JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF COMPUTING AND INFORMATICS

ENHANCING LEACH PROTOCOL TO IMPROVE ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORKS

A Thesis Submitted to The School of Graduate Studies at Jimma University, Jimma Institute of Technology in Partial Fulfillment of The Requirements For The Degree of Master of Science in Computer Networking.

by

Mekdes Ararsa Mideksa

Dec, 2021

Jimma, Ethiopia

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Enhancing LEACH Protocol to Improve Energy Efficiency in Wireless Sensor Networks

By Mekdes Ararsa

Principal Advisor: Mr. Fisseha Bayu (Ph.D. Candidate)

Co-Advisor: Getahun Abera (Msc)

Approved by:

Board of Examiners:

1. Dr Henok Mulugeta(Phd): ____________________ ____________
2. Mr. Yekoye Tigabu((MSc): ____________________ ____________

DECLARATION

I declare that this research entitled **“**Enhancing LEACH protocol to improve energy efficiency in Wireless Sensor Networks” is my own original work, and has not been submitted as a requirement for the award of any degree in Jimma University or elsewhere.

Mekdes Ararsa Mideksa ___________________ _________________

As research Adviser, I hereby certify that I have read and evaluated this thesis paper prepared under my guidance, by Mekdes Ararsa Mideksa entitled “Enhancing LEACH protocol to improve energy efficiency in Wireless Sensor Networks” and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science in Computer Networking.

Advisor: Mr. Fisseha Bayu (Ph.D. Candidate) ________________ __________

Co - Advisor: Mr. Getahun Abera ________________ __________

ABSTRACT

In this paper we introduce enhanced LEACH protocol based on low-power adaptive cluster hierarchy in order to make the network energy consumption efficient and extend the life time of nodes in the network. We use the modified threshold function to select the cluster head node, by taking residual energy and node distance as a parameter. The center of gravity node is also presented to help cluster head to finish its transmission and increasing the service duration. In the multihop communication between clusters, in order to calculate the fitting factor of the next hop, we derived a new formula, which takes into account the angle, remaining energy, and distance. According to simulation data the total residual energy of the Enhanced LEACH protocol is decreased, while the network life time is increased.

Keywords: WSN, LEACH , E-LEACH

ACKNOWLEDGMENT

I would like to thank my family for their support and encouragement throughout my journey and their willingness to do everything by helping me in my aspects of life and in the successful completion of this degree. My special thanks to my advisors for their kindly support and my friend Mr Kassahun Geresu for his countless guide.

Finally, I dedicate this thesis to my family. my mother Fantu Dhaqaba and brothers Mr. Yonas and Ermias Ararsa, whose dream for me have resulted in this achievement and without their loving childhood and nurturing, this success would not have been possible without their unconditional love and support.

ABBREVIATION

ADC: Analog to Digital Converters

BCH: Base Station Cluster Heads

CH: Cluster Head

CMOS: COMPUT Metal Oxide Semi-conductor

CPU: Central Processing Unit

DECSA: Distance Energy Cluster Structure Algorithm

EEHC: Energy Efficient Heterogeneous Clustering Scheme

EECS: Energy Efficient Clustering Scheme

EPCR: Enhanced Power Controlled Routing

GN: Gate Node

GPS: Global Positioning System

IEEE: Institute of Electrical and Electronics Engineers

E-LEACH: Enhanced Low-Energy Adaptive Hierarchy

LEACH: Low-Energy Adaptive Clustering Hierarchy

LEACH-C: Low-Energy adaptive Clustering Hierarchy centralized

MAC: Media Access Control Address

MEMS: Micro Electro Mechanical Systems

QoS: Quality of Service

PCR: Power Controlled Routing

TDMA: Time Division Multiple Access

VLSI: Very Large Scale Integration

WSN: Wireless Sensor Network

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CHAPTER 1

INTRODUCTION

1. Background

A wireless sensor network is one type of wireless network includes a large number of circulating, self-directed, low powered devices called sensor nodes named motes. Sensor nodes are small electronic devices, ranging in size from a small coin to a matchbox, which have been designed, built, and programmed as stand-alone sensors, electronically transmitting their data to other sensors which is ultimately collected at a main station called a sink, or base station.[1] The devices sense a range of phenomena: used to monitor physical or environmental conditions like sound, pressure, temperature, and cooperatively pass data through the network to the main location as shown in the figure.

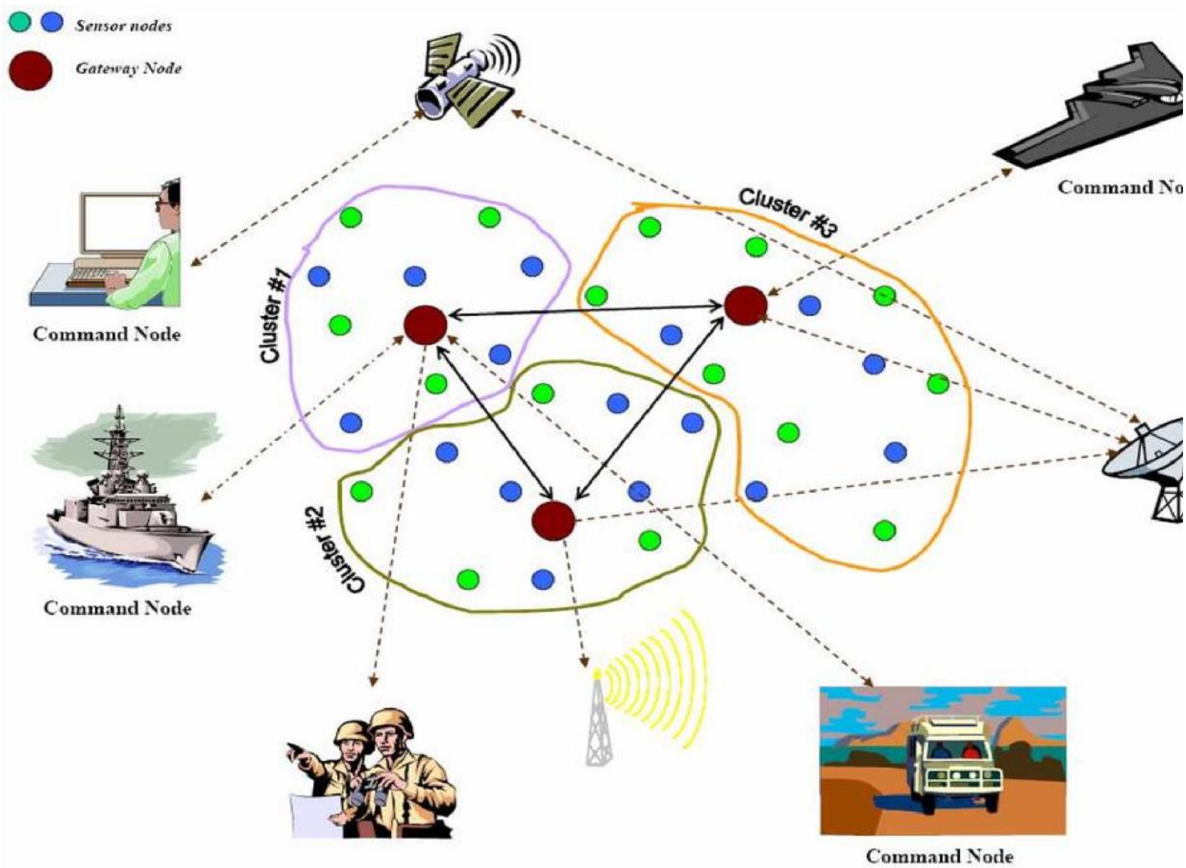

Figure 1 Multi functions of wire less sensor network[2]

The wide applicability of sensor networks in areas such as safety, research and military have made them a popular topic in the research community. Their ability to sense phenomena without human presence, in potential harsh or hostile environments, make them an invaluable resource [1].

Improvements in hardware technology have resulted in low-cost sensor nodes, which are composed of single chip embedded with memory, processor, and transceiver. Low-power capacities lead to limited coverage and communication range for sensor nodes compared to other mobile devices. Hence, for example, in target tracking and border surveillance applications, sensor networks must include a large number of nodes in order to cover the target area successfully. Unlike other wireless networks, it is generally difficult or impractical to charge/replace exhausted batteries. That is why the primary objective in wireless sensor networks design is maximizing node/network lifetime, leaving the other performance metrics as secondary objectives. Since the communication of sensor nodes will be more energy consuming than their computation, it is a primary concern to minimize communication while achieving the desired network operation. To reduce the network traffic and hence conserve the battery power, routing protocols direct that data is collected at one of the sensors, and that sensor will transmit one aggregate transmission for more efficient network traffic. This process is called data fusion. However, the medium-access decision within a dense network composed of nodes with low duty-cycles is a challenging problem that must be solved in an energy-efficient manner [2].

WSN is used to collect the raw data from harsh environment like natural climate, health applications, forests fire, volcanoes, military operation, household instruments and many more. This is done because human interaction is very minimal and may cause serious damage; to avoid this sensor networks are preferred to do all these kinds of works. A typical WSN has some terminologies used during their working which are sensor nodes, sensed data, sensor network, processing power, battery consumption [3].

There are two kinds of sensor nodes are used in WSN i.e. homogeneous sensor nodes and heterogeneous sensor nodes. Homogeneous sensor nodes have similar key features like battery power, processing power, nodes range etc. for each node but heterogeneous sensor nodes key feature for every node may vary and may include collection different types of homogeneous nodes with different battery power, processing power, nods range etc.

Homogeneous nodes are battery constraints, where heterogeneous nodes are much more reliable. The core function of both sensor nodes are to sense or collect the raw data and then pass it to the sink node, where an accurate and effective decision can be made to work accordingly. Collection of multiple sensor nodes is called the wireless sensor nodes.

There is no. of sensor nodes which are deployed in a WSN with or without heterogeneity of sensor nodes [4].

Every sensor node has limited battery power which is consumed during sensing or transmission of sensed packets (this process includes receiving power, sending power). Nodes also consume battery power while they are in sleep mode or in idle mode. The main problem of WSN is there battery lifetime as battery of sensor nodes are not replaceable and nor chargeable because of remotely deployment of senor nodes. Secondly stochastic deployment of sensor nodes may increase the transmission burden of nodes. So we prefer an energy efficient WSN which consume as less energy as possible. To implement this hypothesis clustering is proposed and used which is much better alternative. Clustering is the process of isolating the WSN to create smaller but manageable WSNs which are equal in size and shaped but may vary in included number of nodes with the sole purpose to increase the lifespan of wireless network. As discussed in [7], *clustering* is more manageable and effective technique to increase the lifetime we proposes enhanced LEACH protocol based clustering for homogeneous sensor network to prolong the system lifetime.

Research Motivation

The recent developments in engineering, communication and networking has led to new sensor designs, information technologies and wireless systems. Such advanced sensors can be used as a bridge between the physical worlds with the digital world. Sensors are used in many equipment, industries, machines and environments to help prevent infrastructure failures, accidents, protect natural resources, protect wildlife, increase productivity, and provide safety. Small, low-power, and inexpensive sensors, controllers, and actuators have resulted from the downsizing of processing, computing, and sensing technologies. As a result, the primary goal of this thesis is to enhance energy efficiency of the wireless sensor network.

Statement of the problems

WSNs suffer from several limitations related to network resources, among which energy is the most important resource because it determines the lifetime of the sensor network. Sensor nodes are usually powered through batteries, which must be recharge or replaced when depleted. But sensor nodes are usually deployed in hostile environments where it is impossible to access them and replace their batteries. For these non-rechargeable batteries, a sensor node should be able to operate until its mission time has passed or the battery can be replaced. To save energy, there are existing techniques like improving routing protocols, energy harvesting mechanisms like using solar energy source, clustering. Among the energy improving techniques proposed by different researchers Clustering solves multiple problems in wireless sensor network. Where as LEACH clustering protocol is used in many researches as a basement protocol to improve the network life time of sensor nodes. LEACH protocol is consider to be homogeneous sensor networks where all the sensor nodes are designed with the same battery energy. A homogeneous network consists of sink and sensor nodes equipped with equal capabilities, like computational energy and storage capacity. dissemination in homogeneous networks is done using flat and hierarchical [19] typologies. Since flat routing protocols need to maintain large routing tables and the transmission distance between sensor nodes is limited, they are not suitable for large-scale networks, while hierarchical routing protocol can not only improve these problems, but also reduce network energy consumption and extend network life cycle [3]. Therefore,we select hierarchical routing protocol (LEACH protocol) .

