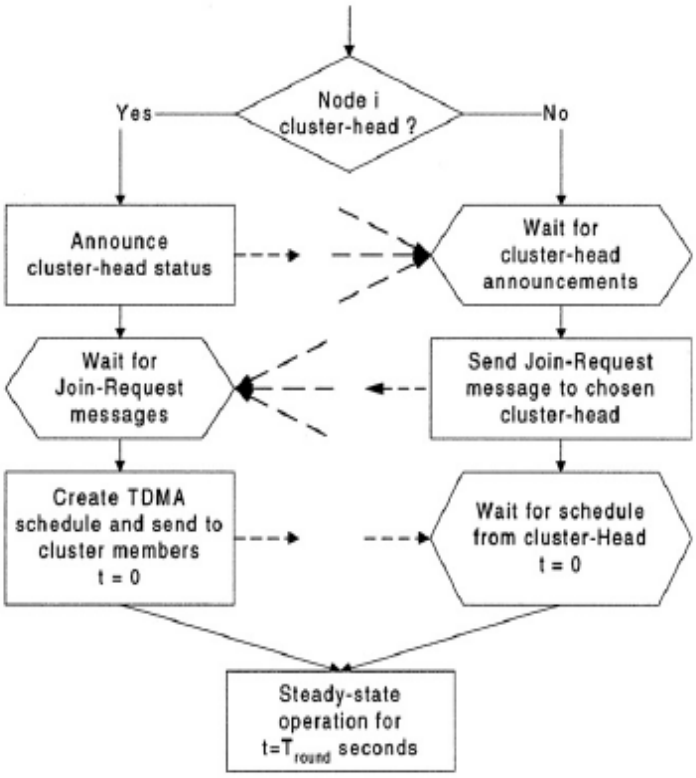


Figure 2.2.2.1: Flowchart of the setup-stage of LEACH [4]

Steady stage: During the steady stage, each cluster head (CH) waits to accept data from the sensor nodes and transmits the data to the BS. After a while, the network returns to the setup stage and new CHs are elected.

2.2.3 Drawbacks of LEACH protocol

Though LEACH protocol is very popular to all, it has some weaknesses described below-

- The CHs are chosen randomly: The cluster heads are randomly chosen with the stochastic method without considering the residual energy of the nodes [5].
- Irregular and unpredictable cluster formation: CHs are not equally distributed which leads to non-uniform cluster creation [5].

- Single-hop communication from CHs to BS: Every cluster head attaches directly to the BS and does not cover a gap between it and the BS. If it is distant, then, power is consumed [5].
- CH is always on: The cluster head is always on and continuously transmits data to the BS. If the CH is damaged, then the whole cluster will be damaged.

2.2.4 Variations

Different successors in the LEACH protocol that exists in literature can be categorized on various parameters such as mobility, reliability, centralization, homogeneity, safety, stability, etc. But the most fitting grouping would be based on three phases of LEACH to be the specific determination of CHs, the formation of clusters, data transmission and miscellaneous [3].

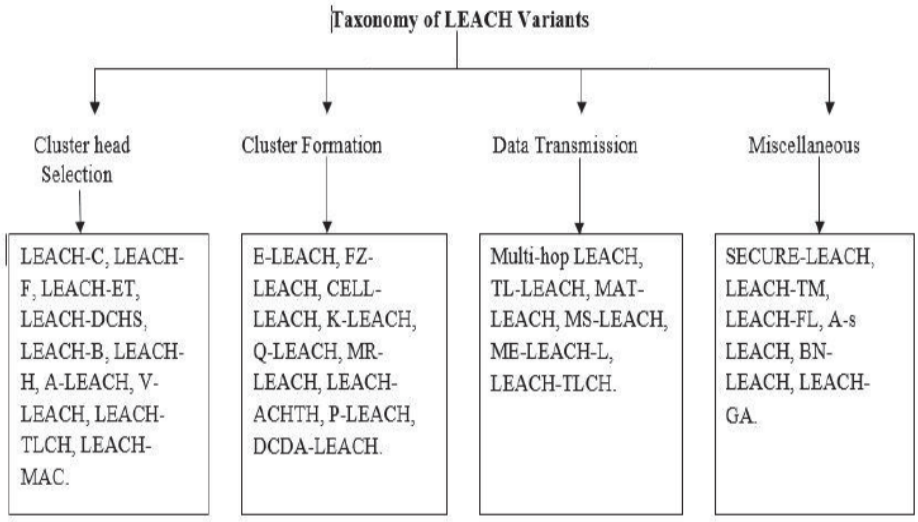


Figure 2.2.4.1: Classification of LEACH [5]

2.2.4.1 Cluster Head selection-based protocols

LEACH-B: It uses a decentralized algorithm in which the nodes know their location and the address of the recipient. This means that the data will not be aggregated at CH [4]. LEACH-B environs the following techniques, CH election algorithm, cluster creation,

and data transmission with diverse access. Every member node of the cluster selects its CH by measuring the energy wastage in the route between its final receiver and itself. The performance of LEACH-B is better than the existing LEACH.

LEACH-C (*Centralized LEACH*)**:** LEACH-C utilizes a centralized way for higher distributing the CHs within the network. The information about the position of the nodes and their energy level is transmitted to the BS at the beginning of every round. Then the BS chooses the nodes with remaining energy more than average are considered as the applicant and then the BS will choose a group of cluster heads from the candidate [6].

LEACH-F: It is a centralized and location-based protocol that uses simulated annealing for making stationary clusters. The BS chooses the clusters and cluster heads and broadcasts clusters identity of each node. The first node in the node ID list is chosen as first CH, the second node as the next CH and so on [5]. This approach does not allow the mobility and the progressive nature of the sensor networks [5].

V-LEACH: This protocol incorporates a secondary CH (Vice cluster head) that acts as a CH when the CH dies. In this way, the member nodes will able to transmit the data to the base station. This approach increases the lifetime of WSN [9].

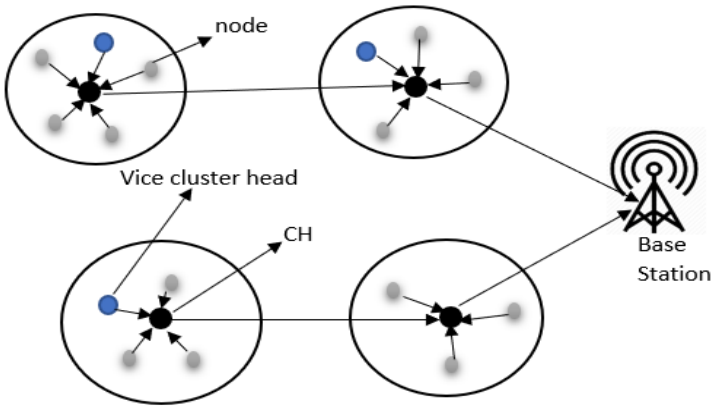


Figure 2.2.4.1.1: V-leach protocol

LEACH-TLCH: This protocol makes a secondary CH based on the remaining energy and distance between the BS and CH. This secondary cluster takes up the duty of CH to

gather and fuse data, sends the fused data to the CH and finally, it delivers to the BS [5]. Thus, the TLCH enhances the lifetime of WSN by avoiding the early death of the CHs.

A-LEACH (*Advanced LEACH*)**:** This protocol seeks to balance the distribution of energy wastage among the nodes by modifying the threshold function. The threshold function comprises two components-G_p and CS_p where G_p refers to General probability and CS_p refers to the state probability of current [10]. The threshold function equation [10]-

$$T=G_p + CS_p$$

$$= \frac{k}{N-k\ (r\ mod\ \frac{N}{k})} + \left(\frac{En\_current}{En\_max} * \frac{k}{N}\right)$$

Where k = Expected number of cluster heads in a round
N = Total number of nodes in the networks

2.2.4.2 Cluster formation-based protocols

LEACH-E (Energy LEACH)**:** In this protocol, if the remaining energy of a node is more than the listed energy, the node becomes a CH, otherwise the node becomes a general node. The rest of the stages are the same as existing LEACH [11][5].

