# Energy Efficiency in Wireless Sensor Network Through NN-LEACH

A thesis submitted in partial fulfilment of the
requirements for the award of the degree of

**DOCTOR OF PHILOSOPHY**
**in**
**Computer Applications**


**By**
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**Supervised by**
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**Co-Supervised by**
**Dr. Ajay Shriram Kushwaha**



**LOVELY PROFESSIONAL UNIVERSITY**
**PUNJAB**
**2021**

# Candidate's Declaration

I now declare that the thesis entitled **"Energy Efficiency in Wireless Sensor Network Through NN-Leach"** is submitted to the Department of Research, Lovely Professional University, Phagwara, Punjab, to fulfill the requirements for the award of Degree of Doctor of Philosophy in Computer Applications. It is a bonafide record of my own and original research work carried under the supervision of Dr. Manmohan Sharma, School of Computer Applications, Lovely Professional University, Phagwara and Dr. Ajay Shriram Kushwaha, Department of BCA, School of Computer Science & Information Technology, Jain (Deemed-to-be University), Bangalore, India.

I further declare that the matter presented in this thesis has not been submitted for the award of any other degree/diploma of this University or any other University/Institute.

**(Avinash Bhagat)**
**Research Scholar**

# Certificate

I certify that the candidate carried out the work incorporated in the thesis Energy Efficiency in Wireless Sensor Network Through NN-Leach submitted by Avinash Bhagat under my supervision/guidance. To the best of my knowledge:

i. The candidate has not submitted the same research work to any other institution for any degree/diploma, Associateship, Fellowship, or other similar titles.
ii. The thesis submitted is a record of original research work done by the Research Scholar during the period of study under my supervision, and
iii. The thesis represents independent research work on the part of the Research Scholar.

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# Letter of Candidacy

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Dated: 15th March 2018

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**Subject: Letter of Candidacy for Ph.D.**

Dear Candidate,

We are very pleased to inform you that the Department Doctoral Board has approved your candidacy for the Ph.D. Programme on 07th October 2017 by accepting your research proposal entitled: "ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORK THROUGH NN-LEACH" under the supervision of Dr. G Geetha .

As a Ph.D. candidate you are required to abide by the conditions, rules and regulations laid down for Ph.D. Programme of the University, and amendments, if any, made from time to time.

We wish you the very best!!

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**Avinash Bhagat**

# ABSTRACT

The wireless sensor networks (WSN) have massive potential to facilitate and affect distinct areas of the industry, improving the daily life of individuals', and also observe ecological surroundings via use of sensor nodes. Wireless sensor network (WSN) is an dense interconnected collection or network of sensor nodes known as motes. These motes are collecting the information from the surrounding environment, process this information and send the information in form of data to the users. Wireless sensor network has many issues like localization of nodes, data aggregation, clustering, routing, and battery supply, but the main constraint in using these motes is that these are autonomous and low powered devices with small batteries.

In a typical environment, motes transmit the data directly to the base station i.e., the motes farther from the bases station consumes more energy than the motes nearer to the base station, causing imbalance energy dissipation. Therefore, energy consumption is one of the main challenges while working with these motes. To resolve this problem wireless sensor networks requires an energy efficient infrastructure to connect a large number of motes without energy imbalance and also to enhance the lifetime of the WSN.

Several algorithms and techniques were proposed by the researchers to minimize the energy consumption in the wireless sensor networks. Clustering of the motes is one of the proficient topological control techniques to increase the networks performance in terms of energy efficiency and scalability. Energy is dissipated during the cluster formation, cluster head selection, routing between the cluster head & base station, and data aggregation. It is critical to keep power dissipation low during cluster formation by employing an energy efficient clustering and routing strategy. Furthermore, due to the non-static nature of process environments and the inherent constraints of various hardware and software resources, selecting optimal routing for the kind of environment is quite difficult.

Clustering and routing have focused on maintaining the network's stability and lifetime. The primary task is to enhance the network lifetime and reduce the power utilization via a two-step approach of clustering and routing the sensor nodes with the help of the proposed NN-LEACH protocol. As a secondary objective, our target is to find out the optimal path for the proposed approach that can best fit this type of network. Finally, this research aims to design an optimized

and energy efficient routing protocol for the transmission of data in wireless sensor networks using NN-LEACH.

To achieve the research objectives Rendezvous LEACH protocol approach is used. The term Rendezvous means collecting data from all the nodes. As mobile sink (MS) cannot be remained closer to every node in the cluster, therefore the data/information collection task is assigned to a specialized node designated as rendezvous node (RNs) or rendezvous point (RPs). A novel approach needs to be developed for using rendezvous node (RNs) or rendezvous point (RPs). Rendezvous node (RN) is defined as a point closer to the area of mobile sink (MS). Whenever, mobile sink (MS) comes closer to rendezvous node (RN), rendezvous node sends the information to it. Mobile sink (MS) notifies rendezvous node (RN) about its arrival by sending a signal or beacon.

Initially, at the first step cluster heads are selected using hop field neural network technique based on the factors used to measure the performance of nodes like remaining energy, distance factor of nodes, initial set up of energy, etc. This approach uses the concept of the maximum energy left in the nodes, so that, the performance of the nodes must be increased and energy utilization is controlled in an equilibrium manner. After the selection of cluster heads, all other nodes in the network are associated with a nearest cluster heads, to form different clusters in the network. In the second step data aggregation has been applied by using the approach of a Non-dominated Sorting Genetic Algorithm.

There are several challenges in WSNs, but routing is most crucial, as the whole network's lifetime depends on its optimal path usage. Several routing mechanisms such as ACO, PSO, ABC, TABU, GA, Flower pollination, cuckoo search, social spider, Meer cat techniques have been added to the swarm optimization technique. Hybrid ACO-PSO-based routing has been proposed to reduce the problems in optimal path usage. In the third step, hybrid ACO-PSO routing is implemented to move around the static sensor motes. Moving sink mote follow a fixed path trajectory to collect data from other motes within the sensing area of the network. It will take the optimal route for transferring the information. Thus, in this manner, the lifetime of the overall network increases.

To improve the quality of service in the wireless sensor networks, this research is focused on the routing protocols based on the swarm intelligence. It investigates parameters considered for improving QoS in wireless sensor networks under various realistic scenarios and assesses their efficacy in the wireless sensor network environment. The statistical data confirm the protocol's efficiency based on several performance assessment criteria: dead nodes, alive nodes, packet transferred, and average remaining energy. The overall competence of the routing protocols are obtained through the statistical analysis. For further analysis of the effectiveness of the suggested approach, the following metrics were utilized: living nodes, which represent the number of motes that remained active in time. The following parameter is dead nodes, showing how many motes are dead in the current network round; the remaining energy parameter is defined as the total remaining energy in the network upon completion of the data transfer. Another key figure in the performance: the number of data units delivered successfully at the receipt is called performance divided by the total number of packets transferred from sender to receiver. The total number of successful data packets received is therefore computed for a network or network segment. Average end-to-end latency has also must be taken into account. Due to several variables, data is sent from the sender to the recipient. The first two measures are required to quantify network performance at the corresponding delivery rates. Dividing the number of packages sent by the sender is the number of packets the recipient receives in one attempt.

Currently, many energy-saving strategies exist, and many more are needed to consume less energy while producing exact results. The problem may be solved by employing the suggested technological hybrid framework of NSGA-HNN-ACO-PSO-RZLEACH for improving the routing mechanism in WSNs while considering energy conservation. During the setup phase, rendezvous nodes are chosen, followed by the cluster head, using the Hopefield neural network technique. NSGA is used to aggregate data at cluster heads or rendezvous nodes during the steady-state phase. A hybrid ACO-PSO method is used to transport aggregated information to the base station. The suggested framework's performance is compared to two existing methods. Compared to previous techniques, this technological framework effectively replicated experimental situations that extended network lifetime by up to 16% and enhanced energy optimization by up to 26%. The statistical findings validate the protocol's efficiency based on different performance assessment criteria such as Dead nodes, Alive nodes, Packet Transferred, and Average Remaining Energy. It would also enhance QoS in many actual situations, such as service-as-condition and transmission-as-condition. This hybrid technological framework employs a unique technique for picking a cluster head based on characteristics such as energy used and the amount of time it takes for all nodes to die in the given situation. Compared to simple RZLEACH, the suggested architecture increased network lifespan by 16% and HNN-ACO-RZLEACH by 9%. Energy usage is reduced by 26% compared to basic RZLEACH and 4% compared to HNN-ACO-RZLEACH.

Simulations with three distinct settings will be conducted in MATLAB. RZLEACH, which has an appointment node, is the initial configuration. The second configuration of NSGA ACO RZLEACH is utilised. NSGA HNN ACO/PSO RZLEACH is the third proposed configuration. In the beginning, n nodes are assessed in a predefined zone, and the first node die results are obtained, the teenth (1/4) of all death nodes, and all die nodes. Three criteria are utilized for area scalability: nodes dead, nodes living, and energy residue. These are 150X150, 200X200, 250X250, 300X300 and 500X500 specifications. The first, the second, and third teenth and every dead node for the first three different methods, namely RZLEACH, HNN-ACO-RZLEACH, and NSGA-HNN-ACO-PSO-RZLEACH, are simulated initially by 300 Nodes and 100m x 100m area. Scaling the area to 150m by 150m, 200m by 200m, 250m by 250m, 300m by 300m, 350m by 350m, 400m by 400m, 450m by 450m, and 500m by 500m repeats the procedure. The appropriate categorized data were given in the table combined with connected parameters, supportive factors and influencing features. The outcomes of the simulation generated the output values of the number.

The diverse types of applications can be used for tracking an object in a particular terrain; they can be used for medical purposes for healthcare for space applications, agriculture, and so forth. These wireless sensor networks are crucial to the formation of the internet of things and internet of things, and wireless sensor networks are critical components for building smart cities

The proposed method has some limitations, such as the security and privacy-based parameters not being integrated into node-based clusters. The proposed research approach is always best interns of best nearest route identification. Additional precautions or parameter-based metrics are required to avoid data breach security. This research is more compatible with stand-alone-based stations. It has deployed the data in WSNs, which will upgrade the network's performance. It can be extended in multiple-base-station deployment. More QoS components will be integrated for improving the quality of various services. In the plan to integrate extended versions of Feistel cipher-based schemes used for WSN block-cipher design for security by using CPB crypto primitives, which are added advantage to the current proposed approach for implications security and privacy parameters. The new generation attacks neither increased with time nor made the network complicated and mitigating against WSN and other fields, respectively.

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# 1 Introduction and Overview of Wireless Sensor Networks

The chapter presents an overview of wireless sensor networks, sensor node architecture, protocol stack applications, and operational challenges in the wireless sensor network. The motivation for the research work is to reduce the research gap, and the objectives of the research work are described. The chapter concludes with the contributions of the research work and the organization of the thesis.

## 1.1 Overview of Wireless Sensor Network

A wireless sensor network comprises sensing, computing, and communication elements that allow an administrator to perceive and respond to events and in a specified environment. The environment here can be a physical entity, a genetic system, or an IT framework. Sensor networks are an essential technology system that will experience significant deployment in the next few years for several applications, ranging from data gathering, national security, surveillance, and health-related activities [1]–[10]. WSN or wireless sensors network is defined as a group of small sensing nodes called motes deployed in an area with one or more leading nodes called base stations or sinks, as shown in Figure 1.1. These motes are tiny in terms of physical size, sensing, processing, and communication capabilities; in addition to sense, one is also interested in control and activation.

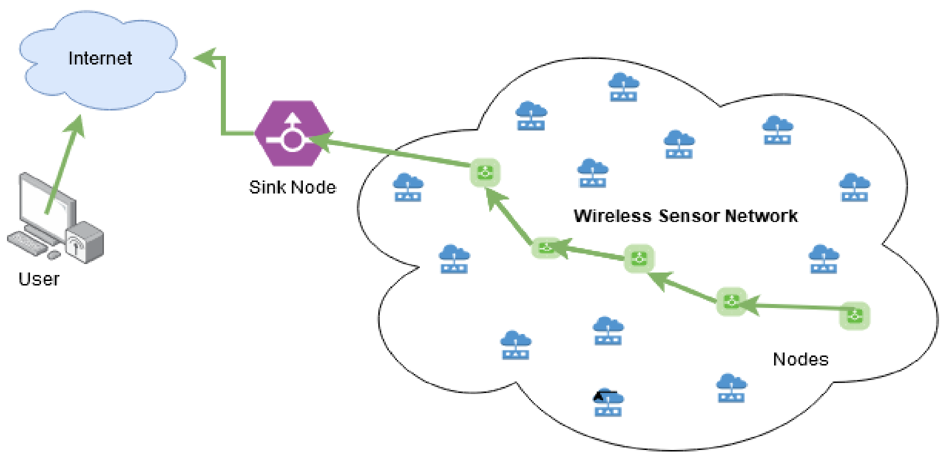



***Figure 1.1: Example of Wireless Sensor Network. Adapted from*** [11]

## 1.2 Wireless Sensor Network Architecture

According to the NSF National Science Foundation, emerging technologies reduce the cost, size, and weight of motes or sensor arrays. Integration techniques decrease the size in magnitudes and improve the efficiency in terms of performance and lifetime, thus reducing distance barriers.[12]

### 1.2.1 Hardware Architecture of The Sensor Node

Sensors in a WSN have diverse functions and competencies. As a push of recent advancements in technologies, the field is now explored for many potential applications like ATC, the power grid infrastructure, and weather forecast systems; all these systems use specialized computers that are very expensive. Researchers are trying to find out much less expensive WSNs for applications in physical security, health care, and commerce. It involves multidisciplinary areas like artificial intelligence, database management, power management algorithms, resource optimization, signal processing, systems architectures for operator-friendly infrastructure, and platform technology [13]. Major components of sensor networks are shown in Figure 1.2, which contains an assemblage of scattered or local sensors.

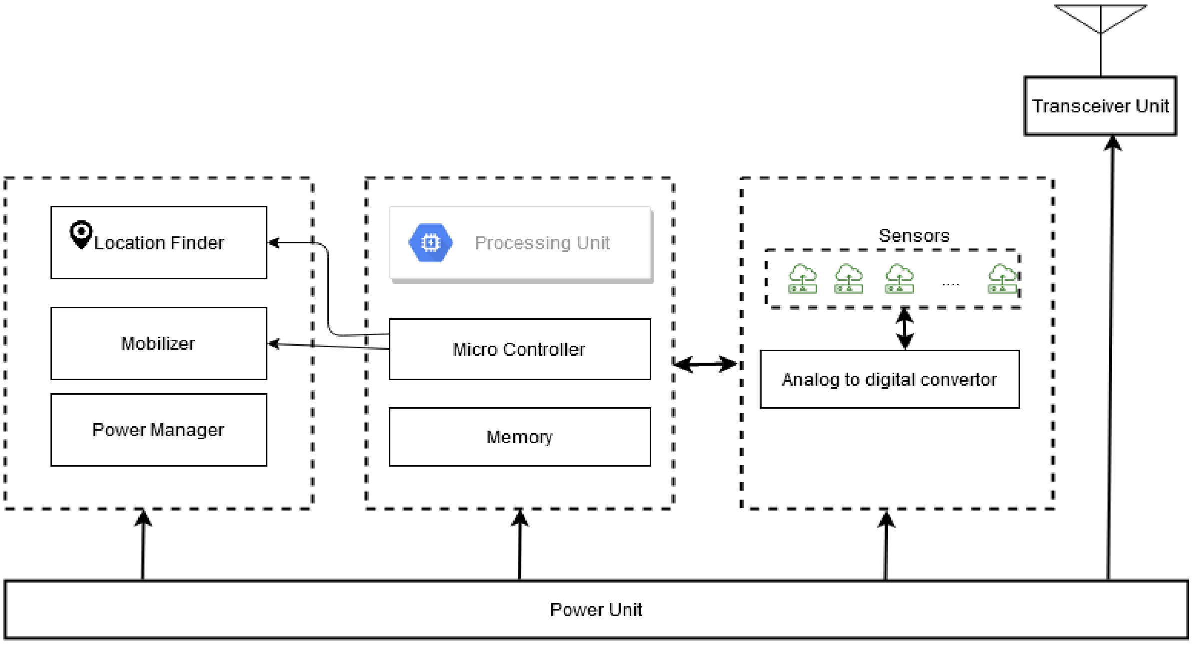



***Figure1.2: Architecture of mobile sensor node. Adapted from*** [14]

The hardware of the sensor consists of four compulsory units and an optional unit.

#### 1.2.1.1 Sensing Unit

A sensor (which is a transducer) is an interface between the processing unit and the sensing field. These sensors are deployed in the application areas and used to measure physical entities like acceleration, light, location, pressure, temperature, etc. these signals generated by these physical entities are analog and need to be converted to digital with the help of analog to digital converter (ADC) unit. The ADC passes these converted digital signals to the processing unit.

#### 1.2.1.2 Memory and Processing Unit

As shown in figure 1.2, the processing unit consists of memory and a microcontroller (8 to 32 bits) [15]; the processing unit is responsible for application execution, encoding & decoding, encryption & decryption for security, interaction with peripherals, post-processing of the data received, pre-processing of the data to be transmitted, and resource management. Data is stored in limited memory consisting of a limited storage chip with a few KB sizes. Some of the popular microcontrollers are ATMEL ATmega32U4 (supported by a full suite of program development tools like C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits.), ATMEGA128L, ATMXT288UD-A, (Figure 1.3), and MSP 430. Data received from ADC is processed by the processing unit for further communication through the transceiver.

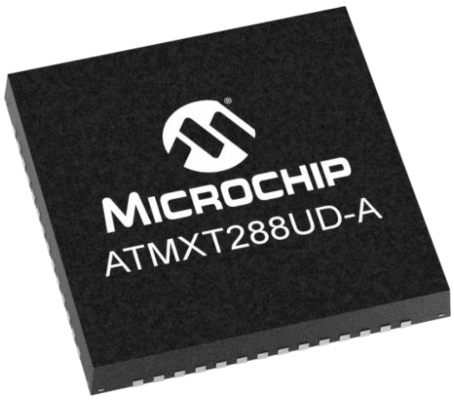



***Figure1.3: Microcontroller ATMXT288UD-A***
***Adapted from: https://www.microchip.com/en-us/product/ATMXT288UD-A***

#### 1.2.1.3 Trans-receiver Unit

This module contains a set(s) of receiver & transmitter used to exchange signals between the sensing unit and the sink node. Packet radio communication is used to exchange information through various communication protocols like Bluetooth, WI-FI, ZigBee, Radar, GPS, etc. comparison of these protocols is shown in Table 1.1.

***Table 1.1: Protocol standards in wireless sensors.***

| **Attributes** | **Protocol Standards** | | |
|---|---|---|---|
| | **Bluetooth** | **Wi-Fi** | **ZigBee** |
| Coverage (meters) | 10 | 50-100 | 10-100 |
| Energy Consumption | Low | Medium | Ultra-Low |
| Frequency(GHz.) | 2.4 | 2.4 | 2.4 |
| Latency(sec) | 10 | 3 | 30 |
| Modulation Technique | GFSK | 64 QAM | QPSK/BPSK |
| Speed | 1Mbps | 54Mbps | 250 Kbps |
| Standards | IEEE 802.15.1 | IEEE 802.11 | IEEE 802.15.4 |
| Topology | Ad-Hoc<br>Small networks | Star / Mesh | Adhoc Star/ Mesh |

#### 1.2.1.4 Power Supply Unit

This unit of sensor node consists of a small lithium battery having limited energy capability. A healthy battery is expected for WSN applications. Some of the sensors come with energy harvesting to recharge the battery. Nature-inspired solar batteries are on the top list of researches. The unit for measuring the energy of sensor nodes is Joule (J).

#### 1.2.1.5 Global Positioning Unit

An optional GPS global positioning system acting as a location finder. Using GPS in mobile sensor nodes results in more energy consumption, an increase in weight, and the cost of the sensors.

### 1.2.2 The Software Architecture of the sensor node

Wireless sensor networks are a service-based architecture. The services provided follow a layered approach, and the services provided at each layer depend upon the exact topology of the network.

The software architecture of a sensing node is shown in Figure:1.4; it consists of a tiny operating system, an application software, a communication module, a processing module, and a sensing module.

An operating system controls the hardware and abstract application software; each node needs an operating system to fill the hardware and application software gap. The traditional OS has needed more computational resources, so in WSN motes, embedded operating systems like TinyOS [16], Mate[17], Magnetos[18] and, MANTIS[19] are some specially designed for data-centric operating systems designed for WSNs with constrained resources.

The architecture consists of three modules sensing, processing, and communication (transceiver) modules. Sensors in sensing units communicate with external peripherals to allow the application being monitored to run. The processing module is responsible for data processing and manipulation, including initialization codes for memory to function properly. The communication of the transceiver module is responsible for performing different communication-related functions like modulation, demodulation, and an integral clock unit. To make the modules workable happen, drivers must be installed either independently with modules or clubbed with OS.

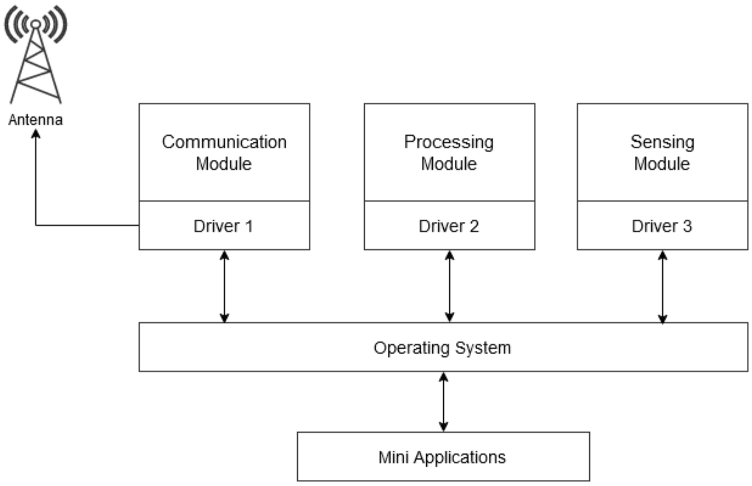



***Figure1.4: Software Architecture of sensing node Adapted from*** [20]

The software architecture of WSN is classified as either basic or cluster-based.

### 1.2.2.1 A Basic Service-Oriented Architecture

In a basic service-oriented architecture is shown in figure 1.5, the client application requests data from the network about surface conditions in a certain area. The client first sends a request to a proxy for the desired information. The proxy connects with the suitable nodes, which determine the surface conditions in the area using cooperative algorithms. The proxy takes the information returned from the nodes, translates it, and sends it back to the client. Such architecture can be realized using the node application structure with the sensor network architecture [4].

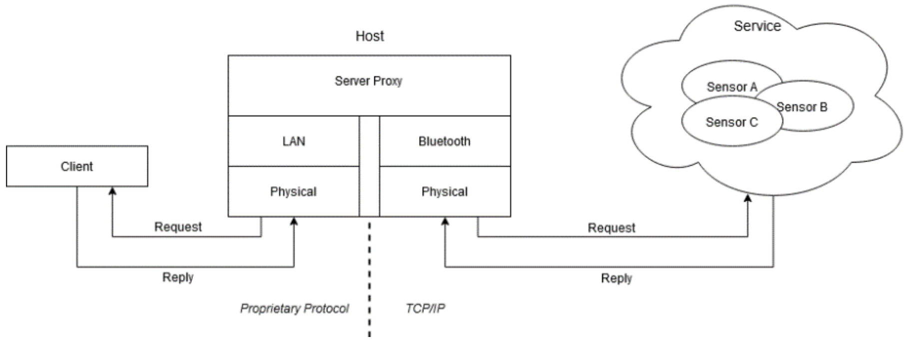



***Figure1.5: Architecture in Sensor Networks. Adapted from*** [20]

The basic architecture and layered approach of the sensor are shown in figure 1.5. and 1.6 respectively, motes interact with the distributed middleware to perform functions asked by individual applications. The administrative terminal, in coordination with an external actor, evaluates the results. The application can assign tasks to the nodes, and the distributed middleware is acting as the coordinator. Figure 1.4 is an example where the client wants information about surface conditions in the area of interest. Client requests proxy via standardized protocols, the proxy communicated with the distributed nodes using a proprietary protocol. Information from the area of interest is calculated using algorithms and sent to a proxy which translates the information in standard protocols and sends it back to the application client [20].

Middleware here refers to the software layer between sensor application and operating system. Middleware hides the complexity of the networking environment; it isolates the application from functions like memory management, network functionality, parallelism, and protocol handling. In a sensor environment, the middleware needs to be adaptive, generic, reflective, and scalable. Designing middleware for WSN is a challenging task; the following challenges are faced while designing middleware for WSN:

1. The need for an application-specific integration, as integrating application information into the network protocol, is a must to improve the performance and save energy.

2. Middleware should be efficient enough to utilize computational and communication resources to the full extent. Computations should be energy aware and data-centric.

3. Middleware should support real-time applications.

4. Middleware should respond to changing topology of WSN.

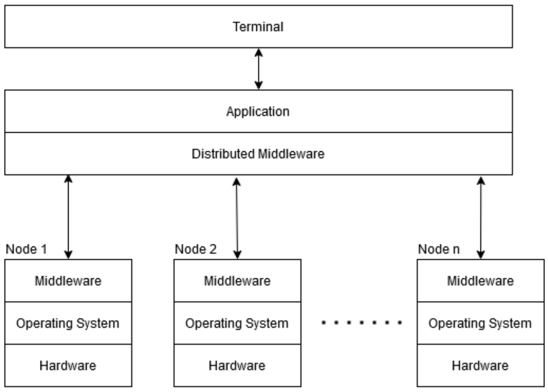



***Figure1.6: Sensor Network Software Architecture Adapted from*** [20]

#### 1.2.2.2 A Cluster-Based Service-Oriented Architecture

To handle the challenges in designing, a middleware was proposed by Krishnamachari et al. [21], uses clustering to handle the challenges mentioned above, and provides application Quality of Service (QoS). In this architecture, motes are grouped in clusters; one of the motes becomes cluster head, only the cluster head interacts with distributed cluster middleware, as shown in figure 1.7. In a cluster-based service-oriented architecture cluster head node is interacting with distributed cluster middleware.

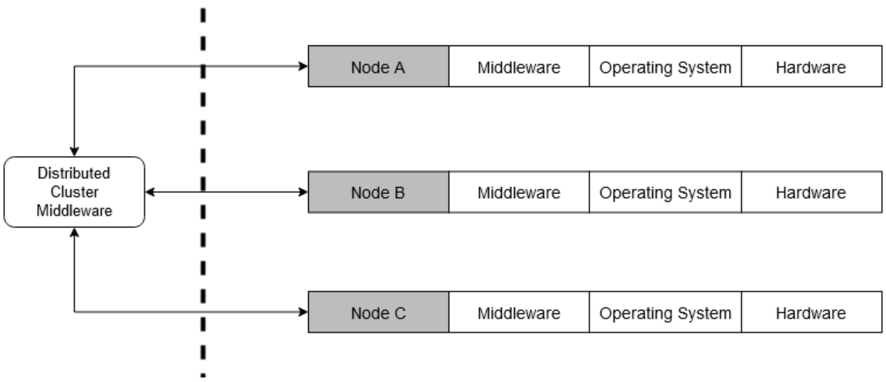



***Figure1.7: Cluster-based software architecture. Adapted from*** [21]

Designing cluster-based WSN has the following challenges:

1. Selection of a cluster head and rotating role of the cluster head to eligible nodes of the cluster.

2. Suppose the size of the cluster is decreased. In that case, power consumption within the cluster reduces but the number of cluster heads increases in the environment, considered leading to managing the cluster head; conversely, if the cluster size is increased, it becomes challenging to handle power crunches.

### 1.2.3 Layered Architecture and Protocol Stack of Wireless Sensor Network

In wireless sensor networks, the motes have two roles, data originators and data routers. Communication is performed for two reasons, source function, i.e., nodes transmitting packets to the sink. Router function, i.e., nodes participate in forwarding the packets received from other nodes to the next destination in the multi-hop path to the sink. The protocol stack used by the sink and all motes is shown in figure 1.8; it consists of five layers i.e. Application Layer, Data Link Layer, Network Layer, Physical Layer and the Transport Layer. Architecture of WSN not only have layers it does have three planes, Mobility, Power and Task Management Planes.

The physical layer manages power and mobility; it deals with modulation, transmission, and receiving techniques. As the sensors are mobile and deal with noisy raw data, ensuring the reliable communication link layer comes into the picture. The link layer is also responsible for managing channel access using MAC to minimize collisions with neighbours' packets. The network layer is responsible for routing data received from the transport layer. As per requirement, software for application can be built and used through the application layer, and the transport layer maintains the flow of data.

Power, mobility, and task management planes monitor the sensor nodes' energy, movement, and task distribution. These planes help the sensor nodes coordinate the sensing task and lower the overall power consumption [22].

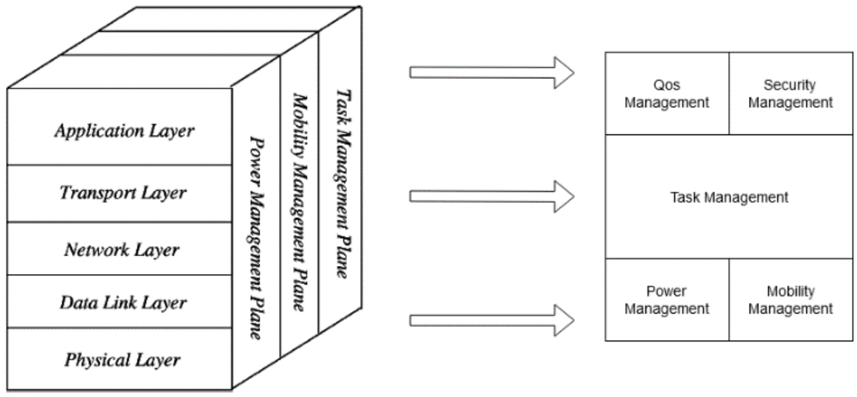



***Figure1.8 Protocol stack architecture of WSN. Adapted from*** [23]

## 1.3 Applications of Wireless Sensor Networks

WSN is used in high-end applications like radiation detection in nuclear plants, advanced weapon sensors, ship submarines, wildlife sensing, chemical plant sensors, and biomedical equipment. Nowadays, they are more useful in biological sensor networks, and the applications are being extended to customer applications. There are many more applications like ATC, border infiltration, industrial automation, traffic monitoring, video surveillance, and weather forecasting [2]. Wireless sensors have made their place in many applications which primarily affect society and individual at large, few areas where WSN are applied are:

### 1.3.1 Commercial Applications

Commercial applications include air traffic control, assembly line and workflow, asset management, appliance control, automated automobile maintenance telemetry, blind bridge, and highway monitoring, detecting structural faults in aircraft, buildings, and ships, detecting toxic agents, drapery, environmental management in industrial and office buildings, human tracking, inventory control, and shade controls.

### 1.3.2 Environmental Monitoring Application

Wireless sensors can be used outdoors to detect floods, forest fires, microclimates, precision agriculture, endangered species tracking, and other environmental applications. These sensors can be used in hard-to-reach areas, such as disaster-prone areas, to detect earthquakes, tsunamis, and volcanic eruptions and build monitoring networks to improve employee and public safety.

### 1.3.3 Health Care Applications

Body-worn medical sensors help access information rapidly, leading to an improved tracking system, like drug administration, collecting and managing historical databases of clinical data, providing chronic & elderly assistance, remote monitoring biological and physiological data, tracking patients and doctors in hospital premises, telemedicine, etc.

### 1.3.4 Home Automation Applications

Unlike automated meter reading, capturing detailed electric, water, & gas utility usage data for home automation, instrumented environment, tracking pets & children, control of temperature, residential power, and monitoring applications for room light controlling, lawn, and garden watering using RFID tags

### 1.3.5 Military Applications

Battle damage assessment, battlefield surveillance, biological monitoring for agents detecting chemical attacks, detecting nuclear attacks, monitoring equipment, monitoring deleterious forces, multimedia surveillance, etc.

### 1.3.6 Industrial Process Control

One of the challenges in chemical plants is to monitor the state of pipelines; tiny wireless sensors can be put in the machines that are unreachable to humans to alert failure, if any. Wireless sensor networks can also be used to monitor the manufacturing process and types of equipment.

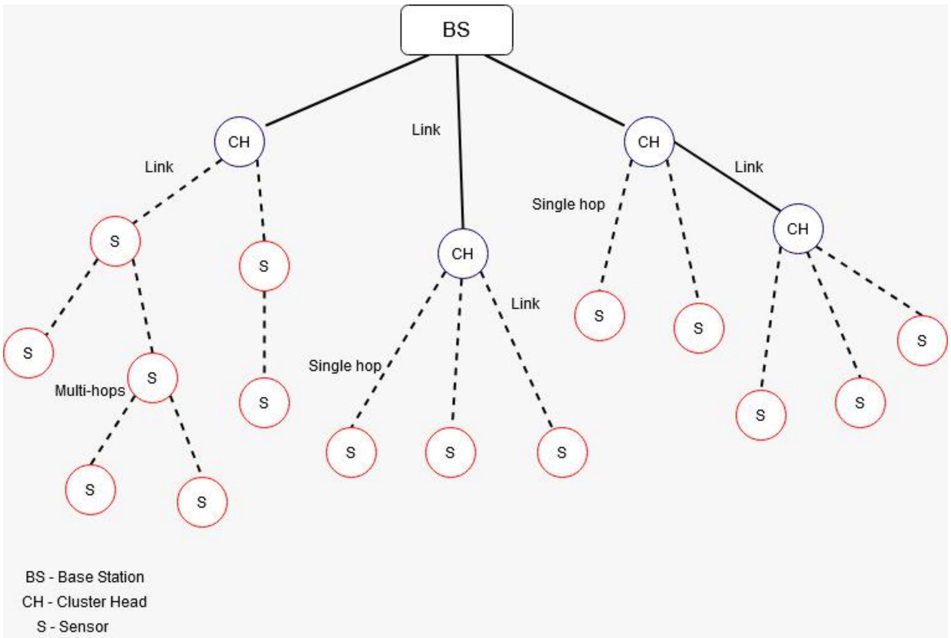



***Figure1.9: Sensor Network Management. Adapted from*** [24]

## 1.4 Characteristics of Wireless Sensor Networks

The characteristics of wireless sensors networks are:

### 1.4.1 Application Significance

WSN follow many-to-one traffic pattern its definitive work is procuring the climate information. Different sensor networks application process different the physical signals, a sensor networks routing protocols can't be applied efficiently to the other one. Application pertinence is one of the main issues to the WSN [25].

### 1.4.2 Battery Operated

Motes are power exhaustive so the algorithms and protocols devised should have considerations for battery energy preservation. Motes transmitting data consumes more energy than the computing motes e.g., transmitting of a single bit of data may consume more energy than executing three thousand lines of codes. So, motes generally have limited computational capabilities [26].

### 1.4.3 Distributed Sensing and Processing:

WSN are robust is nature as it has distributed as it is capable of the large number of sensor node is distributed uniformly or randomly. WSNs each node is capable of collecting, sorting, processing, aggregating and sending the data to the sink. Therefore, the distributed sensing provides the robustness of the system.

### 1.4.4 Communication Capabilities

Motes communicate to several hundred meters only; communication bandwidth of senor network is narrow. To run the network smoothly is challenging as the motes are influenced buildings, rains storms etc.

## 1.5 Operational Challenges in Wireless Sensor Networks

The positioning of wireless sensor networks has to face technical challenges like developing a low power consumption communication setup with nodes capable of self-organizing themselves. The selection of components plays a vital role in managing power in wireless sensor networks. A typical sensor network management is shown in figure 1.9. As data fusion needs nodes to be synchronized, the synchronization protocols for sensor networks must address the limitations of these networks and other technical issues. Some of the challenges faced by WSNs are shown in figure 1.10


***Figure 1.10: Challenges in Wireless Sensor Networks. Adapted from*** [27]

### 1.5.1 Diverse Applications

Sensor networks have a wide range of diverse applications. The requirements for different applications may vary significantly. No network protocol can meet the needs of all applications. The design of sensor networks is application specific.

### 1.5.2 Dynamic and Unreliable Environment

In addition to nodes, failure of nodes or energy depletion keeps on changing the topology of thus making it a dynamic. The wireless sensor network is also unreliable as the medium used over here is wireless which is more prone to noise resulting in signal attenuation.

### 1.5.3 Energy Capacity

The WSN should support low power consumption, and the challenge here is to communicate highly compressed data over common bandwidth channels. In WSN, the sensors are placed remotely and users auxiliary power sources for the operations.

Wireless sensor networks do not have online power sources as sensors are placed remotely where it is not practical to put power lines. To ensure extended functions of the devices are challenging, and low power consumption techniques are the critical factor. Power efficiency in WSNs is generally accomplished by lowering the duty-cycle operation. Reducing data volume in a local network and using multi-hop networking for long-distance communications, optimized CMOS chipsets in WSNs are the key to commercialization success [28], [29].

### 1.5.4 Hardware Resource

The processing and storage capacity of the sensor nodes has limitations. These hardware constraints have severe consequences in software development and designing of network protocols.

### 1.5.5 Network Management

Centralized algorithms consume a tremendous amount of energy, putting a constraint on WSNs, making it infeasible to depend on centralized algorithms to implement network management solutions. As an alternative, motes make the localized decision in collaboration with their neighbouring motes, i.e., without global knowledge. Thus decentralization leads to non-optimal routes.

### 1.5.6 Real-Time Operation

WSN needs to perform for longer lifetimes for many real-time applications. Enabling a long-running wireless sensor network leads to challenges like fluctuating energy sources and energy storage.

### 1.5.7 Scaling

The number of sensor nodes deployed is application-dependent. Some applications may require few nodes, and on the other hand, many applications require a large number of nodes, which puts constraints on the scaling of the network. In some networks, a node is deployed manually, and in others, it is done randomly. In some areas, node deployment is scattered, and in some areas, it is dense. Thus, it requires that sensor nodes must organize themselves into a communication network.

### 1.5.8 Secure Localization

The usefulness of a wireless sensor network depends upon its ability to locate motes in the network accurately. Unfortunately, an attacker can effortlessly hack nonprotected location data by sending inappropriate signal strengths or rerunning signals, etc.

### 1.5.9 Self-Management

Wireless sensor network nodes are deployed in isolated locations, and they should be able to adapt to changes in the network, manage network configuration without any human intervention.

### 1.5.10 Synchronization

Many applications like environment monitoring, navigation, or vehicular tracking require global clock synchronization to provide a standard synchronized clock. A synchronized local clock helps to analyze data and predict future system behavior. Some applications contain energy-hungry equipment like GPS, some management protocols like Network Time Protocol (NTP) do required synchronization and consume a lot of energy. The unsynchronized clock may lead to incorrect estimations. Thus, synchronization is application-dependent and needs to be appropriately applied.

## 1.6 Research Domains in Wireless Sensor Networks

As a large amount of data is gathered, algorithmic methods play an essential role. The infrastructure allied with motes of the wireless sensor network, which in turn are environment embedded in the device. Based on the applications in which these networks are used. Wireless Sensor Networks is a hot topic of research for the last 25 years, and the study can be classified as shown in Table 1.2 [30]:

*Table 1.2 Research topic Area, frequency of publications*

| Research Topic Area | Frequency of Publication | Research Topic Area | Frequency of Publication |
|---|---|---|---|
| Deployment | 9.70% | Middleware and task | 2.42% |
| Target tracking | 7.27% | Wireless radio and link characteristics | 2.12% |
| Localization | 6.06% | Network monitoring | 2.12% |
| Data gathering | 6.06% | Calibration | 2.12% |
| Security | 5.76% | Geographic routing | 1.82% |
| Routing and aggregation | 5.76% | Compression | 1.82% |
| MAC protocols | 4.85% | Taxonomy | 1.52% |
| Querying and databases | 4.24% | Capacity | 1.52% |
| Time synchronization | 3.64% | Topology control | 1.21% |
| Robust routing | 3.33% | Mobile nodes | 1.21% |
| Lifetime optimization | 3.33% | Link-layer techniques | 1.21% |
| Applications | 3.33% | Detection and estimation | 1.21% |
| Transport layer | 2.73% | Programming | 0.91% |
| Hardware | 2.73% | Diffuse phenomena | 0.91% |
| Distributed algorithms | 2.73% | Software | 0.61% |
| Storage | 2.42% | Power control | 0.61% |
| Resource-aware routing | 2.42% | Autonomic routing | 0.30% |

## 1.7 Fault Tolerance in WSN

Loosing data or communication link is one of the major problems of a mote, these problems are because of factors like ecological impact, battery exhaustion, physical damage, radio waves interference, etc. Fault-tolerance is the capability of a network to deliver a level of functionality without disruption even if there are faults in the network [31].

Therefore, the fault-tolerance of a network is considered to be one of the most critical issues in WSNs. Besides the fault-tolerance, the network lifetime is another challenge faces the wireless networks that requires energy-efficient techniques to maximize the system lifetime. Although a single virtual backbone reduces the overall energy consumption of the network, the nodes in a VB have an extra load of communication and computation. This leads to consuming their energy faster than other nodes in the network. An intuitive way to solve this problem is to construct multiple VBs and switch the work between them periodically [10].

## 1.8 Organization of Thesis

Overall work done and presented here is structured into seven chapters. Following the introduction to wireless sensor networks in this chapter, issues of energy efficiency are addressed in chapter 2; Chapter 3 presents literature reviewed during the research, beginning with a brief review of protocols for WSNs and their classifications, followed by a literature review on clustering techniques, and LEACH and its successors. Chapter 4 is the review of clustering techniques in wireless sensor networks. Research methodology and proposed framework are discussed in Chapter 5, Experimentation and results are discussed in chapter 6, recommendations and future work is discussed in Chapter 7.

# 2 Energy Issues in the Layer of Wireless Sensor Networks

WSN is usually positioned in a non-accessible environment; these sensors get power from tiny batteries and methods for power saving like changing batteries is not an available option. Designing and managing power requirement of wireless sensor network is a challenging task.

OSI a functional model organized as layers where a layer provides services to the upper layer. The efficiency of a network is evaluated in terms of parameters like availability, delay, jitter, reliability, throughput, security, etc., in conventional models; energy consumption is hardly an issue [32] [33]. In traditional networks, the focus of researchers is layer-based components, assuming that changes made in one layer will automatically affect the overall system, but it doesn't work. Many of the energy minimization models focus only on sending and receiving data neglecting other parameters. Most current energy minimization models focus on sending and receiving data, while rest parameters were neglected [10]. In the years 2000 and 2002, Heinzaleman et al. [8] [34] proposed a model focusing on sending and the power consumption model focused on the cost of transmitting and receiving data packets using a single hop approach to avoid retransmission energy dissipation. An idea of flexile cross-layer architecture enhanced information sharing among wireless networks [9] [35]–[38].

## 2.1 Physical Layer

Motes of WSN need a radio connection as a physical layer; when radio signals are transmitted or received energy is dissipated, the physical layer performs modulation and coding of data at the transmitter end and demodulation and decoding at the receiver end. The radio channel has three modes: active, idle, and sleep. Energy is saved by observing a low-power listening approach called duty cycle listening, periodically turning the receiver off and on at the physical layer [39]. When channel is idle radio sources are turned off the save energy; energy management is important while switching between states [40]. Dynamic Voltage-Frequency Scaling (DVSC) [41], a technique to allocate CPU time to the task, works at the kernel level to minimize energy consumption. Changing algorithms of communication among sensors and altering the sequence of task execution helps in a substantial improvement in energy dissipation. Clustering technique is also used to minimize energy consumption [42] [43] [44] [45].

## 2.2 Link Layer

The link layer has received a notable amount of consideration from the researchers. The energy of the sensor is consumed more during data transmission is due to three significant activities sending and receiving packets and sitting idle. Younis et al. l [46] proposed energy-aware routing using multi-hop data transmission instead of direct sensor link communication. Saadawi et al. l [1] found at the link layer, energy consumed is either due to collision during packet transmission of nodes or due to keeping receivers in active mode. Manisha et al. [55] compared the energy consumption of the processor and radio transmission in nodes in both sleep and operational methods. They discovered that radio transmission in nodes plays a significant role in energy management and sensor lifetime extension, and they all followed a conventional design principle.

## 2.3 Medium Access Control Layer

The main concern of MAC layer protocols is in dealing with energy issues due to idle listening, the collision of packets, over hearing, and control packet overheads while designing MAC layer protocols for wireless sensor networks. Efficiently employing residual energy of sensors is the primary target of framing MAC protocol for wireless sensor networks [47] [48]. In traditional networks code division, multiple access is used to avoid the collision; however, using original CDMA requires significant changes in the sensor and sensor network design; for example, CDMA requires ample storage for codes storages. Thus, scalability suffers. Transmission time in CDMA is also more, resulting in more energy consumption. Due to these limitations, designers use only a portion of CDMA [47]. Switching the radio in sleep and on mode can also be one of the possible solutions to save energy in the link layer, which requires a medium to be shared, e.g., TDMA, or using two radios for separate channels. The time-sharing approach causes the problem in scaling; due to the need for prescheduling control messages, the time-sharing approach adapts slowly to traffic flow [48].

## 2.4 Network Layer

The network layer working can reduce the network's energy consumption and ultimately improve its lifetime; this section studies these strategies. Minimizing energy consumption may be accomplished by limiting communication range, lowering reporting sensors, lowering the quantity of data transmission, allocating energy according to node needs, and achieving energy efficiency through non-uniform energy distribution [58]. Shaoqing et al. [49] proposed energy-efficient cooperative communication to minimize the monitoring of energy dissipation at the node level.

### 2.4.1 Topology

Connectivity maintenance, duty cycle or redundant nodes, identification of redundancy, and self-configuration are some of the challenges while determining the best topology. Protocols that aim to establish robust topology are called topology control protocols; these protocols consider deploying energy-efficient nodes and their maintenance during network lifetime to achieve thoroughgoing connectivity with the lowest energy consumption [50] [3].

Cluster-based energy conservation protocol performed better than Geographic Fidelity when the movement of nodes is minimum and Geographic protocols performed better when nodes movement was high [3]. Various topologies, such as ad-hoc, clustered, hybrid, mesh, tree, etc., 2D or 3D provide a virtual backbone for routing, denser is the population more is the power dissipated, selection of proper topology helps in energy management [6].

### 2.4.2 Routing

Routing protocols should be designed in such a way that they are energy efficient as routing activity consumes a lot of energy in wireless sensor networks. Homogeneous networks have equal capabilities. In contrast, heterogenous networks have different capability nodes; optimization techniques are made per node capability. SPIN (Sensor Protocols for Information via Negotiation) [51] is a routing technique based on node flooding. In LEACH [8] algorithm, the cluster head node results in data flow management, resulting in an enhanced lifetime, improved security, and scalability; LEACH's only drawback is not guaranteeing the optimized route. Intanagonwiwat et al. [52] gave directed diffusion data-centric, localized multi-path delivery for multiple sources, sinks for finding an optimized path. Most of the energy management techniques use Dijkstra to find the shortest path [53]. Fengyuan Ren et al. [54] proposes that energy efficiency can be improved by finding out minimum energy path and packets are forwarded through that path. Hwang et al. [55] proposed another protocol for energy-efficient routing for WSNs with holes created due to uneven deployment.