LEACH protocol adopts a hierarchical network structure and is the first clustering routing protocol designed by Cui et al. [4]. In the traditional LEACH protocol a node becoming a Cluster-head depends on the random number generated by itself and threshold value which is too random. Recent researchers improved the LEACH protocol and prolong the network life cycle by improving cluster head selection mechanism, focusing on the residual energy of nodes and distance. However most of the researches ignored the impact of residual energy, distance and angle respectively when selecting next hop cluster head node in the multihop communication in inter-cluster transmission on network[4][5] .

So In this paper a Modified threshold function is used to select the cluster head node, which consider the residual energy and node distance as a parameter. The center of gravity node is also presented to help cluster head (CH) to finish its transmission and increasing the service duration. In the multihop communication between clusters, in order to calculate the fitting factor of the next hop, we derived a new formula, which takes into account the angle, remaining energy, and distance. MATLAB is used as an implementation tool to compare the proposed solution results so with LEACH and LEACH-C protocol by the comparison parameters of network live nodes, dead nodes and the number of packets transmitted to Gate node and residual energy of the network under the three protocols.

Research Questions

The questions have been examined in this thesis paper are formulated as follows:

1. What appropriate algorithm has been developed to improve energy efficiency in the LEACH protocol of WSN?

2. How much is the proposed E-LEACH effective than LEACH and LEACH-C?

3. Does E-LEACH has good total energy effectiveness over LEACH and LEACH-C for WSN?

Contributions

Within this thesis, we propose Enhanced LEACH protocol to prolong and improve the network life time as the key contributions of the proposed work is to reduce extra energy consumption by

- Formulate a mechanism to select next hop cluster head node in multihop data transmission in inter-cluster communication.
- Introduce center of gravity node to help cluster head (CH) to finish its transmission and increasing the service duration.

Objective

General Objective

The main objective of this research work is to enhance LEACH protocol to improve energy efficiency in wireless sensor network.

Specific objectives:

1. To develop mathematical model to select the center of gravity node.
2. To formulate a mechanism to select the next hop cluster head node for multihop communication.
3. To implement the proposed enhanced LEACH protocol algorithm.
4. To evaluate the performance of enhanced LEACH protocol.

Research Methodology

To achieve the objective of the thesis the following steps will be used:

Literature Review: We reviewed literature's, published related works, books and journals to gather information about study area related to the thesis.

Experimentation: experimentation on proposed E-LEACH algorithm is employed to

achieve the objective of the study.

Tools: MATLAB R2018a software is used as a tool to study and obtain experimental results and to implement, to simulate and to analyze the performance of the proposed algorithm. MATLAB [41] relative to others simulation environment, its programming syntax is simple and it contain built-in complex mathematical expressions.

Scope of the Study

The scope of this study is to develop a mechanism to select the next hope cluster head node for multi-hop communication in inter-cluster transmission where it considers remaining energy, distance, and angle of cluster head at the same time. where Energy is the first element, and distance is the second element and angle will be considered when the difference between energy and distance is not big so the data transmission to the gate way node will be effective and reduce link failure. We will use the traditional LEACH and its extension LEACH-C protocol. This work is limited to defining the cluster size and number of node in a cluster.

Thesis Organization

The organization of thesis is structured as follows. Chapter 2 presents and discusses the conceptual review of WSN Chapter 3. related work in the area of WSN was described in Chapter 4, the design for the proposed algorithm is presented, based on abstract reasoning about its fundamental building blocks. In Chapter 5, simulation results of proposed solution is evaluated and analyzed, The conclusion and future work is described. under Chapter 6. Some particular aspects are described in the appendices.

For reasons of clarity and brevity, they are not part of the main body of the thesis.

CHAPTER 2

LITERATURE REVIEW

Overview of Wireless Sensor Networks

Currently, WSN (Wireless Sensor Network) is the most standard services employed in commercial and industrial applications, because of its technical development in a processor, communication, and low-power usage of embedded computing devices in which the sensor nodes are either static nodes or mobile nodes. These nodes can be used in various real-time applications to perform various tasks like smart detecting, a discovery of neighbor node, data processing and storage, data collection, target tracking, monitor and controlling, synchronization, node localization, and effective routing between the base station and nodes. [4]Wireless sensor nodes consist of a micro-controller, various sensors, and a radio transceiver that is powered by a battery. The major applications of WSNs are economics, environmental monitoring, mining, meteorology, seismic monitoring, acoustic detection, health care applications, process monitoring, infrastructure protection, context aware computing, undersea navigation, smart spaces, inventory tracking and tactical military surveillance. There are two sets of challenges to WSNs; hardware and environment. The main hardware constraints are limited battery power and low-cost requirements. i.e., the sensor nodes should be energy efficient, low complexity algorithms required for micro-controllers and use of only a simplex radio [9].

In WSNs Usually, the sensor nodes are deployed on land, underground and under water environments and that forms a WSN. Based on the sensor nodes deployment, a sensor network faces different challenges and constraints. Types of the WSNs are terrestrial, underground, multi-media and mobile WSNs. WSNs are classified to two According to the resources of the sensor nodes homogeneous and heterogeneous WSNs [10] [11].

Homogeneous wireless sensor networks: a wireless sensor network is said to be homogeneous if all of its sensors have the same storage, processing, battery power, sensing and communication capability. With purely static clustering (cluster heads once elected, serve for the entire lifetime of the network) in a homogeneous network, it is evident that the cluster head nodes will be over-loaded with the long range transmissions to the remote base station, and the extra processing necessary for data aggregation and protocol co-ordination. As a result the cluster head nodes expire before other nodes. However it is desirable to ensure that all the nodes run out of their battery at about the same time, so that very little residual energy is wasted when the system expires[13] [4]. Data collection in these types of networks is based on the data dissemination structure. Flat and hierarchical typologies are two well-known data distribution and collecting architectures that have been extensively explored in homogeneous networks. In a hierarchical network, sensor nodes are organized within clusters, such a way that, CHs serve as simple relays for data transmission. Because CHs have the same transmission capacity as sensor nodes, the upper bound of throughput may be used to calculate the minimal number of clusters necessary. Of course, the increased throughput gained by clustering comes at the expense of extra nodes that serve as CHs. Data aggregation in a hierarchical network involves combining data in CHs which reduces the number of transmitted messages to BS. Therefore, network efficiency is increased in terms of energy consumption[33].

Heterogeneous wireless sensor network, two or more different types of nodes with different battery energy and functionality are used. The motivation being that the more complex hardware and the extra battery energy can be embedded in few cluster head nodes, thereby reducing the hardware cost of the rest of the network. However fixing the cluster head nodes means that role rotation is no longer possible. When the sensor nodes use single hopping to reach the cluster head, the nodes that are farthest from the cluster heads always spend more energy than the nodes that are closer to the cluster heads. On the other hand when nodes use multi-hopping to reach the cluster head, the nodes that are closest to the cluster head have the highest energy burden due to relaying. Consequently there always exists a non-uniform energy drainage pattern in the network [12] [13] [14].

Type of Resource Heterogeneity are Computational Heterogeneity, Link Heterogeneity, and Energy Heterogeneity.

Computational Heterogeneity: Computational Heterogeneity, means that the heterogeneous node has a more powerful microprocessor, and more memory, than the normal node. With the powerful computational resources, the heterogeneous nodes can afford complex data processing and longer-term storage.

Link Heterogeneity: Link Heterogeneity means which the heterogeneous node has high bandwidth and long distance network transceiver than the normal node. Link heterogeneity can provide a more consistent data transmission.

Energy Heterogeneity: Energy Heterogeneity, means that the heterogeneous node is line powered, or its battery is expendable. Among above three types of resource heterogeneity, the mainly important heterogeneity is the energy heterogeneity since both computational heterogeneity and link heterogeneity will consume extra energy resource.

Components of Wireless sensor networks

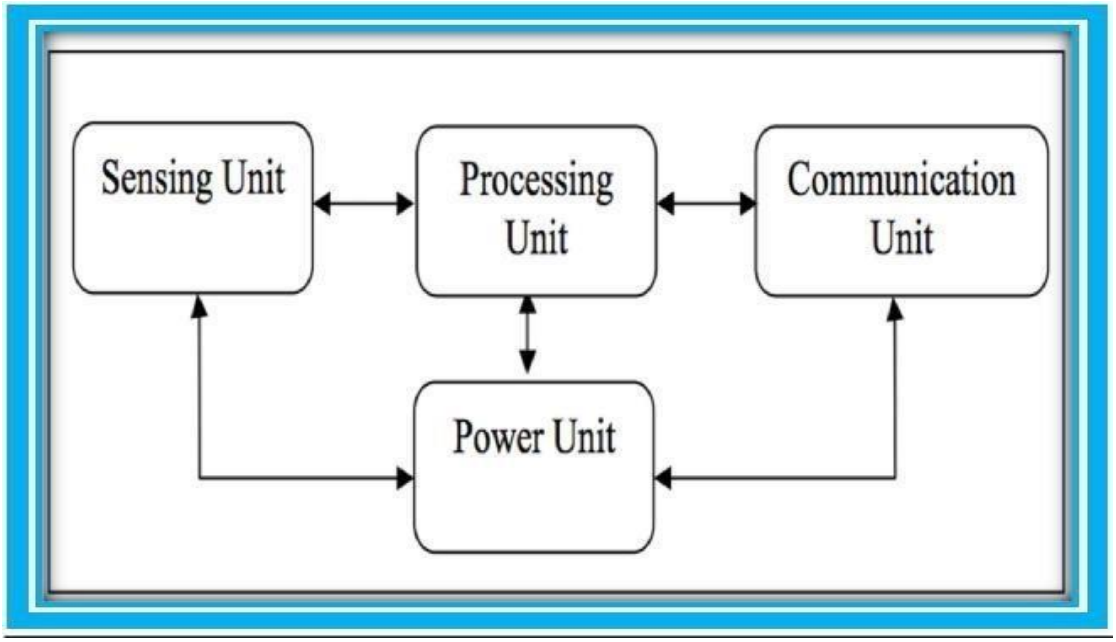

Figure 2: components of wireless sensor network [22]

The basic components of a sensor node described as follows:

1. Sensing Unit: It senses the environment through transceiver. Sensing unit [22] has two sub units, sensors and ADC. Sensors are considered as a vital part of any WSN. They are basically hardware devices that generate a signal proportional to the event or condition being monitored or measured. The sensed signal is converted to digital form using analog-to-digital converters (ADC) as the micro controllers can only process digital data. Desired characteristics of a sensor node include small size, low power consumption, being adaptive to the environment, and being independent and able to work unattended.

Based on power or energy supply requirement, sensors [22] are categorized as; active sensors, passive and Omni-directional sensors, and passive and narrow-beam sensors, and are described as follows:

Active sensors: This category of sensors actively surveys the surroundings, for instance, a radar sensor or a seismic sensor that produces shock waves.

Passive and Omni-directional sensors: These sensors monitor the data without really affecting the environment by active investigation. Normally, they are self-powered. Power is required only to magnify their collected analog data. Further, these sensors pick up the sensed data from all directions; they are not directional.

Passive and narrow-beam sensors: Sensors of this category are passive; however, they have distinct view of direction of measurement. Usually devices such as cameras are used. In addition to these units, a wireless sensor node may be equipped with extra units such as a global positioning system (GPS) device, and a motor to move the sensor node in specific directions, among others. Of course, such components must be built into a small module with low power expenditure and low fabrication cost.

Based on their applications, sensors are classified into the following groups and described as follows in [23] [24]:

Accelerant meters: These group of sensors are based on the Micro Electro Mechanical sensor technology. They are used for patient monitoring which includes pacemakers and Vehicle dynamic systems.

Biosensors: sensors of this group are based on the electro chemical technology. They are used for food testing, medical care device, water testing, and biological warfare agent detection.

Image Sensors: These are based on the CMOS (COMPUT metal oxide semiconductor) technology. They are used in consumer electronics, biometrics, traffic and security surveillance and PC imaging.

