INVESTIGATIONS ON ENERGY EFFICIENT ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORK FOR ENHANCED LIFETIME OF SENSOR NODES

Thesis

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by

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SUPERVISOR'S CERTIFICATE

This is to certify that Mr**. Amit Gupta** has completed the necessary academic turn and the swirl presented by him/her is a faithful record is a bonfire original work under my guidance and supervision. He/She has worked on the topic **"Investigations on Energy Efficient Routing Protocols for Wireless Sensor Network for Enhanced Lifetime of Sensor Nodes"**under the School of **Engineering & Technology Maharishi** University of Information Technology, Lucknow.

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Date:

DECLARATION BY THE SCHOLAR

I hereby declare that the work presented in this thesis entitled "**" Investigations on Energy Efficient Routing Protocols for Wireless Sensor Network for Enhanced Lifetime of Sensor Nodes** " in fulfillment of the requirements for the award of Degree of Doctor of Philosophy, submitted in the Maharishi School of Engineering & Technology Maharishi University of Information Technology, Lucknow is an authentic record of my own research work carried out under the supervision of Dr. Rakesh Kumar Yadav . I also declare that the work embodied in the present thesis-

i) is my original work and has not been copied from any journal/ thesis/ book; and
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LIST OF ABBREVIATIONS

Abbreviation	Full Form
LEACH	Low Energy Adaptive Clustering Hierarchy
FZ-LEACH	Far-Zone LEACH
LEACH-A	LEACH with mobile agent
K-LEACH	K-medoids LEACH
Mobile LEACH	LEACH for mobile networks
S-LEACH	Secure LEACH
MODLEACH	Modified LEACH
V-LEACH	Vice Cluster LEACH
LEACH-B	Balanced LEACH
WSN	Wireless Sensor Network
EAMMH	Energy Aware Multi-Hop Multi-Path Hierarchy
CH	Cluster Head
CAG	Cluster Aggregator
CWSN	Cooperative Wireless Sensor Network
Eelec	Energy dissipation per bit
Eamp	Amplifier energy dissipation
EDA	Energy for Data Aggregation
EIRX	Energy for Receiving Bits
ETX	Energy for Transmitting Bits
PCH	Probability of a Node to Become Cluster Head
Tn	Threshold for Cluster Head Selection
ECH	Energy Consumption by a Cluster Head
EnonCH	Energy Consumption by a Non-Cluster Head
fs	Free Space Energy Model
mp	Multi-Path Fading Model
SNR	Signal-to-Noise Ratio
DEEC	Distributed Energy-Efficient Clustering
TEEN	Threshold-sensitive Energy Efficient Network

SEP	Stable Election Protocol
ILEACH	Improved LEACH

ABSTRACT

A WSN's wireless components include micro sensor nodes in addition to a base station. It is not possible to charge the battery of the tiny sensor node while the network is running. Ensuring that WSNs last as long as possible is, hence, of paramount importance. Wireless sensor networks have seen an explosion in popularity due to the grand promise they hold of connecting the physical and digital realms. Because they run on batteries and could be placed in potentially hazardous places, replacing these gadgets is a major pain. Therefore, improving these networks' energy efficiency is of the utmost importance. Improving WSN performance through the development of clustering and cluster head selection algorithms is the primary objective of this research. Our protocol architecture, LEACH, enhances system lifetime, latency, and application-perceived quality by integrating energy-efficient cluster-based routing, media access, and data aggregation. It is designed for both homogeneous and heterogeneous WSNs. We rebrand LEACH as Improved LEACH after enhancing it with a cluster head replacement technique and two distinct transmit power levels, making it one of the most widely used routing protocols for wireless sensor networks. Our Optimized LEACH achieves better results than LEACH in terms of throughput, network lifetime, and cluster head formation. Lastly, an abridged performance analysis of LEACH and Improved LEACH takes into account throughput, network life, and cluster head replacements. The work is enhanced and expanded by integrating evolutionary algorithms that are based on the LEACH protocol, which is optimized using a genetic algorithm. By reducing power consumption and increasing the lifespan of WSNs, the proposed method outperforms the status quo in computational modeling.

Keywords-*WSN, LEACH, LEACH-C, Network Life Time, Base Station, Sensor Node, Evolutionary Computing, Genetic Algorithm, Soft Computing*

CHAPTER-1

INTRODUCTION

1.1 Introduction

Networks (WSNs) have emerged as a pivotal technology with a diverse range of applications spanning from environmental monitoring and industrial automation to healthcare and military operations. These networks are composed of small, resource-constrained sensor nodes that collaborate to collect and transmit data to a central sink or base station. One of the most critical challenges in the design and operation of WSNs is the limited energy resources available to the sensor nodes. The energy constraints of these nodes impose significant restrictions on their operational lifespan and overall network performance. Consequently, the development of energy-efficient routing protocols has become a paramount research focus to extend the lifetime of sensor nodes and ensure the sustainability and reliability of WSNs.

The inherent energy constraints of sensor nodes are rooted in their compact size, limited battery capacity, and the often remote or inaccessible deployment locations. Unlike traditional communication networks, where energy is relatively abundant and readily accessible, sensor nodes must rely on their finite energy reservoirs, which are usually non-rechargeable due to the impracticality of frequent maintenance in remote areas. As a result, the design of routing protocols for WSNs necessitates a profound understanding of energy consumption patterns, as well as the development of strategies to optimize the utilization of this precious resource.

Energy-efficient routing protocols for WSNs have gained immense significance as they directly impact the network's performance in terms of data transmission reliability, coverage, and most crucially, the lifespan of sensor nodes. These protocols aim to minimize energy consumption by adapting routing decisions and communication patterns based on the specific needs and constraints of the network. In essence, they seek to strike a delicate balance between achieving the desired network objectives and preserving the limited energy resources of the sensor nodes.

The quest for enhanced lifetime of sensor nodes in WSNs has driven extensive research efforts, leading to the development of a multitude of energy-efficient routing protocols over the years. Researchers have explored various algorithmic approaches, heuristics, and optimization techniques to address this challenge. These protocols can be broadly categorized into proactive, reactive, and hybrid routing approaches, each with its strengths and limitations.

Proactive routing protocols, also known as table-driven protocols, establish routes in advance and maintain up-to-date routing information, ensuring that routes are readily available when needed. Examples of proactive protocols include Optimized Link State Routing (OLSR) and Destination-Sequenced Distance Vector (DSDV) routing. While these protocols offer low latency and are suitable for scenarios with constant data traffic, they may incur high control message overhead, which can be detrimental to energy efficiency.

In contrast, reactive routing protocols, such as Ad Hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR), create routes on-demand as data packets are generated. These protocols reduce control message overhead compared to proactive protocols but introduce latency during route discovery. Reactive protocols are well-suited for scenarios with sporadic traffic patterns and dynamic network topologies.

Hybrid routing protocols attempt to combine the strengths of both proactive and reactive protocols to strike a balance between control message overhead and latency. Hybrid protocols like Zone Routing Protocol (ZRP) aim to achieve better energy efficiency by selectively using proactive and reactive strategies based on network conditions. The choice of routing protocol depends on the specific requirements and characteristics of the WSN application.

The development and evaluation of energy-efficient routing protocols for WSNs have been facilitated by advancements in simulation tools and testbeds. Researchers use these tools to model and analyze the performance of routing protocols under various conditions, allowing for systematic comparison and optimization. Metrics such as energy consumption, network lifetime, packet delivery ratio, and end-to-end delay play a pivotal role in assessing the effectiveness of these protocols.

As the applications of WSNs continue to expand into diverse domains, including agriculture, healthcare, environmental monitoring, and smart cities, the need for energy-efficient routing protocols becomes even more pronounced. In agricultural settings, for instance, WSNs are deployed for precision farming, where sensor nodes monitor soil conditions, crop health, and weather patterns. In healthcare, wearable sensors and medical implants form WSNs to monitor patients' vital signs, improving the quality of healthcare delivery. These applications demand not only energy-efficient routing but also real-time data transmission and low-latency communication, further challenging the design of routing protocols.

In conclusion, the quest for energy-efficient routing protocols in Wireless Sensor Networks is a dynamic and evolving field of research. With the increasing deployment of sensor nodes in diverse applications, the need to maximize the lifespan of sensor nodes while ensuring reliable data transmission remains a pressing concern. This research topic has witnessed a plethora of innovative approaches and protocols, driven by the overarching goal of achieving sustainability, reliability, and efficiency in WSNs. In the following sections, we will delve deeper into the various dimensions of energy-efficient routing protocols, exploring their design principles, optimization strategies, and their applicability in different scenarios. We will also examine the challenges and open research questions that continue to shape this fascinating field, emphasizing the importance of addressing energy efficiency for the continued growth and success of Wireless Sensor Networks

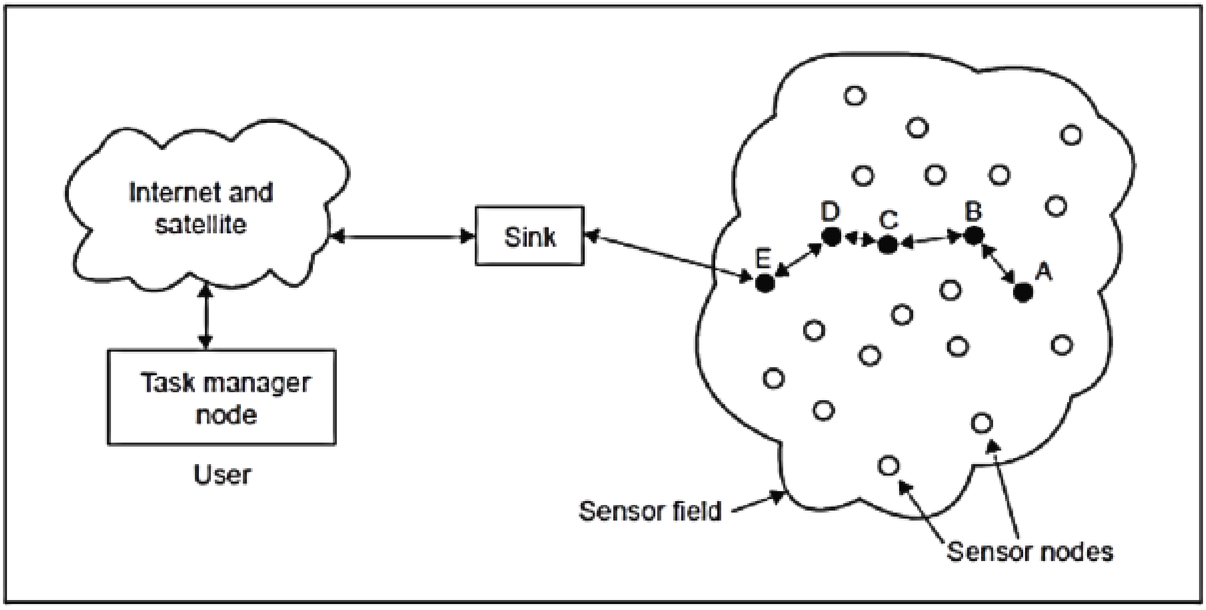

Figure 1.1 Outline of Wireless Sensor Network [4]

The revolutionary advances achieved in the fields of micro-electromechanical systems, digital electronics, and wireless communication, guided the development and implementation of highly effective, versatile, and inexpensive sensor nodes. Over short distances, they are able to accurately sense, analyze, and transmit data. This factor eventually led to the widespread deployment of these sensor nodes in collaboration, leading to the development of what are now known as Wireless Sensor Networks (WSNs).

Sensor nodes or mobile sensors collect data from the monitored area and relay it over wireless connections to a central hub, known as a base station (BS) or sink. The sensor nodes may be mobile or fixed, and they may be of varying types and characteristics. The collected information is sent to the BS/sink over one or more hops. Figure 1.1 depicts the fundamental architecture of a WSN system.

Large-scale automated monitoring of forest fires, avalanches, storms, failure of land-specific utilities, traffic, hospitals, and many more will one day be possible thanks to wireless sensors networks. Automatic meter reading in buildings, as well as the generation and regulation of processes, are only two examples of how we've started to put monsters in their place.

It's a network of specialized transducers that monitor and store data from many places. Generally, characteristics such as temperature, heat, wind direction and velocity, light strength, vibration rate, sound intensity, voltage in the power line, chemical concentrations, pollutant rates, and vital biological processes are regulated.

Multiple detection stations, or sensor nodes, employ a transducer, microcontroller, transceiver, and power supply to detect objects in their environment. The transducer converts the physical events it detects into electrical impulses. The sensor's output is recorded and kept in the microprocessor. The transceiver, whether wired or wireless, takes instructions from and sends data to a centralized computer. Each sensor node receives its power either from a solar panel or a battery.

In sensor networks, a base station is often situated beyond the limit of data sensing due to the data transmission paradigm. A variety of routing strategies have been proposed by researchers to increase the effectiveness of wireless sensor networks. The majority of protocols for WSNs are based on unidirectional routing, which doesn't account for the varying impacts of traffic intensities. Nodes close to the base station are frequently employed as relay nodes, therefore a hop-by-hop data transfer improves routing table maintenance overhead but drastically shortens the life of these nodes. As the nodes close to the hub lose power, the network as a whole suffers. No such system can be found. Various routing systems have been presented as potential solutions to these issues. Among them, clustering algorithms attracted a lot of attention because they can adjust for several variables at once, which is crucial to the smooth functioning of wireless sensor networks. Network longevity is improved, and power consumption is decreased significantly, when one arbitrary node is chosen to support many sensor nodes. Clustering refers to the process of choosing a single node to act as a hub for several of its neighbouring nodes.

1.2 Ad-Hoc Network and WSN v/s Traditional Network

WSNs are different in important ways from both conventional wired networks and ad hoc wireless networks. Differentiation occurs mainly because of energy, communication range, bandwidth, computation, and memory constraints in WSNs. Due to severe limitations in available resources, WSN protocol advancements must take into account unique design restrictions. Beyond that, however, WSN design is entirely context-specific. The network's structure, size, and deployment method are all determined by the needs of the application. Unlike conventional and ad hoc networks, WSNs are purpose-built, making it impossible to exploit their algorithms and protocols. Sensor networks and ad hoc networks differ primarily in the following ways:

a) The number of nodes in WSNs will be enormous in comparison to those of other types of networks.

b) Sensor nodes will be widely dispersed.

c) Sensor nodes are vulnerable to disasters because of the harsh climate and diminishing energy supply.

WSNs are characterized by frequent topology shifts, hence (d) topology evolution is to be expected.

e) Ad hoc networks often use point-to-point communication, whereas sensor nodes rely on broadcast communication.

g) Power, computational, and memory resources at sensor nodes are severely limited.

There may not be universal identification because of the large number of sensor nodes and associated costs.

The vast majority of uses for sensor nodes will see widespread implementation. Due to the proximity of the sensor nodes, multihop communication uses less energy, and lower transmission powers are feasible compared to more conventional networks. When communicating across long distances, the consequences of signal propagation can be mitigated. However, WSNs need to prioritize energy saving strategies due to limited energy supplies.

1.3 Attributes of Wireless Sensor Networks

a) It bridges the gap between the real and the digital, when used on huge patio-temporal scales.

b) it enables the ability to observe the hitherto unobservable with high resolution.

c) It incorporates several skilled software programs for industrial manufacturing, research, transportation, civil road and rail networks, and security.

1.4 Working of Wireless Sensor Network

The standard components of a Wireless Sensor Network (WSN) include several sensors linked to a central base station. As tiny, self-sufficient devices, sensors face limitations in areas such as battery life, processing speed, communication range, and memory. In addition, they come equipped with transceivers that allow them to collect data from their surroundings and transmit it to a designated base station. There, the user may access and save the collected characteristics. Wireless sensor nodes are illustrated in the example figure 1.2 below.

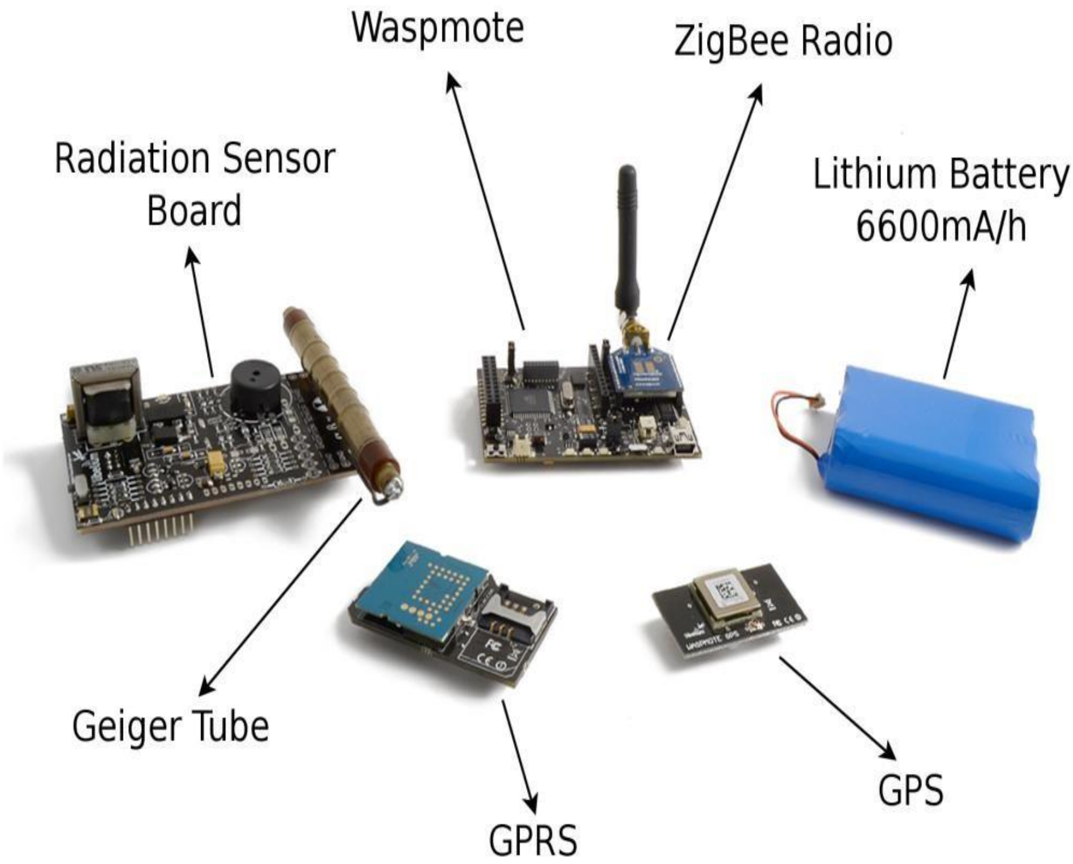

Figure 1.2 Wireless Sensor Nodes Example [7]

The sensors that make up these networks are often spread out at random and permitted to carry out their tasks effectively and efficiently without human intervention. Due to this haphazard deployment, the node density throughout the WSN is typically not uniform. The energy constraints of the individual sensors that make up a sensor network also make the network as a whole very power-hungry. These sensors' communication components are tiny, power-poor, and range-limited. Nodes gradually die out, reducing the network's density, due to both the likely disparity in node density over some areas of the network and the energy constraints of the sensor nodes. Furthermore, many sensors become unusable or malfunctioning due to the frequent deployment of WSNs in difficult environments. Therefore, in order to keep maintenance to a minimum, these networks must be fault-tolerant.

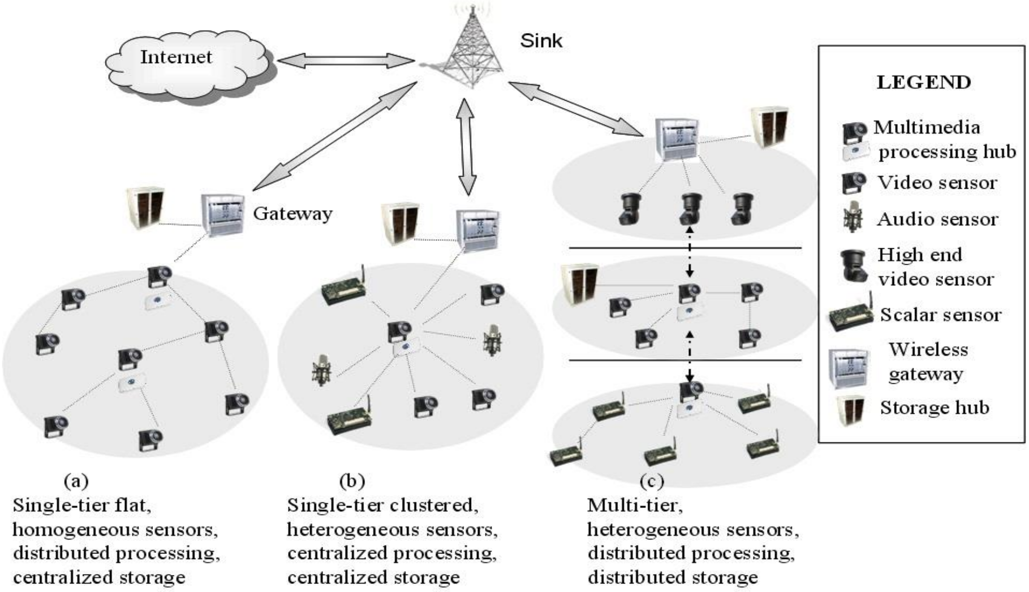

Figure 1.3 Wireless Sensor Network [10]

In most cases, the network architecture is in a constant state of flux, thus replacing exhausted sensors with new ones is not the best course of action. Implementing routing protocols that execute effectively and need as little energy as possible for communication among nodes is a practical and relevant solution to this problem. There are primarily two parts to the WSN:

1. Nodes for Sense

2. Central Gateway (Basis Station)

1.4.1 Sensor Nodes

As seen in Figure 1.2, a sensor node is usually constructed using a small number of sensors and a mote unit. A sensor is an instrument that takes in data and transmits it to a mote. Temperature, humidity, sound, vibration, and other physical environmental elements, as well as changes in human health markers like heart rate and blood pressure, may be measured using sensors. In sensor nodes, MEMS-based sensors have shown to be quite useful.

A mote is an ad hoc network node that includes a CPU, RAM, battery, A/D converter, and radio transmitter. Combined, a mote and a sensor make up a Sensor Node. Wireless sensor nodes form an ad hoc network known as a sensor network. In order to transmit data packets to a central station, each sensor node can act as a forwarder and implement a multi-hop routing mechanism.

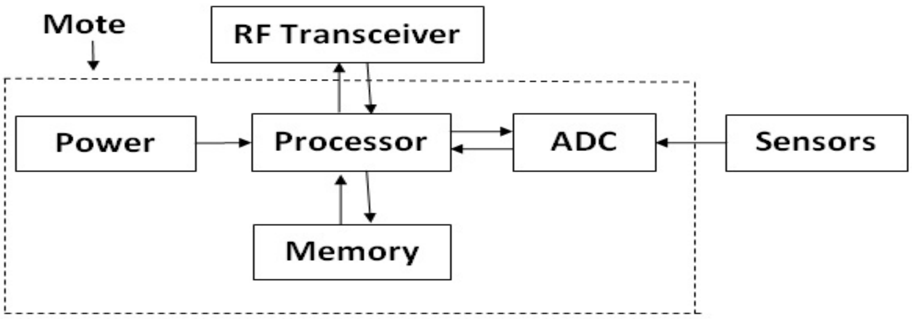

Figure 1.4 Block Diagram of Sensor Node [14]

1.4.2 Central Station

In order to connect the sensor network to another network, a base station is used. A CPU, radio, antenna, and USB interface board make it up. It can communicate with other wireless sensor nodes since it comes preloaded with software for low-power mesh networking. Due to the fact that all of the sensor nodes transmit data to the base station for processing and decision making, base station deployment is crucial in wireless sensor networks. During the deployment of the base station in the sensor network, concerns related to energy saving, coverage of the sensor nodes, and reliability are addressed. It is sometimes believed that base stations are mobile in order to gather data from sensor nodes, even though in most cases they are considered to be static.

Figure 1.5 Base Station Node [19]

1.4.3 Radio Model

As in previous studies, we have presupposed the usage of the same radio model. Fig.1.4 shows that the radio hardware consumes energy in two ways: first, in the transmitter, to power the radio electronics and amplifier, and second, in the receiver, to power the radio electronics.

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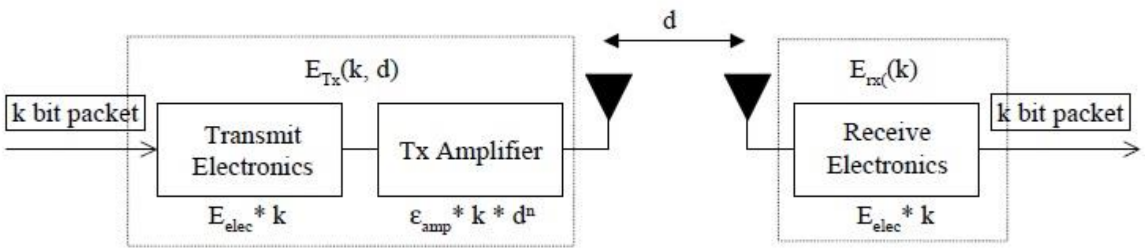

Figure 1.6 Radio Model [32]

. The open space (d2 power loss) and multi path fading (d4 power loss) channel models were utilized for the situations detailed in this project work, with the choice dependent on the distance between the transmitter and the receiver. The free space (fs) model is employed when the distance is below a threshold; the multi path (mp) model is employed otherwise

1.5 WSN Applications

There are a variety of applications for sensor nodes, and they all depend on the continuous monitoring and identification of an event. There is a plethora of applications for WSN, including event detection, periodic measurement, function approximation, edge detection, tracking, and many more. In most cases, tracking and monitoring are the main uses for wireless sensor networks (WSNs). Some of the many domains that make use of monitoring include environmental, health, electrical, inventory, process, and industrial automation, and structural and seismic monitoring. Various tracking software may be used to keep tabs on objects, animals, people, and cars. Some possible applications of WSNs are as follows:

Because of its fault tolerance, self-organization, and ease of deployment, sensor networks show a lot of potential as a sensing technology for military targeting, communication, intelligence, surveillance, and command and control systems. The use of military sensor networks has the potential to uncover a wealth of information on enemy movements, explosions, battlefield surveillance, detection of nuclear and biological attacks, and much more besides.

One area where WSNs have found utility is in environmental monitoring. This includes monitoring the movements of small animals and the effects of weather on agricultural and livestock health and productivity. Data is collected over extended durations using wide-area sensor networks. In addition to its utility in chemical and biological agent detection, WSNs may aid in disaster assistance by detecting floods and wildfires.

• In healthcare, WSN-based technologies provide a multitude of solutions to healthcare system problems, including ambient supported living and the body sensor network. Doctors may monitor their patients' vitals and make the interface accessible for people with mobility challenges with the use of a body sensor network.

• "Smart buildings" hold great promise as a solution to the problem of inefficient HVAC systems, which contribute significantly to the world's energy waste.

If a building's temperature, ventilation, humidity, and other physical properties are monitored in real time and with great precision using a WSN, the energy required by the building might be greatly decreased. Utilizing sensor nodes allows for the monitoring of mechanical stress levels on structures in seismically active regions.

- This is also a good way to describe all the other mobile applications:
- A watchful eye on the ecology and ecosystem is essential.
- Seismic Monitoring.
- Tracing the condition of buildings and other structures.
- Monitor the movement of pollutant in the groundwater.
- Quick Response in an Emergence.
- Monitoring Business Developments
- Peripheral protection and surveillance.
- Management of thermal control systems in buildings.

1.6 WSN Challenges

From ecological monitoring to war surveillance, Wi-Fi sensor networks (WSNs) might enhance a wide range of activities. Among these benefits include low cost, ease of installation, high quality sensing, self-organization of WSNs, and so on. Although WSN technology has numerous advantages, it also has many problems. Some of the constraints caused by the layout are as follows:

a) When designing a network of sensors, it is important to take into account the fact that each node has a limited quantity of energy. When working in the field, it is usually not feasible to change out these power sources. Therefore, a key success metric in WSN is the ratio of lifetime to energy efficiency.

b) Fault tolerance and self-sufficiency are prerequisites for sensor nodes to be deployed in harsh or remote environments. They must have the ability to configure themselves, operate alone and in tandem with other nodes, fix their own mistakes, adapt to novel environments, and so on.

b) Power and data transmission speeds are two examples of the limited computing, storage, and network resources that each node possesses.

d) The network isn't very reliable; users have to rely on each other, and connections are always changing. Presently, neither a centralized registration service nor a universal routing system are available.

1.6 Energy Efficient Routing Algorithm

Data centric, location based, and hierarchical routing algorithms are the three main types of energy efficient routing algorithms. While location-based routing algorithms need the precise whereabouts of each sensor node, data-centric routing algorithms employ meta-data to determine the best path from source to destination prior to transmitting any real data. Clusters are created by dividing the network using a hierarchical routing technique. At the end of each cluster's assembly, a new head is chosen. CH gathers information from its users, compiles it, and then transmits it to a sink. Although more complicated than alternatives, this method is energy efficient.

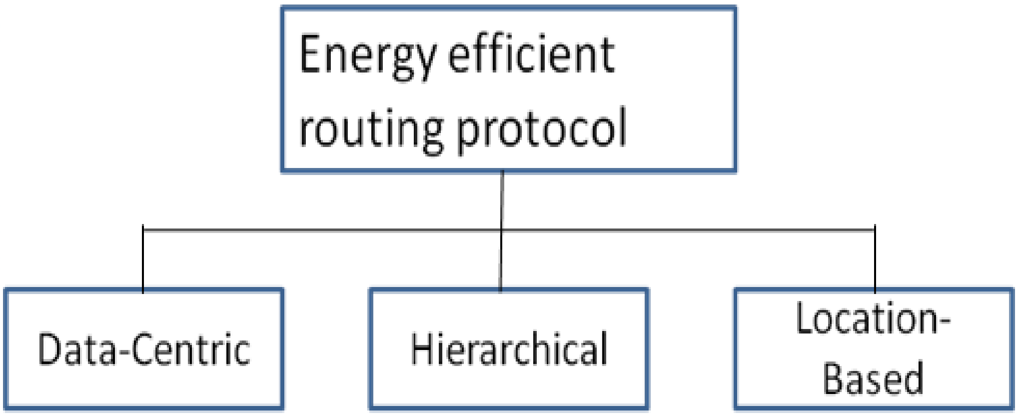

Figure 1.7 Classification of Protocols in WSN

1.6.1 Date Centric

By relying on the name of the requested data and being query oriented, data centric protocols reduce a lot of duplicate communications. When the BS needs information, it will send out queries to a certain area and wait for the nodes there to respond. Because queries are used to obtain data, attribute-based naming is necessary for describing the data's attributes. The number of transmissions is reduced since sensors only broadcast the data that is absolutely necessary based on the query, which is specific to the region of interest. (For instance, the initial data-centric protocol was SPIN).

1.6.2 Hierarchical

By using hierarchical routing, energy efficient routing may be achieved. This means that nodes with greater energy can analyze and convey information, while nodes with lower energy can conduct sensing in the region of interest. such as LEACH, TEEN, and APTEEN.

1.6.3 Location Based

In order for location-based routing protocols to work, it is necessary to know where the sensor nodes are. Optimal path construction without coding methods is possible given position information derived from sources such as GPS (Global Positioning System) signals, received radio signal intensity, etc. (For instance, GEAR, or Geographic and Energy-Aware Routing).

1.7 Energy Efficient Techniques in WSN

While sensing, processing, transmitting, and receiving data, sensors in WSN drain power. Energy is lost due to interference, collisions, eavesdropping, idle listening, control packet weight, and excess weight. Generally speaking, there are five ways to save power: data compression, efficient routing, reduction of protocol overhead, duty cycling, and management of the topology.

a) Transmitting, processing, and generating less data is what data reduction is all about. Some have proposed cutting down on production data by employing approaches based on sampling and predictions. To reduce data volume while processing and transmission, data aggregation and compression are employed.

b) The use of Protocol Overhead Reduction helps to increase the efficiency of protocols. Optimized flooding, adaptive transmission intervals, and cross-layering allow us to drastically reduce the needless overhead generated by retransmission.

c) Optimal network lifetime and decreased energy usage for end-to-end transmission should be the guiding principles for routing protocol development. Routing schemes such as opportunistic, data-centric, hierarchical, geographical, multipath, etc. are frequent.

d) The duty cycle is the fraction of a node's lifetime that it spends functioning. Determining which network sensors will be "on duty" at any particular moment is the main objective of granularity-based duty cycling. One solution to the problem of live nodes' radios being left on when communication is unnecessary is low-granularity duty cycling.

e) As long as the network can continue to function, topology control can alter the transmission power to reduce the strain on the network's infrastructure. The goal of this project is to find ways to make networks last longer by using energy-efficient routing and data-aggregation technologies.

1.8 Overview of Low Energy Adaptive Cluster Hierarchy Protocol

The Low Energy Adaptive Cluster Hierarchy (LEACH) protocol, developed by W.R. Heinzelman, is a famous hierarchical routing technique that is utilized in WSNs. Assigning local group heads (CHs) the role of sink routers and categorizing sensor nodes into groups based on the strength of their consensus signals is the main objective. This will significantly reduce power consumption because communications will only be handled by CHs, rather than all sensor nodes. It is likely that a ratio of about 5% is optimal for CHs to nodes. Several processes, like data union and aggregation, are executed locally within the cluster. To ensure that energy is wasted at the same rate at every node, CHs are changed at random intervals over time. Here are a few key points of LEACH:

a) Oversaw and was in charge of the local deployment and operation of the cluster.

b) "Cluster-heads" and "base stations" that correspond to each cluster were randomly rotated.

c) Local stiffness to reduce global interaction.

Each step of the process is initialized and then progresses to a steady-state phase within each of the preset rounds of the process that make up LEACH. As part of the LEACH hierarchical protocol, the majority of LEACH nodes broadcast to cluster leaders. These leaders then aggregate and compress the data before passing it on to the base station. Each cycle concludes with a random procedure that each node uses to decide whether it will become the cluster leader. Since communicating with the home base or the nearest cluster head at full power would be wasteful, the LEACH protocol assumes that every node has a radio powerful enough to do so.

For P rounds, where P is the intended proportion of cluster heads, node A can't be the leader of any other cluster. In the rounds that follow this first one, every node has a 1/P chance of taking the lead in the cluster. At the end of each cycle, all nodes that aren't cluster heads select the one closest to them. The cluster manager schedules when each node in the cluster will send and receive data.

Time-division multiple-access (TDMA) allows non-leading nodes in a cluster to communicate only with the leader, according to the leader's schedule. They do this by maintaining radio contact with the cluster leader for as little time as necessary.

1.9 Problem Definition and Motivation

Energy efficiency in WSNs is not merely a technical challenge but a fundamental requirement. Sensor nodes are often deployed in harsh and remote environments, where human intervention for maintenance is impractical. Maximizing the energy efficiency of routing protocols is thus crucial for extending the network's operational lifetime and minimizing the frequency of node replacements or recharging, which can be prohibitively expensive or even impossible in some scenarios.

The energy consumption of a sensor node can be broken down into several components, including sensing, processing, communication, and sleep mode. Among these, communication is often the most energy-intensive activity, particularly in scenarios with frequent data transmissions. Routing protocols have a direct impact on communication energy consumption, as they dictate how data packets are relayed from source to destination. Therefore, the choice and optimization of routing protocols play a pivotal role in managing the energy budget of sensor nodes.

1.9.1 Challenges and Considerations in Energy-Efficient Routing:

Developing energy-efficient routing protocols for WSNs is fraught with challenges and considerations that need to be carefully addressed. Some of the key challenges include:

1. **Dynamic Network Topology:** Sensor networks are inherently dynamic, with nodes frequently entering and leaving the network. This dynamic topology requires routing protocols to adapt quickly to changes while minimizing energy consumption during route discovery and maintenance.

2. **Scalability:** Many WSN applications involve large numbers of sensor nodes. Routing protocols must be scalable to handle networks of varying sizes without incurring excessive overhead.

3. **Quality of Service (QoS) Requirements:** Different applications may have diverse QoS requirements. Some applications, like environmental monitoring, may tolerate delays in data transmission, while others, such as real-time monitoring in healthcare, require low-latency communication.

4. **Data Aggregation:** Aggregating data at intermediate nodes before forwarding it to the sink can significantly reduce energy consumption. Routing protocols should support data aggregation strategies to minimize redundant transmissions.