## 2.5 Transport Layer

The transport layer deals with the mechanism of congestion control, which is entirely different for the guided and unguided media. In unguided media, packets need to be retransmitted, dissipating more energy. Scheuermann et al. [56] simulated in a wireless network and testified that throughput is satisfactory up to a specific optimal load beyond that throughput falls rapidly. They used traditional TCP/IP hop by hop backpressure technique to avoid congestion. Results show an increase in throughput and reduced delay in various topologies.

## 2.6 Application Layer

Data collected from all nodes is processed in application layer. The application layer eliminates the redundant and compresses it before transmitting it to the destination keeping energy transmission in view. Routing protocol performs data aggregation using data fusion to combine several unreliable data measurements to produce a more accurate signal. The ultimate goal is to consume less energy while transmitting all the data to the sink to improve the network's lifetime [57] [58].

## 2.7 Energy Harvesting

Weddell et al. [59], Kansal et al. [60] used an energy harvesting system to enhance network life time by recharging nodes after energy depletion to energy, many harvesting technologies like kinetic energy, solar energy, thermal energy, and vibration technologies. These technologies are classified as predictable, unpredictable, partially controlled, and fully controlled. Due to the erratic behavior of available power, energy management is a bit different from battery operated devices. Hybrid techniques can be used for different nodes due to different work load.

## 2.8 Conclusion

By looking into the above constraints in energy management, different approaches are proposed at different layers. We have offered various techniques for cluster head selection, routing, and data aggregation.

# 3 Literature Review

## 3.1 Introduction

WSN has widespread application possibilities, such as air pollution monitoring, area monitoring, commercial applications, environmental/earth sensing, forest fire detection, health care monitoring, home applications, industrial monitoring, landslide detection, military applications, and water quality monitoring [74-77]. Limited power source, the low processing power of nodes, low bandwidth, and absence of conventional addressing technique make designing of routing algorithm challenging task.

Energy-efficient routing algorithms can be categorized as Communication architecture, Network Structure, Reliable Routing, and Topology Based Scheme [62]. Routing algorithms can also provide Flat and Hierarchical protocols[63]. In the WSN, all motes of flat routing algorithms have similar functions and tasks. These networks are often utilized for smaller networks. Directed diffusion, Flooding, Gossiping Rumour, SPIN, and other flat routing algorithms are examples.

On the contrary, the entire network has separate entities called clusters; all the clusters elect few motes as cluster heads by comparing them to specific benchmarks. Data aggregation techniques are applied by the CH on the motes of its cluster and aggregate the compressed data to the BS. CHS dissipates more energy than any other mote of the cluster as it provides more services. To make a balance on energy consumed within the cluster head is deployed on rotation. The architecture of the hierarchical routing algorithm is energy efficient and is scalable.

Heinzelman et al. [8], in the year 2000, proposed the first-ever hierarchical algorithm named LEACH, "Low energy adaptive clustering hierarchy." Based on LEACH, many hierarchical algorithms have been developed; some of them are EECS [64], HEED [65], PEGASIS[66], TEEN[67], and T-LEACH[68].

The objective of LEACH and its variants are to increase the energy efficiency, increase coverage area, scalability, effective data aggregation, minimum delay, provide security to data and robustness. The most common and significant aim of these algorithms is to reduce energy dissipation [63].

## 3.2 LEACH "Low Energy Adaptive Clustering Hierarchy"

Clustering is the technique of effectively arranging mote and control approach, which can improve networks' network lifetime and scalability. Energy efficiency in the LEACH clustering algorithm for WSN is achieved by selecting CH randomly. The operation of LEACH has multiple rounds, as in Figure 3.1. All the rounds constitute two phases set-up and steady-state phase, as shown in Figure 3.2.

### 3.2.1 Setup Phase

During the setup phase, CHs are elected, motes associate themselves with CH to create a cluster. In the process of CH election, all the motes produce a random number between 0 and 1; if the random number is less than threshold Th (rnd), the mote becomes CH for the current round; the threshold value is selected using selection equation 3.1 [69] as follows:

$$Th_{(rnd)} = \begin{cases} \dfrac{p}{1 - p * (rndmod\,\frac{1}{p})}, & if\ n \in G \\ 0, & otherwise \end{cases} \tag{3.1}$$

*P* indicates the sought-after % of motes to be elected as CHs from all the motes, rnd means the present round, and *G* is the number of motes that were not part of the process of cluster head election in the last 1/*P* rounds. The mote which turns into cluster head in round *rnd* will not be participant mote for next 1/*P* rounds. Thus, all the mote gets a chance to become the CH, leading to a uniform distribution of energy consumption by motes. When a mote is chosen as CH, it broadcast an ad message to all the motes. Contingent upon the strength of the signal, motes join one of the clusters. The new add message is based on equation 3.1. After forming the cluster, avoid collision CHs plans and follow the TDMA aired to all the motes of the concerned cluster. Motes that are not active go into sleep mode.

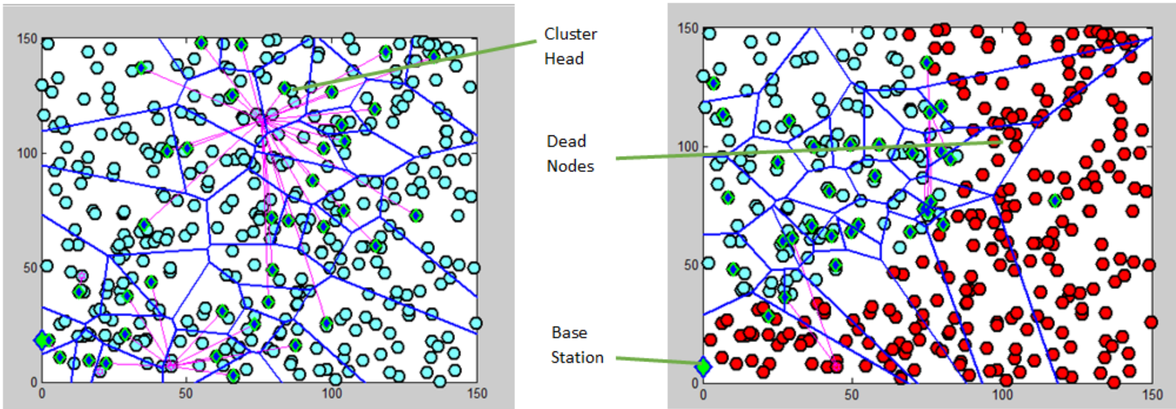



***Figure 3.1: LEACH Algorithm, the illustration of two rounds.***

### 3.2.2 Steady-State Phase

The steady-state phase follows the setup phase. During this phase, data sensed by motes is transmitted to CH, data gathered by CH is further sent to the base station following the TDMA schedule. While one mote is sending data to CH, other motes remain in sleep mode resulting in a reduction in the intracluster collision, enhancing the battery life of motes.

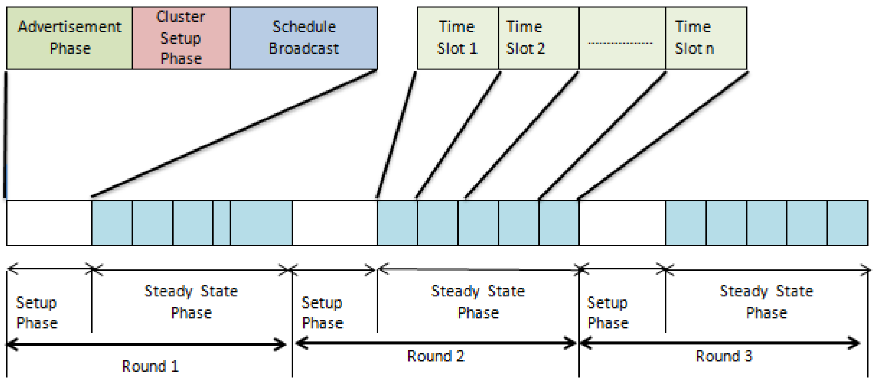



***Figure 3.2: LEACH Operations. Adapted from*** [70]

LEACH algorithm randomly gives equal opportunity to motes to become the CH at least once throughout their entire life. The rotation of the CH in a random manner results in enhanced network lifetime [71].

Since the cluster head is picked at random, the same mote may be cluster head many times. After a few rounds, none of the motes have enough energy to become CH. In LEACH formation of clusters is random. The positioning of the CH is not well defined in LEACH. CHs as CHs may be positioned near the center of the member clusters. In another scenario, the location cluster head may be near the boundaries of the concerned clusters, resulting in higher energy dissipation during intracluster communication, resulting in degradation in the network's overall performance. To improve the performance single-hop and multi-hop communication model is used.

## 3.3 LEACH Successors Using Single Hop Communication Model

CH receives data from member motes of the concerned cluster in this model; gathered data is then transferred to the BS [30]. The communication process plays an essential role in attaining efficiency. If the network area is small, single-hop communication is beneficial as overhead, cost, and delay are reduced, resulting in increased network lifetime.

In the variants of LEACH, researchers focused on cluster head selection, creation of clusters, and communication within the cluster. This section discusses major LEACH variants which have an improvement over LEACH.

### 3.3.1 LEACH-C

Although distributed cluster formation in LEACH has many advantages, it does not guarantee even the placement of CH motes. Poor cluster setup even in a single round degrades the overall performance of the algorithm.

In 2002, Heintzelman et al. [34] proposed LEACH-centralized, an algorithm using central control algorithms to create clusters during the setup and steady-state phase like the basic LEACH algorithm. Whereas LEACH-C distributes the cluster head evenly over the entire network area, excellent clusters are formed. Overhead does not increase as the base station executes the steady-state phase.

The base station plays a vital role in creating better clusters by calculating the average energy of motes. All the motes whose energy is more than average can participate in the cluster head selection process. The average energy contained by the network *Eavg* is given in Equation 3.2.

$$E_{avg} = \frac{\sum_{i=1}^{N} E_i}{n} \qquad (3.2)$$

The remaining energy of the ith mote is Ei. The total motes are denoted by *n.* If the average distance between elected CH and the BS is $d_{tBS}$, $e_{fs}$ is transmission fields and $e_{mp}$ receiving fields for both free space and multipath, respectively, and if there are *n* motes uniformly deployed in an area, then K can be determined using Equation 3.3,

$$K = \sqrt{\frac{N}{2\pi}\frac{e_{fs}}{e_{mp}}}\frac{M}{{d_{tBS}}^2} \qquad (3.3)$$

Heinzelman et al. [34] used a simulated annealing probabilistic algorithm [72] for finding optimal energy dissipation of motes within the cluster by reducing the squared distance between motes and CHs. After the selection of CH among motes, the base station BS broadcasts information to all the motes. Thus, BS elects the CH, and the rest of the motes joins the clusters. The steady-state phase of LEACH and the proposed LEACH-C algorithm is same.

LEACH-C is centralized, so it is less scalable, as BS makes cluster head selection more energy-efficient than LEACH. In LEACH-C, we need to define the position, requiring GPS to specify the location, and GPS is a costly device.

### 3.3.2 DCHS – LEACH

In the year 2002, Handy et al. [73] proposed a modification in LEACH Deterministic Cluster Head Selection LEACH where CH selection is changed to reduce energy dissipation for prolonging network lifetime, achieved by modifying the threshold T (n) value for electing the cluster head as in equation 3.4 and using a deterministic approach of CH selection resulting in low energy consumption.

$$T(n)_{new} = \frac{P}{1 - P(rmod\frac{1}{P})} \frac{E_{ncurrent}}{E_{nmax}} \quad (3.4)$$

Where $T(n)_{new}$ is the modified threshold value, $E_{ncurrent}$ represents the current energy of the node, and $E_{nmax}$ is the initial energy of the mote. Initially, this worked out, but later on, after a few rounds, the network stopped. The problem is solved by providing another energy model as in equation 3.5.

$$T(n)_{new} = \frac{P}{1 - P\left(rmod\frac{1}{P}\right)} \left[\frac{E_{ncurrent}}{E_{nmax}} + \left(r_s div\frac{1}{P}\right)\left(1 - \frac{E_{ncurrent}}{E_{nmax}}\right)\right] \quad (3.5)$$

With these modifications, the lifetime of the network is enhanced by 30 %. The lifetime of microsensor networks can be obtained, but overall performance is degraded due to frequent cluster formation.

### 3.3.3 Security-Based LEACH (SLEACH)

Ferreira et al. [74] presented SLEACH in 2005, the first block set to incorporate building blocks from SPINS [86], a block set that employs the symmetric-key approach and preserves the prime properties of LEACH. Motes of the network are under high-security breach from within as well as outsiders. It was assumed that the base station is trusted and so works only on outside attacks only. The proposed algorithm has introduced two primary security features to the original LEACH, authentication of data and freshness. Freshness tells whether the data is new or old, and authentication means the receiver can authenticate the transmitter. Two symmetric keys are proposed in their work, the master key shared with the BS and the group key shared with all the motes. All motes communicate a counter with the BS for freshness.

The proposed method does have some limitations

a) No security mechanism is there while the formation of clusters. Any unknown node can join the cluster.

b) Data sensed by cluster participants may breach security.

c) The proposed algorithm does not provide security from internal threats to the network.

Oliveira et al. [75] addressed these drawbacks in their proposed algorithm TB-LEACH.

### 3.3.4 Time-Based LEACH (TB-LEACH)

In 2008 Oliveira et al. [75] proposed a Time-Based LEACH, which is different from LEACH only in the cluster-head selection method. Nodes with the shortest time interval will become cluster heads. A constant number of cluster heads are required to a counter is set with all the motes. When the counter's value reached a specific matter, motes no longer is a competitor of cluster-heads. So to obtain the maximum lifetime of the network, the partition of the cluster should be balanced. The number of CHs must be in dominance, and the network needs an optimal CHs amount. It is a distributed algorithm.

TB-LEACH results in a significant improvement in energy dissipation. The authors demonstrated they verified that it experiments to provide a longer lifetime in contrast to LEACH. It is not fit for more extensive networks as cluster heads and base stations are communicating directly.

### 3.3.5 Unequal Clustering LEACH (U -LEACH)

In the single-hop model method, the cluster head sends the aggregated date directly to the base station causing more energy consumption by the distant base station. Thus energy consumed is directly proportional to distance. In 2010, a clustering algorithm based on unequal LEACH containing more setup phases.[76]. The paper proposes a different cluster heads selection phase. Present work suggests two elements of competitive distance and residual energy percentage for any mote to be a part of the cluster head election. Authors have taken the unequal size of circular clusters; cluster nearer to the base station are more significant than the cluster at a far distance.

The proposed clustering mechanism minimizes the LEACH Algorithm's hotspot problem, balances the energy, and enhances the network's lifetime. The disadvantage of the proposal is intracluster data transmission between clusters nearer to the base station.

### 3.3.6 Genetic algorithm-based LEACH

In the year 2011, Singh et al. l.[77] their survey found Nature-inspired Computing (NIC), i.e., Bio-Inspired, Evolutionary Computing, and Swarm Intelligence algorithms, can be utilized to tackle complicated problems in modest ways. Liu et al. l.[78] proposed a genetic algorithm based LEACH( LEACH-GA) which suggested probability-based cluster head selection. In the beginning, all motes are CCH (candidate for cluster head selection process). They generate a random number Rnd, which is compared with threshold value Threshold(s), and if Rnd is less than Threshold(s) and probability value PROBsat is 0.5, the mote becomes cluster head. The rest of the motes send theirs sends their id and location information to the base station. Base station uses a genetic algorithm, evolutionary optimization process, probability transitions, non-deterministic rules, mutation operators, and crossover. Relations of equation 3.6 define probability $PROB_{OPT}$ for n motes and $K_{OPT}$ clusters

$$PROB_{OPT} = \frac{K_{OPT}}{n} \tag{3.6}$$

The performance of LEACH-GA is superior to LEACH regarding energy efficiency, but overhead cost and scalability is an issue.

### 3.3.7 FL-LEACH

Al-Maqbeh et al.[79] in the year 2012 presented a fuzzy logic algorithm called FL LEACH (Fuzzy-Logic based LEACH). Presenters have employed fuzzy logic to find the number of CHs. Fuzzy logic depends on the density of the nodes of the network. Fuzzy logic can find the required number of CHs without knowing network information. FL-LEACH uses a hybrid of LEACH-GA and LEACH, through inference fuzzifier uses several nodes of the given network. The simulation results show that FL-LEACH performs better than basic LEACH and its variant LEACH-GA in terms of the network's lifetime. The disadvantage of the proposed algorithm is the assumption of uniform node distribution and neglecting energy restriction for CH selection.

### 3.3.8 Energy Potential LEACH (EP-LEACH)

In the year 2013, Xiao et al. [80], EP-LEACH used the energy harvest technique[81] to improve the lifetime of LEACH motes have rechargeable energy bank which gathers energy from its atmosphere. It is different from LEACH in the CH selection phase. The motes with more energy have more probability of becoming CH, and mote can often become a CH. Accordingly, the threshold equation 3.7 of LEACH is reformulated in equation 3.7, [80] based on the proposed two modifications.

$$T_k(i) = \frac{F_k(i)}{\sum_{r \in N_k} F_r(i)} \; X \; P \; X \; |N_k| \tag{3.7}$$

Where $N_k = \{r | D(r,k) < D_t\}$ D(r, k) is the distance between nodes k and r, $D_t$ is the threshold distance between neighboring nodes.

### 3.3.9 Improved LEACH (I-LEACH)

In 2013 Beiranvand et al. [82] proposed a new idea in the CH section for improvement in LEACH. CH is selected by considering parameters like distance from BS, the number of neighboring motes, and their remaining energy. Motes find these parameters from equations 3.8 and 3.9, [82]. The number of motes in the neighborhood is defined by its coverage area of radius $R_{ch}$, given by Equation 3.8.

$$R_{ch} = \sqrt{\frac{(M * M)}{(\pi * K)}} \tag{3.8}$$

$$T(n) = \begin{cases} \left(\frac{p}{1-p*(r \bmod \frac{1}{p})} * \frac{E_c}{E_{avg}} * \frac{Nbr_n}{Nbr_{avg}} * \frac{dt_o BS_{avg}}{d_{to} BS_n}\right), & if\ S \in G \\ 0, & otherwise \end{cases} \quad (3.9)$$

Where K number of clusters are deployed in *MXM* area, the improved threshold *T* (*n*) is shown in equation 3.9. Randomly generated number is compared with *T* (*n*); the mote with a randomly generated number less than the threshold becomes the cluster head for the current round. Arrangement of motes in the given network reduces energy dissipated per mote, thus increases network lifetime.

### 3.3.10 MOD-LEACH (M-LEACH)

In 2013, Mahmood et al. [83] proposed MOD-LEACH. The algorithm introduces efficient cluster head replacement. In primary LEACH cluster head is replaced after each round, but in the proposed algorithm, if after the going around, if the existing CH does not consume much energy and contains energy more than the threshold, it will remain cluster head for another round. Thus, the energy of CH and cluster members are saved. The algorithm proposed using two-level power to boost signals for three modes of transmission, intra-cluster, inter-cluster transmission, and data aggregation from cluster head to base station. The problem with the proposed algorithm is different levels of amplifier signals and their synchronization overhead.

### 3.3.11 Vice Cluster LEACH (VC- LEACH)

In 2015, Sasikala et al. [84] proposed a concept of vice CH in V-LEACH. Because of poor CH selection in LEACH, some of the CHs die before completing the current round; vice cluster head will take over the role of cluster head when the original CH dies before completing its current round. There are three types of motes in VLEACH, CH, member motes of the cluster, and VCH, which work as CH in case CH dies. Thus V-LEACH results in more efficient data delivery and energy efficiency.

### 3.3.12 LEACH Successors Using Multi Hop Communication Model

Data transfer between the BS and CH situated at far distances is done via relay nodes or motes, which are now cluster heads. The radio model interprets that energy consumed by motes is proportional to the distance between sender and receiver. Energy consumption is proportional to $d^4$ if the distance is more than the threshold distance. As the distance between transmitter and receiver is a significant factor, researchers aimed their research at cluster formation and size of the cluster. The present section confers widespread multi-hop communication.

### 3.3.13 LEACH-B

In 2003 Depedri Mahmood *et al.* [7] proposes new strategies for cluster creation and selecting cluster heads from motes. The proposed algorithm uses the multihop approach. The clusters chosen by the researchers is $N_{a;}$ the motes are $N_{TOTAL}$ distributed uniformly in the area of consideration, i.e., SXS square meter. Average motes in each cluster are $N_{TOT}$/Na, where non-cluster head motes are (($N_{TOTAL}/N_a$) - 1). All of the cluster heads dissipate energy while transmitting their packets while retransmitting the packets received from other cluster heads to the next cluster head until they reach the base station and energy consumed in advertising. The threshold value is calculated by equation 3.10:

$$T_p(t_i) = \begin{cases} \left( \dfrac{N_a}{N_{TOTAL} - N_a \left( rmod \left[ \frac{N_{TOTAL}}{N_a} \right] \right)} \right), & : C_p(t_i) = 1 \\ 0, & : C_p(t_i) = 0 \end{cases} \qquad (3.10)$$

Node p’s selection as cluster head depends on the chosen number between 0 and 1. Node is eligible to become cluster head if it is less than a threshold Tp(ti). Network lifetime in LEACH-B is better than LEACH, but it does not perform well in data aggregation tasks.

### 3.3.14 TL-LEACH-B

In 2006 Loscri et al. [85] proposed a model having a two-level hierarchy of the clusters. Data is aggregated at two levels, firstly at the local base station of the cluster and then at the main base station resulting in the efficient distribution of energy load an increased lifetime of the network, as shown in figure 2.3, [85]. The proposed protocol is feasible for extensive networks.

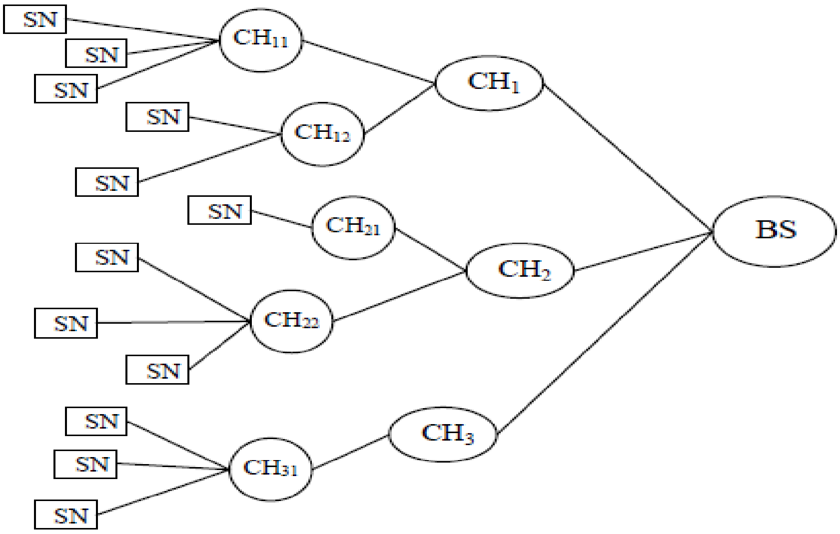



***Figure 3.3: TL-LEACH Operations Adapted from*** [85]

### 3.3.15 LEACH-Mobile

In 2006, Kim et al. [86] proposed a protocol LEACH-M for moving nodes. Clustering is similar to LEACH. The second phase, i.e., the steady-state phase, is different. According to TDMA, data aggregation is CH feels that any of the nodes is not sending data in more than two rounds, then the time slot allotted to that node is withdrawn. During the subsequent TDMA schedule, a join request is sent to all the motes, which decide to join a cluster.

### 3.3.16 E-LEACH

In 2007 Xiangning et al. [87] proposed E-LEACH The CH selection and data transmission between the CH and the BS have been improved in E-LEACH over the LEACH protocol. Energy LEACH is an updated version of LEACH with different CH selection criteria. The probability of a node to be elected as CH in the first round is the same for all the nodes as all have equal energy. Whereas in the next rounds, the residual energy of motes is a significant factor in the selection of CH. Field strength energy is given by equation 3.11, [87]:

$$E_{fi} = \frac{-E_R}{D_i^2} \tag{3.11}$$

$E_{fi}$ is field energy, $E_R$ is residual energy of the $i^{th}$ node, and Di is the distance between the $i^{th}$ node and sink.

### 3.3.17 LEACH-ME

In the year 2008, Kumar et al. [88] proposed an extended version of [86]; LEACH-ME's primary focus of the protocol is on the election of CH. Motes change their clusters and cluster heads as motes are mobile. Relative motions of the nodes among each other, a function defining relativity measure wrt its immediate neighbors are given as in equation 3.12:

$$M_x(t) = \frac{1}{n-1}\sum_{y=0}^{n-1}\left|D'_{xy}(t)\right| \tag{3.12}$$

Dxy is the distance of node xth to all yth neighbouring nodes; motes aggregate data according to the TDMA schedule issued by corresponding cluster heads. If presently a node is not sending data to the cluster head, it goes in sleep mode to save energy.

### 3.3.18 C-LEACH

In 2010 Asaduzzaman et al. [89] proposed a cross-layer cooperative diversity protocol for LEACH-based WSN. Multiple input multiple output framework based on cooperation was proposed. Multiple CHs are within a single cluster across a layer. After aggregation of data from the motes of the cluster, all the CHs cooperatively send data towards the sink.

### 3.3.19 LEACH-Density

In 2010, Liu et al. [90] proposed LEACH-D (LEACH based on Density of node distribution) to attain improved network lifetime; the researcher suggested that threshold value as in equation 3.13 is a function of node distribution density to improve connectivity and electing cluster head. The formation of a cluster depends upon the degree of connectivity. Thus, motes join the cluster by looking into the energy attained by the cluster head.

$$Th(i) = \frac{p}{1 - p(r mod \frac{1}{p})} \cdot \frac{E_{iresidual}}{E_{initial}} \cdot \frac{D_i}{D_{avg}} \tag{3.13}$$

Th(i) is the threshold for $i^{th}$ round $E_{iresidual}$ is present residual energy of mote, $E_{initial}$ is initial energy of the mote, $D_i$ is the degree of connectivity, and $D_{average}$ is average connectivity degree of the network.

### 3.3.20 Far Zone LEACH

In 2011, Katiyar *et .al.* [91] proposed FZ-LEACH; researchers have presented a concept of the far zone to reduce communication cost among intracluster in large clusters. The setup phase is similar to LEACH, whereas in the steady-state phase far zone is created, and motes of the cluster contributed power to the cluster head as in HEED [65].

### 3.3.21 MR-LEACH

In 2012, Taruna et al. [92] proposed multi-hop routing LEACH; the protocol was proposed to remove drawbacks of multilevel clustering, consuming much more power. The proposed protocol reduced the average distance of CH to BS, the researcher used equal clustering levels were used to enable global TDMA.

### 3.3.22 Cell-LEACH

In 2012 Yektaparast et al. [93] proposed a C-LEACH model in which the whole network is partitioned in hexagonal cells. All the clusters are divided into seven compartments, with one of the motes acting as cell heads. Data packets aggregated by cell heads are sent to cluster heads further cluster heads transmit to the base station, as shown in figure 4 redrawn from [93].

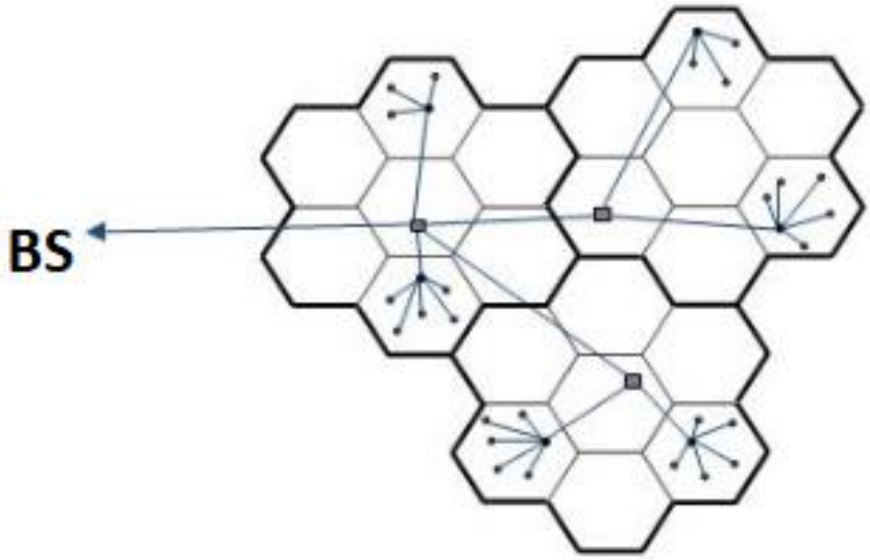



***Figure 2.4: Cell LEACH data sent from cell-heads to CH and then to BS. Adapted from*** [94]

### 3.3.23 SAGA-LEACH

In the year 2014, Zhang et al.[95] proposed the LEACH-SAGA (Simulated Annealing and Genetic Algorithms). SAGA LEACH and LEACH are different by the process of CH selection process. The proposed method uses a simulated annealing and genetic algorithm to elect CH, while normal LEACH uses a random approach. Factors considered are the residual energy of motes, the distance of CH from the cluster center, and the average energy of the cluster. The controller algorithm is implemented at the BS. The performance of the proposed protocol is better in terms of network lifetime;

CHs are evenly distributed, and the energy requirement is less. The proposed protocol cannot handle scalability, and overhead is high due to complexity.

### 3.3.24 MF LEACH

In 2018 Sharma et al. [96] proposed "LEACH Mobile Fuzzy" implemented FIS based LEACH with reactive model and enhanced parameters. The protocol performed worked well in terms of alive nodes, first node , half node and all nodes dead. The proposed work provides effective improvement in terms of energy efficiency.

### 3.3.25 Improved LEACH

In 2019 Liang et al. [97] proposed an approach to improve the routing using "Improved LEACH, authors proved that probability of excessive CH distribution can be reduced by adding an ant colony algorithm The protocol significantly prolonged the lifetime of wireless sensor networks compared with the LEACH protocol and increase the energy efficiency per node in per round.

### 3.3.26 MG LEACH

In 2019 Hicham et al. [98] proposed "MG LEACH" in which data transmission was done by an intermediate cluster head, to send more data and extend the network lifetime.

### 3.3.27 MW LEACH

In 2020 Khedri et al. [99] proposed “MW LEACH" – Multi weight LEACH, the protocol has lower complexity and longer life time, the protocol outperforms state-of-the-art protocols based on performance metrics of throughput, energy consumption, packet delivery, network lifetime, and latency.

### 3.3.28 ESO LEACH

In 2021 Gaurav et al. [100] proposed enhanced algorithm which works on the principle of meta particle swarm enhancement for initial clustering of nodes to minimize the random nature of LEACH the lifespan of ESOLEACH protocol is two fold that of LEACH

## 3.4 Analysis of LEACH Successors

A subjective analysis of LEACH successors is introduced in Table 1. These algorithms are arranged in chronological order. All the mentioned algorithms are compared on various parameters like cluster formation techniques (distributed or centralized), complexity, delay, energy efficiency, overhead, and scalability. The Basic LEACH algorithm has some limitations, which are addressed in LEACH successors. These algorithms/models show better performance than LEACH in several features like complexity, delay, energy efficiency, overhead, scalability, etc.; the following conclusion is made from the survey.

1. All the LEACH variants are designed to improve energy efficiency.
2. Few of the LEACH variants addressed security-related issues, but the algorithm proposed increases energy consumption, latest lightweight cryptography techniques can be used to save energy.
3. Optimization techniques are proposed only on finding the number of clusters and CH selection. Optimization of routing and data aggregation needs to be looked upon.
4. Renewable energy is a promising research area in WSN. None of the variants utilized renewable energies. Solar power, thermal energy, wind energy, etc., can be used to increase energy efficiency.
5. Mobility and network coverage are not discussed in any of the LEACH variants.
6. GPS is the only tool used as a location finder in LEACH and its variants. GPS requires a significant volume of energy resulting in increased cost.

*Table 2.1 Analysis of LEACH successors using single-hop and multi-hop communication models.*

| LEACH Successor | Year | Communication Model | Cluster formation | Complexity | Delay | Energy Efficiency | Overhead | Scalability |
|---|---|---|---|---|---|---|---|---|
| LEACH | 2000 | Single Hop | Distributed | Lower | Less | Moderate | Higher | Lower |
| LEACH C | 2002 | Single Hop | Centralized | Lower | Less | Highly efficient | Less | Lower |
| LEACH DCHS | 2002 | Single Hop | Distributed | Moderate | Less | Highly efficient | Higher | Lower |
| LEACH B | 2003 | Multi-Hop | Distributed | Moderate | Less | Highly efficient | Higher | Lower |
| SLEACH | 2005 | Single Hop | Distributed | Complex | Less | Very High | Higher | Moderate |
| TL-LEACH B | 2006 | Multi-Hop | Distributed | Lower | Less | Highly efficient | Less | Lower |
| LEACH M | 2006 | Multi-Hop | Distributed | Complex | Less | Highly efficient | Higher | Higher |
| LEACH E | 2007 | Multi-Hop | Distributed | Complex | Less | Highly efficient | Higher | Lower |
| TB LEACH | 2008 | Single Hop | Distributed | Complex | Less | Moderate | Higher | Moderate |
| LEACH-ME | 2008 | Multi-Hop | Distributed | Complex | Higher | Moderate | Higher | Higher |
| U LEACH | 2010 | Single Hop | Distributed | Complex | Less | Highly efficient | Less | Lower |
| C LEACH | 2010 | Multi-Hop | Distributed | Complex | Higher | Highly efficient | Higher | Lower |
| LEACH D | 2010 | Multi-Hop | Distributed | Complex | Less | Very High | Higher | Very High |
| LEACH GA | 2011 | Single Hop | Distributed | Complex | Less | Highly efficient | Higher | Lower |
| FZ LEACH | 2011 | Multi-Hop | Distributed | Complex | Higher | Highly efficient | Higher | Higher |
| FL LEACH | 2012 | Single Hop | Distributed | Complex | Less | Lower | Less | Higher |
| MR LEACH | 2012 | Multi-Hop | Distributed | Complex | Higher | Highly efficient | Less | Lower |
| CELL LEACH | 2012 | Multi-Hop | Distributed | Complex | Less | Moderate | Very High | Very High |
| EP LEACH | 2013 | Single Hop | Distributed | Complex | Less | Very High | Higher | Lower |
| I LEACH | 2013 | Single Hop | Distributed | Complex | Less | Highly efficient | Moderate | Lower |
| SAGA LEACH | 2014 | Multi-Hop | Distributed | Complex | Less | Highly efficient | Moderate | Higher |
| M LEACH | 2015 | Single Hop | Distributed | Complex | Less | Highly efficient | Less | Moderate |
| V LEACH | 2015 | Single Hop | Distributed | Complex | Less | Very High | Higher | Lower |
| MG LEACH | 2019 | Multi Hop | Distributed | Complex | Less | Moderate | Very High | Very High |
| MW LEACH | 2020 | Multi Hop | Adaptive | Lower | Less | Lower | Very High | Very High |
| ESO LEACH | 2021 | Multi Hop | Distributed | Complex | Less | Highly efficient | Moderate | Lower |

## 3.5 Mobile Sink and Rendezvous Nodes

Another approach used to reduce energy dissipation is mobile sink MS approach. Mobile sink collects the aggregated data from the motes, movement of the mobile is either in the concerned area or around it. The movement of the sink can be on fixed trajectory (controlled) or it moved randomly (uncontrolled). Moving sink increases the life time of the network [101]. Mobile sink it is not always closed to all the motes to collect data. One more intermediate points called Rendezvous Points [102] near the trajectory of controlled mobile sink data is sent from normal motes to rendezvous nodes to base station [103].

## 3.6 One Hop Field Neural Network

In 2008 Shen et. all [104] proposed Hopfield Neural Network approach to solve broadcast scheduling problem in WSN. Authors mapped discrete energy problem to Hopfield neural network to find time division multiple access schedule for communicating nodes to minimize the cycle length and maximize the node transmission.

## 3.7 Conclusion

This chapter presents a comprehensive survey of single-hop communication in LEACH and its successors. Cluster formation technique, delay, energy efficiency, overheads cost, scalability, etc., are comparatively analysed for LEACH and its variants. It is proved by the researchers that LEACH variant algorithms are an improvement over the basic LEACH algorithm. The main achievement of any newly proposed algorithm in WSN is to enhance energy efficiency. According to this survey, significant of the mentioned algorithms are distributed in nature. While CH selection, energy is a considerable parameter considered by all the researchers. Apart from this, the researcher has looked into other parameters like distance from the BS, the density of motes, location of motes, renewable energy usage, and the minimum number of CHs. Many researchers have used probabilistic clustering approaches; presently, deterministic methods are also becoming popular; the drawback of deterministic methods is that they consume more energy and are complex. All variants discussed in this chapter claimed to be better than LEACH. Concept of using mobile sink and rendezvous node is also included the chapter.

# 4 Clustering Techniques in Wireless Sensor Networks

## 4.1 Introduction

Clustering is a topology management technique that can group nodes to improve the efficiency of the network by managing resources and rotating responsibilities among nodes to provide fairness. In ad-hoc networks, as the number of nodes is very high and is not a reliable network, significant issues in such networks are topology management [105]. Generally, clustering includes two main phases: grouping nodes and allocating responsibilities. A cluster is a group of member motes and one cluster head to manage the cluster in data transfer. Cluster head transfers the data directly or indirectly to the network's base station (BS), as shown in figure 4.1.

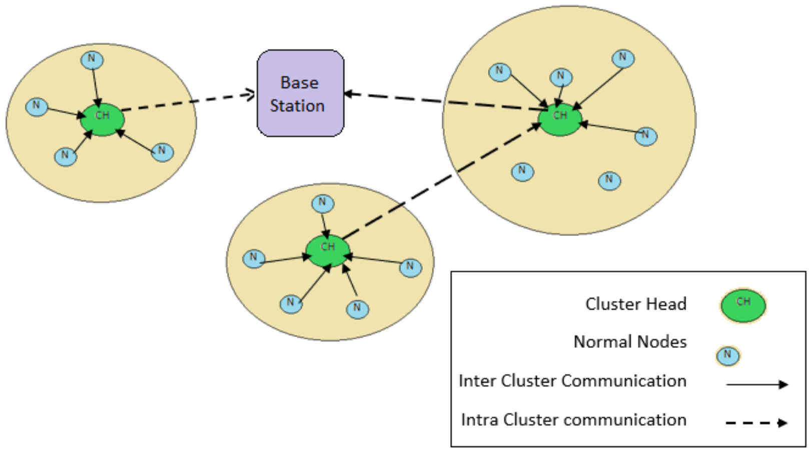



***Figure 4.1: Inter-cluster and intra cluster communication. Adapted from*** [106].

Grouping sensor nodes into clusters overcomes the drawbacks found in Multi-Hop transmission, thus helps to reduce consumption of energy and improves the network lifetime. In clustering, groups are formed, and each group has one leader called Cluster Heads (CHs). CHs performs the task of data fusion and aggregation, thus improves energy consumption. CHs node behaves as the pathway between the sensor node and the BS. The cluster formation process consists of a two-level hierarchy, where CHs nodes are at a higher level and cluster members at the lower level. Cluster member sends their information to CHs. Then CHs removes the redundant data and sends that information directly or through the intermediate communication with other CHs nodes to BS. Different algorithms were proposed to decrease the energy consumption of the sensor. LEACH algorithm is the first and popular WSNs dynamic clustering algorithm that adopts entire sensor nodes to be homogeneous.

## 4.2 Clustering objectives

The primary objective of creating clusters is:

1. **Enhancing network lifetime: Dissimilar to mobile systems, wherever portable products (e.g., phones), energy administration is the secondary concern;** they can be recharged when its battery becomes dead. At the same time, WSN has limited battery life. So, maximizing the network's lifetime is a rising issue and significant challenge while designing WSN. So, to deal with this issue, clustering helps reduce energy consumption and enhance the lifetime of WSNs.
2. **Fault tolerance**: is used to address issues related to node failure, various techniques are designed. To cope with this issue, either the concept of proxy cluster-heads is used (when either node fails or has less transmission energy) or CH rotation can be the solution. Fault tolerance is one of the essential objectives while designing a clustering algorithm.
3. **Fill handling** is another outline objective while designing clustering protocol. It is unquestionably required not to overweight the CHs as it leads to quick depletion of energy. So, in each cluster, even distribution of node is essential, as CHs perform the task aggregation of data or other signal handling task.

## 4.3 Clustering Parameters

The parameters related to clustering are as given below:

1. **Cluster Count:** It is one of the essential parameters in clustering. Usually, the number of clusters is fixed as CHs are arranged before. As CHs are selected randomly, thereby result in variable clusters in numbers.
2. **Intra-Cluster Topology:** Intra-cluster topology is categorized as either single-hop connectivity or multi-hop connectivity. In single-hop intra-cluster topology, the nodes transmit information sensed to CHs directly, i.e., data is directly transmitted

from node to CH. However, in some cases, multi-hop Node-to-CH communication is also required. Its sensor node sends data to the intermediate node, which then further transmits data to the cluster.

3. **Nodes and CH Mobility:** In the case of the fixed position of sensor nodes and CHs, there is not to oversee inter-cluster and intra-cluster, and in case of a variable number (mobility) of CHs or nodes, continuous maintenance is required.
4. **Node Type and Role:** Nodes can be classified as homogenous and heterogeneous. Homogenous nodes are those with the same processing capabilities. At the same time, heterogeneous nodes are those having different processing capabilities.
5. **Cluster Formation Methodology:** Cluster formation methods are categorized into two types centralized and distributed. A centralized approach has one or more nodes that divide the network and controls the cluster. In the distributed process, clustering is performed in a distributed manner, i.e., without coordination.

## 4.4 Cluster Head Selection Parameters

CHs can be selected either randomly or through certain probability depending upon some parameters like remaining energy or connectivity in a homogenous environment. While for heterogeneous environments, CHs are picked with the one having higher processing capability.

Various parameters are taken into consideration while the election of cluster head is:

1. **Initial Energy:** It is considered as one of the essential parameters while selecting CH. It is defined as the energy of sensor nodes at the start of an algorithm.
2. **Residual Energy:** It is defined as the energy that remained in the sensors. As CH is selected randomly in rounds, we consider the residual energy that remained in the sensors in the previous round for selecting CH in the next round.
3. **Average Energy of Network:** The sum of energy remained in sensor nodes by the number of nodes and is used as reference energy for every node. In CH selection, nodes having higher energy will only participate in a network.

## 4.5 Classification of Clustering Protocols

For WSNs, the clustering algorithms can be categorized as Probabilistic (Random / Hybrid) clustering algorithms and non-Probabilistic clustering algorithms.

### 4.5.1 Probabilistic Clustering

In the Probabilistic (Random or Hybrid) clustering approach, either clusters are formed randomly or based on some criteria (residual energy). In the primary measure, i.e., in the random selection process, each sensor node is assigned to select initial CHs. Clustering algorithms following this approach have benefits such as flexibility, fast, uniform, and complete distribution. At the same time, in the secondary criterion, the election of CHs depends on some measure, such as residual energy. The benefit of using a secondary approach helps to reduce energy consumption and thus enhances network lifetime.

### 4.5.2 Non-Probabilistic Clustering

Non-Probabilistic clustering algorithm uses specific criteria to elect CHs and form clusters, depending on sensor nodes connectivity or degree and information gathered from the nodes located close to it. Many hierarchical clustering protocols including APTEEN- Adaptive Threshold-Sensitive Energy Efficient Network [107], EECS-Energy Efficient Clustering Scheme [64], EEMC- Energy-Efficient Multilevel Clustering [108], HEED-Hybrid Energy-Efficient Distributed [65], LEACH- Low Energy Adaptive Clustering Hierarchy [8], PANEL- Position-Based Aggregator Node Election[109]], PEGASIS- Power-Efficient Gathering in Sensor Information Systems[66], TEEN- Threshold-Sensitive Energy Efficient Sensor Network [67], and T-LEACH-Threshold LEACH [68] were proposed by applying different factors [63].

## 4.6 Types of Clustering Algorithm

Following are the types of clustering algorithm for dynamic clusters:

### 4.6.1 Event-to-Sink Directed Clustering

Classical clustering provides pre-event solutions to form clusters that needlessly create too many clusters Bereketli et al., in the year 2009 [110] proposed a need-based clustering algorithm named Event-to-Sink Directed Clustering (ESDC) protocol for WSN.

Any discovered event is reported to sink, and the information collecting node collects the data and transfers it to the cluster head.

1. No cluster is formed until an event occurred.
2. Clusters are created such a manner that data is transmitted directionally from the sensing node to sink; the flow of data is almost unidirectional

Bereketli et al. [110] have performed simulation on the proposed Event-to-Sink Directed Clustering algorithm and related it with the popular LEACH algorithm. The proposed protocol consumed 50 %less time per hop than basic LEACH.

### 4.6.2 Load balanced clustering scheme

Another approach presented by Shujuan et al. in 2009 [105] is the load-balanced clustering strategy. It is a multihop approach in which assistant nodes bear the load of CH to aggregate the data to the base station. The cluster head and its assistant are selected based on distance and residual energy. The working of the load-balanced cluster scheme is shown in figure4.2 [111]

Simulations were performed using NS-2 and found that the LBCS prolongs the network lifetime longer than EECS and the basic LEACH algorithm. The drawback of the LBCS algorithm is that nodes nearer to the cluster head get more data to transmit and thus dissipate heat, causing in deprecation of energy.