Motion Detectors: These are based on the Infra-Red, Ultrasonic, and Microwave or radar technology. They are used in video games and simulations, light activation and security detection

2. Micro-controller unit/ Processing unit: The CPU (also called the electronic brain) of a sensor node [23] is composed of a microprocessor and a flash memory. In most of sensor nodes, it includes connectors to add external processing units and sensors to the main unit easily. Making decision and dealing with collected data are the crucial functions of the CPU. The CPU stores data in flash memory until enough data is collected. Once enough data is collected by the system, then microprocessor unit of the CPU puts the data in envelopes, because envelopes provide great efficiency in data transmission. Then, these envelopes are sent to the radio for broadcast. Meanwhile the CPU communicates also with other nodes in the same way it deals with data to maintain the most effective network structure. The CPU is connected to the base and it interacts with the sensors and radio. Flash memories are employed due to their cost-effectiveness characteristics; they offer high capacity at low cost. Memory requirements are application dependent. The required memory type can be divided into two major classes: data memory and program memory.

3. Transceiver Unit (Communicating Unit): The term transceiver signifies the combined functions of transmitter and receiver. Transceiver has mainly four operational states which are Receive, Transmit, Idle and Sleep. The Radios operating in the idle state of operation consume power roughly equal to that used in receive state. Hence, it is recommended to turn down the radios instead of running them in the idle state when not sending or receiving data. Moreover, a lot of power is spent switching from the sleep state to the transmit state in order to send a packet. Sensor nodes utilize the industrial, scientific and medical (ISM) frequency band, which is available free of charge and does not require a license. There are different choices of wireless transmission media including: infrared and radio frequency. Infrared medium is inexpensive; however, it requires line of sight and cannot penetrate opaque objects and walls. Moreover, it is sensitive to atmospheric situations. Infrared does not require antennas, so it has limited broadcasting capacity. Communication based on radio-frequency (RF) is the most-often used means of communication in WSNs. Typically, WSNs use the communication frequencies between 433MHz and 2.4GHz [23] [24].

4. Power Unit: In WSNs [24] when a sensor node collects data/signal, it consumes power. Moreover, power is consumed even more for communication and data processing operations. Power is typically stored in batteries or capacitors. There are two major types of batteries that are used in sensor nodes: chargeable and non-rechargeable batteries. Moreover, batteries can be classified depending on the electrochemical material used for electrode as nickel–cadmium (NiCd), nickel zinc (NiZn), nickel metal hydride (Nimh) and lithium-ion. Most WSNs employ power-saving policies in order to extend the life of the batteries in their nodes. Among such schemes that are used are the dynamic power management and dynamic voltage scaling schemes. The first technique shuts down parts of the sensor node that are not presently active. The second scheme changes power levels based on the unpredictable workload. This is performed by changing voltage besides the frequency, which allows achieving decrease in the power consumption. The power unit [25] usually consists of one or more batteries, providing 3V - 4.5V, generally with a capacity ranging between 1700mAh – 2700mAh. The node can be fitted with various sensors for acoustic, photo, temperature, pressure etc. based applications.

Each node may also optionally be fitted with 11an interface for plugging-in an actuator for performing any mechanical actions on an application specific basis.

Wireless sensor network characteristics

Wireless sensor networks have characteristics that are different from traditional wireless network such as wireless ad hoc networks. The main characteristics of the wireless sensor network are summarized [26][27] as follows:

Unattended operation: In most cases, once nodes are deployed, wireless sensor networks have no human intervention. Hence the nodes themselves are responsible for reconfiguration in case of any changes.

Dynamic network topology: It is an important aspect of the sensor networks. The life cycle of a sensor network may be represented in three phases with respect to the topology and its maintenance. During the deployment phase, the nodes are dropped into their positions in an ad hoc manner. The nodes need to self-organize into a communicating network. The Post-deployment phase topology maintenance consists of topology changes induced due to the failure of the nodes, failure of radio links, or arrival of some mobile obstacles. The Re-deployment phase deals with the deployment of nodes to replace failed nodes. In each of the three phases, a sensor network should be capable of seamlessly organizing itself to stream data to the base-station.

Limited power: Sensor Networks are highly sensitive to energy usage. They may, probably, be deployed in hostile environments, where it may not be possible to refresh energy sources. Hence, energy consumption is a major issue, and energy-aware protocols or applications are desirable. Energy consumption is observed at three stages, node communication, sensing and processing. Optimizing the three processes will lead to a reduction in the energy consumed.

Distributed sensing and processing: the large number of sensor node is distributed uniformly or randomly. WSNs each node is capable of collecting, sorting, processing, aggregating and sending the data to the sink. Therefore the distributed sensing provides the robustness of the system.

Node mobility: Mobility of the nodes creates a dynamic network topology. Links will be dynamically formed when two nodes come into the transmission range of each other and are torn down when they move out of range.

Self-organization: the sensor nodes in the network must have the capability of organizing themselves as the sensor nodes are deployed in an unknown fashion in an unattended and hostile environment. The sensor nodes have to work in collaboration to adjust themselves to the distributed algorithm and form the network automatically.

Design Issues of Wireless Sensor Network

The design issues of wireless sensor network architecture mainly include the following [16] [17] [18]:

Energy Consumption

In WSN, power consumption is one of the main issues. As an energy source, the battery is used by equipping with sensor nodes. The sensor network is arranged within dangerous situations so it turns complicated for changing otherwise recharging batteries. The energy consumption mainly depends on the sensor nodes' operations like communication, sensing & data processing. Throughout communication, the energy consumption is very high. So, energy consumption can be avoided at every layer by using efficient routing protocols[16].

Localization

For the operation of the network, the basic, as well as critical problem, is sensor localization. So sensor nodes are arranged in an ad-hoc manner so they don't know about their location. The difficulty of determining the sensor's physical location once they have been arranged is known as localization. This difficulty can be resolved through GPS, beacon nodes, localization based on proximity.

Coverage

The sensor nodes in the wireless sensor network utilize a coverage algorithm for detecting data as well as transmit them to sink through the routing algorithm. To cover the whole network, the sensor nodes should be chosen. There efficient methods like least and highest exposure path algorithms as well as coverage design protocol are recommended.

Clocks

In WSN, clock synchronization is a serious service. The main function of this synchronization is to offer an ordinary timescale for the nodes of local clocks within sensor networks. These clocks must be synchronized within some applications like monitoring as well as tracking.[16]

Computation

The computation can be defined as the sum of data that continues through each node. The main issue within computation is that it must reduce the utilization of resources. If the life span of the base station is more dangerous, then data processing will be completed at each node before data transmitting toward the base station. At every node, if we have some resources then the whole computation should be done at the sink.

Production Cost

In WSN, the large number of sensor nodes is arranged. So if the single node price is very high then the overall network price will also be high. Ultimately, the price of each sensor node has to be kept less. So the price of every sensor node within the wireless sensor network is a demanding problem.

Hardware Design

When designing any sensor network's hardware like power control, micro-controller & communication unit must be energy-efficient. Its design can be done in such a way that it uses low-energy.

Quality of Service

The quality of service or QoS is nothing but, the data must be distributed in time. Because some of the real-time sensor-based applications mainly depend on time. So if the data is not distributed on time toward the receiver then the data will turn useless. In WSNs, there are different types of QoS issues like network topology that may modify frequently as well as the accessible state of information used for routing can be imprecise.

Wireless Sensor Network protocol stack

This kind of protocol stack is applicable in different places such as hospitals, schools, roads, buildings as well as it is used in different applications such as security management, disaster management & crisis management, etc. There are two types of wireless sensor network protocol stack used in wireless sensor networks which include the following. Layered Network, and Clustered protocol stack. These are explained as following below [19] [20] [21].

Layered Network protocol stack

This kind of network uses hundreds of sensor nodes as well as a base station. Here the arrangement of network nodes can be done into concentric layers. It comprises five layers as well as 3 cross layers which include the following.

The five layers in the protocol stack are:

- Application Layer
- Transport Layer
- Network Layer
- Data Link Layer
- Physical Layer

The three cross layers include the following:

- Power Management Plane
- Mobility Management Plane
- Task Management Plane

These three cross layers are mainly used for controlling the network as well as to make the sensors function as one in order to enhance the overall network efficiency.

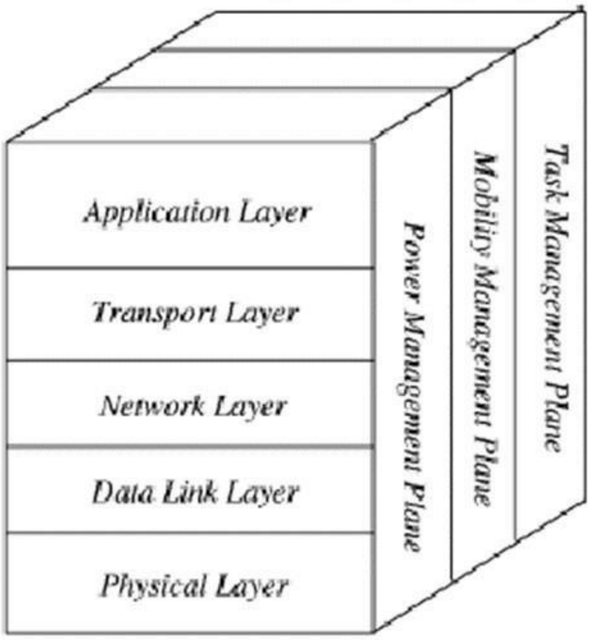

Figure 3: layered protocol stack

Application Layer

The application layer is liable for traffic management and offers software for numerous applications that convert the data in a clear form to find positive information. Sensor networks arranged in numerous applications in different fields such as agricultural, military, environment, medical, etc.

Transport Layer

The function of the transport layer is to deliver congestion avoidance and reliability where a lot of protocols intended to offer this function are either practical on the upstream. These protocols use dissimilar mechanisms for loss recognition and loss recovery. The transport layer is exactly needed when a system is planned to contact other networks.

Network Layer

The main function of the network layer is routing, it has a lot of tasks based on the application, but actually, the main tasks are in the power conserving, partial memory, buffers, and sensor don't have a universal ID and have to be self-organized. The simple idea of the routing protocol is to explain a reliable lane and redundant lanes, according to a convinced scale called metric, which varies from protocol to protocol. There are a lot of existing protocols for this network layer, they can be separate into; flat routing and hierarchical routing or can be separated into time driven, query-driven & event driven.

Data link layer

The data link layer is liable for multiplexing data frame detection, data streams, MAC, & error control, confirm the reliability of point–point (or) point– multi point.

Physical Layer

The physical layer provides an edge for transferring a stream of bits above physical medium. This layer is responsible for the selection of frequency, generation of a carrier frequency, signal detection, Modulation & data encryption. IEEE 802.15.4 is suggested as typical for low rate particular areas & wireless sensor network with low cost, power consumption, density, the range of communication to improve the battery life.

Clustered Network protocol stack

This kind of network protocol stack is extremely used due to the data fusion property. In every cluster, every node can interact through the head of the cluster to get the data. All the clusters will share their collected data toward the base station. The formation of a cluster, as well as its head selection in each cluster, is an independent as well as autonomous distributed method.

In this architecture, separately sensor nodes add into groups known as clusters which depend on the "Leach Protocol" because it uses clusters. The term 'Leach Protocol' stands for "Low Energy Adaptive Clustering Hierarchy". The main properties of this protocol mainly include the following.

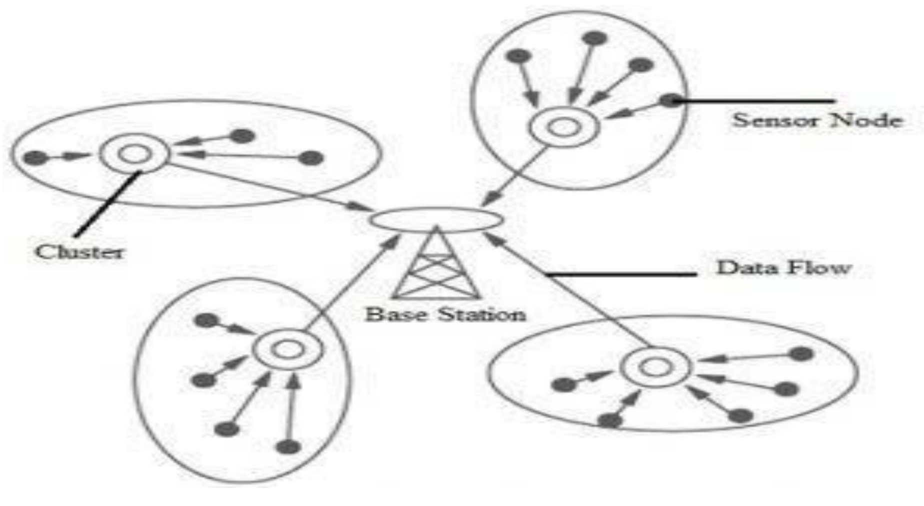

Figure 4: Clustered protocol stack[14]

- This is a two-tier hierarchy clustering.
- This distributed algorithm is used to arrange the sensor nodes into groups, known as clusters.
- In every cluster which is formed separately, the head nodes of the cluster will create the TDMA (Time-division multiple access) plans.
- It uses the Data Fusion concept so that it will make the network energy efficient.