Cell-LEACH: In this protocol, the sensor network once divided into cells with different sensors. A sensor inside the cell is chosen as the head of the cell [12]. A cluster is formed with seven neighboring cells with a cluster head. In the following phases, every old head chooses a new cell head dynamically using the remaining energy of nodes and replaces it [12][5]. The cell head gathers data from the cell members and directly communicates with CH. Finally, CH sends data to BS [5].

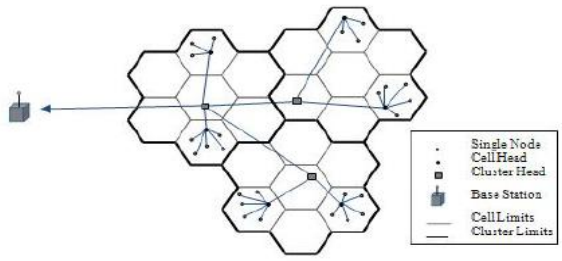


Figure 2.2.4.2.1: Packets sent from cell-heads to cluster-heads and then to BS [12]

Q-LEACH [18]: This protocol divides the cluster into four sectors which are called quadrants. At first, the position of the nodes is provided to the BS which arranges the nodes into four quadrants. In each section, some nodes are elected as cluster heads based on the threshold value. The nodes choose their cluster head based on the contiguity. The rest of the steps are the same as the actual LEACH. The lifetime of WSN is prolonged by this protocol.

2.2.4.3 Data Transmission Based Protocol

Multi-hop LEACH [17]: The distance between CHs and BS is not considered in the LEACH algorithm. So, the multi-hop LEACH allows contact between CH and BS through multi-hops by finding the best path between CHs and BS in order to lessen energy dissipation. The procedure of Multi-hop LEACH shown in fig. 2.2.4.3.1.

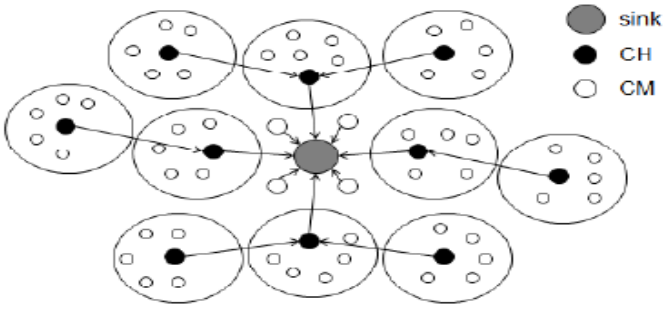


Figure 2.2.4.3.1: Multi-hop LEACH [13]

MS-LEACH: This protocol incorporates multi-hop and single-hop transport principles. If the actual area size of the cluster is less than the area size of the threshold, no action will take place, i.e. cluster members must interact with single-hops. Otherwise, the Dijkstra algorithm is used to determine the minimum pathway of energy consumption for multi-hop communication between the CH and member nodes [19].

2.2.4.4 Miscellaneous Protocols

BN-LEACH (Bayesian *Networks LEACH*)**:** This protocol uses the Bayesian network for the selection of the cluster head and it uses three parameters-distance, remaining energy, and density of nodes. Dynamic zoning and greedy methods ensure uniform distribution of CHs. The nodes are served in zones according to their distance from BS. In each zone, the nodes with uppermost probability to become a CH for the present round [5]. This network lives longer than LEACH.

S-LEACH (*Secure LEACH*)**:** This protocol uses one-way hash chains to add security to LEACH. It uses symmetric processes to prevent six types of attacks on wireless sensor networks that have been explained in S-LEACH [14].

2.3 Research Summary

The use of the wireless network is rising very rapidly but there are specific restrictions on Wireless Sensor Networks (WSN). One of the main limitations is power consumption. So, the efficiency of power consumption and increasing network lifetime are a challenge. To overcome this challenge, many researchers proposed various protocols to enhance the lifespan and abate the power consumption of WSN. LEACH is a routing protocol for WSN that reduces communication energy and enhances the network lifespan [3]. Although LEACH protocol has increased network stability and reduced power consumption, but not as expected, many researchers have proposed various updated LEACH that shows a better result than the existing LEACH.

LEACH-B is a cluster head selection-based protocol. In LEACH-B The node of the cluster selects its head by calculating the dissipated energy along the route between the final recipient and itself. It shows better performance than the existing LEACH. LEACH-C uses a centralized way for higher distributing the CHs and it selects CH based on residual energy. LEACH-F is a centralized and location-based protocol that utilizes simulated annealing for making stationary clusters and BS selects the clusters and CH and broadcasts clusters identity of each node. V-LEACH is a cluster head selection-based protocol that incorporates a secondary CH that acts as a CH when the cluster head dies. LEACH-TLCH protocol makes a secondary CH based on remaining energy and distance between the BS and CH. A-LEACH is another protocol that attempts to balance the energy dissipation distribution between the nodes by changing threshold function. LEACH-E is a cluster formation-based protocol that forms the cluster based on residual energy and if the node's remaining energy is greater than the listed energy, the node turns into a cluster head, otherwise, the node becomes a general node. The Cell-LEACH protocol splits the sensor network into cells with different sensors and inside the cell there is CH and a cluster is formed with seven neighboring cells with a CH. Q-LEACH arranges the nodes into four quadrants and selects some CH based on the threshold value. The multi-hop LEACH allows contact between cluster head and base station through multi-hops by finding a better path between CHs and BS.

MS-LEACH protocol incorporates the multi-hop and single-hop transport principles. BN-LEACH uses the Bayesian network for the selection of the CH and S-LEACH uses symmetric processes to prevent six types of attacks on WSN. All of the above updated LEACH shows better performance than the existing LEACH, which means they enhance the lifetime of WSN and reduce power consumption. Although all of the above updated LEACH has increased the stability of the network and has reduced the power consumption of WSN yet power consumption and stability of WSN are a major issue.

Our research purpose is to prolong the lifetime of WSN and to decrease power consumption. For this, we proposed an updated-LEACH named RECH-LEACH which performance is better than the actual LEACH. The RECH-LEACH protocol has enhanced

the lifetime of WSN and also reduced power consumption. The details of the RECH-LEACH protocol are described in chapter-3.

2.4 Scope of the Problem

There are some problems with the LEACH protocol. In the LEACH protocol, the cluster head is selected randomly based on the threshold value without considering residual energy. So, it uses more energy. Furthermore, The LEACH protocol cannot adequately prolong the network lifetime. So, we proposed an updated LEACH named RECH-LEACH which consumes less power and enhances network lifetime. In our proposed system we consider the residual energy for reducing power consumption. In our proposed method the CH is selected randomly only the first round and from the second round, the CH is elected with the highest remaining energy and formed the clusters. In this way, we were able to reduce power consumption and hence also able to prolong the network lifetime.

2.5 Challenges

Though our proposed RECH-LEACH protocol is more energy-efficient than the existing LEACH protocol, still there are some challenges in it.

1) Power management challenges: Sensors require energy for several operations. Energy is dissipated in data collection, data processing, and data communication [15]. In LEACH protocol energy consumption is more. So, reducing power consumption is a major challenge.

2) Security challenges: In LEACH and its descents protocol, various attacks e.g. sinkhole attack, Sybil attack, jamming attack, black hole attack, grey hole attack, flooding attack, wormhole attack, spoofing attack, etc. may have occurred. So, our protocol is no exception. There is also the possibility of different attacks. So, ensuring security is a big challenge.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Before the invention of LEACH protocol, it was pretty challenging to consume less energy in wireless sensor network. After the regular implementation of LEACH protocol, it has squelched the energy dissipation of sensor nodes of WSN. This clustering centric protocol works with forming clusters and setting a CH for each cluster. These cluster heads obtain data from the sensor devices of a cluster then process the data and delivers it to the BS. The task of data accumulation is ascribed to these CHs. So, flawless data collection is completely reliant on these CHs. If a CH dies due to low power or any other reasons, data compilation from that cluster will be very challenging. Therefore, a CH must have the capability and must have enough energy to do data transmission and accumulation appropriately. Considering all these facts, CH selection in LEACH is the most vital part of the whole process.

