

OPTIMIZING SUPER CLUSTER HEAD SELECTION IN LEACH USING TYPE-2 FUZZY LOGIC

*Thesis submitted in partial fulfillment of the requirements for the award
of degree of*

**Master of Engineering
in
Computer Science and Engineering**

Submitted By
**Japman Kaur Dhaliwal
(801632012)**

Under the supervision of:
Dr. Sharad Saxena
Associate Professor



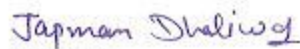
**COMPUTER SCIENCE AND ENGINEERING DEPARTMENT
THAPAR INSTITUTE OF ENGINEERING AND
TECHNOLOGY
PATIALA – 147004**

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "*Optimizing Super Cluster Head Selection in LEACH using Type-2 Fuzzy Logic*", in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Computer Science and Engineering* submitted in Computer Science and Engineering Department of Thapar Institute of Engineering and Technology, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Sharad Saxena* and refers other researcher's work which are duly listed in the reference section.

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(Dr. Sharad Saxena)
Associate Professor,
CSED, TIET, Patiala

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ABSTRACT

With the advancements in technology, the communication networks have also shifted to wireless networks from wired networks. Wireless Sensor Networks (WSNs) is a wireless network that is growing manifold. It is a widely accepted wireless mean of communication of the current generation. WSNs have been proved to be cost effective networks as they save energy and indirectly reduce the maintenance cost, and hence enhances the lifetime of the network. In order to make an energy efficient network, numerous routing protocols have been proposed. But out of these, clustering approaches have gained significant interest, due to their efficient selection process of the cluster head (CH) and aggregation of data. LEACH is the foremost clustering approach and has proven to be quite effective as compared to other protocols. Clustering approaches are known for balancing various key factors that affect the overall operation of WSNs. Clustering guarantees increased stability, less load as all nodes send data to the CH instead of direct communication to Base Station (BS), is more robust in nature as it can cope up to various network changes and ensures load balancing which prolongs the network lifetime. In this work, an energy efficient Super Cluster Head (SCH) selection approach by enhancing the traditional LEACH protocol is proposed. The approach has considered the distance between the SCH and BS along with remaining battery and centrality. The Type-2 Fuzzy inference system is applied for optimizing the SCH selection. The results prove that the proposed LEACH – Type-2 Fuzzy approach is proficient than the traditional LEACH - Fuzzy approach in terms of network lifetime, number of dead nodes and alive nodes.

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
BS	Base Station
CH	Cluster Head
CHEF	Cluster Head Election mechanism using Fuzzy Logic
CSMA	Carrier-Sense Multiple Access
EEFL-CH	Energy-Efficient Fuzzy Logic Cluster Head
FIS	Fuzzy Inference System
FL	Fuzzy Logic
FL-TEEN	Fuzzy Logic - Threshold sensitive Energy Efficient sensor Network
F-MCHEL	Fuzzy based Master Cluster Head Election LEACH
FND	First Node Dead
GPS	Global Positioning System
HEED	Hybrid Energy-Efficient Distributed clustering
HND	Half Node Dead
LEACH	Low-Energy Adaptive Clustering Hierarchy
LEACH-C	Low-Energy Adaptive Clustering Hierarchy - Centralized
LEACH-ERE	Low-Energy Adaptive Clustering Hierarchy - Expected Residual Energy
LEACH-FL	Low-Energy Adaptive Clustering Hierarchy – Fuzzy Logic
LND	Last Node Dead
MN	Member Node
PEGASIS	Power Efficient Gathering in Sensor Information System
PSO	Particle Swarm Optimization
QoS	Quality of Service
RBP	Remaining Battery Power
RSSI	Received Signal Strength Indicator
SCH	Super Cluster Head
SN	Sensor Node
TDMA	Time-Division Multiple Access
TEEN	Threshold sensitive Energy Efficient sensor Network
WSN	Wireless Sensor Network

CHAPTER 1

Introduction

1.1 Wireless Sensor Networks

A Wireless sensor network (WSN) refers to a group of spatially distributed self-governing sensors that are used for monitoring purposes of physical and environmental conditions and organize the collected information at a central gateway known as Base Station (BS). WSN is comprised of sensor nodes that range from a few to thousands in number and all the nodes are interlinked with each other. With the help of various communication channels the central gateway forms the connection with the whole world.

WSNs were initially developed for defense field applications in order to track the activities of enemy from a remote area. But now, WSNs have found wide applications in different domains of the world such as agricultural applications, motion sensors, optical sensors, biometric sensors, machine surveillance, habitat monitoring, underwater monitoring etc., where it is not viable for human to reach in order to monitor the area due to various topographical, physical and political constraints. Wireless sensor networks come under the category of Ad-Hoc networks. Due to the small size of nodes, the amount of energy stored in the nodes is limited. Therefore, these networks undergo energy limitation.

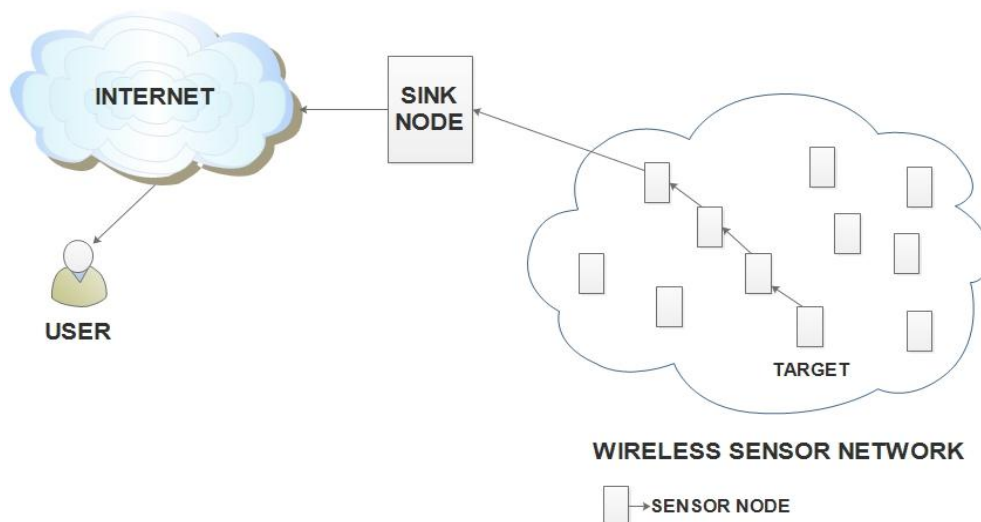


Figure 1: Wireless Sensor Network

Figure 1, depicts that the information is accumulated from various nodes and transmitted to BS where the information is further processed and examined.