Routing in Wireless Sensor Networks

The routing protocol is a process to select suitable path for the data to travel from source to destination. The process encounters several difficulties while selecting the route, which depends upon, type of network, channel characteristics and the performance metrics.[13]

The data sensed by the sensor nodes in a wireless sensor network (WSN) is typically forwarded to the base station that connects the sensor network with the other networks (may be internet) where the data is collected, analyzed and some action is taken accordingly.

In very small sensor networks where the base station and motes (sensor nodes) so close that they can communicate directly with each other than this is single-hop communication but in most WSN application the coverage area is so large that requires thousands of nodes to be placed and this scenario requires multi-hop communication because most of the sensor nodes are so far from the sink node (gateway) so that they cannot communicate directly with the base station. The singlehop communication is also called direct communication and multi-hop communication is called indirect communication.

In multi-hop communication the sensor nodes not only produce and deliver their material but also serve as a path for other sensor nodes towards the base station. The process of finding suitable path from source node to destination node is called routing and this is the primary responsibility of the network layer.

Routing challenges in WSNs

The design task of routing protocols for WSN is quite challenging because of multiple characteristics, which differentiate them, from wireless infrastructure-less networks.

Several types of routing challenges involved in wireless sensor networks. Some of important challenges are mentioned below:

- It is almost difficult to allocate a universal identifiers scheme for a big quantity of sensor nodes. So, wireless sensor motes are not proficient of using classical IP-based protocols.
- The flow of detected data is compulsory from a number of sources to a specific base station. But this is not occurred in typical communication networks.
- The created data traffic has significant redundancy in most of cases. Because many sensing nodes can generate same data while sensing. So, it is essential to exploit such redundancy by the routing protocols and utilize the available bandwidth and energy as efficiently as possible.

Classification of routing protocols

The routing protocols define how nodes will communicate with each other and how the information will be disseminated through the network. There are many ways to classify the routing protocols of WSN. The basic classification of routing protocols are

Hierarchical based routing

Mostly heterogeneous networks apply hierarchical routing protocols where some nodes are more advance and powerful than the other nodes, but not always this is the case, sometimes in hierarchical (clustering) protocols sometimes the nodes are grouped together to form a cluster and the cluster head is assigned to every cluster, which after data aggregation from all the nodes, communicates with the base node .The clustering scheme is more energy efficient and more easily manageable.

Examples are:

Data-centric

In most of the wireless sensor networks, the sensed data or information is far more valuable than the actual node itself. Therefore data centric routing techniques the prime focus is on the transmission of information specified by certain attributes rather than collecting data from certain nodes.

In data centric routing the sink node queries to specific regions to collect data of some specific characteristics so naming scheme based on attributes is necessary to describe the characteristics of data. Examples are sensor protocol for information via negotiation (SPIN).

Destination-initiated (Dst-initiated)

Protocols are called destination initiated protocols when the path setup generation originates from the destination node. Examples are directed diffusion (DD) & LEACH.

Clustering In wireless sensor networks

Clustering is an automated process in which samples are sorted into groups with similar members as part of unsupervised learning. Clustering is considered as one of the most effective approach for managing the network issues of energy and lifetime [23]. The clustering approach saves the energy of WSN by following low-cost communication methods [28]. The network is partitioned into the different node groups called a cluster, and a cluster head (CH) is allocated to each cluster to control the activities of nodes [29]. The CHs can also form their group to reach the BS though multi-hop pattern. The sensed readings of nodes are assembled by the Ch to communicate to the BS[30]

Issues in clustering protocol

The most energy-consuming and essential task of any WSN is to perform the communication. Communication of data and communication within the nodes is the most energy-consuming activity. The WSN is surrounded with various issues and restrictions such as low battery power,restricted computation power,limited bandwidth, etc. Some of the major challenging issues that every clustering protocols in WSN faces are:

Heterogeneity of nodes

In many sensor network applications, the homogeneous type of networks is used in which all the sensors are provided with similar energy, memory, processing capabilities, etc [39]. But when the heterogeneous networks are considered, they are equipped with different processing capabilities, bandwidth, energy and computational power for different groups of nodes. The implementation of routing in homogeneous networks is more straightforward in comparison to the heterogeneous networks where the nodes have different capabilities.

Node deployment

The deployment of nodes in WSN can be performed either manually or randomly. In the manual deployment of nodes, the sensors are deployed manually using some deployment strategy. The nodes in manual deployment follow a pre defined path during the routing [7]. In random deployment, the sensors are placed randomly in the sensing region following an ad hoc substructure. In hostile and inaccessible areas, the nodes are dispersed randomly using the airplanes to deploy them in the working area.

Data aggregation

The sensor nodes which are placed in close proximity can sometimes sense similar or nearly similar data readings. These nodes create redundant data in the network [39]. The network energy is wasted in processing the redundant data which affects the working performance and lifetime of the network. Data aggregation is used in various routing protocols to reduce the redundant packers in the network.

Energy

The limited energy of sensor nodes is mostly spent in communication and computation activities of the network. The energy conservation in WSN plays an essential role as the network life-time is very much dependent on the battery life of sensors in the network. The malfunction or death of the sensor node due to energy depletion while performing the network activities or routing can affect the network performance which can cause the topology change, network reorganization, and rerouting of data packets in the network. The energy of sensor nodes has always been a vital design issue for the clustering protocols in WSN [5][20]

Clustering characteristics

The clustering and routing approaches have several objectives to cover such as fault tolerance, improving net-work lifetime, decreasing delay, minimizing energy usage, collision avoidance, managing coverage and connectivity,load balancing, data aggregation, etc [27]. All the objectives of cluster based approaches aims to improve the network performance. The clustering approach in WSN is used to handle the energy constraints for the longer working of the network. The nodes in clustering are grouped to provide an efficient and scalable network. To perform the clustering process in an efficient manner, various characteristics are taken into considerations [12] which are:

Intra-cluster communication

The connections between the sensor nodes and CH in the protocols of WSN can be in the single hop (direct) or multi-hop links to perform the communication activities. The nodes can communicate with their CH directly if they are closer to CH. The multihop communication is considered in the network when the sensor nodes are far away from CH, and there is a restriction on the sensor communication range.

Inter-cluster communication

The communication among the various clusters in the network is a challenging task as the clusters work in different channels. The CH and BS in the network can be connected using the multi-hop or direct connections. If the quantity of sensors is large then opting the multi-hop policy is an effective choice. In some approaches,there lays are employed to forward the CH information to the BS.

Cluster count

The number of clusters in any clustering protocol can either be predetermined or can be decided during the clustering phases. The cluster count has an important role in defining the efficiency of a clustering technique. The clusters in the network can vary in number depending on the type and application of the network. The CH counts in some schemes are not fixed as the CH is selected randomly or using some predefined techniques.

Cluster head selection

The CH selection in the clustering protocol is performed by considering various parameters (distance between nodes, distance to BS,energy,Ch probability,etc.). The CH selection decides the overall performance of the clustering protocol as the CH has a very crucial role in any clustering protocol [31]. So, CH determination is considered as a critical attribute in clustering. Some approaches nominate the CH randomly from the nodes, but the random selection of CH makes the protocol less efficient.

Formation of cluster

The cluster formation in WSN starts after the CH selection. The CH sends the advertisement message to all the nodes with in the radio range [40]. The nodes respond with a join request message to the CH they want to join. The cluster formation can be performed centrally by the BS in some protocols and in some approaches the cluster formation is performed without the involvement of the CH[41].

Algorithm complexity

In most recent algorithms the fast termination of the executed protocol is one of the primary design goals. Thus, the time complexity or convergence rate of most cluster formation procedures proposed nowadays is constant (or just dependent on the number of CHs or the number of hops). In some earlier protocols, however, the complexity time has been allowed to depend on the total number of sensors in the network, focusing in other criteria first.

Nodes and CH mobility

If we assume stationary sensor nodes and stationary CHs we are normally led to stable clusters with facilitated intra-cluster and inter-cluster network management. On the contrary, if the CHs or the nodes themselves are assumed to be mobile, the cluster membership for each node should dynamically change; thus forcing clusters to evolve over time and probably need to be continuously maintained.

Advantages of clustering

The clustering methodology has several advantages which improves the overall performance of the network [40]. It minimizes energy expenditure and helps in enhancing the network lifetime. Some of the major advantages of clustering in WSN are:

Energy consumption

The energy usage in the clustering can be reduced by minimizing the data communication in the network. The nodes for ward their sensed information to the CH and CH in the cluster transfer the gathered information to the BS [31]. The cluster based structure used in the clustering techniques minimizes the overall energy expenditure of the network.

Investigation of clustering protocols

The clustering protocols are incorporated in the WSN to take the benefits from them in terms of network life, better performance, more scalability, etc. The protocols in this section are classified in the groups of homogeneous clustering protocol. These protocols mainly focus on clustering activities such as CH determination and data communication.

They distinguish from each other on the CH selection methods and processes.

Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH [19] is the first dynamic clustering protocol for hierarchical sensor networks. The CH in LEACH is selected randomly to balance the energy expenditure in the network. It is still treated as a base for several techniques related to clustering in WSN. It can be considered as the probabilistic, random, distributed,and hierarchical protocol used for the clustering. The single-hop communication model is employed to transfer the data to the BS by the CH. The formation of clusters and the CH selection in this protocol is carried out without any central support system. This characteristic results in more robust and scalable routing which minimizes the data transmission to sink. The execution period of LEACH is performed in steps which comprise of the setup and steady phases. The organization of nodes into clusters is performed in the first step. The node generates a random number like N between zero and one in the first step to select the CH. The CH position is designated to a node if N is less than T(n). The threshold T(n) can be given using the formula (1)[1].

Suppose that, at the beginning, a node randomly chooses a number between 0 and 1. If the random number generated by a node is less than T (n), it will become the cluster head of the current round. The expression [2]of T (n) is as follows:

$$T(n)\begin{cases} \dfrac{p}{1-p\times(r \bmod (1/p))}, & \text{if } n<G, \\ 0, & \text{otherwise.} \end{cases} \quad \text{............(1)}$$

In equation (1), r is the current rounds, P is the percentage of nodes which become cluster heads, and G is the set of nodes that have not been elected cluster heads in the 1/P round before the current round. the CH broadcasts the advertisement message to initiate the cluster formation. The nodes become part of the clusters by replying to the CH message. The nodes respond to the CH having the strongest signal for cluster formation. The next step begins after the nodes turn out to be part of the respective clusters. The data in this stage is collected, aggregated and transmitted to the BS by the CH. The correlated data is reduced by employing the aggregation by the CH to save the energy wastage. The sensor transmission is scheduled using the Time Division Multiple Access(TDMA) slots. The slot duration is preset for all the sensors and the overall duration depends on the node count. The limitations of this protocol can be analyzed after some rounds when the random selection policy of CH chooses the low energy nodes as CH which affects the network robustness causing the early death of CH.

Energy Model. The node communication model and energy consumption formula of WSN (wireless sensor network) were proposed in literature [20] and are shown in Figure 1 and formula (2), respectively.