LEACH protocol has an algorithm where the CH selection process does not emphasize on the CH's power, left energy on the node etc. Following this algorithm, CH is nominated based on the threshold value *T (n)* and the random number selected by the sensor nodes. If the randomly picked number is smaller than the threshold, the node turns into CH. It is pretty clear from the CH selection procedure that LEACH protocol does not focus on the energy left on the sensor node.

CH election algorithm, implemented by LEACH protocol, avoids quick energy dissipation of CHs and its data combination efficiently decreases the volume of communication. Consequently, the LEACH protocol extends the network lifetime of routing of multi-hop and static. Nevertheless, there are yet enhancements that could be done in the existing LEACH protocol [4].

Contemplating the issues in LEACH protocol there comes the need for some improvement in the algorithm. Many works have been done on LEACH protocol and still many researches are going on to improve it. Many researchers have proposed numerous

modified versions of LEACH protocol. Such as I-LEACH, B-LEACH, H-LEACH, V-LEACH, O-LEACH, VR-LEACH are the most commons among the newly developed LEACH protocols. Researchers made a few parameter changes in the proposed new LEACH protocols.

We also propose a completely new LEACH algorithm which we call RECH-LEACH. RECH stands for residual energy base CH selection. We named it RECH because the algorithm of RECH-LEACH is designed in such a way that before the selections of CHs, it detects the power of the sensor nodes. After getting the information of sensor nodes energy, it sorts the nodes by energy. Then the nodes with the maximum residual energy are selected as CHs. In every round, the process continues.

The primary objective of the RECH-LEACH is to shrink the energy dissipation and enhance the network lifetime. RECH-LEACH does not select cluster heads arbitrarily instead it selects the CHs based on their energy. That's why the risk of unwanted death of sensor nodes due to high energy consumption diminishes. Our main objective is to make the RECH-LEACH better performed than the conventional LEACH protocol.

3.2 RECH-LEACH: Proposed Algorithm

The new RECH-LEACH protocol working scheme is based on the existing LEACH protocol. There are minor changes in the RECH-LEACH. To comprehend the RECH-LEACH first we have to perceive the mechanism of LEACH protocol. Because our new RECH-LEACH protocol is completely on the basis of the architecture of the LEACH protocol. We have just modified the cluster head selection procedure after the first round. In LEACH protocol in each round a new node is being selected as CH and if a node becomes CH once it cannot be selected as CH in the next *1/P* rounds. LEACH protocol does not envisage the sensor nodes power and energy in terms of CH selection. In our new RECH-LEACH, we have made changes in this consequence. The first round will go on as usual as the current LEACH protocol. In the first round CHs will be selected on the basis of the threshold value and random numbers. The formula of the threshold is:

$$T(n) = \begin{cases} \frac{\mathrm{P}}{1-\mathrm{P}*(\mathrm{r} \bmod \frac{1}{P}} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Following this formula, the threshold is calculated. After that nodes will select a random number between 0 and 1. If the number is below the threshold, the node will become cluster head in the first round. This procedure of cluster head selection in the first round is the same as the conventional LEACH.

After the ending of first-round, we apply the new CH selection algorithm. In the new algorithm, at first, the nodes residual energy will be calculated. The energy left on the nodes which are also known as residual energy or remaining energy will be calculated. The formulas for calculating the residual energy of nodes are:

$$E_{Tx}(1, d) = E_{elec} * 1 + \varepsilon_{fs} * 1 * d^2$$

This is the formula for calculating the total energy consumption due to data transmission. Here, $E_{Tx}(1, d)$ is the energy decreased for transferring 1-bit data, E_{elec} defines the energy reduction occurred by the conveyor and circuit receiver, ε_{fs} is the parameters of amplifier transformation consequent to the technique of the free-space, d is the Euclidean distance between the sensor node and CH as presented above, and l is the packet data [3].

For calculating the whole energy reduction for each node is:

$$E_{Tx}(1, d) = E_{elec} * 1 + \varepsilon_{mp} * 1 * d^4$$

Here, ε_{mp} is the amplifier parameters of transformation correspondent to the multi-path fading model.

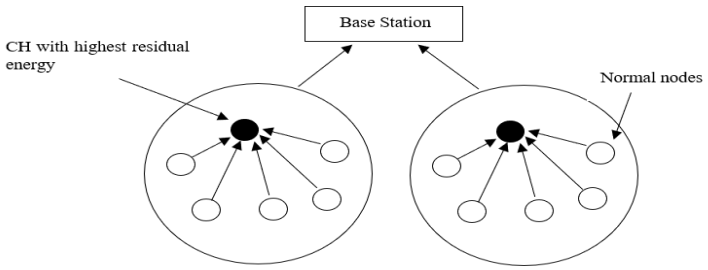


Figure 3.2.1: RECH-LEACH Architecture

Figure 3.2.1 shows the architecture of RECH-LEACH. Here the selected cluster has the highest residual energy than all the nodes of a cluster. Due to this reason, it is selected as CH. This procedure continues in every round.

3.3 RECH-LEACH Algorithm Working Procedure

RECH-LEACH algorithm is almost the same as the LEACH protocol except for the CH election process after the first round is different. After the first round, CH is selected on the basis of residual energy of nodes. The flowchart of the RECH-LEACH algorithm is depicted below:

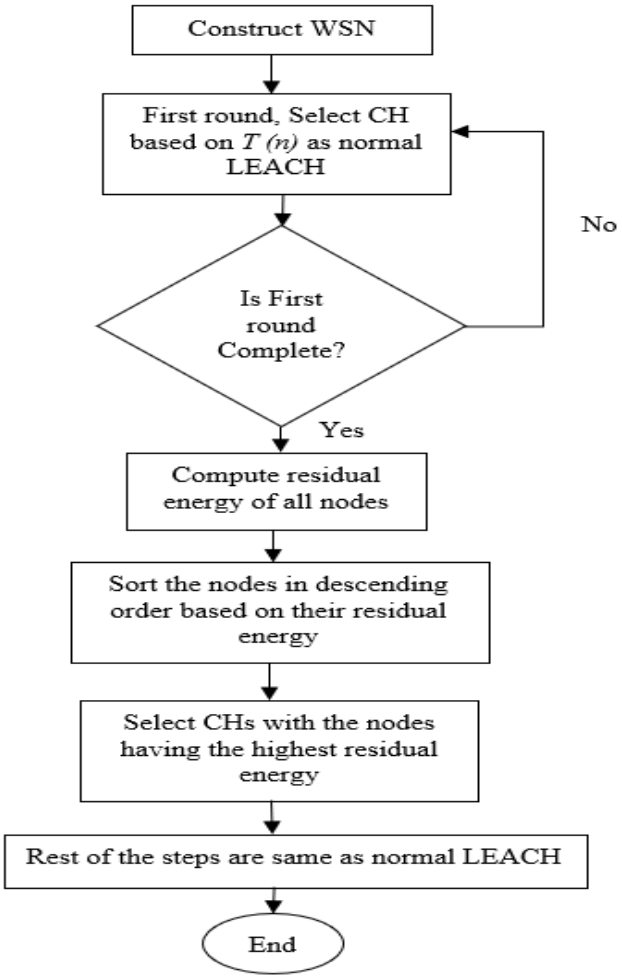
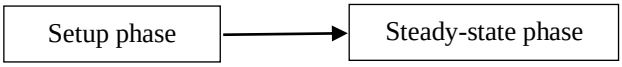


Figure 3.3.1: Flowchart of RECH-LEACH

The flowchart 3.3.1 describes the whole RECH-LEACH algorithm. The RECH-LEACH algorithm's mechanism is divided into two phases same as the normal LEACH algorithm. The two phases are the setup phase and the steady-state phase.