Hence, the WSNs may be described as a network that is comprised of geographically distributed nodes that monitor both physical and environmental conditions such as temperature, noise, pressure etc. and after gathering the information it is transmitted to the BS and then towards the location of users.

1.2 Components of WSNs

Wireless sensor networks are comprised of various components such as sensor nodes and base station. A node has several parts such as a radio transceiver, microcontroller, external memory, power source and typically one or more sensors [42] as depicted in Figure 2.

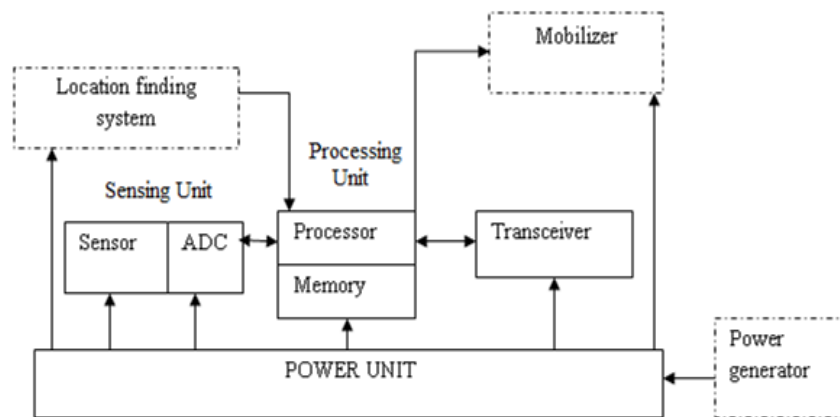


Figure 2: Schematic diagram of a sensor node

Sensor Node: Usually the sensor nodes are comprised of various sensors and processing devices. The sensor may be described as a device that can sense information of the surrounding parameters and further transmits the information to the users. Sensor usually measures the variations in the parameters of surrounding environment like humidity, temperature, etc. and it also measure variation in health parameters of a person like heartbeat, blood pressure etc.

Base Station: Various WSNs are interlinked with the base station. Base station consists of various devices like microprocessor, antenna, radio board and USB interface board. To form the connection with the sensor nodes, the base station unit is already programmed with the low powered software implemented over the mesh topology. Each and every node in the WSN handover the information gathered by it to the BS. Therefore, it is mandatory to implement the base station in WSNs. Moreover, this data is processed and examined at BS for making the decision. While implementing the BS in WSN, various parameters need to be considered which are: coverage of sensor nodes, energy conservation and reliability of network. Usually the base stations are considered non-varying in nature but in some cases they are considered dynamic to gather the information from sensor nodes.

Controller: It is responsible for performing tasks, information processing and controlling the functionality of the present elements in the node. It possesses important features such as lower energy consumption, low cost, ease of use and programming and is flexible enough to connect to various devices.

Transceiver: It cumulates the functions of a transmitter and receiver thereby named as transceiver. New generation transceivers have built in modes to switch between transmitting and idle mode according to the application requirements.

External Memory: Memory requirements are application specific and are a part of the processing unit.

Power Source: Data communication takes up most of the energy in WSN. Power source can be batteries that are either rechargeable or non-rechargeable. They act as the main source of power as nodes are deployed in somewhat inaccessible locations and changing the battery frequently can be expensive and inconvenient.

1.3 WSN Design Constraints

WSNs are usually different from other wireless networks due to its small size and restricted amount of power supply. In case if there are other wireless communication networks with same principles such as power, size and cost even then the operation is different. Wireless networks vary significantly and the main features that can affect the operation and design of WSNs are:

Deployment: Usually depends on the type of sensors utilized in the network and also on the type of application the implementation technique is used for.

Localization: To determine the appropriate location of sensor nodes, the localization technique is implemented.

Scalability: It represents the capability of the network to extend without increasing the overhead.

Reliability: It represents the efficiency of a network to transmit the authentic information while there is continuous variation in the design of the network.

Responsiveness: It may be described as capability of the network to rapidly adjust itself in accordance with the variation in topology.

Mobility: The technique used to control the mobile nodes and non-stable data paths is known as mobility.

Quality of service implementation: QoS need to be implemented in the network to ensure the timely delivery of data. In various fields, the information should be transmitted within fixed period of time; if it is delayed then it will be of no use.

Security: It ensures that both verification & encoding should be feasible.

1.4 Characteristics of WSNs

Due to various parameters like energy, storage unit and computing power, the WSNs face various limitations. Therefore, it is necessary to design an optimum network so that the network can perform effective operations. Various important attributes of WSN are:

- Least amount of power consumption
- Capability to handle node failures
- Heterogeneity of nodes
- Nodes' Mobility
- Breakdown while transmission of data
- Scalability in large scale implementation of network
- Should operate even in non-favorable environmental conditions.