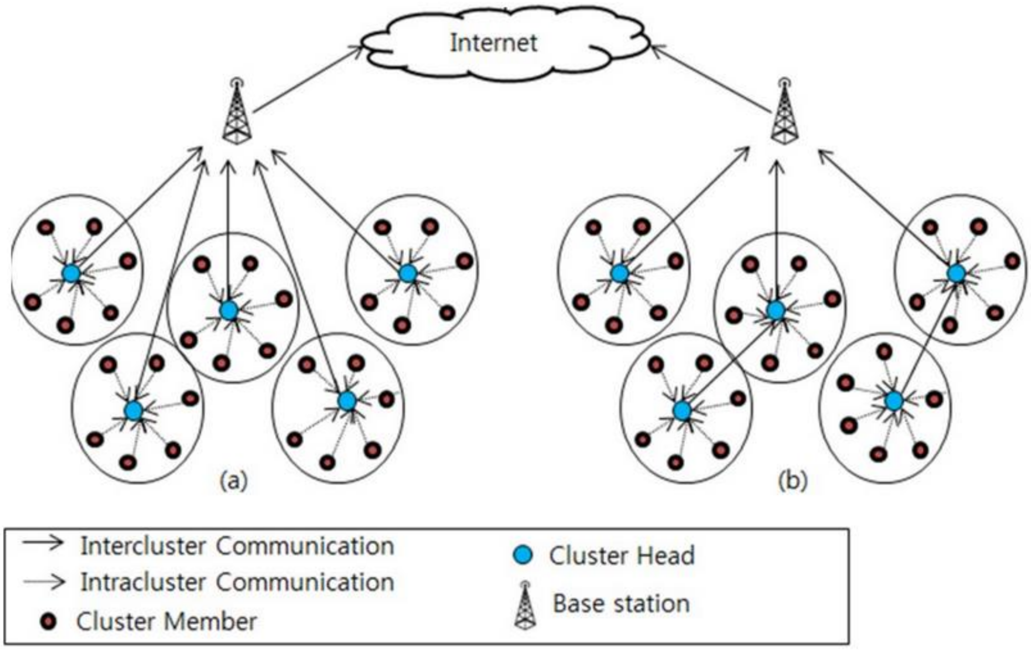



*Figure 4.2: Inter-cluster communication in load balance cluster scheme.* *Adapted from* [106]

### 4.6.3 K-means Algorithm

Sasikumar et al., in the year 2012 [113], proposed a K-means algorithm that uses Euclidian distance and residual energy of nodes to select a cluster head. The cluster head maintains a list of information collected from the member nodes, and a k-mean clustering algorithm is performed on collected data. K-mean algorithm is based on Euclidian distance and energies of all the nodes. Location and energy information of all the nodes is exchanged through messages. Once all the nodes receive data, they run the k-mean algorithm for clustering and electing a cluster head. As every node runs the same algorithm, every node knows under which cluster it belongs and its cluster head. When the whole system depends only on the central node, failure occurs when a central node fails. The performance of the proposed algorithm is better when clustering is achieved by distributed method.

### 4.6.4 Low-Energy Adaptive Clustering

Energy consumption by cluster head is much more than normal nodes, so the need is to rotate the cluster head and normal nodes, i.e., cluster head responsibility is done on a rotation basis. A normal node with minimum threshold energy, the number of times a node has become a cluster head, and the total number of cluster heads needed in the network can participate in the cluster head selection process. In Low Energy, Adaptive clustering cluster head selection is based upon probabilistic factors. Low energy adaptive clustering has a disadvantage initial energy of the node is not a factor to participate in the cluster head selection method as it is a single-hop communication, so it does not work for large-sized networks. LEACH is an effective adaptive clustering protocol.

### 4.6.5 Hybrid Energy-Efficient Distributed clustering

In the year 2004 [65], proposed to HEED an approach that considers only residual energy and node proximity to select cluster head. The main objective of HEED is distributed clustering such that cluster heads are evenly distributed over the network. The major drawback of the HEED is that a more significant number of cluster heads decreased efficiency. It consumes large bandwidth as several iterations are required to make a cluster, and too many packers are broadcasted during iteration.

### 4.6.6 Weight-Based Clustering Protocols

Tondon et al., in the year 2013 [114], proposed a weight-based clustering protocol where weight depends upon remaining energy, no of times the concerned node becomes cluster head and distance of a node from cluster head. The weight of all the nodes is found after each iteration of clustering. Clusters are framed for heterogenous networks so that there is an even distribution of energy among all clusters, resulting in increased lifetime and throughput of WSN.

### 4.6.7 Sleep Schedule Mechanism ESSM

Runze et al., in the year 2018 [115], highly denser modes results in collision and energy dissipation. To sort out the problem authors proposed an energy efficient sleep scheduling mechanism. The proposed approach will schedule the sensors into the active or sleep mode to reduce energy consumption effectively.

A comparison between various cluster techniques is discussed in table: 4.1 given below:

*Table 4.1 Analysis of LEACH successors using single-hop and multi-hop communication models.*

| Cluster Approach | Cluster Count | Communication. | Mobility | Node Type | Cluster formation method. | Cluster Head Selection |
|---|---|---|---|---|---|---|
| Event-to-Sink Directed Clustering [70] | Variable | Multi Hop | Fixed | Heterogenous | Distributed | Energy / Direction |
| Load balanced clustering scheme [71] | Fixed | Multi Hop | Fixed | Homogeneous | Distributed | Energy / Direction |
| K-means Algorithm [72] | Fixed | Multi Hop | Mobile | Heterogenous | Centralized | Energy / Euclidian Distance |
| Low-Energy Adaptive Clustering [42] | Variable | Single Hop | Limited | Homogeneous | Distributed | Probability / Random |
| Hybrid Energy-Efficient Distributed clustering [73] | Variable | Single Hop | Limited | Homogeneous | Distributed | Probability / Energy |
| Weight-Based Clustering Protocols [17] | Variable | Multi-Hop | Limited | Homogeneous | Distributed | Weight Based |

## 4.7 Conclusion

Clustering is a descriptive technique. We have evaluated different clustering algorithms considering several parameters. Our findings show that each method, regardless of approach, has advantages; for example, the K-Mean clustering method can handle enormous data more effectively than little data, whereas hierarchical protocols can manage big and small data.

# 5 Research Methodology

Various kinds of algorithms and techniques are proposed to minimize the energy consumption of routing protocols in WSNs. Multiple techniques such as data aggregation, clustering, and genetic algorithm have been proposed, but none came out proficient and effective. WSNs are defined as wireless networks that consist of various embedded computers that interact or communicate with each other. There are many sub-systems of sensors, namely, actuator, processors, radio, power supply, memory, and sensing sub-system. For the operation of these sensors, a heavy battery is an essential requirement as all the components work together. Thus, the battery is very rapidly recharged. When the battery is fastly discharged, it could lead to a fragmented network situation, so data would not be fetched from the low-powered or dead sensors. Therefore, the low-powered nodes should be immediately recharged before they become dead, which will ease the lifespan of WSNs. For this reason, the dual approach of energy replenishment and Load Balancing is proposed to improve the overall WSNs lifetime.

WSNs are made up of cheap, densely deployed multifunctional sensors with low energy consumption. They communicate with each other to gather spatial and temporal measurements of parameters such as temperature, sound, and many others. WSN is used in various applications, including environment and surroundings surveillance, manufacturing process control, congestion control, machine health monitoring, health checking applications, and home automation. In a sensor system, sensors are arbitrarily set up over an area without a pre-installed infrastructure. All sensors can examine the surroundings, gathering and routing data back to the sink. As sensors in a WSN are mostly battery operated and have inadequate ability, energy utilization turns out to be the primary concern because the network needs to work for a projected period functionally. Naturally, most of the energy consumption of sensors is on two main tasks: sensing and gathering data in the area and uploading information to the sink. Energy utilization on gathering is moderately constant since it only depends on the sampling speed.

Nevertheless, the state of power use on information uploading is quite complex than that of sense. Information uploading consumes a significant quantity of power in sensors for wireless communications, and also, the energy usage is in general non-homogeneous between sensors. Moreover, energy utilization is also dependent on the type of network topology and the position of the data sink. Consequently, the battery of the sensors near sink nodes depletes faster than others, as these sensors need to transmit more data packets. Thus, the energy consumption during data gathering is a significant and challenging issue in WSNs as it mainly finds out network life span. Owing to great practical significances, in the last few years, a lot of research efforts have been dedicated to proficient data collection in WSNs along with ample, innovative schemes.

Our motivation for this work is to minimize the power utilization and enhance the network life span via a three-step approach of clustering, data aggregation, and routing with the help of different protocols.

## 5.1 Brief Objectives of the Research.

1. Using neural network techniques, identify the cluster head.
2. Optimized LEACH clustering routing algorithm using hybrid ACO-PSO technique considering area scalability, node scalability, network lifetime, and alive nodes for static nodes and moving sink.
3. Optimized LEACH clustering routing algorithm using hybrid ACO-PSO technique considering area scalability, node scalability, network lifetime, and alive nodes are moving nodes and moving sink.
4. Inter-cluster data aggregation through NSGA.

## 5.2 Proposed approach

There are several types of research in extending the lifespan of WSNs, but no researcher proposed this approach that can effectively beat the problem of energy scarcity. This technique is a combination of clustering, routing, and data aggregation.

### 5.2.1 Identification of Cluster Head Using Neural Network Technique.

Clustering is one of the proficient topological control techniques as it helps extend the network's energy efficiency and scalability. But it is essential to maintain low power consumption during the clustering to have an efficient clustering and routing protocol. Further, because of the non-static process environments and the natural limitations of different hardware and software resources, choosing efficient clustering for the type of environment is very hard.

Firstly, a Neural network has been applied. It is the approach to control energy utilization in an equilibrium manner. This approach has used the concept of the maximum energy left so that the performance must be increased. So many factors have been included to measure the performance of nodes like remaining energy, distance factor of nodes, initial set up of energy, etc. By depending upon all these factors, the cluster head node has been chosen more appropriately. This concept is used in several routing protocols to handle cluster head selection which will improve the overall lifetime of WSNs. It is a cost-effective technique as there is no need for external power generation to replenish the nodes in the network.

### 5.2.2 Data Aggregation.

In the Second feature, the data aggregation has been applied by using a Non-dominated Sorting Genetic Algorithm.

### 5.2.3 Data Routing.

In the third feature, hybrid ACO-PSO routing is implemented to move around the static sensor nodes. However, the movement uses a fixed path trajectory to collect the energy level data of various sensor nodes within the network's sensing area. It will take the shortest and safer route for transferring the information. Thus, in this manner, the life of the overall network ameliorates. Therefore, we can now say that the approach that we have proposed is one of the best approaches to reducing complexity to a greater extent by avoiding the congested route. This approach is having the idea of generating the area scalability, which means to increase the area like 100m X 100m, 150m X 150m, 200m X 200m, 250m X 250m, 300m X 300m, etc. and also increases the node scalability feature. It contains n number of sensor nodes where n=25, 50, 75, 100, and 125. In this feature, once we have normal nodes that are static on the other side, the base station moves in nature. So, static- moving approach is applied. Another approach is having with moving nodes and moving base station is used which is called moving-moving approach.

Our proposed approach helps overcome the drawback of sensor nodes that will provide an efficient solution that helps increase the lifetime of WSNs. Therefore, in WSNs, the concept of clustering, data aggregation, and routing is implemented that moves along the pre-defined area to recharge the positioned nodes by wireless power transmissions. It firstly calculates the cluster head with the help of a neural network, and then it provides routing within the network in the second step. Therefore, every node maintains the data speed and routing on its own. In this way, the whole network resources are optimally utilized, and the lifespan is also increased. Finally, the statistical outcomes justify that the proposed solution is more efficient and effective than the traditional method.

## 5.3 Network Model

The nodes are randomly placed in the given network. Entire nodes are understood to have initial energy equals to $E_{0.}$ MS (mobile sink) movement is along the y-axis. It is tacit that the base station has limitless energy, and for every round location of sensor nodes and sink can be found. The current system consists of Set-up and Steady phase.

### 5.3.1 Set-Up Phase

The setup phase is divided into three stages, for example, in the essential stage in Task Presentation (TP), Selection of cluster head (CH) and rendezvous node (RN) is done during this part of the phase. Clustering i.e. creation of clusters and election of cluster head is done during subsequent part of set up phase [116]. After the cluster formation, the last stage is called which is known as scheduling (S). In the entire scheduling phase, the message is disseminated from the cluster head to every cluster member. Every node itself arrange their organization in the period of transmission.

#### 5.3.1.1 Task Ordination:

In this phase, firstly, RNs are selected. Initially, all nodes are assumed to be normal nodes. Every hub themselves choose whether they meet RN condition or not. To become a rendezvous hub, the hubs must fulfil a condition. For it, a distance of hub has been contrasted to MS direction. On the off chance that the hub satisfies the condition, the name RN is labeled through them. The situation representing RN is specified underneath equation 5.1.

$$\frac{y_w}{2}(1 + Rx) <= y_y <= \frac{y_w}{2}(1 - Rx) \qquad (5.1)$$

Where $y_w$ addresses the examining area thickness, $y_y$ addresses the hub's location in y-heading, and steady Rx should have esteem < 1. CHs determination happens after the RNs choice. When a hub chooses to turn into a CH, its fortitude depends upon the current CHs rate (for example, from 5% to 10%), check of hubs that have been chosen already as CH beforehand and at the end is, power of sensor hub. As applied the concept of cluster head selection, Hopfield neural network considers proficiency with the arrangement of hubs qualified for cooperation in group head determination. One-Hop field networks are utilized for design review. Weights are doled out to every hub and should take an estimation of + 1 or -1.

T = [ -1 -1 -1 +1;........

+1 -1 +1 -1;........

-1 +1 -1 +1;........

+1 +1 -1 -1 ]

The foremost stricture shows the consumption of energy (ought to be least), the second stricture shows distance (least), the third stricture demonstrates neighbors (greatest), and the fourth stricture shows the proportion of current energy by incredible energy (most extreme). In the best case we have esteem [-1 - 1 +1 +1] and in most pessimistic scenario esteems are [+1 +1 - 1 - 1]. The hubs having the best and normal arrangement of qualities are considered for CH determination.

After accomplishing the suitable arrangement of hubs, the normal of power for all hubs are processed notorious as entrance value (d0). Just those hubs will take part in CH choice who has echelon of power, whichever is more prominent than or equivalent to the given edge. If the hubs don't have the necessary conditions to take an interest in CH determination, it will cause a postponement for 1/pr adjusts. The qualified hubs create a worth that ranges from 0 to 1 arbitrarily. If this number is not precisely the Th (nd), the hub will become CH, and the CH name will be appended. The limits are given by equation 5.2

$$Th(nd) = \begin{cases} \frac{pr}{1-pr*\left(rou mod \frac{1}{pr}\right)} & , nd \in Gr \\ 0 & otherwise \end{cases} \quad (5.2)$$

Everywhere 'pr' addresses the level of CH, 'rou' is present round and 'Gr' addresses the subset of sensors that are not CH. Enduring hubs which don't become CH and RN will go about as would be normal node (NN).

Bunch assortment: initially all the cluster heads and rendezvous nodes are selected with the help of carrier sense multiple access method. Cluster head and rendezvous nodes coordinate with all the normal nodes, which associate themselves with cluster heads. Signal strength assists with deciding the distance; for example, extra the sign strength slighter is the distance.

Bunch Scheduling: during this stage all the cluster heads use time division multiple access method is used to share the schedule to all the motes, Thus the motes can make their schedule of keeping their radio receiver in ON or sleep mode thus energy is utilized in a balanced way.

### 5.3.2 Steady Phase

In the steady phase, the broadcast of information from the sensor node to MS is being performed. This phase is acknowledged as data transmission (DT). In this phase, the shortest routes have been searched to reduce energy utilization. For this, Hybrid ACO/PSO optimization method has been realistic. At first, Ant Colony Optimization (ACO) has come into thought for finding the littlest course from the hub to the sink (which produces the estimations of α-Best and β-Best). The outcomes obtained through the ACO method are given to the PSO algorithm for refinement. It provides a general population-based pursuit technique that uses Pbest, Gbest, and particle force to find coming territory close by request. The PSO calculation is applied to track down the best, most limited courses. Transmission of information happens in the wake of tracking down the briefest route. Expecting that on the whole, adjusts hubs have some knowledge, and all hubs produce data at a similar rate. During its dispensed period, ordinary hubs send their data to CH. NN should maintain the radio mode 'ON' during its allocated instance period to diminish the power utilization. Throughout the information transmission stage, recipients of all CHs and RNs sought to reserved 'ON.' In the wake of getting information from hubs, CH begins accumulating the message assembled and passed the message to the MS or adjoining RN.

### 5.3.3 One-Hopfield Neural Network (HNN)

One-Hopfield Neural Network (HNN) is an area of Artificial Neural Networks (ANN). It is a Recurrent Neural Network that has a synaptic connection pattern [117] [104] Further, the above said points are needed to be considered to get the cluster head using the method of HNN.

A. Prepare weights $T_{xy} = \sum_{c=0}^{M-1} \quad i_x^c i_y^c$ x≠y Where $i_x^c$ is element x of class c exemplar.
B. Put on input on the desired outputs$z = i$.
C. Recapitulate unless the system converge $z_y^+ = f_h(\sum_{x=0}^{N-1} T_{xy} z_x^-$ where, $f_h$ is hard restraint.

### 5.3.4 Ant Colony Optimization (ACO)

Routing is the most imperative factor for measuring the performance of WSNs. Routing is a technique in which data is moved from the source to the destination. Two concepts are defined while go for routing. The first one is optimal routing, in which the shortest path has been searched, and various algorithms have been built to make the way smallest for routing, and the second one is internetwork in which the packets are transferred. This process of transferring the packets over the internet is also called packet switching. Routing is categorized into two processes; one is static routing, and another one is dynamic routing. Static routing makes the routing table which the administrator mostly does, and in dynamic routing, the strategy is maintained by internal or external routing protocols. Although the methods were efficient, still more improvement is needed to overcome the problem. Hence, advanced techniques are still required and should be invented to ameliorate network lifespan. There are several challenges in WSNs, but routing is most crucial, as the whole network's lifetime depends on its optimal path usage.

Several routing mechanisms are discussed in this research work. So, in this thesis, various routing approaches are discussed along with different challenges. Here, the routing approach based on hybrid ACO-PSO is proposed.

In 1996, 'Dorigo' proposed an Ant Colony Optimization technique. Routing protocol [118], ACO is a member of swarm optimization technique that mimics the behavior of natural ants for finding the shortest path from source to destination. At the start of an algorithm, ants move randomly. Once the food is discovered, ants move back to their colonies, leaving "markers"(a chemical substance called pheromones), indicating the path is having a portion of food. When other ants discovered these markers, they start following the path, and while coming back to their colonies, they leave pheromones and populate the path. If the ants follow the same path, that path becomes stronger. Whenever ants bring their food, they leave a marker called pheromones. Using this, ants find the shortest route to food. Since pheromones are a chemical substance that starts evaporating over time, the food source also gets depleted once all the pheromone evaporates.

#### 5.3.4.1 Working of Ant Colony Optimization (ACO)

Let 'num' denotes the count of cities, 'tn' represents the total number of ants. Assuming an ant to be initially at city *x.* An ant *l* movement from city *x* to city *y* depends on

a. Is city *y* has been visited earlier or not. For this check, all ants have a list of cities they already visited. Let $JR_l(x)$ is customary in cities that are not in by ant *l* when ant *l is* on city *x.*
b. Distance $d_{xy}$ from city *x* to *y.*
c. "Artificial pheromone" deposited on edge that connects *x* and *y* is given by *(x,y).*

Let $\tau_{xy}(t)$ denotes the pheromone on edge *(x,y)* at time *t.* When all the ants complete their journey, time *t* increases with value 1. Initially, the amount of pheromone placed on the edge is assumed to be a small positive constant: $\forall(x, y), \tau xy(t = 0) = C$ . At the beginning of the round, ants are assumed to be placed in cities randomly. When an ant *l* is at city *x* and decides to move to city *y*, it checks all the cities attached to the source city, i.e., *x.* Despite visiting all the cities, unvisited cities are firstly examined, and when all the cities are examined only then other cities are considered for visiting. The candidate list of the city contains $n_l$ Closest cities. Cities are arranged in the order of increasing distance is placed in the candidate list. This list is sequentially scanned. Ant *l* selects the city from this list. Once all the cities have been visited as mentioned in the candidate list, then city *y* can be selected using equation 5.3:

$$JR = \begin{cases} \underset{u \in JR_l(x)}{Arg\ Max} \{[\tau xu]^{\alpha}.[dxu]^{-\beta}\} & if\ q \leq q_o \\ JR & otherwise \end{cases} \tag{5.3}$$

Where q be the real random variable that is distributed uniformly in the interval [0,1], $q_o$ be the tuneable parameter ( $0 <= q_o <= 1$) and $J \in J_k(x)$ is the node which is selected randomly using the following probability using equation 5.4:

$$Pro(C_{x,y}|S^{pr}) = \frac{\tau_{x,y}{}^{\alpha} * \eta_{x,y}{}^{\beta}}{\sum_{C_{x,y} \epsilon \mathrm{P}(S^{pr})} \tau_{x,y}{}^{\alpha} * \eta_{x,y}{}^{\beta}} \tag{5.4}$$

Where, $S^{pr}$ is the fractional result, P is a combination of all that path which is set from city x to all its nearest which ant does not stay, $C_{x,y}$denotes pathway from city x towards y, $Pro$ represents the probability, $\tau_{x,y}$ is the quantity of pheromone in the path$C_{x,y}$, $\eta_{x,y}$ is the heuristic factor usually $\eta_{x,y} = \frac{Q}{d_{x,y}}$ , where $d_{x,y}$The distance sideways the cities x and y, Q represents a constant value, and 'α' and 'β' are procedure strictures.

### 5.3.4.2 Flow Chart of Ant Colony Optimization (ACO)

The working of ACO is demonstrated using the flow chart in figure 5.1.

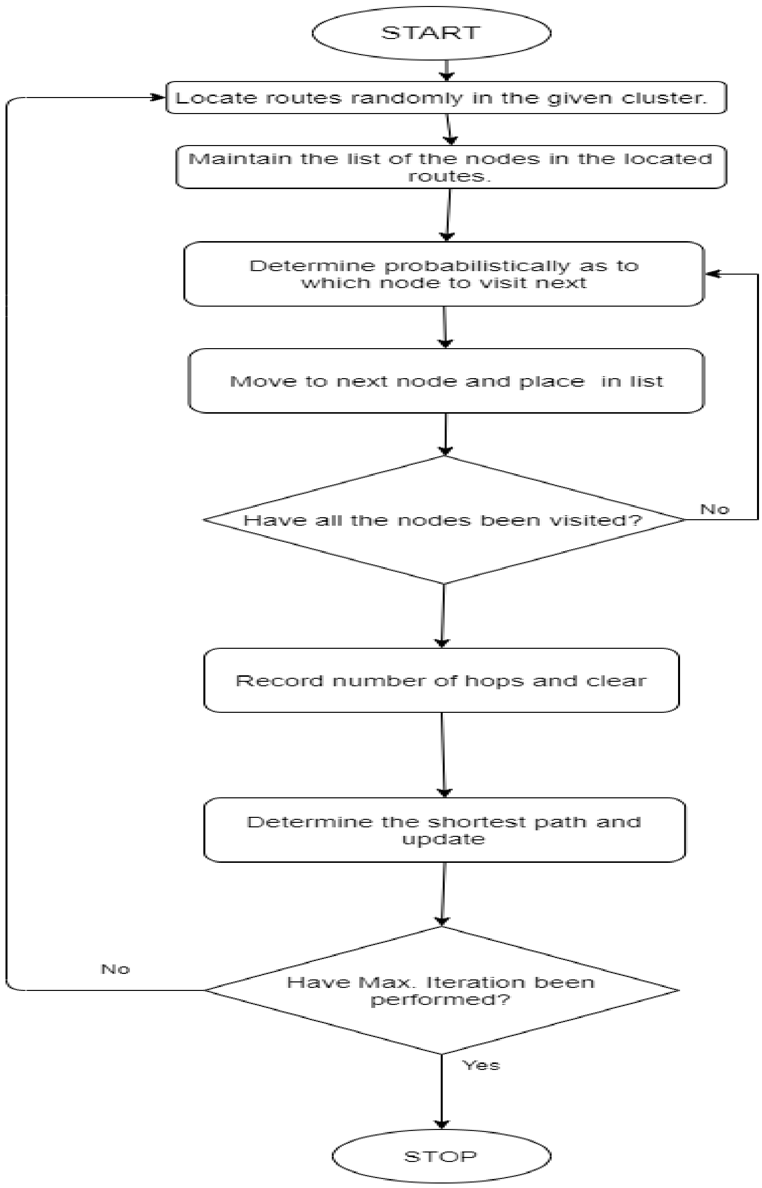



***Figure 5.1 Flow Chart of ACO.***

#### 5.3.4.3 Parameters used in Ant Colony Optimization

##### 5.3.4.3.1 α and β parameters:

$\alpha$ and $\beta$ parameters control the relative impact of trail intensity ($\tau_{,}J(t)$) and distance ($d_{i,J}$). If *α=0* increases the chances of selection of closest cities. If *β=0,* only amplification of pheromone amplification is focused. The use of this technique helps in the rapid selection of tours that is far from optimal.

#### 5.3.4.4 Pheromones Trail:

It is a chemical substance that indicates the path is having a portion of food. When other ants discovered these markers, they start following the path, and while coming back to their colonies, they leave pheromones and populate the path. If the ants follow the same path, that path becomes stronger. As ants bring their food every time, they leave pheromones. Using this, ants find the shortest route to food. Since pheromones are a chemical substance that starts evaporating over time, the food source also gets depleted once all the pheromone evaporates.

#### 5.3.4.5 Local Updates:

During a touring ant *l* is at city x and travels to city y, the concentration of pheromone at location *(x,y)* is$\tau_o$. The trails decay simultaneously so that

$$\tau_{xy} \leftarrow (1 - \rho_x).\tau_{xy} + \rho_x.\tau_o \qquad (5.5)$$

Where $\rho_x( 0 \leq \rho_x \leq 1)$ governs local trail decay.

##### 5.3.4.5.1 Global Updates

By depositing additional pheromone, the best ant reinforces its tour during the end of the iteration as we know that the density of pheromone is inversely proportional to the tour length. So the tour having a more significant pheromone density is considered the best tour reinforced through a global update.

#### 5.3.4.6 Advantages of Ant Colony Optimization

- **a.** It runs in parallel, thus fast in execution
- **b.** Used for dynamic applications.
- **c.** Respond quickly to changes

## 5.4 Proposed Particle Swarm Optimization (PSO)

Particle Swarm Optimization technique is one of the nature inspired technique was prosed by Dr. Eberhart and Dr. Kennedy [112] (1995). This technique mimics the social behavior of bird flocking. Let us consider an example of birds placed randomly in an area, and that area has only a piece of food being searched. The birds do not know the location of food. They only know the distance of food from them. In this case, the simplest technique to get food is to follow that bird closer to food. Bird is called "particle." The particles have some values which can be calculated using fitness function and certain velocity. Every particle updates “best” two values, i.e., the best solution (fitness) called pbest and gbest. Using these two values, particles update their velocities and positions as shown in equations 5.6 and 5.7

velocity[] = veell[] + c1 * ran() * (perbest[] - present[]) + c2 * ran() * (glbest[] -present[])

(5.6)

pre[] = per[] + vel[] (5.7)

vel[] represents velocity of particle, per[] represents current particle, ran () represents random number ranges from 0 to 1 and c1, c2 represents learning factors which is equal to c1 = c2 = 2.

### 5.4.1 Particle Swarm Algorithm

(i) Established boundaries $w_{min}$, $w_{max}$, C1, and C2 between 2 and 2.05, of particle swarm optimization.

(ii) Prepare populace of particle having population ‘P’ varies from 10 to 1000 and preliminary velocity ‘V’ = 10% of the location.

(iii) Adjust$i = 1$.

(iv) Appropriateness of particle is premeditated using $F_x^i = f(P_x^i)$, calculate best particle b index.

(v) Get $Pbest_x^i = P_x^i$ and $Gbest^i = P_b^i$.

(vi) $w = w_{max} - i * (w_{max} - w_{min})/Maxit$ where Maxit fluctuates from the range of 500 to 10000.

(vii) Inform velocity and location of the particle

$$V_{x,y}^{i+1} = \text{w} * V_{x,y}^i + C1 * rand(\quad) * (Pbest_{x,y}^i - P_{x,y}^i)$$

$$V^{i+1}_{x,y} = w * V^i_{x,y} + C1 * rand() * (Pbest^i_{x,y} - P^i_{x,y}) + C2 * rand() * (Gbest^i_{x,y} - P^i_{x,y})$$

$$P_{x,y}^{i+1} = P_{x,y}^i + V_{x,y}^{i+1}$$

(viii) Fitness is evaluated using $F_x^{i+1} = f(P_x^{i+1})$, calculate best particle b index.

(ix) Updating Pbest if $F_x^{i+1} < F_x^i$ Then $Pbest_x^{i+1} = P_x^{i+1}$ else $Pbest_x^{i+1} = Pbest_x^i$

(x) Updating Gbest if $F_{b1}^{i+1} < F_b^i$ Then $Gbest^{i+1} = Pbest^{i+1}$, b=b1, else $Gbest^{i+1} = Gbest^i$.

(xi) If $i < Maxit$ then $i = i + 1$ and moves to step (vi) else moves to step (xii).

Print $Gbest^i$.

### 5.4.2 Flow Chart of Particle Swarm Optimization

The working of the PSO technique is explained with the help of a flow chart, which is given in Figure 5.2.

### 5.4.3 Advantages of PSO

a. Easy Implementation

b. Needs to adjust only a few parameters

c. In terms of global search, it is very efficient

d. Quickly converges

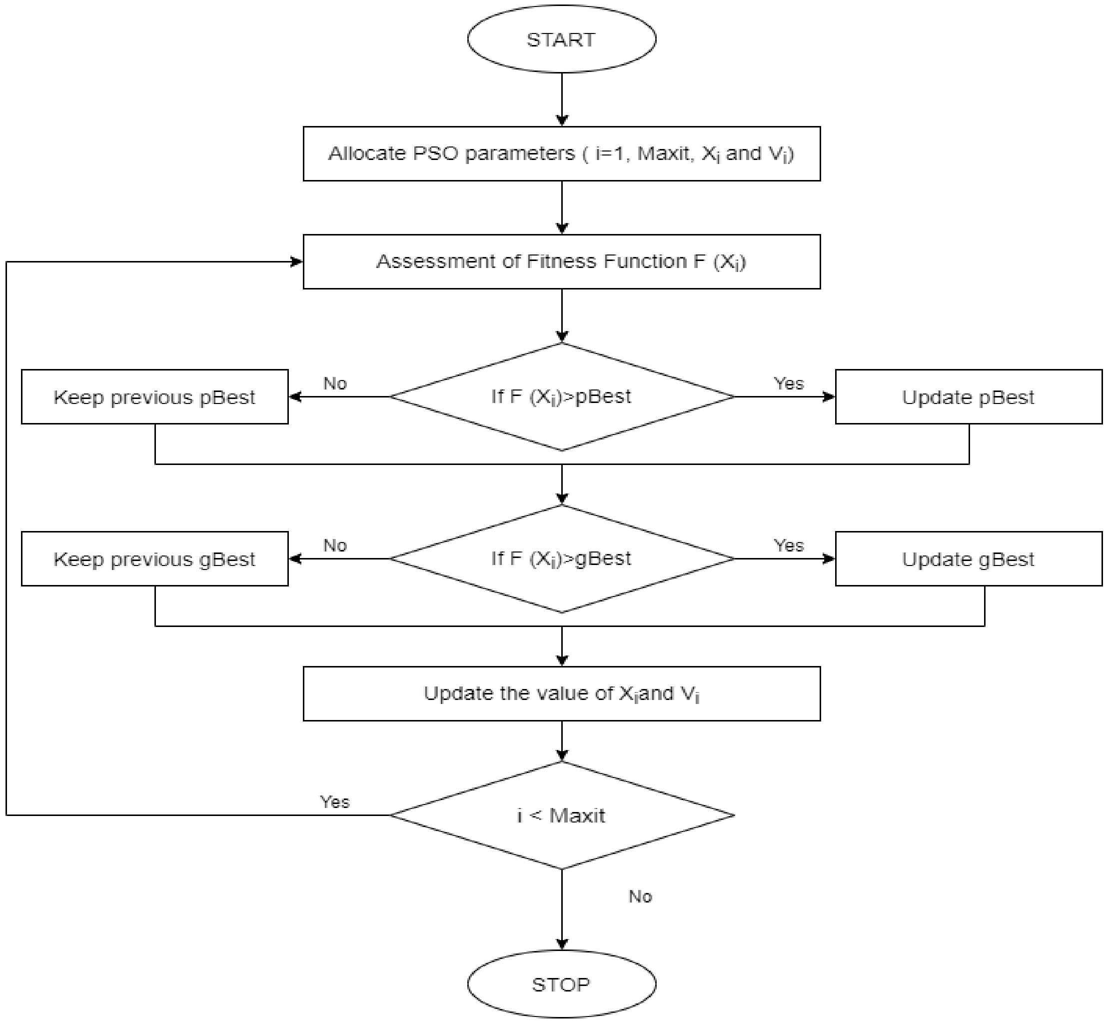



*Figure 5.2 Flow Chart of PSO*

## 5.5 Non-Dominated Sorting Genetic Algorithm

The fundamental to generate the NSGA algorithm came from the genetic algorithm. The genetic algorithm is the base of NSGA. NSGA is an approach that is based on multiple objective optimization techniques. Moreover, the extension of the genetic algorithm is named as NSGA approach. The evolutionary algorithms (EAs) are intentionally evolved to address mono-objective, multi-evenhanded, and many-target enhancement issues, in a specific order, in the course of the last, not many years. Despite specific endeavors in bringing together various sorts of mono-target developmental and non-developmental calculations, there don't exist numerous investigations to bind together each of the three kinds of enhancement issues together. These consist of two techniques that are related to NSGA, the superior technique is called the classical NSGA, and the other one focused on updating, which is called NSGA-II. To enhance the property of adaptive fit for the population of candidate solutions towards the Pareto constraint is the primary outcome or objective of the NSGA-II. The main technique implemented for the operators of the evolutionary approach is just selection, and then makes a crossover of the desired functions and then mutation of the population. The coming population is portioned into sub-population based on the analysis of the Pareto approach [119].

The Pareto front evaluates the similarity factor among every sub-group of the population. The corresponding results and resemblance actions are used to endorse a diverse front of NSGA solutions. The upcoming version of the NSGA is NSGA-II and NSGA-III, which will eliminate the above-said problems better utilizing the approach of Pareto optimal front, which is obtained by Deb et al. in 2001 [120]. The primary highlights of NSGA-II are low computational intricacy, parameter less variety protection, elitism, and real-valued portrayal. NSGA-II carries out elitism for multi-target search, utilizing an elitism-saving methodology. Elitism is presented by putting away all non-dominated arrangements until this point, starting from the underlying populace. Elitism improves the combination properties towards the Pareto-ideal set.

A boundary-less variety safeguarding component is embraced. Diversity and spread of arrangements are ensured without sharing boundaries since NSGA-II receives a reasonable boundary-less niching advancement [120]. It utilizes the swarming distance, which gauges the thickness of arrangements in the goal space. The packed examination administrator directs the determination interaction towards a consistently spread Pareto-boondocks. In NSGA-II, the posterity population Qat is created initially using the parent population Pat, which has a size of Z. Regardless, rather than chasing down the non-ruled front of Qat, the two populations are merged to form a Rat of size 2Z. At that point, non-ruled arranging is utilized to order the whole populace. The new crowd is filled by arrangements of various non-overwhelmed fronts, each in turn. The filling begins with the best non-overwhelmed act and proceeds with the second non-ruled front, trailed by the third, etc. Since the general populace size of Rt is 2Z, not all shows might be obliged in Z openings accessible in the new populace. All fronts which couldn't be obliged are essentially erased. When the last permitted act is being thought of, a more significant number of arrangements in the previous front may exist than the leftover spaces in the new populace. Rather than subjectively disposing of specific individuals from the last front, a niching methodology is utilized to pick the individuals from the previous front, which dwell at all crowded areas in the front. The calculation guarantees that niching will choose an assorted arrangement of arrangements from this set. When the whole populace unites to the Pareto-ideal front, the continuation of this calculation will guarantee a superior spread among the arrangements. The schematic portrayal of the NSGA-II technique is taken from [121] and shown in figure 5.3.

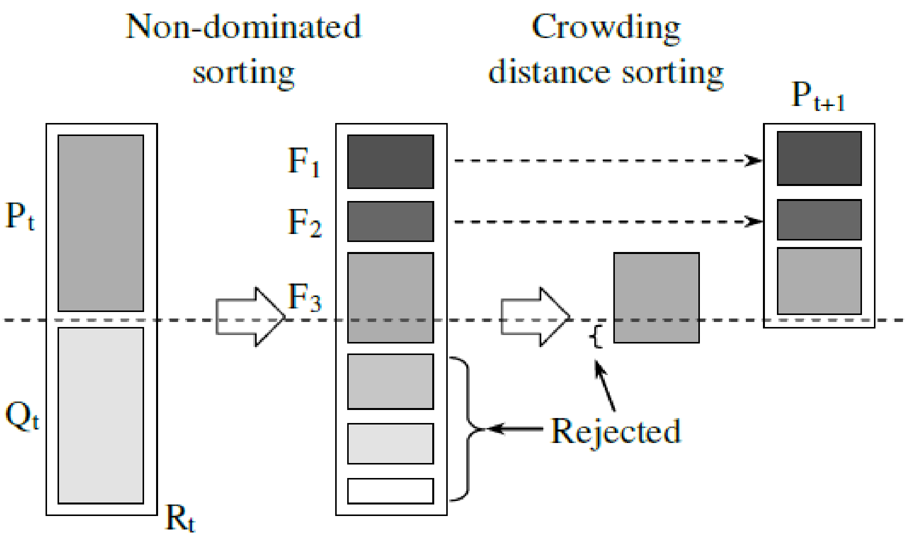



***Figure 5.3 Basics of NSGA***

NSGA-II has been the most as often as possible utilized developmental multi-objective enhancement (EMO) calculation in writing since its proposition [122] [123]. New EMO calculations were nearly continuously contrasted and NSGA-II for execution assessment in 2000-2010. In any case, it is notable that Pareto dominance-based EMO calculations, for example, NSGA-II and SPEA [124], do not function admirably on many-target test issues. As of late, NSGA-III [125] was proposed as a developmental many-objective calculation. NSGA-III has effectively assumed a similar part as NSGA-II: Newly proposed many-target calculations have been contrasted and NSGA-III for execution assessment. For the model, excellent reference bearing based many objective calculations, for example, I-DBEA, MOEA/DD [126], and DEA[127] was shown in examination with NSGA-III on many-target DTLZ [128] and WFG [129] test issues.

Recently proposed transformative many-target calculations are typically assessed by computational trials on the DTLZ [130] and WFG [131] test issues in writing. Since these test issues were planned to utilize a comparative instrument [132], we may need to say that even the most often as possible used many objective calculations (i.e., NSGA-III) have not been assessed on a wide assortment of tests issues. Also, many objective problems are not generally hard for old-style EMO calculations in any event, when they have an enormous number of destinations. Along these lines, it could be conceivable that NSGA-III doesn't outflank old-style EMO calculations, for example, NSGA-II and SPEA in their applications to some other many-target test issues. In this study, we analyze the presentation of NSGA-III in examination with NSGA-II utilizing four astounding.

### 5.5.1 Algorithm for generation of NSGA Procedures

Input: S structured ref points Rs or supplied aspiration points Ra , parent population PARat

Output: PARat+1

1: for i=1, St = ∅,

2: Qat = Recombination + Mutation(Pt)

3: Rat = Pat ∪ Qat

4: (F1, F2, . . .) = Non-dominated-sorting(Rt)

5: Replicate

6: Sat = Sat ∪ Fai and i = i + 1

7: Till |St | ≥ N

8: Last front to be included: Fl = Fi

9: if |Sat | = N then

10: Pat+1 = Sat , break

11: else

12: Pat+1 = ∪ l−1 j=1 Fj

13: Points to be chosen from Fl : K = N − |Pat+1|

14: end if

### 5.5.2 NSGA-III for Mono-and Multi-target Problems

NSGA-III was proposed to take care of many-target streamlining issues having multiple goals, even though NSGA-III was exhibited to function admirably on three-target enhancement issues. Creators of NSGA-III didn't think about any bi-evenhanded or mono-target issues in the first examination. Here, we talk about the capability of utilizing NSGA-III in two-target issues and afterward feature its troubles in down-scaling to take care of mono-target enhancement issues.

The distinctions in working standards of NSGA-II and NSGA-III on two-target issues are illustrated beneath:

1. NSGA-III doesn't utilize any unequivocal determination administrator on Pat during the time spent making Qat. Then again, NSGA-II's determination administrator utilizes a non-ruled position and a swarming distance as an incentive to pick a victor between two attainable people from Pat. It is significant anyway that NSGA-III performs choice if and just if in any event one of the two people being looked at is infeasible. NSGA-III favors possible over infeasible and less violating over additional disregarding people.
2. NSGA-III uses many reference headings to keep up various arrangements, while NSGA-II uses a more versatile plan through its swarming distance administrator for a similar reason.

On the off chance that NSGA-III has a populace size practically indistinguishable from several picked reference headings contrasted with NSGA-II having an indistinguishable populace size as in NSGA-III, the previous will present a milder determination pressure. On average, every populace part in NSGA-III gets related with an alternate reference course and turns out to be too imperative even to consider being contrasted and another person. The solitary determination pressure comes from their mastery levels. Notwithstanding, the following point referenced above may create a critical distinction in their exhibitions. NSGA-III uses a pre-characterized direction instrument to pick assorted arrangements in the populace. However, NSGA-II uses no pre-characterized direction and generally stresses different arrangements on the fly. In this way, if the principal perspective is dealt with somehow or another and more choice pressing factor is presented, NSGA-III may turn into the same or even a preferable calculation over NSGA-II for tackling bi-target advancement issues. Allow us currently to talk about how NSGA-III would chip away at a mono-target advancement issue. In mono-target advancement, the control idea savages to wellness prevalence – a mastery check between two arrangements pick the one having better target esteem. Typically, one arrangement would involve each non-overwhelmed front in a mono-target issue at each age. In this manner, it is required to have N fronts in a populace of size N.

These attributes of mono-target issues influence the working of NSGA-III in an accompanying way:

1. To begin, in NSGA-III, there will be just one reference bearing (the solid line) to which all persons will be connected. Because the suggested population size is the smallest of four times the number of reference headings, NSGA-III will use a population of size four for all mono-target five advancement issues, which is too tiny for NSGA-recombination III's administrator to find appropriate posterity arrangements for all down to earth designs. This is a big challenge in combining a combined computation that will perform flawlessly for various mono-target problems.
2. Additionally, since no express determination administrator is utilized, the calculation will pick an irregular answer for its recombination and transformation administrators. The lone determination impact comes from the world-class saving activity for picking Pat+1 from a mix of Pat and Qat. This is another significant issue, which should be tended to while building up a brought-together methodology.
3. Note likewise that the niching activity of NSGA-III gets ancient for mono-target issues, as there is no understanding of the opposite distance of capacity esteem from the reference course. Each capacity esteem falls on the open line, giving an indistinguishable opposite distance of zero to every populace part.
4. NSGA-III's standardization likewise turns into an old activity for the equivalent above reason. It is presently evident that direct use of unique NSGA-III to mono-target improvement issues will bring about a minuscule populace size and an irregular determination measure, neither of which is suggested for a practical, transformative enhancement calculation. Notwithstanding, the niching and standardization administrators of NSGA-III are fundamental for it to be effective in multi and many-target improvement issues. In this way, a change of NSGA-III is required, so the subsequent brought together methodology gets proficient for mono to many-target issues by making the niching and standardization administrators naturally dead for mono objective issues and dynamic for multi and many-target issues.

## 5.6 Comparison Study

WSNs are made up of cheap, densely deployed multifunctional sensors with low energy consumption. They communicate with each other to gather spatial and temporal measurements of parameters such as temperature, sound, and many others. WSN is used in various applications, including environment and surroundings surveillance, manufacturing process control, congestion control, machine health monitoring, health checking applications, and home automation. In a sensor system, sensors are arbitrarily set up over an area without a pre-installed infrastructure. All sensors can examine the surroundings, gathering and routing data back to the sink. As sensors in a WSN are mostly battery operated and have inadequate ability, energy utilization turns out to be the primary concern because the network needs to work for a projected period functionally. Naturally, most of the energy consumption of sensors is on two main tasks: sensing and gathering data in the area and uploading information to the sink. Energy utilization on gathering is moderately constant since it only depends on the sampling speed.

Nevertheless, the state of power use on information uploading is quite complex than that of sense. Information uploading consumes a significant quantity of power in sensors for wireless communications, and also, the energy usage is in general non-homogeneous between sensors. Moreover, energy utilization is also dependent on the type of network topology and the position of the data sink. Consequently, the battery of the sensors near sink nodes depletes faster than others, as these sensors need to transmit more data packets. Thus, the energy consumption during data gathering is a significant and challenging issue in WSNs as it mainly finds out network life span. Owing to great practical significances, in the last few years, a lot of research efforts have been dedicated to proficient data collection in WSNs along with ample, innovative schemes.

Our motivation for this work is to minimize the power utilization and enhance the network life span via a two-step approach of clustering and routing of sensor nodes with the help of hybrid ACO/PSO. As a secondary objective, our main target is to find out the optimal path for the proposed approach that can best fit this type of network. Finally, this research aims to look for the best suitable routing to help further make a better and professional network for WSNs. The examination has been finished with particle swarm optimization and ant colony optimization, and genetic algorithm.

## 5.7 Hybrid ACO /PSO

In the hybrid ACO/PSO, the PSO is used to redesign the attributes in the ACO, which describes that the assurance of boundary doesn't depend upon counterfeit arrangement, anyway relies upon the pursuit of the particles in the PSO. We furthermore used an improved utilization of ACO; by this methodology, we have found the most restricted way or courses of ants. The yield shows that the updated findings do not simply reduce the number of routes in the ACO. However, also track down the briefest route and spot the farthest way. The result shows that the blend of ACO-PSO performs better than PSO. The ACO and PSO are the two best systems of swarm intelligence. PSO copies the sharing of data procedure. While ACO copies for maturing conduct of subordinate group ants colonization. The blend calculation has been carrying out to exploit the optima flow chart for the hybrid technique of ACP-PSO is shown in figure 5.4. A mixture of ACO/PSO improvement strategies has been applying. As a matter of first importance, Ant Colony Optimization (ACO) has been applying for discovering miniature courses from the hub to the sink (which like this creates the estimations of α-Best and β-Best). The outcomes obtained through the ACO method are given to PSO calculation for refinement. It provides a general population-based inquiry technique that uses Pbest, Gbest and particles current, and stream position for finding combing area. The PSO figuring is applied to find the best, most limited course. Transmission of information happens after tracking down the briefest.

### 5.7.1 Flow Chart of Proposed Methodology

Flow chart of proposed algorithm shows the step-by-step procedure for selecting CH using NN, applying hybrid ACO/PSO to find optimized route, evaluation of energy dissipation, and network performance. Figure 5.5 shows the flow chart of the proposed algorithm.

