# “ENERGY EFFICIENT WIRELESS SENSOR NETWORKS”

***A***

***Dissertation***

*submitted in partial fulfillment of the*

*requirements for the award of the degree of*

**MASTER OF TECHNOLOGY**

**in**

**ARTIFICIAL INTELLIGENCE AND ARTIFICIAL NEURAL NETWORK**

**by**


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**May – 2015**

# CANDIDATE'S DECLARATION

I hereby certify that the dissertation work entitled **"ENERGY EFFICIENT WIRELESS SENSOR NETWORKS"** in partial fulfillment of the requirements for the award of the Degree of MASTER OF TECHNOLOGY in ARTIFICIAL INTELLIGENCE AND ARTIFICIAL NEURAL NETWORK and submitted to the Department of Computer Science & Engineering at Center for Information Technology, University of Petroleum & Energy Studies, Dehradun, is an authentic record of my work carried out during a period from **January**, **2015** to **May**, **2015** under the supervision of **Dr. Rashmi Sharma, Assistant Professor (SS), Ms. Niharika Singh, Assistant Professor, CIT, UPES Dehradun**.

The matter presented in this dissertation work has not been submitted by me for the award of any other degree of this or any other University.

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# ABSTRACT

The rapid technological advancements and science have witnessed Wireless sensor networks (WSNs) as a new powerful tool for monitoring forest areas, natural disaster prediction, supervising an unfriendly process, exploring the universe, security and surveillance applications. Most of the research proposals on WSNs have been developed keeping in view of energy conservation and network's lifetime. One of the fundamental problems is that sensor nodes are operated on a battery which discharges quickly after each cycle of operation. Placing a node at best location can be a very effective optimization for achieving desired objectives. Also, intelligent routing in the network helps in saving energy and thus increases the lifespan of network. It has been found in literature that many deployment techniques, clustering and routing algorithms are applied to solve this problem. The proposed work introduces an energy efficient optimization in two stages of wireless sensor network. First stage involves the energy conservation in deployment phase by getting optimal locations and next stage involves energy conservation in routing phase. The locations are determined for deploying the nodes in an environment using two deployment strategies: 1) Random Deployment Strategy and 2) Genetic Algorithm based Deployment Strategy. Further, the routing is performed by applying hierarchical routing protocols LEACH and Intelligent LEACH protocol considering the random locations given by Random deployment and best locations given by Genetic Algorithm based deployment. LEACH and ILEACH are energy efficient routing protocols which save a significant portion of inner-network communications energy. The result shows that Intelligent ILEACH is an upgraded version of LEACH as it saves energy by considering residual energy, no. of members associated to each node and distance to Base Station during the selection process of Cluster Head. The various simulations have been carried out by using JAVA platform. Results of the simulation shows that the proposed model has been improved the WSN performance and reduces the energy consumption.

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# CHAPTER-1
# INTRODUCTION

Recent advances in sensing, computing and communication technology, researchers see Wireless Sensor Networks (WSNs) as a powerful and promising tool for monitoring as well as controlling the physical world. The integration of micro-electro-mechanical system (MEMS), microprocessor and wireless communication technology have enabled the deployment of large-scale wireless sensor networks for broad range of applications related to national security, smart grid, smart homes, automation, vehicular traffic management, habitat monitoring, precision agriculture, surveillance tasks, health care, and disaster detection. These applications envision smart monitoring and decision making in operations that requires real time information for efficient coordination and planning.

## 1.1 Background

Wireless Sensor Networks falls under the category of one of the most widely used types of Adhoc wireless networks [1]. It builds an infrastructure for monitoring the specified environment (such as biological system, physical world or IT framework) at an economical cost much lower than currently possible. These networks assure decision making, error-free judgments, low maintenance, and high security for gathering different kinds of data. It responds to events in hostile environment, exploiting self-organizing networks of battery-powered wireless sensors that can sense, compute and communicate. WSN has many constraints in terms of its sensor node capability of memory storage, limited battery power, cost, and limited computation capability, but energy constraint has persisted as an important design consideration in sensor networks, especially when they are operated for long durations. Due to nature of WSN, sensor nodes are operated with small capacity DC source and bulk of energy is dissipated because of computation and communication subsystems. In the last decade, extensive research has been done in eliminating energy inefficiencies and identifying alternate power sources that would shorten the lifetime of the network.

## 1.2 Introduction to Wireless Sensor Networks

Wireless sensor network consists of large no. of sensor nodes communicating with each other via radio communications. There are four basic components in network architecture:

(1) A group of sensor nodes

(2) Large no. of associated links (usually, but not always, wireless-based)

(3) Representative of cluster

(4) A set of computational facilities at the base station to handle data aggregation, querying the interests, event handling, and data mining [2].

The base station is responsible for transmitting data to the user for decision making and handling operations. The basic operation is shown in fig 1.1.

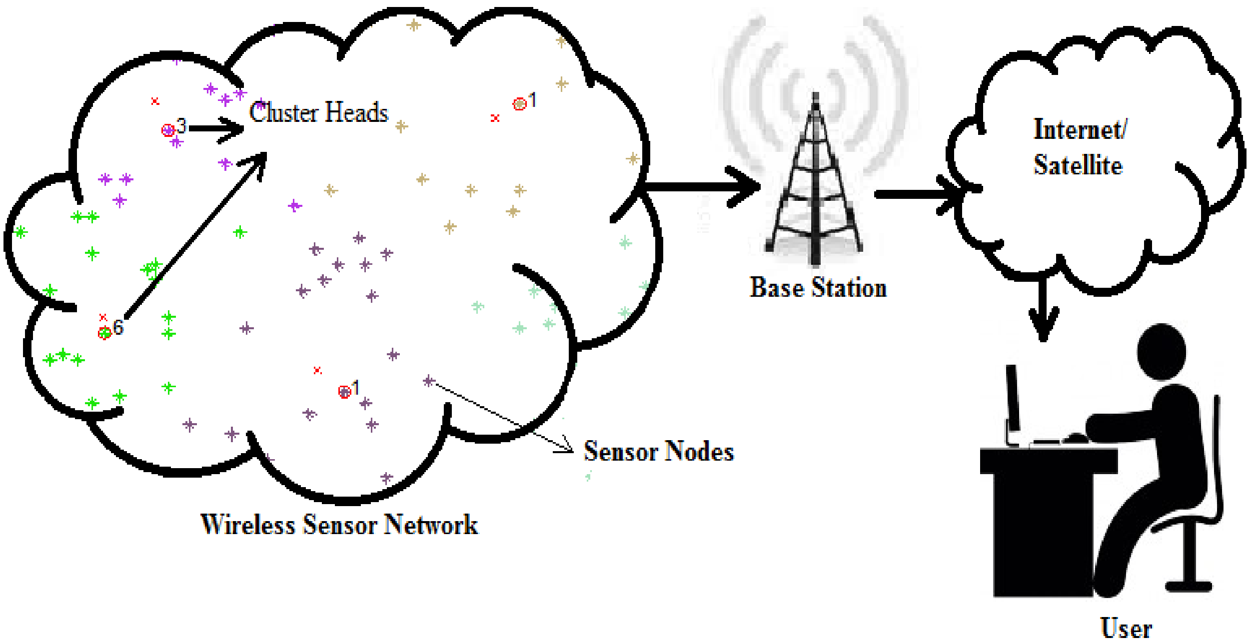


Fig 1.1: Operation of Wireless Sensor Network

### 1.2.1 Sensor Nodes

Each node in the sensor network may consist of one or more sensors and a mote unit as shown in fig 1.2. A sensor is a transducer whose purpose is to detect information and produce a measurable response to a change in a physical condition like temperature, pressure, humidity etc. A mote unit consists of processor, a low power radio, A/D convertor and a portable power supply, and possibly localization hardware, such as a GPS (Global Positioning System) unit or a ranging device. A sensor and a mote unit together form a sensor node.

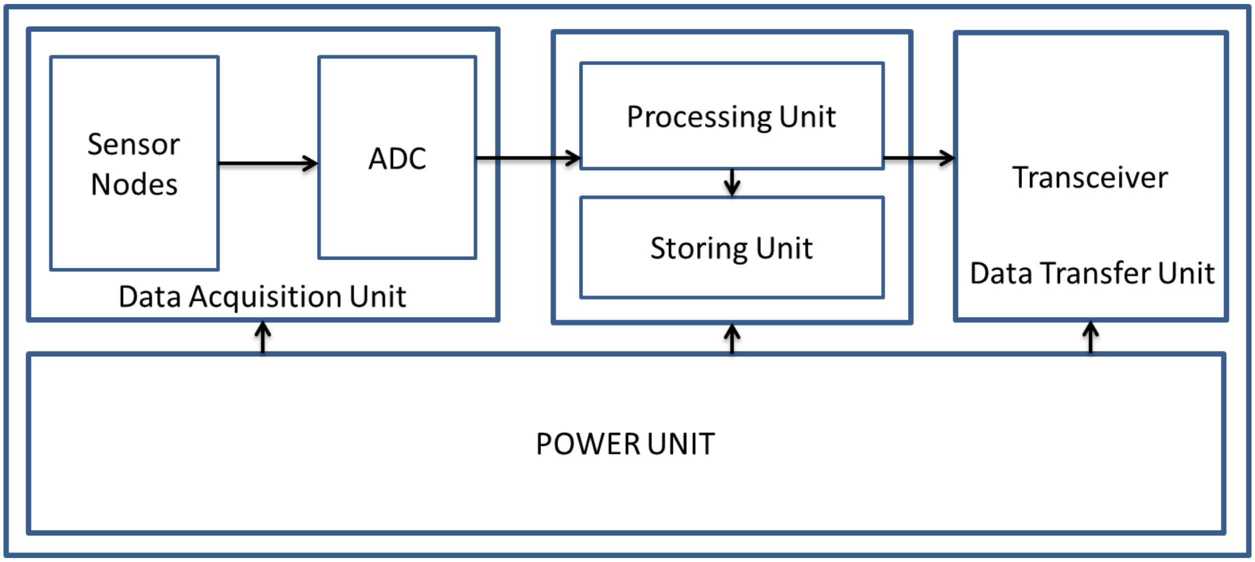


Fig 1.2: Architecture of Sensor Node

The sensor nodes are supplied by non-rechargeable batteries mounted on sensors therefore life time of the battery determines the life span of the network. As each individual sensor operates on restricted battery capacity and after depletion of energy it stops functioning and break the connection which can significantly reduce the efficiency of network. Thus energy usage is a very important concern in a WSN [3]. Sensor nodes can be deployed randomly or manually depends as per application. Although, they are limited in power, computational facilities, storage, transmission range and bandwidth but they can use their processing abilities for carrying out simple computations locally, and transmit the messages to nearby neighbors [2]. In order to send data to main point lot of energy is required and sometimes nearby neighbors sends redundant messages to main point which affects the performance [4]. To reduce this overhead, sensor network is partitioned into clusters and then representative of cluster i.e. Cluster Head is responsible for transmitting data packets to the base station.

### 1.2.2 Cluster

Clustering is a process of grouping objects into set of disjoint classes. In the hierarchical network structure each cluster elects its representative node (CH) and the non-CH nodes periodically transmit their data to the corresponding CH nodes as shown in fig 1.3. The representative nodes (CHs) of every cluster aggregate the data (thus eliminating the redundant data packets) and transmit them to the base station (BS) either directly or through other CH nodes. The cluster preparation leads to 2-level ladder where the CH nodes form the higher level and the non-CH nodes form the lower level [5]. The cluster representative nodes (CHs) spend most of their energy in receiving data packets, aggregating it and then transmitting data to higher distances than the common nodes [4]. And eventually, after sometime they deplete their whole energy and form a hole in the network. In order to balance the power consumption, it is necessary to periodically re-elect new cluster representatives (CHs) in each cluster.

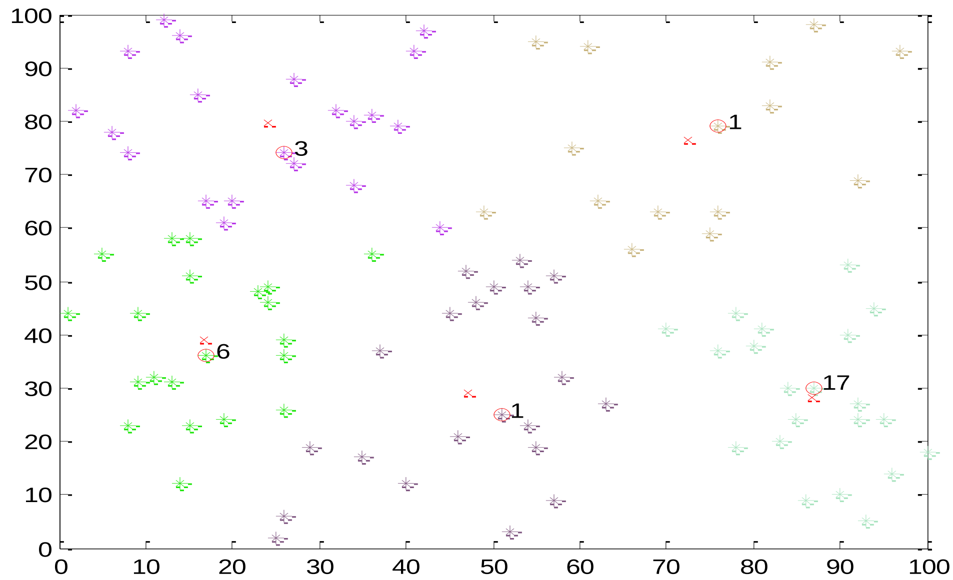


Fig 1.3: Clustering in the network

### 1.2.3 Base Station

The base station provides the connection between the sensor network and another network (PSTN, Internet, etc.) as shown in fig 1.4 [2]. The localization of the base station is an important network design concern as all the sensor nodes handover their data to base station for error free judgments and performing certain operations. The cluster representative nodes (CHs) act as sink for the cluster nodes and in same way base station acts as sink for all CH nodes. The communication between both sinks (i.e. cluster-head and base station) is achieved using fixed spreading code and CSMA. Before transmitting data to the base station, the cluster head ensures the availability of channel i.e. no other cluster head is currently transmitting the data using the base station spreading code [2]. If the channel is sensed busy, it delays the transmission and waits for the channel to become idle.

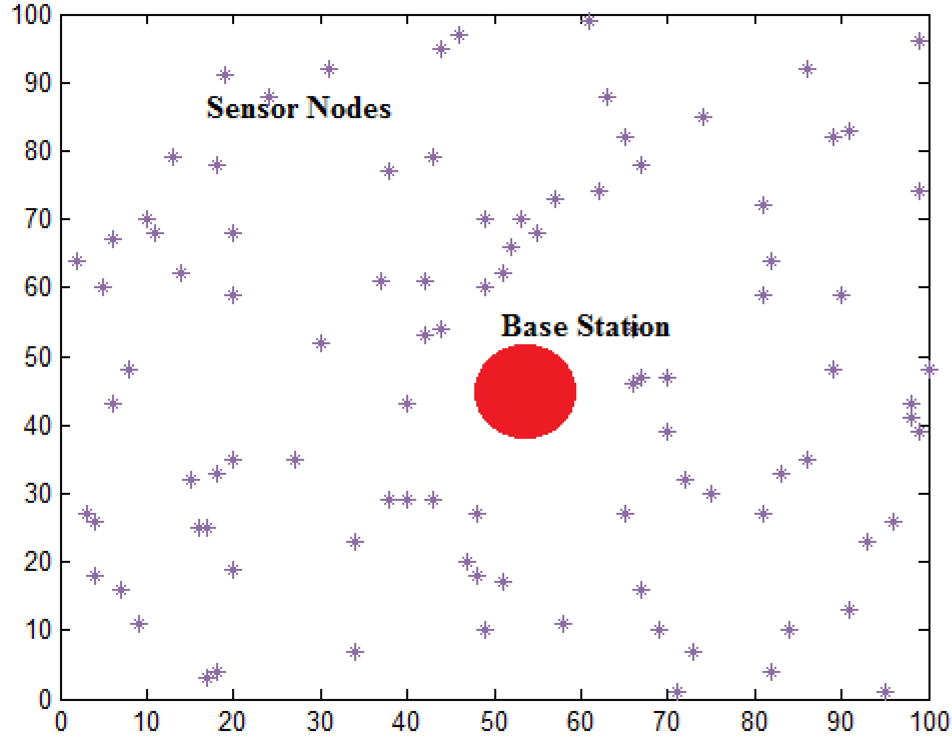


Fig 1.4: Base Station

### 1.2.4 Operation of Wireless Sensor Network

When network is active, various tasks are performed such as deployment of sensor nodes and routing of data transmission, data aggregation, data suppression, data negotiation in order to perform the applications normally. Basically, wireless sensor performs its operation in five stages: site-planning stage, deployment stage, after-deployment stage, functional stage and after functional stage [6]:

a. In site-planning stage, a site survey is conducted to evaluate the conditions and factors affecting the environment for the deployment mechanism.
b. Sensors can be randomly deployed or some proposed deployment schemes are used to get the optimal locations for deployment.
c. The coverage ratio is estimated using different parameters involved in network operation.

d. The functional stage involves the sensing operation of sensor nodes and data is generated by observing the environment conditions.
e. The after-functional stage preserves the network's energy by changing the states of the nodes (active to sleep, sleep to active) and also proper shutting down of network after its operation.