WSNs are usually comprised of various sensor nodes so as to sense the physical parameters of the surrounding. Recently, the WSNs have been widely used in industrial as well as consumer application areas so as to examine the industrial process, health monitoring etc [2]. In the last few years, due to large amount of implementation of WSNs, there is the necessity to develop the protocols for WSNs that are energy efficient, scalable and can efficiently collect the data from the surroundings. To achieve this, it is necessary to form clusters in the WSNs. All the clusters thus formed in WSNs have a cluster head (CH) and execute special operations like fusion of data and its aggregation and other nodes in the cluster are known as member nodes. Thus, the two-level hierarchical design will be acquired by implementing the cluster formation technique. Here, the cluster head node lies in higher level in hierarchical structure and the various member nodes form the lower level.

1.5 Challenges in Wireless Sensor Networks

The nodes in WSNs have restricted amount of storage unit, restricted bandwidth for communication and have power constraints. This will produce new and distinctive problems in managing and processing the data efficiently. In WSNs, various information processing techniques are used like integration of data, multicast and broadcast. To examine the operation of a WSN, network lifespan is a widely considered parameter. Lifespan of any network can be evaluated by the remaining energy of the system. Therefore the biggest challenge faced by WSNs is optimum utilization of energy [46]. Various researches have been conducted to use the energy in an optimum way by the WSNs like: Energy conservation technique, Power conservation method etc. Some significant techniques to overcome these challenges are: Energy aware routing and Hierarchical routing scheme. Major objective behind energy aware routing is to determine the optimum routes in the wireless sensor networks. Various challenges that are faced while implementing the routing technique in WSNs are energy consumption in such a way that accuracy of the network should not be affected keeping in mind the node implementation, link heterogeneity, scalability, varying transmission media, connectivity, coverage, summation of gathered information and Quality of Services. Main objective of hierarchical routing scheme is to make use of the energy of nodes in an optimum way by implementing

the multi-hop transmission technique inside a specific cluster. The creation of cluster depends on the amount of energy stored in the sensors and distance of sensors from the CH. To save the energy in wireless sensor networks, clustering can be an optimum technique. In addition to this, Clustering also helps in improving the lifespan and scalability of the network. In each cluster only one CH is required to choose the optimum path in the network in order to transmit the information to the BS. In very dense networks, clustering technique is effective as it is simpler to coordinate a group of CHs in each cluster rather than controlling all the nodes in the WSNs. The nodes in the network have limited computational ability. The main cause for depletion of energy stored in energy sensors is due to transmission of data from member nodes to the BS.

1.6 Clustering in WSNS

Clustering is the process of grouping of nodes into clusters and selecting a coordinator called cluster head as illustrated in Figure 3. CH selection process impacts the overall network lifetime [41]. The purpose of clustering is to achieve load balancing in nodes and network scalability. It helps in decreasing energy consumption by integrating data aggregation, facilitates reusability of resources and makes the network more stable. The clusters formed in WSNs contain various elements and can be of different types.

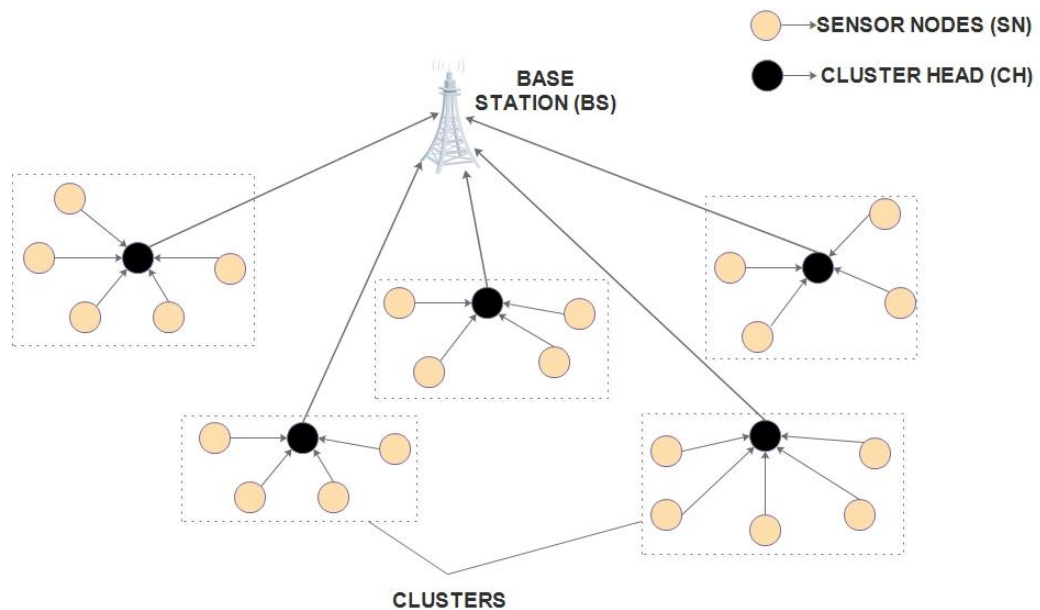


Figure 3: Structural framework of clustering in WSN

1.6.1 Elements of a Cluster

While operating with the clusters formed in WSNs, there are three main elements: first are sensor nodes (SNs), second is base station (BS) and third is a cluster head (CH). Sensor node may be described as a group of sensors present in the network, these are arranged in such a way that they can sense the surrounding parameters and can gather the required information [15]. Major operation of sensor node is to determine various events, execute rapid processing of data locally and after processing transmit the data to BS. But the major limitation is large power consumption that takes place while sensor observes the surrounding parameters and while transmitting the gathered information. The Base station in the cluster may be described as a point where data is processed which is received from various CHs and after processing it is transmitted to the end users. Usually the base stations are assumed to be static and located far away from sensor nodes. CH works as a mediator amid the nodes and BS in the network. It performs similar functions for each and every node in the cluster such as summation of gathered information before transmitting it to the base station, administration of cluster i.e. creation and maintenance and coordination with other CHs.