### 5.7.2 Performance Metrics

The various parameters used to evaluate the proposed algorithm are first node dead, teenth node dead, all nodes dead, packets sent to BS, packets sent to CH, and remaining energy.

a. **First Node Dead:** This parameter indicates when the first node will become dead. The case in which the first node dead occurs late is considered to be the best.

b. **Teenth Node Dead:** This parameter indicates when 50 percent of nodes will become dead. The case in which the death of nodes occurs late is considered to be the best.

c. **All Nodes Dead:** This parameter indicates when all nodes will become dead. The case in which the death of all nodes occurs late is considered to be energy efficient.

d. **Packets sent to BS:** The number of packets received by BS. Using this parameter, the performance of LEACH, RZ LEACH, is compared with the proposed algorithm.

e. **Packets sent to CH:** The number of packets received by CH. Using this parameter, the performance of LEACH, RZ LEACH, is compared with the proposed algorithm

f. **Remaining Energy:** It is characterized as the amount of energy that remained left with sensor motes. It is figured at the starting of every round during performance calculation. This boundary assists with deciding the solidness period, utilization of energy, and lifetime of WSNs. This parameter will help to determine the energy consumption stable period and lifetime of wireless sensor networks.

g. **Network Lifetime:** This parameter helps to evaluate the algorithm performance designed for the reduction of energy consumption. It is measured by the time during which WSNs are operational, i.e., from the beginning to the death of the last alive node. More the network lifetime better will be the approach.

*Table 5.1 Comparison study of different optimization algorithms.*

| Problem Domain | Particle Swarm Optimization | Ant Colony Optimization | Genetic Algorithms |
|---|---|---|---|
| Node allotment | The centralized nature of Particle Swarm Optimization limits the zone of inclusion openings of fixed positioning of the hub. | Distributed nature of Ant Colony Optimization performs better in addressing the portable hub arrangement issue. | Suitable for irregular, just as for deterministic hub organization. |
| Data collection | Moderately appropriate. | An instance of enormous scope and dynamic WSNs can perform better. | Suitable in tracking down the base number of accumulations focuses while routing information to the BS. |
| Routing and clustering procedure | Performs better in choosing the high energy hub as Cluster Heads can efficiently discover the perfect route for each round. | Performs better as far as organization lifetime and information conveyance to the BS. | They are used as a pr-characterized group which helps in the deduction of communiqué space. |

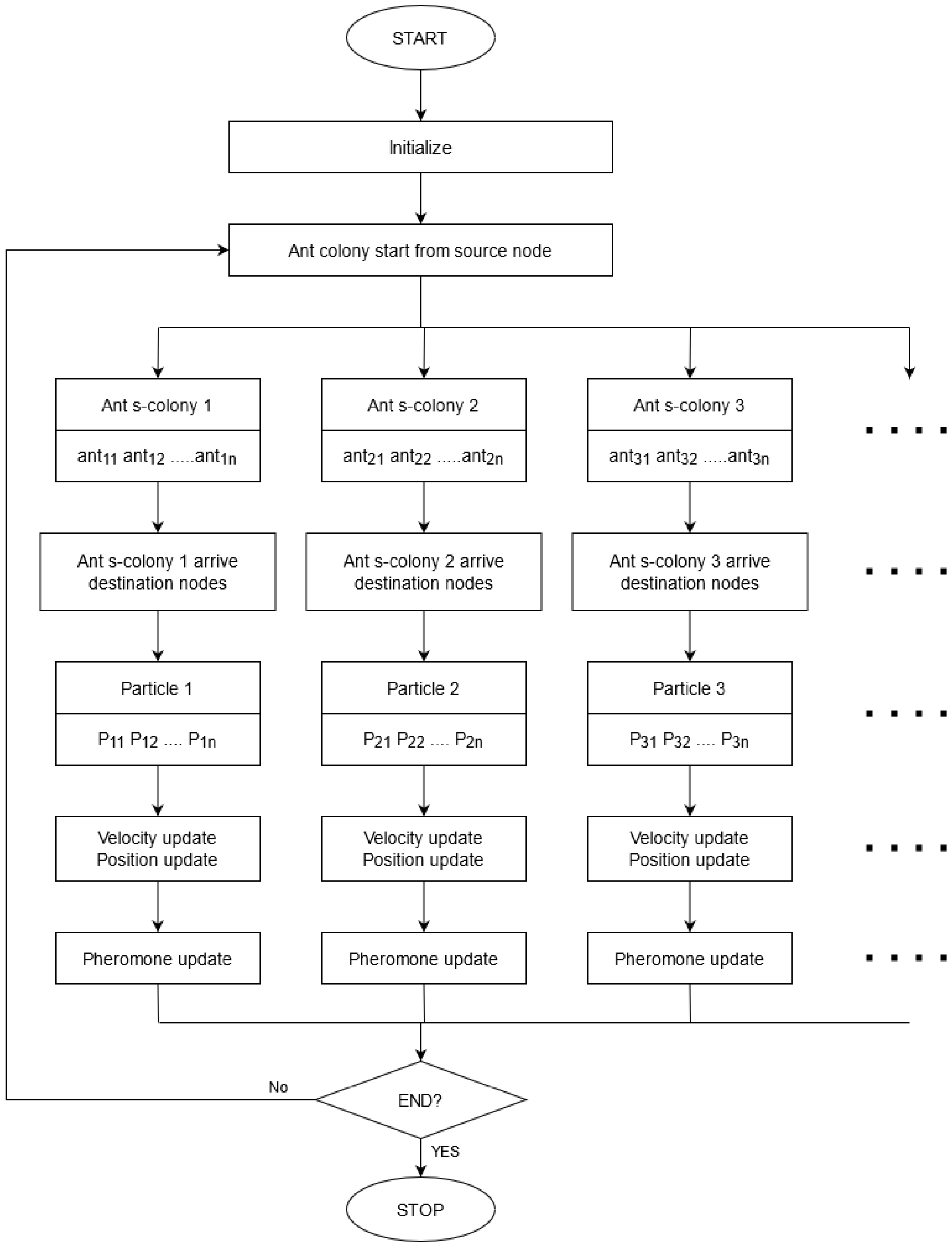



***Figure 5.4 Flow Chart of hybrid ACO/PSO***

### 5.7.3 Simulation

MATLAB is utilized for simulating on account of a simple calculation of results. The boundary debasing the exhibition of the framework has been dismissed. For reproduction, we dissect results, for example, while considering four cases regarding the number of nodes and afterward region-wise.

**CASE 1:** The proposed NN-LEACH is compared with conventional LEACH [8] and Optimized LEACH [133] based on the node scalability by varying the number of motes in the step of 20 (100,120………) up to maximum value of 400 motes.

**CASE 2:** The proposed NN-LEACH is compared with existing RZ-LEACH, ACO-RZLEACH [116] based on the node scalability by varying number of motes and adjusting of the threshold values of various parameters like alive nodes, dead nodes, the packet sent to BS packet sent to CHs, and energy remained.

**CASE 3:** In this case, the adaptability issue is considered for the organization's differing size for the consistent number of hubs (n=100). The presentation of the present framework has been contrasted and existing one for the accompanying local sizes, for example, 50m by 50m, 100m by 100m, 150m by 150m, 250m by 250m, 350m by 350m, 450 by 450 and 500m by 500m against the number of rounds.

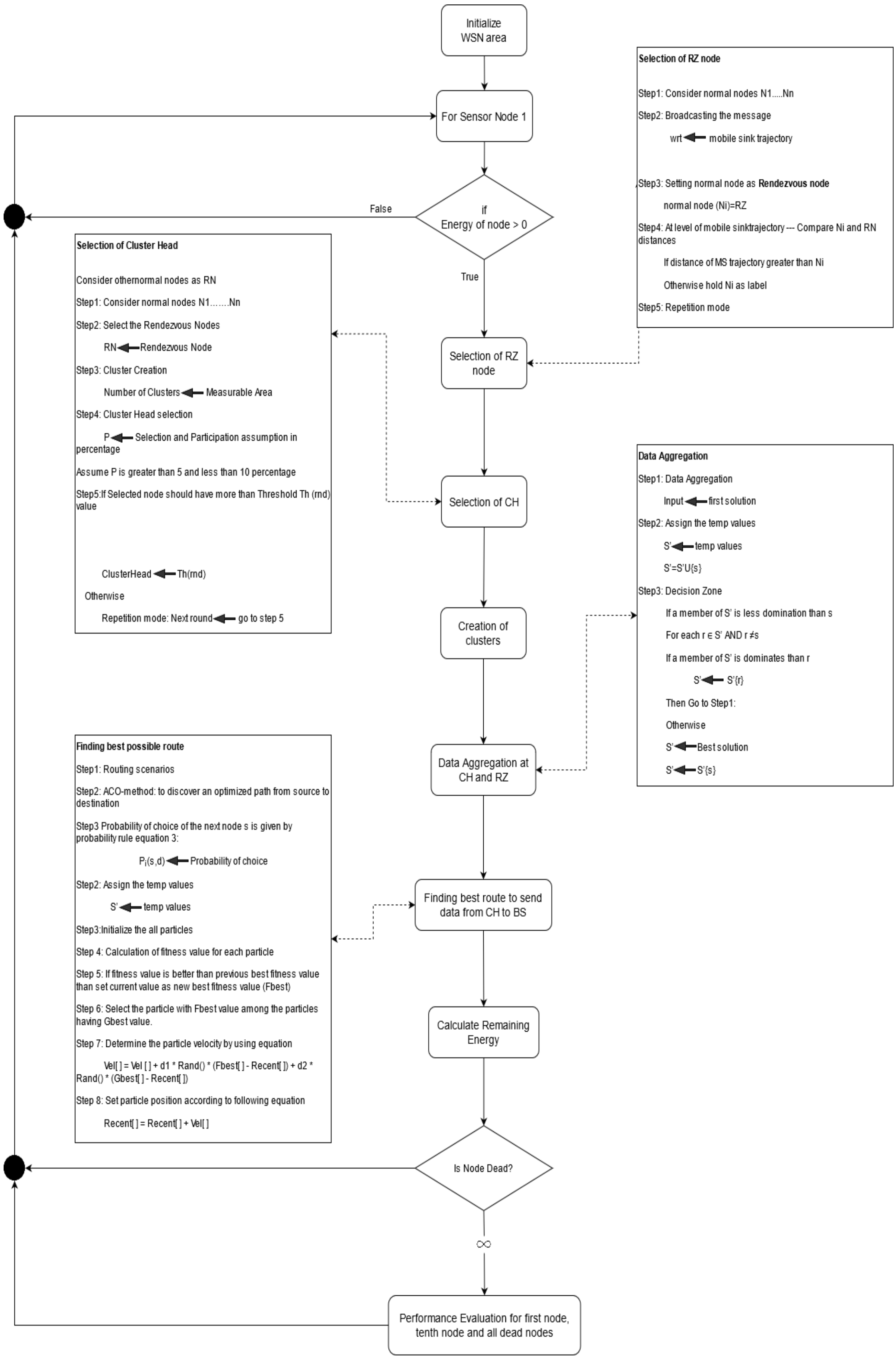



***Figure 5.5 Flow Chart of Proposed Methodology*.**

# 6 Results

Proposed approach is evaluated in this chapter by comparing the basic LEACH [8] and Optimized LEACH [133] in section 1 of the chapter by implementing node scalability. In section 2 of the chapter proposed approach is compared with existing RZ-LEACH and ACO-RZLEACH by implementing area and node scalability.

## 6.1 Evaluating Proposed Model

Simulation is performed on MATLAB version R2014a considering fixed area of 150 m × 150 m. Initially, 100 nodes are taken as sample population sink is moving along y-axis as shown in Figure 6.1. In the present work, we have taken static nodes and mobile sink taking nodes scalability from 100, 120, 140, increasing by 20 nodes and maximum up to 400 nodes as shown in figure 6.1.

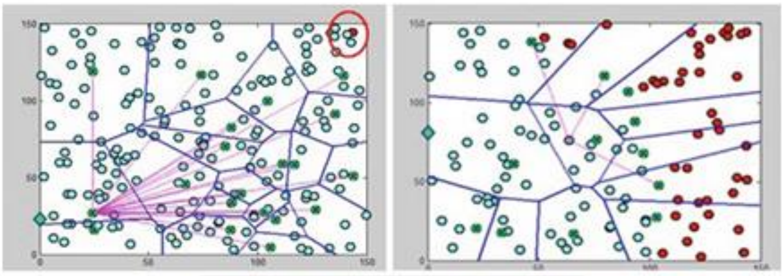


***Figure 6.1 Initial setup with fixed network area of 150 m × 150 m***

Initial parameters used in simulation model are described in Table 6.1.

***Table 6.1: Initial Parameters of Considered Network.***

| Parame | Values | Description |
|---|---|---|
| $E_0$ | 0.3 J | Initial energy |
| $E_{amp}$ | 0:0013 | Energy consumed by the power amplifier on multipath model |
| $E_{fs}$ | 10 pJ/bit/m$^2$ | Energy consumed by the power amplifier on the free space model |
| $E_{RX}$ | 50 nJ/bit | Energy consumed by radio electronics in receiving mode |
| $E_{TX}$ | 50 nJ/bit | Energy consumed by radio electronics in transmit mode |
| $l$ | 4000 bits | Size of data packet |
| $R_X$ | 16% bits | Constant related to the width of region where RN is chosen |
| $X_m$; $Y_m$ | 100 | Length and width of the region in m |

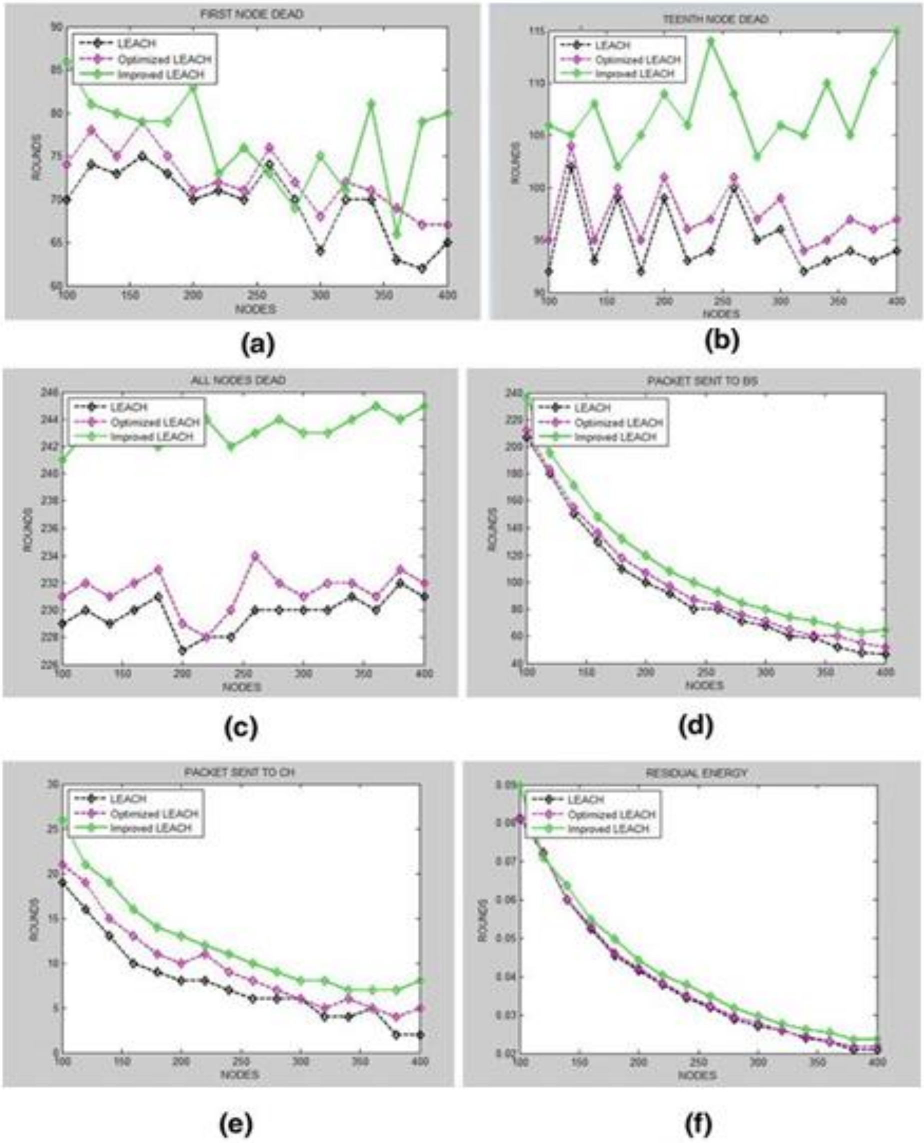



***Figure 6.2 Comparing LEACH, optimized and improved LEACH first node dead (a); 25% nodes dead (b); all nodes dead (c); packets sent to BS (d); packets sent to CH (e); and residual energy (f)***

Nodes are placed randomly in the given area. In the proposed work, the perfor- mance of improved LEACH is compared with LEACH and optimized LEACH observing number of rounds consumed for first, teenth (25%) and all nodes dead as shown in figure 6.1. Other parameters observed are residual energy, packets sent to base station and cluster head after round numbers 100, 120, 140,… 400. Initially, all the nodes are at same energy level, i.e. 0:3 J, and by scaling the nodes, we compare residual energy of the nodes shown in figure 6.2.

*Table 6.2: Simulation results for first, tenth and all nodes dead*

| No. of nodes | No. of rounds for first node dead | | | No. of rounds for tenth 25% nodes dead | | | No. of rounds for all nodes dead | | |
|---|---|---|---|---|---|---|---|---|---|
| | LEACH | Optimized LEACH | Improved LEACH | LEACH | Optimized LEACH | Improved LEACH | LEACH | Optimized LEACH | Improved LEACH |
| 100 | 70 | 74 | 86 | 92 | 95 | 106 | 222 | 232 | 241 |
| 120 | 73 | 78 | 81 | 100 | 104 | 105 | 222 | 233 | 243 |
| 140 | 70 | 75 | 80 | 90 | 95 | 108 | 220 | 233 | 244 |
| 160 | 73 | 79 | 79 | 96 | 100 | 102 | 224 | 234 | 243 |
| 180 | 69 | 75 | 79 | 92 | 95 | 105 | 224 | 234 | 242 |
| 200 | 65 | 71 | 83 | 99 | 101 | 109 | 223 | 233 | 244 |
| 220 | 68 | 72 | 73 | 93 | 96 | 106 | 224 | 233 | 244 |
| 240 | 67 | 71 | 76 | 93 | 97 | 114 | 222 | 232 | 242 |
| 260 | 72 | 76 | 73 | 95 | 101 | 109 | 223 | 235 | 243 |
| 280 | 67 | 72 | 69 | 94 | 97 | 103 | 224 | 235 | 244 |
| 300 | 63 | 68 | 75 | 95 | 99 | 106 | 222 | 234 | 243 |
| 320 | 67 | 72 | 71 | 91 | 94 | 105 | 223 | 233 | 243 |
| 340 | 67 | 71 | 81 | 91 | 95 | 110 | 224 | 235 | 244 |
| 360 | 64 | 69 | 66 | 94 | 97 | 105 | 225 | 234 | 245 |
| 380 | 62 | 67 | 79 | 94 | 96 | 111 | 225 | 234 | 244 |
| 400 | 62 | 67 | 80 | 94 | 97 | 115 | 224 | 235 | 245 |

*Table 6.3: Results for residual energy packets received by cluster head and packets received by base station*

| No. of nodes | Residual energy | | | Packets received by cluster head | | | Packets received by base station | | |
|---|---|---|---|---|---|---|---|---|---|
| | LEACH | Optimized LEACH | Improved LEACH | LEACH | Optimized LEACH | Improved LEACH | LEACH | Optimized LEACH | Improved LEACH |
| 100 | 0.0815 | 0.0817 | 0.0896 | 212 | 214 | 236 | 21 | 23 | 26 |
| 120 | 0.0725 | 0.0726 | 0.071 | 181 | 185 | 195 | 18 | 20 | 21 |
| 140 | 0.0603 | 0.0604 | 0.0636 | 155 | 156 | 171 | 15 | 17 | 19 |
| 160 | 0.0532 | 0.0531 | 0.055 | 135 | 138 | 148 | 13 | 15 | 16 |
| 180 | 0.0460 | 0.0462 | 0.0498 | 118 | 120 | 132 | 11 | 13 | 14 |
| 200 | 0.0421 | 0.0423 | 0.0443 | 107 | 109 | 120 | 11 | 12 | 13 |
| 220 | 0.0383 | 0.0385 | 0.0403 | 96 | 99 | 108 | 10 | 11 | 12 |
| 240 | 0.0350 | 0.0352 | 0.0379 | 88 | 90 | 100 | 9 | 10 | 11 |
| 260 | 0.0325 | 0.0325 | 0.0348 | 82 | 85 | 93 | 8 | 9 | 10 |
| 280 | 0.0294 | 0.0296 | 0.0317 | 75 | 78 | 85 | 8 | 8 | 9 |
| 300 | 0.0026 | 0.0028 | 0.0297 | 71 | 73 | 80 | 7 | 8 | 8 |
| 320 | 0.025 | 0.026 | 0.0277 | 64 | 67 | 74 | 7 | 7 | 8 |
| 340 | 0.0241 | 0.0244 | 0.0263 | 61 | 64 | 71 | 6 | 7 | 7 |
| 360 | 0.0231 | 0.0233 | 0.0254 | 57 | 61 | 67 | 6 | 6 | 7 |
| 380 | 0.0216 | 0.0218 | 0.0236 | 57 | 57 | 63 | 5 | 6 | 7 |
| 400 | 0.020 | 0.022 | 0.0238 | 59 | 57 | 65 | 6 | 7 | 8 |

It is noticed from the graphs Figure 6.2 and Tables 6.2, and 6.3 that proposed LEACH is having better results in terms of number of rounds for first, tenth and all nodes dead for the given population of interest. Further, residual energy is marginally more, and a number of packets sent to base station and cluster head are more in proposed LEACH. All these values lead to reduced energy consumption and hence increased network lifetime. A number of packets sent to base station and cluster head are significant performance evaluator.

## 6.2 Area Scalability

In this part, the outcomes of RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is performed. Further, the performance of the proposed model is checked after running the simulation. Table 6.1 shows the area scalability feature with 300 nodes in each simulation. Also, the nodes are distributed in the 50 m × 50 m area, 100 m × 100 m, 150 m × 150 m, 200 m × 200 m, 300 m × 300 m, 350 m × 350 m, 400 m × 400 m, 450 m × 450 m and 500 m × 500 m. Below table 6.4 illustrates the specifications of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH technique.

***Table 6.4: Area Scalability with number of nodes n = 300***

| **Area in m square Xm X Ym** | **Number of Rounds for all node's dead** | | |
|---|---|---|---|
| | **RZLEACH** | **ACO- RZLEACH** | **NSGA HNN BASED HYBRID ACO/PSO LEACH** |
| 50 X 50 | 496 | 723 | 731 |
| 100 X 100 | 498 | 703 | 733 |
| 150 X 150 | 514 | 731 | 731 |
| 200 X 200 | 524 | 735 | 731 |
| 300 X 300 | 456 | 719 | 733 |
| 350 X 350 | 498 | 724 | 732 |
| 400 X 400 | 461 | 732 | 733 |
| 450 X 450 | 410 | 729 | 734 |
| 500 X 500 | 529 | 702 | 732 |

**Case1: Area = 50m × 50m and Nodes = 300**

We will compare our proposed NN LEACH model with existing RZLEACH and ACO RZ LEACH by considering area 50m X 50 m and number of motes against number of rounds and varying different parameters like alive nodes, dead nodes, and remaining node energy.

Initially, WSNs are considered to be consist of 300 sensor nodes that are randomly placed in the 50m X 50 m region. The black line represents the concert of the RZLEACH, whereas the red line represents the performance of the ACO RZLEACH, and the blue line is delt with NSGA HNN BASED HYBRID ACO/PSO LEACH protocol.

**ALIVE NODES: -** Alive nodes are defined as the number of nodes that are still alive against the timestamp. It represents the lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

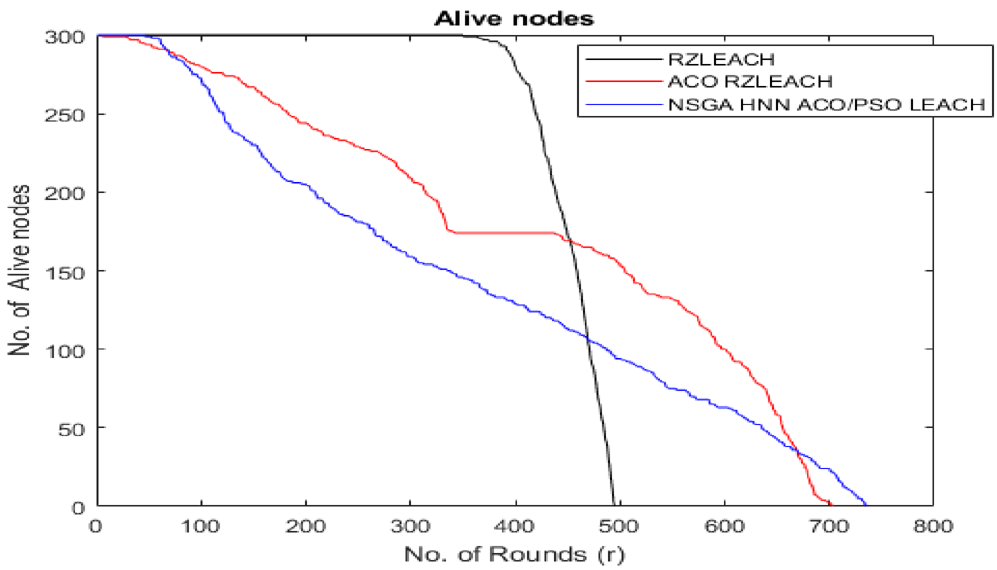



***Figure6.3(a) Alive nodes for area scalability with area 50X50 and nodes =300***

Figure 6.3(a) signifies the number of nodes that are alive during rounds. It is exposed that the First node dead of RZLEACH starts at about 350 rounds. Last node dead at about 496, and First node dead of ACO RZLEACH begins at around 50 rounds and Last node dead at about 723 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the first node dead starts at about 100 rounds and last node dead at about 731 because NSGA HNN BASED HYBRID ACO/PSO LEACH takes time for the best solution initially.

**DEAD NODES: -** Figure 6.3(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; as shown in graph number of dead nodes of the proposed approach is less than the current approaches.

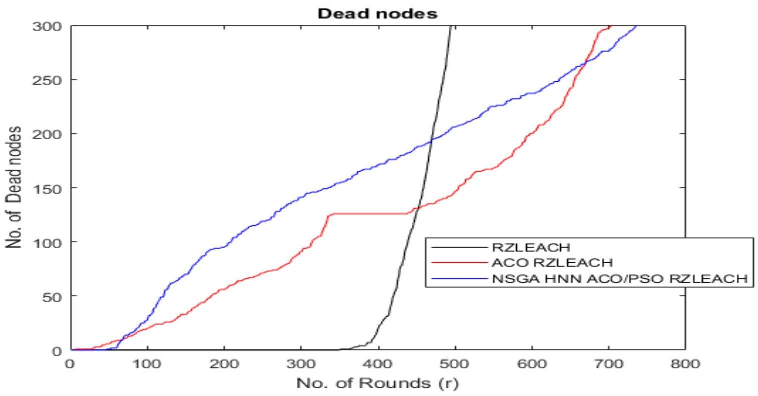


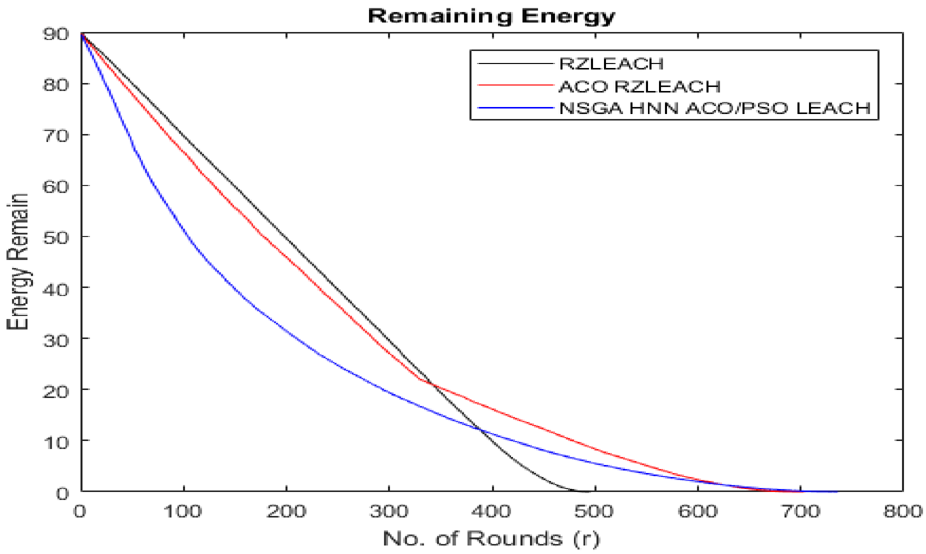

***Figure6.3 (b) Dead nodes for area scalability with area 50X50 and nodes =300***

Figure6.3(b) illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH. In RZLEACH, the nodes are dead at 496 rounds, and for ACO RZLEACH, it is 723 rounds, and for NSGA HNN BASED HYBRID ACO/PSO LEACH, it is at 731 rounds.

**Remaining Energy -** It is defined as the quantity of energy left with sensor mote, or is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power. The average remaining energy diminutions with the upsurge in the number of nodes. It is calculated at the commencement of individual round through the execution of the process that is considered with

$$\mathrm{RemEng(re)} = \sum_{\mathrm{N}=1}^{\mathrm{n}} \mathrm{E_{rr}(Nd)}$$

Where $E_{rr}(Nd)$ is the energy of $Nd^{th}$ node for the $rr^{th}$ round.




(a) Remaining Energy

***Figure6.3(c) Remaining energy for area scalability with area 50X50 and nodes =300***

Figure6.3(c) represents that the remaining energy still present in the case of RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 496,723 and 731, respectively.

**CASE 2*: Area = 100m ×100m and Nodes = 300***

NSGA HNN BASED HYBRID ACO/PSO LEACH effectiveness is evaluated in this section by implementing an area equal to 100m × 100m. This effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

**Alive Nodes: -** It signifies the total number of nodes which are still alive This measurement determines the lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

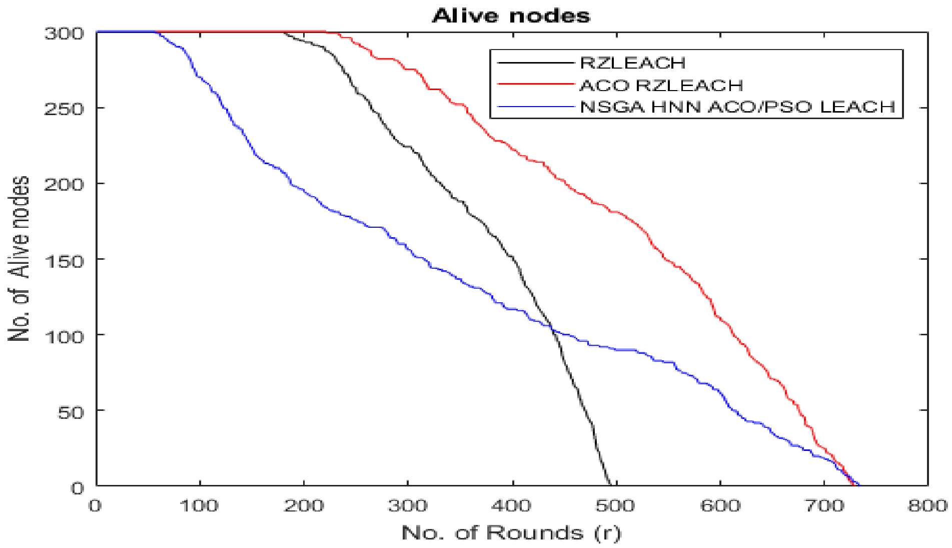



***Figure6.4 (a) Alive nodes for area scalability with area 100 X 100 and nodes =300***

Figure 6.4(a) signifies the number of nodes that are alive against number of rounds. It is shown that the First node dead of RZLEACH starts at about round number190. Last node dead at about at round number 498, and first node dead of ACO RZLEACH starts at around 280 rounds and last node dead at about 703 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the first node dead starts at about 90 rounds and last node dead at about 733 because NSGA HNN BASED HYBRID ACO/PSO LEACH takes time for their best solution initially to select the best path.

**Dead Nodes: -** Figure 6.4(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; it is demonstrated from the diagram that the amount of dead nodes of our planned method is less than the current approaches.

Figure 6.4(b) illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH.

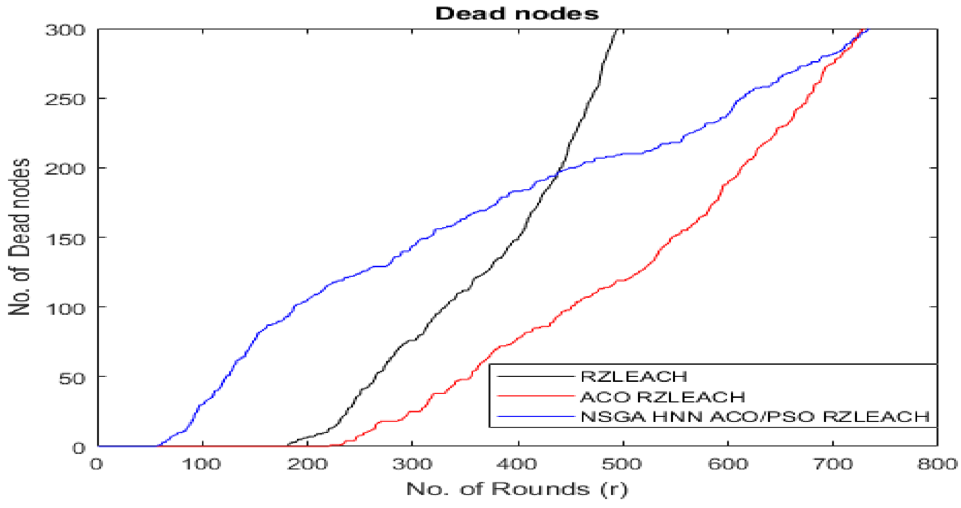
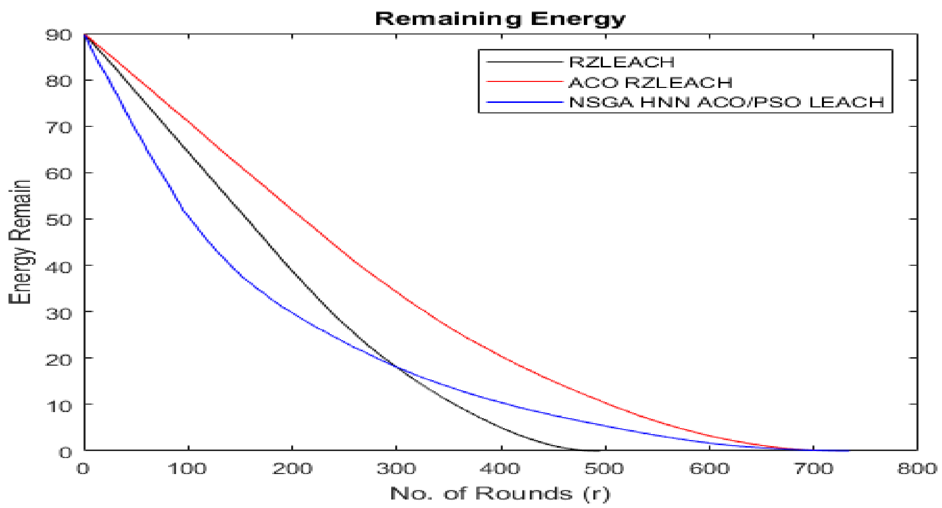



*Figure6.4 (b) Dead nodes for area scalability with area 100 X 100 and nodes =300*

In RZLEACH, the nodes are dead at 498 rounds, and for ACO RZLEACH, it is 703 rounds, and for NSGA HNN BASED HYBRID ACO/PSO LEACH, it is at 733 rounds.

**REMAINING ENERGY: -** It is restricted as the quantity of energy left with sensor mote, or the average remaining energy is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power.




(a) Remaining Energy

*Figure6.4 (c) Remaining Energy for area scalability with area 100 X 100 and nodes =300*

Figure6.2(c) represents that the remaining energy still present in the case of RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 498,703 and 733, respectively.

**CASE 3: Area = 150m ×150 m  and Nodes = 300**

**ALIVE NODES: -** It signifies the number of nodes that are still alive against the timestamp. This measurement demonstrates the whole lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

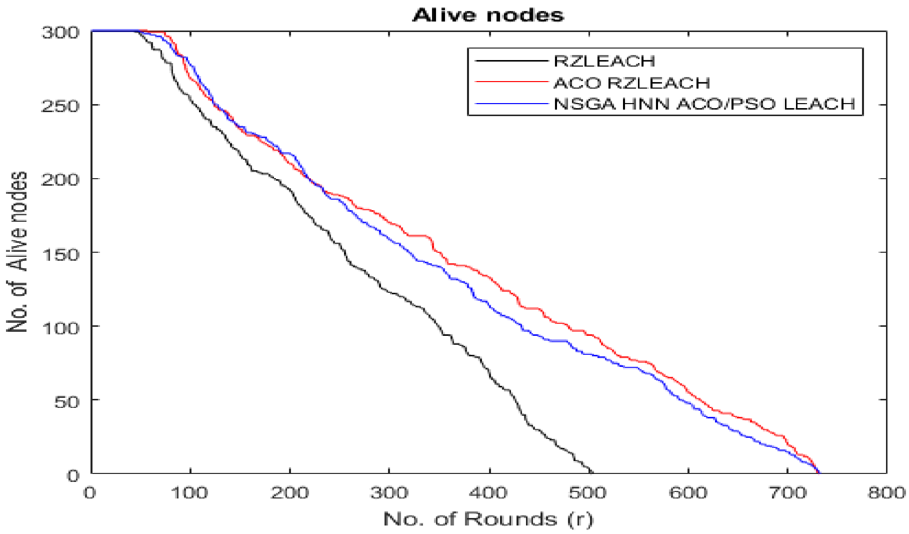



***Figure6.5(a)  Alive nodes for area scalability with area 150X150 and nodes =300***

Figure6.5(a) signifies the number of nodes that are alive during rounds. It is exposed that the First node dead of RZLEACH starts at about 90 rounds. Last node dead at about 514, and First node dead of ACO RZLEACH starts at around 100 rounds and last node dead at about 731 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the first node dead starts at about 100 rounds and last node dead at about 731 because NSGA HNN BASED HYBRID ACO/PSO LEACH takes time for their best solution initially to select the best path.

**DEAD NODES: -** Figure 6.5(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; it is demonstrated from the diagram that the number of dead nodes of our planned method is less than the current approaches.

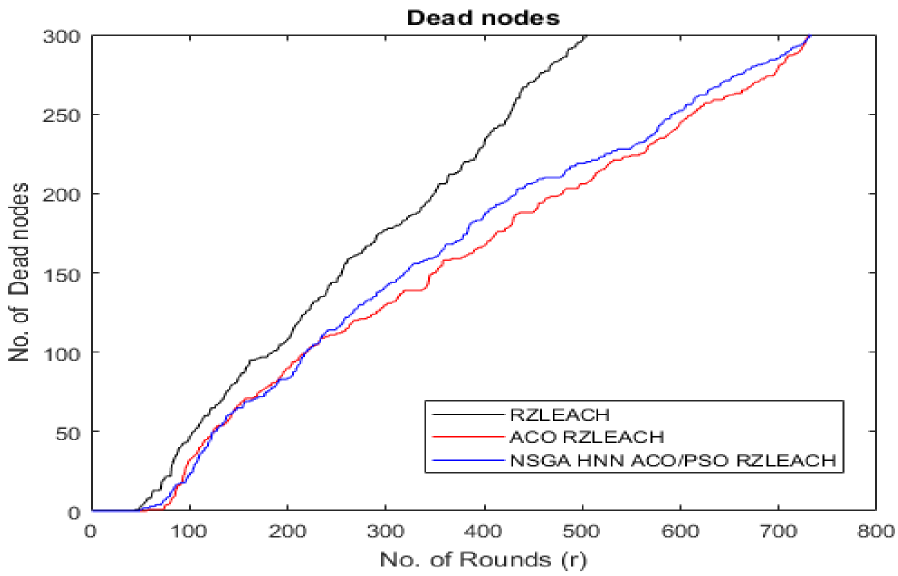
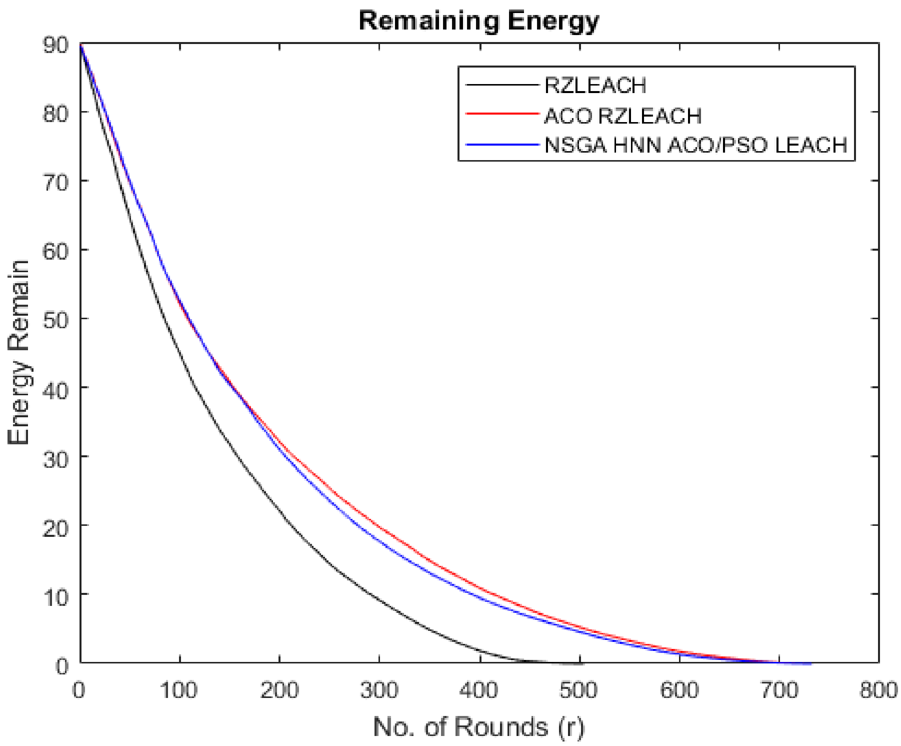



***Figure6.5(b) Dead nodes for area scalability with area 150X150 and nodes =300***

The figure illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH. In RZLEACH, the nodes are dead at 514 rounds, and for ACO RZLEACH, it is 731 rounds, and for NSGA HNN BASED HYBRID ACO/PSO LEACH, it is at 731 rounds.

**REMAINING ENERGY: -** It is restricted as the quantity of energy left with sensor mote, or the average remaining energy is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power. Figure6.5(c) represents that the remaining energy still present in the case of RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 514,731 and 731, respectively.




(a) Remaining Energy

***Figure6.5(c) Remaining energy nodes for area scalability with area 150X150 and nodes =300***

**CASE 4: Area = 200m ×200 m and Nodes = 300**

In this case, the number of nodes is 300 against 200m ×200 m to calculate the performance of various parameters like dead nodes, alive nodes, and energy remained.

**ALIVE NODES: -** It signifies the number of nodes that are still alive against the timestamp. This measurement demonstrates the whole lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

Figure6.6(a) signifies the number of nodes that are alive during rounds. It is exposed that the First node dead of RZLEACH starts at about 50 round, and Last node dead at about 524, and First node dead of ACO RZLEACH starts at around 60 rounds and last node dead at about 735 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the FIRST NODE DEAD starts at about 110 rounds and last node dead at about 731 because NSGA HNN BASED HYBRID ACO/PSO LEACH takes time for their best solution initially to select the best path.

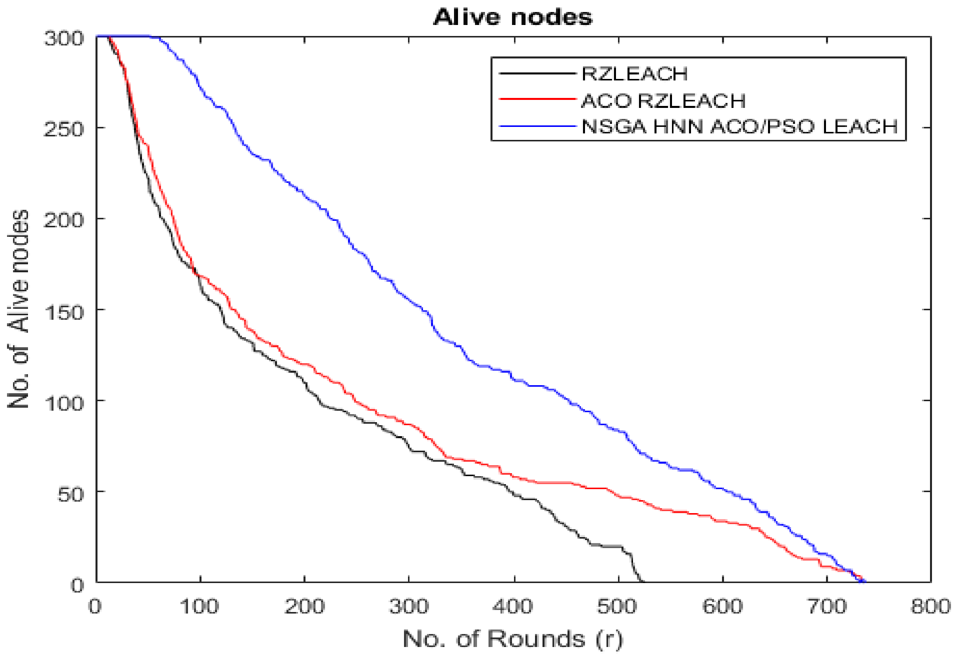



*Figure6.6(a) Alive nodes for area scalability with area 200X200 and nodes =300*

**DEAD NODES: -** Figure 6.6(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; it is demonstrated from the diagram that the amount of dead nodes of our planned method is less than the current approaches.

Figure6.6(b) illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH. In RZLEACH, the nodes are dead at 524 rounds, and for ACO RZLEACH, it is 735 rounds, and for NSGA HNN BASED HYBRID ACO/PSO LEACH, it is at 731 rounds.