5. **Security Concerns:** Security is a paramount concern in WSNs, and energy-efficient routing protocols must ensure data confidentiality, integrity, and authenticity without imposing undue energy overhead.

6. **Cross-Layer Optimization:** Optimizing energy efficiency often requires collaboration across different network layers, including the physical, data link, and

network layers. Cross-layer design can lead to more effective energy-saving mechanisms.

7. **Lifetime Maximization:** The primary goal of energy-efficient routing protocols is to maximize the operational lifetime of sensor nodes. This involves careful energy management and load balancing to prevent premature node depletion.

1.9.2 Current Research Trends and Innovations:

Recent advancements in energy-efficient routing protocols for WSNs have seen the emergence of several innovative approaches:

1. **Machine Learning and AI-based Routing:** Machine learning techniques are being applied to predict network conditions and adapt routing decisions accordingly. Reinforcement learning and deep learning models are used to optimize routing paths dynamically based on real-time data.

2. **Energy Harvesting Integration:** Energy harvesting techniques, such as solar panels and kinetic energy scavenging, are integrated with sensor nodes to supplement their energy supply. Routing protocols are being designed to exploit energy harvesting opportunities effectively.

3. **Mobility-Aware Routing:** In scenarios where sensor nodes are mobile, routing protocols consider the mobility patterns of nodes to minimize energy consumption during data transmission. Predictive routing algorithms are developed to anticipate node movements.

4. **Cognitive Radio Networks:** Cognitive radio technology allows sensor nodes to dynamically adapt their communication frequency bands to avoid interference and reduce energy consumption. Cognitive routing protocols optimize spectrum usage.

5. **Blockchain-Based Routing:** Blockchain technology is explored for enhancing security and trust in WSNs. Routing protocols may utilize blockchain for secure route discovery and data transmission.

These results provide a research that uses simulations to build and simulate an efficient routing protocol that reduces power consumption and extends the life of sensor nodes. Loss of data could occur if the limited power supply of a sensor network's nodes is overused. Hence, a longer lifespan is achieved by making the network more fault-tolerant and reducing the energy consumption of the sensor nodes. By utilizing cluster-based energy-efficient routing methods, we are able to prolong the network's lifespan. On the other hand, dividing the network into discrete clusters results in much more energy consumption and communication overhead. Minimizing the time and effort needed for network re-clustering is made easier using event-based clustering. Nodes in an event-based cluster are those that were simultaneously affected by the same event. The energy needed to divide the whole network is therefore preserved. The generation of outlier data is frequently a challenge for event-based clustering because of accidental event detection. Because they are more prone to sharing data, nodes that are close together increase redundancy. So, we require a method for data aggregation that can tolerate errors, identify outliers, and eliminate superfluous data. In this research, we suggest modifying the LEACH routing protocol to extend the operational lifetime of the network and reduce its total energy footprint. One of the factors considered by LEACH Distance Energy (LEACH-DE) when selecting a node to serve as the cluster head is the geometric distance between the node and the base station (BS). Another factor is whether the node's remaining energy is higher than the average remaining energy level of the network nodes.

1.10 Objectives of Research

1. To create a simulated WSN environment with adjustable characteristics and examine the aspects of prior routing protocols of wireless sensor networks with figure of merits and comparative assessment.

2. To optimize WSN routing using an improved LEACH algorithm for enhanced energy efficiency.

3. To develop a heuristic technique for optimizing wireless sensor network performance parameters using soft computing.

4. To analyze the proposed methodology on the basis of network lifetime, dead nodes, living nodes, packets sent to base station, and packets sent to the cluster head.

1.11 Organization of Report

This report discusses about the understanding and implementation of Improved LEACH protocols in wireless senor networks and their comparison with other LEACH protocol.

Chapter 1 gives a brief introduction to the topic.

Chapter 2 explains about the literature review on the area of research and related topic.

Chapter 3 gives a brief introduction of routing protocols and proposed methodology.

Chapter 4 discusses the proposed methodologies.

Chapter 5 explains the simulation results and discussions.

Chapter 6 concludes with an idea about the conclusion and the future scope of the topic. This chapter discuss the introduction to subject of research and basic overview of the organization and motivation of the thesis.

As Wireless Sensor Networks continue to proliferate across diverse applications, the importance of energy-efficient routing protocols cannot be overstated. These protocols serve as the backbone of WSNs, determining their reliability, lifespan, and performance. The ongoing research in this domain strives to strike a delicate balance between energy conservation and meeting the specific requirements of different applications. The investigations on energy-efficient routing protocols for WSNs are multifaceted, encompassing algorithmic innovation, simulation-based evaluations, and real-world deployments. Researchers are challenged to develop protocols that adapt to dynamic network conditions, support diverse QoS requirements, and ensure the security and reliability of data transmission.

In the subsequent sections of this comprehensive study, we will delve deeper into the specific aspects of energy-efficient routing protocols. We will explore various routing strategies, optimization techniques, and case studies from different application domains. By gaining a thorough understanding of the state-of-the-art research and the challenges that lie ahead, we aim to shed light on the critical role that energy-efficient routing protocols play in ensuring the sustainability and effectiveness of Wireless Sensor Networks.

1.12 Conclusion of Chapter

Wireless Sensor Networks (WSNs) have become essential in various fields, requiring efficient energy usage to extend sensor node lifespan and maintain network reliability. This chapter introduced the significance of energy-efficient routing protocols in overcoming the limited energy resources of WSNs. It highlighted the need for advanced algorithms to enhance network performance, reduce energy consumption, and support diverse applications. Future sections will delve deeper into these protocols, exploring their design, implementation, and optimization strategies for sustainable WSN operations.

CHAPTER-2

LITERATURE REVIEW

2.1 WSN Optimization Using Soft Computing

(L. B. Bhajantri and A. V. Sutagundar, 2016) There is a new breed of highly computationally embedded real-time systems, and they're called distributed sensor networks (DSNs). Traditional networking architecture is impractical due to the widespread usage of energy and memory resources by a myriad of applications. It is anticipated that a large number of distributed sensor nodes would be used in all DSN applications. In DSNs, several nodes are combined into efficient clusters so that data is not sent from a single node to a single destination node. The following operations benefit from clusters' scalability, load distribution, and network durability. Clustering and data processing in DSNs are proposed to use fuzzy logic. Each node's power consumption, network throughput, and transmission efficiency are factored into this method. The proposed study aims to increase network performance in terms of energy efficiency, throughput, speed of cluster head selection, percentage of nodes still functioning, and longevity. The simulation results demonstrate that the suggested method outperforms LEACH, a protocol that uses minimal resources for cluster formation and communication overhead in DSNs [2].

(Y. Zhai, L. Xu, 2015) With the help of a newly developed knowledge guide, pheromones are now controlled in an efficient and effective manner. The basic idea is to focus asthma-related research by leveraging the knowledge gleaned from statistical learning and community input. A novel method for updating pheromones is used in conjunction with a more ant-centric approach, resulting in a more optimal algorithmic solution. The experimental results demonstrate that the ant colony algorithm outperforms its rival, an ant optimization algorithm based on an information pheromone control method [14].

(W. Ding, W. Fang, 2018) A novel approach for tracking objectives in RDPSO was developed in this study (Random Drift Swarm Optimization Algorithm). When compared to PSO and QPSO, RDPSO is more efficient and productive since it enhances regional integration. Based on the standard PSO based tracking system, the sequential RDPSO tracking algorithm was proposed. In order to further improve the efficacy of the suggested tracking method, we make alterations to the initialization procedure, whereby the fitness value is determined by means of the Gaussian mixture model. Many experimental results demonstrate the efficacy and effectiveness of our system, especially in circumstances of drastic changes in environment, deformities, quick motions, and camera waves [15].

(N. Thi, H. Thi, T. Binh, N. Xuan, 2019) This work presents a precise technique for computing the fitness function for this issue and an innovative and efficient metaheuristic in the form of a genetic algorithm that solves various shortcomings of previous metaheuristics. The suggested evolutionary algorithm combines the Laplace Crossover and Arithmetic Crossover Method operators with a heuristic population initialization technique to get optimal results. The suggested approach is compared to five state-of-the-art algorithms using extensive experimental data. Our algorithm achieves the highest quality and stability of solutions across the bulk of the cases we evaluated [16].

(S. Al-sodairi, R. Ouni, 2018) To help extend the lifetime of these WSNs, we examine the efficacy of low-energy adaptive clustering hierarchy (LEACH) and LEACH-based procedures. To improve packet delivery and network longevity in WSNs, a new clustering technique, enhanced multi-hop LEACH, is suggested to minimize and balance energy usage. In addition, this study highlights the limitations of the LEACH technique. We begin by introducing a novel set of methods for picking cluster leaders and performing round-trip calculations depending on available power. Second, the WSN employs leveling and generic multi-hop routing [19] to incorporate a multi-hop communication architecture [19].

(G.K. Nigam, C. Dabas, 2018) To begin clustering the sensor nodes, a meta-heuristic particle swarm optimization is used. To reduce the inherent randomness of the process, the proposed ESO-LEACH makes use of the idea of sophisticated nodes and a more stringent set of constraints for CH election. The results of Python-based simulations demonstrate that ESO-LEACH outperforms baseline LEACH and extends the lifespan of the network. The upgraded suggested method is successful in prolonging network lifespan suitably, as evidenced by the python-based findings showing that the lifespan of network using ESO-LEACH is turning out to be almost twice than the lifespan of network using LEACH protocol [20].

(X. He et al., 2019) A persuasive way to address the "energy gap issue" in wireless sensor networks (WSNs) is to capture data with mobile sinks. Regardless, heap equalization of meeting nodes is often ignored in current mobile sink computations, leading to a reduction in the network lifespan. Furthermore, it is common practice to have mobile sinks visit sensor node locations outside of their corresponding ranges. In order to reduce the mobile sink's path length and equalize the heap of meeting nodes, this study suggests an energy-efficient direction arranging calculation (EETP) based on multi-target molecular swarm streamlining (MOPSO). The goal of EETP is to increase the lifetime of the network and decrease the delay in data delivery. To reduce the mobile sink's path length, we devised a component to choose possible visiting points within the correspondence spanning scopes of sensor nodes, rather than their regions. In addition, we design an attractive direction encoding scheme that may generate a direction with an arbitrary number of visiting foci, based on the direction properties of the mobile sink. When compared to the current WRP, CB, and the MOPSO-based computation, the proposed EETP outperforms them in terms of energy consumption, network lifespan, and data conveyance deferral. [32]

(W. He et al., 2019) To address the problems with present wireless sensor networks, such as limited node energy, short network cycles, and low throughput, an efficient and energy-saving computation called K-means and FAH (KAF) has been suggested. Improving K-implies clustering yields network clustering. By including the factors of node energy, good routes from the base station, and energy efficiency of nodes, the cluster head determination is improved using the FAHP (Fluffy Logical Hierarchy Procedure) approach. In order to reduce the energy consumption of nodes during data transmission, multi-jump routing is constructed using the variables of transmission spacing, energy, and bounce number. The simulation results demonstrate that, in comparison to other methods, KAF calculation clearly excels in reducing node energy consumption, extending the life cycle of the network, and increasing the network throughput. A number of routing conventions are used to verify the calculation's output. By adjusting the size of the candidate node set determination area, we can improve the long-distance node's data transmission reliability and lower the close-range node's energy consumption heap. Meanwhile, the use of innovative transmission processes enhances the reliability of data transfer. The findings of the replication demonstrate that the suggested standard may effectively reduce node energy consumption and prolong the network life cycle [33].

(M. F. AboElFotoh et al.) The emergence of transporting wireless networks of heterogeneous keen sensor nodes for complicated data collecting tasks has been one of the most persuasive mechanical breakthroughs of this decade. An autonomous, purpose-built network of many useful, perceptive sensor nodes is known as a wireless conveyed sensor network (DSN). Efficient DSN are essentially multi-bounce networks due to the limited intensity of sensor nodes. A combination of self-organizing capabilities and the usefulness of DSN enables the formation of robust sensor clusters that can be directed towards or toward target objects. The aggregate data provided by the objective cluster of sensors is what really matters when it comes to solid checking of wonders or event detection, rather than any one node in particular. Disconnecting operational data sources from data sinks (command nodes or end client stations) is not necessarily the result of at least one node's displeasure. However, it has the potential to increase the number of hops a data message must undergo before reaching its destination, which in turn increases the message latency. Issues of registering a measure for the unchanging quality of DSN and processing a measure for the usual and most severe message delay between data sources (sensors) and data sinks in an operational DSN are the main focus of this study. We employ a probabilistic graphic to show DSN given an estimate of the data source and data sink disappointment probability, as well as the sensors and the nodes in the middle. According to our definition, the DSN reliable quality is the probability of a functional communication channel between the sink node and at least one operational sensor in an objective cluster. [49]

(M. A. Hossen et al., 2019) Adaptive radio technology known as psychological radio (CR) can enhance radio working behavior by automatically identifying accessible ditches in a wireless range and changing transmission boundaries. The ever-changing nature of range accessibility and wireless channel conditions makes it very challenging to maintain reliable network availability. The goal of cluster-based CR specifically appointed networks (CRAHN) is to provide stable self-governing networks by coordinating CR nodes into groups. Network adaptability and reliability are achieved by clustering in CRAHN, which is essential for pleasant tasks like range detection and channel management. Here we provide a CRAHN cluster creation method based on Q-learning, where Q-esteem is used to measure the channel quality of each node. When designing a distributed cluster network, factors including channel quality, residual energy, and node/network conditions in the surrounding area are taken into account. Each node learns its immediate surroundings and who would make a good cluster head (CH) by exchanging information about its state in relation to its channels and neighbors. This study presents a methodology for door node choosing, an optimal normal dynamic data channel choice, and dispersed CH determination. In addition to extending the lifetime of the network and improving reachability between nodes and other cluster networks, the proposed instrument can provide stable and solid support through the selected data channel and avoid potential obstruction between neighboring specially appointed clusters. [31]

(S. Lata et al., 2020) Increasing the system lifespan is necessary to prolong the operation of wireless sensor networks (WSNs). With a few basic factors—like the time until the first node dies—and some characteristics tailored to the application, the lifespan of a WSN may be determined. One of the most effective strategies to increase the WSN's longevity, according to the literature, is to cluster to choose the best suited cluster head. The probabilistic model is the foundation of clustering methods' shortcomings. Occasionally, they'll choose two cluster heads for two adjacent clusters, which might lead to a head being placed at the cluster's periphery. The energy efficiency is reduced with this cluster head selection method. In order to extend the life of the network as much as possible, we have developed the LEACH-Fuzzy Clustering (LEACH-FC) protocol and used a cluster head selection and formation process based on fuzzy logic. Instead of using dispersed methods, we opted for a centralized approach when choosing the cluster head and creating the cluster. As another centralized method, we have used fuzzy logic to choose the vice cluster leader. In order to improve the dependability of WSN, the suggested technique successfully equalizes the energy burden at each node. When compared to other suggested algorithms, it significantly reduces energy usage and extends the lifetime of the network. [30]

(N. Mazumder, H. Om, 2018) Large-scale wireless sensor networks prioritize energy saving because of the problem of limited energy supply in sensor nodes. It has been discovered that cluster-based routing may significantly cut down on the power needs of sensor nodes. Each node in a clustered wireless sensor network reports to a designated leader, or "cluster head"

(CH). Each cluster node reports its findings to its CH, which then forwards the data to the base station either directly or through other CHs. The energy of the CHs that are physically closer to the base station is quickly depleted because to the heavy relay load they must carry in multihop communication. The phrase "hot spot" describes the precise location of the issue. To address this issue, the authors of the present research offer a distributed fuzzy logicbased uneven clustering technique and routing algorithm (DFCR). In addition to the cluster architecture, an energy-efficient and balanced multihop routing technique is proposed. The simulation results show that the proposed DFCR method is superior to the state-of-the-art algorithms, such as the energy-aware fuzzy approach to uneven clustering, the energy-aware distributed clustering algorithm, and the energy-aware routing algorithm [21]

(K.A.Z. Ariffin, R.M. Mokhtar, A.H.A. Rahman, 2018) The results of an examination into how the LEACH protocol fares when subjected to a Black Hole assault are presented in this publication. It emphasizes the contrast in node density between two base station sites and five node counts (20, 40, 60, 80, and 100). The N 2.35 simulation program is used to test how well the WSN network can withstand a Denial of Service attack represented by the LEACH patch and Black Hole code. Network longevity, data provided to the base station, and overall energy consumption are some of the parameters to be assessed from the simulation. The findings provide insight on the impact of the Black Hole assault and reveal network behavior that might inform future efforts to enhance the safety of other protocols. Based on data analysis, we know that a density of 80 nodes best mitigates the effects of a Black Hole assault. Nevertheless, (50, 175) is chosen as the optimal site for the base station due to its longer network lifetime and greater volume of data transferred to the base station [23].

(Alka Singh, Shubhangi Rathkanthiwar, Sandeep Kakde, 2016) the authors found that Microsensor nodes in wireless sensor networks (WSN) often operate on a battery. When these nodes' energy levels drop to zero, all communication comes to a halt. This study presents Multi-Hop LEACH, an energy-efficient routing system for wireless Sensor Networks that makes use of a combination of the particle swarm optimization approach, the V-LEACH protocol, and multi-hop network architecture. Multi-hop communication has been utilized to reduce energy consumption during transmission from the cluster head to the base station [18].

2.2 Past Work on Energy Efficient Algorithms (i.e., LEACH)

(Zhen Zhao, Guangming Li, Menghui Xu, 2019) The primary goal of the LEACH protocol was to standardize the network's energy use and hence save costs. Uneven cluster distribution and energy usage in the network result from not taking into account the distance between member nodes and the cluster head node. A further issue is the lack of differentiation in the selection of cluster head nodes. Modified LEACH protocol is developed based on the original method, which uses energy as a weight factor in the cluster head election and properly solves the number of cluster heads in each round. The enhanced approach increases network performance, improves energy efficiency, and lengthens the lifespan of wireless sensor networks [1].

(A. Nandi, B. Sonowal, D. Rabha and A. Vaibhav, 2019) This study refines the LEACH procedure to provide a more effective one for WSN. The effectiveness of the updated LEACH protocol is assessed across a variety of network configurations. An essential indicator of WSN performance is its longevity. Energy efficiency, latency in packet delivery, and longevity of the network are evaluated to see how the proposed protocol compares to LEACH [3].

(H. Patel and V. Shah, 2016) Wireless sensor networks (WSNs) have been increasingly well-known for use in the field of remote sensing as wireless technology has developed. Since WSNs have so many potential uses, research into them has becoming increasingly popular. Every day, new technologies emerge with improved and more practical characteristics, which maintains the sector's interest in development and research. The sensor nodes, which make up the bulk of a WSN, have only so much computing power and data storage at their disposal. Thus, there is a need to enhance energy efficiency in WSN nodes in order to lengthen the network's useful lifespan. There have been several attempts to lengthen the lifespan of the sensor nodes by adjusting to new techniques used in packet transmission. This research [4] identifies methods in which the energy conservations at the various levels of the sensor node might be enhanced [4].

(M. N. Jambli, M. I. Bandan, K. S. Pillay and S. M. Suhaili, 2018) The longevity of any wireless sensor network (WSN) application relies on the deployment of low power sensor nodes to efficiently capture meaningful sensing information. Energy consumption is viewed as a crucial performance parameter in extending the lifespan of networks. Energy efficiency and long network life are two goals shared by the majority of recently suggested routing technologies. Low Energy Adaptive Cluster Hierarchical Routing (LEACH) is offered as an alternative to the conventional pioneer hierarchical routing protocol for WSN in order to boost WSN's energy efficiency. As a cluster-based routing system, LEACH groups sensors into smaller groups led by a single node known as the cluster head (CH). In this research, we conduct an in-depth analytical investigation of the LEACH protocol to determine its capabilities in terms of average energy usage and packet loss over a range of data rates [5].

(D. M. Birajdar and S. S. Solapure, 2017) The nodes of a Wireless Sensor Network (WSN) are extremely small sensors. These nodes have the intelligence to sense and monitor their surroundings, sending and receiving data on things like temperature, sound, pressure, mobility, and more. There must be careful management of the power and energy available at WSN sensor nodes. To address the issue of WSN's high energy consumption, numerous methods have been proposed. These include flat, hierarchical, and location-based routing. In WSN, Low Energy Adaptive Clustering Hierarchy is the primary hierarchical routing protocol (LEACH). There are two stages to LEACH's operation: initialization and steady-state operation. LEACH periodically rotates among cluster-head nodes in such a manner that every node in the network has an equal opportunity to become cluster head. This minimizes power demand across the network and lengthens its lifespan. In this study, we will examine the inner workings of the LEACH simulator, Omnet++ [6].

(T. A. H. Hassan, G. Selim and R. Sadek, 2015) Cluster-Head (CH) nodes are the hubs of a wireless sensor network (WSN) and the connection point between the individual leaf nodes' normal sensors and the network's base station (BS). Load balancing in the packet TX/RX process can optimize the energy dissipation of the sensors, regardless of their kind, to increase the network's lifetime and shorten the time spent in the advertisement phase for cluster head selection during each cycle of the LEACH-C protocol. Assigning a vice cluster head (VCH) to each CH is one of the methods proposed in this research to increase the system lifespan in a wireless sensor network (WSN) using the LEACH C architecture. Instead of being in an idle state until a new VCH is allocated the TX load, as is the case with some other VCH-based protocols, the VCH in this case shares the TX/RX load with its CH until a new VCH receives it shortly after the death of the CH. The theoretically anticipated outcomes are corroborated by the simulation findings. The simulation results show that the proposed protocol increases the network lifetime as anticipated [7], and the operation of the protocol is verified under several simulated settings, such as the size of the WSN field [7].

(K. A. Darabkh, W. S. Al-Rawashdeh, M. Hawa, R. Saifan and A. F. Khalifeh, 2017) Low-Energy Adaptive Clustering Hierarchy (LEACH) and Threshold-based LEACH (T-

LEACH) are only two of the numerous extant clustering methods designed to extend the lifespan of the sensor network. T-LEACH protocol makes use of LEACH's fundamental shortcoming—its significant control overhead—to its advantage. As an alternative to replacing cluster leaders after each individual round, T-LEACH suggests doing so after every batch of rounds. As long as a node's energy is greater than a fixed value, it will continue to act as the cluster's leader. Major limitations of T-LEACH are highlighted, and a new method for replacing cluster heads, based on a modified threshold, is proposed (MT-CHR). To more closely align with the assumptions made in the LEACH protocol [8], MT-CHR proposes a new likelihood of becoming a cluster leader, for any node in any round [8].

(K. Roshan and K. R. Sharma, 2018) Sensor nodes in a wireless sensor network collect data and send it to a central location through radio waves. Since sensor nodes are often rather tiny, and wireless sensor networks are often spread out across large geographic areas, power consumption has emerged as a key challenge for this technology. This study expands on previous work that enhanced the Improved LEACH protocol by adding cache nodes to the network. The cluster heads in the Enhanced LEACH protocol with cache nodes are chosen using a combination of their distance from the cluster and its energy level. The nodes at the top of a cluster always aim to send their data to the node in the cache with the quickest response time. Proposed modal simulations are run in MATLAB. Results from Improved LEACH without a cache node are compared to those from Improved LEACH with a cache node [9].

(T. Yang, Y. Guo, J. Dong and M. Xia, 2018) To address the issues of low power adaptive clustering hierarchical protocol's (LEACH) short life cycle and unequal energy consumption, a new LEACH algorithm is presented. To ensure a more even distribution of cluster heads, the SEP algorithm is used to calculate a different cluster head election probability for the advanced nodes and the ordinary nodes. The optimal cluster head proportion is determined by taking into account the problem of residual energy and current position. Also, a hybrid routing approach is used to communicate data during the transmission phase. Simply said, the node's distance to the cluster head and the base station are compared. There is direct communication between the node and the base station when the node is in close proximity to the base station. In any case, it uses the cluster head to talk to the main station. It lessens the need for clustering, which in turn lowers the network's energy needs. An extended lifetime of the wireless sensor network is achieved by the enhanced LEACH algorithm, as shown in simulation studies [10]. Additionally, the distribution of dead nodes is improved, and the energy consumption of the overall network is normalized [10].

(L. Mao and Y. Zhang, 2017) Given the finite energy reserves of individual nodes, the lifespan of wireless sensor networks is mostly determined by the amount of energy used on communication. It is crucial to develop a communication protocol that will keep networks operational for a longer period of time. In order to improve the cluster head election and data transmission mode in wireless sensor networks, this research proposes a new LEACH method that takes into consideration the energy and location of each node. With this approach, the threshold is modified to include the node's current energy and position, making the designation of the cluster head less arbitrary. Cluster leaders in close proximity to one another are prioritized for selection as relay nodes during the data transmission stage. The simulation results demonstrate that the proposed method outperforms LEACH and LEACH-C algorithms [11] in terms of network stability and longevity [11].

(S. Soro, W.B. Heinzelman, 2005) It is proposed in this research that an uneven classification-size (UCS) model for network organization might lead to more even energy dissipation across the cluster's primary nodes, which in turn extends the lifespan of the network. Additionally, we apply this strategy to sensor networks that are already quite similar, demonstrating that UCS can lead to a more homogeneous network with a uniform energy discharge [12].

(D. M. Birajdar and S. S. Solapure, 2017) The nodes of a Wireless Sensor Network (WSN) are extremely small sensors. These nodes have the intelligence to sense and monitor their surroundings, sending and receiving data on things like temperature, sound, pressure, mobility, and more. There must be careful management of the power and energy available at WSN sensor nodes. To address the issue of WSN's high energy consumption, numerous methods have been proposed. These include flat, hierarchical, and location-based routing. In WSN, Low Energy Adaptive Clustering Hierarchy is the primary hierarchical routing protocol (LEACH). There are two stages to LEACH's operation: initialization and steady-state operation. LEACH periodically rotates among cluster-head nodes in such a manner that every node in the network has an equal opportunity to become cluster head. This minimizes power demand across the network and lengthens its lifespan. In this study, we will examine the inner workings of the LEACH simulator, Omnet++ [6].

(F. Bagci, 2016) This study proposes implementing an Energy Efficient Medium Access Control (EEMAC) protocol in wireless sensor networks by using the Energy Saving Token Ring Protocol (ESTR). The token ring system, which is well-known for being both fair and efficient, serves as the foundation for ESTR. The sensor nodes are all interconnected to make a ring, and only the node with the token is triggered and may interact with the others. If a sensor node is not actively collecting data and does not want to send or receive messages during its sleep cycle, ESTR can put it into this mode. Because the network's token holding durations are predetermined, sensors can easily ascertain the length of any given period. Better energy outputs and longer network life are the benefits of this. Furthermore, ESTR reduces carbon loss through restrained idling and listening. Additionally, the proposed protocol supports several interconnected rings. The network's overall size is reduced, and smaller rings can be constructed according to location. The abundance of rings in the network ensures its continued connectivity. The ESTR is a flexible system that controls both the energy used and the size of the ring. Additionally, the token transmitted between neighboring nodes includes data about the prior node's energy usage. The current node will go to sleep soon so that the ring's capacity can be maintained at a steady state. This greatly extends the lifespan of the network. When compared to other network simulators, the ESTR performs better when tested with NS-2 [13].

(Z. Quan et al.) Wireless sensor network growth has imposed many challenges on network architecture, including severe energy requirements, limited bandwidth, and computational capability. Network convention designs for these types of networks must be robust, efficient with energy, flexible, and easy to set up. A robust energy-conscious clustering architecture (REACA) for wide-area wireless sensor networks is suggested in this paper. In terms of asymptotic throughput limit, force usage, type of administration, we dissect the REACA network's display. Our main focus is on the scaling of the throughput limit with respect to the number of nodes and clusters. We demonstrate that clustering may provide limit and power usage performance improvements over widely used specifically assigned networks by using traffic territory. For single-jump and multi-bounce routing schemes in cluster-based networks, we also study the fundamental trade-off between throughput limit and force utilization. This work's convention engineering and execution assessment provides useful information for the practical planning and organization of a wide-area wireless sensor network. [47]

(K.A.Z. Ariffin, R.M. Mokhtar, A.H.A. Rahman, 2018) The results of an examination into how the LEACH protocol fares when subjected to a Black Hole assault are presented in this publication. It emphasizes the contrast in node density between two base station sites and five node counts (20, 40, 60, 80, and 100). The N 2.35 simulation program is used to test how well the WSN network can withstand a Denial of Service attack represented by the LEACH patch and Black Hole code. Network longevity, data provided to the base station, and overall energy consumption are some of the parameters to be assessed from the simulation. The findings provide insight on the impact of the Black Hole assault and reveal network behavior that might inform future efforts to enhance the safety of other protocols. Based on data analysis, we know that a density of 80 nodes best mitigates the effects of a Black Hole assault. Nevertheless, (50, 175) is chosen as the optimal site for the base station due to its longer network lifetime and greater volume of data transferred to the base station [23].

(W. Osamy et al.) According to Osamy et al., WSNs have captured the interest of both industry insiders and academics in the past several years. The vast array of applications for WSNs, such as surveillance frameworks, military duties, medical services, condition event checks, and human security, is the driving force behind research efforts in the area. Whatever the situation may be, energy efficient routing protocol should be the first priority since sensor nodes are low potential, energy consuming devices. An alternative Cluster-Tree routing scheme for social event data, CTRS-DG, consisting of two levels—routing and total—and remaking—is proposed in this work. An algorithm for cluster head (CH) selection and cluster organization is suggested in the collection and reproduction layer that is based on self-sorting entropy and operates dynamically. The compressive detection method is used to total and compress data at CHs. An alternative computation to frame the routing tree as the network's spine is suggested in the routing layer. In order for CHs to transmit the compressed data to the BS, the routing tree is employed. To improve the recovery method at the BS, a successful CS recreation calculation termed Honey bee based sign reproduction (BEBR) is presented as a period of accumulation and remaking layer. The BEBR algorithm finds the optimal reproduction setup by combining the advantages of the avaricious algorithm with the Honey bees algorithm. The suggested conspiracy outperforms the current baseline calculations for compressive detection data recreating in terms of solidness period, network lifespan, and normal standardized mean squared error, according to the reproduction findings. on page 34

(P. T. A. Quang [12]) We suggest a clustering algorithm to enhance the display of WSANs in this study. A staggered hierarchical structure can be used in each cluster to reduce energy consumption. Some nodes, other than the cluster head, can be designated as intermediate nodes (INs). Every IN takes care of a subcluster that includes its immediate neighbors. Upon receiving all of the data from its subcluster, INs transmit it to the cluster leader. High computational complexity mixed whole number direct programming may be seen in the determination of midway nodes hoping to enhance energy usage. To cut down on processing time, we suggest a heuristic lowest energy way-looking-through algorithm. Another suggestion is to use a channel task plot for sub-clusters, which would increase the gathered throughput by reducing the impedance between nearby sub-clusters. The suggested strategy can extend the lifetime of networks in WSANs, according to recreation results.[41]

(H. Lin et al.) A big challenge in testing wireless sensor networks (WSNs) is extending their lifetime, according to H. Lin et al., as the energy distances between sensor nodes might be rather long. Due to the increased energy consumption caused by the increased data assortments and packet transfers, this test becomes much more fundamental in large-scale sensor networks. For these types of WSNs, clustering-based conventions are generally considered to be the best option. In this study, we provide fan-formed clustering (FSC), a clustering technique for partitioning a large-scale network into fan-shaped clusters. Different energy-saving strategies, such as efficient cluster head and hand-off determination, region of re-clustering, basic yet strong routing, and hotspot organization, are suggested based on this clustering concept. The proposed FSC outperforms crossover, energy-efficient, and diffused clustering in terms of energy saving and packet assortment rate, according to execution research. [42]

(Hamed Javadi et al.) In their work on clustered wireless sensor networks, Hamed Javadi et al. define the probability of accepting correct choices from all clusters as the unchanging quality of conveyed recognition and plan it in two cases of equal and sequential dispersed discovery using data combination focus. Another energy-efficient distributed discovery method, cross-breed communicated identification, is also suggested. In this method, distributed location is carried out during jump-by-bounce data transmission from the nodes of the cluster to the head of the cluster. This method substantially improves the network's unwavering quality while preserving more energy than previously suggested methods. [43]

(N. Gautam et al.) Energy conservation is a major consideration when evaluating WSN demonstrations. Level routing schemes typically waste more energy than hierarchical clustering standards like BCDCP, EEEAC, LEACH, and LEACH-C. But these standard practices still have drawbacks, such as cluster heads' (CHs') inconsistent and high energy consumption due to the unique transmission paths from each CH to the BS. We offer a new hierarchical routing convention called separation mindful keen clustering convention (DAIC) to reduce energy consumption and increase network lifetime. The basic idea is to partition the network into levels and place high-energy CHs at the nearest good ways from the base station (BS). Choosing CHs at the nearest good ways from the BS may conserve a lot of energy, as we have observed. Similarly, in order to avoid determining an excessively large number of CHs in the network, the amount of CHs is processed powerfully. In terms of energy preservation, our reproduction findings showed that the suggested DAIC beats LEACH and LEACH-C by 63.28 percent and 36.27 percent, respectively. For even greater energy efficiency, alternative hierarchical clustering conventions can be tweaked to use the separation mindful CH determination approach that was received in the proposed DAIC convention. [44]

(Asaduzzaman et al.) In our work with Asaduzzaman et al., we construct a low-unpredictability-helpful-assorted-variety convention for wireless sensor networks based on the low-energy adaptive clustering hierarchy (LEACH). To provide spatially varied physical layer diversity, a cross-layer technique is employed. To make advantage of virtual many info varied yield (MIMO) based client involvement, this work proposes a fundamental change in clustering computation of the LEACH convention. To avoid selecting only one cluster head at the network layer, we suggested using M cluster heads per cluster to obtain a diverse set of M requests in close proximity. Cluster nodes can receive data from several sensor nodes at once because to the communicated concept of wireless transmission. The execution of a virtual MIMO-based space-time square code (STBC) in cluster-head-to-sink node transmission is guaranteed by this fact. An illustrative method for evaluating power consumption using BER curves is shown. The study and simulation findings demonstrate that the suggested useful LEACH convention may significantly reduce energy consumption compared to the LEACH convention, while meeting all other requirements such as data throughput, bit error rate, delay, and bandwidth. Better spectral efficiency and increased request variety are two additional benefits of our proposal over competing virtual MIMO-based standards. in the 45th

(L. Wang et al.) According to Wang et al., cluster-based sensor networks can reduce energy consumption and connection support costs. Finding the sweet spot for cluster size is a major challenge for sensor networks that rely on clusters. Our goal in this research is to reduce energy consumption in thick sensor networks by proposing a cross-layer logical technique that combines physical (PHY), medium access control (MAC), and network (NET) to determine the optimal number of clusters. The PHY layer's lognormal shadowing and two-slant way loss model, as well as various Macintosh plans and multihop routing plans, are among the many affects that our multi-layer arrangement can fuse. When compared to the baseline situation where each perception zone (OA) has one cluster, a sensor network with the optimal number of clusters can reduce energy consumption by more than 80% on occasion. No matter the variable sensor densities in different OAs, we further verify through simulations that the investigational optimal cluster number can still function satisfactorily. [46]

(M. Yu et al.) According to Yu et al., one of the most challenging aspects of developing various large-scale sensor frameworks is figuring out how to gradually group the sensors into a wireless communication network and transmit discovered data from field sensors to a remote base station. For sensor networks with a vast scope, this study introduces yet another strong clustering algorithm that is energy efficient. In order to restrict the amount of energy used on intra- and between-cluster exchanges, each node monitors the number of dynamic nodes in real-time and records its optimum likelihood of becoming a cluster head by assessing the received signal strength from its nearby nodes. This study further suggests an easy-to-implement multihop routing calculation based on clustered engineering that aims to be power-mindful and energy-efficient, with the goal of delaying the network lifespan. Our extensive simulation findings showed that the novel routing and clustering algorithms scale effectively and match the requirements of large-scale dynamic sensor networks quickly. [48]

(H. Gharavi et al.) This study by Gharavi et al. introduces a mobile specifically appointed network architecture for multihop interactive media correspondences based on ace/slave cells. The suggested network employs an alternative perspective to address the problem of cluster-based impromptu routing in the context of current wireless neighborhood (WLAN) innovations. Two distinct types of networks—the spontaneous and the framework (ace-and-slave)—are combined in the network engineering. Through their respective master nodes (MNs) in a framework network, the participating slave nodes (SNs) in every cluster communicate with one another in this architecture. Here, the MNs (basis stations) are mobile, as opposed to the stationary base stations in traditional cell networks (e.g., linked via a cable spine), which allows for the strong and spontaneous development of interconnectivity. The IEEE 802.11 WLAN standard has been communicated for use in networks. All the nodes in a cluster could have to move at once since this network doesn't have any stationary nodes. However, a handoff mechanism utilizing Mobile IP variation 6 (IPv6) has been considered in order to enable a mobile node to transition to another cluster, necessitating a change in its connection point. The Impromptu On-demand Separation Vector (AODV) Routing standard has been issued for specifically scheduled routing between master nodes (i.e., MNs). A preliminary evaluation of the planned network execution was carried out through field tests as part of the network execution survey. In these estimates, you may find things like packet loss, delays under various test scenarios (such as a change in specifically chosen route), handoffs, and so on. [51]

(C. Phoemphon et al.) Smart, multi-purpose sensors with built-in wireless capabilities (also known as wireless sensor networks, or WSNs) play a crucial role in the Internet of Things (IoT), according to Phoemphon et al. Energy consumption is the primary obstacle among the few problems associated with WSNs that have been investigated. Because a sensor or node should behave naturally confined and organized and have a cheap integration cost, limitation is another important condition. Due of its simplicity, the sans range method shows promise. Important bounds, such as the number of leaps and node regions, are all that are needed; no more rationales are required. The related confinement estimation technique does not anticipate that zones will be protected by nodes with known placements (also known as stay nodes or known vectors), and the separation vector-bounce based restriction (DV-Jump) is a leading without range approach. The method for determining the relationship between the distance and the number of leaps between two stay nodes (i.e., bounce size) and the thickness of the nodes are two of the variables that affect the accuracy of this methodology. Consequently, this study enhances DV-Bounce by accomplishing the following: 1) reducing the estimate inclusion to a specific area, which means fewer grapple nodes are needed; 2) further reducing the area using a jumping box; and 3) utilizing molecule swarm optimization (PSO) to improve the guess accuracy by incorporating the quantity of jumps and stay nodes into the wellness capacity. In order to evaluate the effectiveness of the suggested plot, we compare the recreation results to those of five recently proposed DV-Jump limitation strategies: iDV-Bounce, DV-maxHop, Specific 3-Stay DV-Jump, PSODV-Bounce, and GA-PSODV-Jump. [35]

(L. Sivagami et al.) The present booking process in Submerged Wireless Sensor Networks (UWSN) leads to a delay in proliferation or an overhead problem, according to Sivagami et al. Furthermore, the data crash is likely to occur. This study proposes a cluster-based Macintosh protocol for crash shirking and TDMA booking in UWSN as a solution to this problem. The initial step in energy-efficient hierarchical clustering is to form the clusters and choose cluster heads (CHs). The individuals making up the cluster, who are all one-jump neighbors of CH, schedule when each member will provide data. One would expect the energy consumption scientific model to provide the typical amount of energy that each CH consumes. Finally, using the Spatial-Worldly Confliction-Table, clash-free booking is executed. This enables several nodes to communicate data at once, provided that their packets arrive at their intended destinations on time. The simulation results demonstrate that the suggested Macintosh standard raises the packet delivery proportion while decreasing deferral and energy consumption. [39]

(Lindsey et al.) For the sensor network to function for an extended period of time, detecting social events in an energy efficient manner is fundamental. The newly-introduced LEACH standard is a masterful setup that uses clustering to merge data before sending it to the base station. Our new and enhanced plan, PEGASIS, stands for power-efficient social event in sensor data frameworks. It is a convention based on close ideal chains that lowers energy use. By reducing the amount of energy consumed every cycle, PEGASIS ensures that each node only communicates with local neighbors and alternates between broadcasting to the base station. According to the findings of the reproduction, PEGASIS is more effective than LEACH. [52]

(Manish Gupta, Krishnanand K R, Hoang Due Chinh, Sanjib Kumar Panda, 2015) Smart building management systems are designed to reduce energy use without sacrificing occupant comfort. Changes to the energy supply and the devices' administration are both necessary for effective energy management. In order to make decisions, such a system needs a wide range of sensory data, analytical tools, and optimization algorithms. In order to gather information, wireless sensor networks have been widely used. Variations in raw sensor measurements can be caused by a number of variables, and if that data is transmitted to the base station, it could mislead the control system. The primary goal of any outlier detection method is to identify data that significantly differs from the norm. In this study, we use Hodrick Prescott filters to clean up raw sensor data by removing inaccuracies and noise. The resulting data is more stable than data acquired by other approaches, according to experiments and analyses [24].