Setup phase: In the first round CHs are selected by following the same procedure in LEACH. After the selection of CHs, clusters are constructed. This CH selection procedure runs only for the first round. When the first round is over the CH selection procedure runs based on our proposed RECH-LEACH algorithm. The residual or remaining energy of nodes is calculated. Then the nodes are sorted in descending order based on their energy. The nodes which have the maximum residual energy are selected as CHs. After the selection of CHs, CHs broadcast advertisement message using CSMA MAC protocol to the remaining nodes which are not CH. The nodes accept the advertisement message transmitted by CHs. Then the nodes determine which cluster it wants to be part of. Then the clusters are formed. Then the CHs set a TDMA for the sensor nodes consisting of a cluster for scheduling a time for the nodes for data transmission.

Steady-state phase: Data communication begins when the TDMA is set for nodes. The nodes existing in the clusters start to transmit data to the CH corresponding to their scheduled TDMA. The CH keeps its receiver turned on to obtain all the data from the sensor nodes. When the CH acquires all the data it compresses the data into a signal using a fusion mechanism. Some data processing is done in the CH. Then the CH sends that combined signal to the BS. This is the whole procedure of the steady-state phase.



The RECH-LEACH algorithm works based on these two stages like the normal LEACH protocol. These two stages run like as a loop until the whole simulation is completed. The steady-state phase is analogous to the conventional LEACH. The changes are done in the setup phase. The setup phase is the stage where cluster heads are selected. We have made the changes in this stage.

The algorithm of RECH-LEACH protocol is represented below:

Notation:

CH: Cluster head

BS: base station

N: sensor nodes

R: random number selected by the nodes

T(n): threshold value

Setup phase:

For First round Every node (N)

  N selects a number (R) within the range 0 to 1

  If (R< T (n))

    N becomes CH

    N broadcasts its CH status

  Else

    N is selected as a normal node

    N gets the adv. message sent by CHs

  End if

End for

//cluster formation stage

For every (CH)

  N selects the CH with highest adv. message signal strength

  N becomes a member of that cluster

End for

For every (CH)

  Set a TDMA schedule for every node

End for

//this upper portion is the same as the LEACH protocol

//RECH-LEACH

If (first round is completed == true)

  Calculate residual energy of every node

  Sort nodes by residual energy highest to lowest

  If (residual energy == highest)

    Select as CH

  Else

    Select as a normal node

Repeat from the cluster formation stage

Now the algorithm of steady-state phase is given below:

Steady-state phase:

For every (N)

  N accrues sensed data from the surroundings

  N transmits the data to the CH as per the TDMA

End for

For every (CH)

  CH fetches data from the nodes

  CH process the data

  CH transmits the data to the BS

End for

3.4 RECH-LEACH Algorithm Implementation Requirements

Wireless sensor network is constructed using an abundant number of sensors and base station. To form a WSN we will need physical sensors, a base station and control center. But as for research purpose, it becomes too much expensive for forming a network. So, instead, the network is created virtually. Creating a network virtually requires a virtual simulator. Virtual simulators can perform the job same as a physical network.

MATLAB, NS2, NS3, Omnet++ are the example of some virtual simulators where an environment of WSN can be created. Our implementation can be done in any of these simulators.

We have done our simulation and implemented the whole algorithm in MATLAB.

CHAPTER 4

EXPERIMENTAL RESULTS AND DISCUSSION

4.1 Introduction

We have run the new RECH-LEACH in MATLAB. We have run the simulation several times. The main goal of our the RECH-LEACH is to reduce the energy dissipation of the sensor nodes and ennoble the lifespan of the network. LEACH algorithm is an algorithm designed for low-powered sensor nodes. It had the same goal as our proposed RECH-LEACH algorithm. Some improvements required in the existing LEACH and RECH-LEACH is one of the improved versions of LEACH. We have changed a few parameters and leave all other things unchanged. The things we have focused on the simulations are:

- Energy dissipation of sensor nodes
- Lifetime of sensor nodes

We have run the simulation based on these two and showed the difference between LEACH and RECH-LEACH for both of these factors.

4.2 Experimental Results

Firstly, we have made a wireless sensor network in MATLAB. We have initialized and assigned some default values for each parameter. For setting a network of 100 nodes we set the value of N = 100 and the side length of area of the network L = 130. If we want to make the network bigger like for 200 nodes the value of L will also increase twice. In any LEACH you must set a probability of nodes to get selected as CH. We have set the probability of getting selected as CH P = 0.1 and for another round we set at like 0.05. If P = 0.1 that means 10 nodes can be CH in a network of 100 nodes. We set initial energy for each sensor node existing in the network. Initial energy means the energy consists of a node at the time of starting the simulation. So, the initial energy value is set $E_i = 0.35$. So now we see the simulation result below after running in MATLAB:

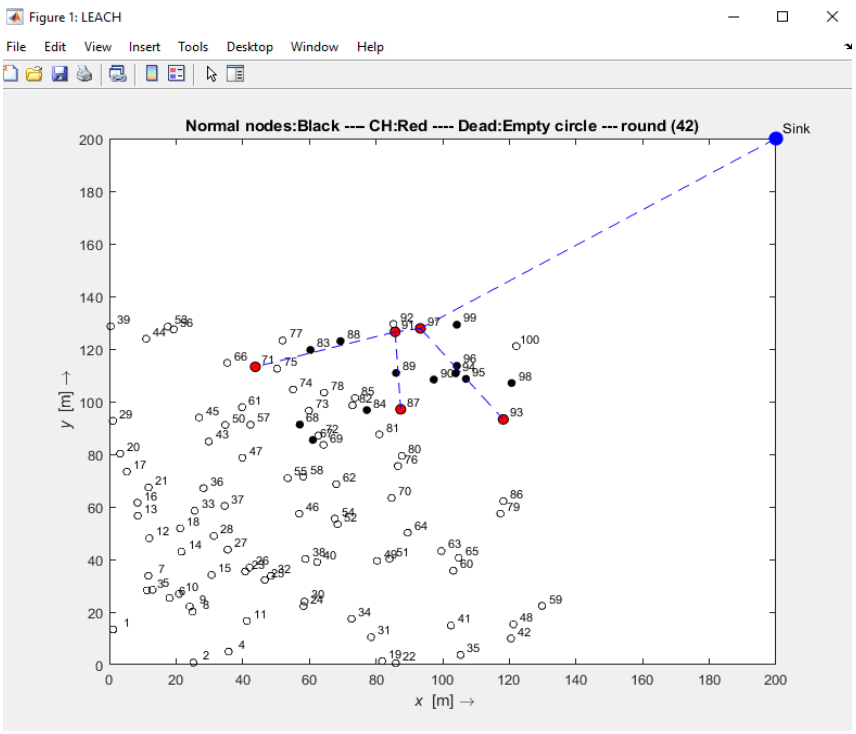


Figure 4.2.1: Normal LEACH protocol of 100 nodes, P = 0.1

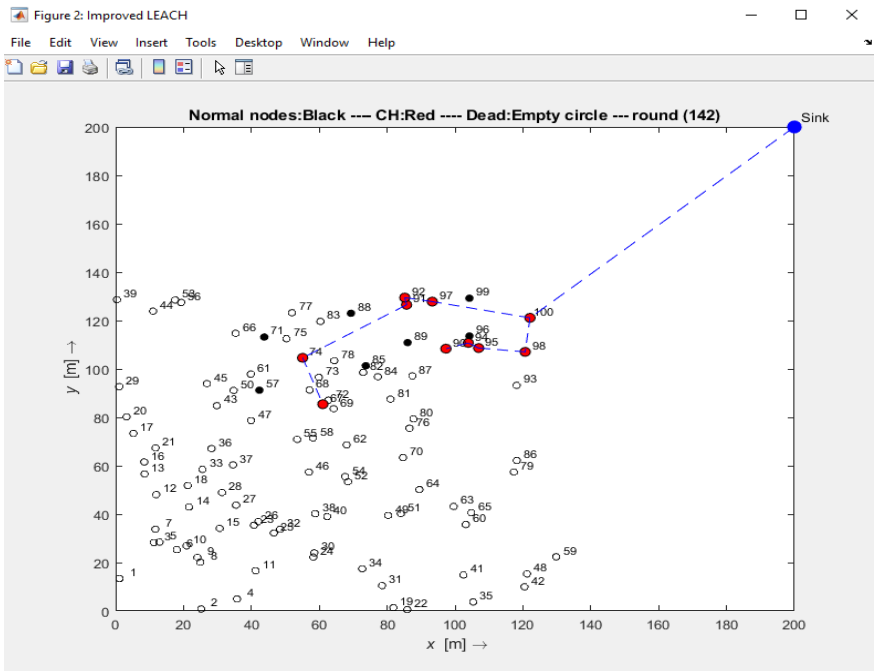


Figure 4.2.2: RECH-LEACH protocol of 100 nodes, P = 0.1

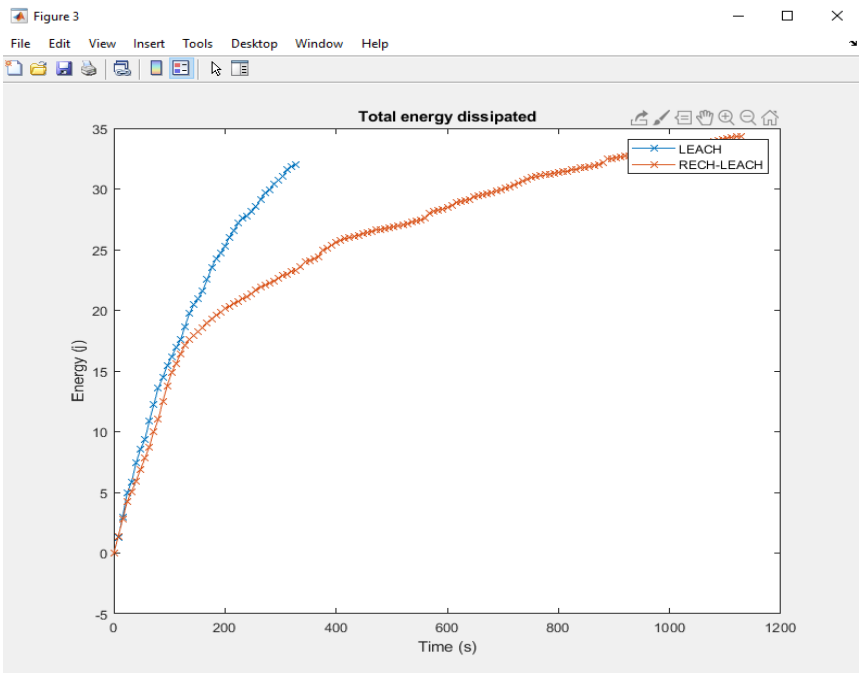


Figure 4.2.3: Energy dissipation of RECH-LEACH and LEACH protocol of 100 nodes, P = 0.1

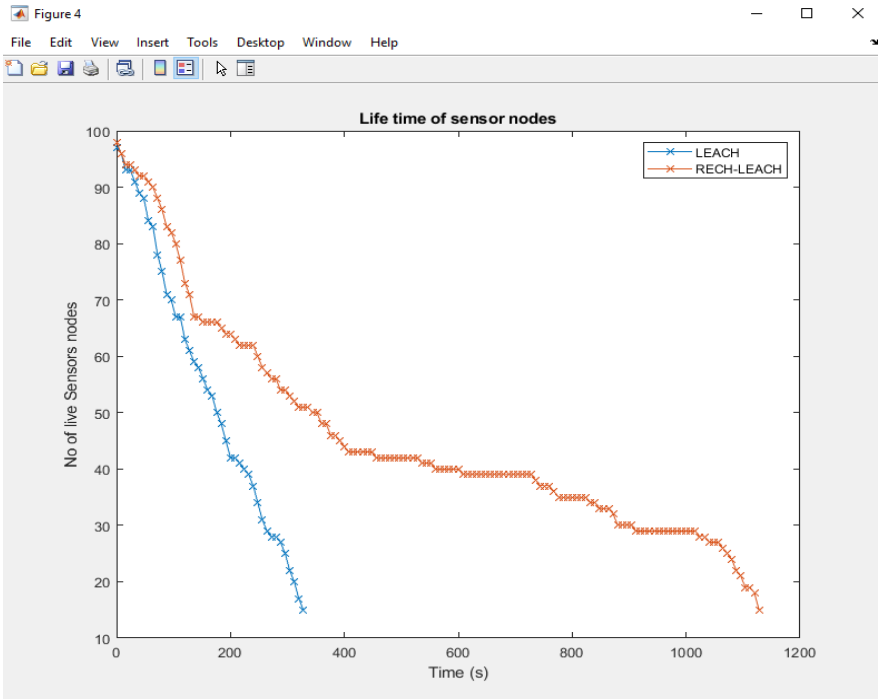


Figure 4.2.4: Lifetime of sensor nodes in RECH-LEACH and LEACH protocol of 100 nodes, P = 0.1