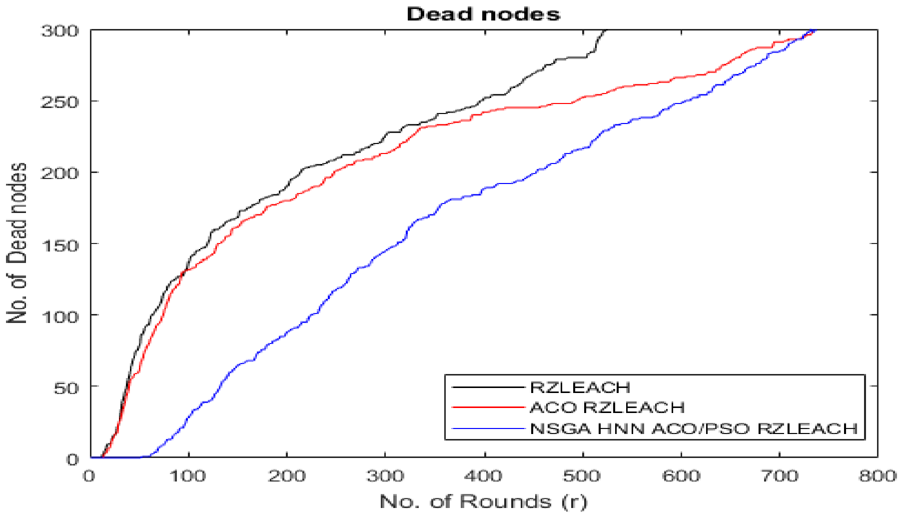



***Figure6.6(b) Dead nodes for area scalability with area 200X200 and nodes =300***

**REMAINING ENERGY: -** It is restricted as the quantity of energy left with sensor mote, or the average remaining energy is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power.

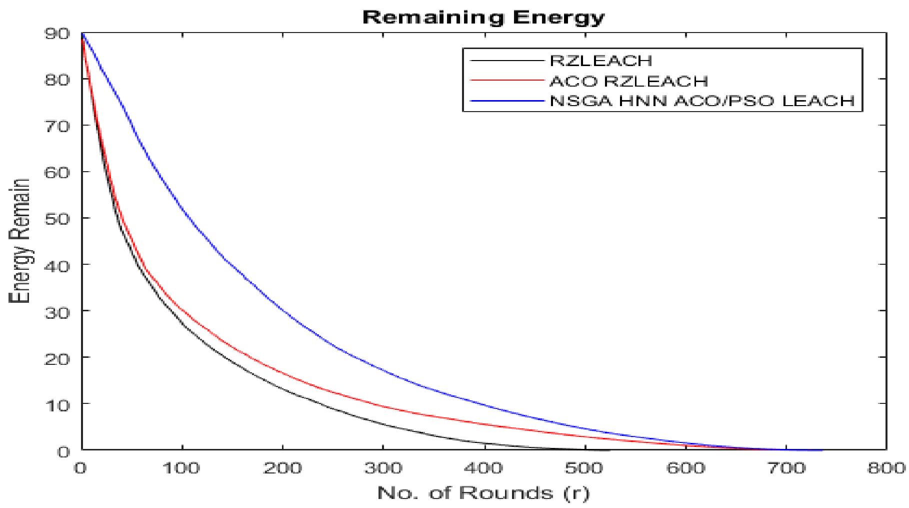



***Figure6.6(c) Remaining Energy for area scalability with area 200X200 and nodes =300***

Figure6.6(c) represents that the remaining energy still present in the case of RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 524,735 and 731, respectively.

**CASE 5: Area = 300m ×300 m  and Nodes = 300**

In this case, the number of nodes is 300 against the area of 300m ×300 m to calculate the performance of various parameters like dead nodes, alive nodes, and energy remained.

**ALIVE NODES: -** It signifies the number of nodes that are still alive against the timestamp. This measurement demonstrates the whole lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

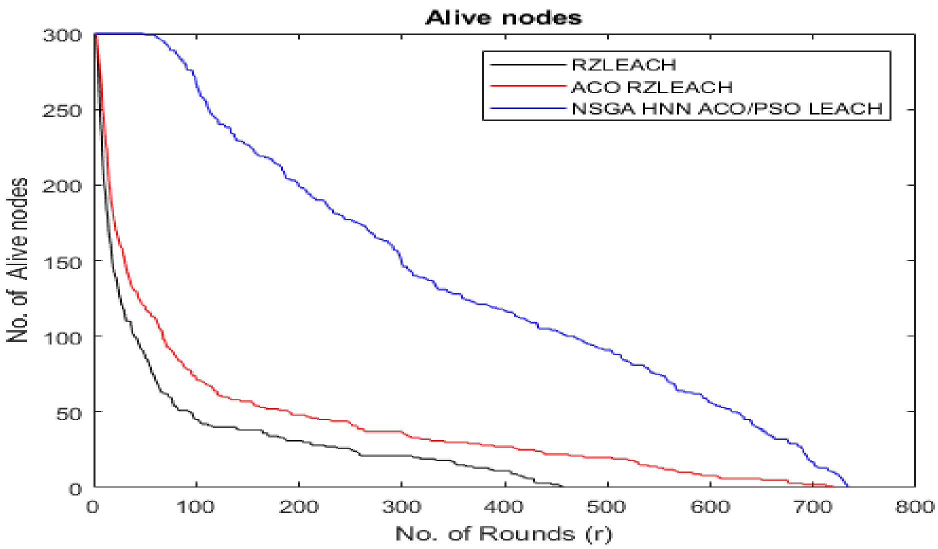



***Figure6.7(a) :Alive nodes for area scalability with area 300X300 and nodes =300***

Figure6.7(a) shows that the stability period of NSGA HNN BASED HYBRID ACO/PSO LEACH is extended than that of the other case. It has been observed that NSGA HNN BASED HYBRID ACO/PSO LEACH has some advantages in terms of alive nodes, which enhance network stability. It has undoubtedly exposed that in the case of active nodes, NSGA HNN BASED HYBRID ACO/PSO LEACH performs better than that of RZLEACH and ACO RZLEACH protocol. It is exposed that the First node dead of RZLEACH starts at about 20 rounds. Last node dead at about 456 and first node dead of ACO RZLEACH starts at around 25 rounds and last node dead at about 719 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the first node dead starts at about 90 rounds and last node dead at about 733 because NSGA HNN

BASED HYBRID ACO/PSO LEACH takes time for their best solution initially to select the best path.

**DEAD NODES: -** Figure 6.7(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; it is demonstrated from the diagram that the number of dead nodes of our planned method is less than the current approaches.

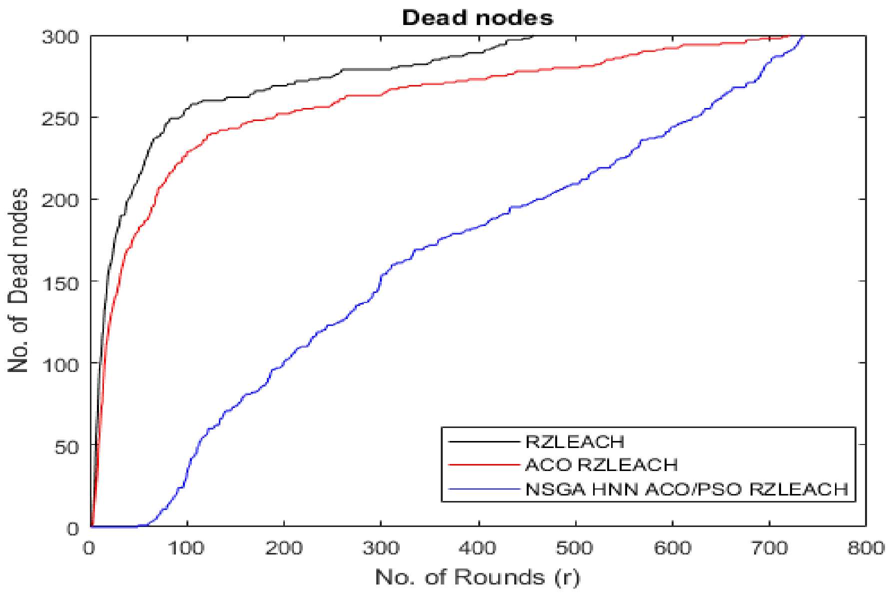



***Figure6.7(b)  Dead nodes for area scalability with area 300X300 and nodes =300***

Figure6.7(b) illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH. In RZLEACH, the nodes are dead at 456 rounds, and for ACO RZLEACH, it is 719 rounds, and for NSGA HNN BASED HYBRID ACO/PSO LEACH, it is at 733 rounds.

**REMAINING ENERGY: -** It is restricted as the quantity of energy left with sensor mote, or the average remaining energy is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power.

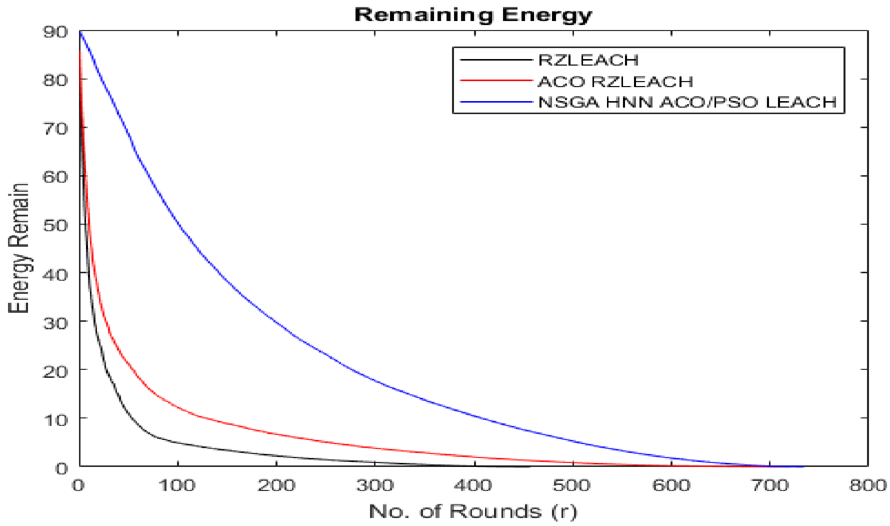



***Figure6.7(c) Dead nodes for area scalability with area 300X300 and nodes =300***

Figure6.7(c) represents that the remaining energy still present in the case of RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 456,719 and 733, respectively.

**CASE 6: Area = 350m ×350 m and Nodes = 300**

In this case, the number of nodes is 300 against the area of 300m ×300 m to calculate the performance of various parameters like dead nodes, alive nodes, and energy remained.

**ALIVE NODES: -** It signifies the number of nodes that are still alive against the timestamp. This measurement demonstrates the whole lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

Figure6.8(a) shows that the stability period of NSGA HNN BASED HYBRID ACO/PSO LEACH is extended than that of the other case. It has been observed that NSGA HNN BASED HYBRID ACO/PSO LEACH has some advantages in terms of alive nodes, which enhance network stability. It has undoubtedly exposed that in the case of active nodes, NSGA HNN BASED HYBRID ACO/PSO LEACH performs better than that of RZLEACH and ACO RZLEACH protocol.

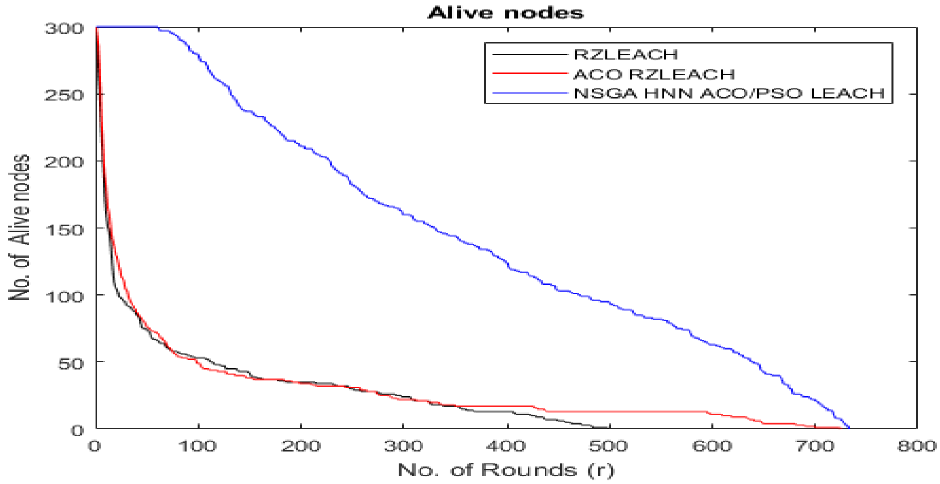



*Figure6.8(a)  Alive nodes for area scalability with area 350X350 and nodes =300*

It is exposed that the First node dead of RZLEACH starts at about 10 rounds. Last node dead  at about 498, and first node dead of ACO RZLEACH starts at around 12 rounds and last node dead at about 724 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the  starts at about 90 rounds and last node dead at about 732 because NSGA HNN BASED HYBRID ACO/PSO LEACH takes time for their best solution initially to select the best path.

**DEAD NODES: -** Figure 6.8(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; it is clearly demonstrated from the diagram that the number of dead nodes of our planned method is less than the current approaches.

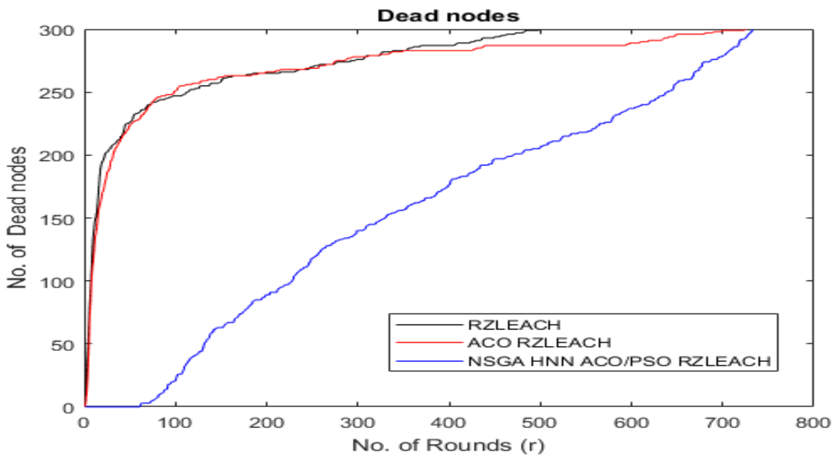
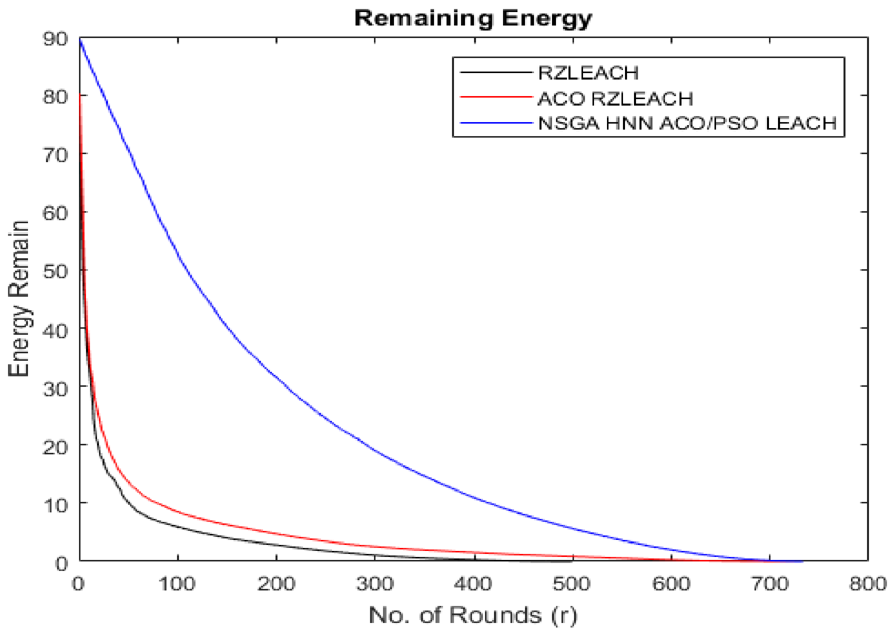


*Figure6.8(b) Dead nodes for area scalability with area 350X350 and nodes =300*

Figure6.8(b) illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH. In RZLEACH, the nodes are dead at 498 rounds, and for ACO RZLEACH, it is 724 rounds, and for NSGA HNN BASED HYBRID ACO/PSO LEACH, it is at 732 rounds.

**REMAINING ENERGY: -** It is restricted as the quantity of energy left with sensor mote, or the average remaining energy is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power.




(a) Remaining Energy

*Figure6.8(c) Remaining energy for area scalability with area 350X350 and nodes =300*

The figure6,6( c )represents that the remaining energy still present in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 498,724 and 732, respectively.

**CASE 7: Area = 400m ×400 m  and Nodes = 300**

In this case, the number of nodes is 300 against 400m ×400 m to calculate the performance of various parameters like dead nodes, alive nodes, and energy remained.

**ALIVE NODES: -** It signifies the number of nodes that are still alive against the timestamp. This measurement demonstrates the whole lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

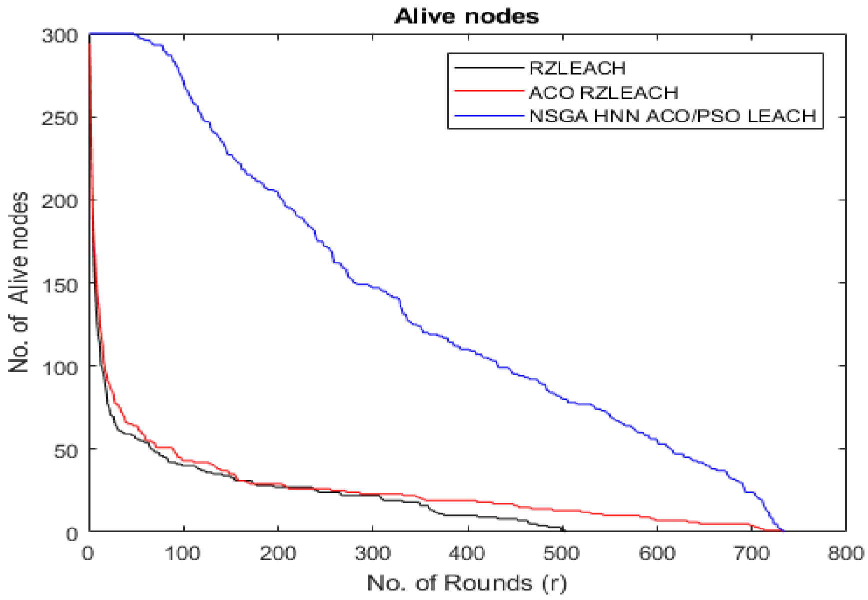



***Figure6.9(a) Alive nodes  for area scalability with area 400X400 and nodes =300***

Figure6.9(a) shows that the stability period of NSGA HNN BASED HYBRID ACO/PSO LEACH is extended than that of the other case. It has been observed that NSGA HNN BASED HYBRID ACO/PSO LEACH has some advantages in terms of alive nodes, which enhance network stability. It has undoubtedly exposed that in the case of active nodes, NSGA HNN BASED HYBRID ACO/PSO LEACH performs better than that of RZLEACH and ACO RZLEACH protocol. It is exposed that the First node dead  of RZLEACH starts at about 9 rounds. Last node dead at about 461, and first node dead of ACO RZLEACH starts at around 11 rounds and last node dead at about 732 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the first node dead starts at about 80 rounds and last node dead at about 733 because NSGA HNN

BASED HYBRID ACO/PSO LEACH takes time for their best solution initially to select the best path.

**DEAD NODES: -** Figure 6.9(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; it is demonstrated from the diagram that the amount of dead nodes of our planned method is less than the current approaches.

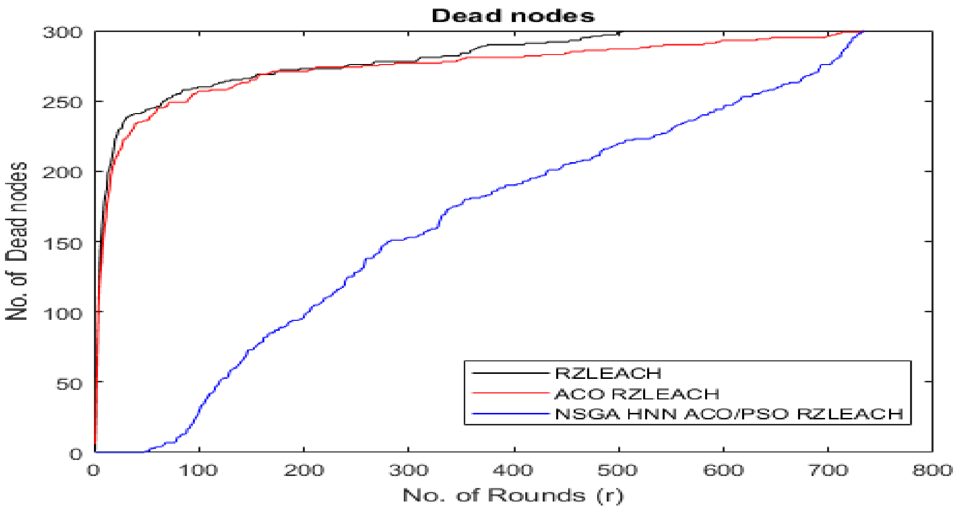



***Figure6.9(b) Dead nodes for area scalability with area 400X400 and nodes =300***

Figure6.9(b) illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH. In RZLEACH, the nodes are dead at 461 rounds, and for ACO RZLEACH, it is 732 rounds, and for NSGA HNN BASED HYBRID ACO/PSO LEACH, it is at 733 rounds.

**REMAINING ENERGY: -** It is restricted as the quantity of energy left with sensor mote, or the average remaining energy is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power.

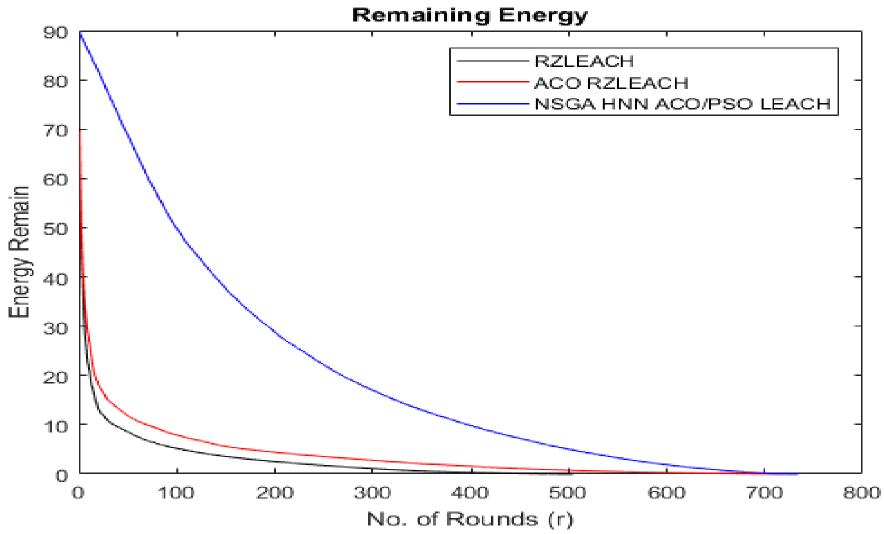



***Figure6.9(c) Remaining Energy for area scalability with area 400X400 and nodes =300***

The figure6.9(c ) represents that the remaining energy still present in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 461,732 and 733, respectively.

**CASE 8: Area = 450m ×450 m and Nodes = 300**

In this case, the number of nodes is 300 against 450m ×450 m to calculate the performance of various parameters like dead nodes, alive nodes, and energy remained.

**ALIVE NODES: -** It signifies the number of nodes that are still alive against the timestamp. This measurement demonstrates the whole lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

Figure6.10(a) shows that the stability period of NSGA HNN BASED HYBRID ACO/PSO LEACH is extended than that of the other case. It has been observed that NSGA HNN BASED HYBRID ACO/PSO LEACH has some advantages in terms of alive nodes, which enhance network stability. It has undoubtedly exposed that in the case of active nodes, NSGA HNN BASED HYBRID ACO/PSO LEACH performs better than that of RZLEACH and ACO RZLEACH protocol.

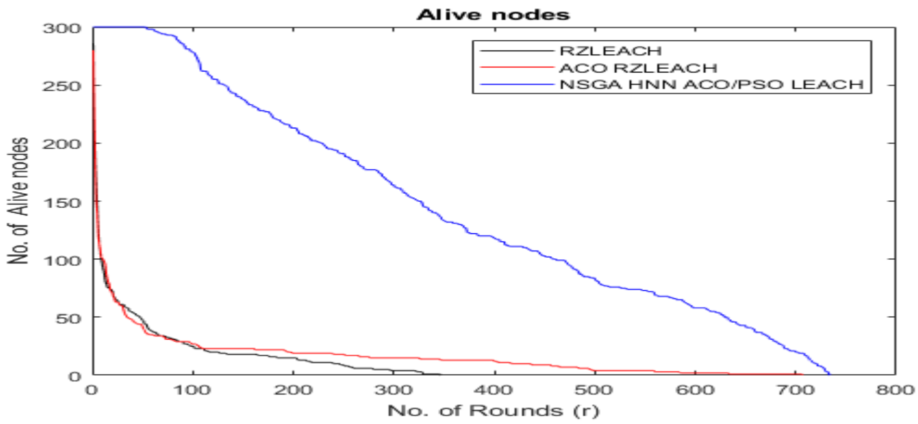



*Figure6.10(a) Alive nodes for area scalability with area 450X450 and nodes =300*

It is exposed that the First node dead of RZLEACH starts at about 5 rounds. Last node dead at about 410, and first node dead of ACO RZLEACH starts at around 7 rounds and last node dead at about 729 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the first node dead starts at about 80 rounds and last node dead at about 734 because NSGA HNN BASED HYBRID ACO/PSO LEACH takes time for their best solution initially to select the best path.

**DEAD NODES: -** Figure 6.10(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; it is demonstrated from the diagram that the amount of dead nodes of our planned method is less than the current approaches.

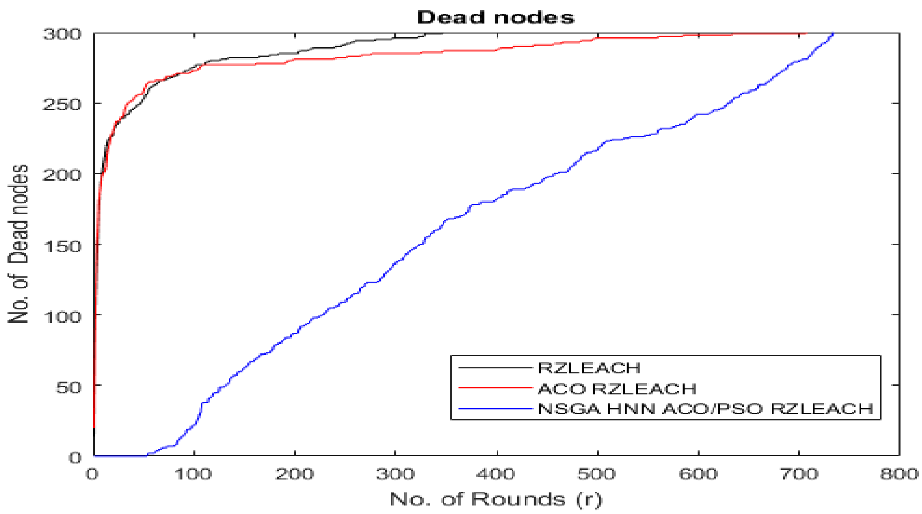


*Figure6.10(b) Dead nodes for area scalability with area 450X450 and nodes =300*

Figure6.10(b) illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH. In RZLEACH, the nodes are dead at 410 rounds, and for ACO RZLEACH, it is 729 rounds, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at 734 rounds.

**REMAINING ENERGY: -** It is restricted as the quantity of energy left with sensor mote, or the average remaining energy is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power.

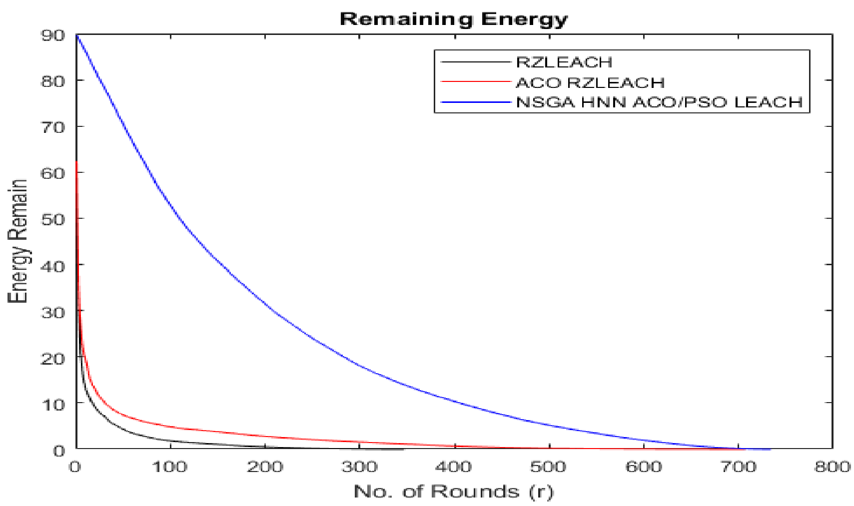



*Figure6.10(c) Remaining Energy for area scalability with area 450X450 and nodes =300*

Figure6.10(c) represents that the remaining energy still present in the case of RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 410,729 and 734, respectively.

**CASE 9: Area = 500m ×500 m and Nodes = 300**

In this case, the number of nodes is 300 against 500m ×500 m to calculate the performance of various parameters like dead nodes, alive nodes, and energy remained.

**ALIVE NODES: -** It signifies the number of nodes that are still alive against the timestamp. This measurement demonstrates the whole lifespan of the system. Essentially, it provides a portion of the covered area of the system after some time.

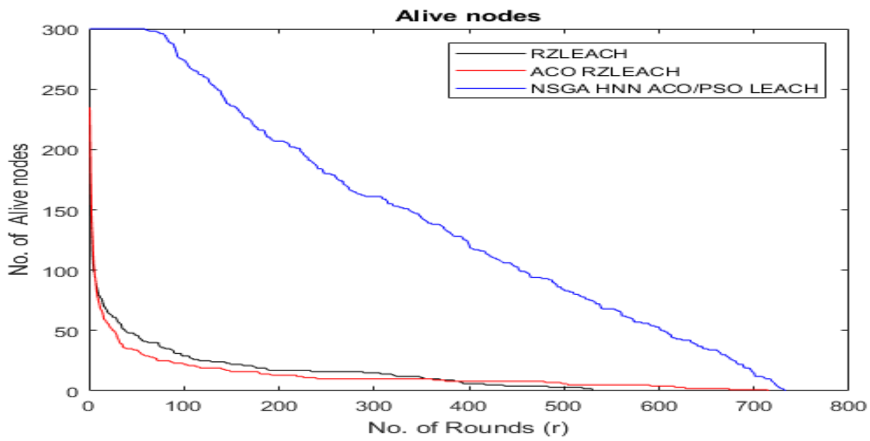



***Figure6.11(a) Alive nodes for area scalability with area 500X500 and nodes =300***

Figure6.11(a) shows that the stability period of NSGA HNN BASED HYBRID ACO/PSO LEACH is extended than that of the other case. It has been observed that NSGA HNN BASED HYBRID ACO/PSO LEACH has some advantages in terms of alive nodes, which enhance network stability. It has undoubtedly exposed that in the case of active nodes, NSGA HNN BASED HYBRID ACO/PSO LEACH performs better than that of RZLEACH and ACO RZLEACH protocol. It is exposed that the First node dead of RZLEACH starts at about 4 round and Last node dead at about 529, and first node dead of ACO RZLEACH starts at around 7 rounds and last node dead at about 702 while for NSGA HNN BASED HYBRID ACO/PSO LEACH, the first node dead starts at about 80 rounds and last node dead at about 732 because NSGA HNN BASED HYBRID ACO/PSO LEACH takes time for their best solution initially to select the best path.

**DEAD NODES: -** Figure6.11(b) displays total number of dead nodes in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH; it is clearly demonstrated from the diagram that the amount of dead nodes of our planned method is less than the current approaches.

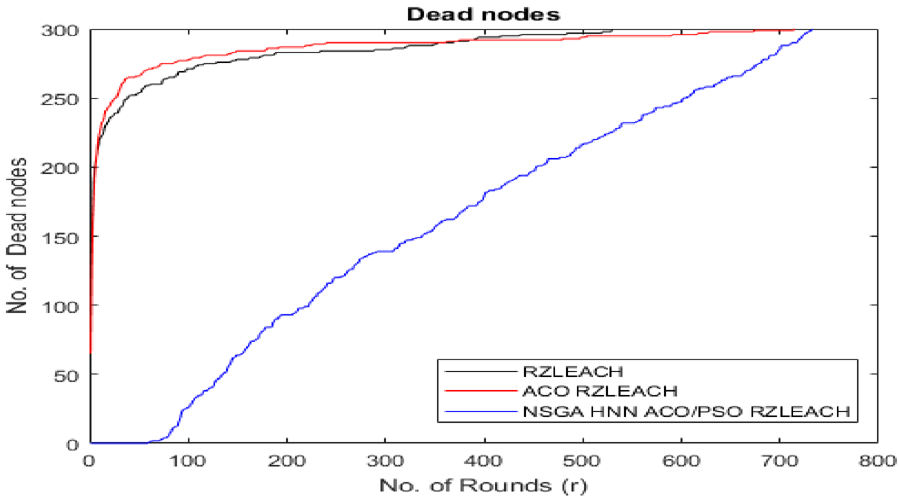



***Figure6.11(b) Dead nodes for area scalability with area 500X500 and nodes =300***

Figure6.11(b) illustrates the behavior of dead nodes in a detailed manner in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH routing protocol. It has been demonstrated that NSGA HNN BASED HYBRID ACO/PSO LEACH proved to be better than RZLEACH and ACO RZLEACH. In RZLEACH, the nodes are dead at 529 rounds, and for ACO RZLEACH, it is 702 rounds, and for NSGA HNN BASED HYBRID ACO/PSO LEACH, it is at 732 rounds.

**REMAINING ENERGY: -** It is restricted as the quantity of energy left with sensor mote, or the average remaining energy is the total residual energy left in a network after the data broadcast is completed. However, in WSNs, the transmission process consumes most of the power.

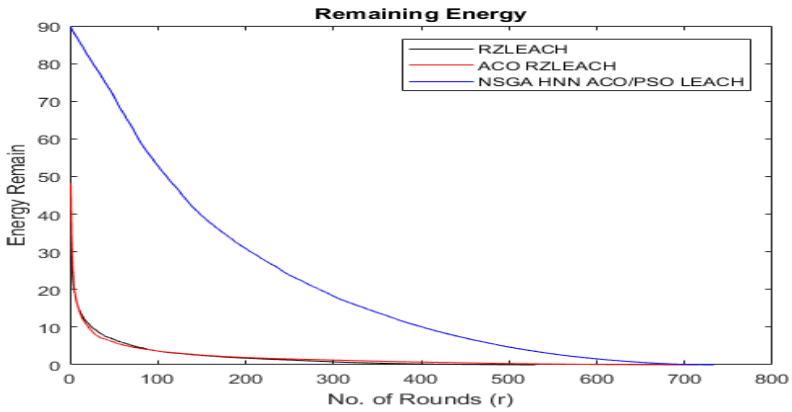



***Figure6.11(c) Alive nodes for area scalability with area 500X500 and nodes =300***

The figure6.11(c) represents that the remaining energy still present in RZLEACH, ACO RZLEACH, and NSGA HNN BASED HYBRID ACO/PSO LEACH is at the round of 529,702 and 732, respectively.

## 6.3 Nodes Scalability

In this scenario, we compared the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol with RZ LEACH, ACO RZ LEACH by varying number of nodes against rounds for various parameters like dead nodes, alive node, and energy remained in the fixed area of 150 m ×150m and having nodes quantity is 50 with sink movement is moving along the y axis in the network. Table 6.2 is showing the respective values.

***Table 6.4: Nodes Scalability with fixed Area Xm=150, Ym=150 and Sink movement = Ym/2***

| | **Number of Rounds for all node's dead** | | |
|---|---|---|---|
| **Number of Nodes** | **RZLEACH** | **ACO RZLEACH** | **NSGA HNN BASED Hybrid ACO/PSO LEACH** |
| 50 | 533 | 726 | 722 |
| 100 | 519 | 735 | 719 |
| 150 | 514 | 721 | 726 |
| 200 | 511 | 731 | 728 |

| | | | |
|---|---|---|---|
| 250 | 508 | 735 | 734 |
| 300 | 514 | 735 | 727 |
| 350 | 516 | 731 | 732 |
| 400 | 501 | 733 | 736 |
| 450 | 508 | 734 | 735 |
| 500 | 507 | 732 | 734 |
| 1000 | 505 | 732 | 738 |

**CASE 1: Area = 150m ×150 m and Nodes = 50 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 50 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

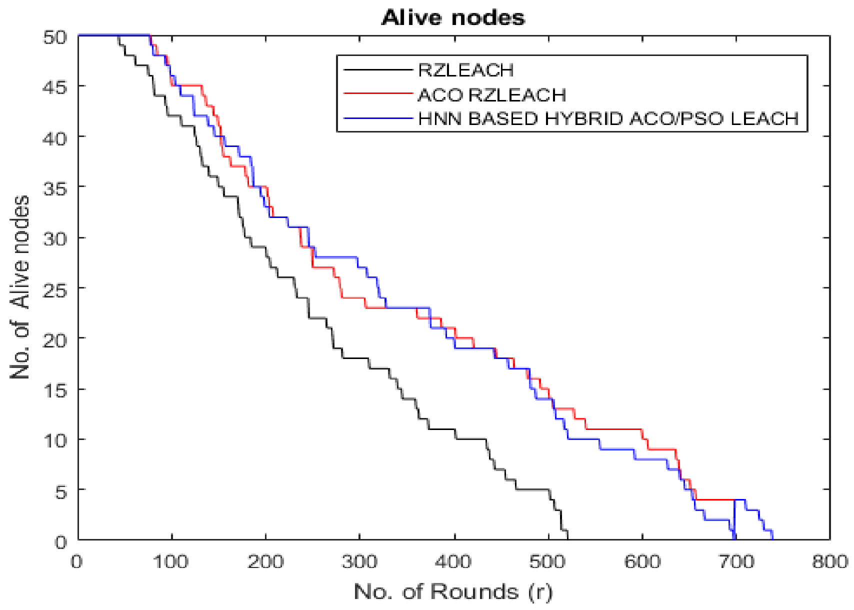



*Figure6.12(a) Alive nodes for area = 150×150 &nodes = 50 & SM= Ym/2*

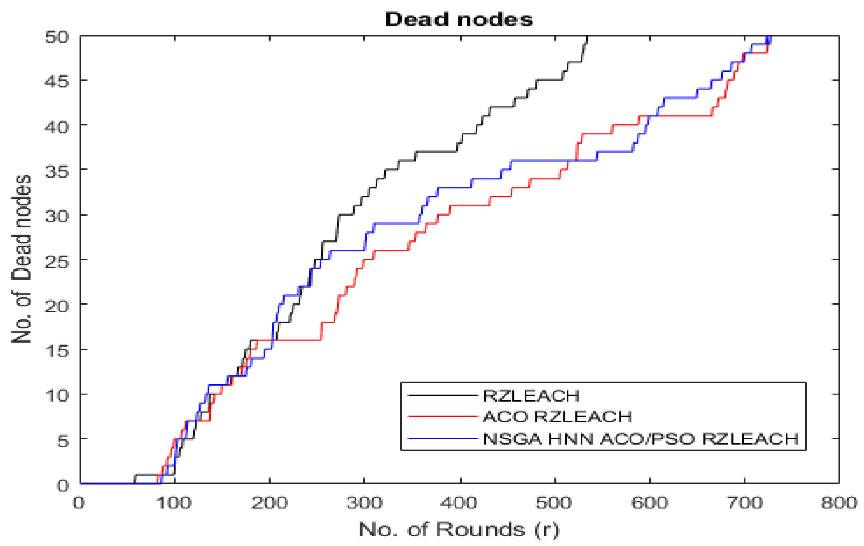



*Figure6.12(b) Dead nodes for area = 150×150 &nodes = 50 & SM= Ym/2*

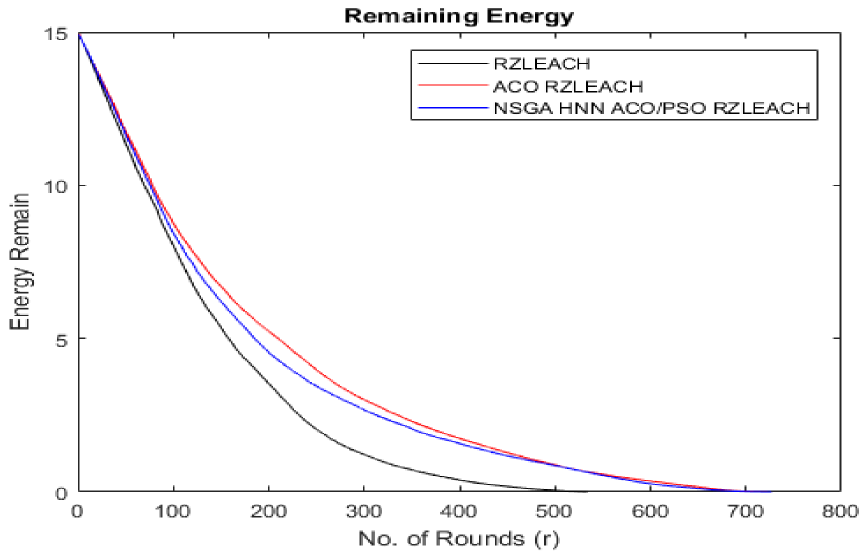



***Figure6.12(c) Remaining energy for area = 150×150 &nodes = 50 & SM= Ym/2***

Figure6.12 (a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 533,726 and 740, respectively.

**CASE 2: Area = 150m ×150 m and Nodes = 100 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 100 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

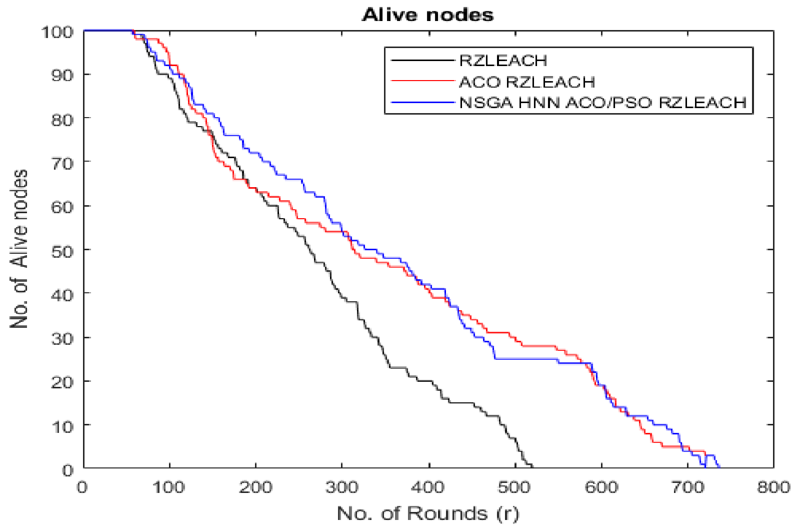



*Figure6.13(a) Alive nodes  for area = 150×150 &nodes = 100 & SM=  Ym/2*

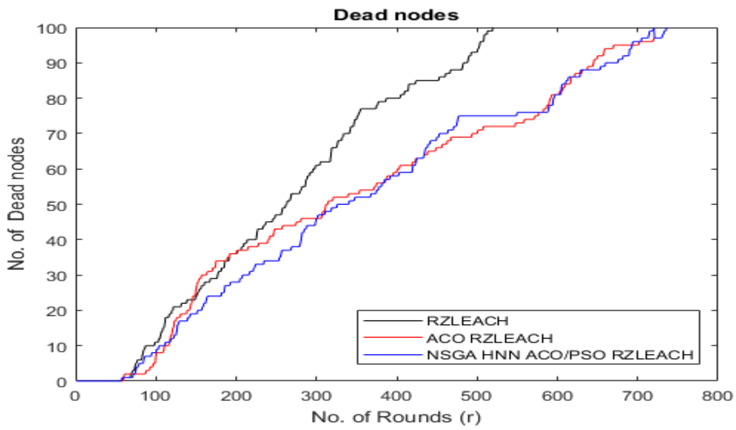



*Figure6.13(b) Dead nodes  for area = 150×150 &nodes = 100 & SM=  Ym/2*

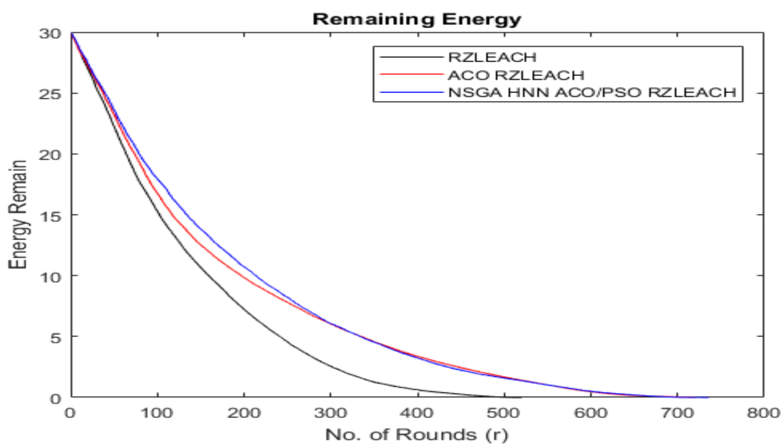



*Figure6.13(c) Remaining Energy  for area = 150×150 & nodes = 100 & SM=  Ym/2*

Figure6.13(a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 519,735 and 740, respectively.