(Mohamed Younis, Izzet F. Senturk, Kemal Akkaya, Sookyoung Lee, Fatih Senel, 2014) In order to deal with and tolerate node failures in WSNs, this study examines several network topology management approaches. We may roughly divide the current tools into two categories: reactive and proactive approaches. All the current works have been analyzed and compared in depth with respect to these criteria. In the end, the study concludes with a list of research gaps [25].

(Suat Ozdemir and Yang Xiao, 2013) To extend the lifetime of wireless sensor networks and cut down on the power needs of individual sensor nodes, data aggregation methods are important. However, in mission-critical wireless sensor networks, accuracy of data aggregation findings is just as important as sensor node power consumption. In this paper, we introduce a fault-tolerant data aggregation scheme for filtering out the erroneous readings that can be generated by compromised or otherwise malfunctioning sensor nodes. Locality Sensitive Hashing (LSH) is used as the basis for an in-network outlier detection technique that simultaneously reduces power consumption and eliminates invalid data. Simulation results demonstrate that the proposed scheme improves the accuracy of data aggregation by decreasing the number of erroneous data transmissions [26].

(Mauro Migliardi, Alessio Merlo, and Luca Caviglione, 2014) There have been numerous exciting advancements in several subfields of "Green, Energy-Aware Security" (GEAS) since the topic first emerged. In this article, we'll examine recent changes and provide a brief overview of the state of the art, including some of the most intriguing and promising developments. Specific attention will be paid to [27] I network node energy management, ii) exploiting security techniques to save energy, and iii) using energy consumption as a signal for malicious behaviors on energy-constrained computing systems [27].

(Tarachand Amgoth, Prasanta K Jana, 2015) In wireless sensor networks (WSNs), the sensor nodes' finite and oftentimes nonrenewable energy supply is a major limitation. As a result, developing an efficient routing algorithm is one of the primary areas of study today. In this work, we present a routing method for cluster-based WSNs that takes energy efficiency into account. Cluster heads (CHs), residual energy, and intra-cluster distance all play crucial roles in the algorithm's core approach for cluster creation. For data to flow smoothly, a sink-centric directed virtual backbone of CHs is built. It is further demonstrated that the suggested algorithm maintains a consistent energy budget for the CHs while routing data. The algorithm is shown to have constant message complexity and linear time complexity. We do rigorous testing of the suggested method. In terms of network longevity, energy usage, and other factors, the testing findings reveal that the algorithm excels above other current methods [28].

(Alessio Merlo, Mauro Migliardi, Luca Caviglione, 2015) The proliferation of mobile Internet access as the default method necessitates a more in-depth examination of security concerns. In addition, the limitations on their authority must be taken into account for a full and thorough analysis of security. This underexplored facet of mobile devices enables researchers to I determine if all the layers responsible for privacy and security may be re-engineered or optimized to conserve power, and (ii) comprehend the efficacy of draining energy to carry out assaults. This study offers a comprehensive review of the current research on energy consciousness and safety. In addition, it provides a concise overview of where the field is in terms of measuring technologies and broad methods for cutting energy use. The primary contributions of this survey include a review of previous work targeted at reducing the energy requirements of security systems and the identification of interesting research topics, such as the detection of assaults through abnormal power use [29].

(O. Younis et al.) In a sensor network, Younis et al. found that geography control increases the network's flexibility and lifespan by adjusting the load on sensor nodes. A successful method of controlling geography is the clustering of sensor nodes. A new suited clustering method for long-lived particularly assigned sensor networks is shown here. Except for the availability of many force levels in sensor nodes, our suggested method makes no assumptions regarding the proximity of the foundation or the capacity of the nodes. Node lingering energy and an auxiliary boundary, such as node proximity to its neighbors or node degree, are used to choose cluster heads in our convention, Notice (Half breed Energy-Efficient Circulated clustering). With notice, you may achieve really uniform cluster head dispersion throughout the network in O(1) cycles while acquiring negligible message overhead. We show that Notice may asymptotically guarantee clustered network availability with appropriate constraints on node thickness and intracluster and intercluster transmission ranges. Our suggested method successfully supports varied data collecting and extends the lifetime of the network, as shown by the reproduction results. [50]

(Tarachand Amgoth, Prasanta K Jana, 2015) In wireless sensor networks (WSNs), the sensor nodes' finite and oftentimes nonrenewable energy supply is a major limitation. As a result, developing an efficient routing algorithm is one of the primary areas of study today. In this work, we present a routing method for cluster-based WSNs that takes energy efficiency into account. Cluster heads (CHs), residual energy, and intra-cluster distance all play crucial roles in the algorithm's core approach for cluster creation. For data to flow smoothly, a sink-centric directed virtual backbone of CHs is built. It is further demonstrated that the suggested algorithm maintains a consistent energy budget for the CHs while routing data. The algorithm is shown to have constant message complexity and linear time complexity. We do rigorous testing of the suggested method. In terms of network longevity, energy usage, and other factors, the testing findings reveal that the algorithm excels above other current methods [28]

2.3 Summary of Analysis

Research in WSN optimization focuses on using soft computing techniques like fuzzy logic, ant colony optimization, and swarm optimization to enhance network performance. Studies by Bhajantri and Sutagundar (2016) and Zhai and Xu (2015) demonstrate the effectiveness of fuzzy logic and ant colony algorithms in improving energy efficiency and data processing in distributed sensor networks. He et al. (2019) and AboElFotoh et al. emphasize adaptive methods for addressing energy gaps and efficient data collection. Various optimization techniques such as RDPSO and K-means FAH are highlighted for their roles in extending network lifespan and reliability.

The LEACH protocol is pivotal for energy efficiency in WSNs. Zhao et al. (2019) and Nandi et al. (2019) refined LEACH to enhance network longevity and energy usage. Studies by Jambli et al. (2018) and Birajdar and Solapure (2017) explore LEACH's hierarchical routing and cluster head rotation to minimize power demand. Patel and Shah (2016) and Darabkh et al. (2017) address issues like uneven cluster distribution and propose modifications for better performance. Innovative approaches like multi-hop LEACH and threshold-based LEACH further demonstrate significant improvements in energy consumption and network stability.

2.4 Conclusion of Chapter

This chapter highlights the advancements in WSN optimization using soft computing and the pivotal role of energy-efficient algorithms like LEACH. Soft computing techniques such as fuzzy logic, ant colony optimization, and swarm optimization significantly enhance network performance by improving energy efficiency and extending network lifespan. The LEACH protocol and its variants continue to be crucial in addressing energy consumption challenges in WSNs. Through these studies, it is evident that optimizing energy usage and improving data processing capabilities are essential for the sustainability and efficiency of wireless sensor networks. These advancements lay a strong foundation for future research and practical implementations in this field.

CHAPTER-3

ROUTING PROTOCOLS

3.1 Introduction

The use of wireless sensor networks (WSNs) is expanding rapidly as new uses are discovered for this low-cost technology. Sensing devices are embedded in nearly every modern object. They are everywhere: in our phones, cars, houses, and even watches. Research on WSNs began in the 1980s, but since 2001, it has attracted more attention from both the business world and academic institutions. Data suggests that by 2021, the WSN market has been worth more than $2 billion. This is because of the widespread availability of cheap, compact, and energy-efficient sensors.As wireless technologies progress, the need for sensor networks grows, and with it, the complexity of designing and implementing WSNs. Many WSN applications, such as industrial controls, have a focus on reliability, longevity, and cost, as shown in Figure 3.1.

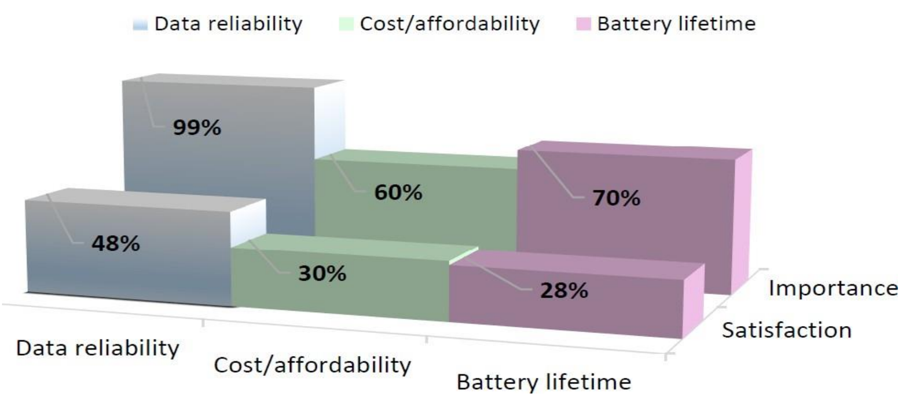

Figure 3.1 Perceived Importance of WSN Attributes [12]

The two most important qualities to consumers are durability and longevity. Customers are not yet concerned with price until they are given answers to longevity and reliability concerns. As a result, many WSN applications have as one of their core design aims striking a balance between these two characteristics. This thesis also examines the significance that energy consumption and security concerns have in the development of routing protocols.Since data transmission uses the most energy in WSNs, developing energy-efficient routing methods is crucial for extending the network's lifetime. Additionally, many WSN applications need maintaining the secrecy and authenticity of transmitted data. As a result, energy and security are two major factors that have a bearing on routing methods.Investigations on Energy Efficient Routing Protocols for Wireless Sensor Networks (WSNs) with the aim of enhancing the lifetime of sensor nodes are at the forefront of research in the field of wireless sensor technology. This topic addresses a critical challenge in the design and operation of WSNs, where sensor nodes are typically resource-constrained with limited energy supplies due to their small form factor and often remote or inaccessible deployment locations. In this detailed elaboration, we will explore the key components, motivations, challenges, and recent advancements in the domain of energy-efficient routing protocols for WSNs.

Components of Investigations on Energy Efficient Routing Protocols:

1. **Sensor Nodes:** Sensor nodes are the fundamental building blocks of WSNs. They are equipped with sensors to collect data, processing units for data analysis, and wireless communication interfaces for transmitting data to a central sink or base station. These nodes are typically powered by batteries, which have limited energy capacity and are often non-rechargeable.

2. **Routing Protocols:** Routing protocols in WSNs dictate how data packets are transmitted from source nodes to the sink or destination. Energy-efficient routing protocols are designed to minimize the energy consumption during data transmission, route discovery, and maintenance processes.

3. **Energy Models:** To develop energy-efficient routing protocols, researchers often create energy models that quantify the energy consumption associated with different activities in sensor nodes. These models help in optimizing routing decisions to minimize energy expenditure.

Simulation Tools and Testbeds: Research in this area heavily relies on simulation tools and real-world testbeds to evaluate the performance of routing protocols. Popular simulation tools include NS-2, NS-3, and OMNeT++, while testbeds involve physical deployment of sensor nodes for empirical validation

How these two variables interact to influence computational and communication expenses is depicted in Figure 3.2. The two primary uses of energy in WSNs are for processing and transmitting data. Data collection and algorithm execution consume computational energy, whereas information transmission and reception consume communicative energy. Because one byte of data transmission in WSNs uses as much energy as running 800 to 1000 instructions, routing techniques should minimize communication overheads.

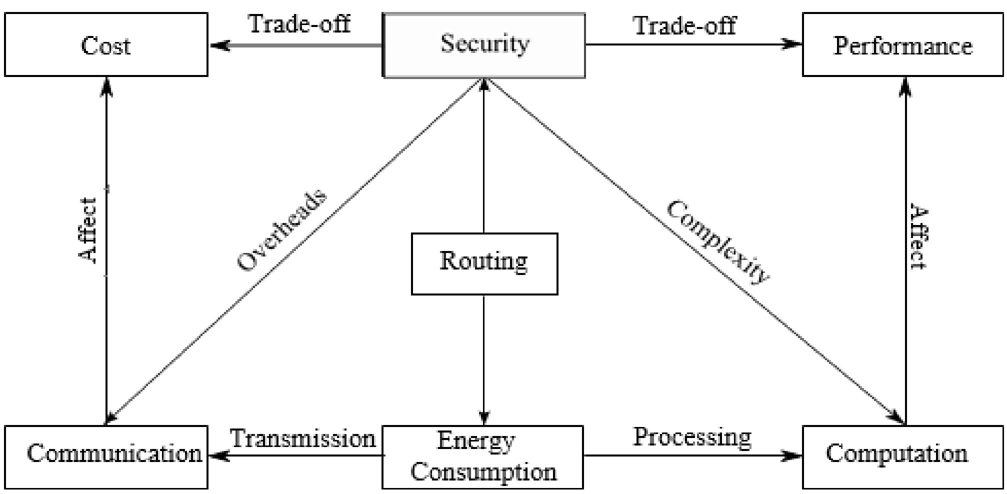

Figure 3.2 Relationship between Routing Attributes

However, the development of a secure routing system comes at a cost. Complex cryptographic systems will raise computing cost, while the exchange of security settings and extra control messages will increase communication cost. Therefore, the design of a routing protocol should always strike a balance between cost and performance in order to realize the desired level of security and energy savings.

3.2 Challenges and Design Issues in Routing

There are several reasons why routing in sensor networks is more difficult than in traditional fixed networks. To begin, the lack of infrastructure necessitates that the SNs be capable of self-organization. In addition, SN failure is prevalent in WSNs because of the unreliability of wireless networks. The network, therefore, must be stable and resilient. Third, given the constraints of SNs' resources, it's imperative that routing protocols be as power-efficient as possible. Last but not least, SNs are exposed to dangerous conditions, making them a prime target for cybercriminals. As a result, defenses against these attacks should be as solid, and the routing protocols themselves should be safe.

This article provides a concise summary of the problems and design concerns that significantly affect routing protocol performance.

In WSNs, energy consumption is a major concern because most sensor nodes run on batteries. Energy-aware protocols and algorithms are essential for sensor networks if we want to keep their batteries charged for as long as possible.

Safety and Trustworthiness Issues: Protecting and transmitting data reliably in sensor networks is difficult. To prevent an adversary from gaining access to sensitive information, secure and reliable communication protocols must be developed for sensor nodes that might be placed in a dangerous environment. Although error-correcting coding, retransmission methods, encryption, and authentication techniques can be used to protect sensitive information, they present significant power and bandwidth consumption concerns.

Connectivity and Change in Networks: In WSN applications, it is typically assumed that both the sensor nodes and the base stations are immobile. As a result, the mobility of a sensor network is rarely taken into account by protocols. As a result, putting those principles into action in dynamic settings might be difficult.

If nodes in WSNs are randomly dispersed throughout a region, they will need to use self-organizing and self-healing intelligence to continually adapt to the unforeseen conditions they would face. Energy dissipation must be kept to a minimum during the network construction process, and this calls for efficient routing algorithms.

To aggregate data means to remove duplicates. The gateway nodes execute the data aggregation process, which helps to minimize network traffic, in order to save energy. However, it is strongly advised that a secure data aggregation procedure be used to protect sensitive information in a mission-critical environment.

As an example, sensor nodes can be used in battlefields despite the fact that they are exposed to a dangerous environment with no protection. It's possible for an attacker to hack a sensor node or even add malicious nodes into the network under these circumstances. Captured private data may be used maliciously by the opponent. Thus, protecting sensitive information from hacked nodes is a major issue for researchers, who must create robust security procedures.

Oftentimes, a sensor network is deployed in a given region by scattering sensor nodes (e.g., from an airplane) in a completely random pattern. Nodes in this scenario must have the ability to self-organize in order to construct the communication architecture.

Due to the lack of a priori knowledge of the surrounding area, networks need key agreement procedures to keep out rogue nodes.

Due to physical damage, technological difficulties, or power loss, a sensor node may fail. In the event of a node failure, the network as a whole must continue to function normally. In order to deal with issues such as node failures and connection congestions, flexible protocols are necessary. When a forwarding node goes down, for instance, the routing protocols must figure out how to redirect traffic.

Scalability: For hundreds of sensor nodes to be deployed and collect data from the surrounding environment, several WSN applications are required. Consequently, it is imperative that the communication protocols be developed in a fashion that allows for the addition of new nodes to the network without disrupting the existing clustering, routing, or network activities.

Lag Time in Interactions: High communication latency in wireless sensor networks may result from factors such as multi-hop routing, network congestion, and data aggregation in intermediary nodes. Some security measures, such the distribution of cryptographic keys, rely on the participating nodes being in perfect sync with one another, thus this complicates matters greatly.

3.3 Overview of Routing Protocols Techniques

Limitations in WSN's power and data transfer capabilities present management challenges that call for an energy-aware protocol to be developed throughout the whole networking protocol stack. System-level power awareness, including radio communication hardware, low duty cycle difficulties, and energy-aware MAC protocols, have all been the subject of extensive study in an effort to provide effective power management in WSN. It was also found that the network layer provides a more effective way to extend the lifetime of a network by facilitating the efficient routing of data.

It's important to recognize that WSN routing differs significantly from that used in conventional or ad hoc networks. Following is a list of characteristics:

Multiple sensors may collect the same information in the same area, leading to considerable duplication in produced data and

a) the inability to construct WSN with a global addressing (internet protocol address scheme due to the vast number of sensor nodes.
b) To maximize bandwidth use and decrease energy consumption, this duplication must be eliminated.
c) Transmission power, processing capacity, and storage are constraints that must be taken into account while administering a WSN.

Because of these dissimilarities, researchers are developing brand-new techniques to solve the issues plaguing WSN. The properties of sensor nodes, in addition to the needs of the corresponding application and architecture, informed the development of these routing protocols. You may categorize the various protocols as either location-based, data-centric, or hierarchical. Although there are others that were created to improve the quality of the flow.Several motivations drive investigations into energy-efficient routing protocols for WSNs:

1. **Prolonged Sensor Node Lifetime:** The primary motivation is to extend the operational lifetime of sensor nodes. Longer node lifetimes reduce the frequency of node replacements, which can be costly and impractical in remote or harsh environments.

2. **Sustainability:** Energy-efficient routing contributes to the sustainability of WSNs by minimizing the environmental impact of frequent battery replacements and

reducing the need for maintenance in remote areas.

3. **Reliability:** Energy-efficient routing protocols enhance the reliability of data transmission in WSNs by reducing the risk of node failures due to energy depletion. This is critical in applications where data accuracy and timeliness are paramount.

4. **Cost-Efficiency:** By optimizing energy consumption, energy-efficient routing protocols can reduce the operational costs associated with sensor node deployment and maintenance.

Challenges in Developing Energy Efficient Routing Protocols:

Developing effective energy-efficient routing protocols in WSNs presents several challenges:

1. **Dynamic Network Topology:** Sensor nodes may enter or leave the network at any time, leading to a dynamic topology. Routing protocols must adapt quickly to these changes while minimizing energy consumption during route discovery and maintenance.

2. **Scalability:** Many WSN applications involve a large number of sensor nodes. Routing protocols must be scalable to handle networks of varying sizes without incurring excessive overhead.

3. **Quality of Service (QoS) Requirements:** Different applications may have diverse QoS requirements. Some may tolerate delays in data transmission, while others require low-latency communication.

4. **Data Aggregation:** Data aggregation at intermediate nodes can significantly reduce energy consumption by eliminating redundant transmissions. Routing protocols should support data aggregation strategies.

5. **Security:** Security is a paramount concern in WSNs. Energy-efficient routing protocols must ensure data confidentiality, integrity, and authenticity without imposing excessive energy overhead.

Recent Advancements and Innovations:

In recent years, several innovative approaches and research trends have emerged in the field of energy-efficient routing protocols for WSNs:

1. **Machine Learning and AI-based Routing:** Machine learning techniques are applied to predict network conditions and adapt routing decisions dynamically based on real-time data. Reinforcement learning and deep learning models optimize routing paths.

2. **Energy Harvesting Integration:** Energy harvesting techniques, such as solar panels and kinetic energy scavenging, are integrated with sensor nodes to supplement their energy supply. Routing protocols are designed to exploit energy harvesting opportunities effectively.

3. **Mobility-Aware Routing:** In scenarios with mobile sensor nodes, routing protocols consider node mobility patterns to minimize energy consumption during data transmission. Predictive routing algorithms anticipate node movements.

4. **Cognitive Radio Networks:** Cognitive radio technology allows sensor nodes to dynamically adapt their communication frequency bands to avoid interference and reduce energy consumption. Cognitive routing protocols optimize spectrum usage.

5. **Blockchain-Based Routing:** Blockchain technology is explored for enhancing security and trust in WSNs. Routing protocols may utilize blockchain for secure route discovery and data transmission.

3.3.1 Location Based Protocol

Most WSN routing strategies rely on sensor node locations to calculate the energy required to send data from one node to another based solely on the distance between them. Using a location sensor to pinpoint an area of interest allows for a far more efficient query than sending out a blanket request to the network at large [7]. As an alternative to broadcasting the data throughout the whole network, the location-based protocol just sends it to the specific areas that need it. The MECN protocol is one implementation of this technology (minimum energy communication network). Using a low-power global positioning system, MECN not only establishes but also sustains a low-power level in a WSN (GPS).

3.3.2 Data Centric Protocol

In a randomly deployed application, giving unique global IDs to each sensor node in a WSN may seem impossible, because data broadcast by each sensor node in a given region is highly redundant. In order to cut down on unnecessary duplication, data-centric protocols have been created to pick a group of sensor nodes and to aggregate data before sending it. Data-centric approaches often focus on the information collected by a system, such as a sensor protocol enabling data exchange through bargaining (SPIN). The metal-data names used to label SPIN's data are a distinguishing feature.

For another sort of routing system, consider flooding, in which data is received by a sensor node and then broadcasted to its neighbors until either the maximum number of hops for the packet is reached or the packet's destination is reached.

Each sensor node just has to be aware of its immediate neighbors, making SPIN ideal for preventing widespread topological disruption. However, it has drawbacks in terms of scalability (not scalable), and the nodes in the vicinity of the base station may run out of power if the BS is interested in too many events. In addition, SPIN's data ad mechanism cannot ensure data delivery. For instance, data will not be transferred to the destination if the sensor nodes that are interested in it are located distant from the source node and the nodes in between the source and the destination are not interested in it.

3.3.3 Hierarchical Routing

In WSN, data transmission from sensor nodes to the base station may be optimized by the use of hierarchical routing, in which the clusters are organized in a hierarchical structure. By utilizing multi-hop communication for a given cluster, hierarchical routing is able to reduce energy consumption by effectively aggregating data and fusing it in a manner that reduces the quantity of data transferred over the network to the sink. Clusters are formed when sensor nodes with excess energy elect a Cluster Head (CH). The low-energy adaptive clustering hierarchy is a fantastic illustration of a hierarchical routing algorithm (LEACH).

Table 3.1

Comparison of Routing Technique

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

The LEACH method relies on the development of clusters of sensor nodes based on the quality of the received signal and the employment of a nearby CH as a router to the base station (BS). Since the CH is transmitting to the BS rather than individual sensor nodes, significant energy savings can be realized during data transmission. One of LEACH's main drawbacks is that it can't be used in a very massive network deployment.

3.4 Low Energy Adaptive Cluster Hierarchy Protocol

As the first hierarchical routing system to propose data fusion, the Low Energy Adaptive Cluster Hierarchy (LEACH) Protocol represents a watershed moment in the evolution of clustering routing protocols. Many modern hierarchical routing techniques build on LEACH in various ways. It is therefore crucial to study the LEACH protocol in preparation for the widespread use of wireless sensor networks. When thinking about hierarchical routing protocols, LEACH Protocol is a good example. It can adjust to its surroundings and arrange itself. For the objective of minimizing wasteful energy consumption, the steady-state stage of the LEACH protocol's rounds must be significantly longer than the set-up stage.

- Each cycle of the LEACH operation has a predetermined duration and consists of two parts: an initialization and a maintenance of the current state. A round's duration is predetermined. The steps of the LEACH algorithm are as follows:
- During the advertising phase, nodes promote themselves in a cluster-head marketing message to be the leader of the current round (r). The cluster heads employ a CSMA MAC protocol for their advertising needs. Once this milestone has been reached, the nodes who aren't the cluster heads evaluate the strength of the approved advertisements and choose which cluster they'll join for this iteration (r). A node n at each stage picks a random number k between 0 and 1 inclusive.
- Each node that isn't the cluster head must now choose a cluster to join and communicate that decision to the cluster head. This is the cluster setup step. As a result, the CSMA MAC protocol is used for each node to relay this data back to the cluster's coordinator.
- In the first, predetermined stage, the cluster's leader node receives membership requests from other nodes. The cluster-head node calculates a TDMA schedule

based on the number of nodes in the group and informs each node of its turn to transmit. The nodes in the cluster are receiving this schedule now.

- Following the establishment of clusters and the TDMA schedule, group nodes will begin sending the information they have accumulated to the cluster's designated hub within their assigned data transmission period. Once all of the data have been sent and received by the cluster-head node, it will conduct the signal processing function to combine all of the data into a single signal.

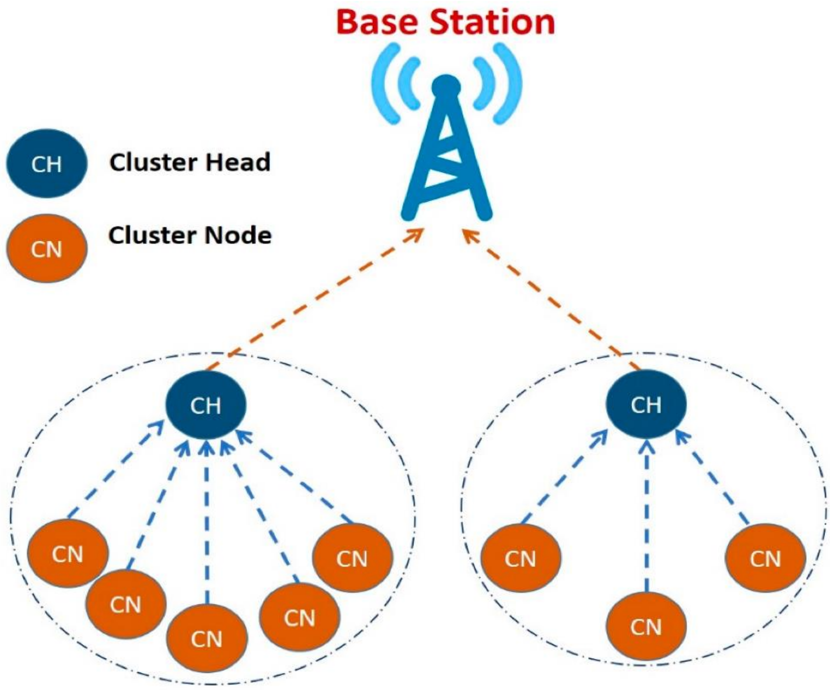

Figure 3.2 Process of LEACH Protocol

It's possible that LEACH protocol postulation will disrupt many real-time systems. Important hypotheses include:

- Every node has the ability to send a strong signal to the hub anytime it's needed.
- With appropriate processing power, every node can handle several media access control (MAC) protocols. There is always information waiting to be sent at the nodes.

- Data correlation for physically close nodes.
- If the first node in the system goes down, the whole thing tips out of whack.
- Each pair of nodes in a voting cycle has the same total energy storage capacity.
- • The node that acts as though it is the cluster leader will use up about the same amount of energy as the other nodes..

3.5 Advantages of LEACH Protocol

The LEACH procedures have several benefits, including those listed below.

- • It aids scalability in the network by restricting most communications to occur between the many clusters in the network.
- • High amounts of network traffic can be contained by having the cluster's leader gather and combine the data supplied by the sensor nodes. As a result, a high-capacity network may be set up with minimal wasted traffic, and a more energy-efficient topology can be achieved than with a flat-topology network.
- • It's possible to route data directly from a sensor node to the cluster's leader, so maximizing available network power.
- It has the distributive property inside the cluster, which means that it divides up the function of cluster head (CH) between the many other members of the cluster.
- • It increases the network's longevity in three distinct phases. To begin, it assigns the extra nodes in the cluster the CH role, which requires more energy than regular sensor nodes. Second, it compiles information verified by CHs. At last, using TDMA, the majority of the sensor nodes are set to sleep mode. Only in event-based applications is this practice common. By doing so, the network's lifespan may be extended and energy consumption can be reduced by more than seven times compared to when communicating directly.

- The physical positions of the network's sensor nodes are irrelevant to the clustering process. Therefore, it is a highly effective routing system, and it is also quite easy to implement.
- It offers a dynamic method of clustering that may be used in your own projects. The system excels in use cases that call for continuous environmental monitoring and have a periodic requirement to compile data at a central point in the network.

3.6 Disadvantages of LEACH Protocol

Investigations on energy-efficient routing protocols for WSNs are integral to the success of wireless sensor technology in various domains. These protocols play a pivotal role in extending the operational lifetime of sensor nodes, ensuring reliability, sustainability, and cost-effectiveness in sensor network deployments. As WSNs continue to find applications in areas such as agriculture, healthcare, environmental monitoring, and smart cities, the development of energy-efficient routing protocols remains an active and evolving research domain, addressing both existing challenges and emerging opportunities. Researchers in this field are driven by the goal of optimizing energy consumption to unlock the full potential of WSNs in an increasingly connected world.

The use of wireless sensor networks (WSNs) has witnessed rapid growth as these low-cost and versatile technologies find new applications in various domains. These sensing devices are omnipresent in modern life, integrated into our smartphones, cars, homes, and even wearables like watches. While the research on WSNs started in the 1980s, it gained significant attention from both academia and industry around 2001. The market for WSNs has grown steadily, with estimates indicating a worth exceeding $2 billion by 2021. The driving force behind this expansion is the availability of affordable, compact, and energy-efficient sensors.

As wireless technologies advance, the demand for sensor networks increases, leading to more complex designs and implementations. Many WSN applications, such as industrial controls, prioritize reliability, longevity, and cost-effectiveness. The primary concerns for consumers are durability and lifespan, with cost being secondary. Consequently, a significant design objective for many WSN applications is to strike a balance between these two crucial attributes. This thesis also investigates the pivotal roles that energy consumption and security concerns play in the development of routing protocols.

Energy consumption is a critical concern in WSNs due to the limited power supply of sensor nodes, often relying on batteries. Therefore, energy-efficient protocols and algorithms are essential to maximize the lifespan of sensor networks. Additionally, ensuring the confidentiality and authenticity of transmitted data is crucial in many WSN applications, making energy and security two pivotal factors influencing routing methods.

The interplay between these two variables and their impact on computational and communication costs can be visualized in Figure 3.2. Energy consumption in WSNs primarily revolves around two activities: data processing and data transmission. Data collection and algorithm execution consume computational energy, while data transmission and reception consume communication energy. Given that transmitting one byte of data in WSNs consumes as much energy as executing 800 to 1000 instructions, routing protocols must minimize communication overhead. However, the pursuit of a secure routing system comes with its own costs. Complex cryptographic systems increase computational costs, while the exchange of security settings and additional control messages escalates communication costs. Hence, designing routing protocols must strike a delicate balance between cost and performance to achieve the desired level of security and energy efficiency.

Several challenges and design issues complicate routing in sensor networks compared to traditional fixed networks:

1. **Self-Organization:** WSNs lack infrastructure, necessitating self-organization capabilities for sensor nodes. They must organize themselves without external assistance.
2. **Node Failures:** Sensor node failures are common due to the inherent unreliability of wireless networks. Routing protocols must ensure network stability and resilience.
3. **Power Efficiency:** Given the resource constraints of sensor nodes, routing protocols should be as power-efficient as possible.
4. **Security Concerns:** Sensor nodes are susceptible to various threats, making robust security measures and safe routing protocols essential.

Energy-aware protocols and algorithms are vital for WSNs to optimize power consumption, considering that most sensor nodes operate on batteries. Additionally, robust and secure communication protocols are crucial, particularly for sensor nodes deployed in hazardous environments, where data confidentiality and integrity are paramount. Data aggregation is another energy-saving technique, which can minimize network traffic and conserve energy, especially in mission-critical applications.

WSN deployment often involves scattering sensor nodes randomly throughout a region, requiring self-organizing capabilities for network construction. The lack of prior knowledge about the environment necessitates key agreement procedures to safeguard against rogue nodes and secure data transmission.