1.6.2 Cluster Types

There are various criteria in order to classify the clusters into different groups as illustrated in Figure 4.

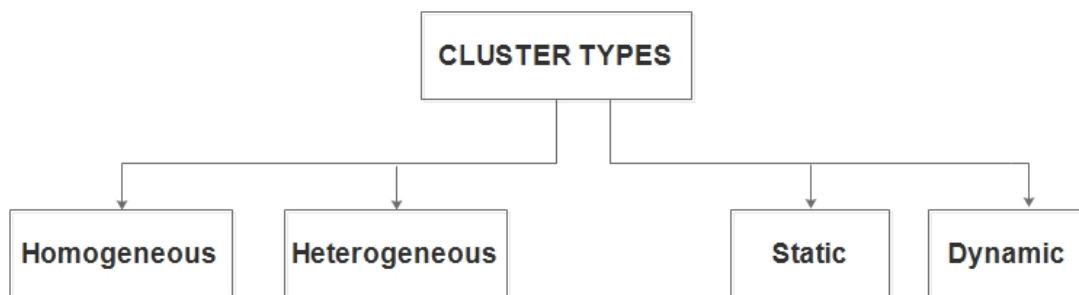


Figure 4: Classification of cluster types

Two broad classifications are given and according to the first classification, the clusters are classified into two groups: homogeneous and heterogeneous clusters. On the basis of second type of classification, the clusters are grouped as static and dynamic clusters [12]. Heterogeneous clusters have different operations and functionality of the sensors. A heterogeneous network contains two types of sensors:

(a) sensors with complex equipments and having high processing abilities. It is usually implemented to form the backbone of wireless sensor networks. These sensors are referred to as CH nodes and hence these work as information collectors and processing units. These sensors collect the data from various other member nodes and (b) participating sensors, these sensors have low ability as compared to the other nodes which is used to sense the desired parameters from the surrounding. In case of homogeneous networks, each and every node in the cluster behaves in a similar manner, such that it can execute similar characteristics and processing abilities. The homogeneous sensors are usually implemented in the battle fields. Here, in this scenario all the sensor nodes can become the CH. In the cluster, role of CH is rotated after a fixed interval of time in order to balance the node, it ensures that the energy consumed by all the nodes in the cluster takes place in a uniform manner and can prevent the cluster from black hole problem. In order to obtain fixed clusters in the network, it is required that the nodes should be heterogeneous in nature and the clusters are formed around the nodes which are having large amount of energy.

In static clusters, features of all the clusters like its size, cluster head, member nodes in the cluster, coverage area of cluster are fixed. The static clusters can be easily implemented, but its use is suitable for limited amount of applications like in cases where the field of sensors is already determined, the targets are fixed and maintenance task can be easily performed like replacement of sensors in the network. The limitations associated with static clusters are that clusters are fixed and decided prior to implementation. So they cannot adjust to changing network architectures. Also as the CH is fixed for every round, it undergoes energy consumption constraint. To use the sensors in an efficient way, dynamic cluster architectures should be used. In dynamic clusters, the sensors can move from one cluster to another and also can support various clusters at different point of time. On receiving the special message the formation of cluster is activated. These special messages are transmitted after a certain interval of time. It can also be activated by occurrence of various events in the network. It is not always required to select the CH and therefore number of messages used while implementation of network reduces significantly. But it is required that the cluster head selection technique, cluster formation and maintenance techniques should exist in the network. Because of the reconfiguration ability of clusters in dynamic clustering, therefore this type of clustering technique can also be implemented to efficiently monitor the moving targets.

1.6.3 Clustering Process

While forming the cluster, it is important to consider the parameters like: size of cluster and the process used to choose the cluster head, technique to prevent inter-cluster and intra-cluster collisions and proper utilization of energy. An efficient clustering technique plays a crucial role in the proper functioning of WSNs. With the help of cluster-based protocols, three stages of cluster formation technique can be easily determined and these stages are: CH selection, cluster formation and packet transmission stage. There are various techniques that can be used to implement all the above mentioned stages.

Clustering process consists of various phases [29] that are depicted in Figure 5.