## 1.3 Characteristics of WSN

The main characteristics of a WSN include:

- Power consumption constraints for nodes using batteries or energy harvesting
- Ability to cope with node failures (resilience)
- Mobility of nodes
- Heterogeneity of nodes
- Scalability to large scale of deployment
- Ability to withstand harsh environmental conditions
- Ease of use
- Cross-layer design

## 1.4 Applications of WSN

- **Safety and Investigation**

  Protection and investigation are two relevant areas of wireless sensor networks. This complex task requires accurate and timely operation in achieving objectives as well as minimizing loss of human lives. WSN are employed in military areas to avoid intruder overpassing the security borders.
- **Environmental Monitoring**

  The environment such as forest areas, threat detection, pollution monitoring, rainfall measurements etc. is being monitored with the help of sensor networks. Prior information about weather helps in managing weather dependent industries such as agriculture. Sensor nodes can be used for measuring the impact of toxic chemicals waste, illegally dumped into the lakes or rivers by manufacturing industries or factories. Chemical threats can be easily identified using sensors in a hostile environment.

- **Automation and Control**

  In our day to day life, various processes are controlled and automated by sensor networks such as washing machines, air conditioners, sprinkler system, automatic door lock, vacuum cleaners, micro-wave ovens and refrigerators. Because of small size, sensor nodes can be placed rapidly and cheaply in remote areas or in hostile environment. The wireless sensor network has increased the production scale by providing information regarding the resources (material, man-power, current stock and supply chain status) and hence found useful in logistics and transportation systems. It has improved the quality by automating various equipment's and controlling various degrading factors of many industries such as chemical, steel, oil and gas, pulp and petroleum industries.

- **Precision Agriculture**

  Many of the farming activities can be made profitable and sustainable with the help of wireless sensor networks. By controlling various soil and atmospheric parameters (climate, irrigation, nutrient supply etc.), it produces best crop condition and thereby increasing the production and minimizing the cost incurred in farming. They may control various diseases by detecting the soil quality, water stress detection and nutrient stress detection.

- **Disaster Response**

  The proper early warnings or predictive disaster detection, flood detection, forest fire detection [10] and landslide detection [8] might be a valuable asset, resource and life saver [13]. The real time information of the disaster prone areas helps in proper planning thus saving human lives to a great extent. When such disastrous event occurs, sensor nodes transmit information to cluster-head for network data aggregation. Further sink node takes the collaborative decision for what to do next.

- **Healthcare**

  Sensors are used in biomedical applications for healthcare by creating body area networks (BAN). A BAN is composed of a collection of tiny, cheap and low-power biomedical nodes, equipped with biomedical sensors, motion detectors and wireless communication devices [11]. Sensors nodes can be worn externally or implanted into human body to measure and observe various parameters. These observations are then used by doctors for various applications such as monitoring cardiovascular diseases, diabetes and asthma, preventing heart-attacks, consulting cases via telemedicine or health-care systems, etc. the use of physiological sensors help doctors in treating patients in their own homes if there is scarcity in local health care staff or hospital beds.

Fig 1.5: Applications of Wireless Sensor Networks

- **Supply chain management**

  Recent developments in RFID along with Wireless sensor networks prove beneficial to supply chain management business. Active transport tracking devices are made by attaching the sensor nodes to crates, roll containers, goods and shipping containers to function as Active Transport Tracking Devices [12]. The use of WSN technology improves the quality of service by actively monitoring the transportation process, verifying factors affecting like temperature, humidity for fresh foods. As they travels through roadways, seaways, these sensors can detect damage occurred due to sudden accidents.

- **Automotive/ Vehicular**

  The recent improvements in wireless sensor networks and real time computing systems have led to the development of Intelligent Transportation Systems (ITS). In these types of smart transportation systems, sensors are installed in vehicles and these sensors communicate among themselves through wireless links with other vehicles. The whole system is monitored with a central monitoring station with the sensor nodes placed at appropriate locations on the roads [14]. This wireless communication between automobiles and automobile to roadside static node communication prevents traffic related problems like Accident Prevention, Collision Avoidance and High-speed detection.

## 1.5 Engineering Challenges

Most envisioned sensor network applications encounter the following challenges [5]:

- **Untethered:** for energy and communication requiring maximal focus on energy efficiency.
- **Ad hoc deployment**: requiring that the system identifies and copes with the resulting distribution and connectivity of nodes.
- **Dynamic:** environmental conditions requiring the system to adapt over time to changing connectivity and system stimuli.
- **Unattended operation:** requiring configuration and reconfiguration be automatic (self-configuration).

To address these technical challenges several strategies are going to be key building blocks/techniques for sensor networks:

- Collaborative signal processing among nodes that have experienced a common stimulus will greatly enhance the efficiency (information per bit transmitted)
- Exploiting redundancy has application when the cost of deploying the initial set of sensors is much less compared to the cost of replacing defective or failed nodes or renewing node resources. Thus redundancy can be exploited to extend system lifetime. Another application is when sensors cannot be positioned carefully; redundancy can be exploited to extend coverage by using a subset of the nodes, which are positioned favorably.
- Adaptive fidelity signal processing can be exploited to strike a balance between energy, accuracy and rapidity of results. The timeliness and accuracy of the signal processing can be adapted keeping in mind the energy resources and latency requirements.
- Hierarchical, tired architecture can greatly contribute to overall system lifetime and capability. Whenever possible, higher capacity system elements can be used to offload drain on small factor elements, while the latter can be exploited to obtain the desired physical proximity to stimuli. Moreover, even among elements with homogeneous capabilities, creating clusters and assigning special combining functions to cluster heads can contribute to overall system scalability and lifetime. However, to ensure robustness, such clustering/hierarchy must be self-configuring and reconfiguring in the face of environmental or network changes.

**1.6 Thesis Outline**

Here is brief description about the chapters which are present in this thesis:
Chapter 2 - This chapter starts with defining the problem description in wireless sensor networks. The various challenges are introduced in this chapter and objectives to be achieved.

Chapter 3 – This chapter emphasis on the literature review of the WSN (Wireless Sensor Networks). The deployment strategies and the routing strategies proposed by various researchers are discussed in this chapter. After that a classification of energy aware routing protocols is done.

Chapter 4 – The proposed algorithm and the system flow is described in this chapter.

Chapter 5 – The system design and the modules which are used in proposed methodology is described in this chapter. The flowchart and pseudo code of the following components is also described here.

Chapter 6 – This chapter includes the results obtained in the simulation of the proposed model.

Chapter 7 – This chapter starts with the conclusion of the thesis and after that future possibility of the project is given.

# CHAPTER-2

# PROBLEM DEFINITION

The sensor nodes are supplied by non-rechargeable batteries mounted on sensors therefore life time of the battery determines the life span of the network. The following are important issues pertaining to WSNs sensor type; sensor placement; sensor power consumption, operating environment etc. Energy efficiency is an important issue in WSN, because the battery resources are limited. So, mechanisms that conserve energy resources are highly desirable, as they have direct impact on network's lifetime.

## 2.1 Main Objective

Since ample amount of unstructured and heterogeneous data is communicated and collected through wireless links at the central gateway, the major portion of energy consumption is due to radio communications. In this project the objective is to achieve energy efficiency to address the target coverage problem, with the objective of designing a reliable scheme for maximizing the network lifetime of a power constrained WSNs deployed for monitoring of a set of targets with known location.

## 2.2 Sub Objectives

1) Find out the mechanism to find optimal locations for deploying the nodes in a network.
2) To increase the network connectivity and coverage ratio.
3) To decrease the no. of dead nodes in the network.
4) To conserve the energy by using intelligent algorithms.

# CHAPTER-3
# LITERATURE REVIEW

In the past few years, coverage and routing have been active research areas in sensor networks. Many studies have focused on characterizing the area coverage and designing algorithms for routing to achieve desired objectives. The proposed methodologies and the routing algorithms are discussed in this chapter.

## 3.1 Deployment Strategies

### 3.1.1 Random Deployment

Random deployment is followed where it is not possible for deploying the nodes manually such as forest areas, hilly areas, underwater or hostile environment. It means without considering any fixed positions for the nodes they are deployed in a certain way. It is fast in practice because the amount of overhead in finding the locations of large no. of nodes gets reduced. An example of random deployment simulated in software is shown in fig 3.1. The sensors locations affect the performance metrics such as energy usage, delay and throughput. There are some limitations of random deployment [16]:

- Since no prior information about the exact location of the sensors is known. Thus, it is quite challenging to configure a failure node.
- The after deployment mechanisms are applied to obtain the desired coverage and connectivity.
- The parameters like no. of nodes, transmission range are controlled for uniform deployment.

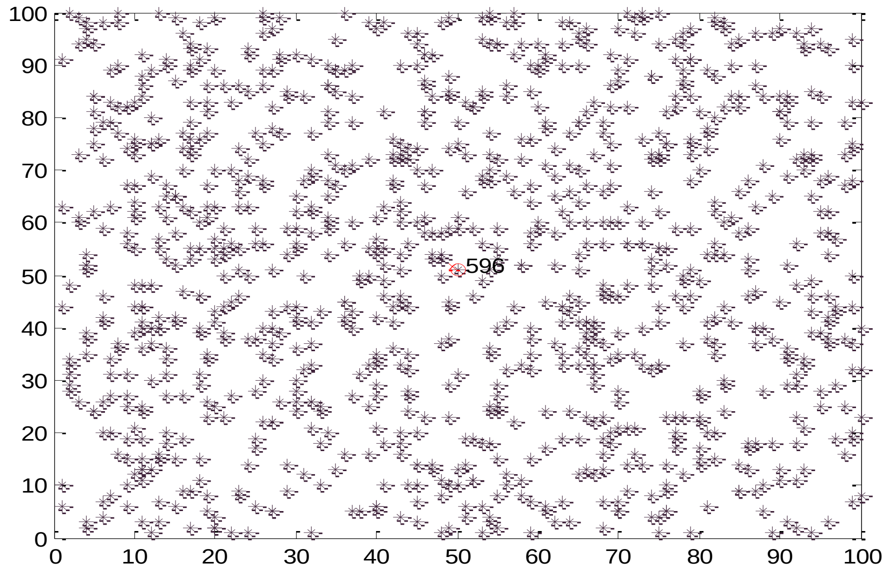


Fig 3.1: Random Deployment

### 3.1.2 Self-Deployment

It is a deployment mechanism in which nodes is placed by getting information from previously deployed nodes with the objective of increasing coverage ratio and maintaining network's connectivity using less no. of sensor nodes as shown in fig 3.2. The attraction or repulsion force between mobile sensors and their neighbors helps in positioning of sensor nodes. The process converges when every sensor arrives at a position with zero virtual force from its members.

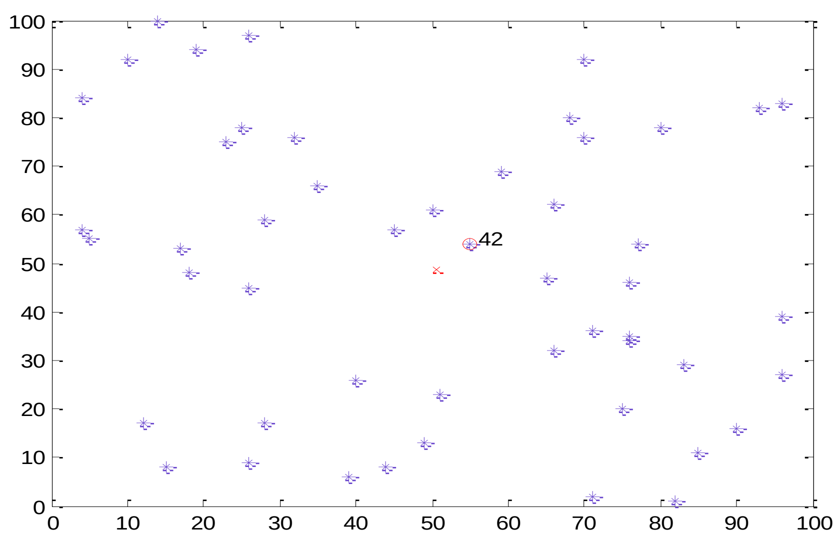


Fig 3.2: Self Deployment

### 3.1.3 Computational Geometry Approach

In this approach, sensing region is partitioned into sites in the form of grids or polygons as shown in fig 3.3. The points inside the polygon are closer to the site inside the polygon than any other sites. The diagram that is obtained after partitioning is called as Voronoi Diagram [17][18]. Voronoi diagram technique can be used when sensors have identical sensing ranges. For sensors having non-identical sensing ranger Multiplicatively Weighted Voronoi Diagram (MW-Voronoi Diagram) [17][19] is used.

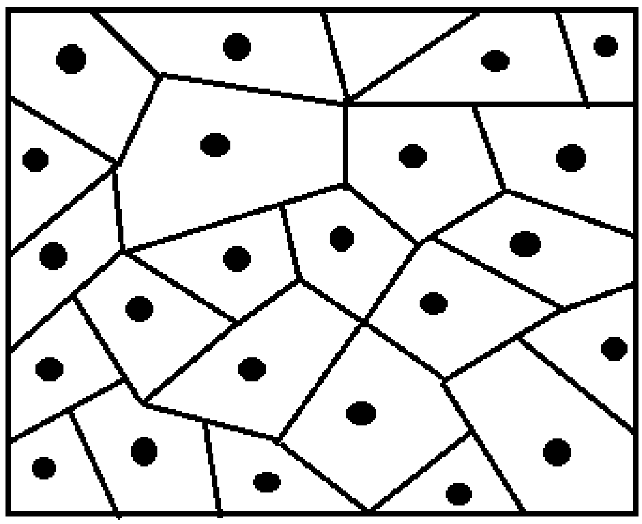

Fig 3.3: Voronoi Diagram

### 3.1.4 Movement-Assisted Deployment:

Sometimes, actual landing positions cannot be controlled due to the existence of wind and obstacles. For such scenarios, mobile sensor nodes are used in deployment to achieve target coverage. Firstly, nodes are deployed in a random fashion and thereafter, redeployment is performed by utilizing the location information from previous deployment.

In 2002, **Howard** [20] has described the potential-field-based approach and **Heo** [21] studied the sensor node deployment problems in terms of energy conservation. **Clouqueur** [22] et al. detected the targets using highest probability with the least no. of sensors in 2002. In the next year, **Dhillon** and **Chakrabarty** [23] have optimized the deployment process by proposing a greedy-heuristic algorithm that strives to achieve target coverage with minimum no. of sensors.

To achieve maximum coverage in the context of underwater WSNs, **Prompili et al.**[22] have proposed a method of placing the sensor nodes in a triangular grid fashion. The nodes are dropped from the surface to the ocean bed, the effect of water current is modeled and a technique is proposed to predict the trajectory of the sensor nodes and to make necessary adjustments for the drop point at the surface. The idea, as depicted in Fig. 3.4, is to pursue a circle packing such that any three adjacent and non-collinear sensors form an equilateral triangle. In this way, one can control coverage of the targeted region by adjusting the distance d between two adjacent sensors. The authors have proven that achieving 100% coverage is possible if $d = \sqrt{3r}$ where r is the sensing range.