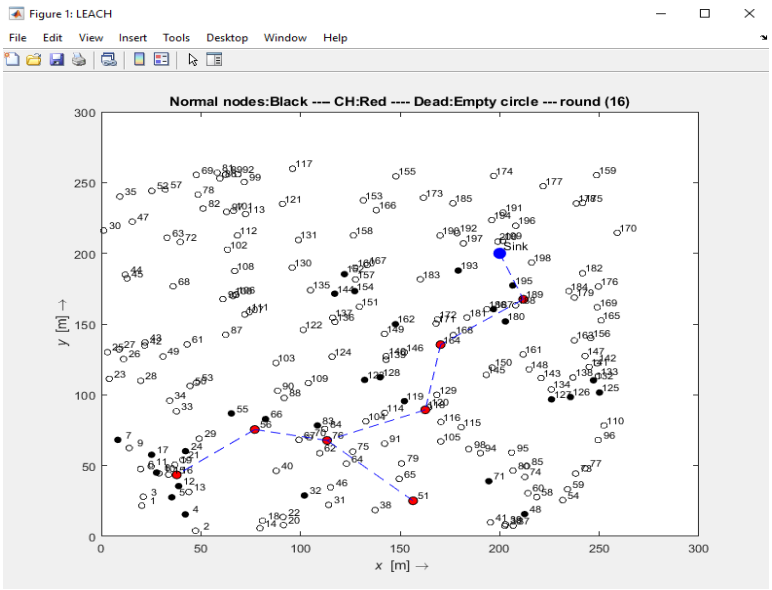


Figure 4.2.5: Normal LEACH protocol of 200 nodes, P = 0.1

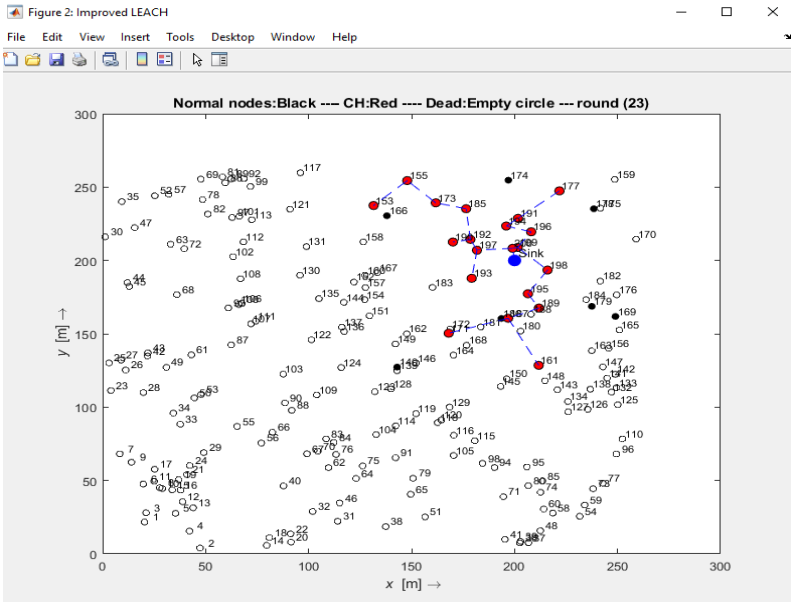


Figure 4.2.6: RECH-LEACH protocol of 200 nodes, P = 0.1

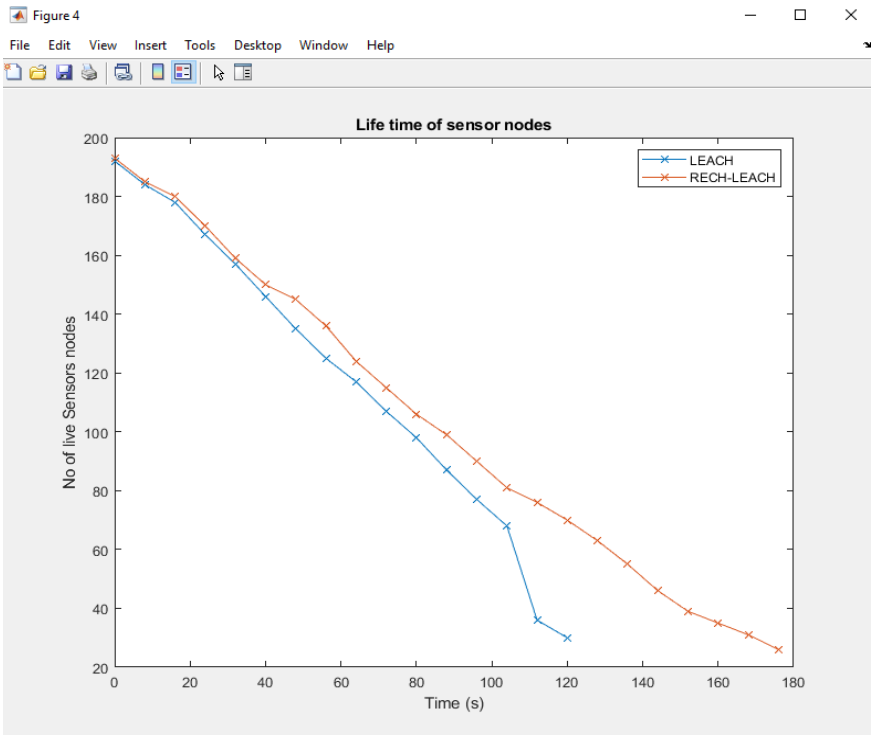


Figure 4.2.7: Lifetime of sensor nodes in RECH-LEACH and LEACH protocol of 200 nodes, P = 0.1

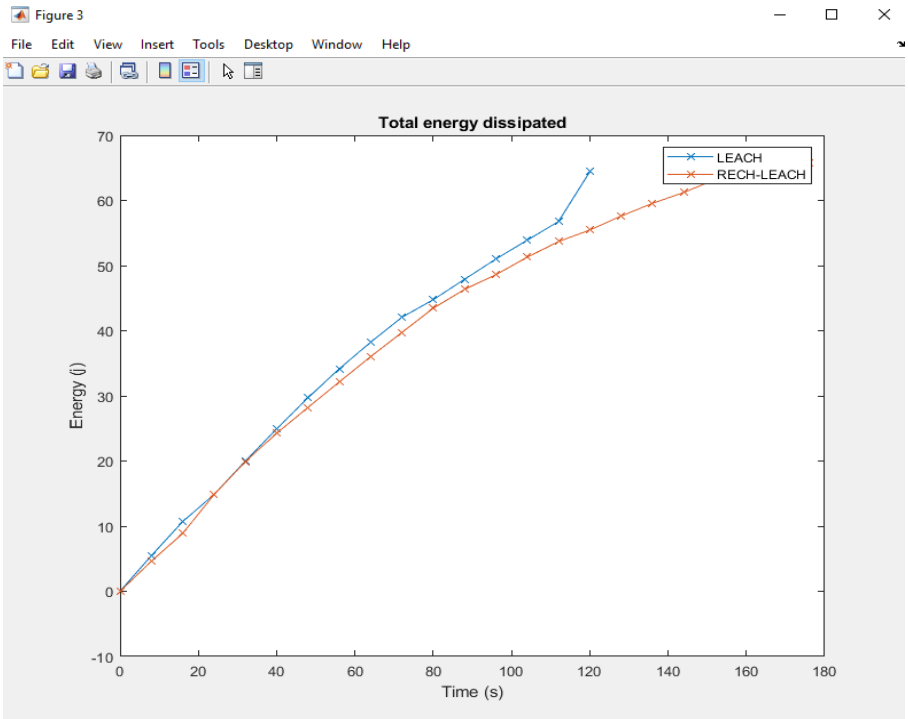


Figure 4.2.8: Energy dissipation of RECH-LEACH and LEACH protocol of 200 nodes, P = 0.1

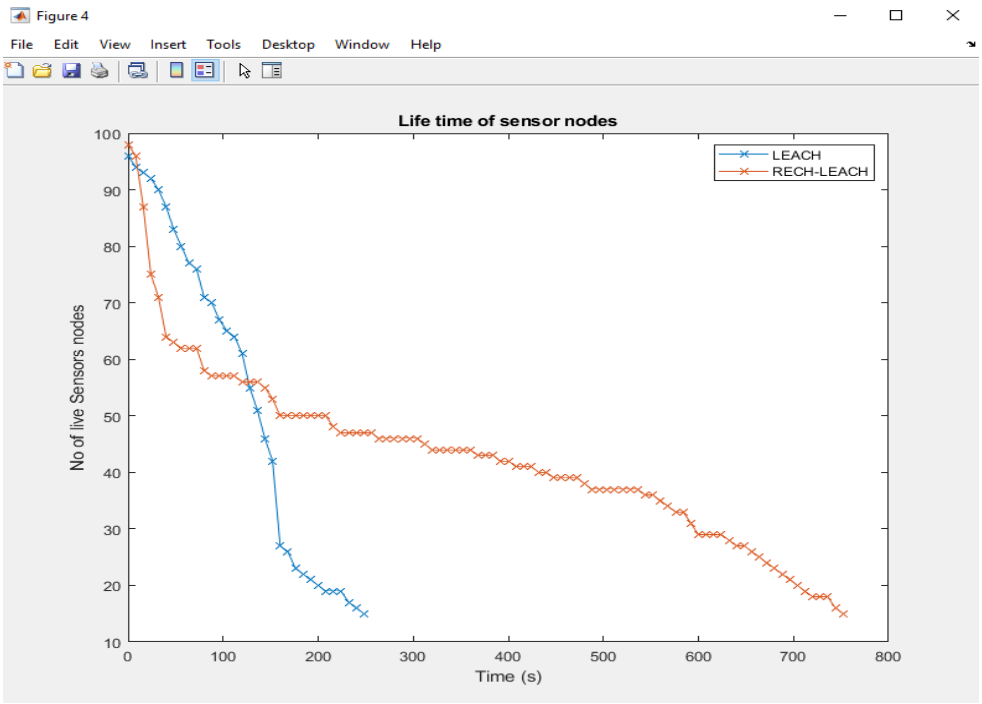


Figure 4.2.9: Lifetime of sensor nodes in RECH-LEACH and LEACH protocol of 200 nodes, P = 0.05