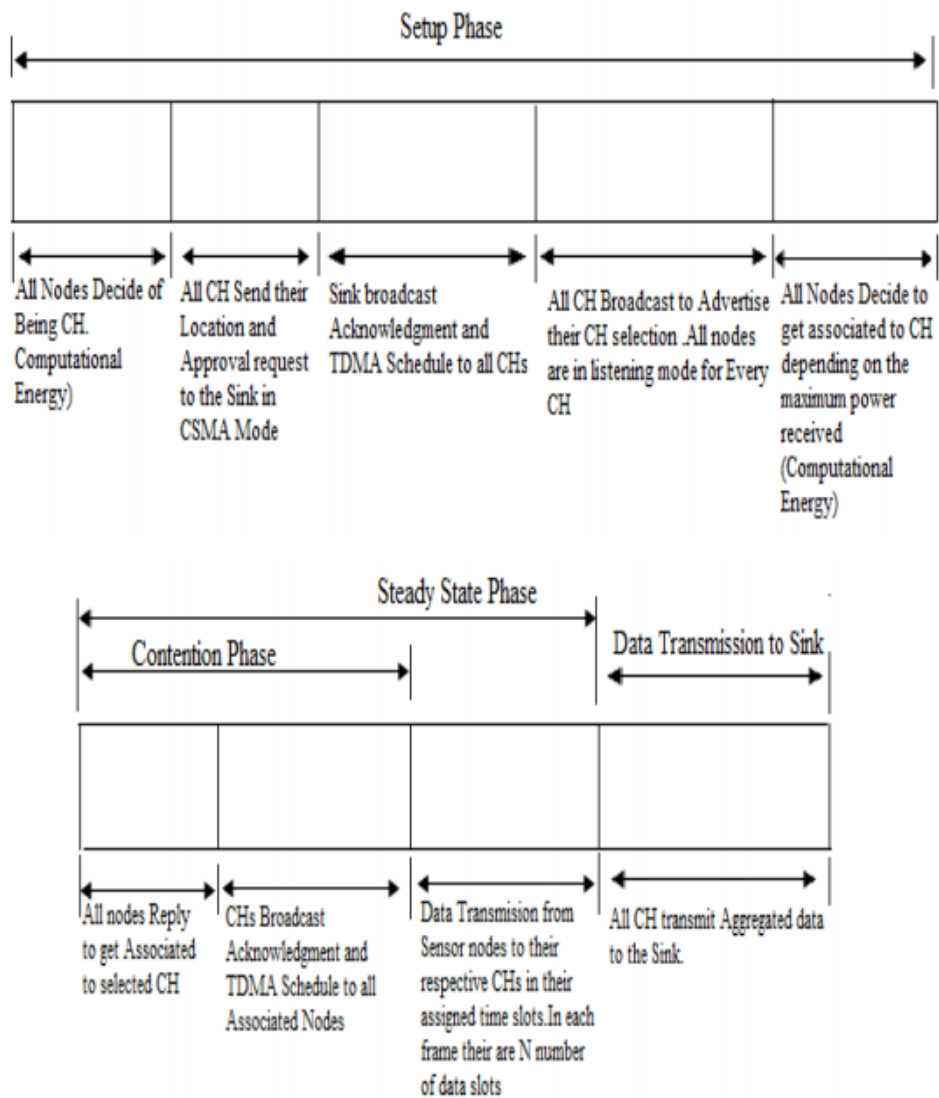


Figure 5: Phases of clustering

Cluster formation is the setup phase for creating cluster type architecture [5]. This phase is further divided into two parts: network model and CH selection. Network model describes various characteristics of the network and contains two parameters: node type and network type. Node type can be either a stationary or mobile. A stationary node does not change its position in accordance with other nodes while a mobile node can do so dynamically. Network type can be centralized or distributed. In centralized type network, BS or CH needs prior information about the whole network whereas in distributed type, nodes do not need knowledge about the network to become a CH. CH selection schemes can be Fuzzy based, Genetic based, ID based heuristic, weight based heuristic etc. Fuzzy based schemes have the ability to combine and evaluate different kinds of parameters in an efficient way [19]. It guarantees improved decision making, reduces resource utilization and improves performance through its effective network deployment, clustering and CH selection process. Operations of fuzzy logic include: determining the input and output, conversion of input values into fuzzy descriptors, selecting shape and boundaries of input and output membership functions, applying suitable if-then rules to the input and converting fuzzy variables to numerical values for obtaining the output. Genetic based (GA) clustering [32] involves maximizing network lifetime in terms of rounds. Clustering phases are the same but clusters are not reformed in every round. It contains static clusters and CH changes dynamically. Network representation is called chromosome and is done in the form of bits and each SN represents a bit. CH node is represented by 1 and other member nodes are represented by 0. In the initial phase, GA commences with a population and evaluates each chromosome by computing the fitness value. There exist certain fitness parameters such as cluster distance, round for first node dead etc. After the evaluation of fitness of the chromosomes, this algorithm selects the best fit chromosomes on the basis of a particular selection method and after that applies respective operators i.e. Crossover and Mutation. So these operations generate a new population which is better than the preceding one for the forthcoming generation. ID based heuristic schemes take ID of a node as a parameter for CH selection and weight based heuristic schemes consider parameters such as energy cost, communication cost, distance etc. for CH selection process.

When the clusters are formed in WSNs, then the communication between nodes to CH and CH to BS is of two types: either intra-cluster or inter-cluster [27]. In case of Intra-cluster communication, the packets are swapped among member nodes and cluster head. The information is transmitted out of the cluster on through the CH so that the collision can be avoided between sensors. It also helps in proper utilization of energy and also prevents the network from black hole problem. This also helps in decreasing the latency in data transmission. In inter-cluster communication, packets have to move from one cluster to another. In case the sensors are implemented with multi-hop transmission system then it will cover a larger distance.

1.6.4 Advantages of Clustering

To solve the previously encountered issues in the network, the cluster-based communication can prove to be very helpful. In cluster based communication model, only CH will help in summation of data so that the energy of member nodes will not be consumed extensively. It helps in reutilization of bandwidth. All the nodes in a cluster transmit the information gathered by them to the CH so that the energy can be utilized efficiently by avoiding the flooding of packets in the network, multiple routes for data transmission and route looping. As the clustering technique helps in enabling assigning of resources in an optimum way, thus it helps in varying the behavior of nodes in the cluster but not of the whole network.

In addition to various advantages, there are various disadvantages associated with clustering technique such as optimal selection of CH. Various paradigms helps in selection of cluster heads only in accordance to the ID number allocated to the node or remaining energy of the sensor [1]. As all the information accumulated by the sensors is transmitted to BS, therefore it can be said that the traffic nearby the BS is high. Hence, the nodes around the BS will discharge immediately. When the energy of surrounding nodes gets exhausted then the BS will remain isolated and therefore the remaining energy on other sensor nodes will not be of any use. Another disadvantage of clustering technique is that while determining the optimum route in the network, the energy is dissipated by flooding and redundant transmission of packets by using various numbers of routes.

1.7 Summary

This section presents an overview of WSNs, its components and the challenges faced while deploying this type of network. WSNs have varied characteristics and there are certain limitations and design constraints associated with it, which can be handled using various routing techniques. The process of clustering and its phases are discussed along with its types and major components. Various CH selection techniques based on Fuzzy Logic, Genetic based and ID, weight heuristics have been described. Clustering as a technique guarantees less energy consumption as the process of CH selection and the process of formation of clusters plays a crucial role in making the network energy efficient. So, in order to attain an energy efficient network, an appropriate clustering approach should be selected for CH selection and data transmission.