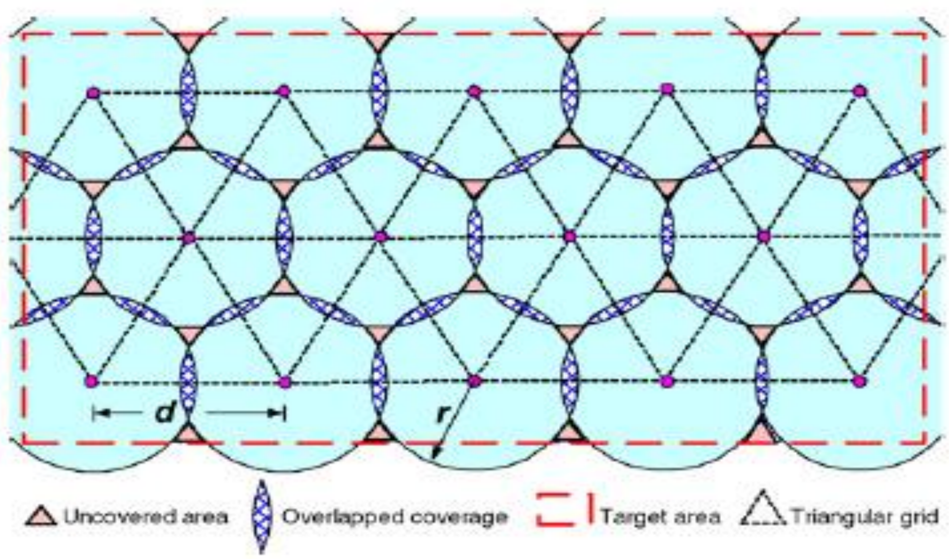


Fig 3.4: Sensor placement based on a triangular grid. Coverage can be controlled by adjusting the inter-node distance ''d''. The figure is redrawn from [22].

**Biagioni and Sasaki** [22] has found a deployment mechanism that considers the target coverage with least no. of sensors and also preserve connectivity in spite of possible failure or energy depletion in a subset of the units.

**Kar and Banerjee** [22] have also considered two issues in the deployment of wireless sensor networks i.e. Coverage and Connectivity. Assuming that sensing and communication radii are equal and identical for all sensors, they define a pattern referred as r-strip as shown in fig 3.5 (a). An *r*-strip is a string of *r*-disks placed along a line such that the distance between the centers of any two adjacent *r*-disks is *r* [22]. Now, tile the entire plane with these r-strips in such a way that all their neighbors are oriented along the x-axis. For even values of integer k, r-strips are tiled on the lines $\boldsymbol{y = k(0.5\sqrt{3} + 1)r}$ and shifted horizontally for odd values of k i.e.

$[\mathbf{0.5}\boldsymbol{r}, \boldsymbol{k}(\mathbf{0.5}\sqrt{\mathbf{3}} + \mathbf{1})\boldsymbol{r}]$ and to ensure connectivity, additional sensors are placed at $[\mathbf{0}, \boldsymbol{k}(\mathbf{0.5}\sqrt{\mathbf{3}} + \mathbf{1})\boldsymbol{r} \pm \mathbf{0.5}\sqrt{\mathbf{3}}\boldsymbol{r}]$ as shown in fig 3.5(b). The goal is to cover the points of interest, fill the gaps and maintain connectivity. For a general convex-shaped finite-size region, connectivity among nodes in horizontal r strips is established by another r-strip placed diagonally within the boundary of the region (Fig. 3.5(c)).

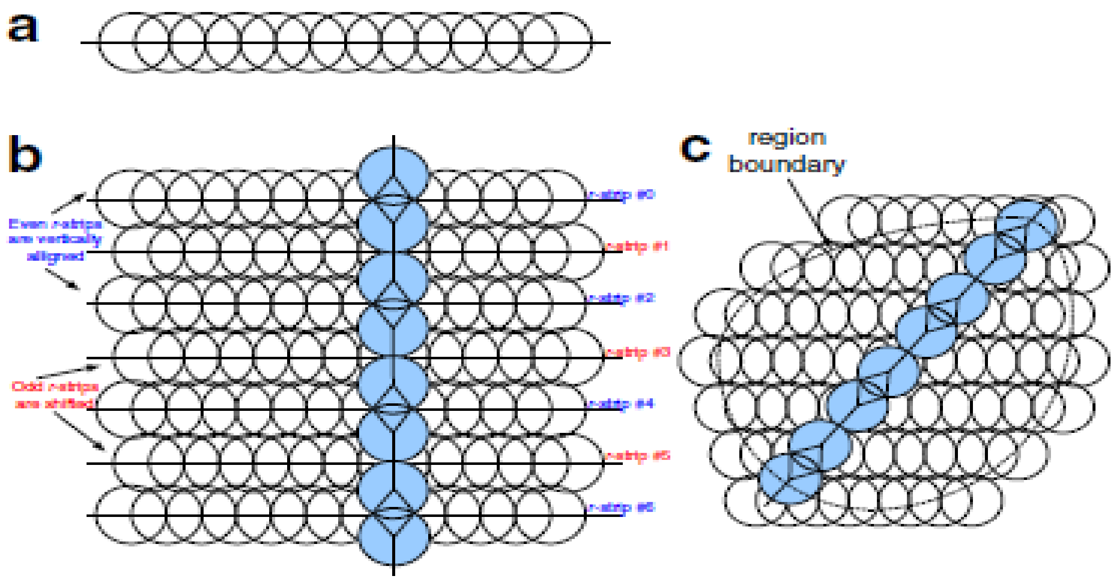


Fig 3.5: Illustration of the placement algorithm in a plane and a finite size region [22].

In addition, vertically placed nodes or diagonal r-strips can become a communication bottleneck since they act as gateways among horizontal r-strips, which may require the deployment of more sensors to split the traffic [22].

**Bredin et al.** [22] have focused on forming K-connected graphs which implies that an area is said to have coverage level k, if there are k-independent paths among every pair of nodes. They modeled the sensing region in the form of graph in which vertices represent the initial set of sensors and edges represent the communication links among sensor nodes. Each edge is associated with a weight which denotes the no. of nodes to be placed to establish connectivity i.e. $w = \left(\frac{\overline{uv}}{r} - 1\right)$, where u and v represents nodes, $\overline{uv}$ is the Euclidean distance between the nodes and r is the sensing radii of a node. In 2005, researchers [22] studied the problem of node deployment in terms of macroscopic parameters such as node density in order to minimize communication energy, limit interference among the nodes' transmission and avoid traffic bottlenecks. They showed the resemblance of the induced electrostatic field between two opposite charges with the traffic flow between sensor nodes and base station.

Network lifetime is considered as an important aspect of wireless sensor networks for increasing the efficiency. The position of nodes directly impacts the life span of network. For example, a uniform node distribution may lead to depletion of energy of nodes which are closer to base station and non-uniform distribution may lead to unbalanced load and cause bottlenecks. The authors of [22] have considered the problem of distributing sensors in accordance with average energy consumption per round while meeting a series of energy and coverage constraints. **Zhang and Wicker** [22] has allocated the cells by partitioning the coverage area into cells, and then assuming that sensors in same cells make same observations, while meeting a series of energy and coverage constraints. In 2006, **Wang** [22] proposed information oriented sensor deployment scheme, which minimizes the expected information loss (EIL) or maximizes the expected information utility (EIU) for a given number of sensors, or minimizes the number of sensors required to achieve a given information threshold.

Some of the researchers studied that the position of nodes not only affects the coverage but also affects other performance metrics such as packet delay. In order to mitigate network deficiencies and to increase network's lifetime, **Hou et al.** [22] have considered energy provisioning problem for a two-tiered wireless sensor network as shown in fig 3.6. In this, every cluster has many micro sensor nodes (MSNs) and an aggregation- and-forward node (AFN) which aggregates the data from all MSNs and then forward it to Base Station (BS). AFNs spend most of their energy in performing critical operations like data aggregation, data forwarding and data fusion. The authors suggested prolonging the lifetime of the AFNs, either by providing them more energy or by placing Relay Nodes (RN) near to them. In addition to it, they formulated the joint problem of EP and relay nodes into a mixed-integer nonlinear programming problem.

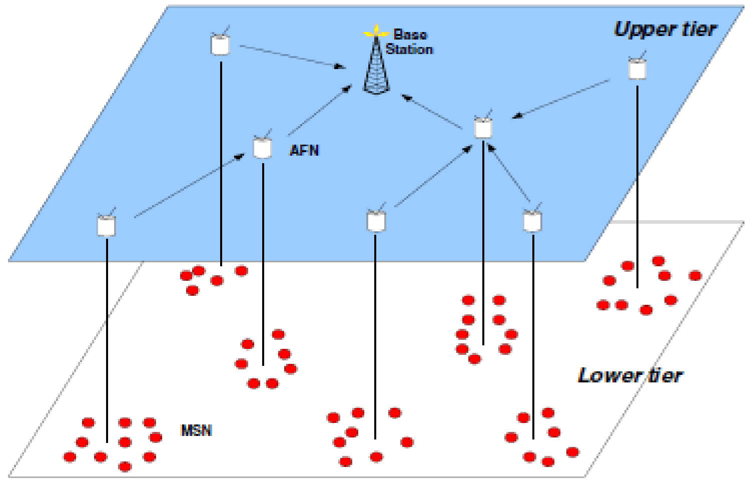


Fig 3.6: Logical view of the assumed two-tier network architecture (redrawn from [22]). MSN stands for micro-sensor nodes.

Unlike the work described earlier, Wang [22] modeled the problem of using minimum number of relay nodes in a network with minimum set covering problem. The authors have extended previous work by considering two sets of relay node 1) First-level Relay Nodes and 2) Second-level Relay Node. For long distances FPRN cannot relay all its traffic to the base station (BS) in one hop because of limited energy, therefore some second-level nodes are needed for transmitting data to base station.

Assembling the nodes into clusters has been widely pursued by the researchers in order to achieve critical design goals of network [22]. Cluster head is elected as leader of the cluster for aggregating the data, removing the redundant packets and transmitting it to base station. Many clustering algorithms are proposed by the research community based on no. of objectives such as load balancing, fault-tolerance, increased connectivity and reduced delay, minimal cluster count and maximal network longevity. One of the earliest clustering algorithms is Linked Cluster Algorithm, given by **Baker and Ephremides** [22], in which nodes having highest ID among its neighbors are selected as Cluster Heads (CHs). **Lin and Gerla** [22] has proposed adaptive clustering for meeting QoS requirements by allocating unique code to every cluster. **Gerla** [22] also proposed Random Competition Based Clustering, in which any node can claim in a cluster for being a CH. The problem lies when two nodes claims at same time, to avoid this problem

RCC explicitly employs a random timer and uses node ID for arbitration. In order to increase the manageability of the WSN, **Oyman and Ersoy** [22] focused on multiple sink network design problem. They employ k-means clustering algorithm i.e. non-hierarchical clustering algorithm for finding the best location for k sink nodes. The network lifetime is estimated based on ratio of no. of unreachable nodes at time t given total no. of nodes. **Youssef and Younis** [22] employed Genetic Algorithm, a heuristic search technique, to reduce data latency by minimizing the hop count between a sensor and one of the gateways. Genetic algorithm often reaches optimal or near to optimal solution, instead of selecting centroid as cluster head (CH), this algorithm strives to place cluster head at or close to the centroid of the cluster.

Most of the researchers also argued for dynamic repositioning of nodes for improving the performance of the network. For instance, after being functional for long time, some of the nodes exhaust their energy and becomes holes in the network. So, it was thought to relocate some of the sensor nodes in the vicinity of the base station which is quite challenging during the regular network operation. It thus requires continuous monitoring, careful data handling and basic relocation issues: when, where and how to relocate to be considered. A mathematical formulation of the node relocation may involve huge numbers of parameters such as location of dead nodes, no. of active nodes, transmission range, residual energy, coverage ratio etc. Wang et al. [22] utilizes nodes ability to relocate and has found Voronoi Diagram Approach useful for deciding where to relocate sensor to prevent bottlenecks, to boost the coverage and to minimize energy consumption. Alternate method, Minimax approach helped researchers in relocation by keeping most of the other vertices of Voronoi polygon within the sensing range and thus minimizing the distance to Voronoi vertex. This usually causes zig-zag movement of sensors rather than direct movement to final destination. Based on application, there is need to redistribute available sensors on demand to improve network topology. For relatively long distances, it is difficult to relocate sensor nodes as they drain a significant amount of energy.

### 3.2 Routing Strategies

To avoid direct communication with the distant destination, sensor networks communicate by forming multi-hop networks. In this regard, routing in such multi-hop networks with no fixed infrastructure and non-reliable wireless links becomes a challenging task in achieving energy efficiency. And also, it is not convenient to use global addressing scheme for such a huge wireless sensor network. Many routing algorithms have been investigated in recent researches. There are some inherent features of WSN, which has been taken into consideration while employing a routing algorithm:

1. Sometimes, getting data is important than getting IDs.
2. Application-specific architecture.
3. Nodes have limited energy, processing and storage capacity.
4. Nodes may or may not be stationary.
5. Getting position of nodes
6. Redundant data

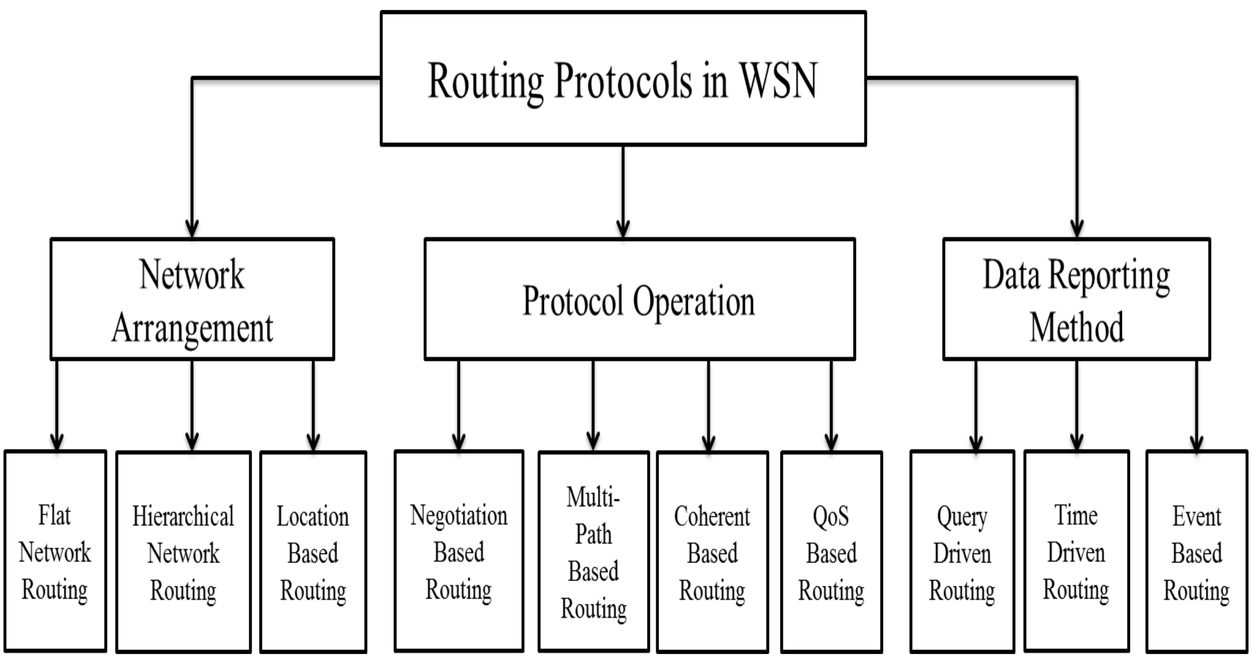


Fig 3.7: Classification of Routing Protocols in WSN (redrawan from [25])

Routing protocols can be categorized according to network arrangement as flat, hierarchical and location based protocols. According to protocol operation, it can be categorized into multi-path based, QoS based, negotiation-based, and coherent based protocols. Furthermore, it can also be categorized into event-driven routing, time-driven routing and query driven routing according to data reporting method [24] as shown in fig 12. From the energy conservation point of view, WSN routing protocols can be categorized as Traffic based, Topology based and Reserved based routing protocols [25] as shown in fig 38.