**CASE 3: Area = 150m ×150 m and Nodes = 150 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 150 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

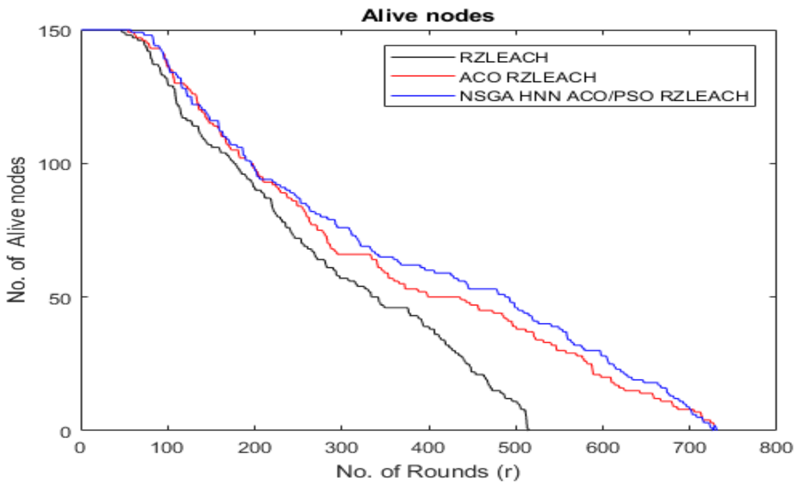



***Figure6.14(a) Alive nodes for area = 150×150 & nodes = 150 & SM= Ym/2***

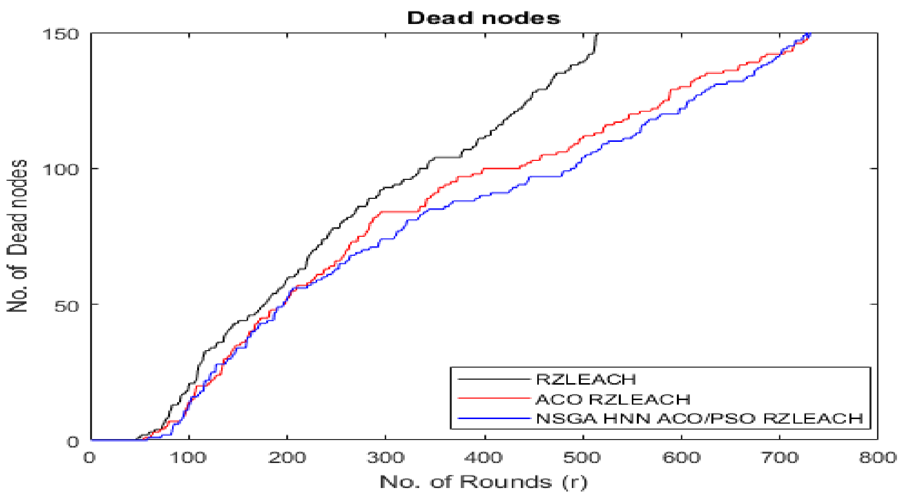



*Figure6.14(b) Remaining Energy  for area = 150×150 & nodes = 150 & SM=  Ym/2*

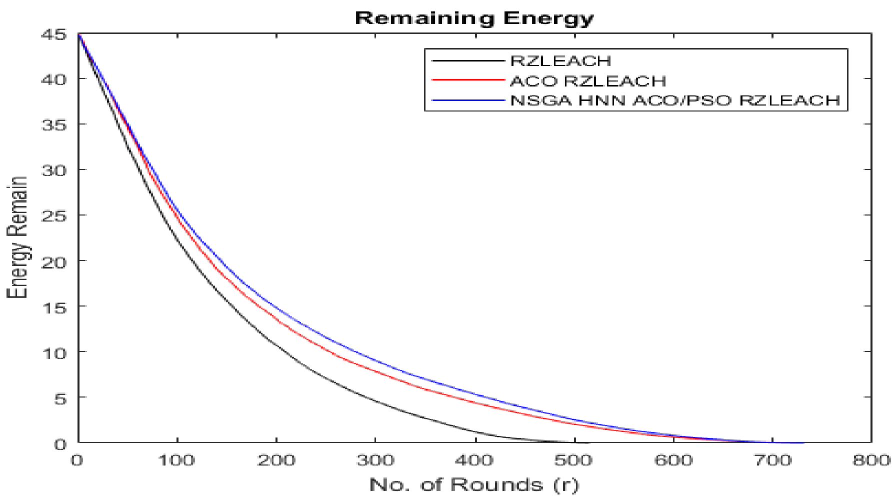



*Figure6.14(c) Remaining Energy  for area = 150×150 & nodes = 150 & SM=  Ym/2*

Figure6.14(a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 514,721 and 726, respectively.

**CASE 4: Area = 150m ×150 m and Nodes = 200 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 200 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

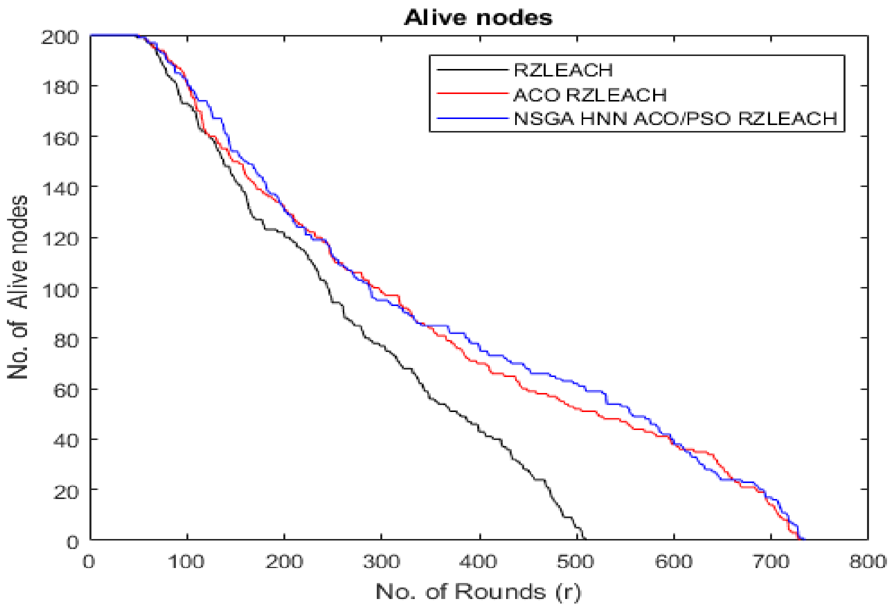



*Figure6.15(a) Alive Node for area = 150×150 & nodes = 200 & SM= Ym/2*

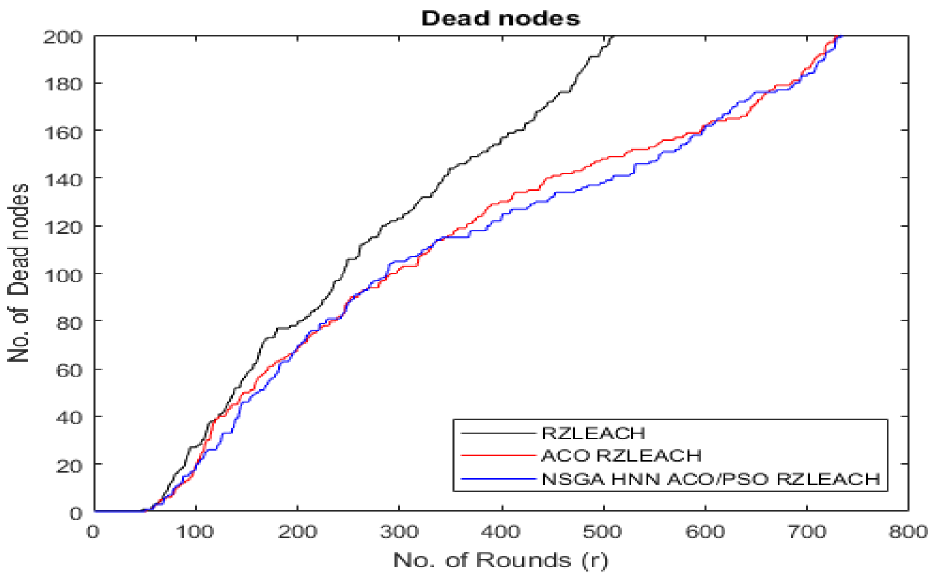



*Figure6.15(b) Dead Node for area = 150×150 & nodes = 200 & SM= Ym/2*

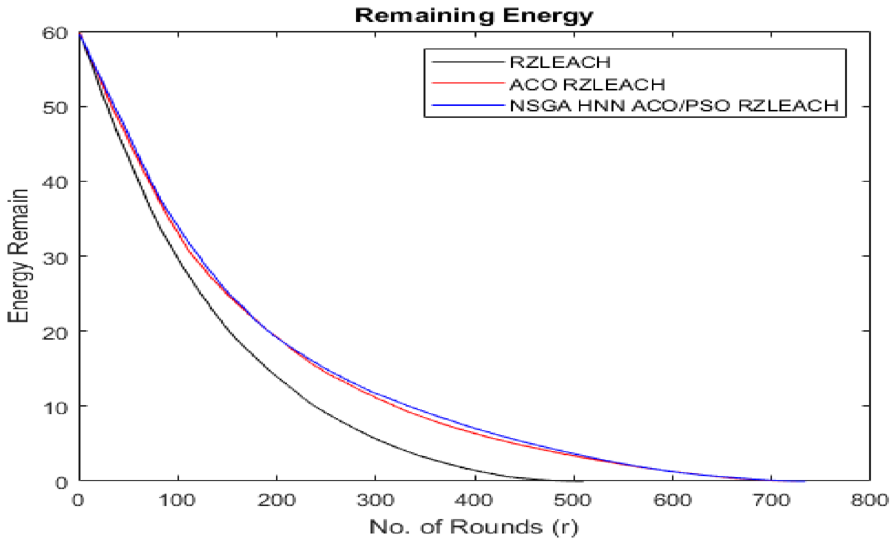



***Figure6.15(c) Remaining Energy for area = 150×150 & nodes = 200 & SM= Ym/2***

Figure6.15(a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 511,731 and 731, respectively.

**CASE 5: Area = 150m ×150 m and Nodes = 250 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 250 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

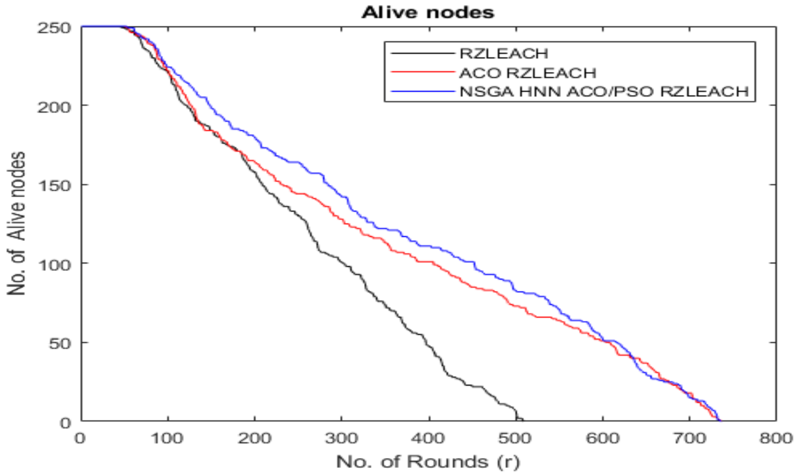



*Figure6.16 (a) Alive nodes for area = 150×150 & nodes = 250 & SM= Ym/2*

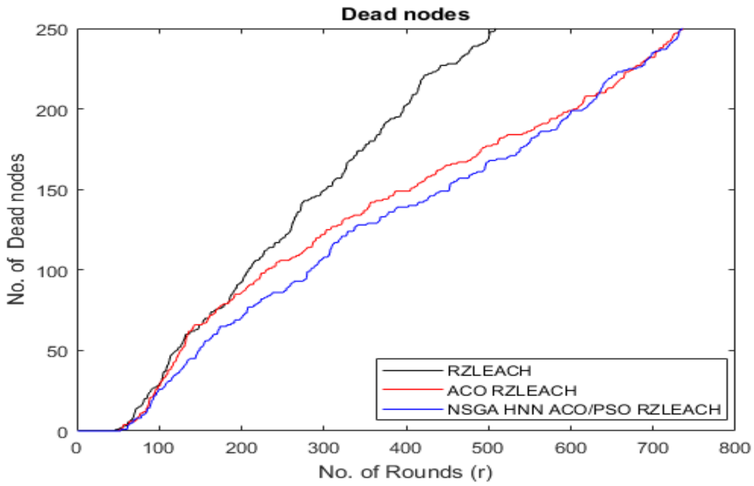



*Figure6.16 (b) Dead nodes for area = 150×150 & nodes = 250 & SM= Ym/2*

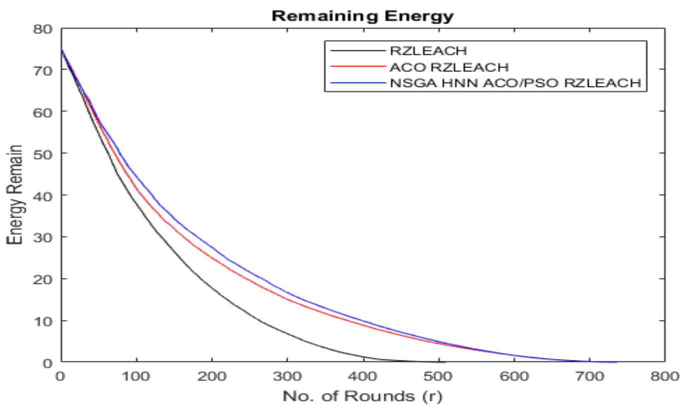



*Figure6.16 (c) Remaining Energy for area = 150×150 & nodes = 250 & SM= Ym/2*

Figure6.16 (a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 508,735 and 735, respectively.

**CASE 6: Area = 150m ×150 m and Nodes = 300 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 300 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

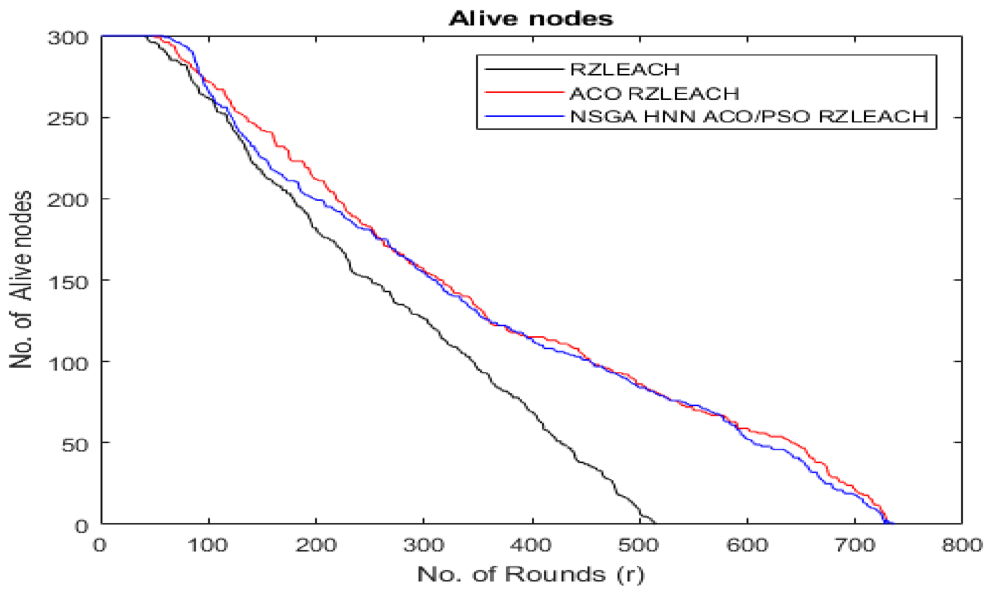



***Figure6.17(a) Alive nodes for area = 150×150 & nodes = 300 & SM= Ym/2***

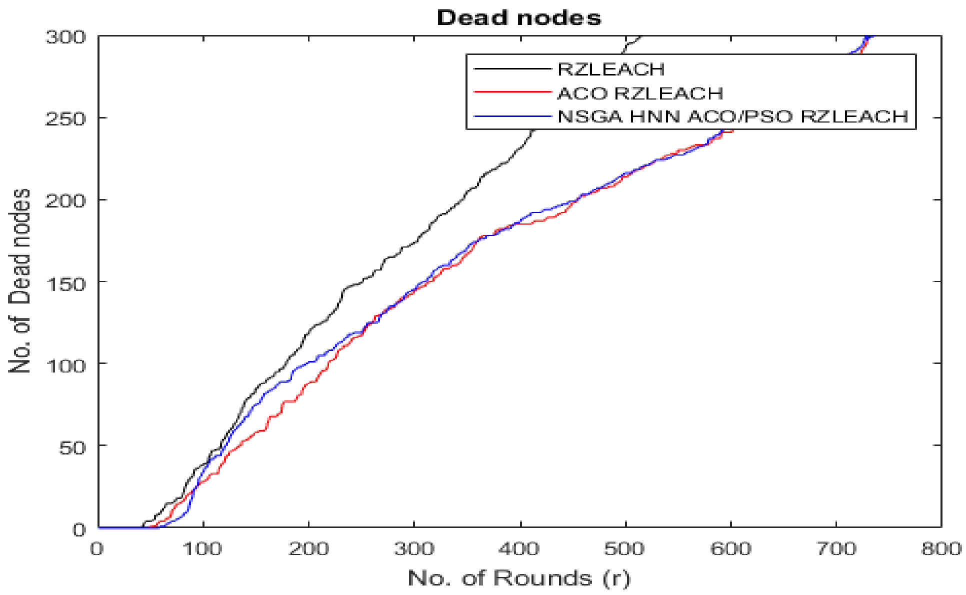



***Figure6.17(b) Dead nodes for area = 150×150 & nodes = 300 & SM= Ym/2***

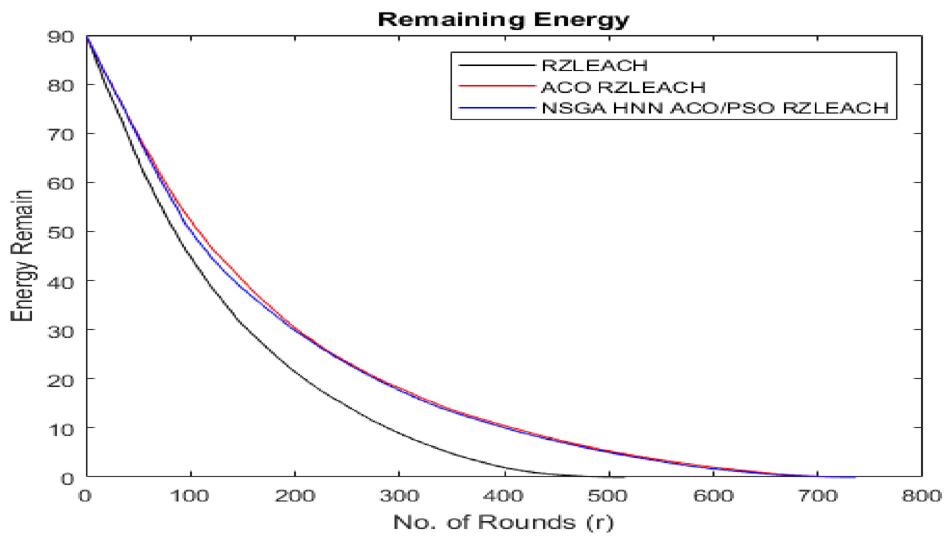



***Figure6.17(c) Remaining energy for area = 150×150 & nodes = 300 & SM= Ym/2***

Figure6.17(a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 514,735 and 727, respectively.

**Case 7: Area = 150m ×150 m and Nodes = 350 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 350 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

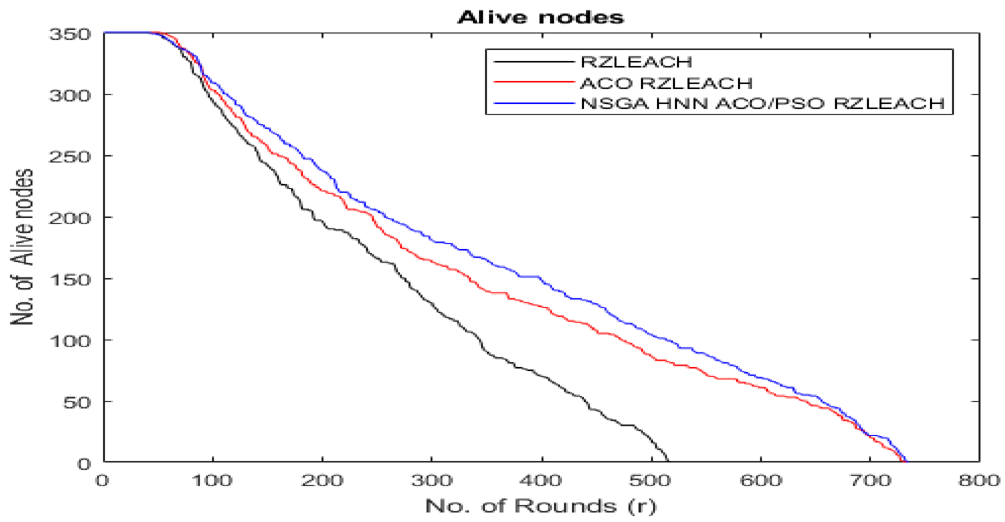



*Figure6.18 (a) Alive nodes for area = 150×150 & nodes = 350 & SM= Ym/2*

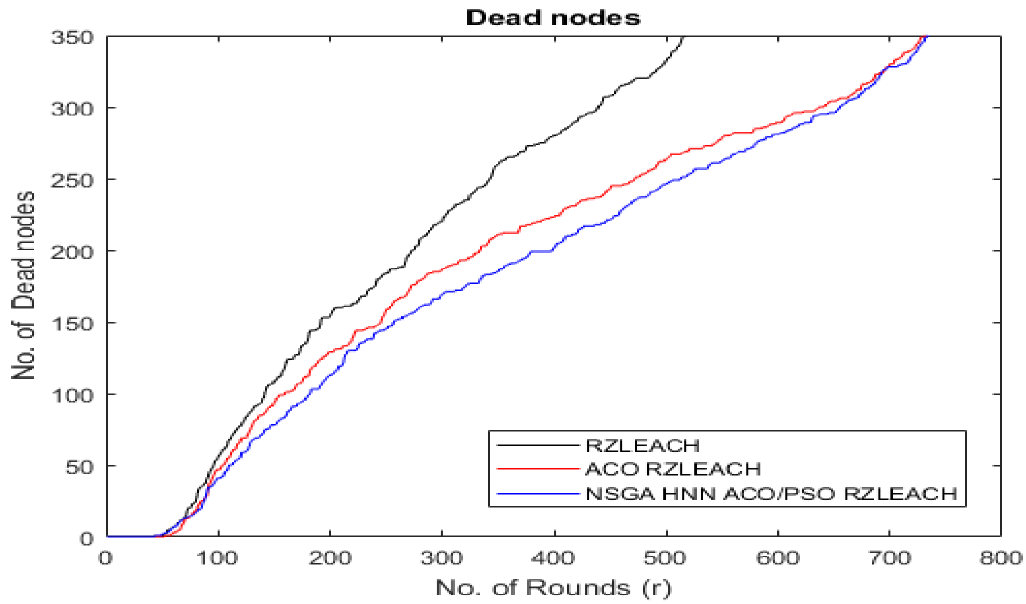



*Figure6.18(a) Dead nodes for area = 150×150 & nodes = 350 & SM= Ym/2*

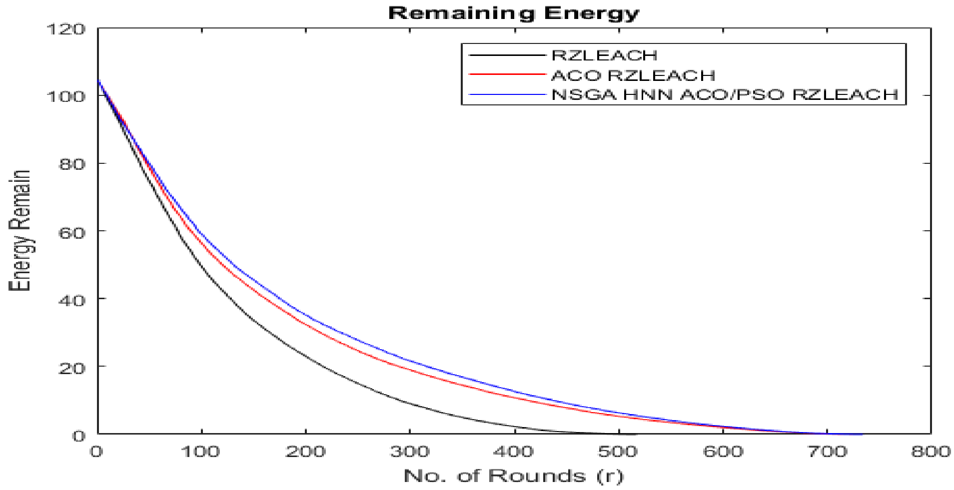



***Figure6.18(a) Remaining Energy for area = 150×150 & nodes = 350 & SM= Ym/2***

Figure6.18(a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 516,731 and 732, respectively.

**CASE 8: Area = 150m ×150 m and Nodes = 400 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 400 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

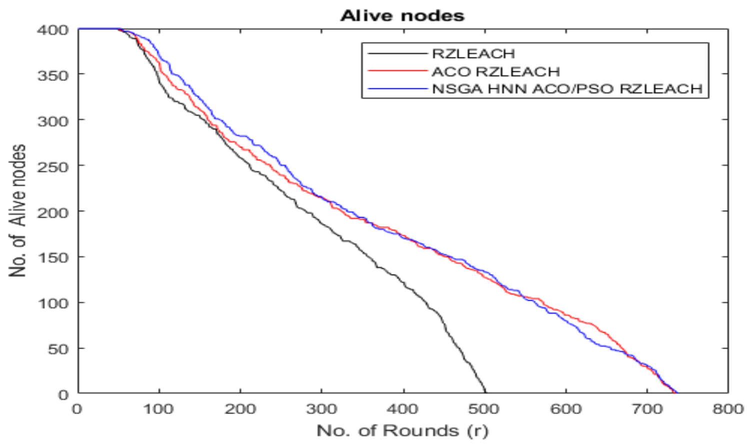



***Figure6.19 (a) Alive nodes for area = 150×150 & nodes = 400 & SM= Ym/2***

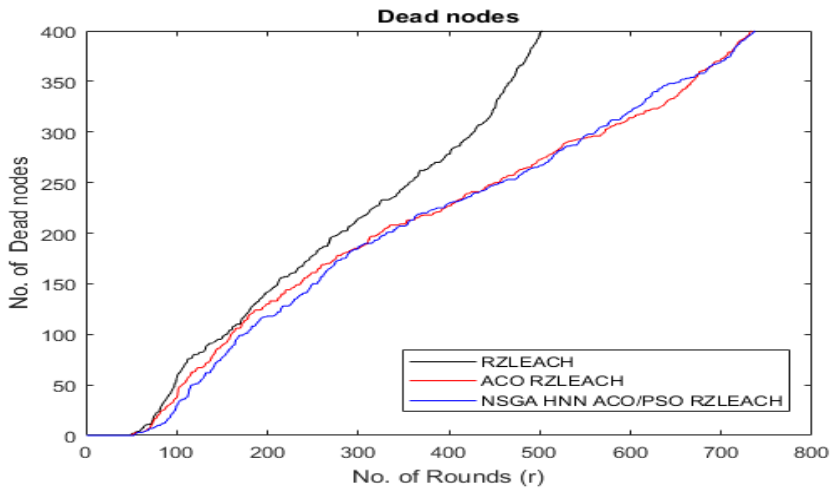



***Figure6.19 (b) Dead nodes for area = 150×150 & nodes = 400 & SM= Ym/2***

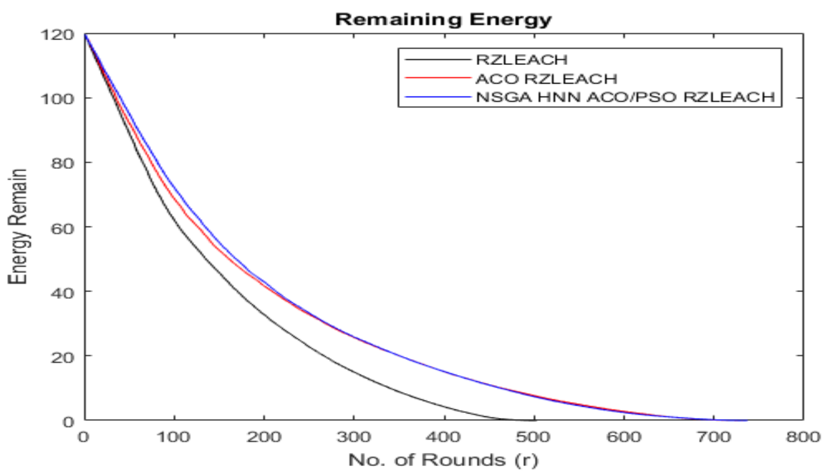



***Figure6.19(c) Remaining energy for area = 150×150 & nodes = 400 & SM= Ym/2***

Figure6.19 (a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 501,733 and 736, respectively.

**CASE 9: Area = 150m ×150 m and Nodes = 450 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 450 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

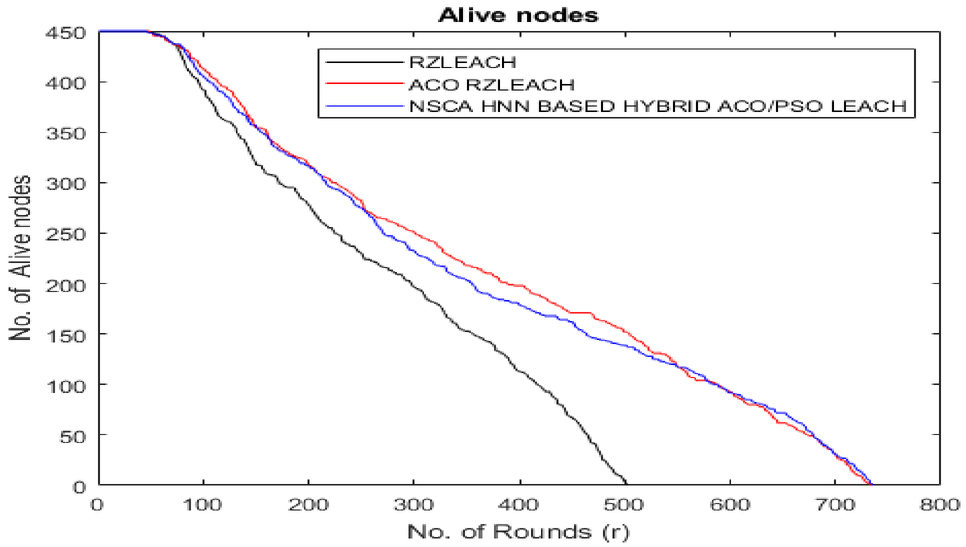



*Figure6.19(a) Alive nodes for area = 150×150 & nodes = 450 & SM= Ym/2*

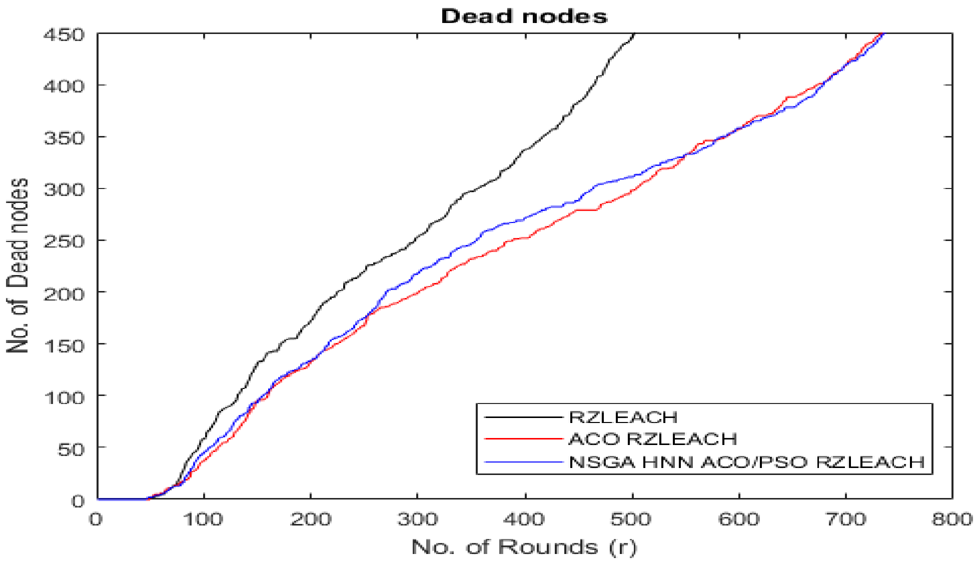



*Figure6.19 (b) Dead nodes for area = 150×150 & nodes = 450 & SM= Ym/2*

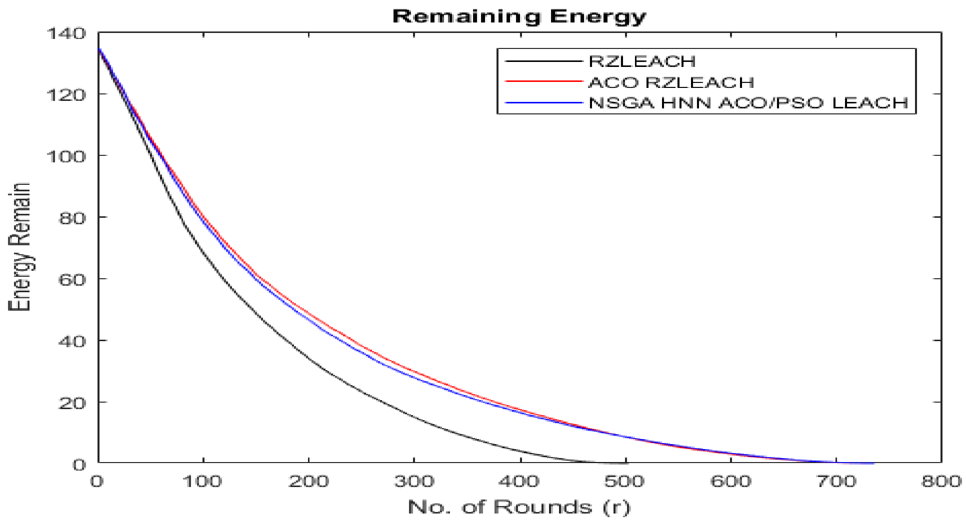



*Figure6.19 (c) Remaining energy for area = 150×150 & nodes = 450 & SM= Ym/2*

Figure6.19(a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 508,734 and 735, respectively.

**CASE 10: Area = 150m ×150 m and Nodes = 500 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 500 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

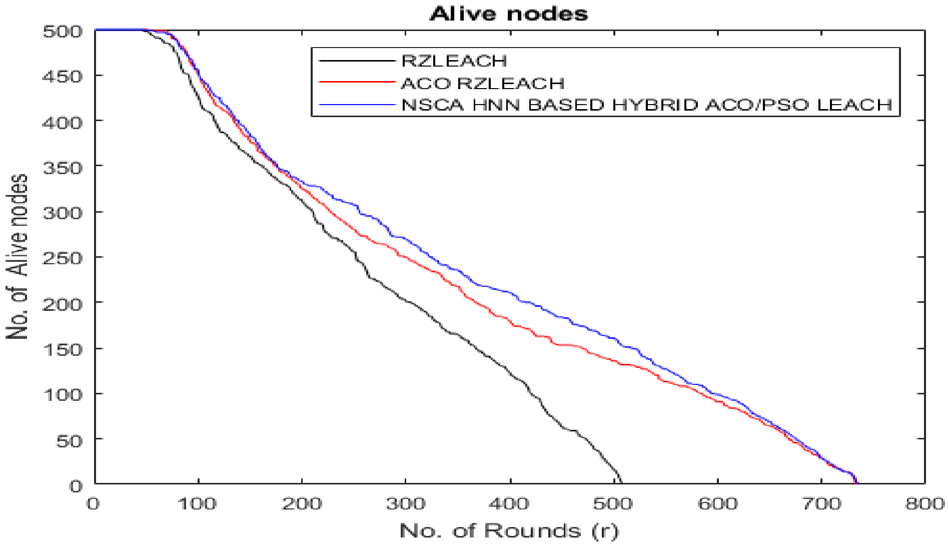



*Figure6.20(a) Alive nodes for area = 150×150 & nodes = 500 & SM= Ym/2*

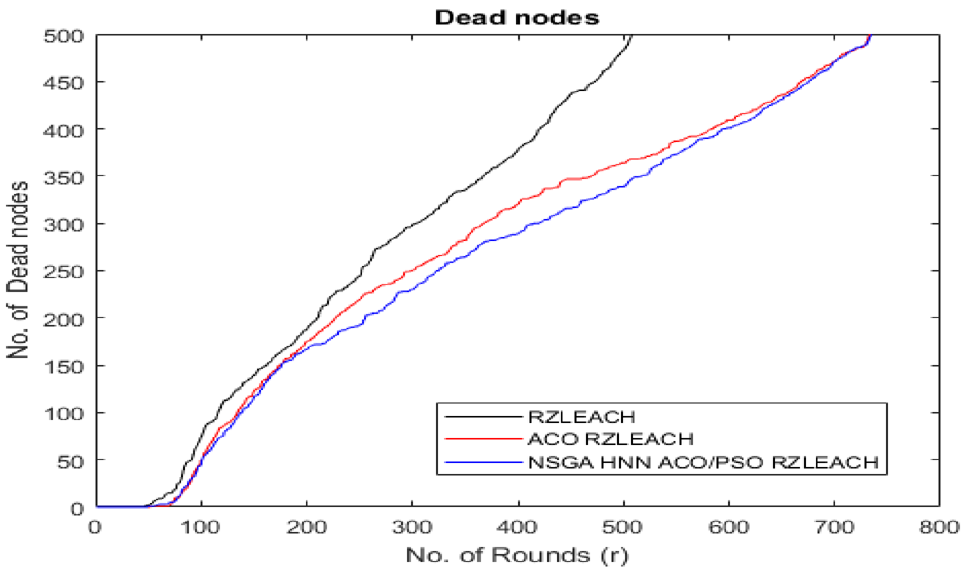



*Figure6.20(b) Dead nodes for area = 150×150 & nodes = 500 & SM= Ym/2*

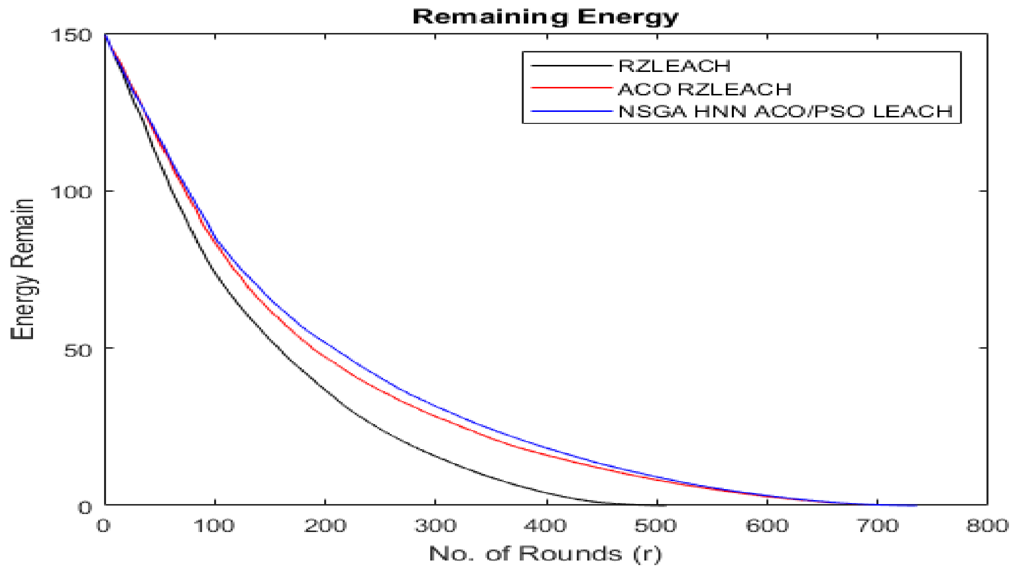



***Figure6.20(c) Remaining energy for area = 150×150 & nodes = 500 & SM= Ym/2***

Figure6.20(a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 507,732 and 734, respectively.

**CASE 11: Area = 150m ×150 m and Nodes = 1000 and Sink movement = Ym/2**

The effectiveness of NSGA HNN BASED HYBRID ACO/PSO LEACH is evaluated in this section by implementing area which is equal to 150m × 150m and nodes are equal to 1000 and Sink movement is Ym/2 means moving along the y-axis, this effectiveness is measured based on Alive node, Dead Node, and Remaining Energy.

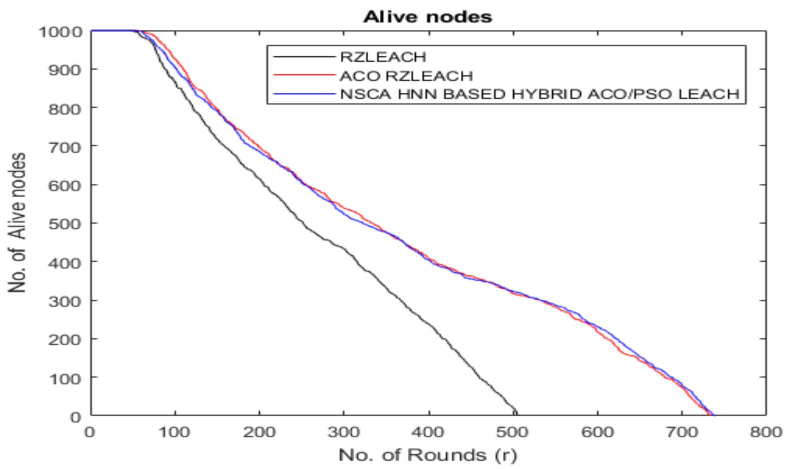



***Figure6.21(a) Alive nodes for area = 150×150 & nodes = 1000 & SM= Ym/2***

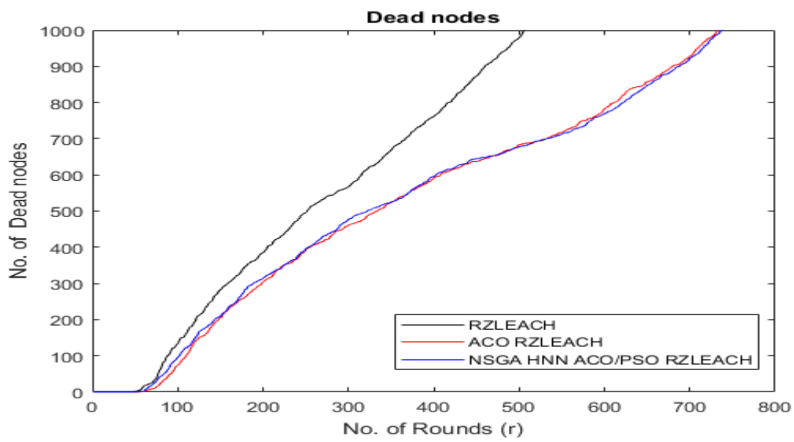



***Figure6.21 (b) Dead nodes for area = 150×150 & nodes = 1000 & SM= Ym/2***

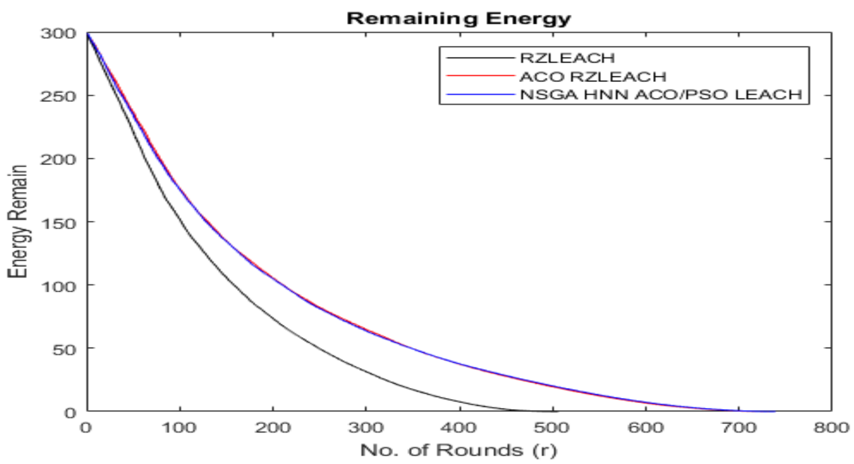



***Figure6.21(c) Remeaning energy for area = 150×150 & nodes = 1000 & SM= Ym/2***

Figure 6.21(a, b, and c) compares RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol against the parameter dead nodes, alive node, and remaining energy. The corresponding values generated after simulation in case of dead nodes, live node, and remaining energy concerning RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 505,732 and 738, respectively.

# 7 Recommendation and Future Work

## 7.1 Introduction

The outcomes of this research work promise change in the WSN applications zone as it increases the overall lifetime of the network through innovative NSGA HNN BASED HYBRID ACO/PSO LEACH technique by utilizing optimization properly. This section concludes the research proposal by illustrating the significant contributions, recommendations, and directions to future work.

## 7.2 Summary of the Major Contributions/ Conclusion

The main objective of the thesis is the performance enhancement of the WSNs, mainly by extending the lifetime of the network through data gathering, clustering, and Routing Techniques. Also, the appropriate mobility Models have been evaluated for WSNs suitability using NSGA HNN BASED HYBRID ACO/PSO LEACH protocol. The practical and research motive focuses on the following:

The numerous applications of WSNs ranging from the implementation by a small-sized industrial checking unit to massive energy environmental screening, all requirements, an operational system. But the power utilization of these operating systems is an extraordinary challenge that requires a robust methodology for improving the way power is utilized, which extends the lifetime of the WSNs. In contrast to other technologies, it tends to be expensive or even impossible to replace depleted batteries because of environmental and other geographical factors. Therefore, the main focus of the research in this field is to design energy proficient protocols while accomplishing the desired network tasks. Like to plug-in the unbalanced traffic flows of WSNs, RZ LEACH, ACO RZ LEACH with the NSGA HNN BASED HYBRID ACO/PSO LEACH protocols were compared with the area scalability and node scalability, and it was found that NSGA HNN BASED HYBRID ACO/PSO LEACH has outperformed among these three protocols. Here, the performance comparison is made with different scenarios. The simulation results establish that the node mobility gives rise to the stability of an NSGA HNN BASED HYBRID ACO/PSO LEACH. It is identified that either the movement of the sink is static or moving in nature, it will enlarge the performance of the NSGA HNN BASED HYBRID ACO/PSO LEACH protocol over the others. With these steps, the performance of NSGA HNN BASED HYBRID ACO/PSO LEACH enhances dead nodes, the last node dead last node dead is delayed by 29 % and 3% more than the last node dead in RZ LEACH, and ACO RZ LEACH MSEEC respectively and similarly, in case of node scalability feature, the results are more accurate in NSGA HNN BASED HYBRID ACO/PSO LEACH protocol is 26% and 3% more than that of RZ LEACH, and ACO RZ LEACH respectively. The results of the experiments are also evaluated by moving the sink, and it is seen that NSGA HNN BASED HYBRID ACO/PSO LEACH outperforms the RZ LEACH and ACO RZ LEACH protocol.

## 7.3 Recommendations

The research activities in the performance evaluation of WSNs are supported by the interests in the technical applications of WSNs, development of the supporting technologies, as well as the demand from the society for the improved performance (speed) because of the explosive increase in the use of WSNs in the daily life. Based upon the research work reported in this thesis, the following recommendations are submitted for use in WSNs:

- Research work has focused mainly on expanding the concert of WSNs. Based on the performance evaluations of WSNs, it is recommended that one of the ways to increase the show of WSNs is to identify the proper clustering and routing techniques that can be combined to form a new model. Thus, an efficient routing protocol is developed to enhance the performance and maintain the stability criteria for the wireless sensor network.