1.8 Organization of Thesis

Chapter 1, gives an overview of WSNs, its characteristics, barriers and issues and the process of clustering in detail. In Chapter 2, literature survey is given that describes the various clustering techniques and substantiates the problem. Chapter 3, includes the problem statement that describes the drawbacks in the conventional approaches. In Chapter 4, proposed energy efficient Super Cluster Head (SCH) selection approach based on LEACH and Type-2 Fuzzy Logic is given. Chapter 5, illustrates the results and discussions of the proposed solution in contrast with the traditional approach. In Chapter 6 conclusion is stated and the possible future prospective in this work is put forward.

CHAPTER 2

Literature Review

Clustering is a technique in WSN in which grouping of nodes is done to form a cluster and all the member nodes communicate the information gathered from the surroundings to a head node known as cluster head. This CH is solely responsible for communication with the BS such that energy saving of member nodes is ensured as they have a mediator in between for the communication with the BS. As most part of the energy is consumed at the transmission phase, clustering helps in reduction of the number of nodes that take part in it. It ensures scalability when large numbers of nodes are considered. It reduces the overall communication overhead for both single hop and multi hop transmission. Various clusters are formed and there are different techniques that can be used in WSNs to form the clusters and for the purpose of CH selection. These two techniques along with various other factors have significant effect on the overall network lifetime and energy efficiency. The clustering algorithms can be classified as Grid based approaches, Hierarchical approaches and Fuzzy Logic based approaches which have been studied and are illustrated in Figure 6.

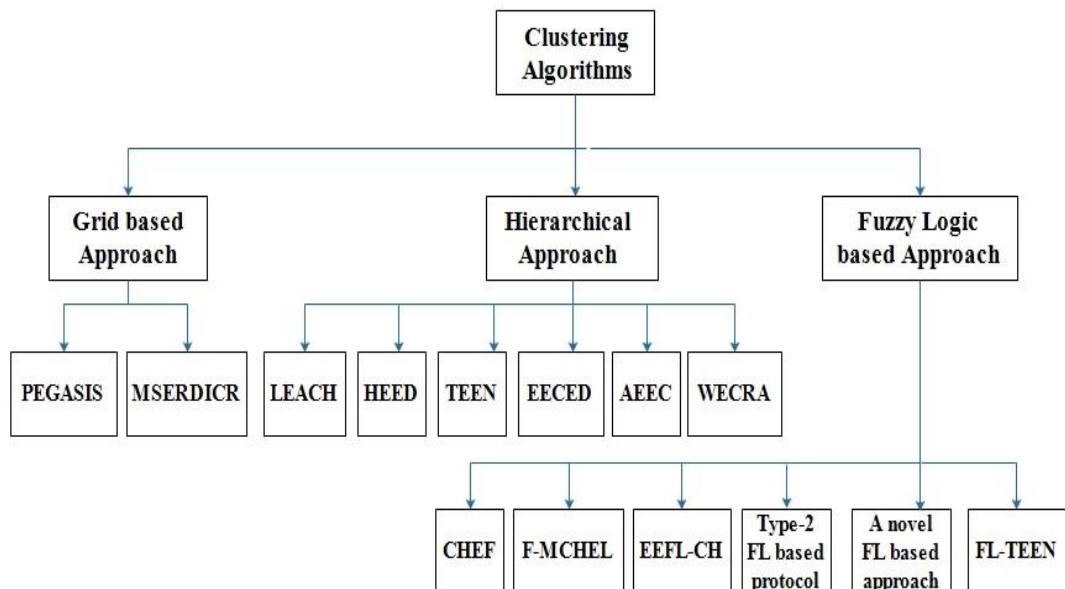


Figure 6: Various types of clustering protocols

2.1 Clustering Based on Grid Schemes

In grid based clustering, all clusters are equal in size and are in the form of square grids present in a 2-D plane. These clusters have a simple framework and overhead for routing is low as the all nodes in a single grid are considered equal. GPS techniques are incorporated with this and due to the square grids; synchronization between the nodes is easier. Grid size is determined based on a parameter called Manhattan Walk which involves presence of two nodes either in horizontal or vertical adjoining grids and they should be inside the range of transmission. After the successful formation of the grid and election of grid head (GH), nodes can communicate with their respective GH and further send information via the GH or through adjacent grids to the BS. Data transmission can be done directly rather than going through the hassle of route creation. This clustering method is beneficial for real time applications.

PEGASIS [34], is a power efficient gathering technique in sensor information systems and is introduced to resolve the issues related to gathering of information. These problems are faced by the ordinary techniques. In this technique, the transmission of data from the node to the BS takes place by transmission of gathered information to the nearest nodes and then it is finally processed to the BS. All the nodes in the sensor network contain equal load therefore it can be said that this technique implements uniform distribution of loads among various nodes. During the process of transmission of data, the nodes form a chain in the network hence the nodes are randomly placed. Base station is responsible for computation of the chain formed and after that the information is disseminated among sensors in the network. This protocol utilizes greedy paradigm to form the chain among the nodes. The chain is formed on the basis of knowledge contained by the sensor nodes. PEGASIS protocol is comparatively better than the conventional protocols such as LEACH. The PEGASIS technique can eliminate the overhead of network gained by forming the dynamic clusters. As in PEGASIS technique there is no need to form the dynamic clusters therefore the count of transmission is reduced in it. One more advantage associated with it is that this technique can also be implemented over the large scale networks because it requires only one transmission from the nodes to the BS in one round. This protocol executes fusion of data within the chain but it is not executed at the termination of the chain.

PEGASIS is based on some assumptions such as sensor nodes contain all the data about the network and are fixed in nature. Also each node contains the knowledge about the position of all the other nodes in the network. Various advantages of PEGASIS over the LEACH protocol are as follows:

- Creation of dynamic clusters is not required in the network.
- Reduces the difference between node acting as a cluster head and member nodes.
- Number of transmissions required in this technique is less.
- In one cycle only one transmission is required between the node and base station.