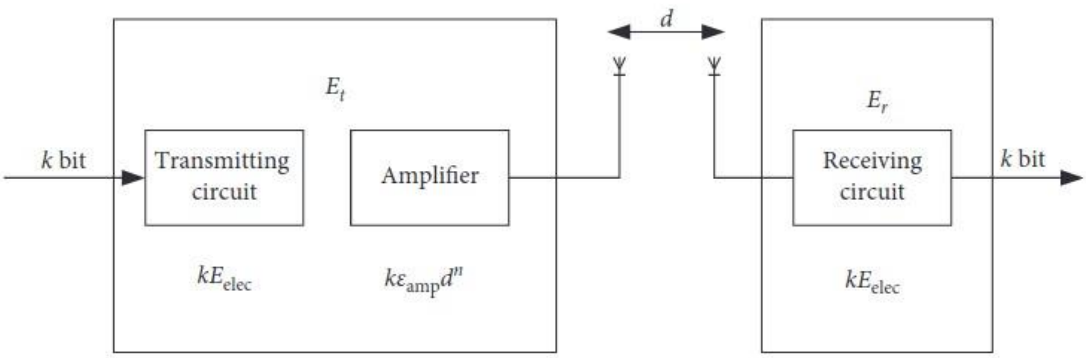

Figure 5:LEACH Node communication model [20]

When the transmission distance is d, the transmission energy consumption of k-bit information is

$$E_t = \begin{cases} kE_{elec} + k\varepsilon_{fs}\mathrm{d}^2, & \mathrm{d} \le \mathrm{d}_0, \\ kE_{elec} + k\varepsilon_{amp}\mathrm{d}^4, & \mathrm{d} \ge \mathrm{d}_0, \end{cases} \qquad \text{…….. ……... (2)}$$

$$\mathrm{d}_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{\mathrm{amp}}}}.$$

In equation (2), d ≤ d 0 is a free space model and d ≥ d 0 is a multipath attenuation model. In general, intra-cluster calculations use d^2 and inter-cluster transmission d^4 . ε_{fs} is receiver sensitivity related amplification. ε_{amp} is magnification energy related to the received noise image. E_{elec} is electricity related to factors such as digital coding.

According to the above, the received energy consumption E_r can be defined as[20]

$$E_r = kE_{elec} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

WSN energy consumption mainly includes transmission energy consumption, reception energy consumption, idle energy consumption, and sleep energy consumption [21]. Research shows that receiving and transmitting energy are the main energy loss. In addition, during data transmission, many redundant nodes will appear. Their idle energy consumption is far greater than the sleep energy consumption, so the sleep mechanism is used to the energy consumption of nodes in the cluster.

CHAPTER 3

RELATED WORK

In this section, we summarize related works that are published on the improvement of energy efficient cluster routing algorithms of wireless sensor networks. Literature show that there have been a number of works that have done on the enhancement of energy efficiency algorithms. Here we have summarized works those that are relevant and related to our study.

In [23] proposes an algorithm to remove the unbalanced cluster formation problem by implementing the distance based clustering which compute the distance between sensor nodes from sink node. On the basis of which clusters are formed but formed clusters are unbalanced which increased the probability of low lifetime of sensor nodes because of the fact that maximum the number of nodes in a cluster higher the chances are that cluster head can be dead before other cluster heads.

According to [24] proposes an algorithm to divide a network using a predefined angle. This formation of clusters can reduce the non-coverage area overhead of sensor nodes.

In [25] Proposes energy efficient clustering scheme (EECS) for data-gathering, which is very critical operation in WSN; this can reduce the data packet and enhance the network processing and reduce the delivery time. EECS elects the cluster head on the basis of residual energy and to reduce the load of network proposed a distance based algorithm among all the cluster heads, so that cluster heads can communicate effectively. Proposed clustering algorithm is superior to HEED and LEACH.

In [33], an energy-efficient network model is proposed that dynamically relocates a mobile BS in cluster-based (CB) networks. At first sensor, nodes are located into an optimal number of clusters. Then, optimal CHs are selected in order to distribute the role of CH among sensor nodes. In this way, load balancing is achieved by dynamically changing the number of alive nodes and decreased communication distance is achieved by determining the location of the moving BS. So, this model aimed at improving network lifetime, data delivery, energy consumption compared to static and random mobile BS network models.

According to [13] proposes an algorithm to prolong the lifespan of wireless sensor networks by balancing the energy consumption in an unequal cluster. This is tightly bound with the location and role of the sensor node. Author discuss the problem arise while forming the unequal clusters which has different number of nodes called heterogeneous clusters. This may increase the load of cluster head nodes and may reduce the processing and lifespan of that particular sensor node.

In [18] proposes an algorithm to prolong the lifespan of senor network by applying the energy efficient heterogeneous clustering scheme (EEHC). Heterogeneous nodes are deployed with different initial energy and processing power. This algorithm use two phase approach i.e. setup phase and steady phase. The main focus is on setup phase where cluster head selection procedure is defined, in which on the basis of their residual energy they elect the cluster head for a cluster. In which weighted election probabilities of each sensor node can be considered to help them to decide the cluster head.

According to [21] proposes two clustering based routing protocols i.e. power controlled routing (PCR) and enhanced power controlled routing (EPCR). Initially the transmission power sensor nodes are similar but transmission power of sensor nodes can be increased while transmitting the data packets form one node to another according to their distance from receiver node. Nodes are associated to the cluster head on the basis of weight and distance for PCR and EPCR routing protocols respectively. This may increase the packet loss in network, so packet recovery mechanism is suggested by authors.

In [27] proposes a DECSA (distance-energy cluster structure algorithm) which consider the residual energy and distance of each sensor node for clustering. DECSA follows the two steps to make wireless sensor network energy efficient i.e. initialization stage and Stable stage. Initialization stage is responsible for cluster formation and election of cluster heads (CH) & Base Station Cluster Heads (BCH).

Any clustering algorithm functions by segmenting the field into clusters headed by a CH. The member nodes, ie, non-CH nodes communicate their data to CH, where the data is processed and aggregated to remove redundancy and sent to the BS. As energy consumption is distributed evenly throughout the network, the overall energy consumption is said to be reduced [26].

LEACH is an energy constrained protocol [14]. The initial CH selection is done randomly such that every node has the chance of becoming CH once in every 1/p epoch [15]. In subsequent rounds, a random number is generated in the range [0, 1] and only if the number is less than threshold TN, formulated by [16], the node functions as CH[16]. The next CH is chosen from the set of non-CH nodes.

After the cluster formation stage, all the elected CHs broadcast a TDMA schedule for non-CH nodes. The sensing nodes transmit the data during the specific allotted time slots. Once the transmission process completes, the frame repeats. Although LEACH is a distributed protocol, it may not be beneficial for large-scale application due to energy constraint.

In a heterogeneous network[16]no of n nodes a fraction of nodes has the extra energy of factor α that are termed as advanced nodes. The SEP algorithm focuses on the weighted election probabilities of each node for the election of CHs according to their respective energies. It ensures a more extended stability period with a better performance than that of LEACH protocol. The DEEC protocol [22] was proposed for networks with different energy level, where the selection of CH can be decided by both initial as well as residual energy [18].

In [29] discuss the different energy efficient routing protocols in WSN's. Many researchers use the LEACH or improved different versions of LEACH to complete their research. And this survey discussed LEACH routing protocol, PEGASIS etc. This research paper also includes the efficiency chart for WSN, which will help in to compare the research results.

The cluster head selection mechanism of the LEACH protocol is to random a node randomly chooses a number between 0 and 1. If the random number generated by a node is less than T (n), it will become the cluster head of the current round, which is too random, and the residual energy of the node is not considered that let link failure to happen. In the communication process, the cluster head far away from GN consumes more energy than the node close to GN and is more likely to be exhausted in the long transmission process, which affects life cycle of the network. In the transmission phase, the cluster head is randomly generated. The public nodes in the cluster use a single hop to transmit information to the cluster head. If the cluster head deviates from the center of gravity, it will increase the transmission energy consumption.

CHAPTER FOUR

PROPOSED MODEL

The methodology that will be followed over the course of this thesis was presented in chapter 1. This chapter describes the model that we proposed for our statement of problem, description for deployment of algorithm on MatLab simulation software.

Proposed Solutions

In this paper we introduce enhanced LEACH protocol based on low-power adaptive cluster hierarchy (LEACH) in order to make the network energy consumption efficient and extend the life time of nodes in the network.

In this paper, we defined three types of nodes: cluster head nodes, ordinary nodes, and center of gravity nodes. The cluster head node collects the information of common nodes in the cluster and fuses it. Then, the information is transmitted between cluster heads until the data packet is forwarded to GN. Common nodes are used to collect surrounding information and transmit it to the cluster head. The center of gravity node is the node closest to the center of gravity of the cluster (selected first during each round calculation considering the residual energy and it location in the cluster). The center of gravity node does not participate in the election of cluster heads, only taking functions as a normal node and an auxiliary cluster head to help the cluster head finish its transmission to Gate way node . To describe more clearly, the LEACH protocol is divided into four stages: cluster stage, stable transmission stage, auxiliary transmission stage, and failure reforming stage.

Clustering Stage

In the practical application, the energy consumption of each node is different due to the influence of many factors such as distance and data volume. For the long- term running network, some nodes are easily depleted of energy prematurely, so that the selected cluster head is not necessarily the best cluster head. Therefore, during the election, the energy of the nodes and distance are considered and a modified *T* (*n*) is used [12]:

$$T(n) = \frac{p}{1-p[\mathrm{rmod}(1/p)]} * \left(\gamma_1 \frac{E_{sv}}{E_v} + \gamma_2 \frac{dcs}{dv}\right). \qquad \ldots\ldots\ldots\ldots(4)$$

In equation (4):

E_{sv} represents the remaining energy of the node,

E_v represents the average value of the energy of all nodes,

d_{cs} represents the distance between nodes and GN, d_v represents the average distance between nodes and GN, γ_1 and γ_2 are weight impact factors, respectively; $\gamma_1 + \gamma_2 = 1$.

Considering the energy and distance of nodes comprehensively, more efficient nodes can be selected as cluster heads by equation (4), so that they can transmit date efficiently. It can realize energy balance, protect nodes with lower residual energy, avoid link failure and extend the network life cycle.

Because clusters adopt the multihop communication method, the cluster head node closer to the gateway consumes energy quickly for transmitting more information and leads to the formation of “hot spots.” For solving this problem, this paper uses a partition type which is the larger cluster radius and the more nodes in the cluster being away from GN.

The wireless sensor network is partitioned according to rules (d, d/2, ..., d/2 ∗ n). As shown in Figure 2, if CH appears in the first divided area, its diameter range is (0, d). When a circle crosses the divided region, three situations occur. When the center of the circle is at the bottom and on the line of the center, the diameter is (0, d), while when it is at the top, its diameter is (0, d/2).