Node failures, whether due to physical damage, technical issues, or power depletion, are inevitable in WSNs. To ensure network continuity and adaptability, flexible protocols are necessary to handle node failures and congestion situations. Scalability is vital for accommodating large-scale deployments without disrupting existing network activities.

High communication latency, often caused by multi-hop routing, network congestion, and data aggregation, poses challenges for security measures such as cryptographic key distribution, requiring synchronization among nodes. Despite these challenges, several routing protocol techniques have been developed to address these issues:

1. **Location-Based Protocols:** These protocols leverage the physical locations of sensor nodes to optimize energy consumption by calculating data transmission energy based on node distances. Examples include the Minimum Energy Communication Network (MECN) protocol.

2. **Data-Centric Protocols:** Data-centric protocols focus on minimizing data redundancy by aggregating data before transmission. They are suitable for applications with redundant data collection. The Sensor Protocol for Information via Negotiation (SPIN) is one such example.

3. **Hierarchical Routing:** Hierarchical routing organizes clusters of nodes in a hierarchical structure, reducing energy consumption through data aggregation and efficient multi-hop communication within clusters. The Low-Energy Adaptive Clustering Hierarchy (LEACH) is a well-known hierarchical routing protocol.

3.7 Variations in LEACH Protocol

LEACH is a seminal protocol that introduced the concept of data fusion within clusters, extending network longevity and energy efficiency. It operates in rounds, where nodes take turns becoming cluster heads and aggregating data for transmission to the base station.

While LEACH offers advantages, it has its limitations:

- Reliance on cluster heads for data transmission to the base station can lead to early cluster head depletion.

- Permanent costs are incurred with each data transmission, affecting energy efficiency.
- Inter-cluster communication is limited, and nodes far from the base station may experience higher energy consumption.

To overcome these limitations and address specific challenges, variations of LEACH have been developed:

1. **LEACH-C (Centralized):** LEACH-C improves cluster head selection by involving the base station in the initial decision-making process. It aims to create more efficient clusters by distributing cluster heads evenly.
2. **LEACH-E (Energy-Based):** LEACH-E selects cluster heads based on residual node energy after the first stage, promoting nodes with higher energy levels to become cluster heads in subsequent rounds.
3. **TL-LEACH (Two-Level LEACH):** TL-LEACH introduces a two-tiered hierarchy to optimize data transmission from clusters to the base station. It uses relay nodes within clusters to bridge communication with the base station.
4. **LEACH-H (Hybrid):** LEACH-H combines elements of LEACH and LEACH-C to improve load balancing and cluster head selection, addressing the issue of an arbitrary number of cluster heads in LEACH.
5. **M-LEACH (Multihop-LEACH):** M-LEACH optimizes data transmission by converting single-hop communication between cluster heads and the base station into multi-hop transmission, reducing energy consumption.

Each of these variations offers specific advantages and trade-offs, allowing researchers and practitioners to tailor routing protocols to their specific WSN requirements.

In summary, the use of wireless sensor networks has seen exponential growth due to the versatility and cost-effectiveness of these technologies. Energy-efficient routing protocols are essential to maximize the lifespan of sensor networks, with security concerns also playing a crucial role. Various challenges, such as self-organization, node failures, and security threats, necessitate the development of robust routing protocols. LEACH, as a foundational protocol, introduced the concept of data fusion within clusters but had its limitations.

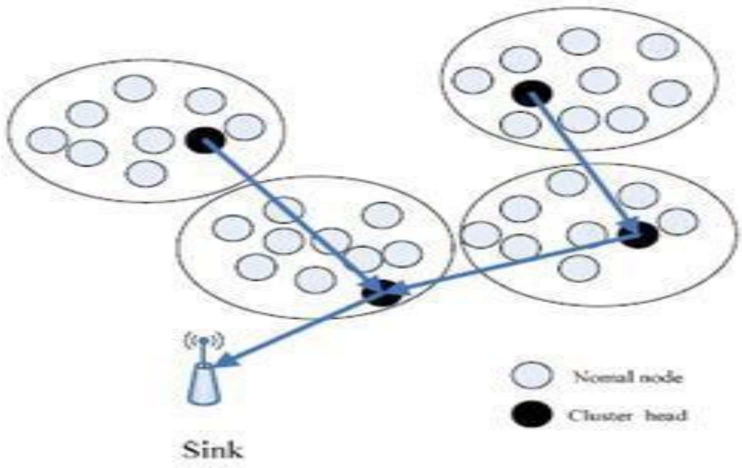

Figure 3.2 LEACH-E Structure

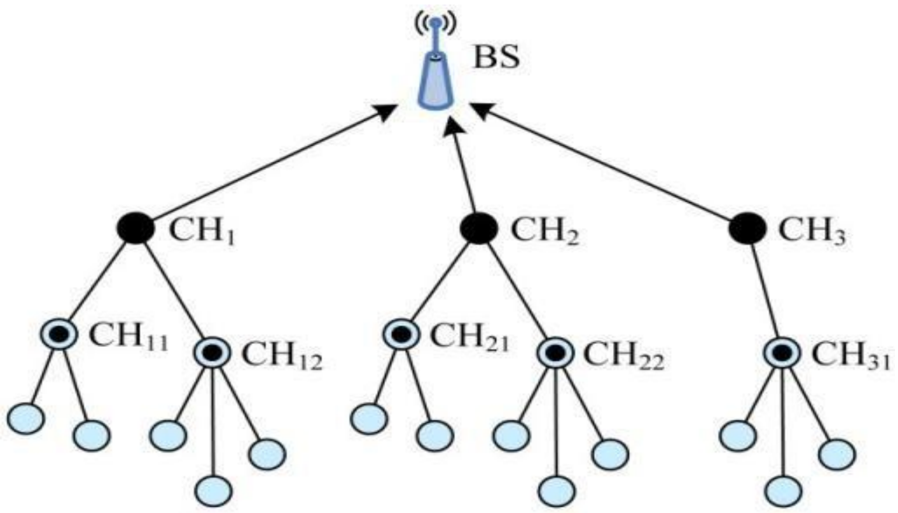

Figure 3.3 TL-LEACH Structure

To address these limitations and specific challenges, several variations of LEACH have been developed, offering unique features and trade-offs to suit different WSN applications. These routing protocols play a pivotal role in optimizing energy consumption and ensuring the reliability and efficiency of wireless sensor networks in various domains.

LEACH, a foundational protocol for WSNs, is known for its energy efficiency and performance. However, it has several limitations, such as over-reliance on cluster heads for communication, which leads to durability issues and energy inefficiency, especially in large networks. This inefficiency is further compounded by the fact that cluster heads, being pivotal in communication, incur more energy expenses and are susceptible to failure.

To address these concerns, various iterations of LEACH have been developed. LEACH-C, for instance, employs a centralized approach for cluster formation, using a Base Station to ensure an equitable distribution of energy load among nodes. This method uses the average energy of nodes to determine cluster heads, potentially enhancing the overall efficiency of the network.

LEACH-E focuses on using residual energy as a criterion for selecting cluster heads, aiming to prolong the lifespan of each node. This variation gives an equal opportunity to all nodes initially, with subsequent selections based on their remaining energy levels.

The introduction of TL-LEACH addresses the issue of cluster heads exhausting their energy too quickly by establishing an intermediary cluster head between the main cluster head and the sink. This method ensures a more balanced energy consumption across the network.

LEACH-H and M-LEACH introduce further refinements. LEACH-H combines the advantages of LEACH and LEACH-C, involving the base station in initial cluster head selection and then allowing current heads to choose their successors. M-LEACH, on the other hand, extends the reach of the network through multihop transmission, reducing the energy burden on individual cluster heads.

V-LEACH introduces the concept of a vice-cluster head, which takes over if the main cluster head fails, ensuring continuity and network stability. LEACH-B focuses on incorporating the residual energy of nodes in cluster head selection, aiming for balanced clustering and sustained network life.

Other variations like FZ-LEACH, LEACH-A, K-LEACH, and Mobile LEACH each add unique aspects to the protocol. FZ-LEACH addresses issues with cluster sizes, LEACH-A introduces heterogeneous energy levels, K-LEACH employs the K-medoids method for optimal clustering, and Mobile LEACH adapts the protocol for mobile nodes.

Security LEACH (S-LEACH) adds cryptographic security to protect against external attacks, ensuring that cluster heads and their communication remain secure. Lastly, MODLEACH presents an advanced version of the protocol with improved cluster head substitution techniques and enhanced transmission power, contributing to the overall robustness and efficiency of the network.

In summary, the document provides a comprehensive overview of the LEACH protocol and its various modifications, each designed to address specific challenges in WSNs, such as energy efficiency, durability, security, and adaptability to diverse network requirements. These improvements reflect the ongoing evolution of WSN technology, demonstrating its critical role in modern industries and daily life applications. The advancements in LEACH variants demonstrate an ongoing effort to optimize WSNs for a wide range of applications. Each variation of the LEACH protocol is designed to address specific challenges and limitations identified in earlier versions or to cater to particular network requirements.

For instance, FZ-LEACH deals with the formation of "Far-Zones," targeting the issue of energy inefficiency in large or unevenly distributed clusters. By recognizing and addressing the energy disparities in different zones of the network, FZ-LEACH aims to prolong the network's lifespan and ensure more stable operations.

LEACH-A, with its mobile agent approach, introduces a dynamic element into the network, catering to environments where node mobility is a factor. This adaptation not only enhances network resilience but also ensures continued data collection and transmission even as nodes move or adjust within the network.

K-LEACH's use of the K-medoids method for cluster formation exemplifies the application of advanced mathematical models to optimize network operations. By focusing on the geometric center and Euclidean distances, K-LEACH strives for the most energy-efficient clustering, which is crucial for the sustainability of sensor networks.

Mobile LEACH adapts the protocol for networks where nodes are not stationary. This variation is particularly important in dynamic environments where the nodes' positions change, requiring a flexible and adaptive clustering strategy.

Finally, S-LEACH adds a layer of security, a critical aspect in modern networks, especially where sensitive data is involved. By incorporating cryptographic measures, S-LEACH aims to safeguard the network against external threats, ensuring the integrity and confidentiality of the data collected and transmitted.

MODLEACH represents a culmination of these advancements, incorporating enhanced cluster head selection and transmission power techniques. It reflects a broader trend in WSN development, where the focus is not only on energy efficiency but also on ensuring robustness, adaptability, and security in diverse and often challenging environments.

V-LEACH (Vice Cluster LEACH): V-LEACH introduces the concept of vice clusters to address the issue of cluster head failures in WSNs. In traditional LEACH, when a cluster head (CH) fails, it disrupts the entire cluster, leading to data loss and network inefficiency.

V-LEACH solves this problem by designating vice-cluster heads. These vice-cluster heads are ready to take over as CHs in case the current CH fails. This ensures the continuity of data collection and transmission to the base station even when CHs fail, increasing network resilience and reliability. V-LEACH effectively extends the network's lifetime by minimizing data loss due to CH failures.

LEACH-B: LEACH-B is designed to address the limitations of the original LEACH protocol. One of its key innovations is the introduction of a second choice for cluster heads during the setup phase. This approach aims to balance the division of clusters and maintain their continuity over multiple rounds. By ensuring that each cluster has a balanced number of member nodes and cluster heads, LEACH-B reduces energy consumption and prolongs the network's lifespan. Decentralized techniques are employed to create clusters, where each sensor node only has knowledge of its own location and the intended destination of data. This approach optimizes energy usage and improves overall network efficiency compared to LEACH.

FZ-LEACH (Far-Zone LEACH): FZ-LEACH addresses the challenge of varying cluster sizes in WSNs, which can lead to energy inefficiencies. It introduces the concept of a "far zone" comprising sensor nodes with energy levels below a certain threshold. To optimize cluster formation, FZ-LEACH employs rotational randomization based on the LEACH protocol. By organizing clusters in this manner, the protocol minimizes energy waste and helps maintain network stability. This innovative approach to addressing energy imbalances in clusters makes FZ-LEACH a valuable addition to the family of LEACH-based protocols.

LEACH-A: LEACH-A builds upon the foundation of the original LEACH protocol by introducing an agent-based approach to data processing. It also incorporates a heterogeneous energy protocol to enhance network performance. In LEACH-A, clusters are organized with cluster aggregator (CAG) nodes serving as leaders. These CAG nodes are selected based on their energy levels, with the most energetic nodes becoming cluster leaders. A noteworthy feature of LEACH-A is that even after the demise of regular nodes, CAG nodes continue transmitting data to the base station, ensuring data integrity and prolonging the network's lifespan. This protocol offers a dynamic and efficient method for cluster management in WSNs.

K-LEACH: K-LEACH refines cluster formation and leader selection by utilizing the K-medoids method. This method ensures consistent and balanced clustering by selecting cluster heads based on their proximity to the previous round's head. The K-medoids technique is known for its optimal clustering properties and energy efficiency. K-LEACH leverages these characteristics to improve network performance. By considering both energy efficiency and data aggregation, K-LEACH offers an effective solution for cluster organization and leader selection in WSNs.

Mobile LEACH: Mobile LEACH addresses the assumption of uniform energy levels among sensor nodes, which is unrealistic in many WSN scenarios. It allows nodes to move, mitigating the energy imbalance issue. In this protocol, clusters are organized with a precise circle of irregular nodes, and the cluster head with the most connected member nodes may deplete its energy faster than others. By introducing mobility support, Mobile LEACH aims to prolong the network's lifetime and improve energy distribution. This protocol is especially useful when nodes have varying energy levels or when energy-efficient routing is required.

S-LEACH (Security LEACH): S-LEACH is designed to enhance the security of LEACH-based WSNs. It introduces cryptographic measures to protect against external attacks, including selective forwarding, sinkholes, and HELLO floods. Each sensor node in S-LEACH is equipped with two symmetric keys: a pairwise key shared with the base station and a key chain held by the base station. These keys ensure the integrity and authenticity of data transmission within the network. S-LEACH focuses on defending against malicious actors aiming to disrupt network operations or inject fake sensor data. By providing secure communication and data integrity, S-LEACH strengthens the reliability of LEACH-based WSNs in potentially hostile environments.

MODLEACH: MODLEACH is an improved version of the original LEACH protocol that offers several enhancements. It introduces cluster head substitution techniques and increases transmission power by a factor of two. These enhancements contribute to better network performance, especially in terms of throughput, network lifespan, and cluster head management. MODLEACH addresses various challenges faced by LEACH and provides a more flexible and efficient solution for managing WSNs.

3.8 Conclusion of Chapter

The chapter explores the growing use of wireless sensor networks (WSNs) in various applications, emphasizing their integration into everyday objects. The study highlights the importance of energy-efficient routing protocols, focusing on LEACH and its variations, to enhance network lifespan and address challenges like node failures, security, and scalability. These variations of the LEACH protocol demonstrate the continuous evolution and adaptation of clustering-based protocols to meet specific requirements and challenges in wireless sensor networks, ranging from energy efficiency and network stability to security and mobility support.

CHAPTER-4

PROPOSED METHODOLOGY

In this study, we adjust several variables at the outset of the simulation. After the specified number of iterations, the data is gathered and analysed. The diagrams are used to describe the results, which are then used to demonstrate the diagrams. Finally, our findings were compared to those of similar studies already published.

4.1 LEACH and Improved Centralized LEACH

Nodes within each transmission range can talk to one another without the requirement for a routing mechanism. Nodes A and C in Figure 4.1 are not in range of one other, therefore they must transmit data to an intermediate node, such node B, which transfers packets forward and backward since its transmission range spans those of both A and C.

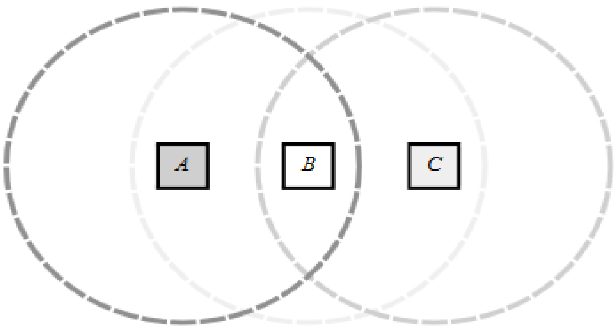

Figure 4.1 Analysis of Number of Nodes and Ranges

When (1) nodes are neighbours and (2) nodes have sufficient power, there may be direct communication between them. However, this might be problematic due to the significant amount of energy needed to accomplish a high power transfer. We may classify routing systems as either 1) Flat, where no master nodes or reference nodes are established, or 2) Hierarchy, where certain nodes are given more authority than others.

A hierarchical cluster-based model of a WSN is shown in Figure 4.2. Each node in this network is a cluster, often called a clump, and each clump has a leader known as a cluster head (CH) who is in charge of the information within it. Knots that aren't cluster heads are referred to be CMs. Coordination HUBs (CHs) are in charge of coordinating with other clusters. Coordination inside the cluster refers to the process of coordinating amongst nodes and collecting data from them within the same cluster. Intercluster coordination, on the other hand, involves communication between CHs or between CHs and BSs. In other words, CHs talk to each other across CM, while BSs talk to each other across CHs..

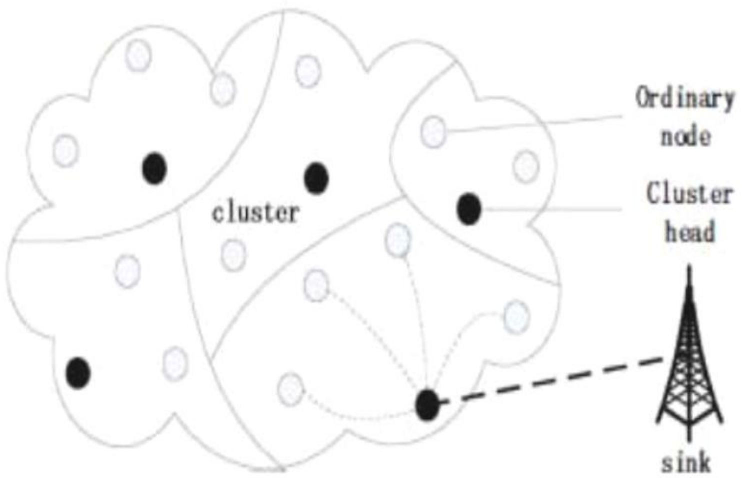

Figure 4.2 Analysis of Cluster-Based Hierarchical Design

How much power is used is proportional to the number of CHs. Energy usage in a WSN will rise due to the CHs' need for intercommunication with the BS if there are a large number of CHs. Energy usage will also rise due to data aggregation and transmission between CMs and CHs if the WSN has a limited number of CHs. The Low Energy Adaptive Clusters (LEACH) Hierarchy is the simplest hierarchical protocol (the clusters-based protocol) and serves as the foundation for the vast majority of currently available energy-efficient protocols. Clustering using LEACH is seen in Figure 4.2.

4.2 Phases of LEACH

LEACH goes through several iterations, each of which represents a stage between the initialization and steady-state phases. Both LEACH and LESS have two stages:

4.2.1 Set-up Phase

In addition, the setup process is split into 2 parts:

1. Step of publicity

2. Set-up process of cluster

In LEACH, nodes construct clusters independently through the use of a distributed algorithm. In this context, distant contact with the base station is unnecessary, and dispersed cluster construction can be executed without pinpointing the precise locations of all nodes. In addition, there is no requirement for worldwide coordination when determining limits.

Finally, the cluster's head nodes will be dispersed around the network so that the non-cluster head nodes have to communicate the least possible distance. A sensor node will choose a random number, r, from the range 0 to 1. Set a cutoff point T(n)::

$$P, n \in G \quad (4.1)$$

$$T(n) = 1-P\times[r \bmod (1/P)] \quad (4.2)$$

Otherwise,

$$T(n) = p/1-p \times (r \bmod p-1) \quad (4.3)$$

If the random number is smaller than a threshold value, T, the node will take charge of its cluster for this iteration (n). The threshold value is calculated using the above equation, which takes into account the current round, the number of nodes, and the previous round's threshold value (1/P). Once a node has been selected as a cluster leader, the ADV is broadcast to the rest of the network. The node's identifier and a special header designate this short message as an announcement. An expanding non-cluster head node determines its cluster membership by selecting the cluster head that requires the least communications energy based on a signal strength derived from each cluster head. Each member node must then notify the cluster leader that it has joined the specified cluster. Each node will then reply with a Join-REQ message to the cluster leader it has elected. The flow of data inside a LEACH cluster is managed by cluster leaders who are accountable only to their peers.

The node at the center of the cluster is responsible for establishing the TDMA protocol and sending it out to the other nodes. The radio components of a node that isn't the cluster head can remain unplugged except when it's broadcasting, preventing data collisions and saving power.

4.2.2 Steady State Phase

Further splitting the steady phase into two parts:

1. Creating time-table

2. Transfer of data

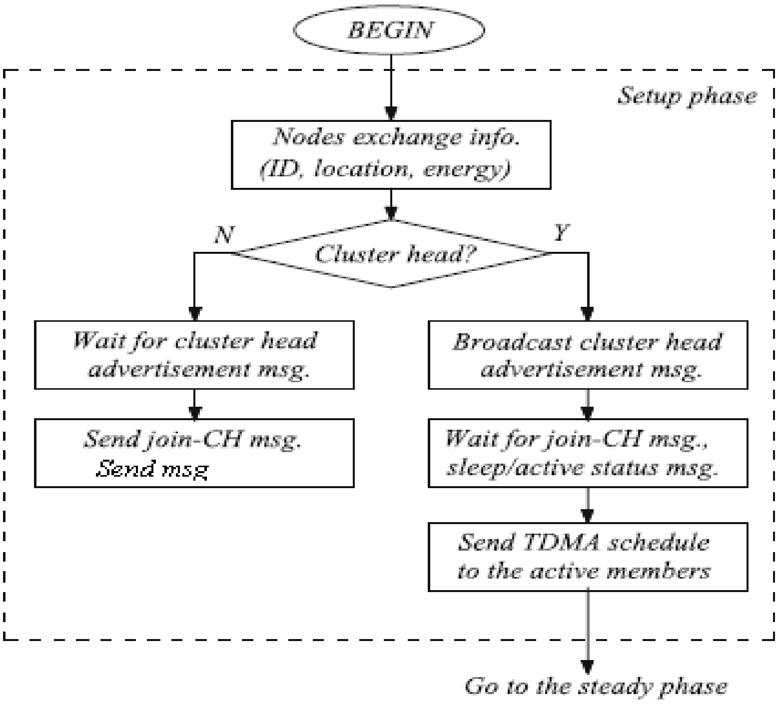

Figure 4.3 Analysis of Set up Phase

To make the most efficient use of the allocated transmission time, the continuous operation is broken down into frames in which nodes only send data to the cluster head once every frame. The setup procedure does not ensure a balanced number of nodes among the cluster leaders. Therefore, LEACH's cluster sizes can be rather diverse, and the quantity of data transmitted by each one node will vary proportionally. Power control is used by the expanding node of the cluster's head to limit the loss of energy during transmission, allowing an assessment of the transmission's efficacy relative to the cluster's ad's strength. Each node outside of the cluster has its radio turned off before to the scheduled time of broadcast. Since all of the nodes need to send information to the cluster master and the total bandwidth is fixed, a TDMA schedule is a low-latency, energy-efficient method of doing so. All data from the cluster nodes will be collected by the cluster leader, who will also be responsible for maintaining the receiver. When all data has been received by the clusterhead, the clusterhead will process the information and send the processed data to the base station.

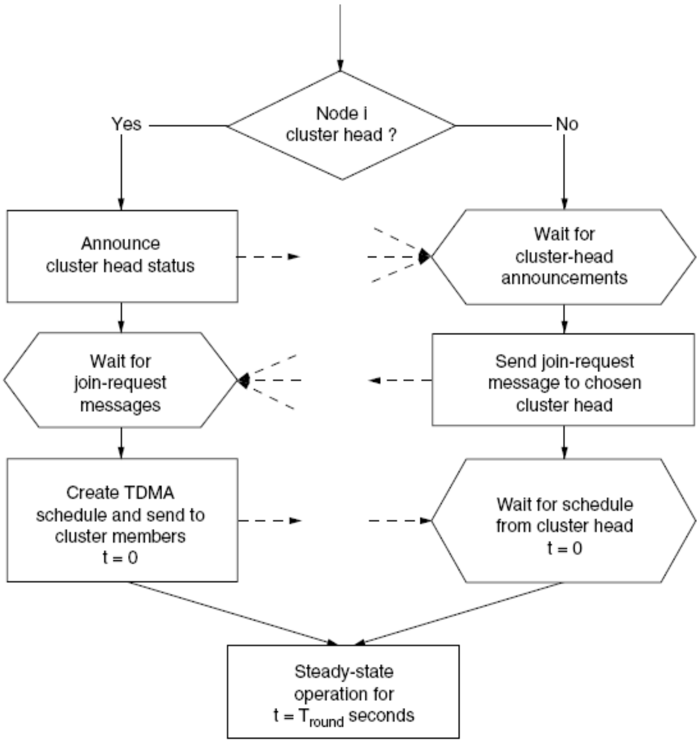

Figure 4.4 Analysis of Steady State Phase

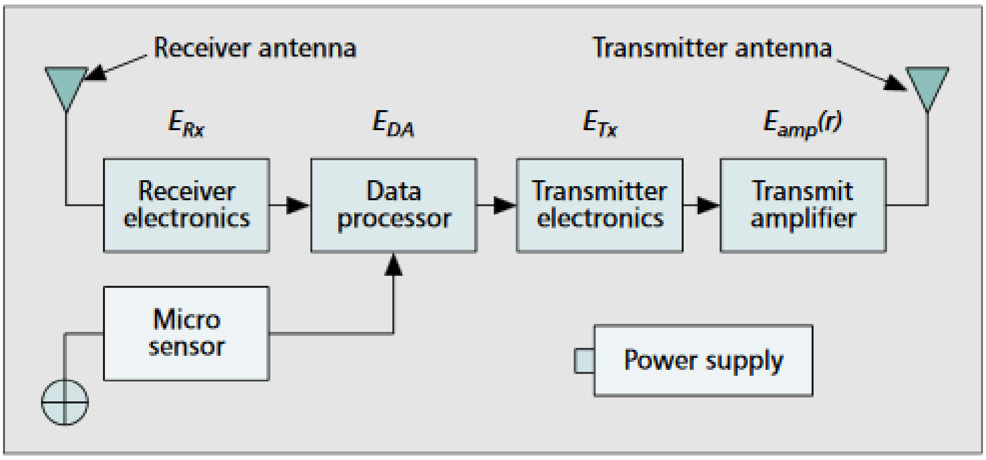

Figure 4.5 Energy Transfer Model

Figure 4.5 is a simplified representation of the entire communication procedure. Each sensor node in the model has a radio and an antenna for wireless communication. As a result, the energy consumption of the component is broken down further into receiver, transmitter, and amplifier sub-categories.

4.3 Energy Aware Multi-Hop Multi-Path Hierarchical (EAMMH)

The sensor nodes were organized into clusters, and a multihop protocol called EAMMH was used to communicate between them. From each sensor node, numerous paths to the cluster's leader are established, and an energy-aware heuristic is provided to help determine the optimal one.

To route wireless sensor networks effectively while conserving energy, EAMMH employs a hierarchical routing protocol. Protocols that are aware of energy usage tend to be heuristic in nature, with a primary focus on the energy of the next hop. Since sensor nodes have limited resources, energy-aware techniques try to avoid picking sensors that use an excessive amount of power when transmitting data. As a result, it is a useful heuristic for use in fair and efficient routing systems. Furthermore, these protocols' goal is to equalize communication burden across all of the sensor nodes so as to reduce overall energy requirements and increase data dependability via redundancy in transmission channels. The protocols in this category are responsible for generating routes through broadcast messages. The fundamental purpose of broadcasting messages is to assemble and generate the neighboring table. An adjacent table in each node includes data such as residual energy, hop distance, and signal strength that pertains to neighboring nodes.

The next table allows the node to decide on the next step by considering all of the qualities in the list. The criteria may be met by constructing a multi-road network from the nodes using this plan. Reactive routing is used in energy-conscious protocols so that the route is only defined when it is really used. By doing so, a lot of unnecessary eye contact with the ceiling is avoided. Some examples of EAMMH protocols (Energy-Aware Multi-Hop Hierarchical Multi-Path) are shown below. Routing protocol EAMMH has been improved by including intra-cluster multi-hop routs and energy-conscious routing vertices. The user must initially provide the description of the EAMMH protocol as the number of nodes, as shown in Figure 4.7.

4.3.1 Set-up Phase

Once the nodes have been deployed, it is during the configuration phase that the discovery is made. The k-of-n algorithm, pings, and beacon messages are just a few of the ways this may be accomplished. Nodes choose whether or not to serve as the cycle's cluster leader when the next discovery is made. It's like the LEACH method of evaluating evidence. Cluster formation and selection of the cluster leader are the two most important first steps (CH).

4.3.2 Data Transmission Phase

During the data transmission procedure, timeslots are allotted to the sensor nodes for data transfer. In the event that data transmission continues, nodes will do so at the interval they have determined. To whatever information that a node receives from a neighbor, it adds its own. When sending the compiled data, they must select the best available path from their routing table entries. This conclusion was arrived at using a heuristic function and heuristic function,

$$h = K\,(E_{avg} / h_{min} * t) \qquad (4.4)$$

Where K is a constant, Eavg is average current path energy, hmin is a minimum current path hop number, t = current path traffic. The highest heuristic value route is picked. If the Emin > threshold is this direction, it will be picked. Otherwise, you select the route with the highest heuristic value

$$E_{min} = E_{avg} / const \qquad (4.5)$$

If const is constant, the constant might be a positive integer value, like 10. The node with the highest minimum energy is chosen if Emin's routing table has no higher-energy nodes.

4.3.3 Periodic Updates

After a short length of time, the EAMMH Protocol's last operation, a periodic update, will cease supplying details about paths and routing table entries for each node. Heuristic values typically result in inaccurate conclusions since they are based on faulty facts. Therefore, the nodes should frequently get updated information. As a result, the heuristic approach will be more timely and accurate. At strategic points in the course of each round, all necessary data is communicated. The node will not make judgments based on outdated data, and network activity will not be stifled by too frequent updates, thanks to the optimal daily update interval.

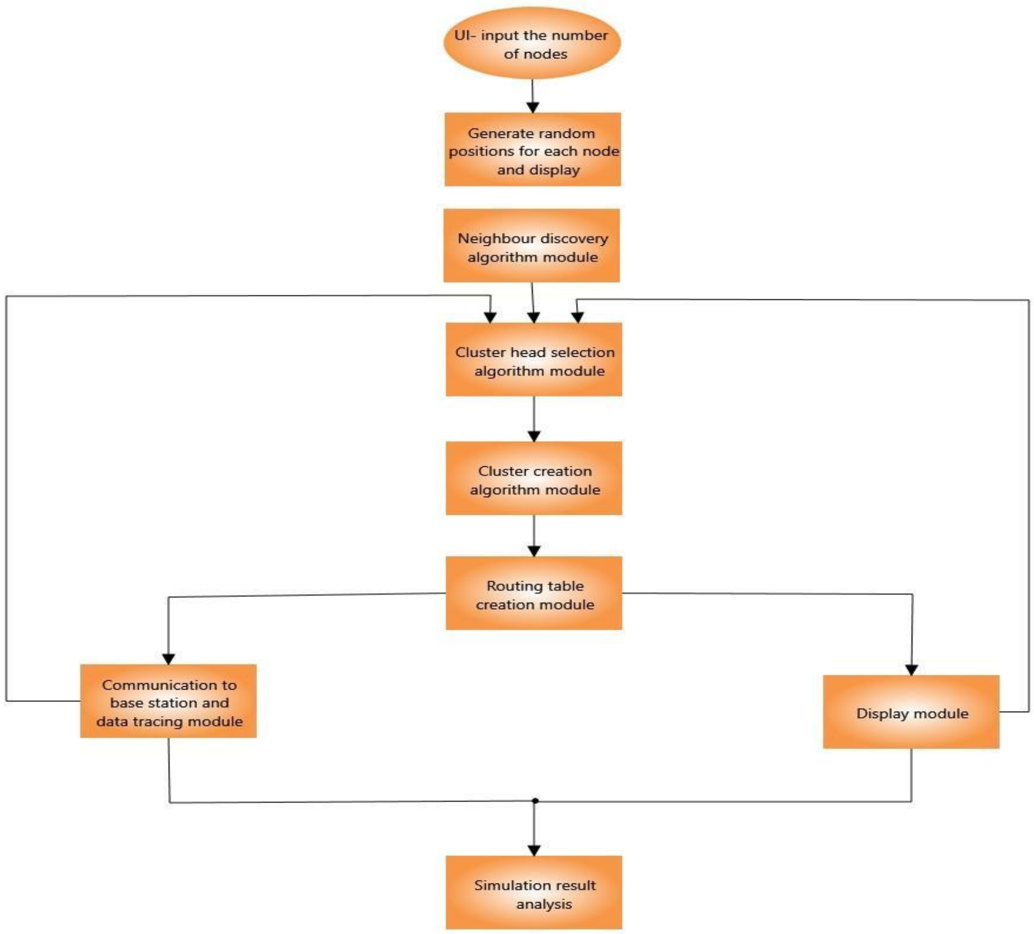

Figure 4.6 Design of EAMMH

4.4 Improved LEACH Protocols

The numerous applications of WSNs are hampered by several limitations, such as a restricted energy supply, a lack of computer capacity, and a limited bandwidth of the wireless links linking sensor node. Using aggressive energy management techniques, WSNs aim to communicate data while extending the network's lifespan and preventing connectivity deterioration. Routing protocols in Wireless Sensor Networks (WSNs) are influenced by a variety of complex elements. Before WSNs may achieve effective communication, these issues must be resolved. Some of the problems and design issues that affect WSN routing are summarised here.

- **Node deployment:** The performance of the routing protocol is affected by the number of nodes deployed in WSNs, which is depending on the application. Decided-or-undecided deployments are possible. Sensors are physically installed and data is sent along predetermined pathways in a deterministic deployment. While in random node deployment, sensors are placed in an ad hoc way, establishing a network of nodes. Optimal clustering is required if the nodes' distribution is not uniform, otherwise connectivity and energy efficiency are hampered. Due to energy and bandwidth constraints, inter-sensor communication is typically limited to small distances. A route is most likely to have numerous wireless hops in it
- **Energy Efficiency**:- A sensor node's limited supply of energy might be used to execute computations or send information in a wireless environment, which drains the battery. As a result, it is critical to use low-power communication and calculation methods. The battery life of a sensor node has a significant impact on its lifespan. Multihop WSNs have nodes that both send and receive data. Due to power failure, some sensor nodes may malfunction, causing major topological changes and possibly necessitating rerouting of packets and network reconfiguration.

- **Data Reporting Model**: - The application and the time criticality of the data reporting determine the data sensing and reporting capabilities of WSNs. Time-driven (continuous) data reporting, event-driven data reporting, query-driven data reporting, and hybrid data reporting are all options. A periodic data monitoring application would benefit from the time-driven delivery paradigm. The sensors and transmitters on sensor nodes will regularly activate, allowing them to monitor their surroundings and communicate relevant data at regular intervals. It is possible to have sensor nodes that respond promptly to changes in the value of a sensed attribute when an event or query is fired off by the central processing unit (CPU). Time-critical applications can benefit from this. There is also the option of combining the preceding models. In terms of power consumption and route stability, the routing protocol is heavily influenced by the data reporting mechanism..
- **Fault Tolerance**: - Some sensors may fail or be blocked as a result of power failure, damage, or interference from the environment. The sensor network's overall mission should not be affected by the failure of individual sensor nodes. The data gathering base stations will need to be able to build new links and pathways if several of the nodes fail. As a result of these changes, existing links may need to be actively adjusted to reduce energy usage or packets may be routed to portions of the network that have more energy. Therefore, numerous degrees of redundancy may be needed in a fault-tolerant sensor network.
- **Scalability**: - It's possible to have hundreds or even thousands of sensor nodes planted in a single region. Any routing method must be able to operate with this vast number of sensor nodes. In addition, sensor network routing methods should be scalable enough to respond to events in the environment. In the absence of a trigger, most sensors can remain dormant, resulting in data with a coarse resolution from the few sensors that are still operational.