Based upon the performance evaluations of NSGA HNN BASED HYBRID ACO/PSO LEACH routing reported in this thesis for improving the lifetime of WSNs, it is concluded and recommended that NSGA HNN BASED HYBRID ACO/PSO LEACH technique should be implemented to improve performance metrics like Alive node, Dead

Node, and Remaining Energy. Finally, NSGA HNN BASED HYBRID ACO/PSO LEACH would not provide the path loss exponent. Path loss exponent depends upon the received signal strength indicator value.

- Other bio-inspired algorithms like cuckoo search, Glow-worm, Meer-cat clan algorithm, etc., must be applied to get better results for routing and clustering.

- Performance evaluations have been focused on suggesting that there is no single universal radio propagation model that fits into all the requirements of WSNs. It is parametric specific, and thus, it is recommended that there has to be a trade-off between the uses of the radio propagation model if the performance WSN is extended.

- Investigations and studies suggest that there is no perfect topology at the Physical Layer that fulfills all the requirements of WSNs. Therefore, a trade-off has to be considered while implementing the type of topology in the WSN. Here, it is recommended that Cluster Topology is the best-suited topology if PDR and Average end-to-end delay are to be taken into consideration. On the other hand, if Throughput is to be considered, Hybrid Topology dominates all different Topologies. If Average Remaining Energy is to be believed, then Star Topology is most recommended.

## 7.4 Future Scope of the Work

We are heading towards a future of miniaturization and wireless connectivity; WSNs can deliver at a meager cost. During this thesis, several avenues for the continuation of this study became evident. The research experiences greatly help to understand various practical problems in WSNs. In this section, some of the opinions related to the issues of WSNs are shared and discussed that are potential research topics for future WSNs.

- Firstly, multiple base stations may be deployed in WSNs, which will upgrade the network's performance.

- Another issue that needs to be investigated is the QoS components.

- An advance improved Feistel cipher-based scheme is also used for WSN block-cipher design for security by using CPB crypto primitives. So that the new generation attacks neither increased with time nor made the network complicated and mitigating against WSN and other fields, respectively.

- Finally, radio propagation models may be studied under different conditions, requirements, specifications, and more complicated hybrid topologies. A better and efficient topology could be investigated and proposed for the proposed models.

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# Annexure I

## List of Abbreviation

| | |
|---|---|
| ACO | Ant Colony Optimization. |
| ADC | Analog to Digital Converter. |
| ANN | Artificial Neural Network. |
| APTEEN | Adaptive Threshold-Sensitive Energy Efficient Network |
| BPSK | Binary Phase Shift Keying. |
| BS | Base Station |
| CDMA | Code Division Multiple Access. |
| CH | Cluster Head |
| EA | Evolutionary algorithms |
| EECS | Energy Efficient Clustering Scheme. |
| EEMC | Energy-Efficient Multilevel Clustering. |
| GPS | Global Positioning System. |
| HEED | Hybrid Energy-Efficient Distributed. |
| HNN | Hopfield Neural Network. |
| IEEE | Institute of Electrical and Electronics Engineer. |
| J | Joule. |
| KB | Kilobytes. |

| | |
|---|---|
| LEACH | Low-Energy Adaptive Clustering Hierarchy |
| MAC | Media Access Control |
| MS | Mobile Sink |
| NIC | Network Interface Card |
| NSF | National Science Foundation. |
| NSGA | Non-dominated Sorted Genetic Algorithm. |
| NTP | Network Time Protocol. |
| OS | Operating System |
| OSI | Open Systems Interconnection |
| PANEL | Position-Based Aggregator Node Election. |
| PEGASIS | Power-Efficient Gathering in Sensor Information Systems. |
| PSO | Particle Swarm Optimization |
| QAM | Quadrature Amplitude Modulation |
| QoS | Quality of Service |
| QPSK | Quadrature Phase Shift Keying |
| RF | Radio Frequency |
| RFID | Radio Frequency Identification. |
| RN | Rendezvous Nodes |
| TEEN | Threshold-Sensitive Energy Efficient Sensor Network. |
| T-LEACH | Threshold Low-Energy Adaptive Clustering Hierarchy |
| TDMA | Time Division Multiple Access. |

# Annexure II

## List of Publications

| S No. | Title of paper with author names | Name of journal/conference | Published date | Issn no/ vol no, issue no | Indexing in Scopus/ Web of Science/UGC-CARE list |
|---|---|---|---|---|---|
| | NHAP-RZLEACH-Based Hybrid Framework to Enhance Network Lifetime in Wireless Sensor Networks | Lecture Notes in Networks and Systems / Proceeding of First Doctoral Symposium on Natural Computing Research: DSNCR 2020 | 19/03/2021 | https://doi.org/10.1007/978-981-33-4073-2_38 Print ISBN 978-981-33-4072-5 Online ISBN 978-981-33-4073-2 Lecture Notes in Networks and Systems, vol 169. Springer, Singapore. | H-Index 8 (https://www.scimagojr.com/journalsearch.php?q=21100901469&tip=sid&clean=0) |
| | A Review of LEACH Successors Using Single-Hop and Multi-Hop Communication Model. | Communications in Computer and Information Science book series (CCIS, volume 1206) | 22/04/2020 | https://doi.org/10.1007/978-981-15-4451-4_1 Print ISBN 978-981-15-4450-7 | H-Index 45 https://www.scimagojr.com/journalsearch.php?q=17700155 |

| | | | | | |
|---|---|---|---|---|---|
| | | / International Conference on Futuristic Trends in Networks and Computing Technologies<br><br>FTNCT 2019 | | Online ISBN<br><br>978-981-15-4451-4<br><br>Communications in Computer and Information Science book series (CCIS, volume 1206) | 007&tip=sid&clean=0 |
| | Optimization of LEACH for Developing Effective Energy-Efficient Protocol in WSN. | Advances in Intelligent Systems and Computing book series (AISC, volume 1059)<br><br>/ Proceedings of International Conference on Innovative Computing and Communication. | 17/11/2019 | https://doi.org/10.1007/978-981-15-0324-5_17<br><br>Print ISBN<br><br>978-981-15-0323-8<br><br>Online ISBN<br><br>978-981-15-0324-5<br><br>Advances in Intelligent Systems and Computing book series (AISC, volume 1059) | H Index 34<br><br>https://www.scimagojr.com/journalsearch.php?q=5100152904&tip=sid&clean=0 |
| | Clustering techniques in wireless sensor networks. | Journal of the Gujarat Research Society | October 2019 | Volume 21<br><br>Issue 6<br><br>ISSN: 0374-8588 Volume 21 | UGC-CARE |

# Annexure III-

## Publications Reprints

# NHAP-RZLEACH-Based Hybrid Framework to Enhance Network Lifetime in Wireless Sensor Networks

**Avinash Bhagat and Ajay Shriram Kushwaha**

**Abstract** A lot of energy conservation techniques already exists, and many more are required to use less energy to perform highly accurate results. The problem can be reducible by using this proposed technical hybrid framework of NSGA-HNN-ACO-PSO-RZLEACH for enhancing the routing mechanism in WSNs in consideration of energy conservation. During the setup phase, rendezvous nodes are selected followed by the selection of cluster head using the Hopfield neural network approach. During the steady-state phase, data is aggregated at cluster head or rendezvous nodes using NSGA. Aggregated data is routed to the base station using a hybrid ACO-PSO approach. The performance of the proposed framework is equated with two prevailing algorithms. This technical framework successfully simulated with the experimental scenarios to extend the network lifetime up to 16% and improved energy optimization up to 26% compared to existing approaches. This research is more applicable in the field of wildlife search and for tracking objects.

**Keywords** Ant colony optimization · Cluster head · LEACH · Wireless sensor network · Particle swarm optimization

## 1 Introduction

WSN are deployed in many applications like agriculture, border surveillance, environmental monitoring, disaster management, natural disaster prevention, traffic management in smart cities, weather forecasting, etc. Sensor nodes in WSN are made up of a sensor unit capable of observing physical characteristics like acoustics, gas, moisture level, pressure, temperature, vibrations, etc. [1]. As these sensing nodes are smaller in size, it has constraints like bandwidth, connectivity, coverage,

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 413
V. H. Patil et al. (eds.), *Proceeding of First Doctoral Symposium on Natural Computing Research*, Lecture Notes in Networks and Systems 169,
https://doi.org/10.1007/978-981-33-4073-2_38

energy, fault tolerance, localization problem, processing power, scheduling, synchronization, etc. Sensor nodes are placed at remote and harsh locations, so recharging and battery replacement is a challenge [2]. Energy efficiency is a major issue which affects the performance of the WSN, so protocols used in WSN need to be flexible and energy-efficient so that minimum energy is lost during transmission. Energy dissipation in LEACH is lesser than traditional protocols as flexibility in creating clusters and electing CHs in rotation allows even energy distribution among all nodes. Inappropriate selection of data aggregation techniques can lead to power inefficiency in LEACH. One of the techniques to improve energy efficiency is moving the sink inside or around the environment to collect data from nodes [3]. Movement of mobile sink has limitations, the mobile sink must move near the clusters to collect data, it cannot be closed to all the nodes for all the time, so the concept of rendezvous node was evolved. This research has analyzed past inventions that are related to the implications of RPs over MSs [4].

## 2 Related Work

**Kennedy et al. proposed PSO** in 1995, inspired by the social behavior of fish schooling and birds flocking an idea of solving parameters-based optimization problems to solve many problems including clustering and routing problems [3]. PSO is simpler to implement, parameters in this approach are very less, it is a robust technique, it is more efficient in finding global optimal than ACO, coverage is fast, does not overlap, and can run parallel computations [5].

**Dorigo et al.** 1996 proposed another nature-inspired technique called ACO [6] the social behavior of ants inspired. In contrast to genetic algorithms, ACO provides a better quality solution with less computational time, ACO can provide parallel searches among the population, provides rapid discovery, and has good adaptability to change in distance [7]. Problems with ACO are its uncertainty to time convergence, and it depends upon the sequence of results and difficult in theoretical analysis.

Meng et al. 2008 proposed GCA [8] to overcome the drawbacks of the Bee-Sensor-C algorithm. Aim of genetic clustering algorithm is to create dynamic clusters with minimum energy and maximum lifetime, and a drawback of the method is some of the clusters cause hot spot problem.

**Adamou et al**. 2012 suggested an algorithm named artificial bee colony (ABC) to address clustering problems. It is formulated from the foraging deeds of the honeybee. In ABC, base station initializes and executes the formation of clusters and routing [9].

**Attea et al.** 2012 proposed evolutionary-based clustered routing protocol (ERP) [10] evolutionary protocols or biological inspired protocols are efficient enough to reduce cluster routing problems in WSN and increase the WSN lifetime.

**Zhu et al.** 2013 developed EBUC [11] to use unequal clusters to create a balance in energy consumed among clusters and within a cluster resulting reduction in wastage of energy and prolonged lifetime.

**Lavanya et al**. 2017 proposed another multi-objective EA for optimization. Authors proposed the use of non-NSGA-II for cluster head selection and were able to reduce energy consumption, thus enhancing network lifetime to four times that of LEACH [12].

## 3 System Model

The proposed NSGA HNNA ACO/PSO-RZLEACH model follows the following steps:

1. Initialization followed by deployment of WSN is the first and foremost step in this process.
2. The Hopfield algorithm of the neural network is applied to all the motes to find CHs.
3. Once the clusters heads are evaluated, the member motes are attached to CH to create clusters.
4. Exploring the path between CHs and BS, a hybrid of ACO-PSO optimization algorithm is applied to fulfill this task.
5. The path searching is done between base stations and cluster heads, and then, data is transmitted.
6. The data transmission is followed by dissipation evaluation of the energy followed by determining the energy remaining.
7. In the evaluation of dead nodes, a node is dead when it is left with no energy. If the mote is dead, the algorithm jumps to step 8, else moves to step 2.
8. Now, a sum up is done for dead nodes.
9. This step determines whether all the nodes dead. If they are, then go to step 10, else go to step 2.
10. Toward the end, evaluation of the lifetime of the network is done.

As shown in the flowchart (Fig. 1) initially, a sample region containing a fixed number of motes placed randomly is considered. A mobile sink MS moves from mid of the area considered, and it has unlimited energy. Initially, all the motes have equal energy $E_i$. Like LEACH, the proposed algorithm NSGA HNNA ACO/PSO-RZLEACH has several rounds, these rounds are further divided into setup and steady-state phase. The first step in the setup phase is electing a rendezvous node and CH, the next step of the phase is the creation of clusters around all cluster heads, and final stage of this phase is scheduling when the cluster headsets a schedule for member motes to transmit its data to rendezvous node. During the steady-state phase, aggregated data is transmitted to the mobile sink. Data is aggregated once by all the nodes in each round.

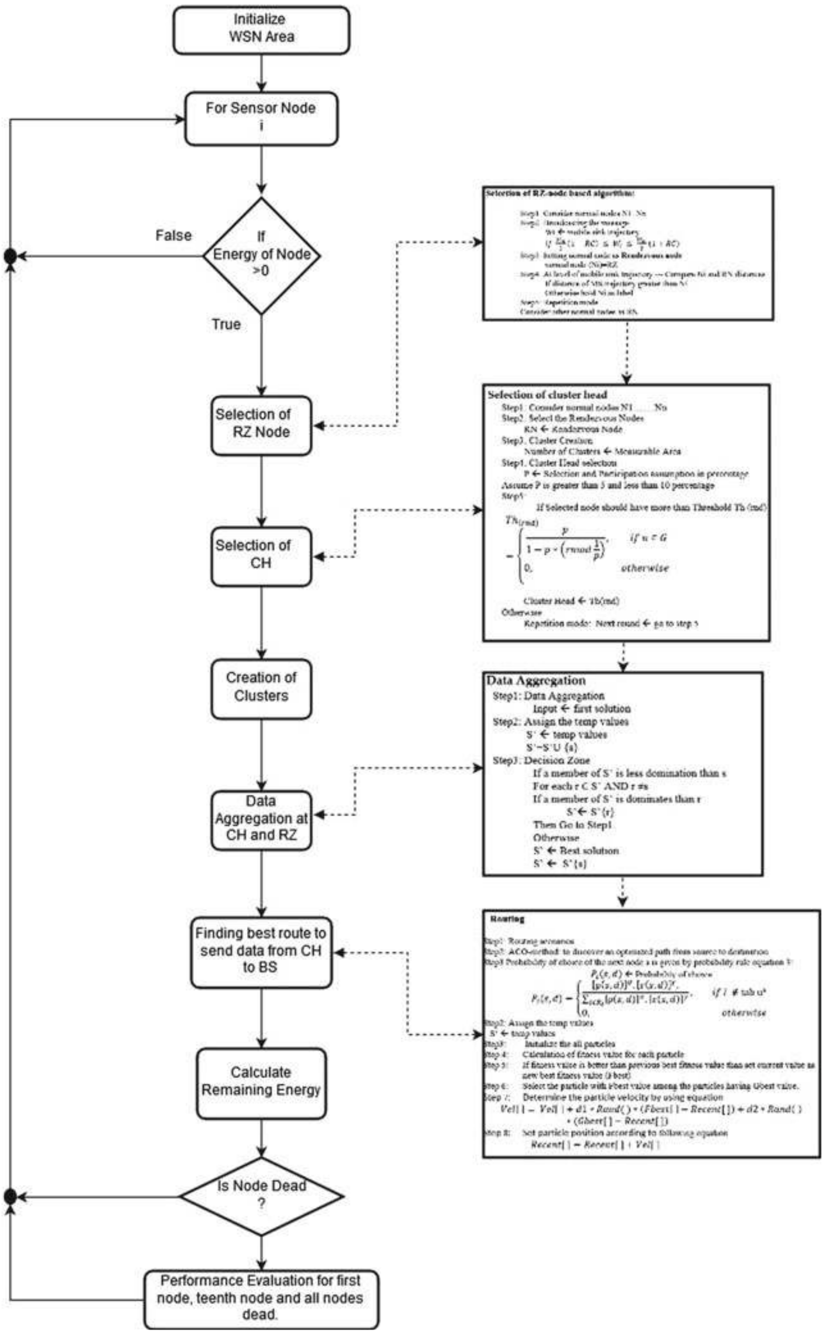


**Fig. 1** Flowchart of the proposed model

### 3.1 Selection of Rendezvous Node

Initially, all the motes are normal nodes NN, and the selection of a normal node as rendezvous node RN depends upon the distance from the mobile sink trajectory. A node becomes RN if the following condition is met

$$\text{if } \frac{w_{\text{in}}}{2}(1 - RC) \le W_i \le \frac{w_{\text{in}}}{2}(1 + RC) \ \ \text{if} \frac{w_{\text{in}}}{2}(1 - RC) \le W_i \le \frac{w_{\text{in}}}{2}(1 + RC) \tag{1}$$

### 3.2 Selection of RZ-Node-Based Algorithm

Step 1 Consider normal nodes N1…Nn
Step 2 Broadcasting the message
wrt: mobile sink trajectory

$$\text{if } \frac{w_{\text{in}}}{2}(1 - RC) \le W_i \le \frac{w_{\text{in}}}{2}(1 + RC) \ \ \text{if} \frac{w_{\text{in}}}{2}(1 - RC) \le W_i \le \frac{w_{\text{in}}}{2}(1 + RC)$$

Step 3 Setting the normal node as **rendezvous node**
normal node (Ni) = RZ
Step 4 At the level of mobile sink trajectory, compare Ni and RN distances
If the distance of MS trajectory greater than Ni
Otherwise, hold Ni as a label
Step 5 Repetition mode
Consider other normal nodes as RN.

### 3.3 Selection of Cluster Head

All the motes generate a random number between 0 and 1 for the election of cluster head, and conditionally, the mote participates in cluster head selection for the ongoing round if the number is lower compared to the threshold value Th (rnd) and the threshold value is found using Eq. (2) as follows:

$$Th_{(rnd)} = \begin{cases} \frac{p}{1-p*\left(r \bmod \frac{1}{p}\right)}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

where $P$ indicates the sought-after percentage of motes to become CHs among all motes, $r$ means the current round and $G$ are the motes that have not participated in CH selection in past $1/P$ rounds. A node that turns into CH in round r cannot take part in the next $1/P$ rounds. In this way, every mote gets the chance to become the CH, and thus, energy consumption by motes is distributed uniformly.

#### 3.3.1 Selection of Cluster Head

Step 1 Consider normal nodes N1…Nn
Step 2 Select the rendezvous nodes
RN ← Rendezvous node
Step 3 Cluster creation
Number of clusters ← measurable area
Step 4 Cluster head selection
P ← Selection and participation assumption in percentage
Assume P is greater than 5 and less than 10 percentage
Step 5 If selected node should have more than threshold Th (rnd) value is found using Eq. (2).
Otherwise: Repetition mode: Next round.

### *3.4 Data Aggregation*

Data aggregation is done using non-sorted genetic algorithm techniques (NSGA), which is a decision-making approach that uses multiple mathematical optimizations to solve multiple problems simultaneously at an instant of time. The approach is a bookkeeping solution performed using a faster algorithm. All the solutions from the population are compared with the other solutions, and the dominated solution is accepted. The initial population size can be selected randomly. To sort a population of size P granting non-dominance [13]. LEACH protocol randomly gives equal opportunity to motes to become the CH at least once throughout the entire lifetime.

#### 3.4.1 Data Aggregation

Step 1 Data Aggregation
Input() first solution
Step 2 Assign the temp values
S' () temp values
S' = S'U {s}
Step 3 nDecision Zone
If a member of S' is less domination than s
For each r ∈ S' AND r ≠ s
If a member of S' is dominated than r
S'() S'{r}
Then, go to Step 1:

Otherwise
S' ()Best solution
S' () S'{s}

### 3.5 Routing

In the ACO approach, search activity is done by agents copying the behavior of blind ants. The motivation was taken from the real ants, how they could establish the shortest path from their colony to food source and back. Ants use to lay variable quantity pheromone to mark the path [14]. Ants are moving from their colony to the food, an obstacle is put on the path, and now, ants have to decide either to go in the left or right direction. Some of the ants move left, and some of the ants move right and drop pheromone on the way. After some time, the intensity of pheromone in the right direction is more than in the left direction, and thus, a new short path is found which is followed.

In ACO protocol used to design optimal path, assume following differences between artificial ant real ants:

- Our ants have memory but real ants do not have.
- Our ants are not completely blinded.
- A discrete-time environment is considered.

Our ultimate aim is to send the data to BS through MS via RZ or CH during the steady-state phase of the proposed method. To transmit data to the final destination needs to identify the routes through which energy consumption is minimum to enhance network lifetime. To find an optimized path between source and destination, apply ACO, which has the constraint of pheromone stagnation resulting in premature convergence. PSO is used to update pheromone parameters, we apply the PSO approach to find personal and global best routes is given by probability [15] rule Eq. (3):

$$P_i(s,d) = \begin{cases} \frac{[\rho(s,d)]^{\sigma} \cdot [\varepsilon(s,d)]^{\gamma}.}{\sum_{s \in R_s} [\rho(s,d)]^{\sigma} \cdot [\varepsilon(s,d)]^{\gamma}}, & \text{if } i \notin \text{tab u}^s \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

where $s$ represents a present surrounding node, $d$ represents destination, i.e., base station, $\rho(s,d)\rho(s,d)$ represent pheromone values, $\varepsilon(s,d)\varepsilon(s,d)$ represent energy efficiency, RS represents present receiver node, Us represents data of already received packets and $(\sigma, \gamma)$ represents parameters for controlling pheromone intensity. Initially, we find short routes and apply PSO to get the best routes. It is a population-based technique that uses particle fitness (Pbest), overall best experience (Gbest). To find the Pbest and Gbest, we use Eq. 4 and 5

$$\text{Vel}\,[] = \text{Vel}[] + d1 * R\text{and}() * (F\text{best}[] - \text{Recent}[])$$

$$+ d2 * R\text{and}() * (G\text{best}[] - \text{Recent}[])$$

$$\text{Vel}\ [] = \text{Vel}[] + d1R * \text{and}() * (F\text{best}\ [] - \text{Recent}[]) + d2 * R\text{and}() * (G\text{best}[] - \text{Recent}[]) \quad (4)$$

$$\text{Recent}[] = \text{Recent}[] + \text{Vel}[]\text{Recent}[] = \text{Recent}[] + \text{Vel}[] \quad (5)$$

where Vel[] represents the velocity of the particle, Recent[] represents the current particle value, $F_{\text{best}}[]$ represents the best fitness value, and $G_{\text{best}}[]$ represents the best global value. $R_{\text{and}}()$ is the function which contains values between (0,1). $d1$ and $d2$ are learning factor whose value is 2.

#### 3.5.1 Routing

Step 1 Routing scenarios

Step 2 Step 2: ACO-method: to discover an optimized path from source to destination

Step 3 Probability of choice of the next node s is given by probability rule Eq. (3): $P_i(s, d) P_i(s,\ d)$ Probability of choice

$$P_i(s,\ d) = \begin{cases} \frac{[\rho(s,d)]^{\sigma} \cdot [\varepsilon(s,d)]^{\gamma}.}{\sum_{s \in R_s} [\rho(s,d)]^{\sigma} \cdot [\varepsilon(s,d)]^{\gamma}} & \text{if } i \notin \text{tab u}^{s} \\ 0, & \text{otherwise} \end{cases}$$

Step 4 Assign the temp values S' temp values

Step 5 Initialize the all particles

Step 6 Calculation of fitness value for each particle

Step 7 If fitness value is better than the previous best fitness value, then set current value as the new best fitness value (Fbest).

Step 8 Select the particle with Fbest value among the particles having Gbest value.

Step 9 Determine the particle velocity by using equation

$$\text{Vel}[] = \text{Vel}[] + d1 *\ \text{Rand}() * (F\text{best}[] - \text{Recent}[]) + d2 * \text{Rand}() * (G\text{best}[] - \text{Recent}[])$$

Step 10 Set particle position according to the following equation

$$\text{Recent}[] = \text{Recent}[] + \text{Vel}[]$$

## 4 Simulation

Simulations are performed in MATLAB where three setups are considered. The first setup is RZLEACH which is basic LEACH with rendezvous node. In the second setup, NSGA ACO RZLEACH is taken. Third and the proposed setup is NSGA HNN-ACO/PSO RZLEACH is taken. Initially, n nodes are considered in a predefined area is considered, and we take results for first node dead, tenth ($1/4^{th}$) of total nodes dead, and all nodes dead as shown in Fig. 2. Three parameters, dead nodes, alive nodes, and the remaining energy are taken for area scalability 150*150, 200*200, 250*250, and 300*300.

Initially, simulation for 300 nodes and an area of 100 m × 100 m is performed to find out the first node, tenth node, and all nodes dead for three different approaches, i.e., RZLEACH, HNN-ACO-RZLEACH, and NSGA-HNN-ACO-PSO RZLEACH. The entire process is repeated by the scaling area to 150 m × 150 m, 200 m × 200 m, 250 m × 250 m, and 300 m × 300 m. Table 1 shows the initial parameters for the considered framework simulation. Table 2 shows the outputs from the simulation by the number of rounds in which the first node, the tenth node, and all node dead.

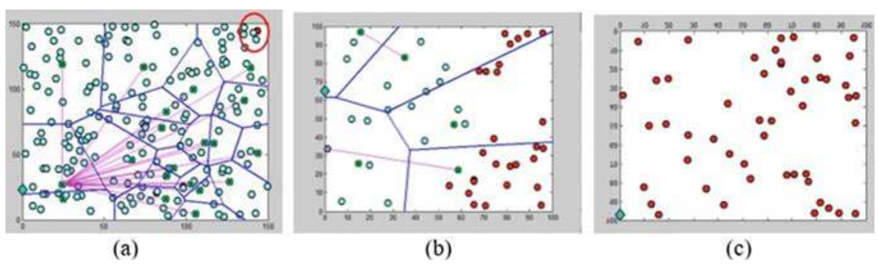

**Fig. 2** Simulation results **a** first node dead; **b** 1/4th of nodes dead, **c** complete nodes dead

**Table 1** Initial simulation values

| Simulation parameter | | |
|---|---|---|
| Parameters | Values | Description |
| $E_0$ | 0.3 J | Initial energy |
| $E_{amp}$ | 10 pJ/bit/m$^2$ | Energy dissipated for amplification by multi-path routing |
| $E_{fs}$ | 10 pJ/bit/m$^2$ | The energy dissipated for amplification by the free space model |
| $E_{RX}$ | 50 nJ/bit | The energy dissipated in receiving mode |
| $E_{TX}$ | 50 nJ/bit | Energy consumed in transmitting mode |
| $L$ | 4000 bits | Size of data packet |
| $n$ | 300 | Number of nodes (Varied for node scalability) |
| $R_X$ | 16%bits | Constant related to the region |
| $X_m$; $Y_m$ | 150*150 | Area of the region (Varied for area scalability) |

**Table 2** Simulation results, rounds for first, tenth, and all nodes dead

| Region dimension | No. of rounds | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | First node dead | | | 25% of nodes dead | | | All nodes dead | | |
| | RZ LEACH | HNN-ACO RZ LEACH | NSGA-HNN-ACO/PSO RZ LEACH | RZ LEACH | HNN-ACO RZ LEACH | NSGA-HNN-ACO/PSO RZ LEACH | RZ LEACH | HNN-ACO RZ LEACH | NSGA-HNN-ACO/PSO RZ LEACH |
| 100 m × 100 m | 200 | 250 | 50 | 300 | 400 | 150 | 496 | 731 | 727 |
| 150 m × 150 m | 60 | 70 | 80 | 139 | 156 | 262 | 502 | 748 | 760 |
| 200 m × 200 m | 20 | 32 | 69 | 37 | 49 | 139 | 522 | 724 | 729 |
| 250 m × 250 m | 4 | 6 | 47 | 15 | 17 | 199 | 489 | 720 | 730 |
| 300 m × 300 m | 1 | 2 | 42 | 8 | 10 | 129 | 432 | 722 | 731 |

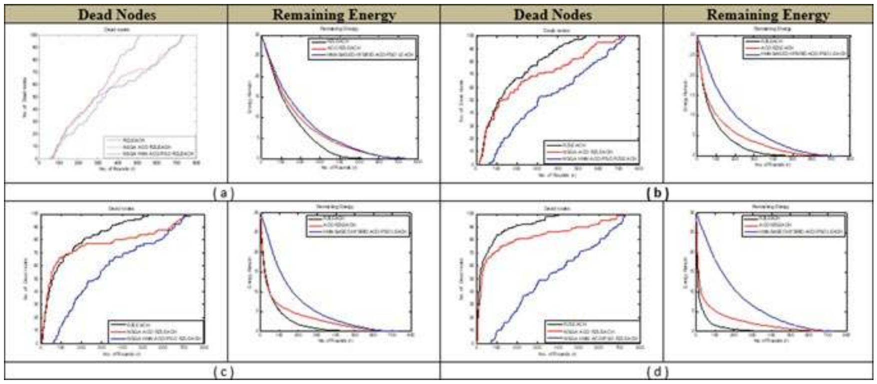


**Fig. 3** Graphs for dead nodes and remaining energy with area **a** 150 m × 150 m; **b** 200 m × 200 m, **c** 250 m × 250 m; **d** 300 m × 300 m

Parameters are considered for the quality of the network and define the lifetime of the network. Graphs in Fig. 3 show that the proposed framework performed well with sizes 250 m × 250 m and 300 m × 300 m. Table 2 shows that when network area is increased the network lifetime is improved with the proposed framework.

## 5 Results and Analysis

The present paper proposes a new framework, HNN-ACO/PSO RZLEACH which is an enhancement over RZLEACH, this framework adopts the novel approach for cluster head selection based on parameters like energy consumed, and time is taken for all the nodes dead in the given scenario. Proposed framework improvement in the network lifetime by 16% compared to basic RZLEACH and 9% compared to HNN-ACO-RZLEACH. There is a reduction in energy dissipation 26% compared to basic RZLEACH and 4% compared to HNN-ACO-RZLEACH.

## 6 Conclusion and Future Scope

The cluster head is the main energy consumer, so the selection of cluster head plays an important role in saving energy. The present paper proposes a Hopfield neural network for cluster head selection. Energy consumption is a major design issue in routing aggregated data to the base station, and the hybrid ACO-PSO approach proposed in the framework. Further, the work can be extended to bigger networks by using nature-inspired technologies.

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# A Review of LEACH Successors Using Single-Hop and Multi-Hop Communication Model

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**Abstract.** LEACH model was proposed 19 years back and research community from the field of WSN has been exploring LEACH variants. To discover unseen areas in the field of WSN it is a great idea to study approved variants of LEACH through the time. Present paper studies the popular and approved versions of LEACH. The study categorizes all the variants in single and multi-hop communication mode, depends upon packets transmitted from the CH and the BS. The paper makes a comparative analysis based on parameters like cluster formation, complexity, energy efficiency, overhead, and scalability. Advantages and disadvantages of all the variants are discussed. Finally, the paper suggests upcoming research in the field of WSN.

**Keywords:** Cluster · Cluster head · Clustering algorithm · Energy efficiency · LEACH · Routing algorithm · Motes · Wireless sensors

## 1 Introduction

WSN or wireless sensors network is defined as a group of small sensing nodes also called motes are deployed in an area with one or more leading nodes called base stations. These motes are very small in terms of physical size, sensing, processing, and communication capabilities [1–5]. WSN has widespread application possibilities, such as air pollution monitoring, area monitoring, commercial applications, environmental/earth sensing, forest fire detection, health care monitoring, home applications industrial monitoring landslide detection military applications and water quality monitoring [2, 5, 6]. Limited power, the low processing power of nodes, low bandwidth, and absence of conventional addressing technique makes designing of routing algorithm challenging task.

Heinzelman et al. [4] in the year 2000 proposed the first-ever hierarchical algorithm named LEACH, "Low energy adaptive clustering hierarchy". Based on LEACH many hierarchical algorithms have been developed, some of them are EECS [5], HEED [6], PEGASIS [7], TEEN [8] and T-LEACH [9].

The objective of LEACH and its variants are to increase the energy efficiency, increase coverage area, scalability, effective data aggregation, minimum delay, provide security to data and robustness. The most common and significant aim of these algorithms is to reduce energy dissipation [10].


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### 1.1 LEACH "Low Energy Adaptive Clustering Hierarchy" Algorithm

Clustering is the technique of effectively arranging mote and control approach which can be used to improve the network lifetime and scalability of networks. Energy efficiency in LEACH clustering algorithm for WSN is achieved by selecting CH randomly. The operation of LEACH has multiple rounds as in Fig. 1. All the rounds constitute two phases set-up and steady-state phase as shown in Fig. 2 redrawn from [4]. During the setup phase, CHs are elected, motes associate themselves with CH to create a cluster.

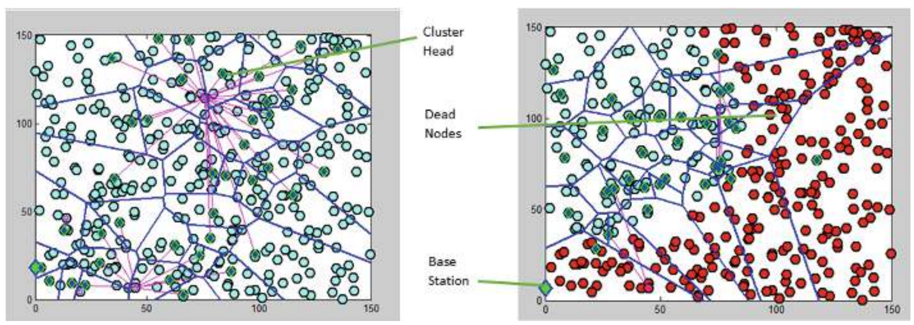


**Fig. 1.** Leach algorithm, the illustration of two rounds.

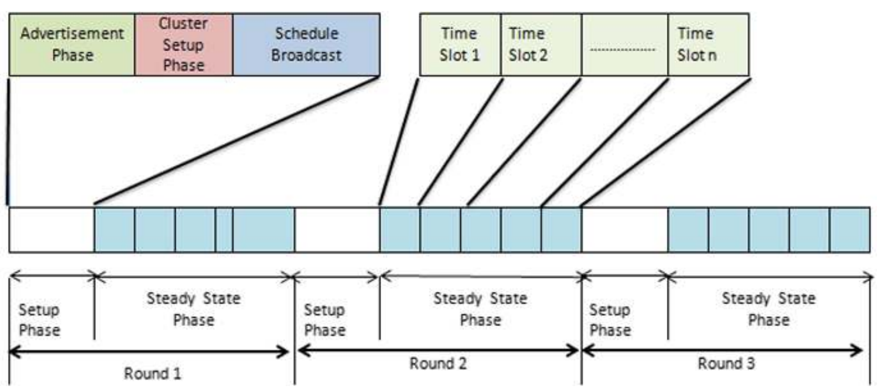


**Fig. 2.** LEACH operations

In the process of CH election, all the motes produce a random number between 0 and 1, if the random number is less than threshold *Th (rnd)*, the mote becomes CH for the current round; the threshold value is selected using selection Eq. (1) as follows:

$$Th_{(rnd)} = \begin{cases} \frac{p}{1-p*\left(rnd mod \frac{1}{p}\right)}, & if\ n \in G \\ 0, & otherwise \end{cases} \tag{1}$$

Where $P$ indicates the sought after % of motes to be elected as CHs from all the motes, rnd means the present round and $G$ are the numbers of motes which were not part of the process of cluster head election in last $1/P$ rounds. The mote which turns into cluster head in round *rnd* will not be participant mote for next $1/P$ rounds. Thus, all the mote gets a chance to become the CH, leading to a uniform distribution of energy consumption by motes. When a mote is chosen as CH, it broadcast an ad message to all the motes. Contingent upon the strength of the signal, motes join one of the clusters. New ad message is based on Eq. 1. After forming the cluster, in order to avoid collision CHs plans and follows the TDMA aired to all the motes of the concerned cluster. Motes which are not active go into sleep mode.

Steady-state phase follows the setup phase. During this phase data sensed by motes is transmitted to CH, data gathered by CH is further sent to the base station following the TDMA schedule. While one mote is sending data to CH other motes remains in sleep mode resulting in a reduction in the intracluster collision which enhances the battery life of motes.

As cluster head is chosen randomly, so the same mote may be cluster head again and again. After a few rounds, none of the motes have enough energy to become CH. In LEACH formation of clusters is random. The positioning of the CH is not well defined in LEACH, CHs as CHs may be positioned near the center of the member clusters, while in another scenario the location cluster head may be near the boundaries of the concerned clusters, resulting in higher energy dissipation during intracluster communication. Resulting in degradation in the overall performance of the network. To improve the performance single-hop and multi-hop communication model is used.

## 2 LEACH Successors Using Single Hop Communication Model

In LEACH, CH receives data from member motes of the concerned cluster, gathered data is then transferred to the BS. Communication process plays an important role in attaining efficiency. If the area of the network is small, single-hop communication is beneficial as overhead, cost and delay are reduced, resulting increased network lifetime. In the variants of LEACH, researchers focused on cluster head selection, creation of clusters and communication within the cluster. This section discusses major LEACH variants which have an improvement over LEACH.

### 2.1 LEACH-C

Although in the year 2002 Heinzelman et al. [11] proposed LEACH-centralized, an algorithm using central control algorithms in the creation of clusters during the setup and steady-state phase like basic LEACH algorithm. Whereas LEACH-C distributes the cluster head evenly over the entire area of the network thus excellent cluster are formed. Overhead do not increase as the steady-state phase is executed by the base station. The average energy contained by the network $E_{avg}$ is given in Eq. 2.

$$E_{avg} = \frac{\sum_{i=1}^{N} E_i}{n} \tag{2}$$

Where the remaining energy of the $i^{th}$ mote is $E_i$. And the total motes is denoted by *n*. If the average distance between elected CH and the BS is $d_{tBS}$, $e_{fs}$ is transmission fields and $e_{mp}$ receiving fields for both free space and multipath respectively and if there are *n* motes uniformly deployed in an area then K can be determined using Eq. 3,

$$K = \sqrt{\frac{N}{2\pi}\frac{e\text{fs}}{e\text{mp}}\frac{M}{{d_{tBS}}^2}} \tag{3}$$

In LEACH-C, is centralized so it is less scalable, as cluster head selection is done by BS so it is energy efficient than LEACH. In LEACH-C we need to define position so we require GPS to define location and GPS is a costly device.

### 2.2 DCHS-LEACH

In the year 2002 Handy et al. [12] proposed a modification in LEACH Deterministic Cluster Head Selection LEACH where CH selection is changed to reduce energy dissipation for prolonging the network lifetime, achieved by modifying the threshold T (n) value for electing the cluster head as in Eq. 4 and using a deterministic approach of CH selection resulting low energy consumption.

$$T(n)_{new} = \frac{P}{1 - P\left(r \bmod \frac{1}{P}\right)} \frac{E_{ncurrent}}{E_{nmax}} \tag{4}$$

Where $T(n)_{new}$ is modified threshold value $E_{ncurrent}$ represents the current energy of the node and $E_{nmax}$ is the initial energy of the mote. Initially, this worked out but later on after a few rounds the network stopped. The problem is solved by providing another energy model as in Eq. 5.

$$T(n)_{new} = \frac{P}{1 - P\left(r \bmod \frac{1}{P}\right)} \left[\frac{E_{ncurrent}}{E_{nmax}} + \left(r_s div \frac{1}{P}\right)\left(1 - \frac{E_{ncurrent}}{E_{nmax}}\right)\right] \tag{5}$$

With these modifications, the lifetime of the network is enhanced by 30%. The lifetime of microsensor networks can be obtained but overall performance is degraded due to frequent cluster formation.

### 2.3 Unequal Clustering LEACH (U-LEACH)

In the single-hop model method, the cluster head sends the aggregated date directly to the base station causing more energy consumption by the distant base station, thus energy consumed is directly proportional to distance. In the year 2010, a clustering algorithm based on unequal LEACH that contains more setup phases was proposed by Ren et al. [13]. The paper proposes a different cluster heads selection phase. Present work suggests two elements of competitive distance and residual energy percentage for any mote to be a part of the cluster head election. Authors have taken the unequal size of circular clusters, cluster nearer to base station are larger than the cluster at a far distance.

Proposed clustering mechanism minimizes the hotspot problem of LEACH Algorithm also balances the energy and enhances the lifetime of the network. The disadvantage of the proposal is intracluster data transmission between clusters nearer to the base station.

### 2.4 Genetic Algorithm-Based LEACH

In the year 2011 Singh et al. [14] in their survey found Nature-inspired computing (NIC) i.e. Bio-Inspired, Evolutionary Computing, and Swarm Intelligence algorithms can be utilized to tackle complicated problems in modest ways. Liu et al. [15] proposed a genetic algorithm based LEACH (LEACH-GA) which suggested probability-based cluster head selection. In the beginning, all motes are CCH (candidate for cluster head selection process) they generate a random number Rnd which in-turn is compared with threshold value Threshold(s) and if Rnd is less than Threshold(s) and probability value PROBsat is 0.5 the mote becomes cluster head. Rest of the motes send theirs sends its id and location information to the base station. Base station uses a genetic algorithm, evolutionary optimization process, probability transitions, non-deterministic rules, mutation operators and crossover. Probability $PROB_{OPT}$ for n motes and $K_{OPT}$ clusters is defined by relations of Eq. 6

$$PROB_{OPT} = \frac{K_{OPT}}{n} \tag{6}$$

The performance of LEACH-GA is superior to LEACH regarding energy efficiency but overhead cost and scalability is an issue.

### 2.5 Energy Potential LEACH (EP-LEACH)

In the year 2013 Xiao et al. [16] EP-LEACH used energy harvest technique [17] to improve the lifetime of LEACH motes have rechargeable energy bank which gathers energy from its atmosphere. It is different from LEACH in CH selection phase. The motes with more energy have more probability to become CH and mote can become a CH many times. Accordingly, the threshold equation of LEACH is reformulated in Eq. 7 [16] based on the proposed two modifications.

$$T_k(i) = \frac{F_k(i)}{\sum_{r \in N_k} F_r(i)} X\,P\,X\,|N_k| \tag{7}$$

Where $N_k = \{r|D(r,k) < D_t\}$ D(r, k) is a distance between nodes k and r, $D_t$ is threshold distance between neighboring nodes.

### 2.6 Improved LEACH (I-LEACH)

In the year 2013 Beiranvand et al. [18] proposed a new idea in the CH section for improvement in LEACH. CH is selected by considering parameters like distance from BS, the number of neighboring motes and their remaining energy. Motes find these parameters from Eqs. 8 and 9 [18]. The number of motes in the neighborhood is defined by its coverage area of radius $R_{ch}$, which is given by Eq. 8.

$$R_{ch} = \sqrt{\frac{(M * M)}{(\pi * K)}} \quad (8)$$

$$T(n) = \begin{cases} \left(\frac{p}{1-p*\left(rmod\frac{1}{p}\right)} * \frac{E_c}{E_{avg}} * \frac{Nbr_n}{Nbr_{avg}} * \frac{dt_o BS_{avg}}{d_{to} BS_n}\right), & if\ S \in G \\ 0, & otherwise \end{cases} \quad (9)$$

Where K number of clusters are deployed in *M*M* area. Improved threshold *T*(*n*) is shown in Eq. 9. Randomly generated number is compared with *T*(*n*), the mote whose randomly generated number is less than the threshold becomes the cluster head for the present round. Arrangement of motes in the given network reduces energy dissipated per mote thus increases network lifetime.

### 2.7 Vice Cluster LEACH (VC-LEACH)

In the year 2015 Sasikala et al. [19] proposed a concept of vice CH in V-LEACH. Because of poor CH selection in LEACH, some of the CHs die before completing its the current round, vice cluster head will take over the role of cluster head when the original CH dies before the completing its present round. There are three types of motes in VLEACH, CH, member motes of cluster and VCH which works as CH in case CH dies. Thus V-LEACH results more efficient in data delivery and energy efficiency.

## 3 LEACH Successors Using Multi Hop Communication Model

Data transfer between the BS and CH situated at far distances is done via relay nodes or motes which are now cluster heads. Radio model interprets that energy consumed by motes is proportional to the distance between sender and receiver. Energy consumption is proportional to $d^4$ if the distance is more than the threshold distance. As the distance between transmitter and receiver is a major factor, researchers aimed their research on cluster formation and size of the cluster. Present section confers about popular multi-hop communication.

### 3.1 LEACH-B

In the year 2003 Depedri Mahmood *et al.* [20] proposes new strategies for cluster creation and selecting cluster head from motes. The proposed algorithm uses multihop approach, the clusters chosen by the researchers is $N_a$ the motes are $N_{TOTAL}$ distributed uniformly in area of consideration i.e. SXS square meter. Average motes in each cluster are $N_{TOT}/N_a$ non-cluster head motes are $((N_{TOTAL}/N_a) - 1)$ of all the cluster heads is dissipated while transmitting their own packets, retransmitting the packets received from other cluster heads to next cluster head until it reached the base station and energy consumed in advertising. The threshold value is calculated by Eq. 10:

$$T_p(t_i) = \begin{cases} \left(\frac{N_a}{N_{TOTAL} - N_a\left(rmod\left[\frac{N_{TOTAL}}{N_a}\right]\right)}\right), & : C_p(t_i) = 1 \\ 0, & : C_p(t_i) = 0 \end{cases} \tag{10}$$

Node p's selection as cluster head depend upon chosen number in between 0 and 1. Node is eligible to become cluster head if it is less than a threshold Tp(ti). Network lifetime in LEACH-B is better than LEACH but it does not perform well in data aggregation task.

### 3.2 LEACH-ME

In the year 2008 Kumar et al. [21] proposed an extended version of [22], LEACH-ME primary focus of the protocol is on the election of CH. Motes change their clusters and cluster heads as motes are mobile. Relative motions of the nodes among each other, a function defining relativity measure wrt its immediate neighbors are given as in Eq. 12:

$$M_x(t) = \frac{1}{n-1}\sum_{y=0}^{n-1}\left|D'_{xy}(t)\right| \tag{11}$$

Where Dxy is the distance of node $x^{th}$ to all $y^{th}$ neighboring nodes. Motes aggregate data according to TDMA schedule issued by corresponding cluster heads, if presently a node is not sending data to cluster head it goes in sleep mode to save energy.

### 3.3 C-LEACH

In the year 2010 Asaduzzaman et al. [23] have proposed a cross-layer cooperative diversity protocol for LEACH based WSN. Multiple input multiple output framework based on cooperation is proposed. Multiple CHs are within a single cluster across a layer. After aggregation of data from the motes of the cluster, all the CHs cooperatively send data towards the sink.