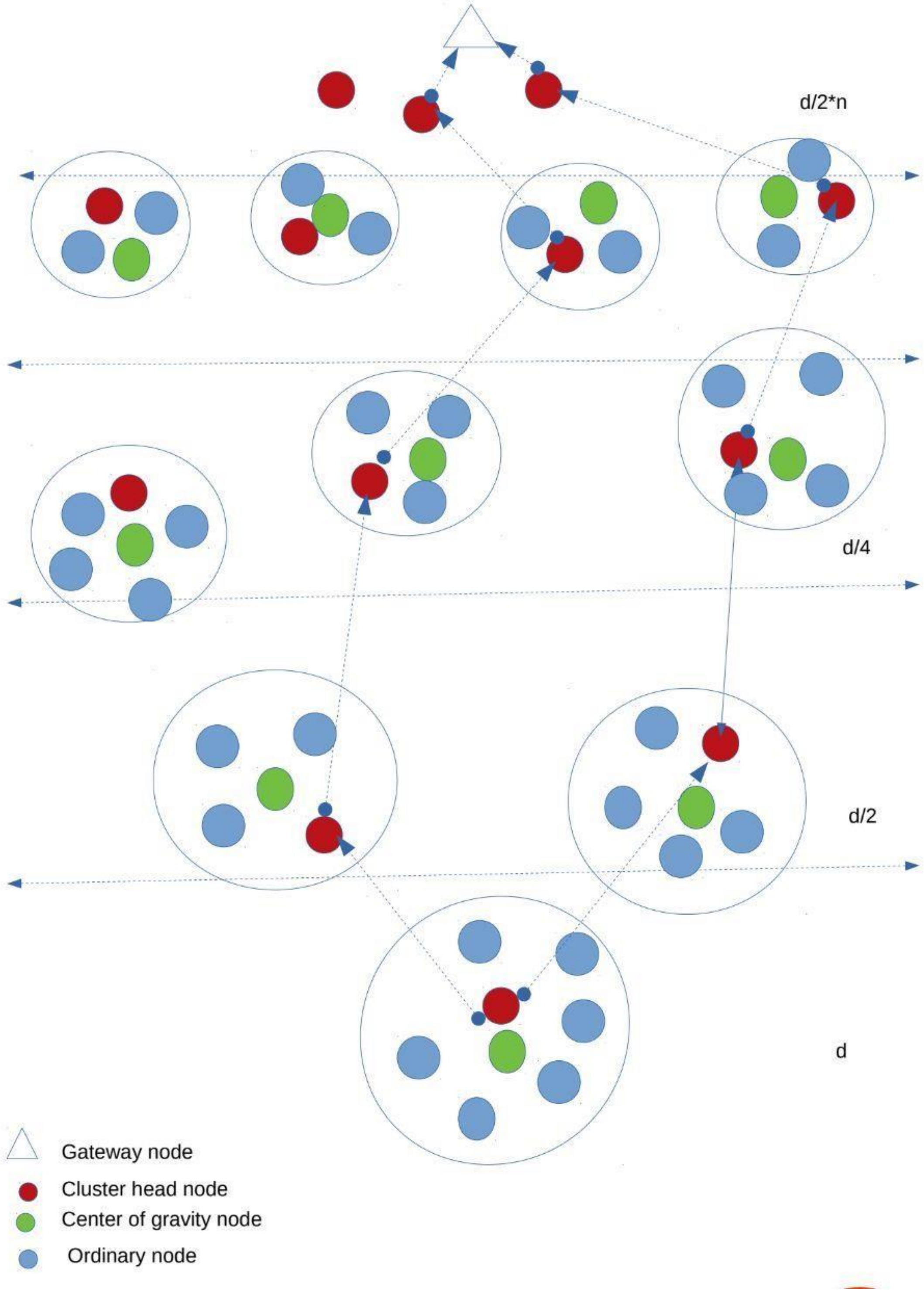

Figure 6:E-LEACH protocol network structure

Stable Transmission Phase.

In the stable transmission process, CH is not far away from the center of gravity. Currently, the center of gravity node is just a normal node and only undertakes the task of collecting data. This stage is divided into intra-cluster transmission and inter-cluster transmission.

In order to find redundant nodes in the cluster, when intra-cluster transmission is performed, the cluster head node will identify the nodes with redundant data, and then use the sleep mechanism to make these nodes enter the sleep state. When a node chooses to sleep, a sleep message is issued to notify the surrounding nodes that it is not working. At the end of a round, nodes choose to start or sleep based on perceived intensity and detection contribution, as well as coverage and connectivity, and inform their neighbors of their decision.

When performing inter-cluster transmission, CH forwards packets to adjacent nodes. When cluster head selects the next jump, factors such as the remaining energy, distance, and angle of cluster head should be considered at the same time. Energy is the first element, and distance is the second element. When the difference between energy and distance is not big, the appropriate angle should be considered. Therefore, we propose the measurement formula (5):

$$F=\{ E * \sin\alpha * d-1, \alpha \in (0, 0.5\pi), \quad E * \sin(\pi - \alpha) * d-1, \alpha \in (0.5\pi, \pi)\} \ldots.(5)$$

The value of *F* in formula (5) can be used as the metric for choosing the next hop CH. The greater the value of F, the more likely the CH will be the next hop, where *E* is the remaining energy of the next hop CH, α is the angle formed by CH, the next hop CH and GN, in which CH is the vertex, and *d* is the distance from GN to CH.

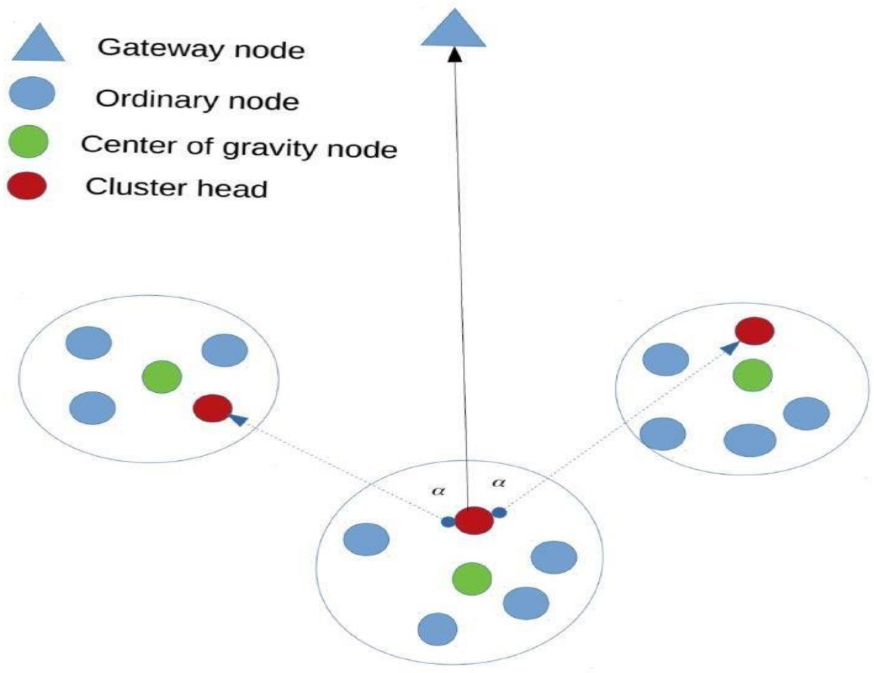

Figure 7: Routing and angle diagram among clusters

According to Figure 6, the nodes close to the gateway node bear heavy transmission load, so these nodes are set as cluster heads, which only assumes the responsibility of collecting the previous hop information and transmitting the information to GN, so as to reduce the burden. In the next round, when the residual energy value of these nodes is lower than the remaining energy value of the whole node, they should consider going to the cluster close to them with the highest total residual energy, so as to avoid the situation of premature exhaustion of the minimal cluster energy. Then, they become ordinary nodes, thus enhancing the transmission capacity of adjacent clusters and saving minimal clusters.

Auxiliary Transmission Phase

In this stage, CH is far from the center of gravity of the network, which takes over the work of CH. At this stage, it has two characteristics: high energy value and never acting as a CH. The working mechanism is that the center of gravity node transmits the collected information to CH, which then forwards the information to the next hop. In every round, after the selection of CH, the center of gravity node is declared by taking the average energy of each cluster is calculated and this average energy is taken as a threshold for the selection of center of gravity node. Also, for every cluster member in the list, its distance from other cluster member nodes is compared. The node with center distance and maximum energy is declared as center of gravity node. The center of gravity node mostly remains near the center of every cluster and also has adequate energy to receive the data from other cluster members, aggregate it and transmits to the CH.

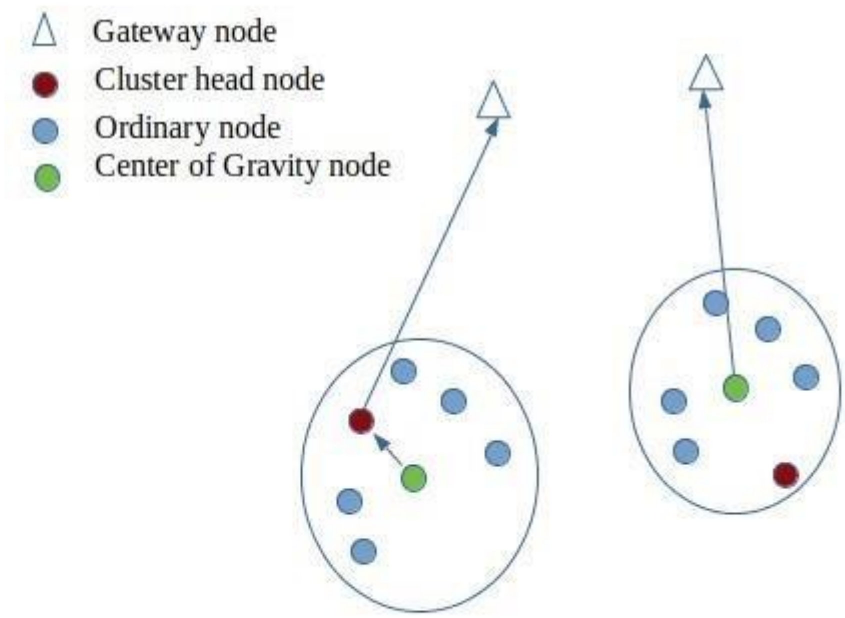

Figure 8:Coordination diagram of center of gravity node and cluster head.

Failure Reformation Phase

If CH's energy consumption is high, the center of gravity node is initiated, and it evaluates whether information needs to be conveyed to GN by comparing the distance between CH and the center of gravity node to GN. CH's function is currently determined above and below the center of gravity node. The center of gravity node assumes CH work and then transmits the information to CH, which subsequently transmits the information to GN, as indicated in Figure 8's left figure. The center of gravity node is close to the gateway node, as indicated in Figure 8's right figure; in this case, CH becomes an ordinary node, and the center of gravity node becomes a new CH. Simultaneously, because CH is a higher-energy node in the cluster, if it does not represent the function that CH should have, the cluster is in a state of failure and must be redeployed (rotation mechanism).

CHAPTER FIVE

SIMULATION RESULTS AND EVALUATION

In this chapter, simulation results are discussed for the network scenario to compare the results model of the proposed solutions with LEACH and LEACH-c by the parameters of network live nodes, dead nodes, the number of packets transmitted to gateway node and residual energy of the network under the three protocols

Experiment and Discussion

The enhanced LEACH technique is compared to LEACH and LEACH-C in the same simulated environment.

We primarily compare the amount of alive nodes, dead nodes, data packets, and the network's remaining energy across the same number of rounds which is 5000. Assume the network consists of 200 nodes dispersed in a 200 x 200 plane. The Initial energy of nodes is 0.5 J. The proposed enhanced LEACH technique will be represented by E-LEACH in all simulation figures in this research.

The E-LEACH protocol operation flow chart is shown in Table 1, and the simulation experiment parameters are shown in Table 2.

Table 1: The E-LEACH protocol running process.

Table 1: Algorithm 1 CH selection in E-LEACH 1:
initialize Nodes(Node), rounds(rmax), energy of nodes(E_r), number of clusters(c) and distance(d)
2: for round = 0 to rmax do
3: Calculate the distance and energy of all nodes from other cluster members using equation 4.
4: for k = 0 to C do
5: D_{min} = 0
6: for i = 1 to n do
7: if Node[i].cluster == k then
8: if D_{min} == 0 then
19: if Node[i].E_r > E_{kt} then {Check for re- quired condition}
11: D_{min} = Node[i].distance
12: Node[i].type = CH
13: end if
14: else if Node[i].E_r >
E and Node[i].distance < D_{min} then

```
Node[i].type = CH
{Assign node as CH.}
end if
end if
end for
```

Table 2: Simulation experiment parameters.

Parameter	Parameter value
Network size	200m× 200m
Number of nodes	200
*E*elec	50 nJ/bit
Efs	100*pJ*/(bit · *m*2)
*E*amp	0.0013*pJ*/(bit · *m*4)
Initial energy	0.5 J
d0	87m
Packet size	4000 bits

Comparison of the Numbers of Dead Nodes

The bar graph in Figure 9 As the bar graph shows the comparison of the corresponding round numbers under the three protocols such as one node dying, half of the nodes dying, and all nodes dying during the 5000 rounds of CH elections in the network. The abscissa is the number of dead nodes, and the ordinate is the number of rounds. From the first node death indicator, the E-LEACH protocol achieved a performance improvement of about 87.5% compared with the LEACH protocol. According to the index of half node death, the E-LEACH protocol extends the life cycle by 30% compared with the LEACH protocol and about 35% longer than the LEACH-C [23]. According to the index of death of all nodes, LEACH protocol died when it was around 1300 rounds, LEACH-C [23] died when it was around 1100 rounds, and the E-LEACH died when it was around 2500 rounds. The network life was increased by 16.7% compared to LEACH protocol and 26.7% compared to LEACH-C [23]. From the above comparison, we can see that it can balance the network energy. Its advantages are as follows: the delay of the death of the first node reflects the efficiency of the network' utilization energy; the death time of the last node is prolonged, which realizes the purpose of prolonging the network life cycle.