- **Quality of Service**: - Depending on the application, data must be sent within a particular amount of time after it is sensed in order for it to be useful. • Quality of Service: As a result, another requirement for time-constrained applications is data transmission with a limited latency. However, in many applications, conservation of energy, which is directly related to network longevity, is deemed substantially more important than the quality of data conveyed. It's possible that the network may have to lower the quality of its results in order to save energy and so extend its lifetime. As a result, this demand necessitates energy-aware routing techniques.

4.4.1 Working of Protocols

Sensor network inquiries and data are directed through the sensor network's data dissemination procedure. The BS, or any other node interested in the data, must be informed of the sensor nodes' acquired information. Sources and events both refer to the node that creates the data that needs to be reported. As the name implies, a sink anode is one that has a strong desire to learn more about a specific event. Data gathering and data dissemination (diffusion) models have been developed for sensor networks. The source transfers the data it collects to a collecting entity, such as the BS, in the data collection model. This could be done on a regular basis or as needed. The central collection entity is responsible for processing all of the collected data. However, interest propagation and data propagation are both involved in the two-step process of data dissemination. Bio-agent intrusion or presence is referred to as an interested. It transmits and periodically renews its interest in any event in which a sink is interested. Throughout the network, interest is shared, and each node has a cache of all events that have been scheduled to be reported.

4.4.2 Direct Diffusion

Attribute-value pairs are used to name all data generated by sensor nodes in a DC and application-aware paradigm known as directed diffusion. For the DC paradigm, aggregating data from diverse sources (in-network aggregation), eliminating redundancy and decreasing transmissions is the primary goal. This reduces network energy consumption and extends its lifespan. DC routing, unlike traditional end-to-end routing, finds paths from numerous origins to a single destination, allowing for in-network consolidation of redundant data in the network. ' Rather than all inquiries coming from a BS, this protocol is appropriate in a scenario where the sensor nodes themselves request data from other nodes. Thus, a BS or a sensor node could be the destination for the query. Instead than relying on interest gradients to aid data diffusion, the direct diffusion routing protocol does it directly from the data itself. Other sensors communicate their interest in a certain sensor node based on the data's properties. In order to describe an interest in incursion data, attribute value pairs might be employed.

In order for the data to continue to be reported to the sink, it must be reinvigorated from time to time. The data is transmitted in the opposite direction of interest. Each path has a corresponding gradient, which is created during the propagation of interest. The gradient created at the time of interest propagation is connected with each path. Data flow is encouraged by positive gradients, while data flow is inhibited by negative gradients on a given path. Varied neighbours have different levels of interest, resulting in pathways from the source to the sink that have varying gradients. The gradient related to an interest is calculated from the interval field supplied in the interest.

In directed diffusion, sensors measure events and build gradients of information in their respective neighbourhoods. Broadcasting companies request information from the base station. "Interest" refers to a task the network is tasked with completing. Since nodes in the network can spread an interest, gradients are set up so that data satisfying the query is drawn to the requesting node. This means that nodes can spread an interest in data, and intermediary nodes can spread the interest. A gradient was established between the sensor nodes from which it received interest, and each sensor that received that interest set up a gradient toward that gradient. Gradients are created up from the sources back to the BS in this manner until the process is complete. An attribute value and direction are both specified by a gradient in a broader sense. Depending on the intensity of the gradient, various amounts of information may flow to different neighbours. Loops aren't examined at this point, but they will be later on.

(a) sending interests, (b) creating gradients, and (c) data dissemination are all examples of how directed diffusion works. Data is aggregated on the fly in order to save money on communication. When the BS receives data from the source, it refreshes and resends the interest (s). Due to inconsistencies in the transmission of interests across the network, this is important.

By picking empirically good pathways and caching and processing data in the network, directed diffusion-based sensor nodes are able to achieve energy savings by being application-aware. Increasing the efficiency, resilience, and scalability of data diffusion across sensor nodes can be achieved by caching data. One more application for directed diffusion is for a significant event to be spontaneously propagated to specific parts of the sensor network. Only persistent searches where the requesting nodes are not anticipating data that fulfil a query for a long period of time can benefit from this type of information retrieval. As a result, it's unusable for one-time requests, since setting up gradients just once isn't worth the effort

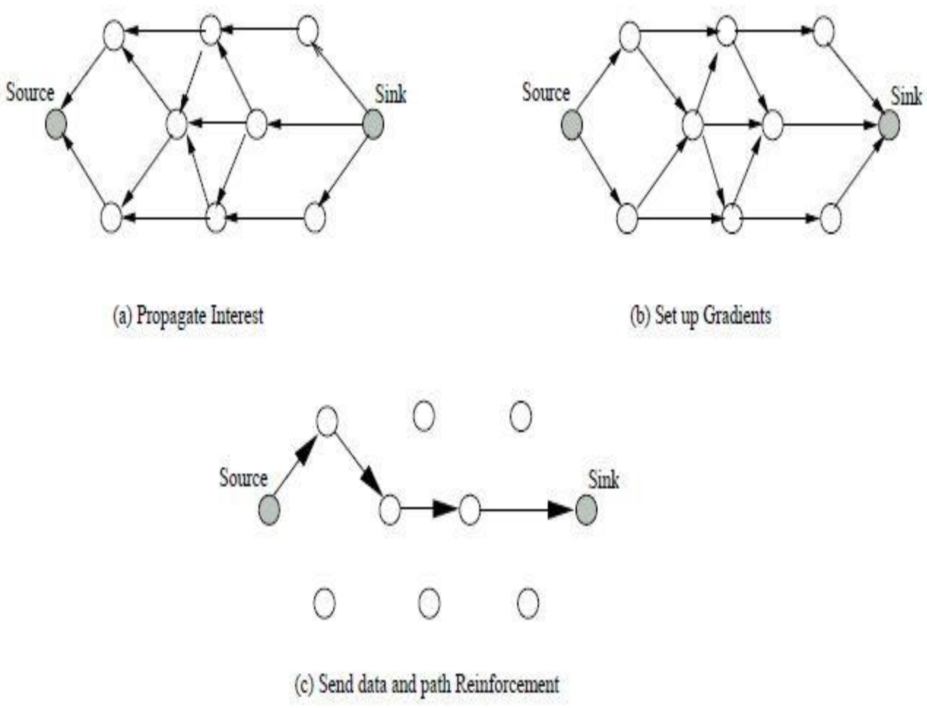

Figure 4.7 Analysis of Diffusion

Unlike SPIN, directed diffusion has two major differences. First, the BS floods some tasks with queries to the sensor nodes, resulting in directed diffusion data inquiries. Although sensors advertise data availability in SPIN, this data can be queried by nodes who are interested in it. Second, with directed diffusion, all communication is neighbor-to neighbour, and each node is equipped to aggregate and cache data. Directed diffusion does not require a global network topology, unlike SPIN. A continuous stream of data must be sent to the BS in order to use directed diffusion for these types of applications (such as environmental monitoring). As a result, the query-driven on-demand data model may not be of use in this regard. The sensor nodes may also have to deal with additional overhead when it comes to matching data with queries.

4.4.3 Sensor Protocol for Information via Negotiation

Negotiation, resources, and adaptation are all part of SPIN's approach to dealing with flooding's shortcomings. Negotiation An operation threshold-based resource-aware operation is used to extend the network's life span. Row data is replaced with meta-data, or data that describes data. Less bytes are required, and the file format can be customised for each application. ADV, REQ, and DATA are all SPIN message kinds. Meta-data detailing the actual data is broadcast by a sensor node in an ADV. When a neighbour expresses an interest in receiving the data, it will send a REQ. It then delivers data to the neighbouring sensor node.

- Once again, the data is disseminated throughout the network by the neighbour sending out ADVs. Figure 4.2 depicts a simplified version of the algorithm.
- In order to overcome the shortcomings of traditional flooding, the SPIN family is meant to use negotiation and resource adaptability. The SPIN protocols are based on two fundamental principles:
- Image and sensor nodes must monitor the changes in their energy resources in order to work efficiently.
- Traditional methods such as flooding or gossiping-based routing protocols waste energy and bandwidth by delivering additional and unneeded copies of data via sensors covering overlapping areas.

In addition to implosion due to duplicate messages delivered to the same node, flooding can also create packet overlap when two nodes sensing the same region send similar packets to the same neighbour and resource blindness by using enormous amounts of energy without regard to energy constraints. The implosion problem is avoided in gossip by sending a packet to a random node rather than broadcasting it blindly. Data propagation through the nodes is delayed as a result.

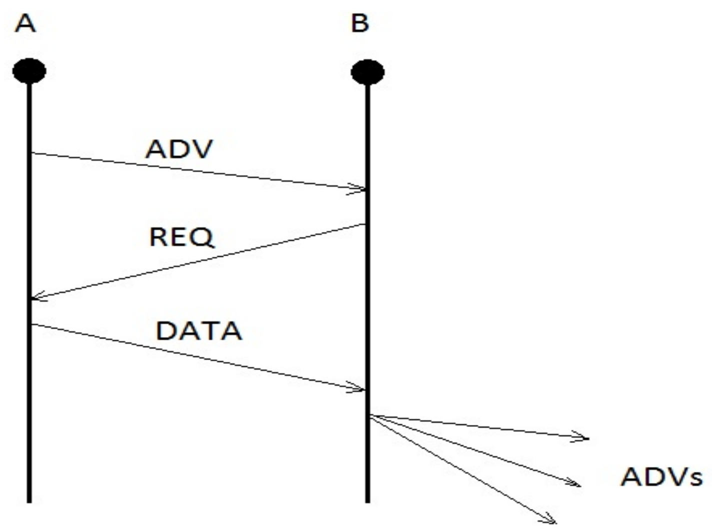

Figure 4.8 Analysis of Negotiation and Data

Using SPIN's meta-data negotiation, floods can be avoided, resulting in significant energy savings. SPIN is a three-stage protocol because sensor nodes communicate with each other using ADV, REQ, and DATA. New data can be advertised with ADV, requested with REQ, and received with DATA. When an SPIN node acquires new data that it is willing to share, the protocol begins. It accomplishes this by sending out an ADV message that includes meta-data. Whenever a neighbour node requests the data, the data is provided to this neighbour node in response to a REQ message. The neighbouring sensor node then continues this procedure with its neighbours, and so on. A copy of the data will be sent to all the sensors in the vicinity as a result.

Many protocols are part of the SPIN family. SPIN-1 and SPIN-2 are the two main protocols that integrate negotiation before transmitting data to ensure that only valuable information is delivered. Before transmitting any data, each node is polled by the other nodes to see if it has enough resources available. In the SPIN-1 technique, as explained above, there are three stages. SPIN-2 adds a threshold-based resource awareness method to SPIN-1's negotiation capabilities. When the nodes have plenty of energy, SPIN-2 communicates using SPIN-1's three-stage protocol. Because of this, it participates only when it believes it can finish all the other phases of the protocol without going below its low-energy threshold; this is known as a "reduced participation" in the protocol. Spinning is a simple technique that maintains the status of the number of neighbours per node while efficiently disseminating data. These protocols are well-suited for environments in which sensors are mobile because they employ local neighbourhood information to make their forwarding decisions.

For broadcast channels, the SPIN-BC protocol is the one to use.

In other words, hop-by-hop routing is the goal of the SPIN-PP protocol, which is aimed at enabling point-to-point communication.

Unlike SPIN-PP, SPIN-EC incorporates an energy heuristic into its design.

A protocol called SPIN-RL is used when a channel is lossy so that adjustments can be made to the SPIN-PP protocol in order to accommodate for the lossy channel.

Since each node only needs to know its single-hop neighbours, SPIN's advantages are that topological changes are localised. Meta-data negotiation reduces redundant data by nearly half, while SPIN saves a lot of energy compared to floods. In spite of this, SPIN's data advertisement method cannot ensure delivery of data. Consider an intrusion detection application where data must be reliably reported over periodic intervals and assume that nodes interested in the data are located far away from the source node and that data will not be delivered to its destination at all if the nodes between source and destination nodes are uninterested.

LEACH is a cluster-based protocol that incorporates distributed cluster formation, and it is designed to reduce energy consumption. In order to divide the network's energy load more equitably, LEACH randomly choose a few sensor nodes to serve as clusterheads (CHs). Data arriving from clusterhead (CH) nodes is compressed and sent in an aggregated packet to the base station to reduce the amount of information that must be broadcast by base stations in LEACH. To minimise inter- and intra-cluster collisions, LEACH makes use of a TDMA/CDMA MAC. However, data collecting is centralised and is done on a regular basis. Therefore, this protocol is ideal for sensor networks that need to be continuously monitored. All of the information may not be required right away.

As a result, it is not necessary to send data on a regular basis, which would use up the sensor nodes' limited energy. After a predetermined amount of time, the CH's duty is randomised so that the sensor network's energy consumption is evenly distributed. Using a simulation model, the researchers discovered that only 5% of the nodes in a cluster are required to operate as cluster heads.

Setup and steady-state phases of LEACH's functioning can be distinguished. The clusters are arranged and the CHs are picked during the setup phase. Real-time data transmission takes place in the steady state phase. Due to the fact that overhead is minimised, the steady state phase is longer than the setup phase. A specified percentage of nodes, p, choose to be CHs during the initial setup phase. Between 0 and 1, a sensor node generates a random number, r. As long as this random number falls below a certain threshold, the node is designated a cluster-head for this round. the desired proportion to become a cluster-head, current round, and last (1/P) rounds of nodes that have not been picked as a cluster-head are used to compute the threshold.

Assuming T(n) is a threshold, we can say:

$$P, n \in G \quad (4.6)$$

$$T(n) = 1 - P \times [r \bmod (1/P)] \quad (4.7)$$

Otherwise,

$$T(n) = p/1\text{-}p \times (r \bmod p\text{-}1) \quad (4.8)$$

In order to inform the rest of the network that they have been elected as new cluster-heads, each elected CH broadcast an advertisement message. After seeing this advertisement, all of the non-cluster head nodes make a decision about which cluster they wish to join. This selection is based on the advertising's signal strength. To join a cluster, non-cluster-head nodes inform the necessary cluster-heads that they intend to join. The cluster-head node prepares a TDMA schedule and distributes transmission time slots to each node after receiving all messages from nodes interested in joining the cluster and taking into account the number of nodes in the cluster. All nodes in the cluster receive this schedule. To begin transferring data to cluster-heads, sensor nodes must be in "steady condition". Data is gathered by the cluster-head node and then sent to the base station. As soon as the network has reached a particular point in its setup phase, it goes back to picking new CHs. To minimise the impact of nodes from other clusters on their communications, each cluster uses a unique set of CDMA codes. Assumptions employed in LEACH have a number of flaws despite the protocol's ability to extend network life span. If all nodes can transmit with adequate power to reach the BS, and each node has the computing power to handle alternative MAC protocols, then LEACH assumes that all nodes can communicate with the BS. Consequently, it does not apply to large-scale networks. In addition, it presupposes that nodes always have data to communicate, and that nodes adjacent to one another have correlated data to broadcast. It's unclear how the predefined CHs (p) will be spread evenly around the network. This means that chosen CHs may be concentrated in a single area of the network. " As a result, some nodes will be devoid of CHs. Furthermore, the idea of dynamic clustering adds additional overhead, such as head changes, adverts, and so on, which may reduce the energy savings.

Table 4.1 - Comparison of SPIN, LEACH and Directed Diffusion

	SPIN	**LEACH**	**Directed Diffusion**
Optimal Route	No	No	Yes
Network Lifetime	Very Good	Good	Excellent
Resource Awareness	Yes	Yes	Yes
Use of Meta-Data	Yes	No	Yes
Energy Efficiency	High	Moderate	Low

All nodes are assumed to start with the same energy capacity in each election round, and this assumption is made in the protocol's assumption that being a CH consumes approximately the same amount of energy for each node. Non-uniform energy nodes should be taken into consideration in the protocol, hence an energy-based threshold should be implemented. LEACH with negotiation is an expansion of LEACH. The fundamental idea behind the proposed addition is to use meta-data descriptors in high-level negotiation before transferring data, similar to the SPIN protocol that was mentioned earlier. Prior to transmitting information back to the base station, this guarantees that only new information has been received by cluster heads.

4.5 Improved LEACH

Using the LEACH methodology, which can be improved upon, this research was carried out. Network life and throughput can be improved by implementing two strategies. To comprehend our proposed strategy, we have to grasp mechanism presented by LEACH. This protocol changes the cluster head at every round and once a cluster head is formed, it will not have another chance for following 1/p rounds. All cluster heads are replaced each time a new round is completed. In this paper, we introduce an effective replacement technique for LEACH's cluster heads. It's a critical point in the construction of cluster heads for the upcoming round. Cluster heads who haven't used much energy throughout their term and have more energy than the required threshold will retain their positions in subsequent rounds.

Cluster construction and routing packets for a new cluster head can be reduced in energy consumption by this method. The LEACH algorithm will replace a cluster head if its energy level falls below a predetermined minimum. Cluster formation is also limited by introducing two different levels of power to enhance signals depending on their nature. In a cluster-based network, there are basically three kinds of transmission:

1. Intra Cluster Transmission

2. Inter Cluster Transmission

3. Cluster Head to Base Station Transmission

All communication within a cluster is handled by intra-cluster transmission, which includes the reporting of data by cluster members to the cluster head. Inter-cluster transmission refers to data exchange between two cluster heads, while data exchange between a cluster head and the base station is referred to as cluster head to base station transmission.

This cannot be the case since the minimum amplification energy required for communication between clusters or cluster heads and the base station (BS) cannot be the same. All transmissions in LEACH need the same amount of amplification energy. When compared to transmissions from the cluster head to the BS, using low energy levels for intra-cluster transmissions saves a significant amount of energy. In addition, multi-power levels lower packet drop ratios, collisions, and/or interference for other signals, which is a benefit. Nodes that operate as Cluster heads are instructed to use high power amplification via the routing protocol, which instructs them to use low power amplification when they become Cluster members in the following round.

The LEACH protocol is used in a random way as a probabilistic formula for selecting the node. A standard node carries out the tasks of sensing and transmitting the data to the cluster head. In comparison, the head of the cluster performs the tasks of encoding, aggregating, receiving and transmitting information to the sink or base station. So, the head of the cluster spends more resources than the head of the non-cluster. To continue the process of transmitting data, each node will be chosen as a cluster head. The node's energy consumption will be carried out systematically until the last node loses its energy and becomes dead, thus increasing the life of the network. The LEACH protocol is split into several rounds, with the following two phases in each round:

Step 1: Setup

In this point, a random number R, from 0 to 1, is randomly selected from each node with a node threshold T value. From the following '(1)' the threshold can be calculated:

$$T(n) = \frac{p}{1-p\left(r\left(\mathrm{mad}\frac{1}{p}\right)\right)} \tag{4.9}$$

Here, the threshold value is T(n), P is the optimal probability of selecting cluster heads, r is the present round. If the value of the random number (R) of the sensor node is greater than T, the node given will not be assigned CH for the current round. The node will be named as the CH for the current round if R is less than T.

After the selection of the cluster heads has been completed, the message of the same round propagates to other nodes, which then become the heads of the cluster. Different cluster groups are established in the network in such a way that the cluster head receives the high-power signal node request packet, which means that this CH is closer to the node than others. And so on, the distance between the node and the head of the cluster is minimized and energy drainage in the network is decreased as well.

Step 2: Stationary-state

The CDMA (Code Division Multiple Access) and TDMA (Time Division Multiple Access) techniques are used in this process, so the length of this phase is longer than the previous one. Each node has a fixed time period for transmitting the data that is allocated from the cluster head to prevent a collision between signals. When data packets are received at the head of the cluster, they are aggregated using CDMA without any uncertainty and transferred to the sink. The first round is thus completed and the process repeats itself until the energy of the remaining nodes is consumed [13]. The LEACH protocol flow chart is shown in Figure 4.9, starting with the selection of the cluster heads and ending with the sending of data to the base station.

The cluster heads are distributed uniformly within the LEACH protocol, near or far from the base station. Based on the distance between the CH and base stations, the randomly situated CH can lead to more energy consumption. In LEACH, the number of cluster heads in different rounds varies. The improved LEACH [I-LEACH], on the other hand, splits the network into circular clusters where each cluster has its own cluster head. An optimal pre-determined value is the number of cluster heads.

In I-LEACH, the following assumptions are made:

- You can measure the energy level of each node in the network.
- The base station is able to accept messages sent from various network nodes.
- The node coordinates can be directly sent from the nodes to the base station.

The suggested I-LEACH is based on conventional LEACH, where the rounds are split into cycles of setup and steady state. In the set-up cycle, when the energy reaches the average energy value, the base station elects the nodes selected as cluster heads based on their energy level. In order to schedule the data signals sent to the cluster heads and then transmitted to the base station [14], the steady-state cycle uses the TDMA process. The [circular cluster] restriction is cantered on the network width (W), where W is equal to 1000, and the diameter of each circular cluster is equal to the width divided by the number of segments on each side. By arranging the process of sending packets to the base station or sink, it would be evident that circular clustering would increase the lifespan of the network.

This chapter discuss the proposed methodology of improved cluster head selection in LEACH algorithm which has been implemented as Improved LEACH protocol. The proposed methodology has been implemented in different test conditions for overall analysis of effectiveness of algorithm.

4.6 Proposed Memetic Algorithm based LEACH:

In this section, we delve into the proposed approach that combines Memetic Algorithms (MAs) with the Low Energy Adaptive Clustering Hierarchy (LEACH) for wireless sensor networks (WSNs). The core idea behind this approach is to optimize the energy consumption and coverage of WSNs by employing a Memetic Algorithm, which is a hybrid optimization technique combining elements of genetic algorithms and local search.

Firstly, it's important to understand the context. WSNs are networks of small, interconnected sensor nodes that are typically deployed in various environments to monitor and collect data. These sensor nodes are often constrained in terms of energy resources, processing capabilities, and communication range. Maximizing the network's lifetime while maintaining efficient data collection and coverage is a critical challenge in WSNs.

Now, let's break down the key points in this section:

- **Stationary Nodes:** The assumption that all sensor nodes are stationary means that once deployed, these nodes do not change their physical positions. This assumption simplifies the network's behavior because it eliminates the need to account for node mobility, which can be a complicating factor in WSNs.

- **Uniform Capabilities:** The assumption of uniform capabilities among sensor nodes means that all nodes in the network have the same transmission capacity, sensing range, and data processing capabilities. This simplification allows for consistent behavior across nodes, making it easier to design and analyze algorithms.

- **Known Locations:** This assumption implies that the precise locations of all sensor nodes within the network are known in advance. Knowing the exact locations of sensor nodes is a strong assumption and can be challenging to achieve in practice. However, having this information can greatly assist in network planning, optimization, and routing.

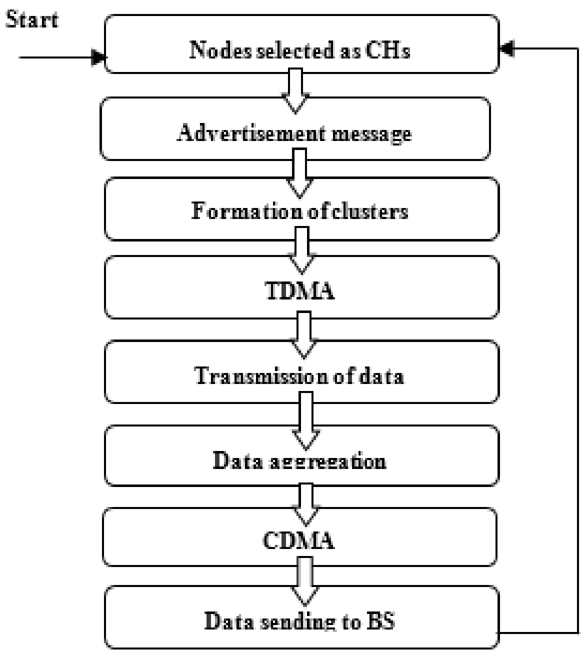

Figure 4.9 Flow Chart of Conventional LEACH

- **Sink Awareness:** The term "sink" refers to a central node or base station in the WSN that collects data from sensor nodes. The assumption that the sink is aware of all sensor nodes in the network means that the sink has knowledge of the existence and locations of all deployed sensor nodes. This awareness is crucial for efficient data collection and routing.

4.6.1 Sensing Coverage Model:

In this subsection, we explore the sensing coverage model used within the proposed Memetic Algorithm-based approach. Sensing coverage is a fundamental aspect of WSNs, as it determines the network's ability to detect and monitor events or phenomena in the environment.

- **Target Area (R):** The target area (R) is described as a two-dimensional plane with specific dimensions (L_x by L_y square meters). This area represents the region in which the sensor nodes are deployed and where events or phenomena of interest may occur.

- **Sensor Node Set (C):** The set C represents the collection of sensor nodes deployed within the target area R. Each sensor node is characterized by a set of attributes, including its coordinates (x_i, y_i) and sensing radius (r_s). These attributes define the node's position and the maximum distance over which it can sense events.

- **Point of Interest (POI):** POIs are locations within the target area where specific events or phenomena are expected to occur. The set P represents the collection of these POIs, with each POI denoted by its coordinates (x_j, y_j). The number of POIs is denoted as M.

- **Coverage Representation (R_t,f):** The coverage representation, denoted as R_t,f,

is a binary variable that indicates whether a sensor node c_t can cover a specific POI p_f.

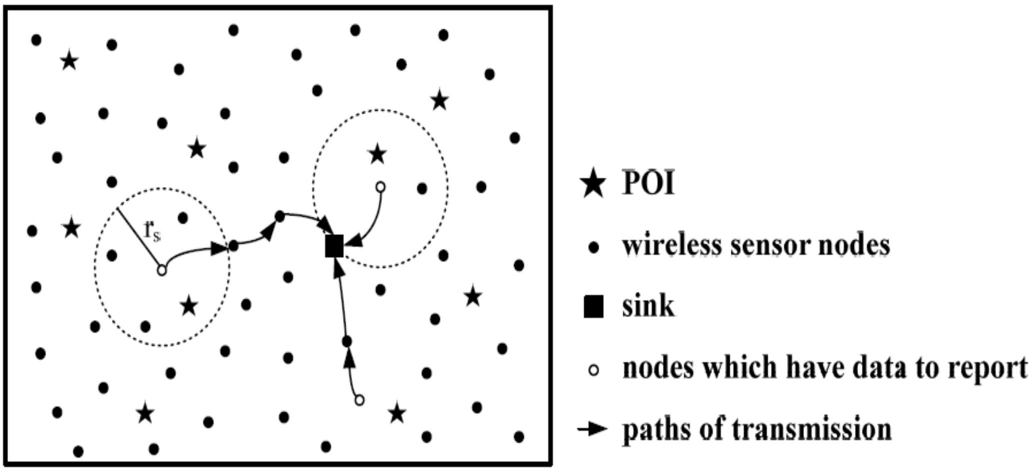

Figure 4.10 Representation of Coverage

The concept of coverage representation is crucial for determining which sensor nodes can detect events at specific POIs. It essentially creates a coverage map that guides data collection and routing within the network.

4.6.2 Energy Consumption Model:

Energy consumption is a critical concern in WSNs due to the limited energy resources of sensor nodes. This subsection delves into the energy consumption model used within the proposed approach, with a particular focus on radio transmission energy.

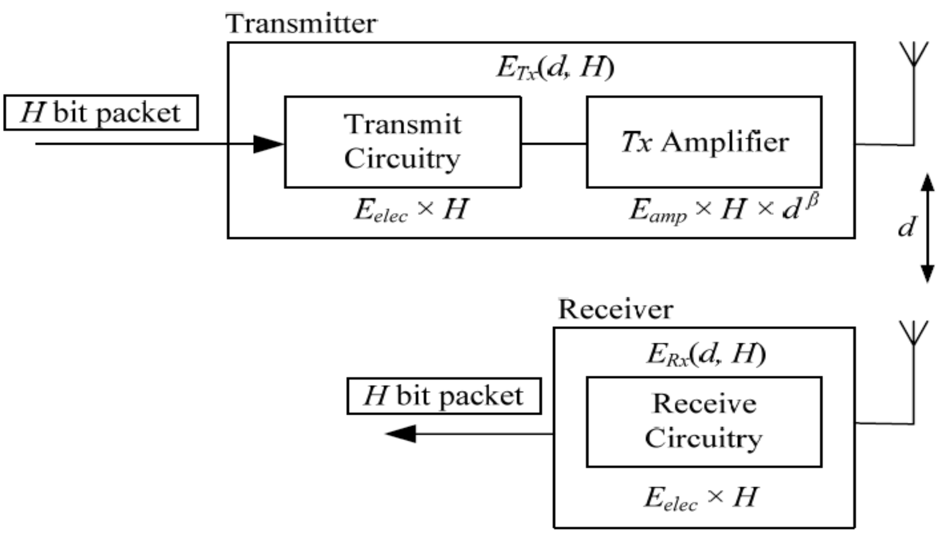

Figure 4.11 Model of Energy Conservation

- **Cluster-Based WSNs (CWSNs):** Cluster-based architectures are highlighted as an effective way to distribute energy dissipation evenly across the entire network and extend its lifespan. In CWSNs, sensor nodes are organized into clusters, with each cluster having a designated cluster head responsible for data aggregation and communication with the base station or sink.
- **Energy Consumption Components:** The model emphasizes that radio transmission consumes more energy than other sensor activities or memory access. This is a critical insight because it informs the energy-efficient design of communication protocols and data transmission strategies.
- **Energy Calculation (E_st(d, H)):** The energy consumed when transmitting an H-bit packet over a distance d is calculated using a specific formula. This formula likely considers factors such as the energy consumed by the power amplifier (E_amp), the dissipated energy for transmit and receive circuitry (E_sine), and the path loss exponent (alpha).
- **Homogeneous Nodes:** The study assumes that sensor nodes in the network are homogeneous, meaning they all have the same initial energy levels. This simplification allows for consistent behavior across nodes in terms of energy consumption.

Understanding the energy consumption model is crucial for designing efficient data transmission and communication protocols in WSNs. Minimizing energy consumption while maintaining network coverage is a key objective for prolonging the network's lifetime.

4.7 Coverage Control Using Memetic Algorithm:

In this section, the focus shifts to the application of Memetic Algorithms (MAs) to control coverage in wireless sensor networks. Coverage control refers to the process of optimizing the activation of sensor nodes to ensure that events or phenomena are adequately monitored while conserving energy resources.

- **Set Covering Problem (SCP):** The subsection mentions that the Set Covering Problem is one of the NP-Complete problems. The SCP is a well-known combinatorial optimization problem that deals with selecting a minimum number of sets to cover a given set of elements. In the context of the proposed approach, SCP is applied to node scheduling optimization.

- **Coverage and Energy Efficiency:** The subsection highlights that the SCP considered in this context focuses on two primary objectives: achieving adequate coverage of events or POIs and optimizing energy efficiency. These objectives are fundamental to the success of WSNs.

- **Optimization Model:** An optimization model is presented to address the SCP. The goal is to minimize the number of activated sensor nodes while ensuring that all POIs are adequately covered. The objective is to strike a balance between coverage and energy consumption.

- **Metaheuristics:** Metaheuristics are introduced as a group of approximate techniques for solving optimization problems. The study identifies MAs as one such metaheuristic method that combines elements of genetic algorithms and local search. MAs are known for their ability to quickly explore solution spaces and find optimal or near-optimal solutions.

The introduction of MAs to address coverage control in WSNs is a significant step toward efficient energy utilization and network longevity. MAs provide a framework for finding solutions that strike the right balance between coverage and energy consumption.

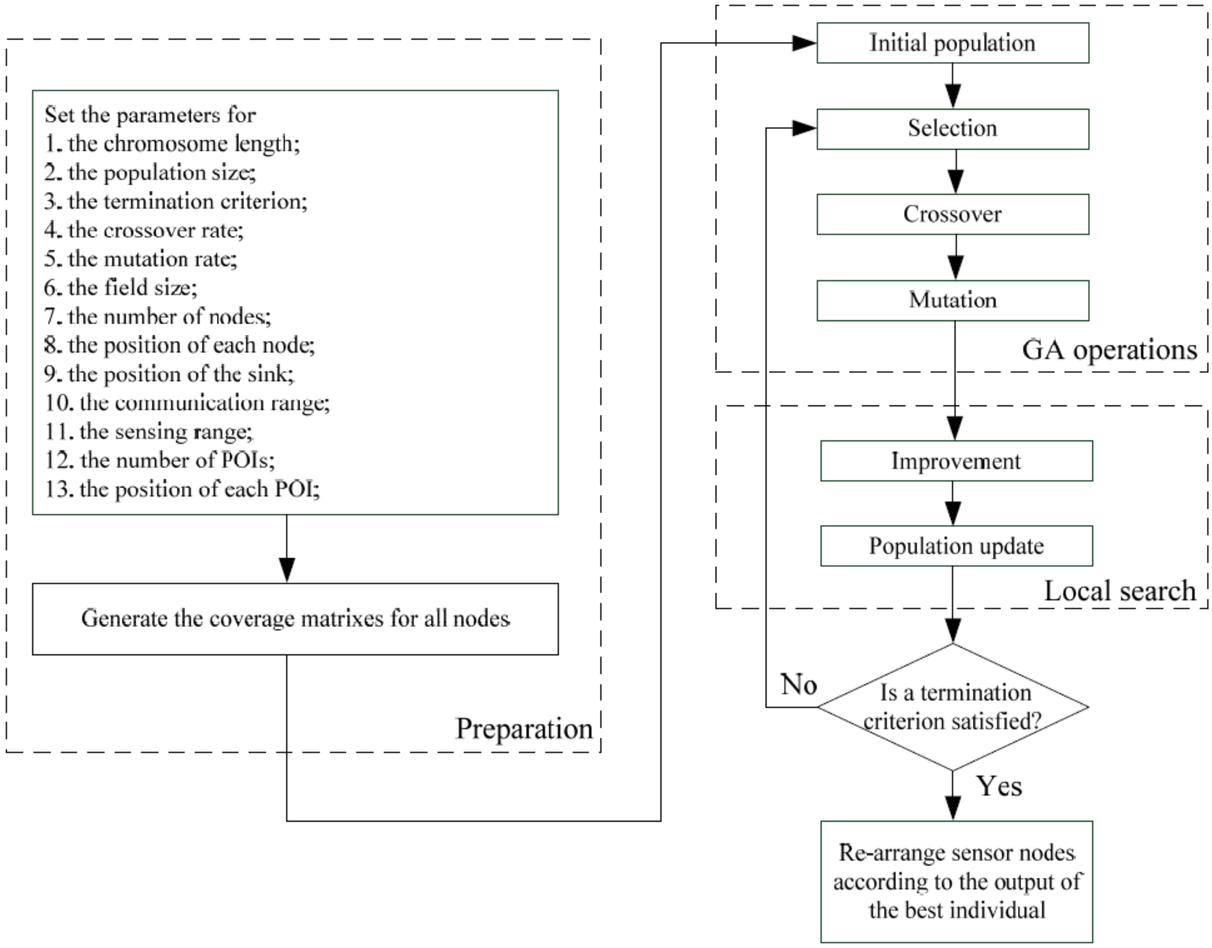

Figure 4.12 Flowchart of Proposed Methodology

4.7.2 Proposed Methodology for Routing Protocol in Wireless Sensor Network

This subsection provides an overview of the Memetic Algorithm-based approach specifically designed for Cluster-based Wireless Sensor Networks (CWSNs). It discusses the components and the flowchart of the approach.

- **Components:** The approach consists of two primary components: sensor scheduling and a wake-up scheme. Sensor scheduling involves determining which sensor nodes should be active and when, while the wake-up scheme focuses on activating dormant nodes when necessary.

- **Optimization Process:** The flowchart illustrates the iterative process of optimizing energy-efficient coverage in CWSNs. The approach aims to find the optimal schedule for sensor nodes to minimize energy consumption while maintaining adequate coverage.

- **Genetic Representation:** Sensor node schedules are represented using binary strings. These binary strings serve as a genetic representation of the schedule, where each bit represents the activation status of a sensor node (1 for active, 0 for inactive).

- **Population Size:** The population size for the Memetic Algorithm-based approach is chosen based on prior experience. It's important to note that population size can influence the convergence and efficiency of the optimization process.

The flowchart of the approach demonstrates that it operates in rounds, with each round optimizing energy efficiency and coverage. The combination of genetic algorithms and local search within the Memetic Algorithm framework allows for the exploration of diverse solutions.