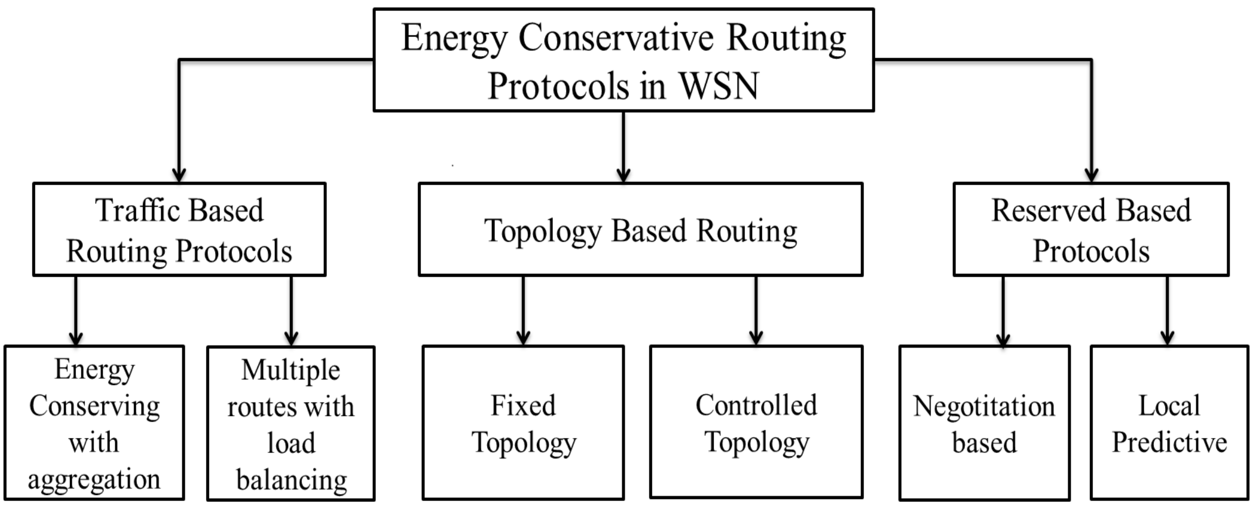


Fig 3.8: Energy Conservative Routing protocols in WSN [25]

### 3.2.1 Traffic Based Routing Protocols

The protocols which conserve energy by controlling the traffic flow are added into this category. It is sub-categorized into two classes:

1) **Energy Conserving with aggregation**

   By aggregating the data from different sources, it helps in sending the same data with less power by removing duplicates of data. Although, node responsible for aggregation and then transmission consumes more energy than other nodes but it saves energy by minimizing the no. of hops required to transmit the data. Thus conserves overall network energy and prolongs the network's lifespan.

2) **Multiple routes for load balancing**

More than one route is constructed and data collected from different sources is spread between the routes. The workings will not breakdown as power is dissipated evenly among all nodes.

### 3.2.2 Topology Based Protocols

1) **Fixed topology**

   For some applications, the network design can be decided before deployment phase. It reduces the overhead complexity and cost of designing a wireless sensor network.

2) **Controlled Topology**

   In this topology is controlled by adjusting the power (varying transmission range), choosing the state of nodes (active or sleep), by partitioning the network, selecting hybrid approach (partitioning and power adjustment). Hierarchical protocols come under controlled topology classification group.

### 3.2.3 Reserved Based Protocols

1) **Negotiation based**

   Before any data transmission negation based protocols assign descriptors to the collected data of the nodes so that no duplicates messages are transmitted over the network.

2) **Local Predictive**

   These protocols utilize the adjacent property of nodes, which states that the members or nodes which are very close to each other may have similar data sets. So the need is to distribute the data to the other nodes which are not having data.

Some of the routing techniques according to above categorization are explained below:

- **Sensor Protocols for Information via Negotiation (SPIN)**

  Kaulik et.al. [26] proposed this family of adaptive protocols to efficiently disseminate information among sensors in an energy-constrained sensor network. SPIN uses metadata negotiation and resource -adaptation to overcome several deficiencies of traditional dissemination approaches. Using metadata names, nodes negotiate with each other about the data they possess. This negotiation ensures that nodes only transmit data when necessary and never waste energy on useless transmissions. Because the nodes are resource aware, they are able to cut back on their activities whenever their resources are low to increase their longevity. SPIN uses three kinds of messages for communication:

1.ADV - When a node has data to send it advertises using this message containing metadata.

2.REQ - A node sends this message when it wishes to receive some actual data.

3.DATA - Data message containing the data with a metadata header.

The four specific SPIN protocols are:

*1.SPIN-PP*: This point-to-point communication protocol assumes that two nodes can communicate with each other without interfering with other nodes communication and also that packets are never lost. A node, which has information to send, advertises this by sending an ADV to neighboring nodes. The nodes that are interested in the data express their interest by sending a REQ. The originator of ADV then sends the data to the nodes that sent a REQ.

*2.SPIN-EC*: This protocol just adds energy heuristic to the previous protocol. A node participates in the process only if it can complete all the stages in the protocol without going below a energy threshold.

*3.SPIN-BC*: This broadcast channel based protocol differs from the previous protocols in that nodes do not immediately send out REQ messages on hearing an ADV. Instead each node waits a random amount of time before sending out the REQ message. The other nodes whose timers have not yet expired cancel their timers on hearing the REQ, thus preventing redundant copies of REQ being sent.

*4.SPIN-RL:* This protocol was designed for lossy broadcast channels by incorporating two adjustments. First each node keeps track of the advertisements it receives and re-requests data if a response from the requested node is not received within a specified time interval. Second nodes limit the frequency with which they will send data. Every node waits for predetermined time before servicing requests for same piece of data.

- **Direct Diffusion**

  Directed Diffusion comes under energy conservation with aggregation category of traffic based routing protocols. This protocol has data centric paradigm and it is also called as application aware protocol as the data sensed is named by attribute-value pairs [25]. Because of data centric pattern it accumulates data from multiple sources, removes duplicate sets and minimizes the no. of transmissions. In direct diffusion, the base station circulates interests (task/event) throughout the network while specifying the gradients. The interest spreads over the network and each node tells interest to its neighboring members by assigning an attribute-value pair. The nodes which receive the interest set up a gradient towards the nodes from which they have received. Each node looks up the cache and sees whether it is a new interest or recently performed interest. If the interest is recently performed by the node then it suppresses this interest to avoid increase in traffic flow. The procedure continues till the convergence condition (if the gradients are set up). When interests fit gradients, the best route is chosen from multiple paths according to local rule to send data to base station. The aggregated tree is thus generated by suppressing the recently sent data and aggregating the new one.

- **Rumour Routing**

  Unlike directed diffusion, this routing mechanism [25] routes the queries to nodes which have noticed the particular event thus forms a single path to destination. When a particular node discovers an event, it adds up the event discovered in the local cache called event cache. A long lived packet named agent is generated in order to circulate local events information to the far away nodes. It merges the event cache with the event cache of visited nodes and updates the routing table with shortest paths while circulation. If the query is triggered by a node, then nodes knowing the route respond to the query by looking up the event cache. The objective is to reduce the communication cost by accumulating the data and to find shortest routes for transmitting data from source to sink.

- **Low Energy Adaptive Clustering (LEACH):**

  It is a hybrid topology control - based protocol which includes distributed cluster formation combined with MAC layer techniques. The operation is separated into two phases: The set-up phase; LEACH randomly selects a few sensor nodes according to a certain function as cluster heads (CHs) and rotate this role to evenly distribute the energy load among the sensors in the network. LEACH algorithm has some disadvantages; such as it does not take geographical position of sensors in consideration [27] and the energy of the nodes away from BS has been quickly evacuated. **LEACH-C** [28] is the modified form of LEACH protocol. It forms better clusters by using a centralized control algorithm via dispersing of CH-nodes. In this algorithm CH is selected according to the residual energy which reduces the probability of failure of CH and increases the network's lifetime.

- **LEACH sub-CH**

  Leach sub-CH [29] is an improvement of LEACH algorithm. In the basic LEACH algorithm the cluster head eventually dies because of overhead tasks and much more energy dissipation as compared to other nodes. As cluster head is responsible for receiving data from other nodes and transmitting data to the base-station, if it will die then cluster will become useless. Also, there will be no alternate path for the cluster nodes to send data to BS. In LEACH sub-CH protocol, there is a sub Cluster-Head which will be responsible for whole operations of CH if the CH dies.
- **PEGASIS algorithm** [30] is a greedy algorithm that forms a chain structure of sensor nodes. It is an improved version of LEACH algorithm that makes the path more even-distributed and takes rounds in transmitting to the base station. But the disadvantage of this algorithm is that all nodes need to have general knowledge about network chain structure.
- Younis and Fahmy (2004) have proposed **Hybrid Energy-Efficient Distributed clustering (HEED) algorithm** [31]. It periodically selects cluster heads by considering various factors like remaining energy and number of neighbors. But this algorithm does not consider geographical position of nodes.

# CHAPTER-4

# PROPOSED METHODOLOGY

The new energy efficient multi-stage WSN architecture framework has been proposed for prolonging the network's lifetime. The proposed architecture considers two types of deployment mechanisms:

1) Random Deployment and

2) Multi-Objective Genetic Algorithm based deployment.

With those locations, routing is performed in the network using LEACH protocol and ILEACH protocol and performance is calculated and compared in terms of energy consumed and other performance metrics. The proposed architecture has been designed for decision making and for minimizing energy inefficiencies.

## 4.1 Deployment Phase

### 4.1.1 Random Deployment Mechanism

Random deployment gives the random locations for deploying sensors in the defined workspace with the help of pseudo random generator. If the deployment method is selected as "Random" in the proposed model, then random locations has been given to the routing phase of the network.

### 4.1.2 Proposed Deployment Mechanism

In proposed deployment, multi objective Genetic Algorithm is employed to find out the optimal locations at where sensors can be placed in the defined workspace so that energy can be conserved and functioning period of sensors can be increased. The proposed deployment model works same as genetic algorithm, but it is different in selection mechanism. First, random population is generated. Second, fitness value is calculated considering total energy consumption and network connectivity as two objectives. In the model, the energy consumption can be calculated using either of the ways: 1) without clustering 2) with clustering (K-means). The energy consumption is then calculated using radio energy model. After getting both the objectives value, fronts are calculated using non-dominated sorting. It gives the best individuals from the population. Now, population is evolved using conventional crossover and conventional mutation mechanism. The procedure is called repeatedly till maximum no. of iterations considered in the model design.

### 4.2 Routing Phase

In the routing phase of the network, two routing algorithms are considered i.e. LEACH and ILEACH routing protocols. LEACH and ILEACH protocol are different in Cluster Head selection phase of the network. LEACH protocol gives the probability for selecting next cluster head to be chosen for that particular cluster. But, ILEACH is an intelligent leach protocol which considers various factors such as residual energy, no. of neighbors, and distance from Base Station. If deployment method is “Random”, then it evaluates performance of the network considering random locations. And, if deployment method is “Proposed”, then it evaluates performance considering optimal locations generated by proposed deployment mechanism. The results are calculated using both these protocols and performance is evaluated and compared.

## 4.3 System Flow


Fig 4.1: Flowchart of Proposed System Flow

# CHAPTER-5

# FUNCTIONALITY OF NETWORK DESIGN

The main network design paradigms used and their functionality are discussed and explained architecture are explained below:

## 5.1 Modified Genetic Algorithm Based Deployment

### 5.1.1 Multi-Objective Optimization

It is a method of optimizing two or more than two conflicting objectives simultaneously such as reducing cost while improving quality, minimizing risk while maximizing profit. For all conflicting objectives, it is not possible to get a single optimal solution (global maximum or global minimum) which satisfies every objective. In that case, there exist a number of non-dominated solutions which are best as compared to other solutions when all objectives are considered and worst in one or more objectives. These non-dominated solutions are also known as Pareto Optimal solutions [33]. Now selecting a particular solution from number of non-dominated solutions requires domain knowledge and factors affecting the problem. Mathematically,

$$\begin{array}{lll} \text{Min/Max} & a_i(x) & i=1,2,3\ldots\ldots m \\ \text{Sub. to} & b_j(x) \geq 0 & j=1,2,3\ldots.m \\ & c_k(x) = 0 & k=1,2,3\ldots..m \end{array}$$

In the proposed model, two objectives are considered

1) Total Energy Consumption
2) Network Connectivity

Since two conflicting objectives are considered in the model, therefore it is a multi-objective optimization problem. NSGA has been determined as one of the most efficient multi-objective algorithm which is based on Goldberg's suggestions.

### 5.1.2 Non Dominated Sorting Genetic Algorithm (NSGA)

Genetic algorithm, is a heuristic search technique and is helpful in finding the optimal or near to optimal solution from a large set of populated points, therefore it can be used to capture best solutions. NSGA [33], Non Dominated Sorting Genetic Algorithm NSGA is an improvement of Genetic Algorithm which works by ranking the population on the basis of non-dominance and give best individuals from the population. NSGA [33], Non Dominated Sorting Genetic Algorithm has been determined as one of the most efficient multi-objective algorithm which is based on Goldberg's suggestions. In the proposed model, essence of NSGA has helped in getting the best individuals from the population.

#### 5.1.2.1 Flow of Proposed Deployment Mechanism

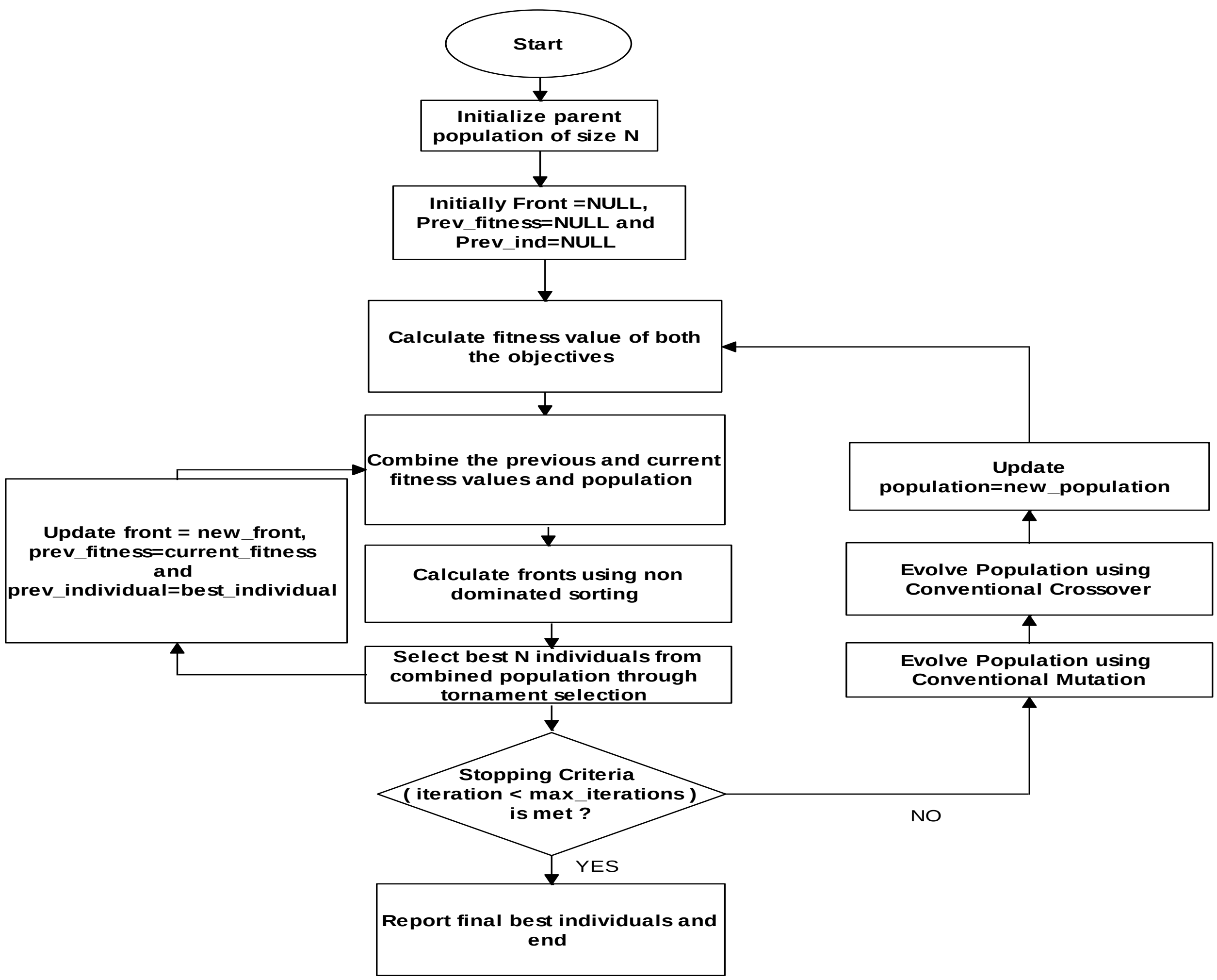


Fig 5.1: Flowchart of modified GA based Deployment

#### 5.1.2.2 Pseudo Code of Proposed Deployment Mechanism

**Step 1**: Parameter Declaration

dimension=n*n

individualLength = (n * 2);

noOfObjectives = 2;

popSize = 10;

maxIter = 2;

elitism = 1;

tournamentSize = 2;

crossoverRate = 0.5;

mutationRate = 0.5;

prev_fitness = NULL,

prev_individual=NULL and fronts=NULL

**Step 2**: Generate initial random population

For i to popSize

For j to individualLength

Pop[i][j]=rnd.next(dim)

**Repeat steps 3 to 9 until max_iterations:**

**Step 3**: For i to popSize

Calculate fitness function

**Step 4:** Combine the previous and current fitness values and population

**Step 5**: Calculate fronts by using non dominated sorting, considering combined fitness value as input parameter to front calculation function.