This protocol also encounters various obstacles that are faced by the LEACH protocol. One more drawback in PEGASIS technique is that it cannot be implemented in large scale WSNs because there are a large number of nodes involved and hence there is limited information about the nodes.

Rui Chen et al. [7], proposed a clustering based algorithm i.e. rule driven and event based mechanism. (MSERDICR) is a rule driven immune clustering technique that reduces the energy consumption in a network for unexpected events and also provides a solution regarding the problem of unbalanced distribution of energy consumption. MSERDICR algorithm, implemented a biological immune system based mechanism for the dynamic clustering algorithms. In this algorithm, network is split into a few virtual grids or clusters. After cluster formation, position of the sink node is adjusted by using the controlled mobile technique for remaining energy scanning known as e-scan. This approach can save the energy utilization to a maximum level. The three parameters such as the moving range of BS, minimum energy standard and grid size based on which the efficiency of this algorithm were studied by using several simulation environments. It is proved that MSERDICR had best performance level in case of moving range of the BS that is in one round, the side length of a cluster is 10, and minimum energy standard is around 65% of the average energy in the cluster when compared to the algorithms such as MSEERP, GAP and TDD.

2.2 Clustering based on Hierarchical schemes

When considering energy depletion as the main issue, other mechanisms might not be that feasible as compared to hierarchical mechanisms. Energy depletion due to collection and distribution of data is minimized by this scheme. Nodes are organized into clusters and a head node (CH) is selected depending on the remaining energy of nodes. The main role of CH is to accumulate the information from neighboring nodes and forward it to the BS and thus overcome energy constraints for the transmission of data.

LEACH [43], is a low energy adaptive type clustering hierarchy protocol which distributes the load of energy uniformly between all the nodes in the network. It is an adaptive technique and can automatically organize itself in the network. If for the entire system lifetime, cluster head is fixed, then it can be commonly seen that cluster head would die quickly because of selection of some unlucky sensors and this will lead to halt of the useful lifetime of other nodes in those clusters.

The communication of data in LEACH paradigm exists between the sensor node and CH. CH receives the information from member nodes in the cluster and then further transmits it to the sink node. After forming the cluster, it is required to choose the CH on the basis of a probabilistic equation. All the nodes in the cluster have possibility to become the CH. When the CH is selected then the next stage will execute in which the gathered information is transmitted to the BS and this stage is also known as steady state. With the help of second stage the maximum overhead of the whole network will reduce. The data transmission to the BS takes place by using the TDMA technique that depends upon the CH and also on the number of member nodes.

LEACH protocol has tendency to organize itself automatically and also it is adaptive in nature. With the help of LEACH protocol the cluster heads are rotated within the cluster so that the energy will be uniformly distributed within the cluster. Two assumptions are made before implementing the LEACH protocol that are:

1. BS is located at a far away distance from the nodes and also the position of BS is static.
2. All the nodes present in the network are similar and have limited amount of energy storage unit.

The cluster in LEACH protocol is formed on the basis of strength of the signals. After completion of cluster formation process the signals are transmitted to the BS by the CH. Various features of LEACH protocol are:

- Helps in creation of localized cluster and also maintains the operation of that cluster.
- The cluster heads formed in the cluster are not static, they rotate dynamically.
- Overall communication will be reduced by compression.

The LEACH protocol executes only for a fixed period of time and each execution is comprised of two stages. Here the first stage is known as setup stage whereas the second stage is named as steady phase. The execution time of the two stages is already defined.

The limitations of LEACH protocol are:

- Due to the large time requirement for the execution of LEACH technique, therefore this is unsuitable for time bound applications.
- The sensor nodes that come across the path of hot spot will lose their energy immediately and this is known as Hot spot problem.
- For different stages the count of cluster varies.
- In large scale networks where various numbers of nodes are used, this protocol cannot be implemented.

In WSNs, the LEACH protocol can be easily implemented and has shown good results. This technique can be used for both networks either containing static node or dynamic node. Due to various advantages associated with the LEACH protocol such as minimum control signal required, reutilization of bandwidth, low consumption of power, etc. it is optimum for automatic WSNs in which movable sensor nodes are implemented.

TEEN [3] is an improved form of LEACH and it is introduced for temperature sensing networks and follows a data centric approach. It is suitable for environments where monitoring of sudden changes needs to be done. Two threshold values for the process of filtering data collection are used called hard threshold and soft threshold. During the clustering phase, these values are broadcasted. If sensed data of nodes is more than hard threshold value, the node saves this data and transmits it based on its own time slot. The soft threshold value comes handy to prevent failure that might be caused during data collection. Major disadvantages of TEEN protocol are: it cannot

be deployed over the large scale network containing large number of nodes where large proportion of energy is consumed, and the clusters formed by this protocol are unbalanced in nature. Reason behind the unbalanced cluster formed is that the CHs are randomly selected. By implementing TEEN protocol there is no significant increment in the lifespan of the WSNs as the CHs are not selected on the basis of residual energy of nodes.

In HEED [23] the CH selection is done on the basis of remaining energy on the sensor nodes. In case, if two sensor nodes have same amount of remaining energy then another parameter that is distance is taken into consideration. This protocol can be implemented on homogeneous nodes only. The homogeneous nodes may be described as the sensor nodes containing same amount of energy. Main reasons for implementing the HEED protocol are:

- To improve the lifespan of the network by distributing the amount of energy utilization of nodes.
- To execute the clustering process again and again for fixed time intervals.
- Selection of CH in an optimum way.
- To reduce the controlling overhead in the network.