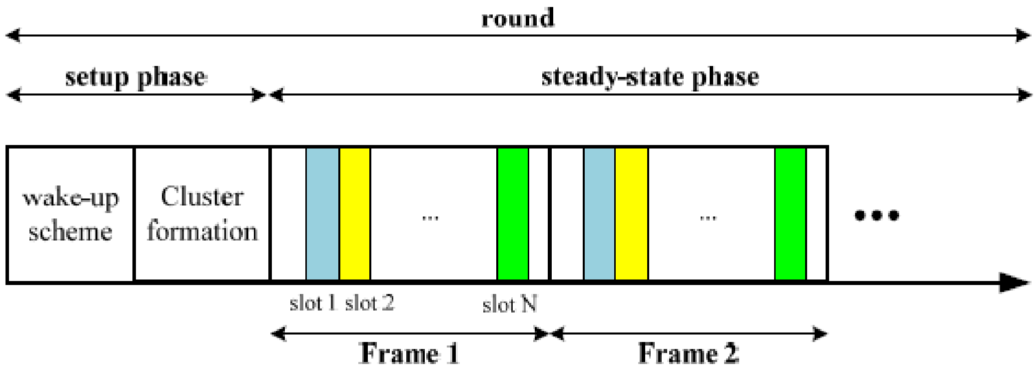

Figure 4.13 Analysis of Time Slot Arrangement

4.7.3 Fitness Function:

This subsection introduces the fitness function, a crucial element in the optimization process, used to evaluate the quality of solutions generated by the Memetic Algorithm-based approach.

- **Fitness Function:** The fitness function is a mathematical function that quantifies how "good" or suitable a particular solution (represented as a chromosome) is within the context of the optimization problem. In this case, the fitness function is designed to assess the quality of the sensor node schedule.
- **Objective:** The primary objective of the fitness function is to minimize the number of activated sensor nodes while ensuring adequate coverage of POIs. This dual objective aims to achieve energy efficiency without sacrificing coverage.
- **Coverage Vector:** To evaluate coverage, a binary coverage vector is proposed for each node. This vector indicates whether a specific POI is covered by a sensor node. It essentially summarizes the coverage information.
- **Fitness Calculation:** Fitness is calculated based on coverage and node activation, taking into account weighting coefficients and exponential factors. The fitness function is designed to reward solutions that achieve high coverage with fewer activated nodes.

The fitness function serves as a critical component of the Memetic Algorithm, guiding the search for optimal solutions. By evaluating the trade-off between coverage and energy consumption, the fitness function helps identify solutions that strike the right balance.

4.8 Local Search Scheme:

In this subsection, a local search scheme is introduced as a strategy to further enhance the quality of solutions generated by the Memetic Algorithm-based approach.

- **Local Search:** Local search is a strategy used in optimization to iteratively improve candidate solutions. It operates by making small modifications to a solution and evaluating whether these modifications lead to a better solution.
- **Chromosome Modification:** The local search scheme targets specific alleles within chromosomes for modification. In the context of the Memetic Algorithm-based approach, alleles correspond to individual sensor nodes, and modifying them implies altering the activation status of these nodes.
- **Improved Solutions:** The goal of the local search scheme is to find improved node schedules and coverage solutions. By iteratively exploring slight variations of the current solution, it aims to identify solutions that are superior in terms of coverage and energy efficiency.

The use of a local search scheme within the Memetic Algorithm framework enhances the algorithm's ability to fine-tune solutions. It helps in the refinement of node schedules, ultimately leading to better overall network performance.

4.9 MA Termination:

This section addresses the termination criteria for the Memetic Algorithm-based approach, explaining when and how the optimization process comes to an end.

- **Termination Criteria:** The termination criteria define the conditions under which the Memetic Algorithm-based approach concludes its evolutionary process. These criteria are essential for ensuring that the optimization process does not continue indefinitely.

- **Evolutionary Process:** The approach is characterized by an iterative and evolutionary process that aims to find optimal or near-optimal solutions. Each iteration, or generation, explores potential solutions and seeks improvements.
- **Convergence:** Rapid convergence is emphasized as a desirable outcome. Convergence refers to the point at which the algorithm has found a satisfactory solution, and further iterations are unlikely to significantly improve the solution.

The termination criteria are crucial for controlling the behavior of the Memetic Algorithm-based approach. They prevent excessive computational time while ensuring that the algorithm adequately explores the solution space to find high-quality solutions. In summary, this section provides a comprehensive understanding of the proposed Memetic Algorithm-based approach for coverage control in wireless sensor networks. It covers various aspects, including assumptions, models, optimization techniques, and termination criteria. The approach aims to strike a balance between energy efficiency and coverage, crucial factors in the successful operation of WSNs.

4.10 Conclusion of Chapter

The chapter investigates various parameters such as initial energy, node density, and system size in WSN simulations, focusing on metrics like dead nodes, alive nodes, packets sent, and rounds until node death. LEACH and EAMMH protocols are analyzed, highlighting energy consumption and cluster management. LEACH's setup and steady-state phases, energy-efficient hierarchical clustering, and improved centralized LEACH are discussed. The study also introduces the Memetic LEACH protocol, which optimizes energy usage and extends network life through efficient node scheduling and coverage models.

CHAPTER-5

RESULT ANALYSIS

Initial energy, node density, and system size have all been tinkered with in simulations of the system. Number of dead nodes, number of alive nodes, number of packets sent to sink node, and total number of rounds till all nodes die have all been compared. The effectiveness of the suggested technique with regard to operational variables has been demonstrated through simulation and comparative analysis.

5.1 Simulation and Result

MATLAB provided a detailed overview of a simulation study in the context of Wireless Sensor Networks (WSNs) and the use of Memetic Algorithms to optimize network parameters. Here are some key points and observations from the information you've provided:

i. **Objective**: The primary objective of the simulation study is to optimize energy efficiency and network lifetime in WSNs while maintaining coverage of Points of Interest (POIs).

ii. **Simulation Tools**: MATLAB is used for conducting simulations of different protocols, including LEACH and EAMMH (Energy Aware Multi-hop Multi-path Hierarchical protocol) followed by improved LEACH and Proposed Memetic LEACH.

iii. **Simulation Parameters**: Various simulation parameters are considered, including the probability of cluster head selection, initial node energy, node density, and system size. These parameters are adjusted to evaluate their impact on network performance.

Wireless Sensor Networks (WSNs) have gained significant importance due to their widespread applications in monitoring and data collection in various fields, including environmental monitoring, healthcare, agriculture, and industrial automation. However, one of the most significant challenges faced by WSNs is the limited energy resources of individual sensor nodes. These nodes are often battery-powered and deployed in remote or inaccessible locations, making it challenging to replace or recharge their batteries. Therefore, optimizing energy efficiency is a critical concern in the design and operation of WSNs.

To address the challenges of energy efficiency and network longevity in WSNs, researchers often turn to simulation tools. MATLAB, a widely used computational software, is a popular choice for simulating and analyzing WSNs. Simulations allow researchers to experiment with different protocols, settings, and scenarios in a controlled environment before deploying actual sensor networks. This approach enables the evaluation of various strategies without the cost and complexity of physical deployments.

5.2 Simulation Parameters and Scenarios

In the provided information, the simulation study focuses on two primary protocols: LEACH (Low Energy Adaptive Clustering Hierarchy) and EAMMH (Energy Aware Multi-hop Multi-path Hierarchical protocol). To assess their performance, the study considers several key parameters:

1. **Round Number vs. Dead Nodes**: The number of rounds in the simulation is compared to the number of dead nodes. This metric provides insights into how long the network can operate before nodes run out of energy.

2. **Average Node Energy vs. Round Number**: This parameter assesses how the average energy of individual sensor nodes evolves over time during the simulation. It helps in understanding energy consumption patterns.

3. **Probability of Cluster Head Selection**: Varying probabilities of cluster head selection are examined. This parameter reflects the likelihood of a sensor node becoming a cluster head, a critical role in WSNs for data aggregation and communication.

4. **Node Density**: Different node densities, representing the number of sensor nodes deployed in a given area, are considered. Node density impacts network coverage and communication.

5. **Initial Node Energy**: The study assumes that nodes have equal initial energy levels. This assumption simplifies the simulation but may not reflect real-world scenarios where nodes may have varying energy levels due to manufacturing variations or initial energy storage conditions.

6. **Static Node Deployment**: The nodes are considered to be static, meaning they do not move once deployed. This assumption simplifies the simulation but may not account for scenarios where nodes need to adapt to changing conditions.

7. **Homogeneous Node Distribution**: The nodes are assumed to be homogeneously distributed throughout the simulation area. This simplification helps in controlling variables but may not represent real-world deployment scenarios.

8. **Data Transmission Requirement**: All nodes are expected to transmit data to a sink node. This requirement ensures that nodes are actively participating in data collection and transmission.

5.3 Simulation Results: Energy Efficiency and Dead Nodes (LEACH AND EAMMH)

The simulation results presented in the provided information offer valuable insights into the performance of LEACH and EAMMH under different conditions. The following paragraphs delve into the detailed analysis of these results.

In the first set of simulations, the probability of cluster head selection is set at 0.01 (1% of nodes becoming cluster heads). The study examines how energy consumption and the number of dead nodes evolve over rounds for both LEACH and EAMMH. Figure 5.1 shows the average energy versus the round number for EAMMH, while Figure 5.2 presents the same metric for LEACH.

Figure 5.1 reveals that, in the EAMMH protocol, the average energy of each node remains relatively stable around 0.02 over the course of 100 rounds. This suggests that EAMMH manages to distribute energy consumption fairly among nodes, maintaining their energy levels.

In contrast, Figure 5.2 displays LEACH's average energy versus the round number, indicating that LEACH also maintains an average energy of approximately 0.02 per node but exhibits distinct energy fluctuations compared to EAMMH. These fluctuations may be attributed to LEACH's clustering mechanism and the selection of cluster heads.

Moving on to the evaluation of the number of dead nodes, Figure 5.3 illustrates the scenario when there is a 0.01 probability of nodes dying in EAMMH. At the 100th round, the EAMMH method shows a total of 90 dead nodes. This metric provides a critical measure of network longevity, as dead nodes signify the point at which nodes can no longer contribute to network operations.

Figure 5.4 presents a similar analysis but for LEACH. In this case, with a 0.01 probability of nodes dying, 85 nodes have died by the 100th round due to the use of the LEACH method. Comparing Figures 5.3 and 5.4, it becomes evident that EAMMH exhibits a higher number of dead nodes under these conditions. However, this difference in the number of dead nodes may be outweighed by other factors such as energy efficiency and network lifetime.

5.4 Simulation Results: Varying Probability of Cluster Head Selection

The simulation study extends its analysis by considering different probabilities of cluster head selection, specifically 0.5 (50%) and 0.2 (20%). These variations in cluster head selection probability allow for a more comprehensive understanding of how the protocols perform under different conditions. Figure 5.5 displays the average energy versus the round number for EAMMH at a 50% probability of cluster head selection. It shows that the average energy of each node stabilizes around 0.032 over 100 rounds. This indicates that EAMMH maintains energy efficiency even with a higher probability of nodes becoming cluster heads. In comparison, Figure 5.6 presents the same metric for LEACH at a 50% cluster head selection probability. LEACH maintains an average energy of approximately 0.005 per node at the 100th round. However, as with the previous scenario, energy fluctuations are noticeable in the LEACH protocol.

5.4.1 Simulation of Protocols at 0.01 Probability

The results below display the simulation of both the LEACH and the EAMMH protocols at 0.01 chance, which is 1 % of the total nodes that can be cluster head.

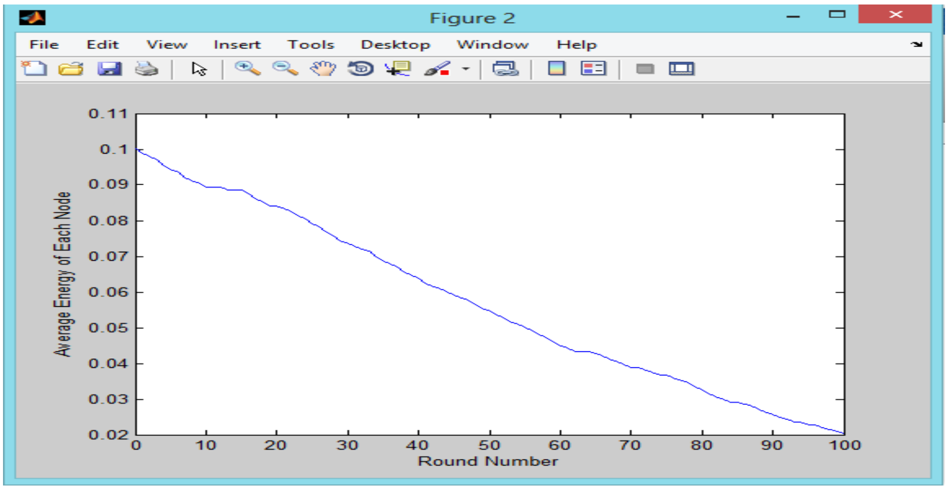

Figure 5.1 Average-Energy v/s Round No. (EAMMH)

Figure 5.1 is a graph depicting the EAMMH protocol's mean energy vs its probability at 1% and 0.01 for the cluster head, respectively. The graph clearly shows that the average energy of each node is 0.02, at the value of 100.

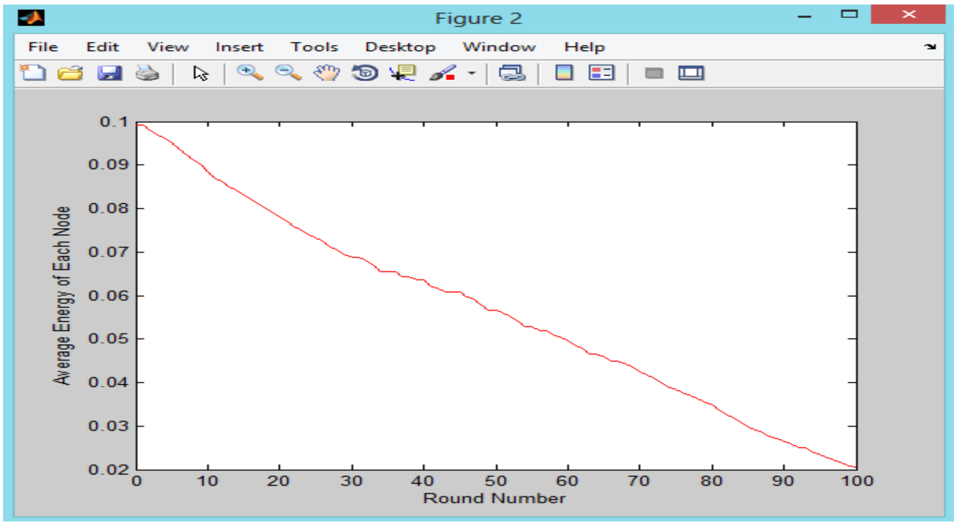

Figure 5.2 Average-Energy v/s Round No. (LEACH)

Figure 5.2 depicts a graph of average energy vs round number for the LEACH process at 1% probability or 0.01 probability for cluster head. The graph clearly shows that the average energy of each node is 0.02, at the value of 100. However, it is also clear that the energy fluctuation in leach is distinct from that in the EAMMH procedure.

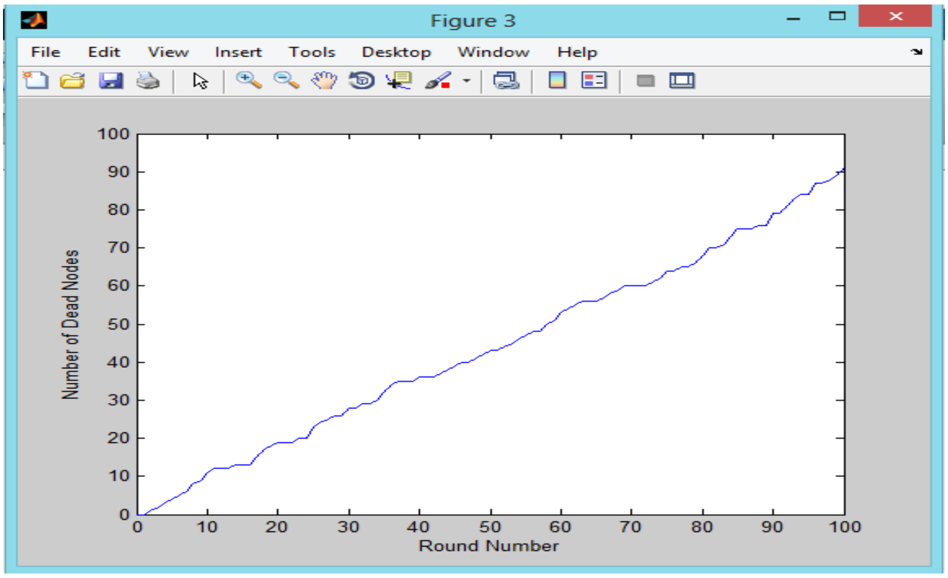

Figure 5.3 Analysis of Dead Nodes v/s Round No. (EAMMH)

The situation of a 1% or 0.01 chance of dead nodes is depicted in figure 5.3. At the 100th iteration, the EAMMH method shows a total of 90 dead nodes.

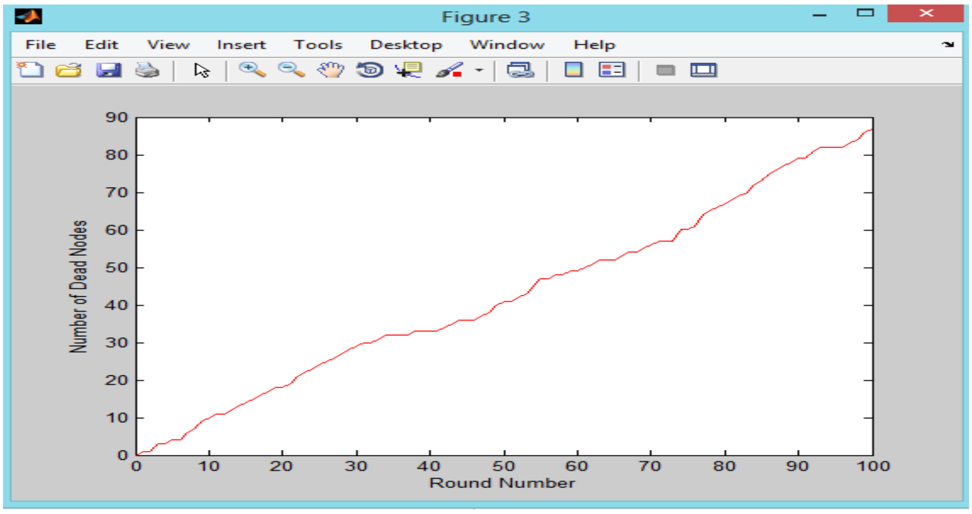

Figure 5.4 Analysis of Dead Nodes v/s Round No. (LEACH)

You can see what happens when there are 1% or 0.01 chance of dead nodes in figure 5.4. On the 100th iteration, 85 nodes have died due to using the LEACH method.

5.4.2 Simulation of Protocols at 0.5 Probability

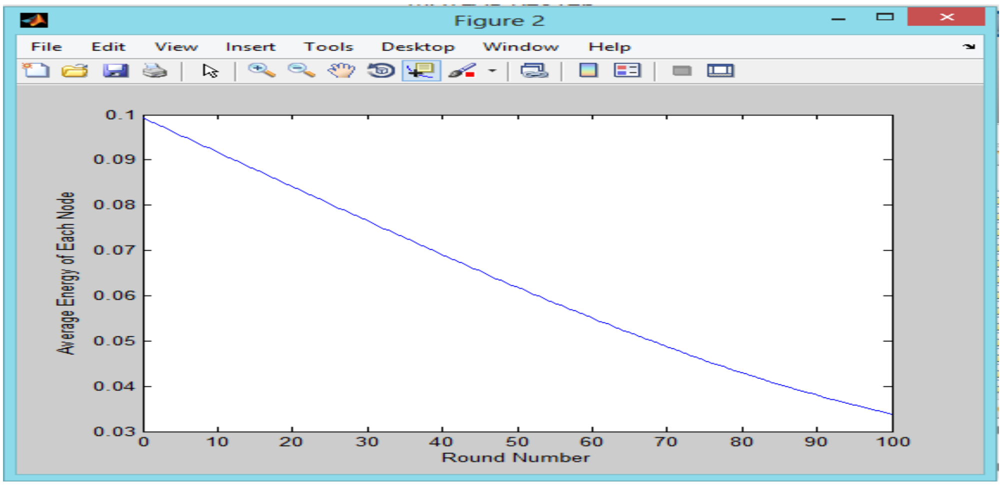

Figure 5.5 Analysis of Average Energy v/s Round No. (EAMMH)

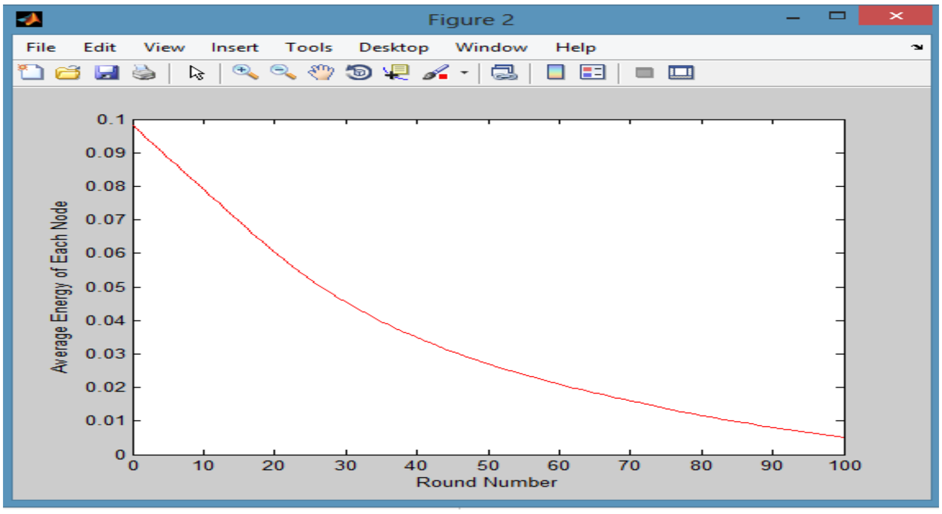

Figure 5.6 Analysis of Average Energy v/s Round No. (LEACH)

The Relationship Between the Average Energy and the Nearest Whole Number (Figure 5.5). (EAMMH)

Figure 5.5 depicts a graph of average energy vs round number for the EAMMH procedure, where the round number represents a 50% chance of being the cluster leader. At the value of 100, the average energy of each node is 0.032 as seen in the graph.

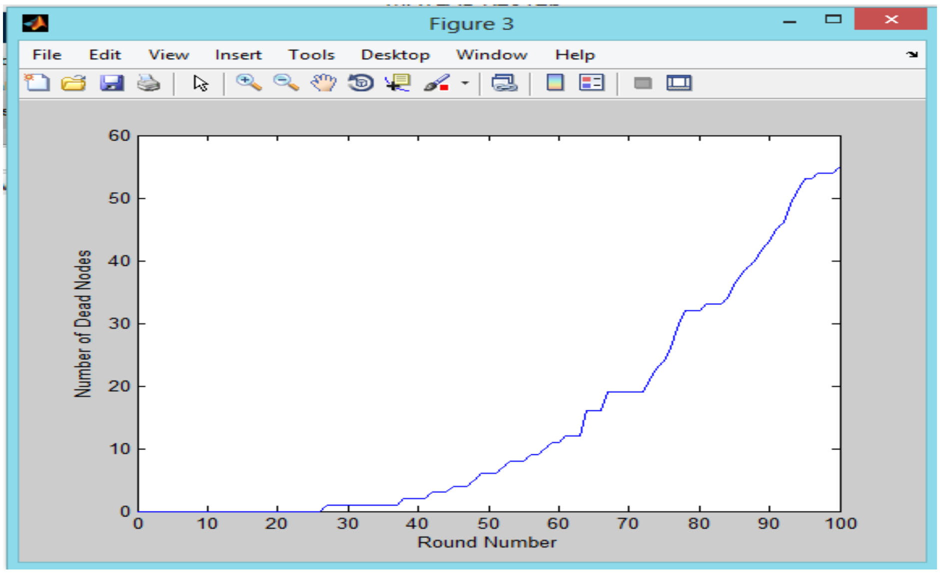

Figure 5.7 Analysis of Dead Nodes v/s Round No. (EAMMH)

Figure 5.6 displays a graph depicting the average energy vs the nearest whole integer for the LEACH process with a probability of 0.5 for the cluster head. The graph clearly shows that the average energy of each node is 0.005 at a value of 100. However, it is also clear that the energy fluctuation in leach is distinct from that in the EAMMH procedure.

Figure 5.7 depicts the scenario of the number of dead nodes with a probability of 0.5. At the 100th iteration, the EAMMH method shows a total of 55 dead nodes.

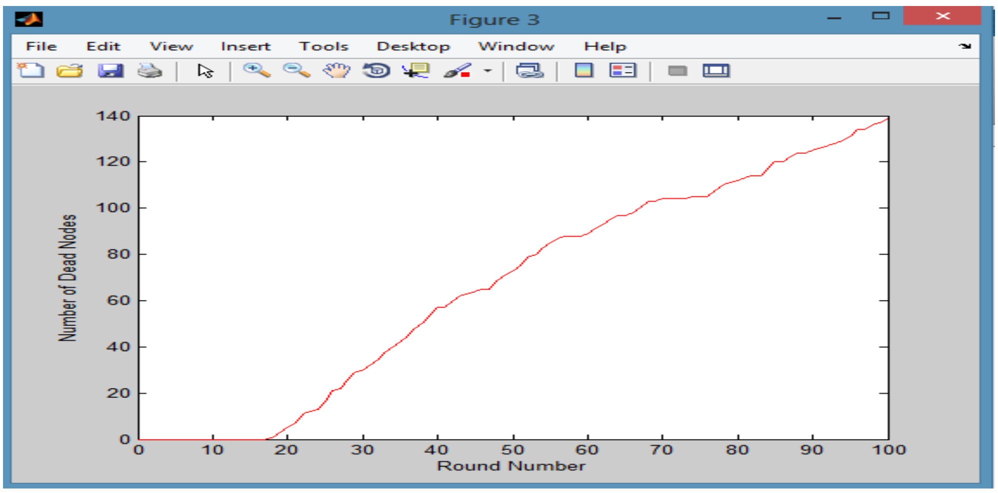

Figure 5.8 Analysis of Dead Nodes v/s Round No. (LEACH)

With a probability of 50%, or 0.5, the number of dead nodes is depicted in figure 5.8. In the 100th iteration, 140 dead nodes have been accumulated using the LEACH method.

5.4.3 Simulation of Protocols at 0.2 Probability

At a probability of 0.2, or 20% of all nodes, EAMMH and LEACH procedures were simulated with the aforementioned outcomes.

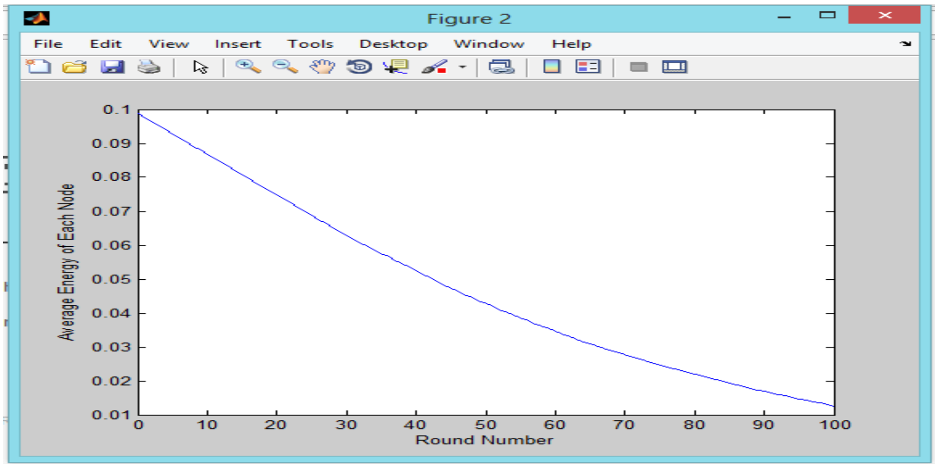

Figure 5.9 Analysis of Average Energy v/s Round No. (EAMMH)

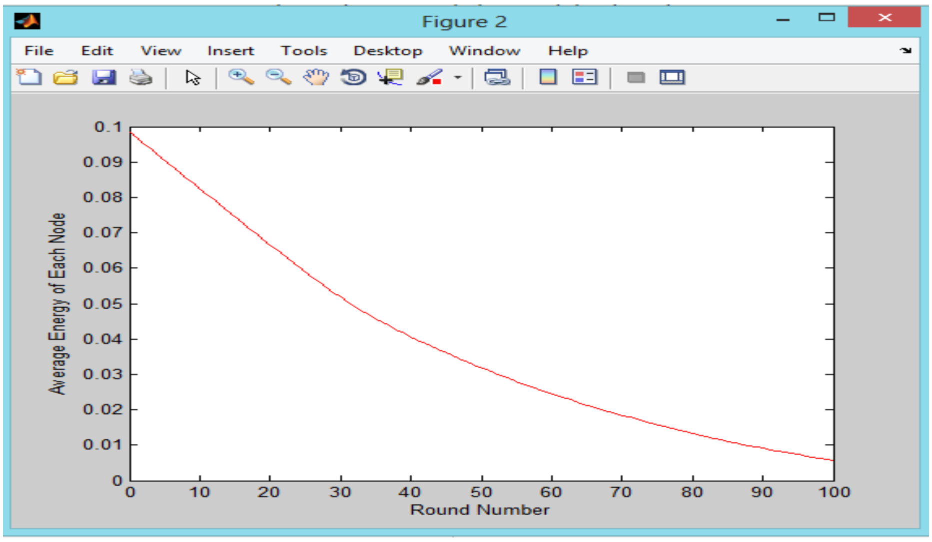

Figure 5.10 Analysis of Average Energy v/s Round No. (LEACH)

Figure 5.9 is a scatter plot depicting the average energy as a function of the round number for the EAMMH procedure at a 2% probability, or 0.02 probability for the cluster head. If we look at the graph, we can see that the average energy of each node is 0.012 at the value of 100. Figure 5.10 is a plot of average energy vs round number for the LEACH process at a 2% probability, or 0.02 probability for the cluster head. At a value of 100, the average energy of each node is 0.0013 as seen in the graph. It is also clear that the energy fluctuation in leach differs from the EAMMH procedure. Figure 5.12 depicts the situation of the number of dead nodes with a 2% or 0.02 probability. The 100th iteration of the LEACH algorithm shows a total of 130 dead nodes.

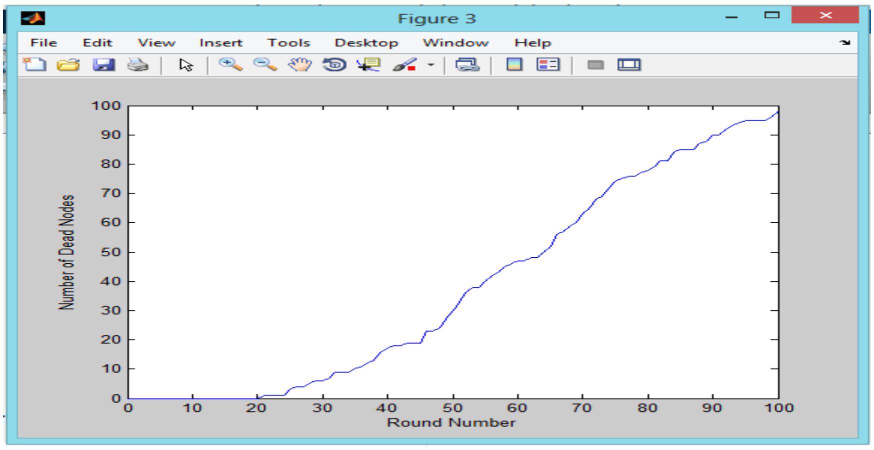

Figure 5.11 Analysis of No. of Dead Nodes v/s Round No. (EAMMH)

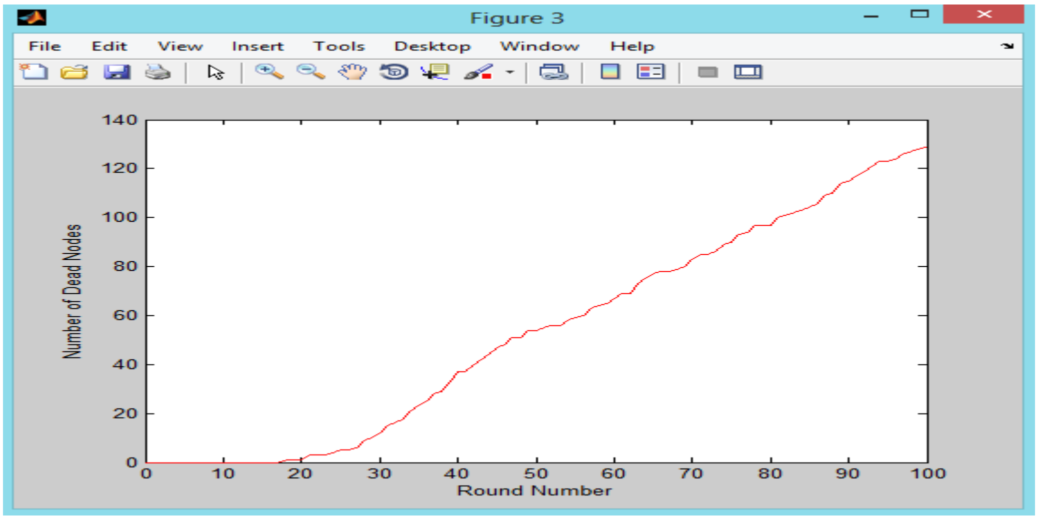

Fig 5.12 Analysis of No. of Dead Nodes v/s Round No. (LEACH)

We may see the scenario of 2%, or 0.02 probability, of dead nodes in figure 5.11. At the 100th iteration, EAMMH has a total of 98 dead nodes. Next, Figures 5.7 and 5.8 provide insights into the number of dead nodes when the cluster head selection probability is set at 0.5 for both EAMMH and LEACH. In Figure 5.7, EAMMH results in 55 dead nodes by the 100th round, suggesting improved network longevity compared to the previous 0.01 probability scenario.

Conversely, Figure 5.8 shows that with a 0.5 probability of cluster head selection, LEACH experiences a more significant number of dead nodes, with 140 nodes dying by the 100th round. This observation indicates that LEACH may not perform as effectively when a higher proportion of nodes become cluster heads.

5.5 Comparative Analysis: LEACH vs. EAMMH

This comparative analysis aims to evaluate the performance of the LEACH protocol and the Evolutionary Algorithm-based Memetic Meta-Heuristic (EAMMH) protocol in optimizing energy efficiency and network lifetime in Wireless Sensor Networks (WSNs). The simulation study conducted in MATLAB considers various parameters and metrics to assess the performance of both protocols.The primary objective of the simulation study is to optimize energy efficiency and network lifetime in WSNs while maintaining coverage of Points of Interest (POIs).MATLAB is used for conducting simulations of different protocols, including LEACH and EAMMH.

Simulation Parameters

The study considers various simulation parameters, including:

- Probability of cluster head selection
- Initial node energy

- Node density
- System size

These parameters are adjusted to evaluate their impact on network performance.The study compares several metrics across different scenarios, including:

- Average node energy
- Number of dead nodes
- Number of alive nodes
- Number of packets sent to the sink node

These metrics are analyzed for different probabilities of cluster head selection and node densities.

1. **Average Energy Performance:**
    - **EAMMH** shows better average energy performance compared to **LEACH**, particularly as the number of nodes increases.
2. **Number of Dead Nodes:**
    - **EAMMH** results in fewer dead nodes compared to **LEACH** in certain scenarios.
3. **Impact of Cluster Head Selection Probability:**
    - As the probability of cluster head selection increases, the average energy of nodes decreases, and the energy fluctuation between protocols becomes more distinct.
    -

4. **Computing Efficiency:**

   - The memetic algorithm-based approach is more efficient in terms of computing time compared to Genetic Algorithms (GAs) and achieves better fitness.

5. **Network Lifetime and Convergence:**

   - The memetic algorithm-based approach extends the network lifetime significantly and maintains a high sensing coverage ratio.

   - It outperforms other methods like EGDG, LEACH-Coverage-U, and LEACH in terms of network longevity.

6. **Deployment Scenarios:**

   - The study considers both uniform and random deployments of sensor nodes and evaluates the performance of the proposed algorithm in both scenarios.