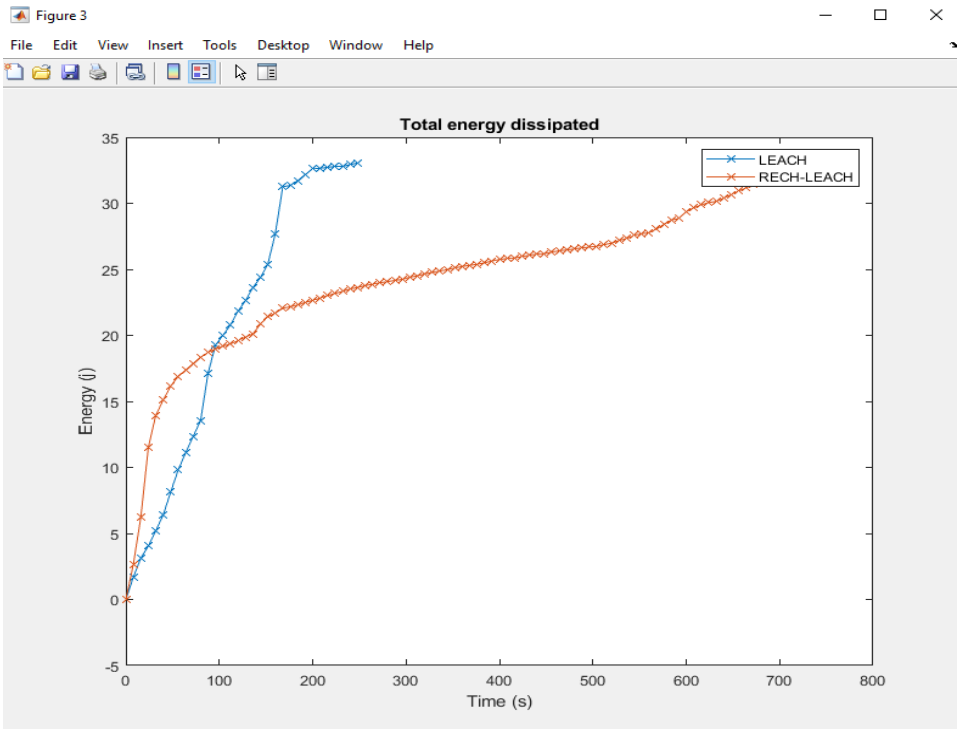


Figure 4.2.10: Energy dissipation of RECH-LEACH and LEACH protocol of 100 nodes, P = 0.05

4.3 Descriptive Analysis

Here in figure 4.2.1, the simulation ran for LEACH protocol of 100 nodes and the probability was given P = 0.1. Figure 4.2.2 is same as 4.2.1 but it is our proposed RECH-LEACH algorithm. Figure 4.2.3 depicts the energy dissipation of LEACH and RECH-LEACH protocol after the whole simulation completion. Figure 4.2.4 shows lifetime of sensor nodes of LEACH and RECH-LEACH after the simulation completion. Figure 4.2.5 – 4.2.10 is same as 4.2.1-4.2.4 but we have changed the nodes number and probability of being CH.

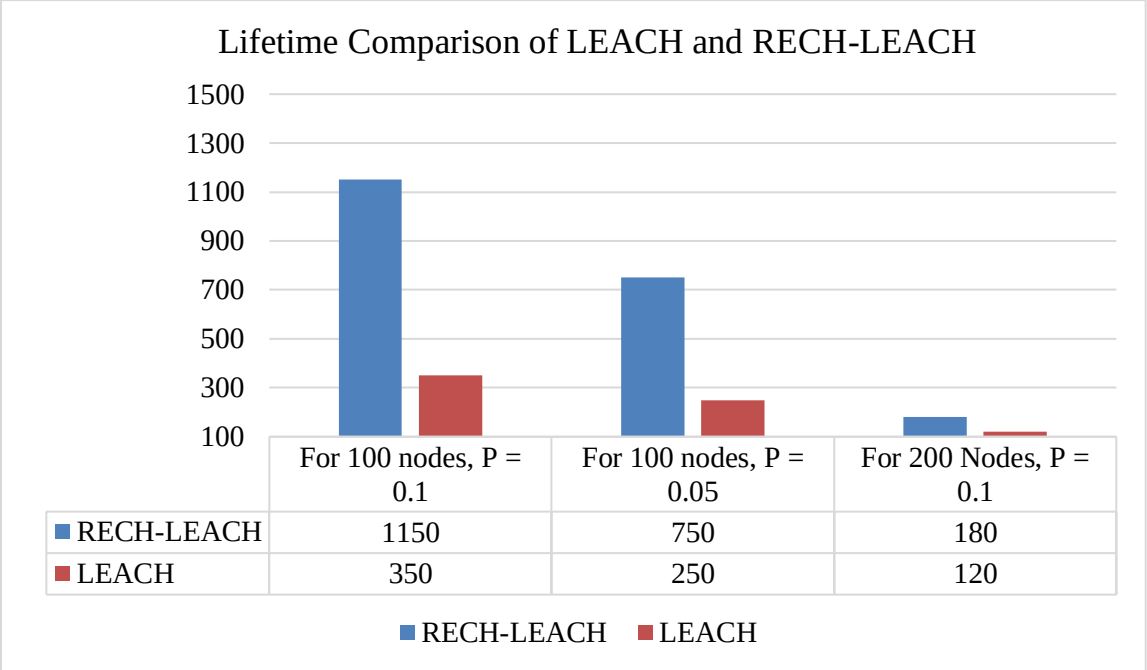


Figure 4.3.1: Comparison bar graph of LEACH and RECH-LEACH

This comparison bar graph 4.3.1 is the portrayal of the three simulations we have done before. Here at the first simulation for 100 nodes and probability, P = 0.1 the number of alive nodes for normal LEACH at time 350s was around 10. It means almost all nodes died at 350s. So, the simulation stops due to the low number of nodes. Again, for RECH-LEACH we can see that the almost all nodes died after 1150s. Which is a big difference comparing to the normal LEACH. This means the nodes died very slowly using RECH-LEACH than the normal LEACH.

The second simulation figure 4.2.5-4.2.8 runs for 200 nodes and the probability of 0.1. The normal LEACH runs for 120s and all nodes died. The RECH-LECH run for 180s and then the nodes die.

The third simulation figure 4.2.9, 4.2.10 is done for a probability of 0.05. We can see for normal LEACH almost all nodes died at around 250s and the simulation stops. But the RECH-LEACH run for almost 750s and then the nodes died that is a huge margin difference.

So, it is clear from all the three simulations that RECH-LEACH increases the lifetime of the sensor nodes far better than the normal LEACH algorithm.

Same as the lifetime graph we can see from figure 4.2.3, 4.2.8 and 4.2.10, the energy initialized at the time of the simulation was 0.35 J (joule). At figure 4.2.3 it is visible that to dissipate total energy 0.35 J it took around 1150s. But in LEACH protocol it took nearly 350s. In figure 4.2.8 it took only 120s to dissipate total energy for LEACH where for RECH-LEACH it took around 180s. Again, in figure 4.2.10 it took 250s to dissipate all the energy of sensor nodes where RECH-LEACH took 750s which is far better than the LEACH. So, it is also clear from the three simulations that energy dissipates more slowly using RECH-LEACH than normal LEACH.

4.4 Summary of the Simulations and Results

After running three consecutive simulations in MATLAB using different probability and number of nodes, we tried to make a comparison between LEACH and our newly proposed RECH-LEACH algorithm. When almost all nodes die and the rounds complete, then the simulation stops. After the simulation is over, two line graph appears for showing the simulation result. One graph represents the lifetime of the sensor nodes and another shows the energy dissipation of the sensor nodes. It is clear from all the three simulations that our proposed RECH-LEACH has a better lifetime enhancement rate and slower energy dissipation rate than the existing LEACH protocol. In every simulation, the

RECH-LEACH protocol functions better in terms of lifetime prolonging and lower energy dissipation rate. As a result, it can be said that RECH-LEACH algorithm is an improvement of LEACH protocol.