**Step 6:** Update previous fitness and previous individual parameters.

**Step 7**: Select best N individuals from population using Non Dominance Sorting

**Step 8**: Selection of parents

p1=random(popSize)

p2=random(popSize)

parent1=pop[p1]

parent2=pop[p2]

**Step 9**: Evolve new population

1) Apply Convential crossover

```
For j=0 to individual_length
if (random1 <= crossoverRate)
        child[j] = parent1[j]
   else
            child[j] = parent2[j]
```

2) Apply Conventional Mutation

```
For j=0 to individual_length
if (random1 <= mutationRate)
       child[j] = random_no(dim)
   new_Population=child
  Pop=new_population
```

**Step 10**: Report final best optimal locations and end.

## 5.2 LEACH Routing Protocol

LEACH protocol, called as Low Energy Adaptive Clustering Hierarchy Protocol introduced by W.Heinzelman [26] is one of the hierarchical clustering algorithm which distributes the sensor nodes into disjoint classes called as clusters. It chooses the Cluster Head (CH), the representative of every cluster. Non-CH nodes of the every cluster sends data to the CH nodes and then data is accumulated and compressed by CH nodes. The CH nodes of the network send data to the base station, the main representative of the network. The problem exists for the nodes selected as CH nodes because they drain out their energy in receiving the data from non-CH nodes, accumulating the data, compressing it and then transmitting it to main station. Hence, it was thought that a recurring order is to be followed for selecting the representatives of the clusters. The recurring order considers the probability formula which is described in algorithm.

### 5.2.1 Operation of Leach Protocol

#### 5.2.1.1 Cluster Head Selection Stage

In this phase, a predetermined function p is considered which denotes the percentage to become the representative of that cluster. The representative selection is done according to probability formula value. The formula is given as:

$$prob = \begin{cases} \frac{p}{1-p*\left(round\ \%\left(\frac{1}{p}\right)\right)} & if\ \ n \in G \\ 0 & \end{cases}$$

Where,

p= percentage of becoming a cluster

G= In last 1/p rounds, set of nodes have not become representative of cluster.

round= Current round

Every node desiring to be the representative chooses a random value in the range 0 to 1. If this random value is less than the probability calculated, then node becomes the representative (CH) of that particular cluster in the current round. The value of G marker is updated to some value of that particular CH node and G is set to zero for other non-CH nodes. The G marker determines the nodes which are not get selected in the previous 1/p rounds. This is done so that representative (CH) selected for current round cannot again become the representative (CH) until all the other nodes got a chance.

#### 5.2.1.2 Cluster Development Stage

After getting elected as representative, it broadcasts a message to other non-CH nodes to join the clusters. Depending upon signal strength, the non-CH nodes decides to be the part of that cluster or not. Non-CH nodes then send acknowledgement message to the representative (CH) node. Depending on the no. of members joined, the CH nodes divide the time slot (TDMA schedule) and assigned to every node belongs to cluster for sending the data.

#### 5.2.1.3 Data Transmitting Stage

During this stage, the non-CH nodes starts sending sensed data to their representative according to pre-given time slot. the representatives (CH) nodes accumulates and compress the data and send data to the base station, the main representative of the network. Each representative of the cluster communicates using CDMA codes in order prevent intra and inter-cluster collisions.

### 5.2.2 Flow of LEACH routing protocol

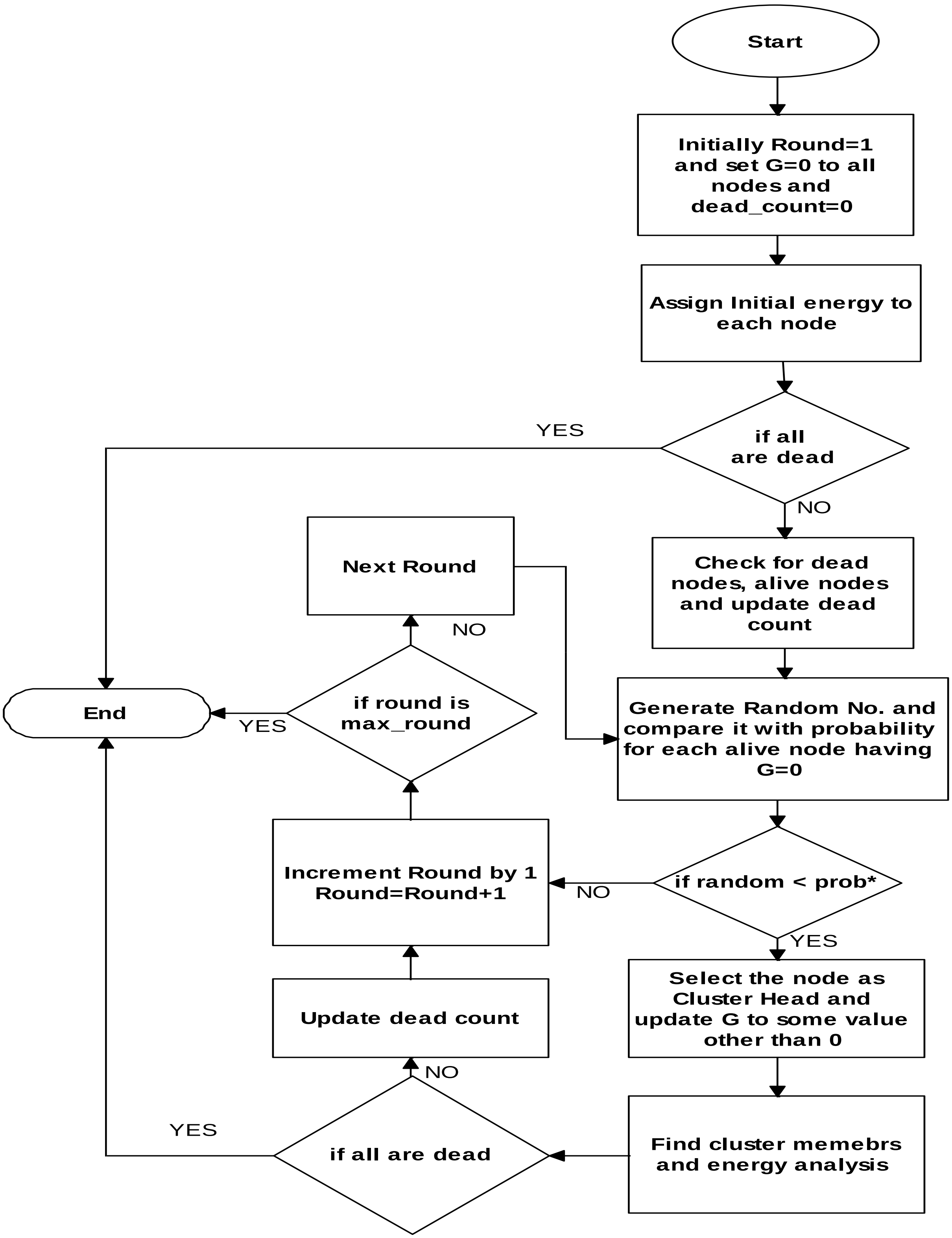


Fig 5.2: Flowchart of LEACH algorithm

### 5.2.2 Pseudo Code of LEACH Routing Protocol

For rounds 1 to max_rounds

**Step 1**: For nodes i to n:

Assign initial energy to each node using Radio Energy Model

**Step 2**: Remaining Energy Calculation

Initial re=0

For nodes i to n:

re=re+ energy[i]

remaining_enegy[round-1]=re

**Step 3**: Check for dead nodes

If(re <= min_energy * n)

Then, All nodes are dead

Else, Calculate no. of dead nodes

Initial deadcount=0;

For nodes i to n:

If(energy[i]<=min_energy)

Then, Increment deadCount by 1

deadnodes[round-1]=deadCount

if(deadCount==n)

Then, lastDead=round;

**Step 4**: Calculate the no. of neighbors of each sensor node

For nodes i to n, check all the nodes j to n

Initial counter ==0;

If (Eucledian_distance[i][j] < transmission range)

{If (energy[j] > min_energy)

Then, increment the counter by 1 }

**Step 5**: Cluster Head Selection and energy analysis

For nodes i to n :

If ( energy[i] > min_energy and G[i] is NULL)

Then, Generate a pseudo random number, r

Calculate probability of getting selected as CH

$$prob = \frac{p}{1 - p * (rounds \,\%\, \left(\frac{1}{p}\right))}$$

If(r<=prob)

Then, set CH[i]==TRUE and set G[i]=some value

(G used as marker for denoting the nodes which got selected as CHs in previous rounds)

Calculate ec, transmission energy of CH node to Base Station

energy[i]= energy[i]-ec ,

energy consumption= energy_consumption +ec

**Step 6**: Update value of G,

if(round%(round.(1/p) == NULL)

then for all nodes i to n, set G[i] = 0

**Step 7**: Finding Cluster members and energy analysis

For nodes i to n :

If(energy[i]>min_energy and is(CH[i]==FALSE)

nearest_CH=clusterheads.get(0)

For ch to clusterheads

If(Eucledian_distance[i][ch] < Eucleadian_distance [i] [nearest])

Then, nearest_CH=ch;

Calculate distance from node I to nearest_CH

Calculate ec, transmission energy of node to nearest CH

energy[i]= energy[i]-ec ,

energy consumption= energy_consumption +ec

Calculate the receiving energy of CH node

energy[nearest_CH]= energy[nearest_CH]-ec ,

energy consumption= energy_consumption +ec

**Step 8**: Set, energy_consumption[round-1]=energy_consumption

## 5.3 Intelligent-LEACH Routing Protocol

I-Leach is termed as Intelligent LEACH protocol; it is an upgraded version of LEACH protocol [32]. It is different from LEACH protocol in the selection procedure for Cluster Heads (CHs). The mathematical probability calculated for selecting CHs in LEACH protocol has not considered the residual energy of the sensor nodes. In I-LEACH, they have formulated the probability formula which considers factors:

1) Residual Energy
2) No. of Neighbors
3) Cluster Head to Base Station distance

The algorithm works if network has following specifications:

1) Initial energy of all nodes should be either NULL or same and they can't be recharged using any alternate power source
2) Locations of nodes are fixed. If randomly deployed, they remain at same location.
3) For each node a distinct ID is provided, also current location and residual energy is known.
4) Nodes must have enough power to communicate with sink node.
5) Every node has a processing and storage unit.

### 5.3.1 Operation of I-Leach Protocol

#### 5.3.1.1 Cluster Head Selection Stage

As already, stated above that ILEACH takes significant attributes such as residual energy, no. of neighbors and distance of node from base station into consideration. For each particular node, no. of neighbors is counted. The more is the no. of neighbors, the more is the chances of getting selected as representative node (CH). The most important factor in determining representative node (CH) i.e. residual energy is calculated for each node. Similarly, the ratio between average distance of nodes to main representative (Base Station) and total distance from node to that point is considered while selecting CH. A predetermined function p is considered which denotes the percentage to become the representative of that cluster. The representative selection is done according to probability formula value. The formula is given as:

$$prob = \begin{cases} \frac{p}{1-p*(rounds\ \%(\frac{1}{p})} * \frac{Curr\_energy}{Avg\_energy} * \frac{neighbor\_count}{Avg\_Neighbors} * \frac{Distance\ from\ BS}{Avg\_Distance} & if\ n \in G \\ 0 & \end{cases}$$

Where,

p= percentage of becoming a cluster

G= In last 1/p rounds, set of nodes have not become representative of cluster.

r= Current round

Curr_energy= Energy of current round.

Avg_energy= Network's average energy in current round

neighbor _count=no. of members/neighbors of node n

Avg_neighbors=Average no. of neighboring nodes

Distance from BS=distance of nodes to BS

Avg_distance=Average distance of nodes to BS

Every node desiring to be the representative chooses a random value in the range 0 to 1. If this random value is less than the enhanced probability calculated, then node becomes the representative (CH) of that particular cluster in the current round. The value of G marker is updated to some value of that particular CH node and G is set to zero for other non-CH nodes. The G marker determines the nodes which are not get selected in the previous 1/p rounds. This is done so that representative (CH) selected for current round cannot again become the representative (CH) until all the other nodes got a chance.

#### 5.3.1.2 Cluster Development Stage

After getting elected as representative, it broadcasts a message to other non-CH nodes to join the clusters. Depending upon signal strength, the non-CH nodes decides to be the part of that cluster or not. Non-CH nodes then send acknowledgement message to the representative (CH) node. Depending on the no. of members joined, the CH nodes divide the time slot (TDMA schedule) and assigned to every node belongs to cluster for sending the data.

#### 5.3.1.3 Data Transmitting Stage

During this stage, the non-CH nodes starts sending sensed data to their representative according to pre-given time slot. the representatives (CH) nodes accumulates and compress the data and send data to the base station, the main representative of the network. To avoid interference, each representative of the cluster communicates using CDMA codes in order to transmit data.

### 5.3.2 Pseudo Code of ILEACH Routing Protocol

For rounds 1 to max_rounds

**Step 1**: For nodes i to n :

Assign initial energy of each node using Radio Energy Model

**Step 2**: Remaining Energy Calculation

Initial re=0

For nodes i to n:

re=re+ energy[i]

remaining_enegy[round-1]=re

**Step 3**: Check for dead nodes

If(re <= min_energy * n)

Then, All nodes are dead

break;

Calculate no. of dead nodes

Initial deadcount=0;

For nodes i to n:

Then, If(energy[i]<=min_energy)

Increment deadCount by 1

deadnodes[round-1]=deadCount

if(deadCount==n)

then , lastDead=round;

break;

**Step 4**: Calculate the no. of neighbors of each sensor node

For nodes i to n, check all the nodes j to n

Initial counter ==0;

If (Eucledian_distance[i][j] < transmission range)

{If (energy[j] > min_energy)

Then, increment the counter by 1 }

**Step 5**: Cluster Head Selection and energy analysis

For nodes i to n, If ( energy[i] > min_energy and G[i] is NULL)

Then, Generate a pseudo random number, r

Calculate probability of getting selected as CH

$$prob = \frac{p}{1-p*(rounds \% \left(\frac{1}{p}\right))} * \frac{Curr\_energy}{Avg\_energy} * \frac{neighbour\ count}{Avg\_Neighbours} * \frac{Distance\ from\ BS}{Avg\_Distance}$$

If(r<=prob)

Then, set CH[i]==TRUE and set G[i]=some value

(G used as marker for denoting the nodes which got selected as CHs in previous rounds)

Calculate ec, transmission energy of CH node to Base Station

energy[i]= energy[i]-ec ,

energy consumption= energy_consumption +ec

**Step 6**: Update value of G,

if(round%(round.(1/p) == NULL)

then for all nodes i to n, set G[i] = 0

**Step 7**: Finding Cluster members and energy analysis

For nodes i to n :

If(energy[i]>min_energy and is(CH[i]==FALSE)

nearest_CH=clusterheads.get(0)

For ch to clusterheads

If(Eucledian_distance[i][ch] < Eucleadian_distance [i] [nearest])

Then, nearest_CH=ch;

Calculate distance from node I to nearest_CH

Calculate ec, transmission energy of node to nearest CH

energy[i]= energy[i]-ec ,

energy consumption= energy_consumption +ec

Calculate the receiving energy of CH node

energy[nearest_CH]= energy[nearest_CH]-ec ,

energy consumption= energy_consumption +ec

**Step 8**: Calculate the average energy per round, average no. of neighbors and average distance and put it in probability formula.