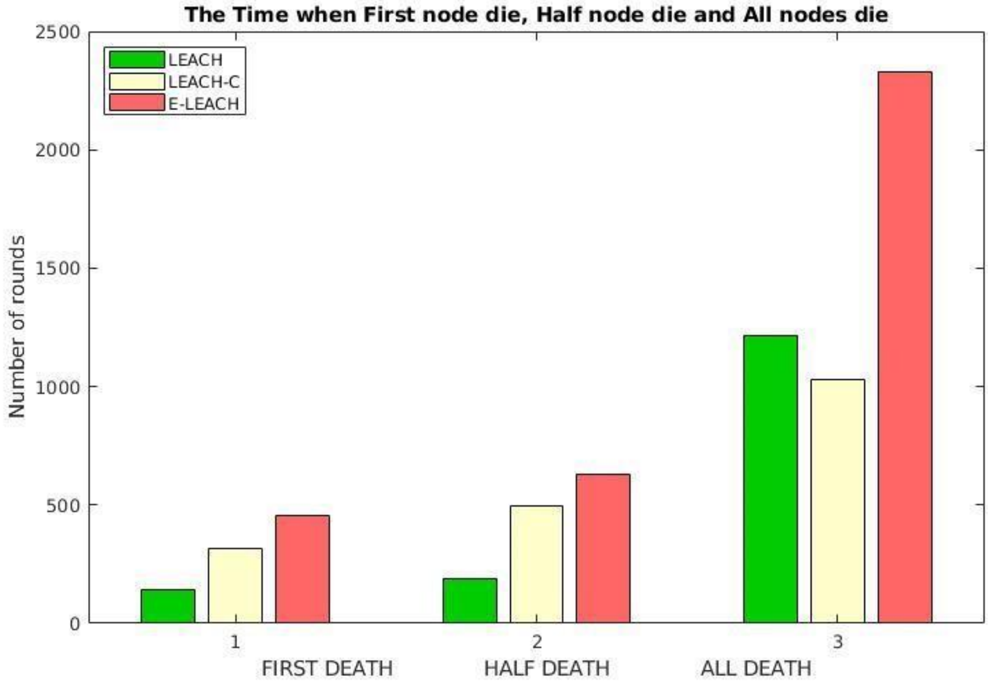

Figure 9 :Comparing the network life cycle

Comparison of the Number of Alive Nodes

The curve in Figure 10 show the comparison of the number of alive nodes when the protocol runs 5000 rounds. The abscissa indicates the number of rounds, and the ordinate indicates the number of alive nodes over time. As can be seen from Figure, the number of alive nodes of the E-LEACH protocol is basically much more than that of LEACH protocol in 5000 rounds. Compared with LEACH-C [23] protocol, the number of alive nodes before 400 rounds of the E-LEACH protocol has little difference. In general, the ELEACH protocol focuses on protecting the lifetime of nodes, so it is better than the other two algorithms in the performance of node alive number.

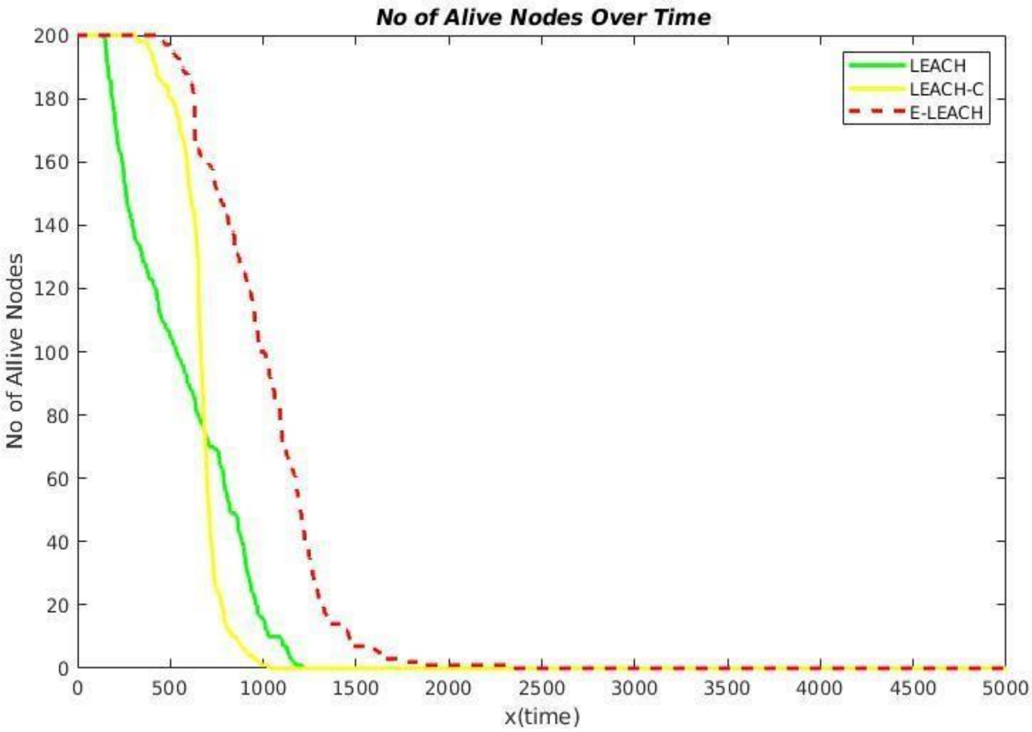

Figure 10: Comparison of the number of alive nodes under the three protocols.

Comparison of the Number of Dead Nodes

As shown in Figure 11, the curve shows the comparison of the number of dead nodes when the protocol runs 5000 rounds. The abscissa is the number of rounds, and the ordinate is the number of dead nodes. As can be seen from Figure, the first dead node appears around round 400 between LEACH-C [23] and the E-LEACH. Before 400 rounds, the E-LEACH protocol and LEACH-C perform significantly better than LEACH in terms of the number of dead nodes, and there is little difference between the two protocols. After 1400 rounds, LEACH nodes die significantly. On the whole, the number of deaths of E-LEACH nodes is balanced which maximizes the lifetime of nodes. By improving the election function and adding new threshold function, the optimized LEACH-C protocol is designed to delay the time of the first dead node, so that more nodes can run until the end, so as to realize the balanced development of the network and improve the scalability of wireless sensor networks.

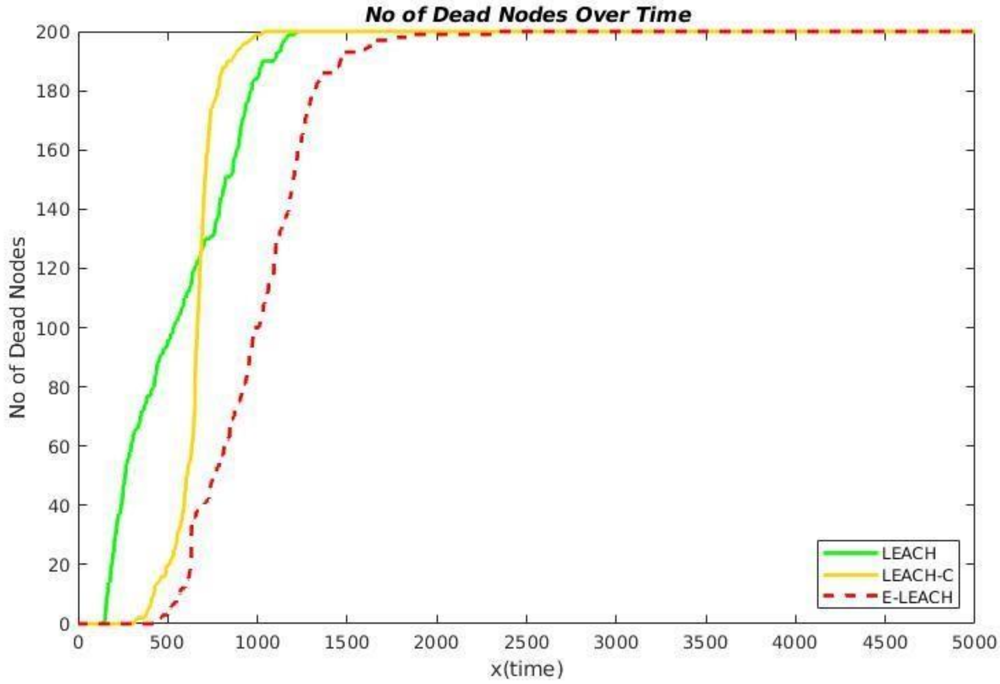

Figure 11: Comparison of the number of dead nodes under the three protocols

Comparison of the Number of Data Packets

As shown In Figure 12, the curve shows the comparison of the number of packets when the protocol runs 5000 rounds. The abscissa indicates the number of rounds, and the ordinate indicates the number of data packets. As can be seen from Figure, the LEACH protocol is compared with LEACH-C and the E-LEACH, and the number of packets exceeds LEACH and LEACH-C [23]. It can be seen that 500 rounds is a turning point which has little difference before 500 rounds and an increasing trend after 500 rounds. This is because a new measurement formula compared with [24] proposed considered the relevant factors of CH election and CH transmission, resulting in uniform energy consumption, reducing the variation of cluster heads and energy consumption, and optimizing the energy receiving efficiency of gateway nodes. The final optimized LEACH significantly transmits twice more packets than LEACH, and about 30% more packets than LEACH-C [23]. It further optimized the scalability of the protocol and made transmission increase twice.

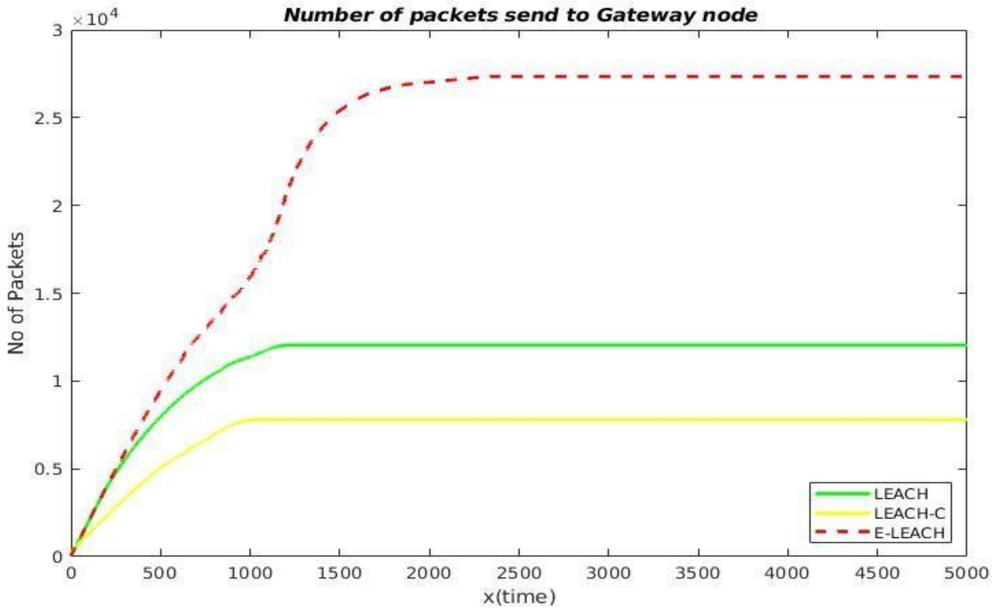

Figure 12: : Comparison of the number of packets transmitted under the three protocols.

Comparison of Network Residual Energy

The majority of the energy used by nodes comes from collecting and transmitting data packets. Only a balanced energy consumption between nodes can ensure the wireless sensor network's long-term viability. The load should be dispersed evenly between the nodes. In 5000 cycles, Figure 13 depicts the network's residual energy under the two protocols. The revised protocol is roughly 35% more energy efficient than the original LEACH total residual energy, with a linear relationship reflecting the decreased energy usage and better balance. The residual energy distribution of nodes is unequal in Figure, indicating polar weathering for the LEACH technique. The alteration of the original threshold function value, especially after the death of the first node, allows all nodes to become cluster heads, increasing unpredictability and increasing energy consumption. Some nodes expire early, whereas others have a lot of energy. It optimizes CH selection by taking into account node residual energy, and nodes in the network consume energy in a uniform manner; nearly all nodes in the network run out of energy at the same time. In the case of the identical initial energy, the simulation results are compared to [4], which shows that its nodes have higher energy at all times and a faster convergence rate. As a result, the E-LEACH protocol has a better energy balance and extends the network's life cycle.