### 3.4 LEACH-Density

In the year 2010 Liu et al. [24] proposed LEACH-D (LEACH based on Density of node distribution) to attain improved network lifetime, the researcher proposed that threshold value as in Eq. 12 is a function of node distribution density to improve connectivity and electing cluster head. Formation of a cluster depends upon the degree of connectivity. Thus, motes join the cluster by looking into the energy attained by cluster head.

$$Th(i) = \frac{p}{1 - p\left(r mod \frac{1}{p}\right)} \cdot \frac{E_{iresidual}}{E_{initial}} \cdot \frac{D_i}{D_{avg}} \quad (12)$$

Where Th(i) is the threshold for $i^{th}$ round $E_{iresidual}$ is present residual energy of mote, $E_{initial}$ is initial energy of the mote, $D_i$ is the degree of connectivity and $D_{average}$ is average connectivity degree of the network.

### 3.5 SAGA-LEACH

In the year 2012 Zhaou *et al.* [25] proposed the LEACH-SAGA ("Simulated Annealing and Genetic Algorithms"). SAGA LEACH and LEACH are different by the process of CH selection process. The proposed method uses a simulated annealing and genetic algorithm to elect CH while normal LEACH uses random approach. Factors considered are the residual energy of motes, the distance of CH from the cluster center and the average energy of the cluster. The controller algorithm is implemented at the BS. Performance of the proposed protocol is better in terms of network lifetime, CHs are evenly distributed and the energy requirement is less. The proposed protocol can not handle scalability and overhead is high due to complexity.

## 4 Analysis LEACH Successors

A subjective analysis of LEACH successors is introduced in Table 1 these algorithms are arranged in chronological order. All the mentioned algorithms are compared on various parameters like cluster formation techniques, complexity, delay, energy efficiency, overhead, and scalability. Basic LEACH algorithm has some limits as discussed in Sect. 1. These limitations are addressed in LEACH successors in Sects. 2 and 3. These algorithms show better performance than LEACH in several features like complexity, delay, energy efficiency, overhead, scalability, etc. following conclusion is made from the survey.

(1) Few of the LEACH variants addressed security-related issues but the algorithm proposed increases energy consumption, latest lightweight cryptography techniques can be used to save energy.
(2) Optimization techniques are proposed only on finding the number of cluster and CH selection. Optimization of routing and data aggregation needs to be looked upon.

(3) Renewable energy is a promising research area in WSN. None of the variants utilized renewable energies. Solar power, thermal energy, wind energy, etc. can be used to increase energy efficiency.
(4) Mobility and network coverage is not discussed in any of the LEACH variants.
(5) GPS is the only tool used as location finder in LEACH and its variants. GPS requires a big volume of energy resulting in increased cost.

**Table 1.** Analysis of LEACH successors.

| LEACH successor | Year | Communication model | Cluster formation | Complexity | Delay | Energy efficiency | Overhead | Scalability |
|---|---|---|---|---|---|---|---|---|
| LEACH C | 2002 | Single hop | Centralized | Lo | Lo | Hi | Lo | Lo |
| LEACH DCHS | 2002 | Single hop | Distributed | Moderate | Lo | Hi | Hi | Lo |
| LEACH B | 2003 | Multi-hop | Distributed | Moderate | Lo | Hi | Hi | Lo |
| SLEACH | 2005 | Single hop | Distributed | Complex | Lo | Very Hi | Hi | Moderate |
| TL-LEACH B | 2006 | Multi-hop | Distributed | Lo | Lo | Hi | Lo | Lo |
| LEACH-ME | 2008 | Multi-hop | Distributed | Complex | Hi | Moderate | Hi | Hi |
| U LEACH | 2010 | Single hop | Distributed | Complex | Lo | Hi | Lo | Lo |
| C LEACH | 2010 | Multi-hop | Distributed | Complex | Hi | Hi | Hi | Lo |
| LEACH D | 2010 | Multi-hop | Distributed | Complex | Lo | Very Hi | Hi | Very Hi |
| LEACH GA | 2011 | Single hop | Distributed | Complex | Lo | Hi | Hi | Lo |
| EP LEACH | 2013 | Single hop | Distributed | Complex | Lo | Very Hi | Hi | Lo |
| I LEACH | 2013 | Single hop | Distributed | Complex | Lo | Hi | Moderate | Lo |
| SAGA LEACH | 2014 | Multi-hop | Distributed | Complex | Lo | Hi | Moderate | Hi |
| V LEACH | 2015 | Single hop | Distributed | Complex | Lo | Very Hi | Hi | Lo |

## 5 Conclusion

The present paper presents a comprehensive survey of single-hop communication in LEACH and its successors. Cluster formation technique, delay, energy efficiency, overheads cost, scalability, etc. are comparatively analyzed for LEACH and its variants. It is proved by the researchers that LEACH variant algorithms are an improvement over the basic LEACH algorithm. The main achievement of any newly proposed algorithm in WSN is to enhance energy efficiency. According to this survey major of the mentioned algorithms are distributed in nature. While CH selection, energy is a major parameter considered by all the researchers apart from this researcher has looked into other parameters like distance from the BS, the density of motes, location of motes, renewable energy usage, the minimum number of CHs. Many of the researchers have used probabilistic clustering approaches, presently deterministic approaches are also becoming popular, the drawback of deterministic approaches is that they consume more energy and are complex in nature. All variants discussed in the paper claimed to be better than LEACH. Some of the areas of scope are discussed in Sect. 6.

## 6 Future Scope

LEACH routing algorithm was proposed 19 years back to enhance the lifespan of the wireless sensor networks. It was done by distributing the load equally for data collection from motes, data aggregation from CH to BS. Absence of proper algorithm to process the selection of CH randomly, placing it in the cluster and single-hop communication mode from CH to BS causes hindrance to network lifetime. Further, several alterations are proposed on basic LEACH to overcome these issues. Many variants of LEACH are working on energy efficiency, the need of the day is to do research on security and renewable energy techniques developments for WSN. A new variant of LEACH which uses a hybrid approach, in which cluster head selection is done by Hopfield neural network, data aggregation is done using NSGA and routing is done by swarm intelligence method.

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# Optimization of LEACH for Developing Effective Energy-Efficient Protocol in WSN

**Avinash Bhagat and G. Geetha**

**Abstract** In the present research paper, the author is trying to improve LEACH for increasing energy efficiency of protocol within wireless sensor network by optimizing Low Energy Adaptive Clustering Hierarchy (LEACH). Optimizing LEACH protocol has certain limitations like routing, aggregation, selection of cluster head (CH) and transmission of data to cluster head which tends to uneven distribution of Energy. Taking this problem into consideration, we are focusing to enhance energy efficiency protocol. We have proposed a solution to improve LEACH by implementing new scheme for selection of cluster head and changing the routing techniques.

**Keywords** Cluster head · Hopfield neural network · LEACH · Mobile sink · Rendezvous node · Residual energy · WSN

## 1 Introduction

Wireless sensor network (WSN) contains a battery function and small sensor nodes which are positioned over a wide geographical area to monitor the events and to accumulate the collected data to a distant centralized location called as base station. Organization of nodes is done in such a way that entire area is covered with wireless nodes. Deployed nodes sense the data from its neighbour and transmit the collected data for further processing. Difference between ad hoc networks and wireless sensor networks is their distinct area of applications. Ad hoc networks mainly focus on communication aspects, whereas WSN focuses more on monitoring and information collection. Wireless nodes are bound by several resource restrictions such as the memory availability, battery power, bandwidth requirement, and the data rate. These tiny nodes may work for a longer duration of time from few months to many years depending upon application requirements. To enhance the network lifetime, many suggestions have been proposed. The power consumption of wireless sensors can be reduced by creating clusters of sensors. Designing a clustering algorithm remains

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a challenging issue [1]. In order to improve network lifetime, use of battery power needs to be employed proficiently. Sleep mode operation is one of the effective methods to increase network lifetime; when needed, they can switch to wake-up mode if node needs to sense environment. Sensor node should communicate through special routing technique like Hopfield neural networks to maximum battery life [2]. Sensor nodes reduce the redundancy of data transmission by collecting data from the neighbouring nodes through cluster heads (CH). Data is collected and then transmitted to mobile sink. Further in research, we have proposed to use Hopfield neural networks routing technique to improve LEACH in which nodes are grouped in the form of clusters using the least distance benchmarks [3]. The routing is done by the ACO-PSO hybrid approach to find optimum routing that connects the elected cluster heads to base station. Nodes are homogeneous and have limited energy. The results based on certain parameters are compared with existing basic LEACH and optimized LEACH [4].

The paper is organized in six sections as below:

- Brief review of the literature presented in Sect. 2.
- The network and radio model of our improved model is discussed in Sect. 3.
- Improved LEACH protocol analysis and simulation is discussed in Sect. 4.
- Simulation parameters, simulation model and results are discussed in Sect. 5.
- Conclusion is done in Sect. 6.

## 2 Related Work

Singh et al. [4] investigated and concluded that even after 16 years of existence of Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, very few measured the utilization of energy during CH selection and cluster formation during simulation.

Arumugam and Ponnuchamy [5] suggested energy-efficient LEACH according to which an optimized energy-aware routing protocol is obligatory for gathering data. As seen, almost all sensor nodes have related impact and equal competences which inspires the need for refining lifespan of the sensor nodes and sensor network. According to the author, the proposed objective of EE-LEACH protocol is to reduce the energy consumption and increase the network longevity.

Mottaghi and Zahabi [4] discussed that the construction of small and smart sensors with a very little cost is a result of wireless sensor network developed from recent development in the area of wireless sensor network, communication and micro-electronic mechanical systems (MEMS). WSN is a decentralized, self-configurable network which is made by large number of interconnected sensor nodes and sink in predesigned sample framework. Sensor nodes send its data to the sink for processing. Sensor nodes use single-hop transmission technique for short distance [6].

The network efficiency can be improved by decreasing distance of transmission, as energy consumption is more in case of long-distance communication. Reduction in distance also improves the network lifetime. The distance can be reduced by using multihop method where each node transfers data through other nodes into sink. All intermediate nodes act as routers, this method reduces the distance of the transmission, and hence, total energy consumption can be reduced. A suitable protocol must be used to select an optimized route for transmitting the data from node to sink. Only drawback of this technique is energy drop rate is very high for the nodes which are located near mobile sink.

Another solution for optimizing energy utilization will be use of clustering techniques where cluster members transmit data to cluster head and collected data by cluster heads is transferred to mobile sink [4].

Heizelman et al. [7] suggested an effective clustering algorithm in which nodes located in a cluster transmit data to CH; this algorithm is also popularly known as LEACH. In LEACH algorithm, the signals received by the cluster head from the nodes of a cluster and then cluster transmit the effective information to the sink after decreasing the total number of bits. The communication ability of the cluster head ends when it uses all its energy and dies, if the cluster head operations are fixed for some specific nodes within the cluster. Therefore, cluster head is not able to communicate to the rest of the cluster members. To distribute energy consumption evenly in considered area, a random rotation structure is followed through all the nodes used by the LEACH. In LEACH, the cluster heads are selected randomly and a node can select the cluster where it belongs. The decision for transmission from each node is done according to the time-division multiple access (TDMA) policy [4, 6, 7]. In LEACH, we follow adaptive clustering and random CH selection on rotation basis allows distributed energy which makes LEACH a better protocol than its counterpart conventional protocols in terms of energy consumption. Data aggregation by CH in LEACH helps for effective utilization of power consumption during data transmission; further, it also helps to reduce energy consumption by implementation of mobile sink. MS gathers data from all the nodes while moving in or around the environment. Sink movement can be controlled or uncontrolled, but the path is controlled and predefined and movement of the mobile sink is uncontrolled and random in specified environment. Mobile sink movement in close proximity of normal nodes decreases the transmission distance and time. Implementation of mobile sink was introduced to increase lifetime of wireless network, increasing distance between two movements and minimizing stopover time and location.

According to study, mobile sink could not be very close from all nodes for gathering data. An idea of Rendezvous Points (RPs) is developed [5] in which RP near trajectory of sink and a node, i.e. rendezvous node located nearby which transmits data to the mobile sink as it passes nearby [4]. Previous studies [4, 6, 8] demonstrated the effectiveness of RPs on the performance of mobile sink. [4, 9, 10], studied the effect of MS movement on a predetermined path which uses RN for data collection. The MS sends beacon signals to notify the RNs of the MS arrival. The advantage of using LEACH algorithm is its self-organization property, each node is free to join any of the clusters, and it decides whether to be CH or not. MS is not a part of CH selection.

According to the present study, cluster head selection is done using Hopfield neural network method and data aggregation is done using hybrid ACO-PSO algorithm to get the optimized results. The present study is sought to preserve the property of self-organization in LEACH algorithm and improve CH selection. The proposed improved LEACH decreases energy consumption in WSNs as compared to traditional LEACH, particularly when the network is large [4, 11, 12].

## 3 Network Model Evolution

Various assumptions made while designing improved LEACH are as follows:

- BS is located far from the sensor network and moving along *Y*-axis.
- Nodes are homogeneous and have limited energy.
- Data is gathered periodically from the given environment.
- The energy needed for transmission from node i to node j is the same as energy needed from node j to node i, for a given signal-to-noise ratio.

Energies required for transmitting and receiving data packets are $E_{\text{elec}} = E_{\text{TX}} = E_{\text{RX}} = 50$ nJ/bit. Energy model to calculate energy consumption during transmission or receipt of data used in present study is given by Eq. (1) [4, 5]. In the model, the energy dissipated to transmit *l* bits of message to another location at distance d metre is given by $E_{\text{Tx}} = \text{E}_{\text{Tx\_Elec}(l)} + \text{E}_{\text{TX\_amp}(l;\, d)}$ as shown in Eq. 1

$$E_{\text{TX}} = \begin{cases} l * E_{\text{TX}} + l * d^2, \text{ if } d < d_0 \\ l * E_{\text{TX}} + l * d^4, \text{ if } d \geq d_0 \end{cases} \quad (1)$$

where

$$d_0 = \sqrt{\frac{E_{\text{mp}}}{E_{fs}}}$$

and $E_{\text{TX}}$ is the energy consumed by the radio electronic circuit for *l* bit transmission, $E_{\text{fs}}$ is the energy consumed by power amplifier on the free space model, and $E_{\text{mp}}$ is the energy consumed by power amplifier in the multipath model. If the transmission distance is less than $d_0$, the energy consumed is proportional to $d^2$, and if the transmission distance is more than $d_0$, the energy consumed is proportional to $d^4$. The total energy consumed to transmit and receive data is given by Eq. 2:

$$E_{\text{Tx}} = E_{\text{Tx}}(l, d) + E_{\text{Rx}}(l) \quad (2)$$

where $E_{\text{Rx}}$ is the energy consumed by a node in receiving mode.

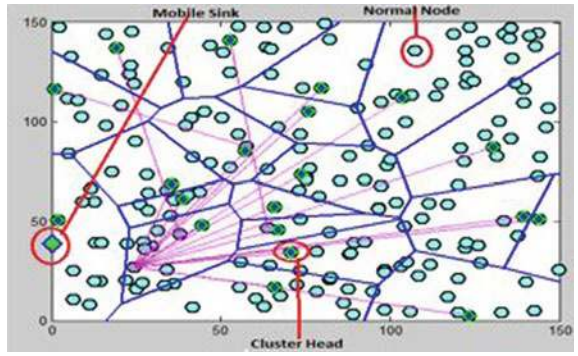


**Fig. 1** Initial setup with fixed network area of 150 m × 150 m

## 4 Improved LEACH

Improved LEACH is the routing algorithm over the optimized LEACH. It works in four main phases: network construction phase, cluster head selection phase, task ordination phase and data transmission phase.

### *4.1 Network Construction Phase*

In this phase, fixed network area of 150 m × 150 m is taken; in this area, initially 100 nodes are placed. Node scalability is taken from 100, 120, 140, up to 400 nodes. It is assumed that position of BS is moving along the *Y*-axis as in Fig. 1. The procedure for the selection of cluster head is discussed in the next section.

### *4.2 Network Construction Phase*

Limitations on the parameters of the network are initialized with number of nodes, initial energy and sink location. Following are the steps to find cluster head using Hopfield neural network.

- Initialize weights, $T_{\mathrm{XY}} = \sum_{c=0}^{M-1} i_x^c i_y^c$,
- where $x \neq y$, $i_x^c$ is element x of class c exemplar and $i_y^c$ is element y of class c exemplar.
- Apply input on the outputs $z = i$.
- Iterate until the network converges.

$$z_y^+ = f_h \sum_{x=0}^{N-1} T_x^y x^z z^x \tag{3}$$

where $f_h$ is hard limiter. The output converges to the best matching exemplar. A single Hopfield, is a popular method of Hopfield neural network is implemented to monitor group of nodes to check eligibility for becoming cluster head. Hopfield network also helps for pattern recall. In this method, we assign weights to every node according to certain decided parameters by taking the value of −1 or +1 [13]

$$T = [+1, +1, +1, +1, \ldots, -1, -1, -1, -1]$$

As per above illustration, first parameter indicates energy consumption (minimum), second parameter indicates distance (minimum), third parameter highlights surrounding nodes in the clusters (which should be maximum), and fourth constraint highlights ratio of consumed energy to allotted energy (which should be maximum). As per one-hop-field method, best case obtained value will be [−1 −1 +1 +1], whereas in worst case obtained values will be [+1 +1 −1 −1]. All nodes with best and average set of values will be considered for cluster head selection [13].

Computation of average energy consumption by all eligible set of nodes is called a threshold value $d_0$. As per condition, only those nodes whose energy level is ≤ threshold value $d_0$ will participate in CH selection and also generate random number between 0 and 1, whereas nodes which do not fulfil required condition lead to wait for 1/*p* rounds. In order to become eligible as cluster head, the number should be less than the threshold *Th*(rnd) [4, 13]. The threshold in our case is given below in Eq. 4.

$$Th_{\text{rnd}} = \left\{ \begin{array}{ll} \frac{p}{1-p*(\text{rmod})\frac{1}{p}}, & \text{if}\, n\, \varepsilon\, G \\ 0, & \text{otherwise} \end{array} \right\} \tag{4}$$

As per above equation, ‘*p*’ represents total percentage of nodes eligible to be cluster head, *r* stands for current round, ‘*G*’ signifies subset of nodes which is selected as cluster head, and all leftover nodes which are not CH and RN will serve as normal nodes [13].

### *4.3 Network Construction Phase*

Let us assume all are normal nodes; each of them decides whether RN condition is satisfied or not. To become RN, a prerequisite is to be placed and all necessary conditions must be satisfied. Distance of nodes is equated with MS trajectory [13]. Nodes which fulfil all necessary conditions will be labelled as RN, and necessary conditions are given below in Eq. 5.

$$\frac{y_{\mathrm{w}}}{2}(1 + R_{\mathrm{x}}) \leq Y_{\mathrm{y}} \geq \frac{Y_{\mathrm{w}}}{2}(1 - R_{\mathrm{x}}) \quad (5)$$

where $Y_{\mathrm{W}}$ stands for sampling region width, $\mathrm{Y_Y}$ signifies position of node in y-direction, and constant $\mathrm{R_x}$ needs to have value less than one [13].

### *4.4 Data Transmission*

To transmit the data, shortest route search is necessary which also helps to optimize use of energy consumption only after creating and establishing schedule of data transmission. Once shortest routes identified, data transmission begins. Let us assume all rounds nodes hold some data, and at the same they also generate data at the same rate. In order to increase the energy efficiency and utilization, all the normal nodes communicate and send data to cluster head in its allotted time frame, and it is also important to keep radio on of normal node. It is also mandatory for all receiving CHs and RNs to be kept ON during data transmission. Once data transmission completes, all gathered data from all the nodes then CH sends data either sent to MS or closest RN [13].

## 5 Simulation Model and Results

Simulation is performed on MATLAB version R2014a considering fixed area of 150 m × 150 m. Initially, 100 nodes are taken as sample population sink is moving along y-axis as shown in Fig. 1. In the present work, we have taken static nodes and mobile sink taking nodes scalability from 100, 120, 140, increasing by 20 nodes and maximum up to 400 nodes. Initial parameters used in simulation model are described in Table 1.

Nodes are placed randomly in the given area. In the proposed work, the performance of improved LEACH is compared with LEACH [7] and optimized LEACH [4] observing number of rounds consumed for first (Fig. 2a), teenth (25%) (Fig. 2b) and all nodes dead (Fig. 2c).

Other parameters observed are residual energy, packets sent to base station and cluster head after round numbers 100, 120, 140,… 400. Initially, all the nodes are at same energy level, i.e. 0:3 J, and by scaling the nodes, we compare residual energy of the nodes shown in Fig. 3f. It is noticed from the graphs Fig. 3 and Tables 2, and 3 that improved LEACH is having better results in terms of number of rounds for first, tenth and all nodes dead for the given population of interest. Further, residual energy is marginally more, and a number of packets sent to base station and cluster head are more in improved LEACH. All these values lead to reduced energy consumption and hence increased network lifetime. A number of packets sent to base station and cluster head are significant performance evaluator. Simulation environment is designed to

**Table 1** Simulation parameters

| Simulation parameter | | |
|---|---|---|
| Parameters | Values | Description |
| $E_0$ | 0.3 J | Initial energy |
| $E_{amp}$ | 0:0013 pJ/bit/m$^4$ | Energy consumed by the power amplifier on multipath model |
| $E_{fs}$ | 10 pJ/bit/m$^2$ | Energy consumed by the power amplifier on the free space model |
| $E_{RX}$ | 50 nJ/bit | Energy consumed by radio electronics in receiving mode |
| $E_{TX}$ | 50 nJ/bit | Energy consumed by radio electronics in transmit mode |
| $l$ | 4000 bits | Size of data packet |
| $R_X$ | 16% bits | Constant related to the width of region where RN is chosen |
| $X_m$; $Y_m$ | 100 | Length and width of the region |

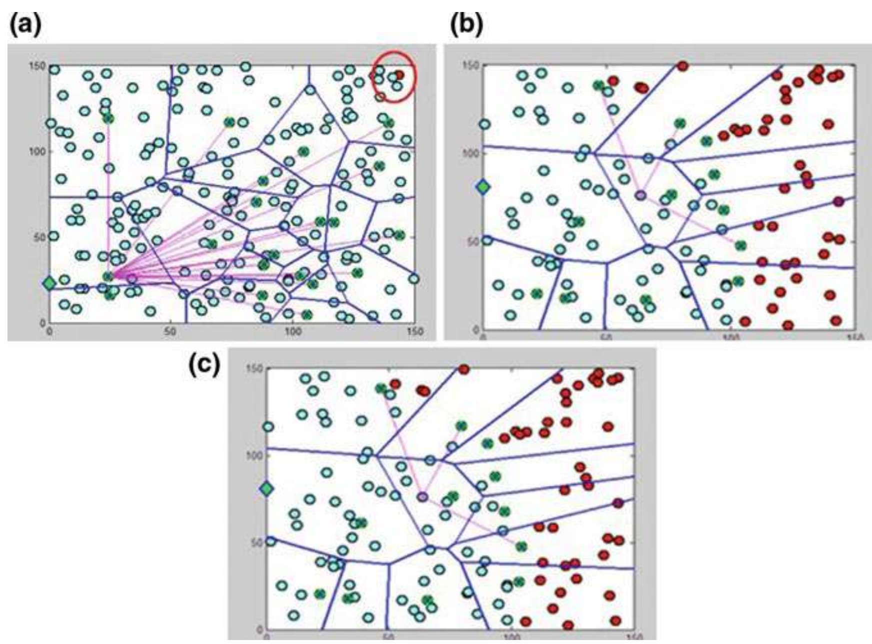


**Fig. 2** Simulation for (**a**) first node dead; (**b**) teenth or 25% nodes dead and (**c**) all nodes dead

send data packets of fixed size of 4000 bits are sent to cluster head and base station, and number of packets sent till all the nodes are dead are counted and compared as shown in Fig. 3d, e shows number of packets sent to cluster head and Fig. 3f shows residual energy.

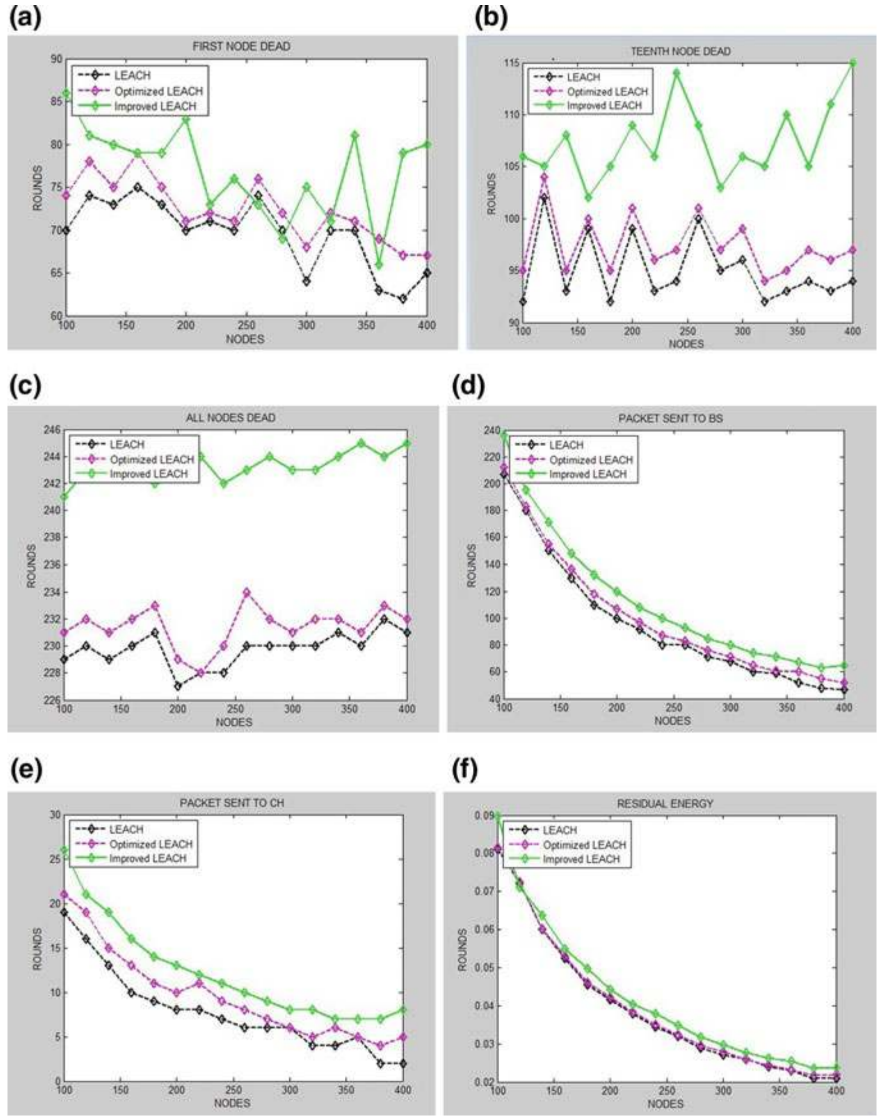


**Fig. 3** Comparison among LEACH, optimized and improved LEACH first node dead (**a**); 25% nodes dead (**b**); all nodes dead (**c**); packets sent to BS (**d**); packets sent to CH (**e**); and residual energy (**f**)

**Table 2** Simulation results for first, tenth and all nodes dead

| | No. of rounds for first node dead | | | No. of rounds for tenth 25% nodes dead | | | No. of rounds for all nodes dead | | |
|---|---|---|---|---|---|---|---|---|---|
| No. of nodes | LEACH | Optimized LEACH | Improved LEACH | LEACH | Optimized LEACH | Improved LEACH | LEACH | Optimized LEACH | Improved LEACH |
| 100 | 70 | 74 | 86 | 92 | 95 | 106 | 222 | 232 | 241 |
| 120 | 73 | 78 | 81 | 100 | 104 | 105 | 222 | 233 | 243 |
| 140 | 70 | 75 | 80 | 90 | 95 | 108 | 220 | 233 | 244 |
| 160 | 73 | 79 | 79 | 96 | 100 | 102 | 224 | 234 | 243 |
| 180 | 69 | 75 | 79 | 92 | 95 | 105 | 224 | 234 | 242 |
| 200 | 65 | 71 | 83 | 99 | 101 | 109 | 223 | 233 | 244 |
| 220 | 68 | 72 | 73 | 93 | 96 | 106 | 224 | 233 | 244 |
| 240 | 67 | 71 | 76 | 93 | 97 | 114 | 222 | 232 | 242 |
| 260 | 72 | 76 | 73 | 95 | 101 | 109 | 223 | 235 | 243 |
| 280 | 67 | 72 | 69 | 94 | 97 | 103 | 224 | 235 | 244 |
| 300 | 63 | 68 | 75 | 95 | 99 | 106 | 222 | 234 | 243 |
| 320 | 67 | 72 | 71 | 91 | 94 | 105 | 223 | 233 | 243 |
| 340 | 67 | 71 | 81 | 91 | 95 | 110 | 224 | 235 | 244 |
| 360 | 64 | 69 | 66 | 94 | 97 | 105 | 225 | 234 | 245 |
| 380 | 62 | 67 | 79 | 94 | 96 | 111 | 225 | 234 | 244 |
| 400 | 62 | 67 | 80 | 94 | 97 | 115 | 224 | 235 | 245 |

**Table 3** Results for residual energy packets received by cluster head and packets received by base station

| | Residual energy | | | Packets received by cluster head | | | Packets received by base station | | |
|---|---|---|---|---|---|---|---|---|---|
| No. of nodes | LEACH | Optimized LEACH | Improved LEACH | LEACH | Optimized LEACH | Improved LEACH | LEACH | Optimized LEACH | Improved LEACH |
| 100 | 0.0815 | 0.0817 | 0.0896 | 212 | 214 | 236 | 21 | 23 | 26 |
| 120 | 0.0725 | 0.0726 | 0.071 | 181 | 185 | 195 | 18 | 20 | 21 |
| 140 | 0.0603 | 0.0604 | 0.0636 | 155 | 156 | 171 | 15 | 17 | 19 |
| 160 | 0.0532 | 0.0531 | 0.055 | 135 | 138 | 148 | 13 | 15 | 16 |
| 180 | 0.0460 | 0.0462 | 0.0498 | 118 | 120 | 132 | 11 | 13 | 14 |
| 200 | 0.0421 | 0.0423 | 0.0443 | 107 | 109 | 120 | 11 | 12 | 13 |
| 220 | 0.0383 | 0.0385 | 0.0403 | 96 | 99 | 108 | 10 | 11 | 12 |
| 240 | 0.0350 | 0.0352 | 0.0379 | 88 | 90 | 100 | 9 | 10 | 11 |
| 260 | 0.0325 | 0.0325 | 0.0348 | 82 | 85 | 93 | 8 | 9 | 10 |
| 280 | 0.0294 | 0.0296 | 0.0317 | 75 | 78 | 85 | 8 | 8 | 9 |
| 300 | 0.0026 | 0.0028 | 0.0297 | 71 | 73 | 80 | 7 | 8 | 8 |
| 320 | 0.025 | 0.026 | 0.0277 | 64 | 67 | 74 | 7 | 7 | 8 |
| 340 | 0.0241 | 0.0244 | 0.0263 | 61 | 64 | 71 | 6 | 7 | 7 |
| 360 | 0.0231 | 0.0233 | 0.0254 | 57 | 61 | 67 | 6 | 6 | 7 |
| 380 | 0.0216 | 0.0218 | 0.0236 | 57 | 57 | 63 | 5 | 6 | 7 |
| 400 | 0.020 | 0.022 | 0.0238 | 59 | 57 | 65 | 6 | 7 | 8 |

## 6 Conclusion

The present paper proposes an improved LEACH protocol which is an enhancement over the optimized LEACH; this protocol adopts the novel approach for cluster head selection based on the parameter energy consumed, distance (minimum), neighbours and ratio of current energy by remaining energy. The overall improvement in case of improved LEACH is 9–15% in terms of packets sent to base station and 7% to 9% in terms of residual energy. Further, the present work can be extended using SWARM optimization techniques to get better results.

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# CLUSTERING TECHNIQUES IN WIRELESS SENSOR NETWORKS

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***Abstract***

*Advancement in communication arises need of networking in all the fields of life. WSN constitute of tiny sensor units with constrained energy. Many energy conservation techniques are popular and many are still under development. Clustering helps in reduction consumption of energy and improves the network lifetime. Paper describes some of the clustering algorithms being used in WSN.*

***Keywords:*** *Clustering, Cluster Head (CH), Wireless Sensor Network (WSN).*

## 1. Introduction

A wireless sensor network consists of sensor nodes, which are cheaper compact and have capacity of sensing, processing, computing and communicating. A wireless Sensor network do have a number of challenges like: application specific deployment, battery backup, data redundancy, frequent topology change, many to one traffic pattern, no global identification, sensing capability and storage Constraints. These nodes are deployed randomly over the area of interest to aggregate the collected data to a centralized location called base station(BS) [1][2]. Main objectives of designing a wireless sensor network are [3]

1. An enormous number of nodes needs to be positioned in small area so reduced size will reduce number of nodes, cost and power consumption.
2. Less cost of node can be primary design challenge.
3. It is almost impossible to change or charge the batteries of the nodes so low power dissipation is an important objective designing of a sensor network.
4. Topology changes and node failure requires that sensors should be able to freely arrange and reconfigure them into the network.
5. Number of nodes required in a network vary with applications another objective of WSNs should be scalable to different network sizes.
6. Another important objective of designing of wireless sensor network is sensors should adapt any variation in sensor density.

7. Application need of wireless sensors network is deployment of sensors in harsh environment thus sensors needs to be fault tolerant thus should be able to do self-calibrate and re-recover. [4] .
8. Military operations need wireless sensors for their sensitive activities thus security is another objective in network designing.
9. Limited bandwidth utility is a constraint in wireless sensor network so communication protocols should utilize bandwidth efficiently.
10. Timely delivery of data is another objective of designing sensor networks.

A wireless sensor node also called as mote with different modules shown below in Fig. 1

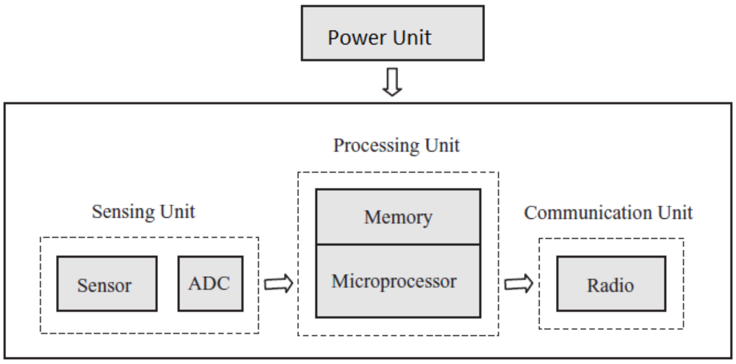


**Figure 1 Sensor Node Structure**

Architecture of a wireless sensor networks can be classified as flat and hierarchical networks. In flat architecture all the nodes are peers, this architecture is not feasible for large networks. Whereas in a hierarchical network, sensor nodes are grouped together to create clusters, where all the cluster members transmit their data to cluster head which in turn send it towards sink.

## 2. Clustering

Grouping of sensor nodes into clusters overcomes the drawbacks found in Multi-Hop transmission, thus helps to reduce consumption of energy and improves the network lifetime. In clustering, groups are formed and each group has one leader called Cluster Heads (CHs). CHs performs the task of data fusion and aggregation, thus improves energy consumption. CHs node behaves as pathway between the sensor node and the BS. The cluster formation process consists of two-level hierarchy, where CHs nodes are at higher level and cluster members at lower level. Cluster member send their information to CHs. Then CHs removes the redundant data and sends that information either directly or through the intermediate communication with other CHs nodes to BS. Different algorithms were proposed to decrease energy consumption of sensor. LEACH algorithm is the first and popular WSNs dynamic clustering algorithm which adopts entire sensor nodes to be homogeneous.

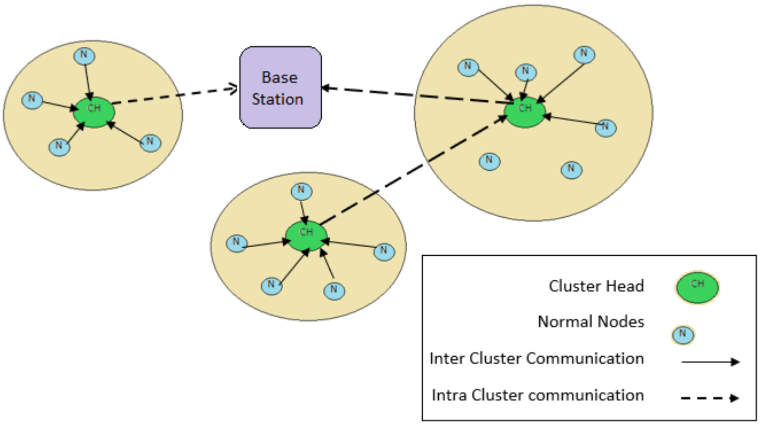


**Figure 2 Inter cluster and intra cluster communication.**

### 2.1. Clustering objectives

This part gives three primary objective that is unequivocally related the center with this research work.

1. **Enhancing lifetime of network:** Dissimilar to mobile systems, wherever portable products (e.g. phones) energy administration is the secondary concern as they can be recharged when its battery becomes dead. While WSN has limited battery life. So, maximizing the lifetime of network is one of the rising issues and one of the major challenges while designing WSN. So, in order to deal with this issue, clustering helps a in reducing consumption of energy and enhancing lifetime of WSNs.

2. **Fault-tolerance**: To address the issue of node failure, various techniques are designed. To cope up with this issue either the concept of proxy cluster-heads is used (when either node fails or has less transmission energy) or CH rotation can be the solution. Fault tolerance is one of the important objectives, while designing clustering algorithm.

3. **Fill handling** Fill handling is another outline objective while designing clustering protocol. It is unquestionably required not to overweight the CHs as it leads to quick depletion of energy. So in each cluster even distribution of node is important, as CHs performs the task aggregation of data or other signal handling task.

### 2.2. Clustering Parameters

The parameters related to clustering are as given below:

1. **Cluster Count:** It is one of the important parameters in clustering. Usually number of clusters is fixed as CHs are arranged before. As CHs are selected randomly, thereby results into variable clusters in numbers.
2. **Intra-Cluster Topology:** Intra-cluster topology is categorized as either single hop connectivity or multi hop connectivity. In single hop intra-cluster topology, the nodes

transmit information sensed to CHs directly i.e. data is directly transmitted from node to CH. However, in some cases multi-hop Node-to-CH communication is also required. In its sensor node sends data to intermediate node which then further transmit data to cluster.

3. **Nodes and CH Mobility:** In case of fixed position of sensor nodes and CHs, there is not to oversee inter-cluster and intra-cluster and in case of variable number (mobility) of CHs or nodes to continuous maintenance is required.
4. **Node Type and Role:** Nodes can be classified as homogenous and heterogeneous. Homogenous nodes are those with same processing capabilities. While heterogeneous nodes are those having different processing capabilities.
5. **Cluster Formation Methodology:** Cluster formation methods are categorized into two types centralized and distributed. Centralized approach has one or more nodes that divides the network and controls the cluster. In distributed approach, clustering is performed in distributed manner i.e. without coordination.
6. **Cluster Head Selection:** In homogenous environment CHs can be selected either randomly or through certain probability depending upon some parameters like remaining energy or connectivity [5]. While for heterogeneous environment CHs are picked with the one having higher processing capability.

### 2.3. Cluster Head Selection Criteria

Various parameters taken into consideration while election of cluster head are:

1. **Initial Energy**: It is considered as one of the important parameters while selecting CH. It is defined as the energy of sensor nodes at the start of an algorithm.
2. **Residual Energy:** It is defined
3. as the energy remained in the sensors. As CH are selected randomly in rounds, so for selecting CH in next round, we consider the residual energy remained in the sensors in previous round.
4. **Average Energy of Network:** It is the sum of energy remained in sensor nodes by number of nodes and is used as reference energy for every node. In CH selection, nodes having higher energy will only participate in a network.

### 2.4. Classification of Clustering Protocols

For WSNs, the clustering algorithms can be categorized as Probabilistic (Random / Hybrid) clustering algorithms and Non-Probabilistic clustering algorithms. In Probabilistic (Random or Hybrid) clustering approach, either clusters are formed randomly or based on some criteria (residual energy). In primary criterion i.e. in random selection process, to each sensor node is assigned with a probability to select initial CHs. Clustering algorithms following this approach have benefits such as flexible, fast, uniform and completely distributed; while in secondary criterion, election of CHs depends on some criterion such like residual energy. The benefit of using secondary approach helps to reduce energy consumption and thus enhances network lifetime.

Non-Probabilistic clustering algorithm uses specific criteria to elect CHs and to form clusters, which depends on sensor nodes connectivity or degree and on information gathered from the nodes that are located closely to it. Many hierarchical clustering protocols including APTEEN [6], EECS [7], EEMC [8], HEED [9], LEACH [10] , PANEL [11], PEGASIS [12], TEEN [13], and T-LEACH [14] were proposed by applying different factors [15].

### 2.5. Types of Clustering Algorithm

Following are the types of clustering algorithm for dynamic clusters:

#### 2.5.1. Event-to-Sink Directed Clustering

Classical clustering provides pre event solutions to form clusters which needlessly creates too many clusters Bereketli et al. in year 2009 [15] proposed a need-based clustering algorithm named Event-to-Sink Directed Clustering (ESDC) protocol for WSN.

Any discovered event is reported to sink, and the information collecting node collects the data and transfer it to cluster head.

1. No cluster is formed until an event occurred.
2. Clusters are created such a manner that data is transmitted directionally from the sensing node to sink, flow of data is almost unidirectional

The authors Bereketli et al. [16] has performed simulation on proposed Event-to-Sink Directed Clustering algorithm and related it with popular LEACH algorithm. Proposed protocol consumed 50 %less time per hop than basic LEACH.

#### 2.5.2. Load balanced clustering scheme

Shujuan et al. in year 2009 [17] proposed Load balanced clustering scheme another algorithm. It is a multihop approach in which load of CH is borne by assistant nodes to aggregate the data to base station. Cluster head and its assistant is selected on the base of distance and residual energy. Working of load balance cluster scheme is shown in figure3 redrawn from [17]

Author have performed simulations using NS-2 and found that the LBCS prolongs the network life time longer than EECS and basic LEACH algorithm. Drawback of the LBCS algorithm is that nodes nearer to cluster head gets more data to transmit and thus dissipate heat causing in deprecation of energy.

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### 2.5.3. K-means Algorithm

Sasikumar et al. in year 2012 [18] proposed K-means algorithm uses Euclidian distance and residual energy of nodes to select a cluster head. A list of information collected from the member nodes is maintained by cluster head and k-mean clustering algorithm is performed on collected data. K-mean algorithm is based on Euclidian distance and energies of all the nodes. Location and energy information of all the nodes is exchanged through messages once information is received by all the nodes, they run the k-mean algorithm for clustering and electing a cluster head. As every node runs the same algorithm, every node knows under which cluster it belongs and its cluster head. When whole system depends only on central node it leads to failure when central node fails. Performance of the proposed algorithm is better when clustering is achieved by distributed method.

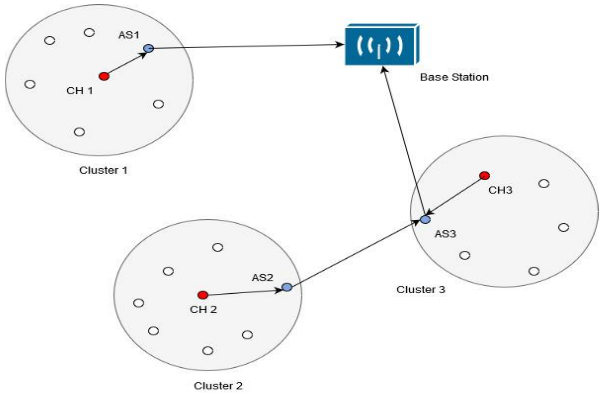


**Figure 3 Inter cluster communication in LBCS**

### 2.5.4. Low-Energy Adaptive Clustering

Energy consumption by cluster head is much more than normal nodes so need is to rotate role of cluster head and normal nodes i.e. cluster head responsibility is done on rotation basis. A normal node with minimum threshold energy, number of times a node has become a cluster head and total number of cluster head needed in the network can participate in cluster head selection process. In Low Energy Adaptive clustering cluster head selection is based upon probabilistic factor. Low energy adaptive clustering has a disadvantage initial energy of the node is not a factor to participate in cluster head selection method. As it is a single hop communication so it does not work for large sized networks. LEACH is an effective adaptive clustering protocol

### 2.5.5. Hybrid Energy-Efficient Distributed clustering

Younis et al. in year 2004 [9] proposed HEED an approach which considers only residual energy and node proximity for selection of cluster head. Main objective of HEED is distributed clustering such that cluster heads are evenly distributed over the network. Major drawback of the HEED is that a greater number of cluster heads decreased efficiency. It consumes large bandwidth as a number of iterations are required to make a cluster and too many packers are broadcasted during iteration.

### 2.5.6. Weight-Based Clustering Protocols

Tondon et al. in year 2013[19] proposed a weight-based clustering protocol where weight depends upon remaining energy, no of times the concerned node becomes cluster head and distance of node from cluster head. Weight of all the nodes is found after each iteration of clustering. Clusters are framed for heterogenous networks in such a way that there is even distribution of energy among all clusters, resulting in increased lifetime and throughput of WSN.

A comparison between various cluster techniques is discussed in the table: 1 given below:

**Table 1:** Comparative analysis of various clustering algorithm

| Clustering Approaches | Cluster Count | Communication | Mobility | Node Type & Role | Cluster Formation Method | Cluster Head Selection |
|---|---|---|---|---|---|---|
| **Event-to-Sink Directed Clustering** [16] | Variable | Multi Hop | Fixed | Heterogenous | Distributed | Energy / Direction |
| **Load balanced clustering scheme** [17] | Fixed | Multi Hop | Fixed | Homogeneous | Distributed | Energy / Distance |

| | | | | | | |
|---|---|---|---|---|---|---|
| **K-means Algorithm** [18] | Fixed | Multi Hop | Mobile | Heterogenous | Centralized | Energy / Euclidian Distance |
| **Low-Energy Adaptive Clustering** | Variable | Single Hop | Limited | Homogeneous | Distributed | Probability / Random |
| **Hybrid Energy-Efficient Distributed clustering** [9] | Variable | Single Hop | Limited | Homogeneous | Distributed | Probability / Energy |
| **Weight-Based Clustering Protocols** [19] | Variable | Multi Hop | Limited | Heterogenous | Distributed | Weight Based |

## 3. Conclusion

Clustering is a descriptive technique. We have presented evaluation of different clustering algorithms considering several parameters and our findings are that irrespective of techniques, each algorithm have its own benefits for example K-Mean clustering algorithm can handle big data more efficiently than small data, whereas hierarchical protocols can handle small data more efficiently.

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