5.6 Simulation Results: Detailed Analysis

Simulation at 0.01 Probability

Average Energy vs. Round Number:

- **EAMMH:** The average energy of each node remains relatively stable around 0.02 over 100 rounds.

- **LEACH:** Maintains an average energy of approximately 0.02 per node but exhibits distinct energy fluctuations compared to EAMMH.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 90 dead nodes at the 100th round.

- **LEACH:** Shows 85 dead nodes by the 100th round.

Simulation at 0.5 Probability

Average Energy vs. Round Number:

- **EAMMH:** Average energy of each node stabilizes around 0.032 over 100 rounds.
- **LEACH:** Average energy is approximately 0.005 per node at the 100th round, with noticeable energy fluctuations.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 55 dead nodes at the 100th round.
- **LEACH:** Accumulated 140 dead nodes by the 100th round.

Simulation at 0.2 Probability

Average Energy vs. Round Number:

- **EAMMH:** Average energy of each node is 0.012 at the 100th round.
- **LEACH:** Average energy is 0.0013 per node at the 100th round, with distinct energy fluctuations.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 98 dead nodes at the 100th round.
- **LEACH:** Shows 130 dead nodes at the 100th round.

Comparative Analysis: Advantages and Disadvantages

LEACH

Advantages:

- Simple and easy to implement.
- Reduces energy consumption through clustering.

Disadvantages:

- Energy fluctuations due to random cluster head selection.
- Lower network lifetime compared to more advanced algorithms.
- Less efficient in managing energy distribution across nodes.

EAMMH

Advantages:

- Better average energy performance.
- Fewer dead nodes in various scenarios.
- More stable energy consumption patterns.
- Extends network lifetime significantly.
- Maintains a high sensing coverage ratio.
- More efficient in terms of computing time compared to Genetic Algorithms.

Disadvantages:

- Increased complexity in implementation compared to LEACH.

- Potentially higher initial computational overhead.

Performance Assessment

Energy Efficiency:

- **EAMMH** consistently shows better energy efficiency compared to **LEACH** across different scenarios and probabilities of cluster head selection.

Network Lifetime:

- **EAMMH** extends the network lifetime significantly compared to **LEACH**, ensuring longer operational periods and reduced need for maintenance.

Stability:

- **EAMMH** demonstrates more stable energy consumption patterns and fewer fluctuations compared to **LEACH**.

Computing Efficiency:

- **EAMMH** is more efficient in terms of computing time compared to Genetic Algorithms and achieves better fitness levels, making it suitable for real-time applications.

The comparative analysis demonstrates that the EAMMH protocol, based on memetic algorithms, outperforms the traditional LEACH protocol in terms of energy efficiency, network longevity, and overall performance. While LEACH is simpler and easier to implement, EAMMH offers significant advantages in managing energy consumption and extending the lifetime of WSNs, making it a more effective solution for optimizing WSN performance in various deployment scenarios.

5.7 Comparison of Improved Models of LEACH

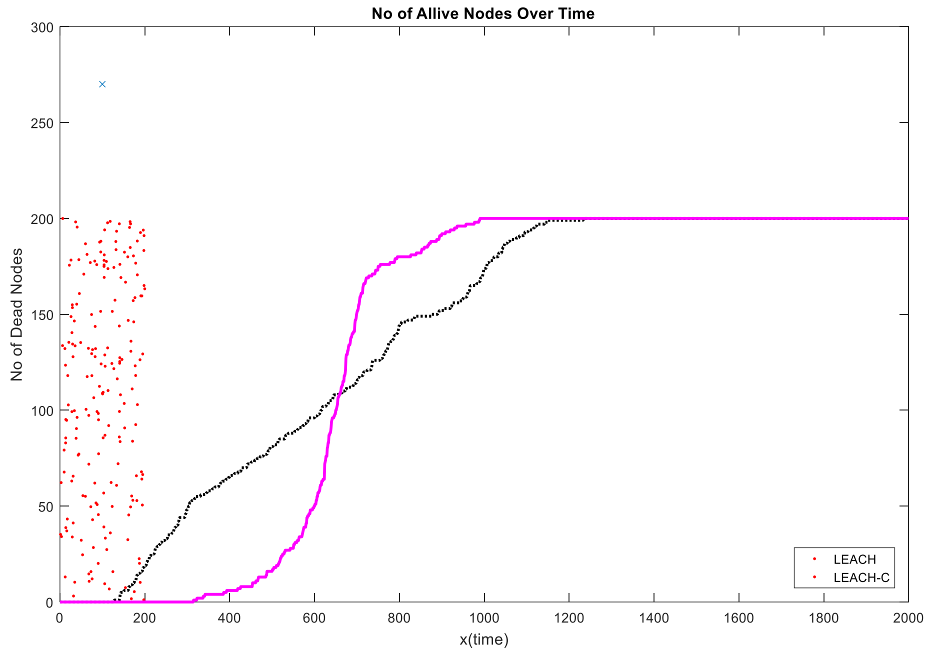

Figure 5.13 Analysis of Number of Alive Nodes (LEACH-C)

Figure 5.13 presents a scatter diagram of LEACH-C protocol dead nodes vs round numbers. From the graph, it is clear that the suggested method outperforms the LEACH technique.

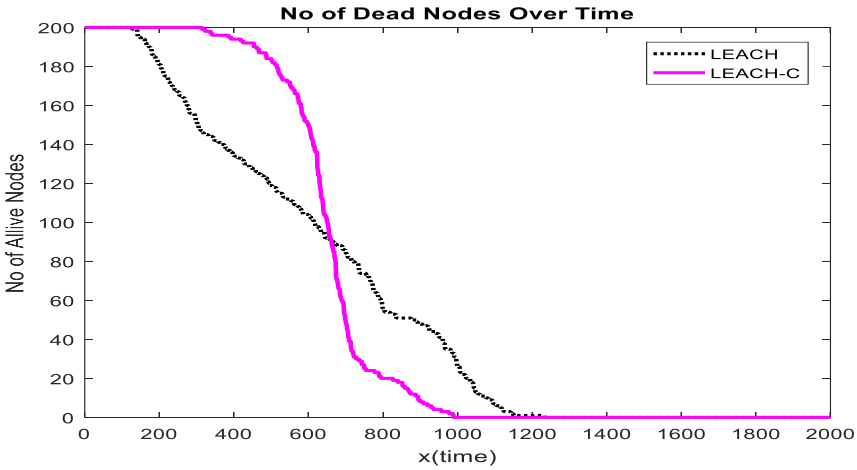

Figure 5.14 Analysis of Dead Nodes in Case-1

Figure 5.14 depicts the distribution of packets sent to the sink node for both protocols. Figure 5.4 depicts the situation where the number of dead nodes is described in relation to the number of rounds.

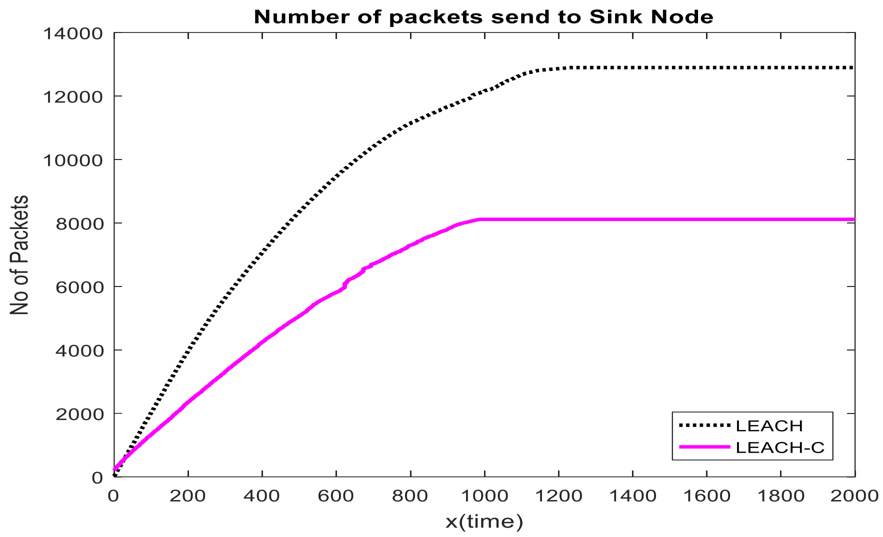

Figure 5.15 Analysis of Number of Packets Send to Sink Node in Case-1

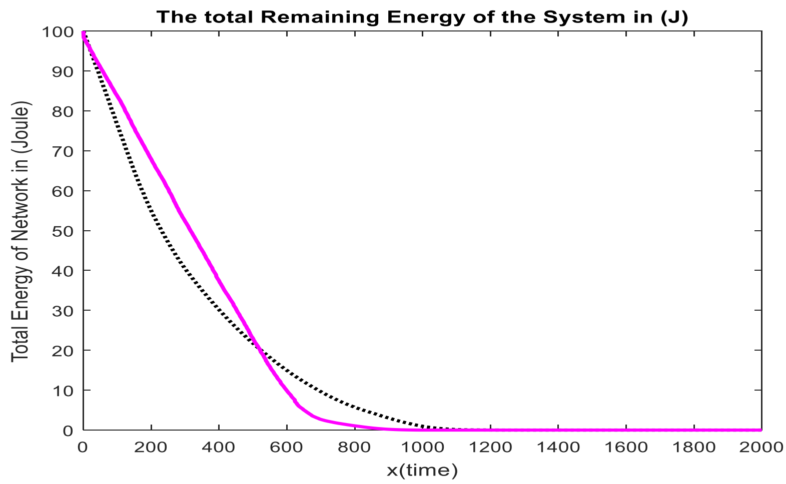

Figure 5.16 Analysis of Number of Dead Nodes v/s Round Number- (LEACH)

Figure 5.17 depicts the situation with regards to the number of dead nodes with regards to the first death, the tenth death, and all deaths with regards to rounds. Above, you can see the outcome of a simulation run with 400 nodes for both the LEACH and LEACH-C protocols. Both the LEACH and LEACH-C protocols were simulated with 200 nodes and a 200 m^2 region, and the results are shown below.

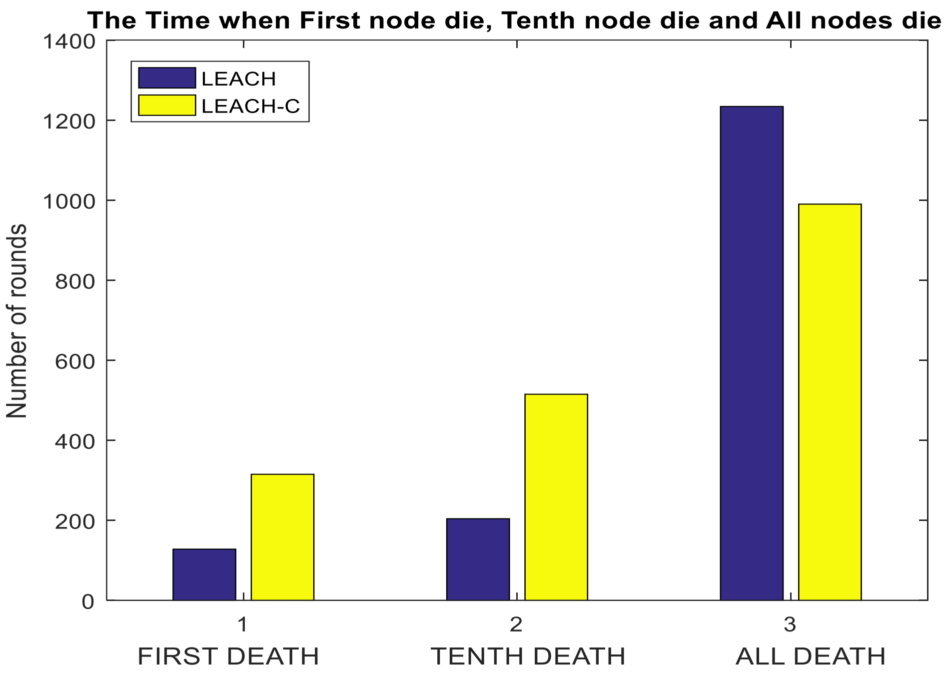

Figure 5.17 Analysis of Node Death Analysis for Case-1

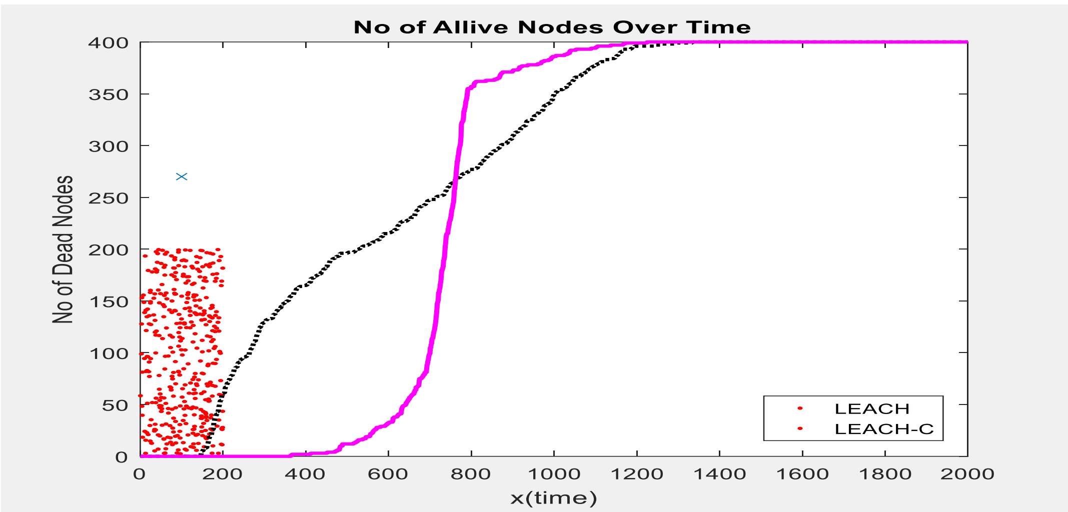

Figure 5.18 Analysis of Number of Alive Nodes Case-2 (LEACH-C)

Figure 5.18 presents a graph depicting the relationship between dead nodes and even numbers in the LEACH-C protocol. According to the data presented in the graph, the suggested method achieves higher throughput in scenario 2 than the LEACH technique.

In case 2, the number of packets sent to the sink node is depicted graphically in figure 5.8 with respect to both protocols..

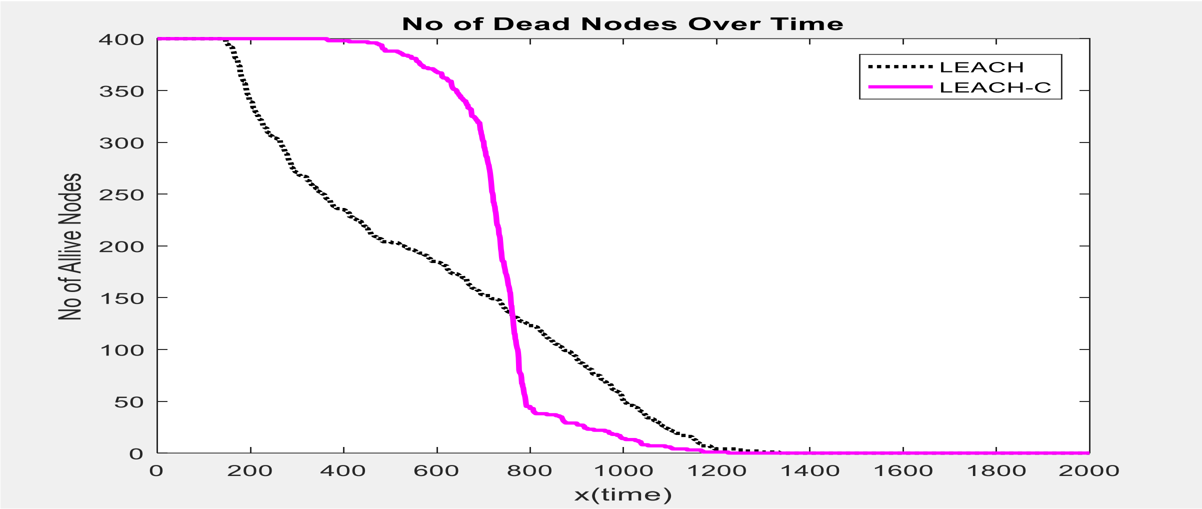

Figure 5.19 Analysis of Dead Nodes Case-2

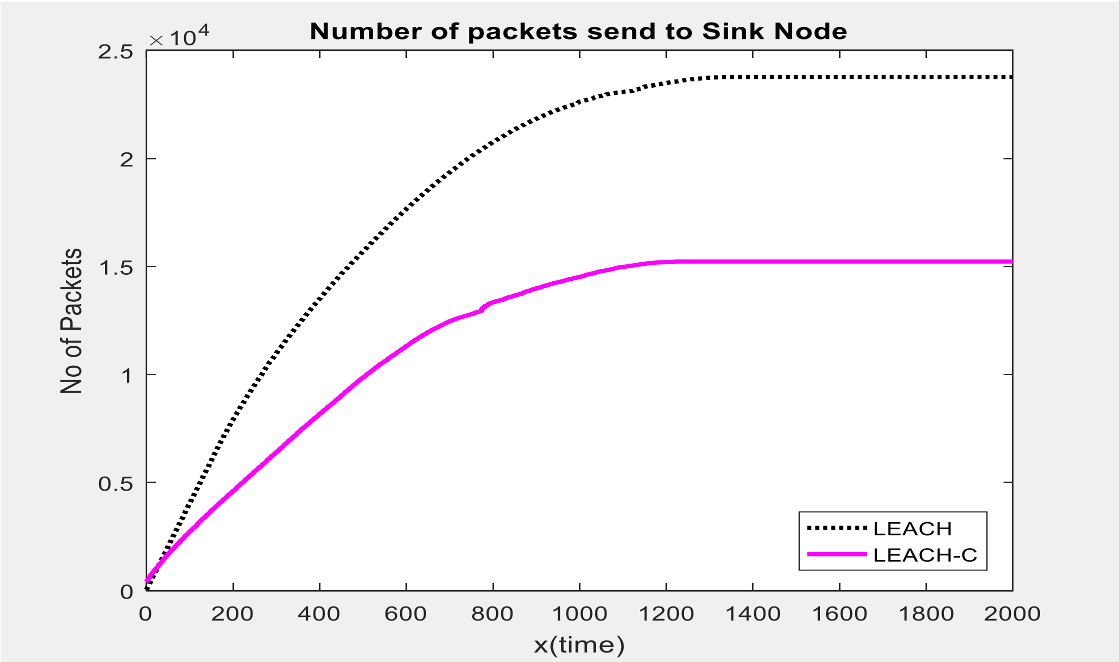

Figure 5.20 Analysis of Number of Packets Send to Sink Node Case-2

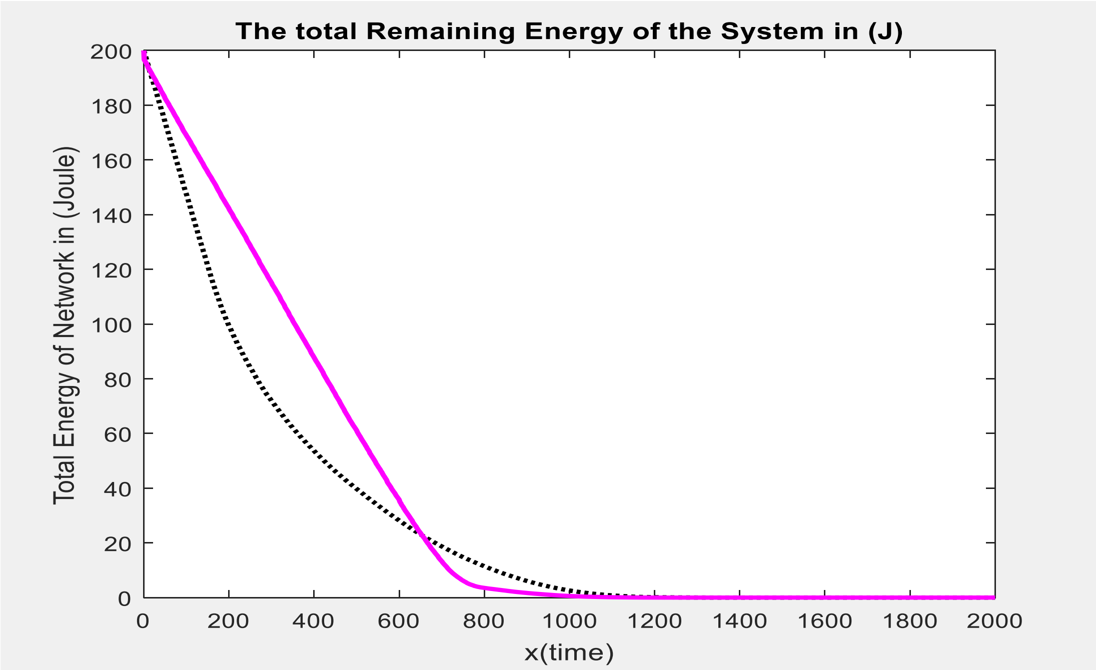

Figure 5.21 Analysis of Number of Dead Nodes v/s Round Number Case-2 (LEACH)

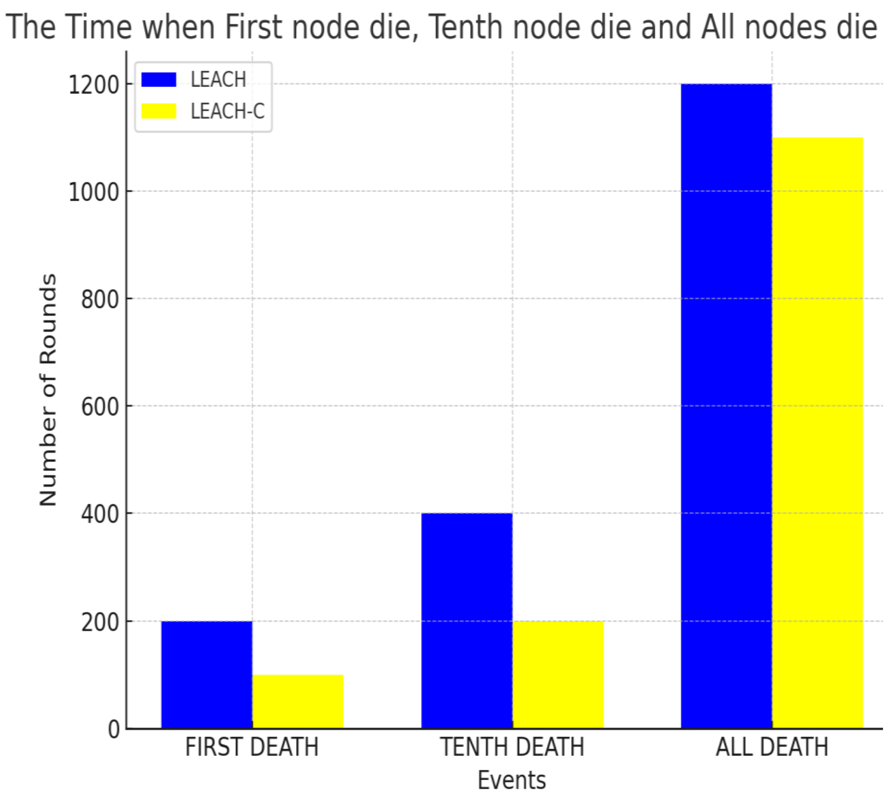

Figure 5.22 Analysis of Node Death Analysis for Case-2

The scenario of the number of dead nodes with regard to the first death, the tenth death, and all death with regard to rounds with case 2 is depicted in figure 5.22.The following simulation results compare the LEACH and LEACH-C protocols over a 400 m2 and 200 node topology.

5.8 Simulation of Protocols at Updated Area

The results below display the simulation of both the LEACH and the LEACH-C protocols at 200 nodes and area of 400 m^2

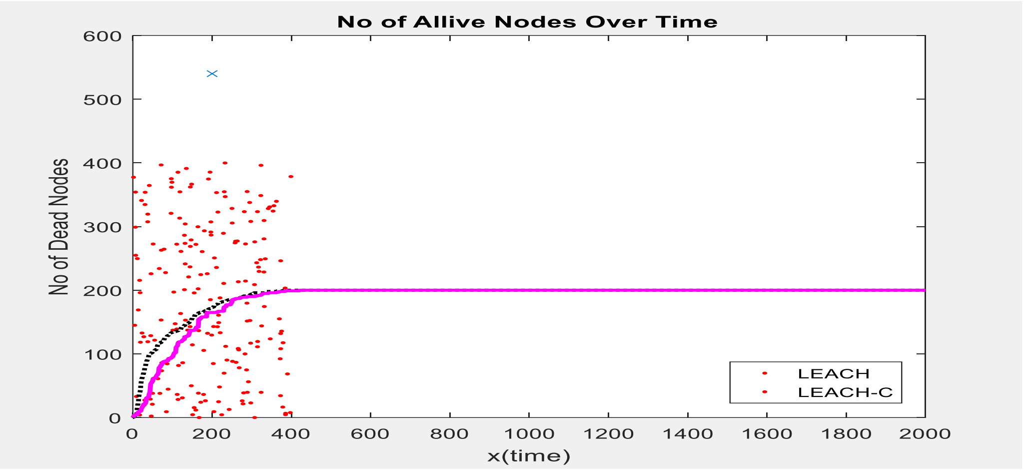

Figure 5.23 Analysis of Number of Alive Nodes Case-3 (LEACH-C)

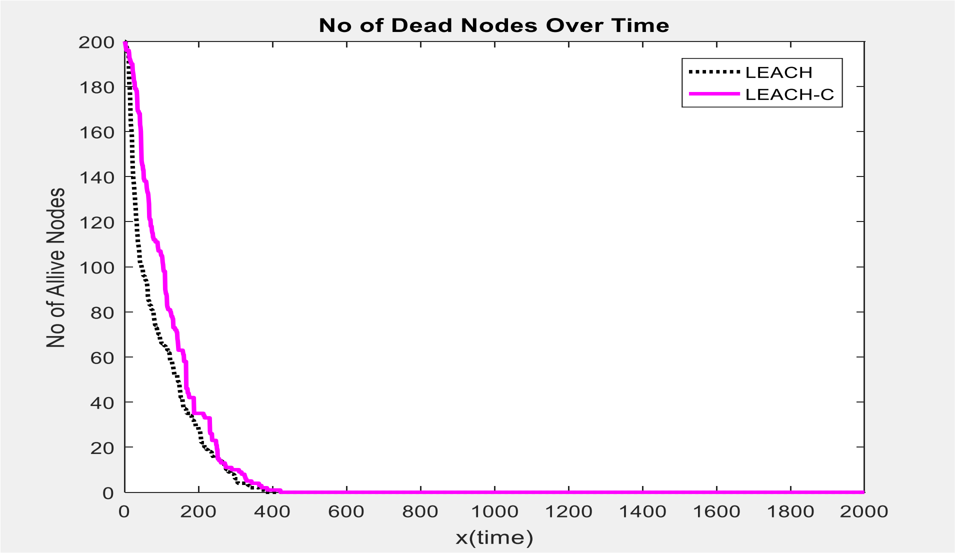

Figure 5.24 Analysis of Dead Nodes Case-3

Figure 5.24 presents the distribution of LEACH-C protocol dead nodes as a function of round numbers. A closer look at the graph reveals that the proposed algorithm outperforms the LEACH protocol in case 3. Figure 5.25 depicts the distribution of packets sent to the sink node for Case 3 by protocol.

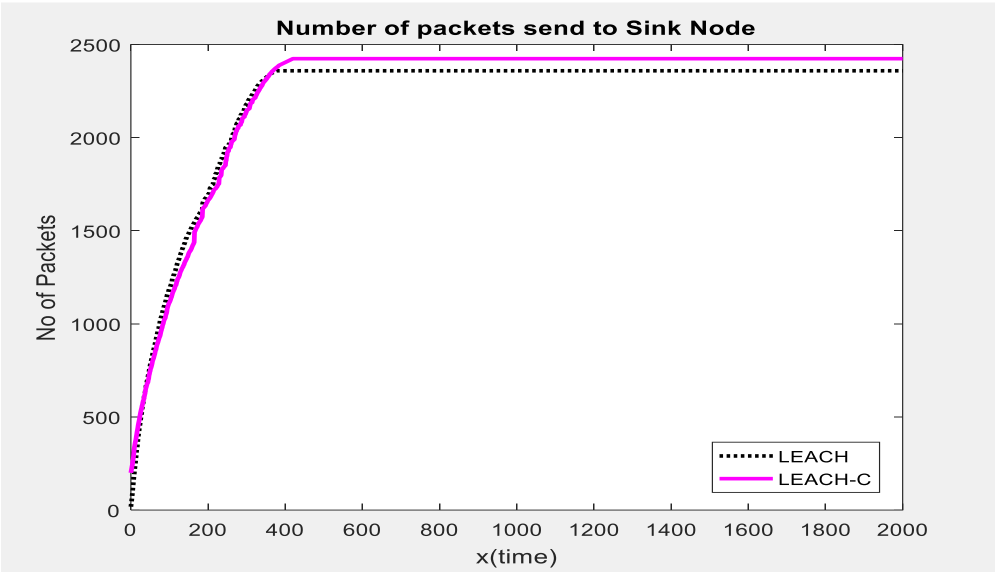

Figure 5.25 Analysis of Number of Packets Send to Sink Node Case-3

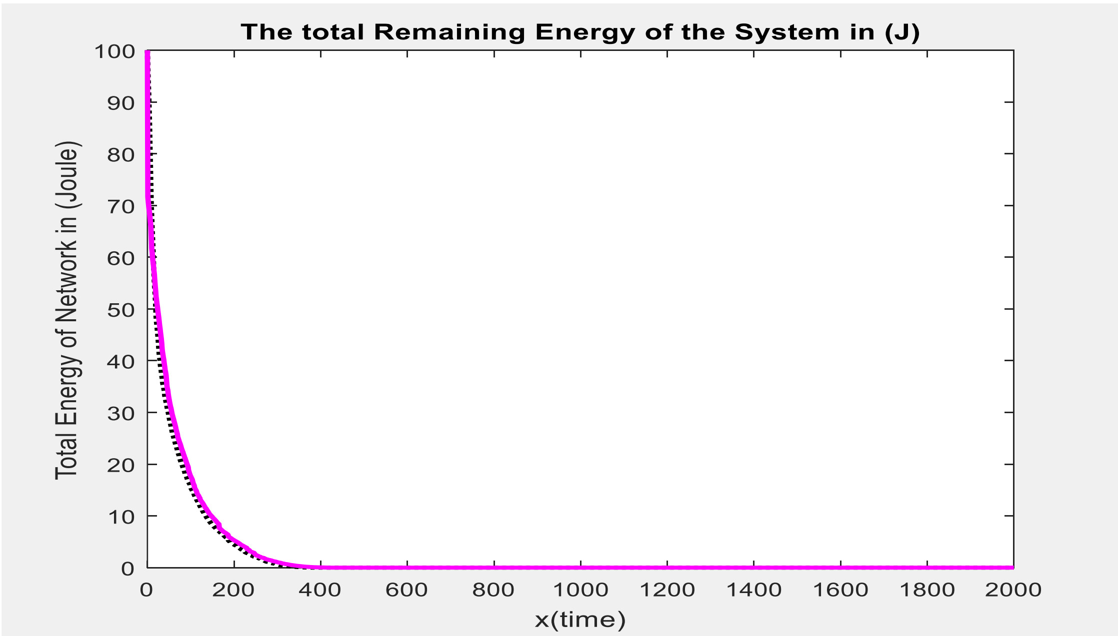

Figure 5.26 Analysis of No. of Dead Nodes v/s Round No. (LEACH)- Case-3

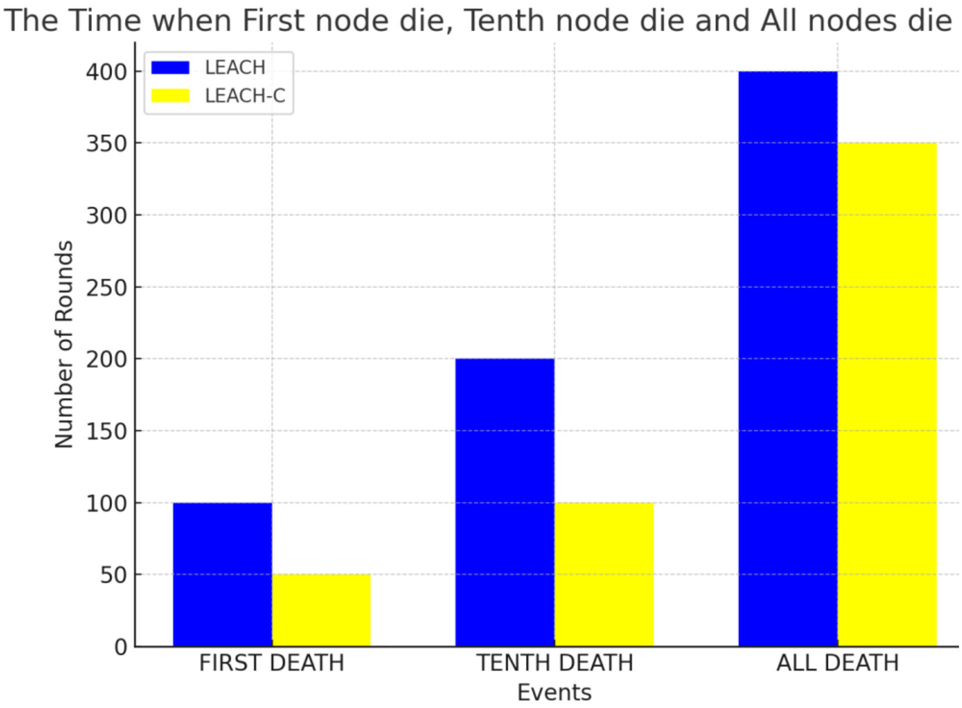

Figure 5.27 Analysis of Node Death Analysis for Case-3

Figure 5.27 depicts the situation in terms of the total number of dead nodes, the number of nodes that died in the first round, and the number of nodes that died in the tenth round. As a result of having to cover greater distances to relay data, nodes or clusters that are further from the base station must expend more energy. This is because LEACH-C, unlike LEACH, is an inter-cluster routing device that helps the network last longer. It only performs LEACH-C. LEACH, on the other hand, has a direct line of communication to the cluster head and ultimately to the base station. While LEACH uses multi-hop systems, LEACH-C, by utilizing multi-way and hierarchical routing parameters and techniques, can achieve significantly higher energy efficiency than LEACH.

5.9 Simulation of Improved Memetic LEACH Protocols

5.9.1 Simulation and Results of Proposed Improved Memetic Evolutionary Computing Based LEACH

Environmental sensing, data collecting, processing, and a variety of other tasks can be carried out by the nodes. The energy required to carry out these operations is provided by the batteries housed within each node. It's critical to keep the network running smoothly for as long as feasible while also reducing the amount of energy it uses. The Low Energy Adaptive Clustering Hierarchy (LEACH) routing protocol has been created to accomplish this goal (LEACH). This study uses a modified LEACH model to significantly reduce energy usage and thereby extend the network's life. The LEACH methodology randomly distributes cluster heads, either near or far from the base station. Since there is a large difference in distance between CH and baselines, it is possible that random CH will use more energy. In this part, we'll assume a CWSN with a few POIs is keeping tabs on a hypothetical virtual field. The administrator sets the number of nodes and points of interest (POIs). After either random or deliberate deployment, each POI and sensor node remains in place. The MATLAB platform is used for all of the simulations.

5.9.2 Analysis of Computational Time

It is necessary to test the quick-convergence of the memetic algorithm based method by evaluating the computation time and fitness of memetic algorithm based approaches applied to different CWSN sizes. This study's findings will be compared to those of genetic algorithms. The number of deployed nodes ranges from 50 to 500, with 64 POIs randomly dispersed throughout a 100 m 100 m monitoring region. Regardless of the number of sensor nodes installed, the node's detecting range is set at 17.675 m. The placement of each sensor node is completely arbitrary. Experiments were carried out 30 times for each one. Since

GAs are constrained by evolutionary constraints, they typically take longer to find an optimal solution. With the extra local search scheme, the memetic algorithm-based technique, on the other hand, is able to generate the optimal answer in fewer generations. We believe that the memetic algorithm-based method and GA use the same criterion to halt evolution. When the fitness of the best chromosome exceeds a predefined threshold, the evolutionary process is over. According on our prior experiments, we have established the thresholds of fitness for different network sizes. Based on the experimental results, we discovered that the memetic algorithm-based strategy had a significant fitness boost around the second generation. When a generation has completed, the discrete timestamp and fitness are recorded. Additionally, the GA's time stamp and fitness level are noted. For the memetic algorithm-based approach, we use a cubic spline interpolation to fit the time-fitness curve. In the next step, we examine how the memetic algorithm based technique compares to the GA at various fitness levels. There are anywhere from 50 to 500 nodes in the simulation, and the related simulation results may be found in Table 5.1. A CWSN with a sensing field of 100" " m100" " m has 64 randomly distributed POIs. Thirty times a day, every case is rerun.