CHAPTER 5

SUMMARY, CONCLUSION, RECOMMENDATIONS AND IMPLICATION FOR FUTURE RESEARCH

5.1 Summary of the Research

Wireless sensor network is one of the most thriving fields of modern times. So, development is required in this field to improve its performance and lifetime. We have selected this research field as it has a flourishing future and needs for monitoring environments current state. The major target of our research was to propose a new algorithm or protocol which will ameliorate the lifespan of the network and decrease the energy consumption of the sensor devices. As we were looking for an energy-efficient algorithm for WSN, we find out about the most used algorithm for that purpose named LEACH. But after we found out it has some constraints too. It makes clusters and selects cluster heads randomly without considering the power or energy of that node. So, we tried to make an improvement in that area. Then we came up with our new RECH-LEACH which is also known as Residual Energy-based Cluster Head selection LEACH. Here in this algorithm we have just modified the CH selection process of the existing LEACH and leave other procedure unchanged. In RECH-LEACH after the ending of first-round, the residual energy of all node is calculated. Then the nodes are sorted highest to lowest based on their energy. Then the CH are selected from the top nodes which have highest residual energy. Remaining processes is same as LEACH protocol. We implemented our algorithm in MATLAB. The aim was to build RECH-LEACH in such way that it improves the lifespan of the network and decreases energy dissipation. After running the simulation several times, we find that each time the RECH-LEACH performs better than the LEACH algorithm. So, we successfully accomplished our goal of the research.

5.2 Conclusion

In this report, we have tried to depict various types of LEACH protocol, their implementation, limitation and challenges. These various modified LEACH protocols are proposed by many researchers. We have tried to find out the challenges they faced and the working procedure they have used in their research. LEACH is mostly used protocol of WSN. But it has some issues. So, we came with an idea of solving an issue of LEACH protocol. We have modified the cluster head election procedure of LEACH protocol and named the new transformed LEACH as RECH-LEACH. After successful implementation of the new algorithm, we have found that the new modified algorithm has fulfilled our goal and functioned better than the existing LEACH protocol. Consequently, the purpose of our research is achieved.

5.3 Recommendations

In RECH-LEACH protocol it performs best when the probability of CH is set 0.1. That means for 100 nodes there will be 10 CH. If the probability is set less than that it becomes challenging to get proper data from the nodes. Because in that case each CH is assigned with more nodes. So, the energy consumption of the CH increases. If around 10% of nodes are assigned as CH, data transmission procedure to the base station will be distributed equally. But when that percentage reduces to less than 10, quick death rate of nodes increases. The same case happens if the probability is set to more than 0.1. CH devours additional energy than normal nodes. So, if more nodes become CH it will require more energy and it will die soon due to the high energy dissipation. So, our recommendation for getting best performance from this RECH-LEACH is set the probability of nodes becoming CH to 0.1.

5.4 Implication for Further Study

RECH-LEACH protocol can be implemented in heterogeneous WSN. It can be implemented in a physical WSN as we have implemented it virtually. LEACH protocol has become a bit antiquated nowadays. A new protocol is required for more energy

efficiency in WSN. A completely new routing protocol can be designed aiming to minimize the energy consumption in sensor nodes.

REFERENCES

[1] Li, Y., Yu, N., Zhang, W., Zhao, W., You, X. and Daneshmand, M., 2011, April. Enhancing the performance of LEACH protocol in wireless sensor networks. In *2011 IEEE conference on computer communications workshops (INFOCOM WKSHPS)* (pp. 223-228). IEEE.

[2] Salem, A.O.A. and Shudifat, N., 2019. Enhanced leach protocol for increasing a lifetime of wsns. *Personal and Ubiquitous Computing*, pp.1-7.

[3] Heinzelman, W.R., Chandrakasan, A. and Balakrishnan, H., 2000, January. Energy-efficient communication protocol for wireless microsensor networks. In *Proceedings of the 33rd annual Hawaii international conference on system sciences* (pp. 10-pp). IEEE.

[4] Tong, M. and Tang, M., 2010, September. LEACH-B: an improved LEACH protocol for wireless sensor network. In *2010 6th international conference on wireless communications networking and mobile computing (WiCOM)* (pp. 1-4). IEEE.

[5] Varshney, S. and Kuma, R., 2018, January. Variants of LEACH routing protocol in WSN: A comparative analysis. In *2018 8th International conference on cloud computing, data science & engineering (confluence)* (pp. 199-204). IEEE.

[6] Heinzelman, W.B., Chandrakasan, A.P. and Balakrishnan, H., 2002. An application-specific protocol architecture for wireless microsensor networks. *IEEE Transactions on wireless communications*, *1*(4), pp.660-670.

[7] Shi, S., Liu, X. and Gu, X., 2012, August. An energy-efficiency Optimized LEACH-C for wireless sensor networks. In *7th International Conference on Communications and Networking in China* (pp. 487-492). IEEE.

[8] Tong, M. and Tang, M., 2010, September. LEACH-B: an improved LEACH protocol for wireless sensor network. In *2010 6th international conference on wireless communications networking and mobile computing (WiCOM)* (pp. 1-4). IEEE.

[9] Singh, K., 2015, October. WSN LEACH based protocols: A structural analysis. In *2015 International Conference and Workshop on Computing and Communication (IEMCON)* (pp. 1-7). IEEE.

[10] Ali, M.S., Dey, T. and Biswas, R., 2008, December. ALEACH: Advanced LEACH routing protocol for wireless microsensor networks. In *2008 International Conference on Electrical and Computer Engineering* (pp. 909-914). IEEE.

[11] Fu, C., Jiang, Z., Wei, W.E.I. and Wei, A., 2013. An energy balanced algorithm of LEACH protocol in WSN. *International Journal of Computer Science Issues (IJCSI)*, *10*(1), p.354..

[12] Yektaparast, A., Nabavi, F.H. and Sarmast, A., 2012, February. An improvement on LEACH protocol (Cell-LEACH). In *2012 14th international conference on advanced communication technology (ICACT)* (pp. 992-996). IEEE.

[13] Antoo, A. and Mohammed, A.R., 2014, July. EEM-LEACH: Energy efficient multi-hop LEACH routing protocol for clustered WSNs. In *2014 international conference on control, instrumentation, communication and computational technologies (ICCICCT)* (pp. 812-818). IEEE.

[14] Gnanambigai, J., Rengarajan, N. and Anbukkarasi, K., 2012. Leach and its descendant protocols: A survey. *International Journal of Communication and Computer Technologies*, *1*(3), pp.15-21.

[15] Sharma, S., Bansal, R.K. and Bansal, S., 2013, December. Issues and challenges in wireless sensor networks. In *2013 International Conference on Machine Intelligence and Research Advancement* (pp. 58-62). IEEE.

[16] Prabha, D. (2014). *Project report on An Energy Efficient Routing Protocol in Wireless Se…*. [online] Slideshare.net. Available at: https://www.slideshare.net/divya_prabha/project-report-on-an-energy-efficient-routing-protocol-in-wireless-sensor-networks [Accessed 25 Oct. 2019].

[17] Chen, Z. and Chen, K., 2013. An improved Multi-hop Routing Protocol for Large-Scale Wireless Sensor Network Based on Merging Adjacent Clusters. *JSW*, *8*(8), pp.2080-2086.

[18] Manzoor, B., Javaid, N., Rehman, O., Akbar, M., Nadeem, Q., Iqbal, A. and Ishfaq, M., 2013. Q-LEACH: A new routing protocol for WSNs. *Procedia Computer Science*, *19*, pp.926-931.

[19] Singh, T.S., Soram, R. and Khan, A.K., 2016, February. Distance based Multi Single Hop Low Energy Adaptive Clustering Hierarchy (MS LEACH) Routing Protocol in Wireless Sensor Network. In *2016 IEEE 6th International Conference on Advanced Computing (IACC)* (pp. 613-617). IEEE.

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