In conclusion, as shown in Figures 9–13 the enhanced LEACH protocol can effectively postpone the first dead node time, safeguard the node's life, and increase network energy on the basis of the transmission of the same data packet in the early stages of WSN. It ensures that more data packets are delivered in the middle and latter stages of transmission, and that the energy of the nodes is balanced. The network's nodes are nearly exhausted at the same time, achieving the goal of extending the network's life cycle.

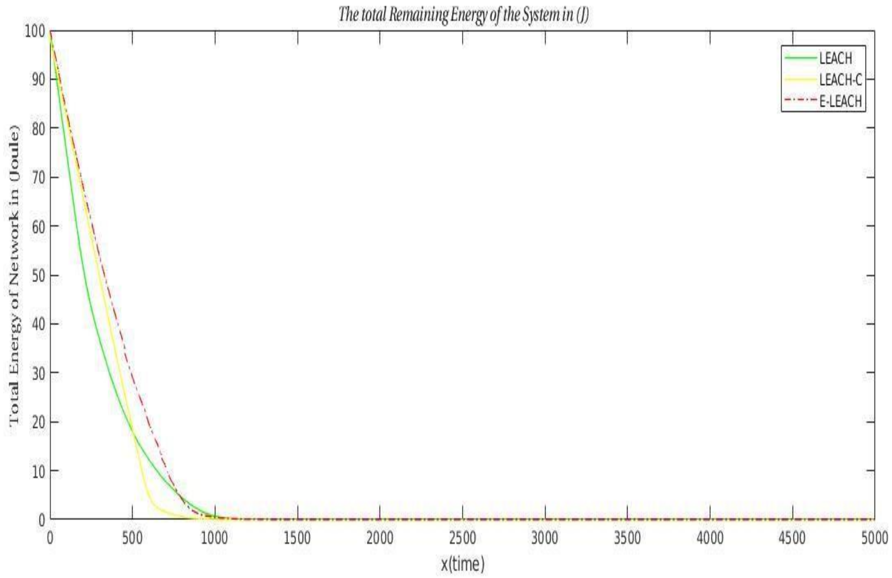

Figure 13: Residual energy of the network under the three protocol

CHAPTER SIX

CONCLUSION AND FUTURE WORK

In this paper the cluster head selection, transmission within clusters, communication between clusters, auxiliary transmission in LEACH protocol are all improved, which addresses the disadvantages of the existing LEACH protocol by taking into account residual energy, transmission angle, and distance to improve energy efficiency in WSNs. It is discovered that it has significant advantages in terms of the number of surviving nodes, network life cycle, and network residual energy through our works simulation comparison. However, based on the number of rounds until all nodes die, it only has 5000 rounds of time, which is not ideal and greatly limits the scope of application.

In our future work, we have a goal to increase the network's performance by reducing the number of rounds in which all nodes die, lowering energy consumption, and extending the network's life cycle. At the same time, we strive to create a LEACH heterogeneous network for real-time environment that is optimal.

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APPENDIX A

```
%%%%%%%%%%%%%%%% E-LEACH Implementation
%%%%%%%%%%%%%%%%

 clear;

% Dimensions of the network range (in

metres) % x_max=200 y_max=200 x=0

y=0

% x coordinates and y coordinates of the base

station % base_x=0.5*x_max

base_y=0.5*y_max

% Total number of nodes in the field

% n=200; %

% Number of Dead Nodes in the initial state %

nodes_dead=0;

%%% Values for the energy parameters %%%

% Initial Energy for a node (unit in Joules)%

Eo=0.5;

% Energy required for communication ( units in Joules/bit)%

Eelec=5*10^(-9);

ETX=50*10^(-9);

ERX=50*10^(-9);

% Energy for the transmitting amplifier(units in Joules/bit/m^2) %

Efs=10*10^(-12)

Emp=0.0013*10^(-12); %  (Energy spent by the amplifier to transmit the
bits) %

% Data Aggregation Energy (units in Joules/bit) %
```

```
EDA=5*10^(-9);

% Size of data package (units in bits)%

k=4000;

% Probability for the cluster head approval % p=0.1; %
i.e. 10 % of the total nodes are assumed to give good
results
% Number of Clusters %

Nc=p*n;

% Present count of operating

Nodes %

nodes_being_operated=n;

temp_val=0; yd1=33

%Percentage of the advanced nodes in the

network m=0.1;

%a is alpha (times the energy of advanced nodes are greater than that of

normal nodes) a=1;

% Maximum number of rounds %

rmax=5000

%%%% End of Parameters %%%%

%Computation of do

do=sqrt(Efs/Emp);

Et=0;

%figure(1
); for
```

```
i=1:1:n

if (i<=5)

        E_LEACH(i).xd=rand(1,1)*x_max;

        E_LEACH(i).yd=rand(1,1)*yd1;

        E_LEACH(i).E=Eo*(1+a);


E_LEACH(i).ENERGY=1

;

E_LEACH(i).type='A';

end     if (i>10 &&

i<=100)

        E_LEACH(i).xd=rand(1,1)*x_max;

        E_LEACH(i).yd=33+rand(1,1)*yd1;

        E_LEACH(i).E=Eo;


E_LEACH(i).ENERGY=0

;

E_LEACH(i).type='N';

end     if(i<=10 && i>5)

        E_LEACH(i).xd=rand(1,1)*x_max;

        E_LEACH(i).yd=66+rand(1,1)*yd1;

        E_LEACH(i).E=Eo*(1+a);


E_LEACH(i).ENERGY=1

;

E_LEACH(i).type='A';

end end
```

```
S2(n+1).xd=base_x;

S2(n+1).yd=base_y;

flag_first_dead_ELEACH=0;

alive_ELEACH=n;

%counter for bit transmitted to Bases Station and to

Cluster Heads packets_TO_BS12=0;

packets_TO_BS22=0;

packets_TO_BS_ELEAC

H=0;

packets_TO_CH2=0;  for

r=0:1:rmax

   %Election Probability for center of

gravity Nodes     padv= (

p*(1+a)/(1+(a*m)) );     %Operations for

sub-epochs     if(mod(r, round(1/padv)

)==0)         for i=1:1:n

            if(E_LEACH(i).ENERGY==1)

E_LEACH(i).G=0;


end

end     end

   dead_ E_LEACH=0;

%Number of dead  Nodes

dead_ E_LEACH=0;

%Number of dead Normal
```

```
Nodes    dead_nrml_
E_LEACH=0;
  tic    for
i=1:1:n
    %checking if there is a dead node
if (E_LEACH(i).E<=0)
dead_ E_LEACH=dead_
E_LEACH+1;


      if(E_LEACH(i).ENERGY==1)
dead_adv_ E_LEACH=dead_adv_
E_LEACH+1;          end

      if(E_LEACH(i).ENERGY==0)
dead_nrml_ E_LEACH=dead_nrml_
E_LEACH+1;
      end
end
    if (E_LEACH(i).E>0)
E_LEACH(i).type='N';          if
(E_LEACH(i).ENERGY==0)
      end
      if (E_LEACH(i).ENERGY==1)
      end
end
    STATS.DEAD_ E_LEACH(r+1)=dead_ E_LEACH;
```

```
STATS.ALIVE_ E_LEACH(r+1)=alive_ E_LEACH-dead_ E_LEACH;
end
%When the first node dies     if
(dead_ E_LEACH==1)
if(flag_first_dead_
E_LEACH==0)
first_dead_ E_LEACH=r
flag_first_dead_ E_LEACH=1;
end     end     for(i=1:1:n)        if(E_LEACH(i).E>=0)
if(E_LEACH(i).type=='N')              distance=sqrt( (E_LEACH(i).xd-
(S2(n+1).xd) )^2 + (E_LEACH(i).yd-(S2(n+1).yd) )^2 );              if
(distance>do)

E_LEACH(i).E=E_LEACH(i).E-((ETX+EDA)*(4000)  +        Emp*4000*(
distance*distance*distance*distance ));
end
if (distance<=do)
E_LEACH(i).E=E_LEACH(i).E- ( (ETX+EDA)*(4000)  + Efs*4000*( distance *
distance ));
end
packets_TO_BS12=packets_TO_BS12+1;
end        end     end
countCHs2=0;     cluster2=1;
for i=1:1:n
if(E_LEACH(i).E>=0)
if(E_LEACH(i).G<=0)
```

```
if(E_LEACH(i).type=='A')

temp_rand=rand;

            if( ( E_LEACH(i).ENERGY==1 && ( temp_rand <= ( padv / ( 1 - padv *
mod(r,round(1/padv)) )) ) )  )        countCHs2=countCHs2+1;

      packets_TO_BS22=packets_TO_BS22+1;

              E_LEACH(i).type='C';

              E_LEACH(i).G=(1/padv)-1;

              C(cluster2).xd=E_LEACH(i).xd;

              C(cluster2).yd=E_LEACH(i).yd;

              distance=sqrt( (E_LEACH(i).xd-(S2(n+1).xd) )^2 + (E_LEACH(i).yd-
(S2(n+1).yd) )^2
);

              C(cluster2).distance=distance;

              C(cluster2).id=i;

              X(cluster2)=E_LEACH(i).xd;

Y(cluster2)=E_LEACH(i).yd;

cluster2=cluster2+1;

              %        Calculation of Energy
dissipated                    distance;

if (distance>do)

E_LEACH(i).E=E_LEACH(i).E-((ETX+EDA)*(4000)  +        Emp*4000*(
distance*distance*distance*distance ));

              end

if (distance<=do)

                E_LEACH(i).E=E_LEACH(i).E- ( (ETX+EDA)*(4000)  +
Efs*4000*( distance * distance ));
```

```
                    end
end                end
end            for i=1:1:n
            if ( E_LEACH(i).type=='A' && E_LEACH(i).E>0 )
               if(cluster2-1>=1)
min_dis=inf;
min_dis_clustera=1;
for c=1:1:cluster2-1
temp=min(min_dis,sqrt(
(E_LEACH(i).xd-C(c).xd)^2 +
(E_LEACH(i).yd-C(c).yd)^2 ) );
if ( temp<min_dis )


min_dis=temp;
min_dis_cluster2=c;
end
end
  %Energy dissipated by  Cluster menmber for transmission of packet
                    if (min_dis>do)
                       E_LEACH(i).E=E_LEACH(i).E- ( ETX*(4000) + Emp*4000*( min_dis * min_dis * min_dis * min_dis));
                    end
if (min_dis<=do)
                       E_LEACH(i).E=E_LEACH(i).E- ( ETX*(4000) + Efs*4000*( min_dis * min_dis));
                    end
```

```
%Energy dissipated by clustre head in recieving
if(min_dis>0)
        S2(C(min_dis_cluster2).id).E = S2(C(min_dis_cluster2).id).E- (
(ERX + EDA)*4000
);
        PACKETS_TO_CH(r+1)=n-dead-cluster2+1;
      end


      E_LEACH(i).min_dis=min_dis;
      E_LEACH(i).min_dis_cluster2=min_dis_cluster2;


end
end
end    end
CLUSTERH
S(r+1)=cluste
r2+1;

    STATS.CLUSTERHEADS2(r+1)=cluster2+1;
    end
  packets_TO_BS_E-LACH=packets_TO_BS12+packets_TO_BS22;
STATS.PACKETS_TO_BS_E-LACH(r+1)=packets_TO_BS_E-LACH;
 end
%%%%%%%%%%%%%%%% PLOTS
%%%%%%%%%%%%%%%%%%
figure(2); r=0:rmax; plot(r,STATS.ALIVE_LEACH(r+1),'-
r',r,STATS.ALIVE_ E_LEACH(r+1),'-g') legend('LEACH','E-
```

```
LEACH'); xlabel('Number of Rounds'); ylabel('Number of Alive

Nodes'); figure(3);

plot(r,STATS.DEAD_LEACH(r+1),'-r',r,STATS.DEAD_

E_LEACH(r+1),'-g') legend('LEACH','E-LEACH');

xlabel('Number of Rounds'); ylabel('Number of Dead Nodes');


figure(4);

plot(r,STATS.packets_sent_TO_BS_LEACH(r+1),'-r',r,STATS.PACKETS_TO_BS_
E_LEACH(r+1),'g')

legend('LEACH','E-LEACH');

xlabel('Number of Rounds');

ylabel('Number of Packets sent to

BS');

%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```