**Step 9**: Set, energy_consumption[round-1]=energy_consumption

### 5.4 K-means Clustering

K-means Clustering: It is a partitioning technique which categorizes the whole data in k number of disjoint clusters by using mean square function value. Due to overheads, it works accurately for small sets of data than large sets of data. This algorithm can be performed either by randomly selecting the initial centers or by choosing some sample points from the data. In the proposed model, the centers are generated randomly using pseudo random generator. The clusters are prepared by determining the closest center for every node using Euclidean distance formula described below. When clusters are prepared, then center values are updated by taking the mean value of cluster center and nearest member. After updating, the clusters are re-prepared by determining the members of every cluster using same formula. The process continues until the convergence condition occurs. The condition can be the max no. of iterations the algorithm has worked repeated iteratively or when the center point in the cluster stops updating.

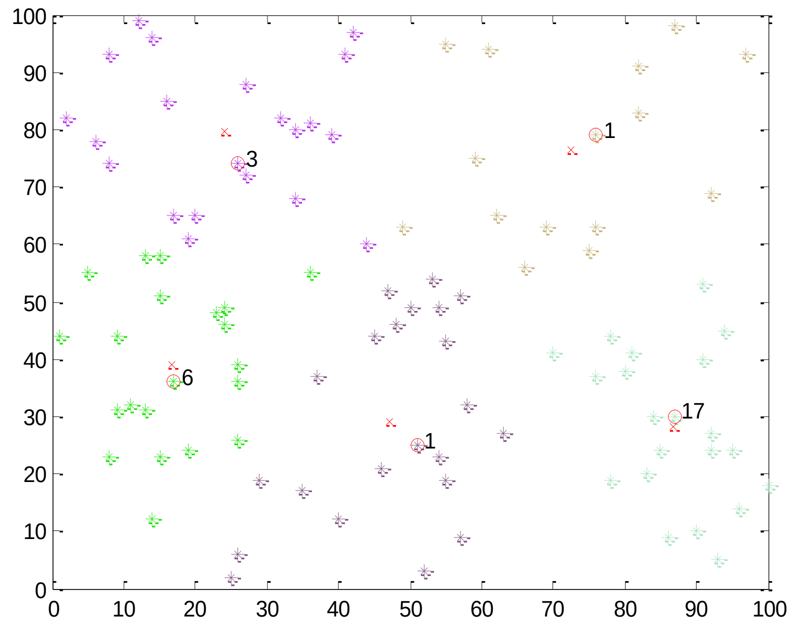


Fig 5.3: K-Means Clustering in the Network

### 5.4.1 Euclidean Distance Formula

The Euclidean distance between two multi-dimensional data points $X = (x_1, x_2, x_3 ... x_m)$ and $Y = (y_1, y_2, y_3 ... y_m)$ is described as follows:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

### 5.4.2 Flow of K-Means Clustering Algorithm

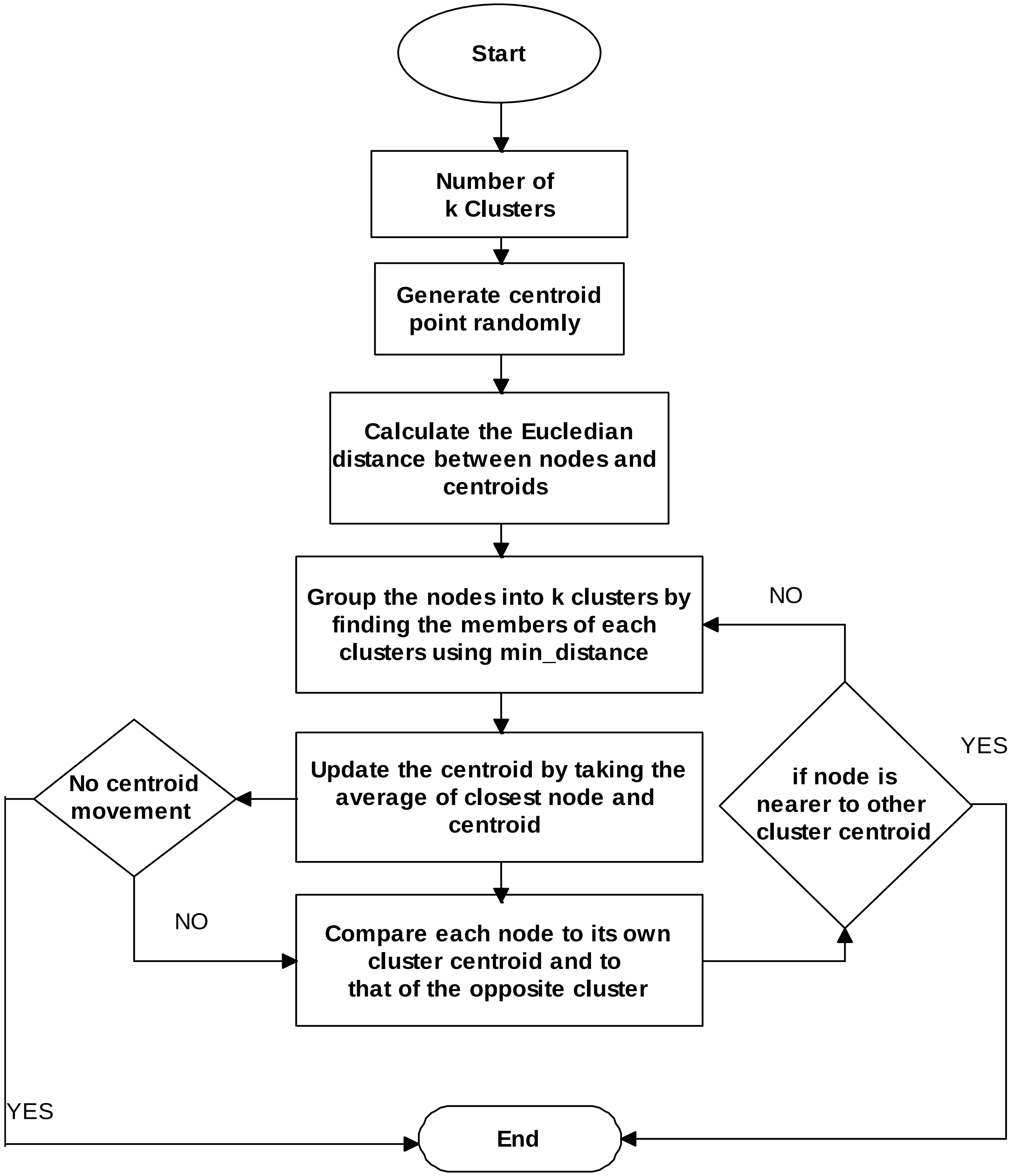


Fig 5.4: Flowchart of K-means Clustering Algorithm

# CHAPTER-6

# SIMULATION RESULTS

The simulation of the proposed work has been done using JAVA platform. The performance of the proposed work has been measured on the basis of energy consumption, network connectivity, no. of dead nodes, successful data routing. The comparison between random deployment and proposed deployment, LEACH and ILEACH routing protocols is shown. To evaluate and compare, the results were obtained by varying the defined parameters like no. of rounds, no. of nodes in a network. The energy calculations are carried out using Radio Energy Model.

## 6.1 System Energy Model

Radio model of energy consumption of the network has been considered, as shown in the Fig 6.1 in this model, wireless sensor network which consist of 100 sensor nodes is considered, and area used is 100x100 square meters. K represents the transmitted data packet size, d is the transfer distance (source node to destination node); $E_{TX}$ is the transmission energy which is dependent on d and k; $E_{RX}$ is the receiving energy that is dependent on the value of k. The following equations are energy consumption relations:

$$E_{TX} = \begin{cases} k\ (E_{elec}+E_{DA})+k \in_{fs} d^2 \ , & d<d_0 \\ k\ (E_{elec}+E_{DA})+k \in_{mp} d^4 \ , & d \geq d_0 \end{cases} \ , \ d_0 = \sqrt{\in_{fs}/\in_{mp}} \qquad (1)$$

$$E_{RX}(k) = kE_{elec} \qquad (2)$$

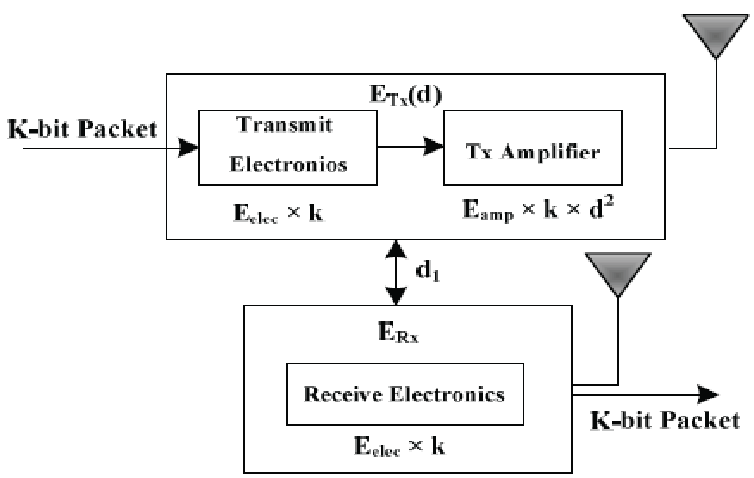


Fig 6.1: Radio Model of Energy Consumption

In accordance with the distance, free space ($d^2$ power loss) and multi-path fading ($d^2$ power loss) channel models are used. Eelec is the electronic energy being consumed by electronic circuits. The parameters $\in_{fs}$ and $\in_{mp}$ is the amount of energy being dissipated per bit in the radio frequency amplifier according to threshold $d_0$. Table 6.1. contains values of parameters used in simulation and table 6.2 contains value of GA parameters.

Table 6.1: Network Parameters used in Simulation

| Parameters | Value |
|---|---|
| Field Size (M×M) | 100m×100m |
| Location of BS | (50,50) |
| No. of Sensor nodes | 100 |
| Initial energy of sensor nodes, $E_{init}$ | 0.5 J |
| $E_{TX}$ and $E_{RX}$ ($E_{elec}$) | 50 nJ/ bit |
| Free Space ($\in_{fs}$) | 10 pJ/bit/$m^2$ |
| Multi-path fading($\in_{mp}$) | 0.0013 pJ/bit/$m^4$ |
| Energy for aggregation ($E_{DA)}$ | 5 nJ/bit/signal |
| Control Packet Size (c) | 32 bits |
| Data Packet Size | 4000 bits |
| $d_0$ | 87.7058 |
| Transmission Range | 20 |

Table 6.2: GA parameters used in network simulation

| GA parameters | Value |
|---|---|
| Individual Length | No of sensor nodes * 2 |
| No. of Objectives | 2 |
| Population size | 10 |
| Maximum iterations | 2 |
| Elitism | 1 |

| | |
|---|---|
| Crossover Rate | 0.5 |
| Mutation Rate | 0.5 |
| Tournament Size | 4 |

The simulation is performed by selecting Random Deployment Method for deploying the 100 nodes randomly in the defined workspace. The simulation is being run for 1000 rounds and it is shown in Fig 6.2.

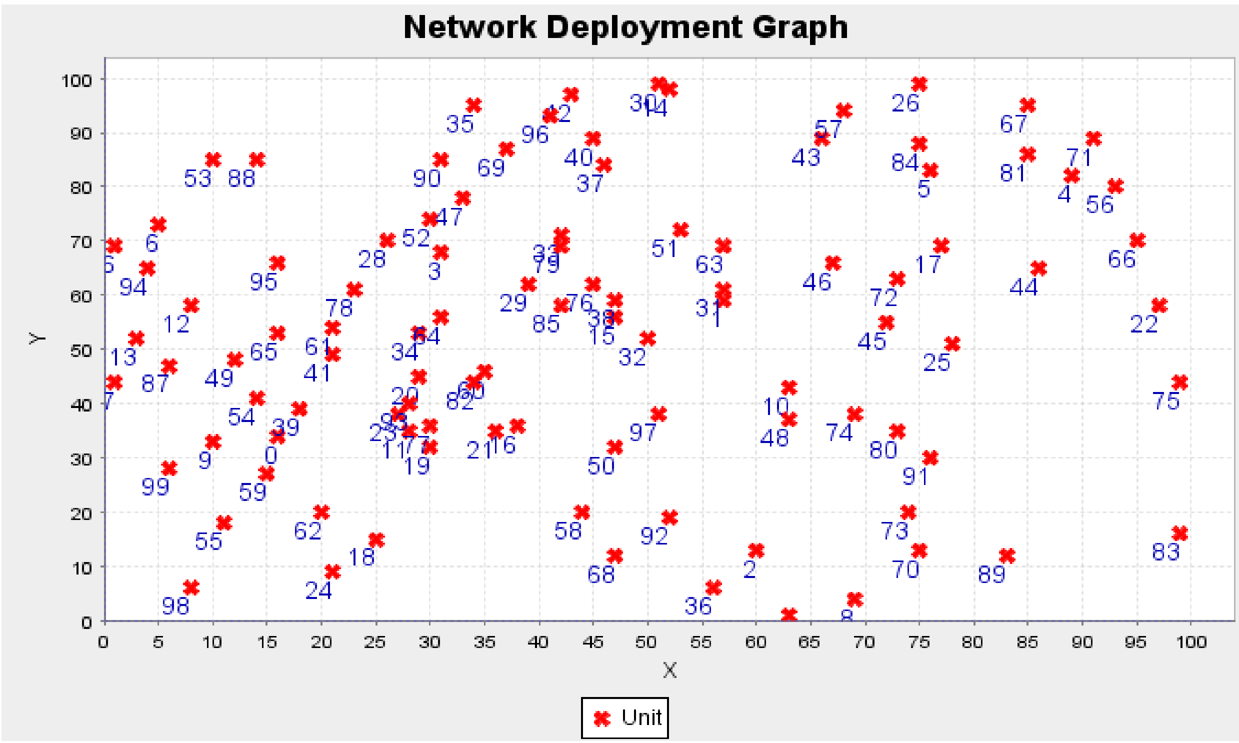


Fig 6.2: Random Deployment (1000 rounds)

The simulation is performed by selecting Proposed Deployment Method for deploying the 100 nodes at optimized locations in the defined workspace. The simulation is being run for 1000 rounds and it is shown in Fig 6.3

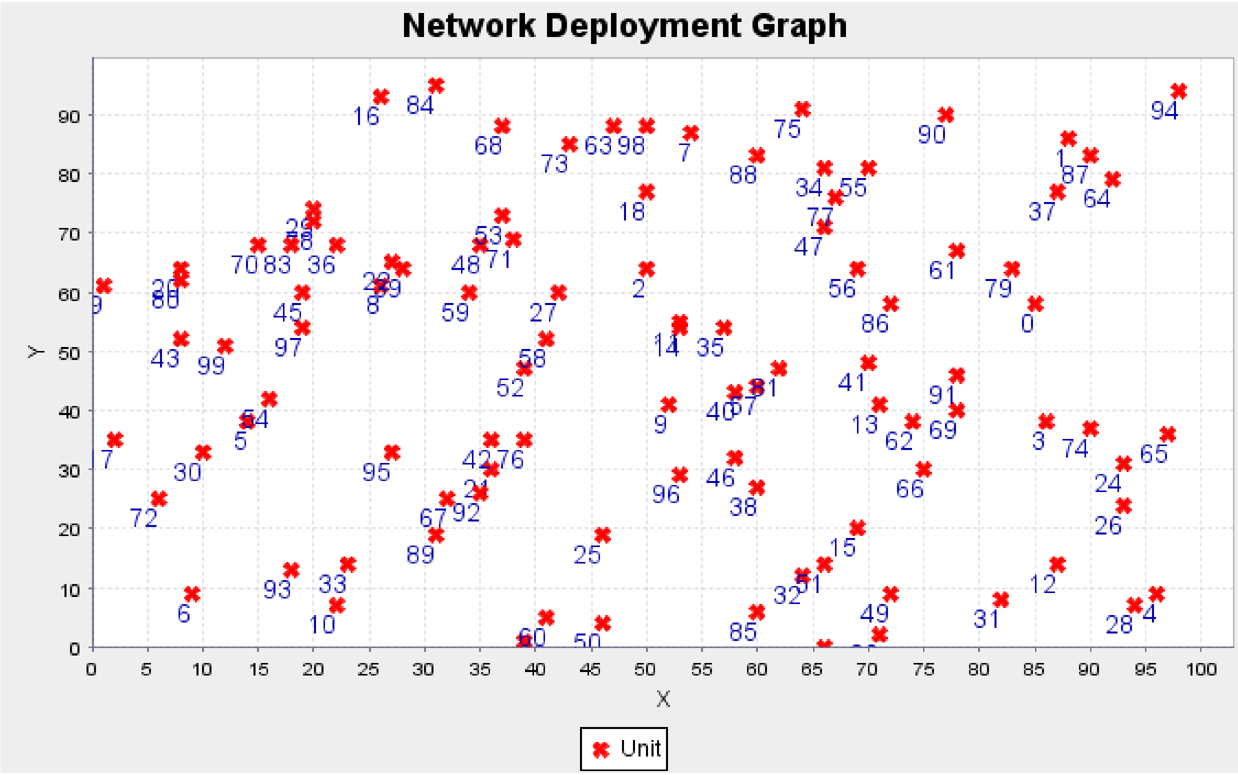


Fig 6.3: Optimized Deployment (1000 rounds)

In the proposed model, multi-objective genetic algorithm is used for getting the optimal locations. When Multi Objective Genetic Algorithm is run, fronts are calculated in order to get best individuals i.e. locations. The pareto front graph thus obtained in simulation are shown below. The pareto front graph 1 i.e. Fig 6.4 considers energy consumption on Y-axis and network connectivity on X-axis and second pareto front graph 2 i.e. Fig 6.5 considers energy consumption on X-axis and network connectivity on Y-axis.