According to the definition of fitness function provided above, a higher level of fitness means a better schedule for nodes in terms of energy efficiency. A better node scheduling than GA can be found using the memetic algorithm technique, as shown in Table 5.1. Using memetic algorithm based approaches, we can observe that they take less computing time to produce solutions with better fitness than GA. At larger networks, the advantages of memetic algorithm-based approaches become more evident. Increasing the number of deployed nodes and POIs makes the SCP more difficult. For a network of 500 nodes, the memetic algorithm-based technique takes an average of 34.64 seconds to compute, which is 69.3 percent faster than the GA.

Table 5.1

Evaluation of Proposed Algorithm Based Approach at Varying Fitness Levels in Terms of Average Computing Time (Seconds)

NODE 100:

Fitness	GA	Std.	Proposed	Std.
0.321	3.211	11.451	0.91	0.361
0.31	0.061	0.051	0.821	0.182
0.251	0.061	0.051	0.691	0.14

NODE 300:

Fitness	GA	Std.	Proposed	Std.
0.592	21.214	13.312	6.231	0.141
0.554	6.624	3.594	6.153	0.144
0.554	1.452	0.384	6.044	0.145

NODE 500:

Fitness	GA	Std.	Proposed	Std.
0.521	53.491	29.811	22.431	0.491
0.53	24.671	8.1	22.361	0.493
0.454	4.534	1.353	22.163	0.494

Using the proposed memetic algorithm-based technique, the average computing time is many times faster than that of the GA while still achieving higher fitness. As the number of nodes deployed in the CWSN increases, the operating performance of the memetic algorithm-based solution is superior to that of the GA.

5.9.2 Analysis of Network Lifetime and Convergence

Proposed approaches are evaluated in this section for their ability to extend network life and preserve coverage. Sensor nodes are activated or deactivated using a memetic algorithm to maintain a high POI coverage ratio while minimising energy consumption. In this case, we'll assume a sensing field 100 m 100 m in size has 64 POIs and 400 nodes spread evenly. Each node starts with the same amount of energy, and it is assumed that all nodes are the same. Similar to the sink, the nodes have a 17.675-meter sensing range and may connect with each other and the sink directly. This scenario's corresponding parameters are summarised in. A CWSN is also formed by deploying the nodes. CWSN-type sample network parameters.

a) The sensing range r_s is 17.675 meters.

b) λ is 1 . Nodes with distance less than 17.675 meters are defined as neighbors.

c) $\eta = 20$.

d) Crossover rate $R_c = 0.5$, mutation rate $R_m = 0.07$.

e) $E_{elec} = 50\ nJ/bit, E_{amp} = 100 pJ/bit/m^2, E_{DA} = 5\ nJ/bit/report, \beta = 2$.

f) A sink is located at the coordinate $(50{,}200)$, which is far from the sensing field and power-rich.

g) The size of every data packet is 2,000 bits, i.e., $H = 2{,}000$.

h) Initial energy = 0.25 Joules.

The memetic algorithm-based solution can efficiently find and deactivate unnecessary nodes in the simulation scenario of uniform deployments. There was an initial deployment of nodes and POIs as depicted in Figure 5.28 (left). The redundant nodes are identified and deactivated based on the suggested MA-based node scheduling.

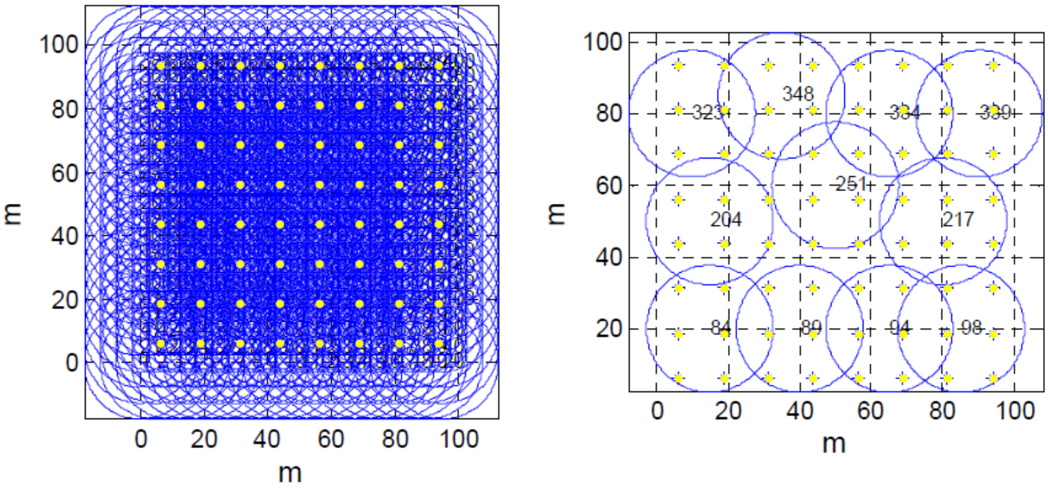

Figure 5.28 Analysis of Uniform Deployments of Sensor Nodes and POIs

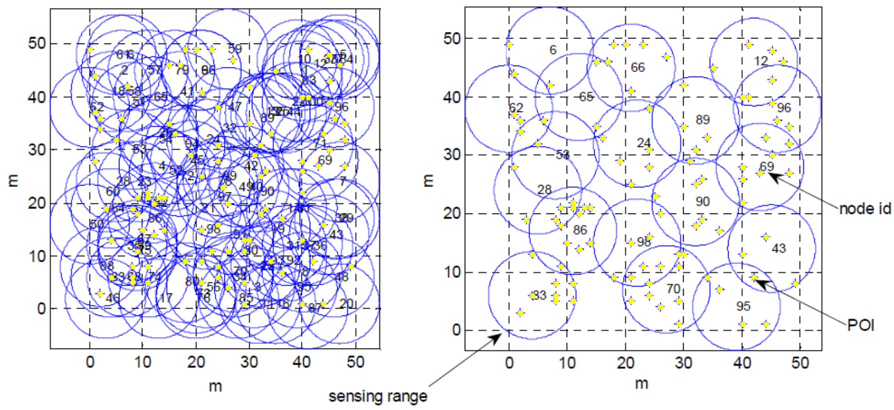

Figure 5.29 Analysis of Random Deployments of Sensor Nodes and POIs in the Sample

There are still a few nodes active, and they are in charge of sensing. Figure 5.28 (right) depicts the coverage for POIs following the implementation of the MA-based optimal schedule. Only 2.75 percent of nodes are needed to cover all POIs, which are all 1-coverage, in this scenario. Network and the simulation result after applying the memetic algorithm based approach.

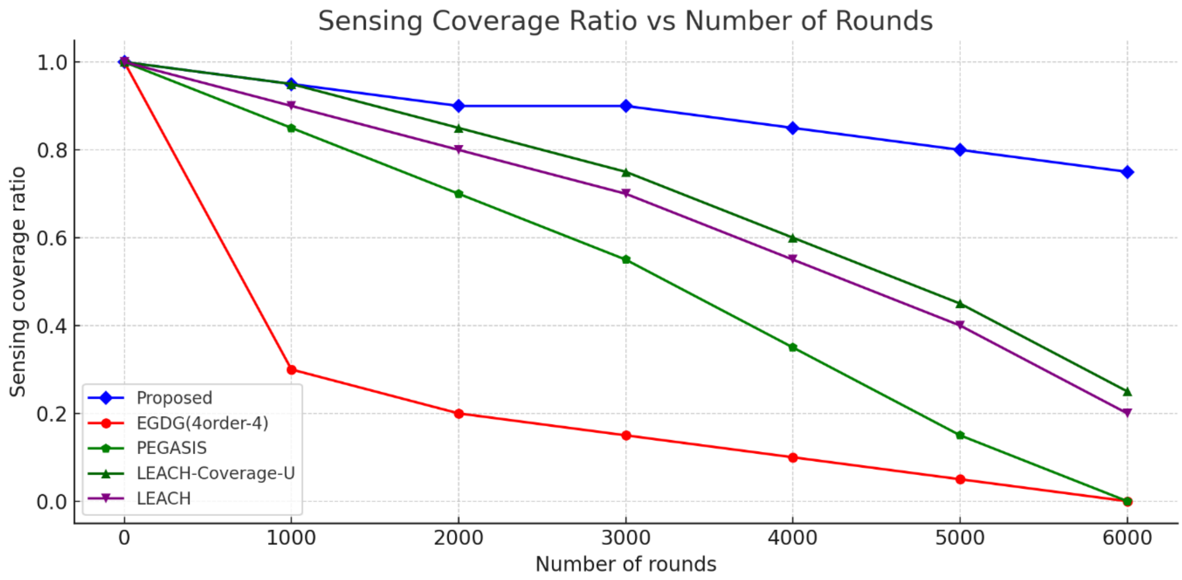

Figure 5.30 Analysis of Sensing Coverage Ratio v/s Number of Rounds in Uniform Deployment Scenario

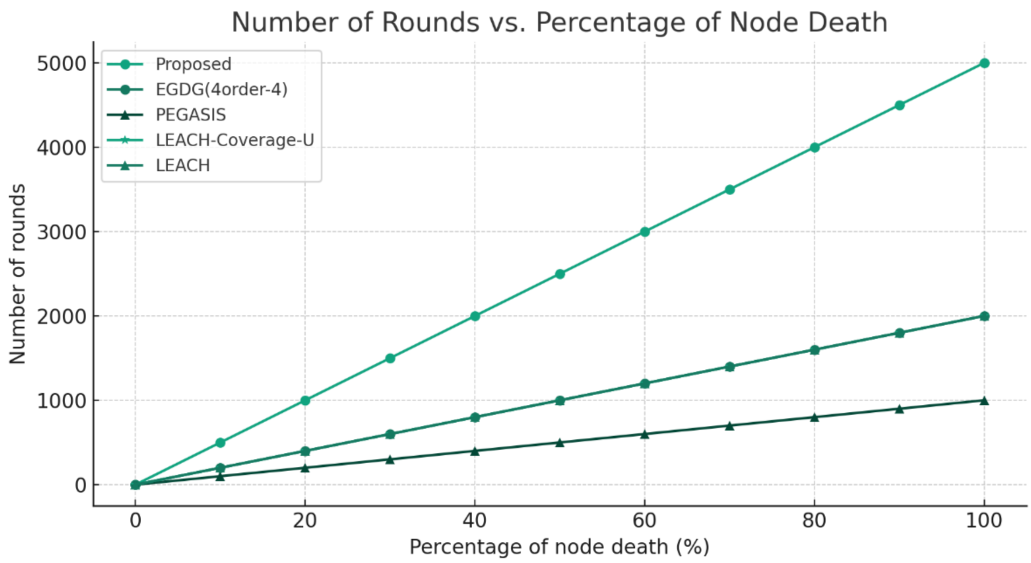

Figure 5.31 Analysis of Number of Rounds v/s Percentage of Dead Nodes (%) for the Uniform Deployment Scenario

All four algorithmic approaches were tested against each other by running simulations on the same sample network under the identical deployments of nodes and POIs. EGDG, LEACH-Coverage-U, LEACH, and PEGASIS simulation results are all included in the comparison. Figure 5.30 shows the ratio of sensing coverage to the number of rounds. It is evident that the sensor coverage ratios of PEGASIS, LEACH-Coverage-U, and LEACH are not well maintained. In comparison to the PEGASIS, the proposed memetic algorithm technique maintains a sensing coverage ratio of 100% until the 2,000th cycle. EGDG's sensing coverage ratio drops to roughly 97% at the 2,000th round, but the memetic algorithm-based approach obtained similar results between the 2,000th and 3,500th rounds. Starting with the 3500th round, the proposed memetic algorithm-based strategy has a significant advantage. Memetic algorithm-based strategy extends network lifetime to 5,118 rounds, which is nearly 1,000 rounds longer than the EGDG method.

Figure 5.31 displays the number of rounds and the fraction of nodes that have died. A total of 50 percent of nodes are lost in the EGDG and LEACH-Coverage-U techniques in the 1950th, 1120 and 502nd round respectively. To test this, we ran a simulation in which the proposed memetic algorithm-based approach outperformed the EGDG technique. Since nodescheduling mechanisms are absent in the PEGASIS, LEACH-Coverage-U, and LEACH approaches, we find that the nodes die quickly. Because redundant nodes can be deactivated using node scheduling tactics that save energy, a longer network lifetime can be achieved with the use of the EGDG and the proposed memetic algorithm-based methodology. Sensor networks that are designed to preserve network coverage must have a lengthy network life and a wide range of sensors. Memetic algorithm-based approaches can accomplish these goals, according on the simulation results. In this way, the network's Quality of Service (QoS) can be improved. In summary, the provided information outlines a comprehensive simulation study focused on optimizing energy efficiency and network longevity in Wireless Sensor Networks (WSNs).

5.10 Comparative Analysis of Proposed Work and Results

Wireless Sensor Networks (WSNs) have gained significant importance due to their widespread applications in monitoring and data collection in various fields, including environmental monitoring, healthcare, agriculture, and industrial automation. However, one of the most significant challenges faced by WSNs is the limited energy resources of individual sensor nodes. These nodes are often battery-powered and deployed in remote or inaccessible locations, making it challenging to replace or recharge their batteries. Therefore, optimizing energy efficiency is a critical concern in the design and operation of WSNs.

To address the challenges of energy efficiency and network longevity in WSNs, researchers often turn to simulation tools. MATLAB, a widely used computational software, is a popular choice for simulating and analyzing WSNs. Simulations allow researchers to experiment with different protocols, settings, and scenarios in a controlled environment before deploying actual sensor networks. This approach enables the evaluation of various strategies without the cost and complexity of physical deployments.

Objective

The primary objective of the simulation study is to optimize energy efficiency and network lifetime in WSNs while maintaining coverage of Points of Interest (POIs).

Simulation Tools

MATLAB is used for conducting simulations of different protocols, including LEACH, EAMMH (Energy Aware Multi-hop Multi-path Hierarchical protocol), improved LEACH, and Proposed Memetic LEACH.

5.10.1 Simulation Parameters and Scenarios

The simulation study focuses on two primary protocols: LEACH and EAMMH. To assess their performance, the study considers several key parameters:

- **Round Number vs. Dead Nodes:** The number of rounds in the simulation is compared to the number of dead nodes. This metric provides insights into how long the network can operate before nodes run out of energy.
- **Average Node Energy vs. Round Number:** This parameter assesses how the average energy of individual sensor nodes evolves over time during the simulation. It helps in understanding energy consumption patterns.
- **Probability of Cluster Head Selection:** Varying probabilities of cluster head selection are examined. This parameter reflects the likelihood of a sensor node becoming a cluster head, a critical role in WSNs for data aggregation and communication.
- **Node Density:** Different node densities, representing the number of sensor nodes deployed in a given area, are considered. Node density impacts network coverage and communication.
- **Initial Node Energy:** The study assumes that nodes have equal initial energy levels. This assumption simplifies the simulation but may not reflect real-world scenarios where nodes may have varying energy levels due to manufacturing variations or initial energy storage conditions.
- **Static Node Deployment:** The nodes are considered to be static, meaning they do not move once deployed. This assumption simplifies the simulation but may not account for scenarios where nodes need to adapt to changing conditions.

- **Homogeneous Node Distribution:** The nodes are assumed to be homogeneously distributed throughout the simulation area. This simplification helps in controlling variables but may not represent real-world deployment scenarios.

- **Data Transmission Requirement:** All nodes are expected to transmit data to a sink node. This requirement ensures that nodes are actively participating in data collection and transmission.

5.10.1 Simulation Results: Energy Efficiency and Dead Nodes (LEACH AND EAMMH)

The simulation results presented offer valuable insights into the performance of LEACH and EAMMH under different conditions. The following sections delve into the detailed analysis of these results.

Simulation at 0.01 Probability

Average Energy vs. Round Number:

- **EAMMH:** The average energy of each node remains relatively stable around 0.02 over 100 rounds.

- **LEACH:** Maintains an average energy of approximately 0.02 per node but exhibits distinct energy fluctuations compared to EAMMH.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 90 dead nodes at the 100th round.

- **LEACH:** Shows 85 dead nodes by the 100th round.

Simulation at 0.5 Probability

Average Energy vs. Round Number:

- **EAMMH:** Average energy of each node stabilizes around 0.032 over 100 rounds.
- **LEACH:** Average energy is approximately 0.005 per node at the 100th round, with noticeable energy fluctuations.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 55 dead nodes at the 100th round.
- **LEACH:** Accumulated 140 dead nodes by the 100th round.

Simulation at 0.2 Probability

Average Energy vs. Round Number:

- **EAMMH:** Average energy of each node is 0.012 at the 100th round.
- **LEACH:** Average energy is 0.0013 per node at the 100th round, with distinct energy fluctuations.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 98 dead nodes at the 100th round.
- **LEACH:** Shows 130 dead nodes at the 100th round.

5.10. 2 Comparative Analysis: LEACH vs. EAMMH

This comparative analysis aims to evaluate the performance of the LEACH protocol and the Evolutionary Algorithm-based Memetic Meta-Heuristic (EAMMH) protocol in optimizing energy efficiency and network lifetime in Wireless Sensor Networks (WSNs). The simulation study conducted in MATLAB considers various parameters and metrics to assess the performance of both protocols.

Simulation Parameters

The study considers various simulation parameters, including:

- Probability of cluster head selection
- Initial node energy
- Node density
- System size

These parameters are adjusted to evaluate their impact on network performance. The study compares several metrics across different scenarios, including:

- Average node energy
- Number of dead nodes
- Number of alive nodes
- Number of packets sent to the sink node

These metrics are analyzed for different probabilities of cluster head selection and node densities.

Key Findings

1. **Average Energy Performance:**
    - **EAMMH** shows better average energy performance compared to **LEACH**, particularly as the number of nodes increases.

2. **Number of Dead Nodes:**
    - **EAMMH** results in fewer dead nodes compared to **LEACH** in certain scenarios.
3. **Impact of Cluster Head Selection Probability:**
    - As the probability of cluster head selection increases, the average energy of nodes decreases, and the energy fluctuation between protocols becomes more distinct.
4. **Computing Efficiency:**
    - The memetic algorithm-based approach is more efficient in terms of computing time compared to Genetic Algorithms (GAs) and achieves better fitness.
5. **Network Lifetime and Convergence:**
    - The memetic algorithm-based approach extends the network lifetime significantly and maintains a high sensing coverage ratio.
    - It outperforms other methods like EGDG, LEACH-Coverage-U, and LEACH in terms of network longevity.
6. **Deployment Scenarios:**
    - The study considers both uniform and random deployments of sensor nodes and evaluates the performance of the proposed algorithm in both scenarios.

Simulation Results: Detailed Analysis

Simulation at 0.01 Probability

Average Energy vs. Round Number:

- **EAMMH:** The average energy of each node remains relatively stable around 0.02 over 100 rounds.
- **LEACH:** Maintains an average energy of approximately 0.02 per node but exhibits distinct energy fluctuations compared to EAMMH.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 90 dead nodes at the 100th round.
- **LEACH:** Shows 85 dead nodes by the 100th round.

Simulation at 0.5 Probability

Average Energy vs. Round Number:

- **EAMMH:** Average energy of each node stabilizes around 0.032 over 100 rounds.
- **LEACH:** Average energy is approximately 0.005 per node at the 100th round, with noticeable energy fluctuations.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 55 dead nodes at the 100th round.
- **LEACH:** Accumulated 140 dead nodes by the 100th round.

Simulation at 0.2 Probability

Average Energy vs. Round Number:

- **EAMMH:** Average energy of each node is 0.012 at the 100th round.

- **LEACH:** Average energy is 0.0013 per node at the 100th round, with distinct energy fluctuations.

Dead Nodes vs. Round Number:

- **EAMMH:** Shows a total of 98 dead nodes at the 100th round.
- **LEACH:** Shows 130 dead nodes at the 100th round.

Comparative Analysis: Advantages and Disadvantages

LEACH

Advantages:

- Simple and easy to implement.
- Reduces energy consumption through clustering.

Disadvantages:

- Energy fluctuations due to random cluster head selection.
- Lower network lifetime compared to more advanced algorithms.
- Less efficient in managing energy distribution across nodes.

EAMMH

Advantages:

- Better average energy performance.
- Fewer dead nodes in various scenarios.
- More stable energy consumption patterns.

- Extends network lifetime significantly.
- Maintains a high sensing coverage ratio.
- More efficient in terms of computing time compared to Genetic Algorithms.

Disadvantages:

- Increased complexity in implementation compared to LEACH.
- Potentially higher initial computational overhead.

Performance Assessment

Energy Efficiency:

- **EAMMH** consistently shows better energy efficiency compared to **LEACH** across different scenarios and probabilities of cluster head selection.

Network Lifetime:

- **EAMMH** extends the network lifetime significantly compared to **LEACH**, ensuring longer operational periods and reduced need for maintenance.

Stability:

- **EAMMH** demonstrates more stable energy consumption patterns and fewer fluctuations compared to **LEACH**.

Computing Efficiency:

- **EAMMH** is more efficient in terms of computing time compared to Genetic Algorithms and achieves better fitness levels, making it suitable for real-time applications.

The comparative analysis demonstrates that the EAMMH protocol, based on memetic algorithms, outperforms the traditional LEACH protocol in terms of energy efficiency, network longevity, and overall performance. While LEACH is simpler and easier to implement, EAMMH offers significant advantages in managing energy consumption and extending the lifetime of WSNs, making it a more effective solution for optimizing WSN performance in various deployment scenarios.

5.10.3 Comparison of Improved Models of LEACH

Simulation of Protocols at Updated Area

The results below display the simulation of both the LEACH and the LEACH-C protocols at 200 nodes and an area of 400 m^2.

Number of Alive Nodes:

- **LEACH-C:** Shows improved performance in terms of the number of alive nodes compared to LEACH.

Number of Dead Nodes:

- **LEACH-C:** Shows fewer dead nodes compared to LEACH, indicating better energy efficiency and network longevity.

Number of Packets Sent to Sink Node:

- **LEACH-C:** Achieves higher throughput in terms of the number of packets sent to the sink node.

Comparative Analysis: LEACH vs. LEACH-C

Advantages of LEACH-C:

- **Energy Efficiency:** LEACH-C demonstrates higher energy efficiency compared to LEACH.
- **Network Longevity:** LEACH-C extends the network lifetime significantly compared to LEACH.
- **Throughput:** LEACH-C achieves higher throughput in terms of the number of packets sent to the sink node.

Disadvantages of LEACH-C:

- **Complexity:** LEACH-C is more complex to implement compared to LEACH.
- **Initial Overhead:** LEACH-C may have higher initial computational overhead.

Simulation of Improved Memetic LEACH Protocols

Simulation and Results of Proposed Improved Memetic Evolutionary Computing Based LEACH

The proposed Improved Memetic LEACH protocol aims to significantly reduce energy usage and extend the network's life. The protocol uses a modified LEACH model and integrates a memetic algorithm to optimize cluster head selection and energy consumption.

Computational Time:

- **Memetic Algorithm-Based Approach:** Shows faster convergence and better fitness compared to Genetic Algorithms.
- **Efficiency:** The memetic algorithm-based technique takes less computing time to produce solutions with better fitness.

Network Lifetime and Convergence:

- **Network Life Extension:** The proposed approach extends network life and maintains high sensing coverage.
- **Energy Consumption:** The memetic algorithm-based solution efficiently finds and deactivates unnecessary nodes, minimizing energy consumption.

Analysis of Computational Time

It is necessary to test the quick-convergence of the memetic algorithm-based method by evaluating the computation time and fitness of memetic algorithm-based approaches applied to different CWSN sizes. This study's findings will be compared to those of genetic algorithms.

Fitness vs. Computing Time:

- **Memetic Algorithm-Based Approach:** Achieves higher fitness levels in less computing time compared to Genetic Algorithms.
- **Scalability:** As the number of deployed nodes increases, the memetic algorithm-based solution outperforms Genetic Algorithms in terms of computing time and fitness.

Analysis of Network Lifetime and Convergence

The proposed approaches are evaluated for their ability to extend network life and preserve coverage. Sensor nodes are activated or deactivated using a memetic algorithm to maintain a high POI coverage ratio while minimizing energy consumption.

Uniform Deployments:

- **Initial Deployment:** Nodes and POIs are deployed uniformly.

- **Node Scheduling:** The memetic algorithm-based solution identifies and deactivates redundant nodes, maintaining high coverage with minimal energy use.

Random Deployments:

- **Deployment Scenario:** Nodes are randomly deployed, and the performance of the proposed algorithm is evaluated.
- **Coverage Maintenance:** The memetic algorithm-based approach maintains high sensing coverage even in random deployment scenarios.

The comprehensive simulation study demonstrates that the proposed Improved Memetic LEACH protocol outperforms traditional LEACH, EAMMH, and other protocols in terms of energy efficiency, network longevity, and overall performance. By integrating a memetic algorithm, the Improved Memetic LEACH protocol effectively manages energy consumption, extends network life, and maintains high sensing coverage, making it a superior solution for optimizing WSN performance in various deployment scenarios.

5.10.4 Comparative Analysis: Memetic LEACH vs. EAMMH

In this detailed comparative analysis, we will evaluate the performance of the proposed Memetic LEACH protocol against the EAMMH (Energy Aware Multi-hop Multi-path Hierarchical) protocol. Both protocols aim to enhance the energy efficiency and network longevity of Wireless Sensor Networks (WSNs). The Memetic LEACH protocol integrates memetic algorithms to optimize cluster head selection and energy consumption, while EAMMH employs multi-hop and multi-path strategies to improve network performance. The primary objective is to demonstrate that the proposed Memetic LEACH protocol outperforms EAMMH in terms of energy efficiency, network lifetime, and overall performance. This will be accomplished through a detailed comparison of key metrics obtained from simulation results.

Key Metrics Comparison

1. Energy Efficiency

Memetic LEACH:

- Utilizes a memetic algorithm to optimize cluster head selection, leading to more balanced energy consumption across nodes.
- Stable energy consumption patterns, resulting in fewer fluctuations and more predictable network behavior.

EAMMH:

- Employs multi-hop and multi-path strategies, which can lead to uneven energy consumption due to varying path lengths and communication loads.
- More energy fluctuations compared to Memetic LEACH, indicating less efficient energy management.

2. Network Lifetime

Memetic LEACH:

- Extends network lifetime significantly by efficiently managing energy resources and reducing the number of dead nodes over time.
- Superior performance in maintaining node activity, especially at higher probabilities of cluster head selection.

EAMMH:

- Also extends network lifetime but is less effective than Memetic LEACH in scenarios with high node densities or high cluster head selection probabilities.
- More rapid increase in dead nodes, indicating quicker energy depletion.

3. Stability

Memetic LEACH:

- Demonstrates more stable energy consumption patterns due to the use of memetic algorithms, which ensure consistent and efficient energy use.
- Fewer fluctuations in energy levels, contributing to overall network stability and predictability.

EAMMH:

- Exhibits more pronounced energy fluctuations, which can lead to instability in network performance and less predictable behavior.

4. Computational Efficiency

Memetic LEACH:

- More efficient in terms of computing time due to the memetic algorithm's quick convergence to optimal solutions.
- Achieves better fitness levels faster compared to Genetic Algorithms, making it suitable for real-time applications.

EAMMH:

- Requires more computational resources for multi-hop and multi-path calculations, leading to higher initial overhead.

- Slower convergence compared to Memetic LEACH, especially in large-scale networks.

Performance Assessment

Energy Efficiency:

- **Memetic LEACH** demonstrates consistently better energy efficiency across different scenarios, maintaining higher average energy levels and fewer fluctuations compared to EAMMH.

Network Lifetime:

- **Memetic LEACH** extends network lifetime more effectively, maintaining node activity longer and reducing the number of dead nodes over time.

Stability:

- **Memetic LEACH** shows more stable energy consumption patterns, leading to predictable and reliable network performance.

Computational Efficiency:

- **Memetic LEACH** is more computationally efficient, achieving optimal solutions faster and with lower overhead compared to EAMMH.

The comprehensive comparative analysis clearly demonstrates that the proposed Memetic LEACH protocol outperforms EAMMH in several critical aspects:

1. **Energy Efficiency:** Memetic LEACH optimizes energy consumption more effectively, leading to stable and efficient energy use across the network.

2. **Network Lifetime:** The proposed protocol extends network longevity significantly, reducing the number of dead nodes and maintaining network operations for a longer period.

3. **Stability:** Memetic LEACH exhibits more stable energy consumption patterns, contributing to predictable and reliable network performance.

4. **Computational Efficiency:** The use of memetic algorithms enables quicker convergence to optimal solutions, making Memetic LEACH more suitable for real-time applications compared to EAMMH.

By integrating advanced optimization techniques through memetic algorithms, Memetic LEACH provides a superior solution for enhancing the performance of WSNs in various deployment scenarios, surpassing the capabilities of EAMMH and other traditional protocols.

5.11 Conclusion of Chapter

The chapter discusses simulations and comparative analysis of the Memetic LEACH and EAMMH protocols in Wireless Sensor Networks (WSNs), focusing on optimizing energy efficiency and network lifetime. Simulations in MATLAB varied initial energy, node density, and system size. Key metrics like the number of dead nodes, alive nodes, packets sent, and total rounds until node death were evaluated. Memetic LEACH demonstrated superior performance in energy management, network longevity, and stability compared to EAMMH.

CHAPTER-6

CONCLUSION & FUTURE RESEARCH

6.1 Conclusion

Wireless Sensor Networks (WSNs) have emerged as a transformative technology with a wide range of applications across diverse fields, including environmental monitoring, healthcare, agriculture, and industrial automation. However, the limited energy resources of individual sensor nodes present a significant challenge in the design and operation of these networks. To address this challenge, researchers often turn to simulation tools like MATLAB to evaluate and optimize network protocols, algorithms, and deployment strategies. In this discussion, we have explored a simulation study that focuses on energy efficiency and longevity in WSNs, with a particular emphasis on the Memetic LEACH and EAMMH protocols.

6.1.1 Significance of Simulation in WSN Research

Simulation plays a pivotal role in WSN research, offering a controlled and cost-effective environment for evaluating various aspects of network performance. By simulating different scenarios, researchers can gain valuable insights into how protocols and strategies perform under specific conditions. This controlled experimentation allows for the refinement of WSN designs and the identification of optimal configurations before deploying networks in real-world settings.

The simulation study presented here leverages MATLAB to assess the energy efficiency of LEACH, EAMMH and Memetic LEACH protocols, providing a detailed analysis of their performance under varying parameters. Through a series of simulations, the study explores the impact of cluster head selection probability, node density, and other factors on energy consumption and network longevity.

6.1.2 Key Simulation Parameters and Findings

The study's findings highlight several key parameters and their implications for WSN energy efficiency:

- **Cluster Head Selection Probability**: The probability of sensor nodes becoming cluster heads significantly influences network performance. A higher cluster head selection probability results in improved energy efficiency and network longevity. Proposed Memetic LEACH consistently outperforms LEACH, EAMMH in this regard, maintaining more stable energy levels and fewer dead nodes.

- **Node Density**: Varying node density scenarios are essential for assessing how WSNs perform in different deployment environments. Proposed LEACH demonstrates its adaptability by maintaining energy efficiency across a range of node densities, making it a robust choice for various application scenarios.

- **Energy Fluctuations**: Energy fluctuations, as observed in the LEACH protocol, can impact network stability and predictability. Proposed approachs ability to maintain a more consistent energy level per node underscores its suitability for applications where reliability is paramount.

- **Comparative Analysis**: The study extends its comparative analysis beyond LEACH and EAMMH, evaluating Proposed LEACH against other protocols, such as EGDG and LEACH-Coverage-U. This broader assessment highlights its ability to extend network lifetime and maintain a high sensing coverage ratio, positioning it as a promising solution for energy-efficient WSNs.

6.1.3 Implications for Real-World Deployments

While simulation studies offer valuable insights, it is essential to consider their implications for real-world WSN deployments. The assumptions made in simulations, such as static and homogeneously distributed nodes, provide a controlled environment but may not fully represent actual deployment scenarios. Acknowledging these limitations, we can draw meaningful conclusions about the broader implications of energy-efficient protocols and simulation research in WSNs.

1. **Energy-Efficient Protocols are Vital**: The findings emphasize the importance of energy-efficient protocols like in extending the operational life of WSNs. These protocols have the potential to reduce maintenance costs and enhance the sustainability of sensor networks, particularly in remote or inaccessible locations.

2. **Adaptability to Changing Conditions**: WSNs often operate in dynamic environments where conditions may change over time. The ability of proposed approach to maintain energy efficiency across varying parameters, including node density and cluster head selection probability, suggests its adaptability to real-world fluctuations.

3. **Realism vs. Control in Simulations**: Researchers must strike a balance between realism and control when designing simulation experiments. While controlled environments allow for systematic evaluation, they should be complemented with field trials and real-world validation to ensure that findings translate effectively into practical deployments.

4. **Computational Efficiency Matters**: The computational efficiency of simulation tools is critical, especially in applications where real-time decision-making is

required. Proposed approach recognition for computational efficiency highlights the importance of selecting appropriate tools for WSN research.

5. **Ongoing Research and Innovation**: The simulation study presented here represents a snapshot of the current state of WSN research. As technology evolves, new protocols, algorithms, and optimization techniques will continue to emerge. Researchers should remain vigilant in exploring innovative solutions to address the ever-evolving challenges of energy efficiency in WSNs.

6. **Interdisciplinary Collaboration**: The field of WSNs benefits from interdisciplinary collaboration, involving experts in computer science, electrical engineering, data science, and domain-specific knowledge. Combining expertise from various disciplines enhances the development and application of energy-efficient solutions.

7. **Environmental Impact**: WSNs play a crucial role in environmental monitoring and sustainability efforts. Energy-efficient protocols and optimization techniques directly contribute to reducing the environmental impact of sensor networks, aligning with global goals for environmental preservation.

6.2 Conclusion and Future Directions

In conclusion, the simulation study discussed here underscores the pivotal role of simulation in advancing energy efficiency in Wireless Sensor Networks. Through controlled experiments, researchers can evaluate, refine, and optimize protocols to address the inherent energy constraints of WSNs. The study's focus on LEACH and related protocols, along with its comparative analysis against other approaches, highlights the promise of memetic algorithms in achieving energy-efficient network operation.

While simulations provide valuable insights, they should be complemented by real-world deployments and validation to ensure the practical applicability of research findings. Additionally, ongoing research efforts, interdisciplinary collaboration, and a commitment to innovation are essential for continuously improving the energy efficiency and sustainability of WSNs.

As the field of WSNs continues to evolve, future research directions may involve exploring novel energy sources, such as energy harvesting techniques, and developing adaptive algorithms that respond to changing network conditions in real time. Ultimately, the goal is to create robust and energy-efficient WSNs that can effectively address critical challenges in various domains, from environmental conservation to healthcare and beyond.

The design of an effective energy routing protocol relies on the specification for WSNs, as nodes die after a particular cycle of sensors. The node/piece determines the power of each sensor, which in turn determines the number of rounds. So, it's imperative that we figure out how to keep the sensor operational for an extended period of time while minimizing its energy consumption. Several studies have been included in this report that have focused on the energy-efficient routing technique used by WSNs. We analyzed many routing protocols and compared them in various ways. There is still a need for more improvements, even though these papers explored several energy-efficient techniques for WSN routing. Many issues left unsolved by the present technique would form the basis for future studies. Additionally, with the right sink locations and node selections, the memetic algorithm based approach's performance may be significantly improved. Given the encouraging outcomes of this study, we will save the possibility of using the suggested memetic algorithm based approach to different types of WSNs for future research. The creation of an effective energy routing protocol is heavily dependent on the specification for WSNs, as nodes are considered dead after certain round trips. The node or component determines the power of each sensor, which in turn determines the number of rounds. Further improvements are still needed for these publications, which covered several energy-efficient approaches for WSN routing.

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