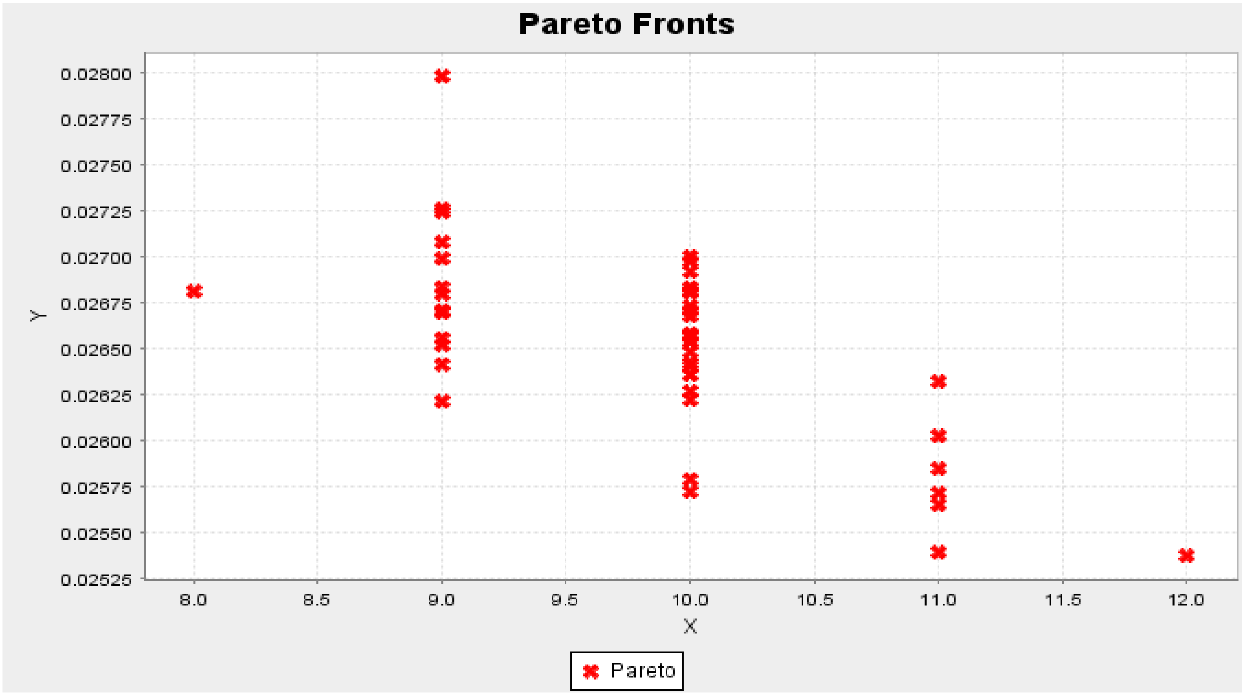


Fig 6.4: Pareto Front Graph 1

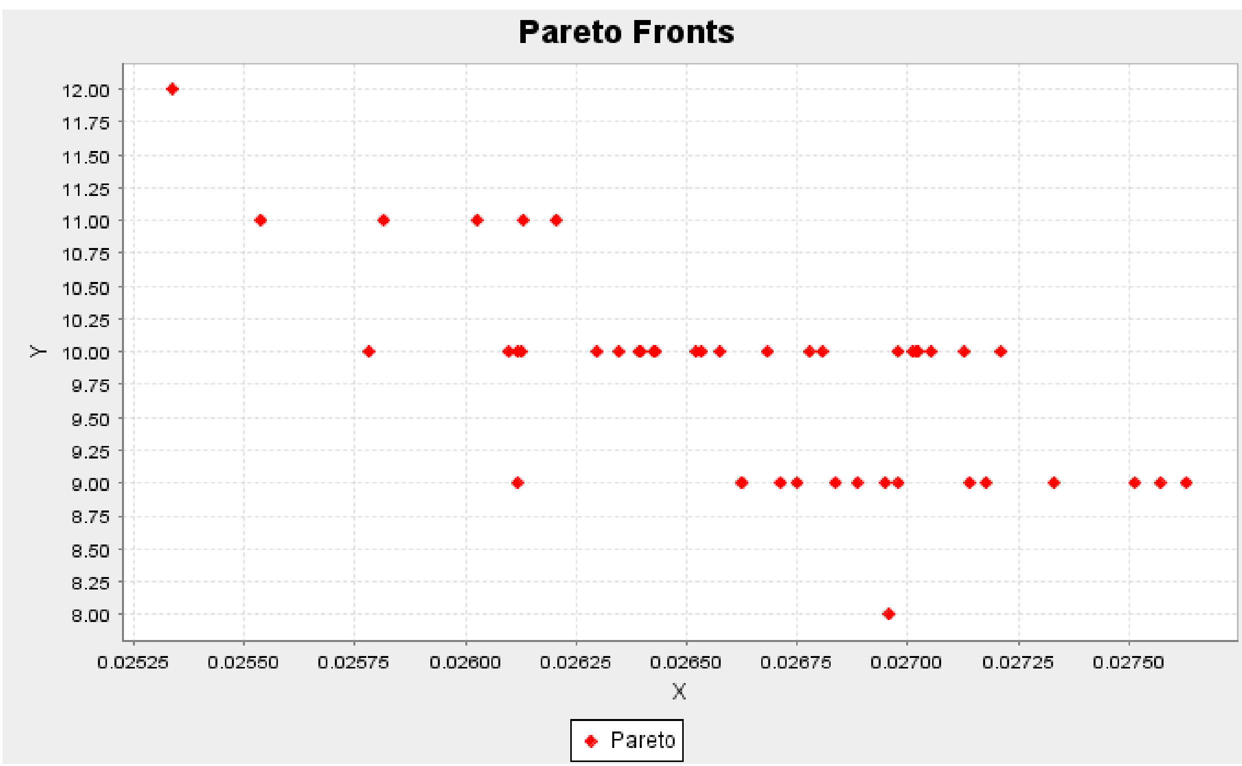


Fig 6.5: Pareto Front Graph 2

The simulation is performed by applying both the routing algorithms LEACH and ILEACH on the random locations generated by random deployment method. The results are shown in fig 6.6 and the effectiveness of ILEACH protocol over LEACH protocol is analyzed by comparing no. of dead nodes when the simulation is run for 1150 rounds. The no. of dead nodes calculated using ILEACH protocols are lesser than the no. of dead nodes calculated using LEACH protocol.

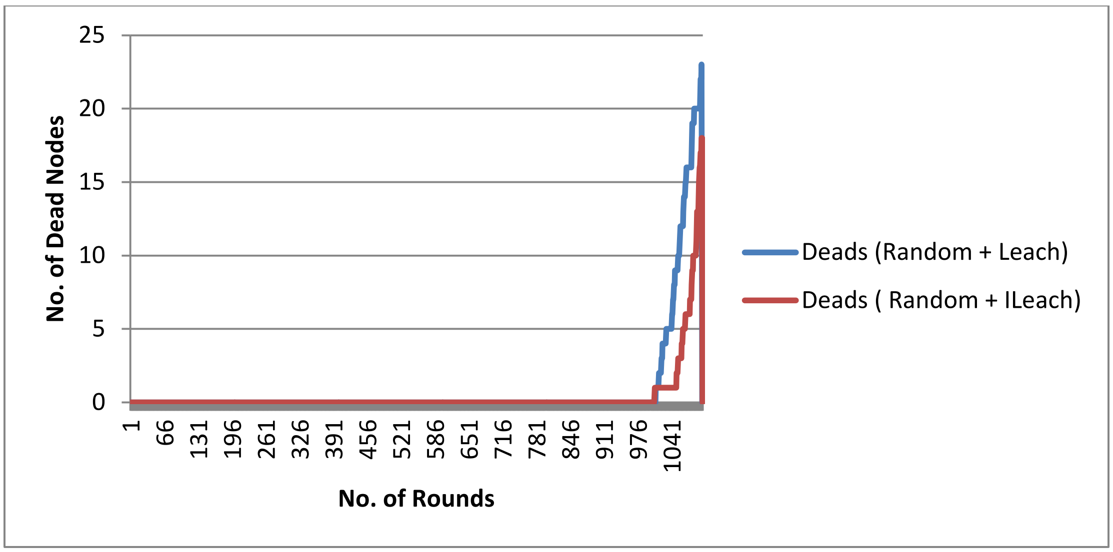


Fig 6.6: No. of Dead Nodes Vs Time (in no. of rounds)

The simulation is performed by applying both the routing algorithms LEACH and ILEACH on the optimal locations generated by modified Genetic Algorithm method. The results are shown in Fig 6.7 and the effectiveness of ILEACH protocol over LEACH protocol is analyzed by comparing no. of dead nodes when the simulation is run for 1100 rounds. The no. of dead nodes calculated using ILEACH protocols are lesser than the no. of dead nodes calculated using LEACH protocol.

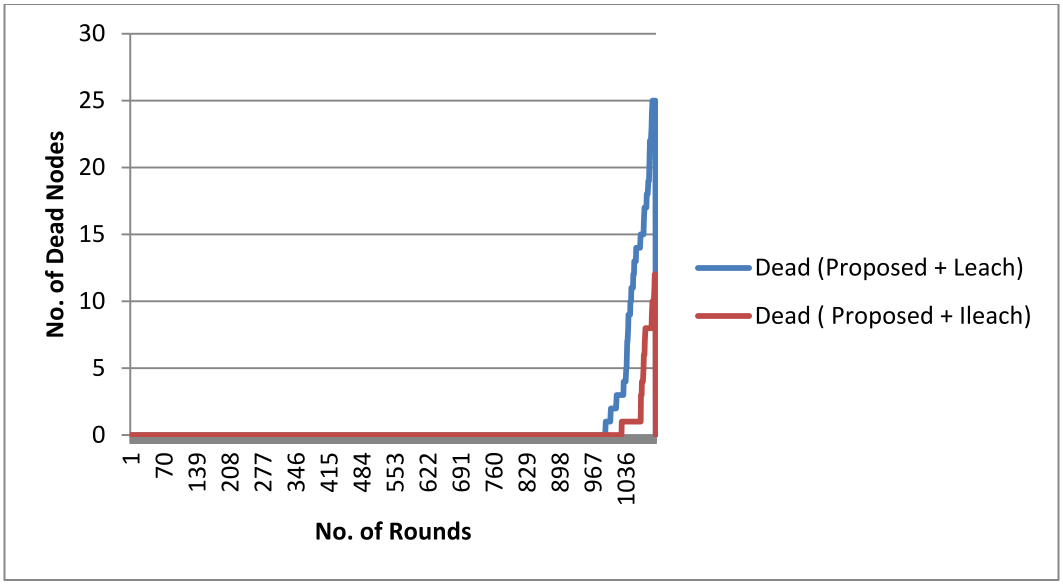


Fig 6.7: No. of Dead Nodes Vs Time (in no. of rounds)

The simulation is performed by applying ILEACH routing algorithm on the optimal locations generated by modified Genetic Algorithm method and the random locations generated by random deployment method.

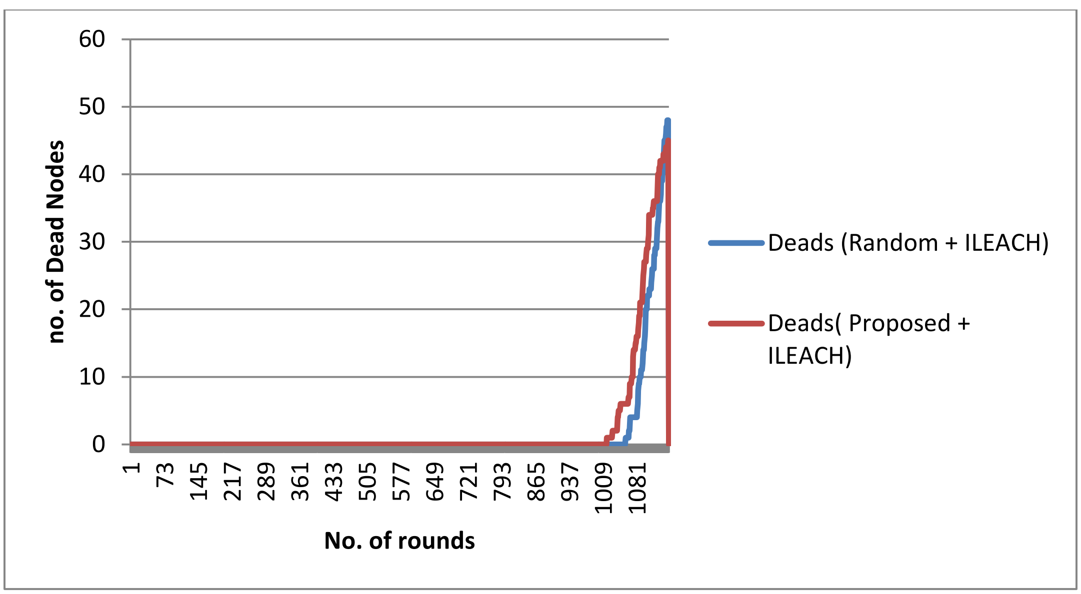


Fig 6.8: No. of Dead Nodes Vs Time (in no. of rounds)

The results are shown in Fig 6.8 and the effectiveness of optimal locations find out by modified GA method over locations find out by randomly is analyzed by comparing no. of dead nodes when the simulation is run for 1100 rounds. The dead nodes calculated using modified GA and ILEACH algorithm is lesser than the random deployment and ILEACH algorithm.

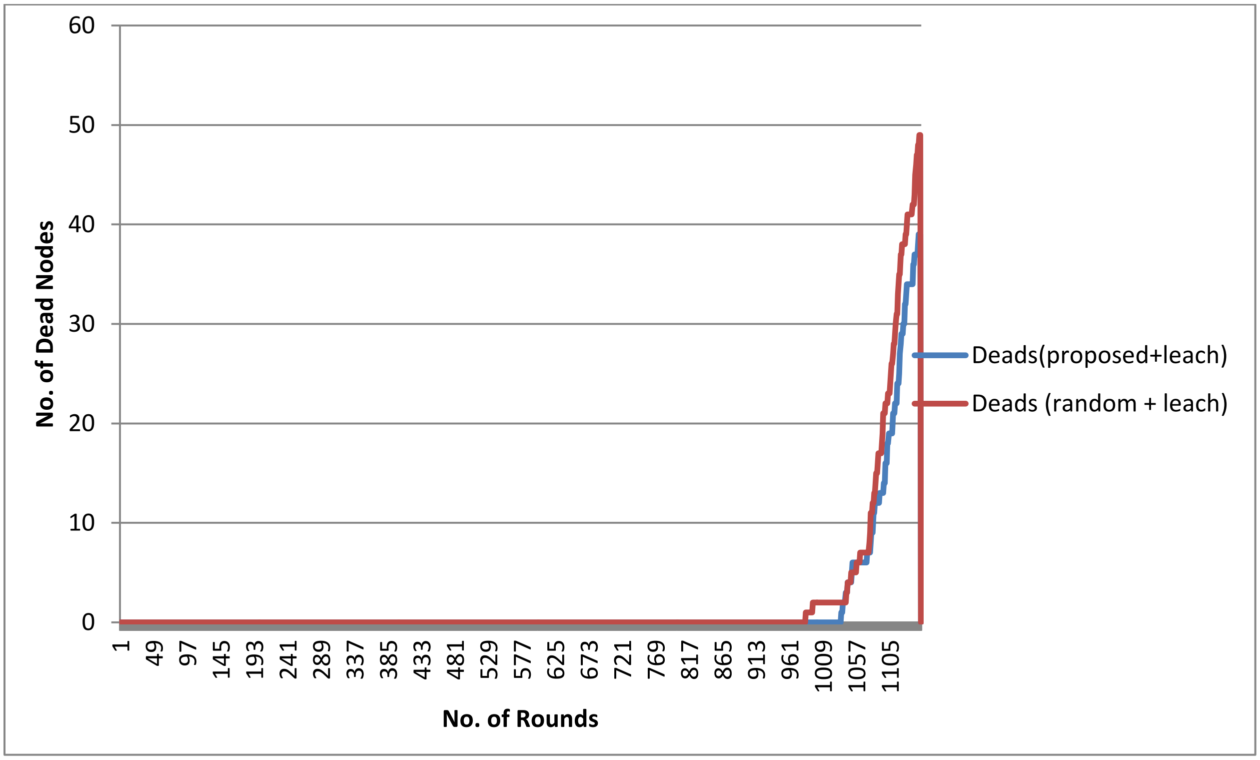


Fig 6.9: No. of Dead Nodes Vs Time (in no. of rounds)

The simulation is performed by applying LEACH routing algorithm on the optimal locations generated by modified Genetic Algorithm method and the random locations generated by random deployment method. The results are shown in Fig 6.9 and the effectiveness of optimal locations find out by modified GA method over locations find out by randomly is analyzed by comparing no. of dead nodes when the simulation is run for 1150 rounds. The dead nodes calculated using modified GA and LEACH algorithm is lesser than the random deployment and LEACH algorithm.

The simulation is performed by applying LEACH routing algorithms on random locations generated by random deployment method and ILEACH on the optimal locations generated by modified Genetic Algorithm method. The results are shown in Fig 6.10 and the effectiveness of ILEACH and proposed model over LEACH and random deployment model is analyzed by comparing no. of dead nodes when the simulation is run for 1100 rounds. The no. of dead nodes calculated using ILEACH protocols and modified GA method are lesser than the no. of dead nodes calculated using LEACH protocol and random deployment method

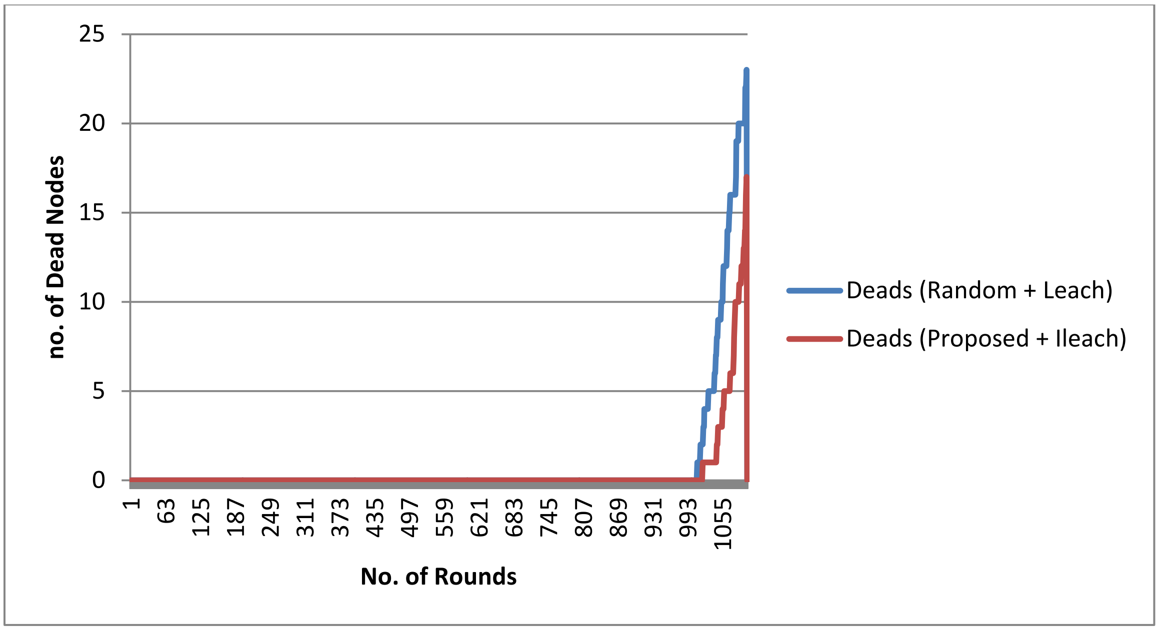


Fig 6.10: No. of Dead Nodes Vs Time (in no. of rounds)

The comparison is analyzed by getting the results of LEACH algorithm and ILEACH algorithm. The factor on the basis of which the results are compared is first dead node, no. of dead nodes per round, energy efficiency.

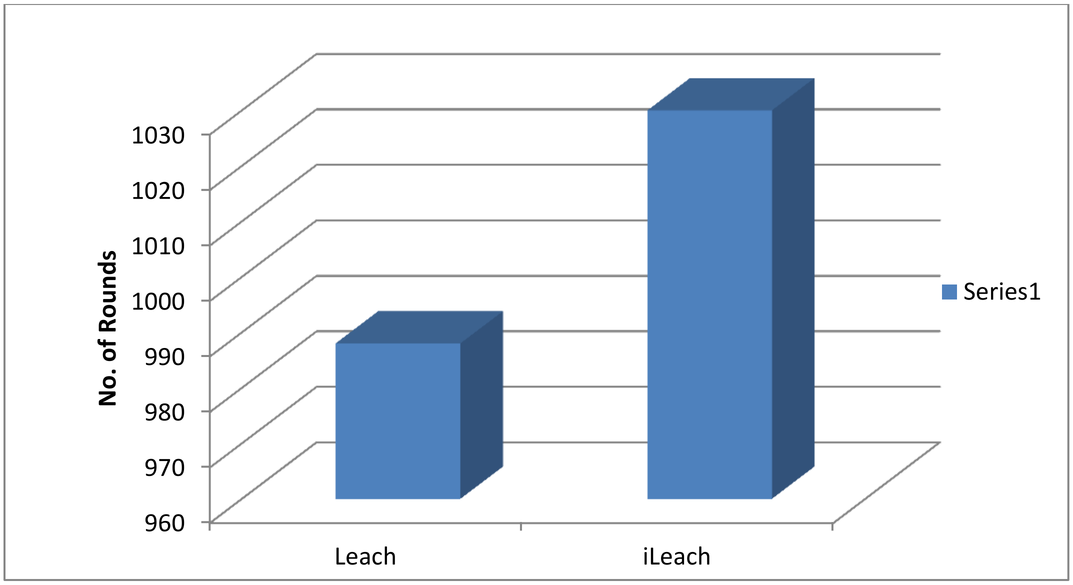


Fig 6.11: First dead node Vs Time (No. of Rounds)

The result in Fig 6.11 shows that first dead node came at 998 round using LEACH algorithm and first dead node came at 1030 round. This is the effectiveness of using Intelligent LEACH protocol.

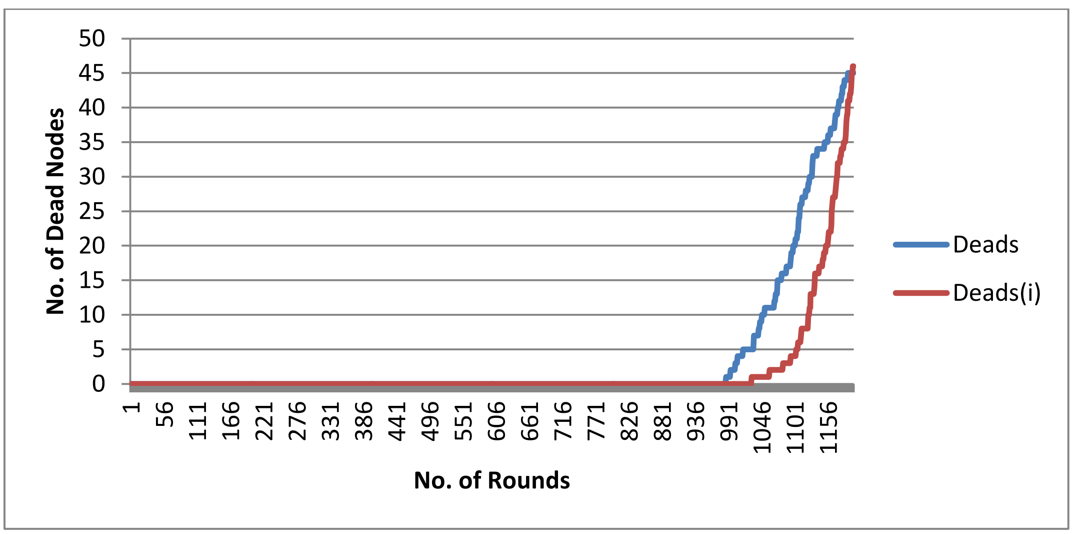


Fig 6.12: No. of Dead Nodes Vs Time (in no. of rounds)

The result in Fig 6.12 shows the effectiveness of ILEACH protocol over LEACH protocol with respective of no. of dead nodes.

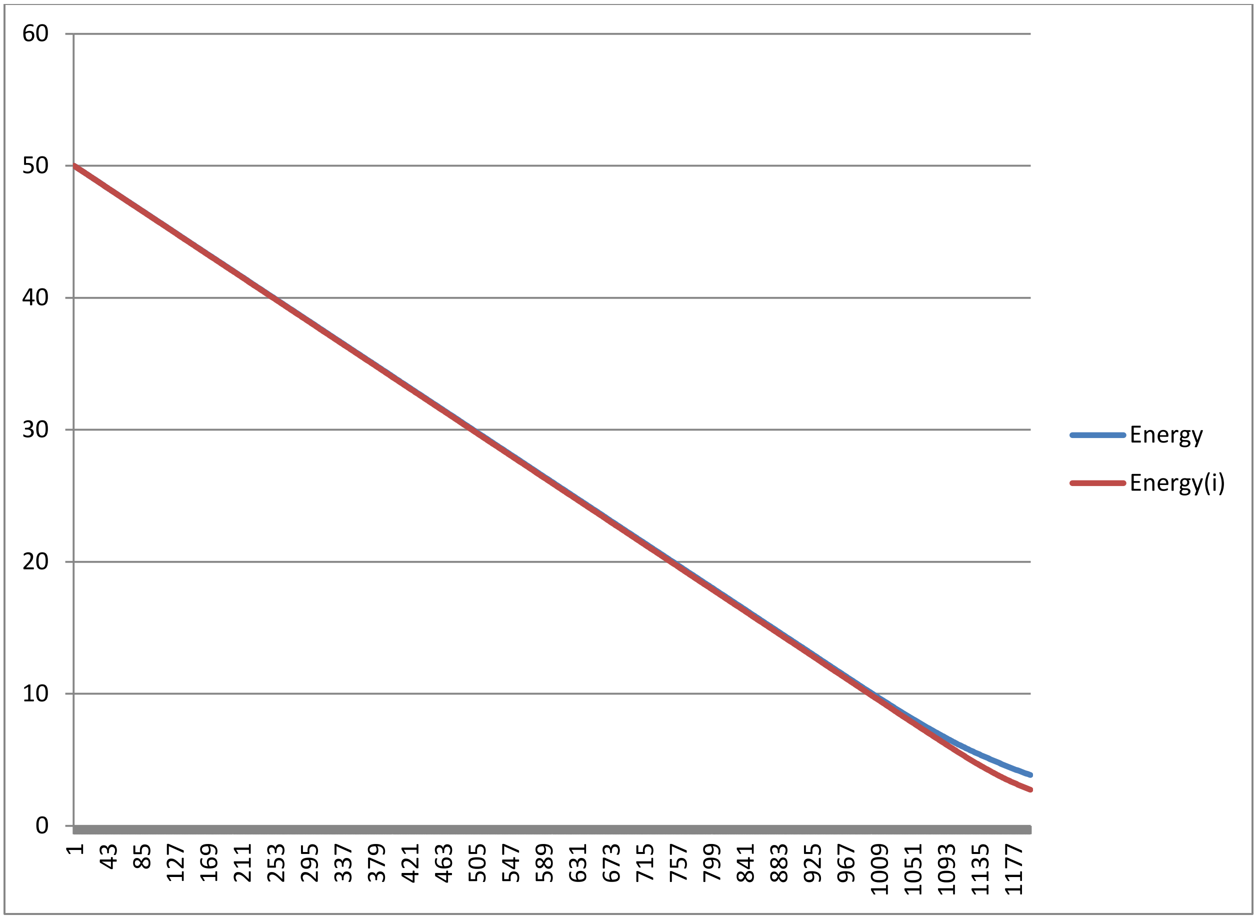


Fig 6.13: Energy Consumption Vs Time (in no. of rounds)

The result in Fig 6.13 shows the effectiveness of ILEACH protocol over LEACH protocol with respective of no. of dead nodes.

# CHAPTER-7

# CONCLUSION AND FUTURE SCOPE

Recent developments in wireless communications have enabled the development of low-cost, low-power WSNs with wide applicability. Minimizing energy consumption and hence prolonging the network lifetime are key requirements in the design of optimum sensor networking protocols and algorithms. Node clustering is a useful energy-efficient approach to reduce the communication overhead and exploit data aggregation in sensor networks. The classification of the different clustering approaches according to the energy conservative criteria is done, and further the results are observed using LEACH and ILEACH routing protocols. Also, two types of deployments of sensor nodes possible for the wireless sensor networks i.e. Random and modified GA-based deployment are discussed. We evaluated the total energy consumption for both the cases. The results have been observed and compared by calculating the energy required for data transmission by modified GA-based proposed model and when the nodes in the sensor network are deployed randomly. By selecting optimal deployment strategy with intelligent routing, the average energy consumption of the WSN is reduced and the WSN lifetime is extended as compared to other algorithm.

Although the performance of the presented protocols is promising in terms of energy efficiency, further research is needed to address issues such as the consideration of node mobility and cost effectiveness. There might be situations such as battle environments where the BS and possibly the sensors need to be mobile. In such cases, frequent update of the position of the command node and sensor nodes and propagation of that information through the network may excessively drain the energy of nodes. New routing algorithms are needed in order to handle the overhead of mobility and topology changes in such an energy-constrained environment Another interesting issue for routing protocols is the integration of WSNs with wired networks. More specifically, most of the applications in environmental monitoring require the data, gathered from the sensor nodes, to be transmitted to a server, so that further analysis can be done. On the other hand, the requests from the user's side should be made to the BS through Internet. Since the energy-efficiency routing requirements of each environment are quite different, further research is needed to face this kind of situations.

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