Otgonchimeg Buyanjargal et al. [22] described that Wireless sensors networks are used in many areas like environmental surveillance, health monitoring, intelligent transportations, etc. The WSN contains many small wireless devices which have a limited amount of energy and memory and these small, autonomous devices are used to sense the data in its surroundings. It uses many energy efficient algorithms so that every part of the network can work efficiently since it is one of the most challenging issues related to the WSN. To overcome this problem or drawback, many researchers have developed the Energy Efficient cluster based protocols like LEACH, DEEC etc. but not much focus was on event driven WSN protocols since their main consideration is on continuous networks. The modified version of LEACH for Event-Driven Wireless Sensor Networks, an efficient clustering algorithm is proposed (EECED). The main objective is to extend the lifetime of the network and to distribute energy equally on each node. In EECED, the node with more remaining energy is a preferable candidate node for CH. In this the Elector node is also used for selecting CH, the role of elector node is to gather the data energy of nearest nodes.

Simulation is used for performance comparison analysis of EECED algorithm with the existing LEACH protocol.

Otgonchimeg Buyanjargal et al. [21] depicted that the WSN is a network which is comprised of small terminal nodes which are not too costly and are also easy to deploy. These terminal nodes are utilized to send the data from source node to destination nodes successively. The difference among wired or wireless network is that the wireless sensor networks are more sensitive towards consumption of energy. It has been stated in this work that the energy is one of the key factor that needs to be considered while designing a network. This field has gained a lot of attention and the author in this paper had proposed an algorithm that is a modification to conventional LEACH protocol. LEACH is one of the effective protocols designed in WSNs. The protocol that is proposed by the author is called “Adaptive and Energy Efficient Clustering Algorithm for Event-Driven Application in Wireless Sensor Networks (AEEC)”, and it improved efficiency by creating balance between the energy consumption of nodes. The residual energy of the nodes is considered for the selection of CH. An electro node is employed in the network that is responsible for gathering information about the energy value of the nearest located node and also helped in the selection of cluster head. The proposed protocol and the conventional LEACH protocol have been compared by analyzing the results obtained.

S. Taruna et al. [39] stated that, in today’s era a number of advanced researches are performed in WSNs as it has become a field of interest for scientists. A WSN is divided into small clusters which consist of sensors, these sensors collect the data by sensing the surrounding environment and send the data to the BS. The important point is that the sensor’s lifetime is dependent on the energy consumed by them. The major fact that the sensor nodes die in the network as energy gets exhausted quickly due to the size limitation of the nodes poses to be a constraint and a variety of energy efficient mechanisms have been designed for solving this issue and to preserve the network lifetime. An Event Driven Hierarchical clustering technique has been defined to cater to the problem of energy consumption. In an event driven energy protocol, whenever an event ID is detected by the sensors then data related to that event is passed on to the cluster which has higher remaining energy power and which is near to the sink node. In Simulation it is observed that event driven routing protocols enhance the lifetime of the network as compared to other protocols.

Ping Yang et al. [28] described the special networks that are event-driven WSNs. These are those networks in which only the nodes that are driven by any event participate in the network communication. The information to the sink node is processed through these event driven nodes. The author pointed out the problem of battery power recharging and replacing in the case of these wireless networks for effective communication and transmission of data along with the increased lifetime of the network. A protocol has been designed that chooses the CH on the basis of weight values of the event driven nodes. Along with the weight values, the excited intensity, the residual energy and the distance amid the nodes is also considered while deciding the cluster head of each cluster. The increased efficiency of the network is proved by comparing the proposed mechanism (WECRA) with the conventional TEEN protocol. Ezmerina Kotobelli et al. [9] stated that, in today's world, WSNs are used in many fields so as to gather the data from its surroundings. The author studied the issues on energy efficiency in WSN. The proposed work called modified LEACH provided a novel approach for clustering where the cluster heads are considered static so as to increase the energy consumption criteria of the nodes. Comparison of the work is done by using LEACH protocol and it is proved that the proposed work is easy to understand and implement in comparison to the LEACH protocol.

R. Rajeshwari et al. [30] stated that sensor networks are combination of many sensor nodes. These nodes sense the data from its surroundings and send that collected data to the base stations in the form of data packets. As lifetime of a node is based on the energy of battery, so it is mandatory to utilize the energy consumption by these nodes effectively. To reduce the battery consumption, it is mandatory to reduce the traffic on each and every node along with the minimized number of transmissions of data to the BS. By using clustering approach scalability, reduced energy utilization and improved performance of network can be obtained. CHs create the aggregated form of data gathered by sensors locally. This technique reduces the size of the data by compressing it and this compressed data is forwarded to the base station.

Summary of various hierarchal clustering techniques is presented in Table 1.

Table 1: Literature Review of Hierarchal based clustering techniques in WSNs

Year/Author	Title	CH selection approach	Research Findings
2015 Rajeshwari et al.	Towards Energy Efficient Cluster Based Approach In Wireless Sensor Networks Using Mobile Sink	Hierarchal clustering, CH selection based on probability and weight heuristics	<ol style="list-style-type: none"> 1. Static network is taken into consideration. 2. Three types of nodes are included namely normal, advance and super nodes. 3. Data compression technique is applied in order to reduce the volume of data transmitted. 4. For data compression, nodes need to have large storage and high computational power.
2015 Kotobelli et al.	A Modified Clustering Algorithm in WSN	CH selection based on LEACH	<ol style="list-style-type: none"> 1. CH chosen with same energy as previous one. 2. CH selection is made static for better stability. 3. Network lifetime calculated by giving two different values of initial energy to nodes. 4. Not susceptible to dynamic changes in the network.
2015 Yang et al.	An Energy Effective Routing Algorithm for Event-driven Wireless Sensor Networks	CH selection based on weight values, excited intensity, residual energy and distance among nodes	<ol style="list-style-type: none"> 1. Event driven WSNs discussed in which nodes participate only after occurrence of an event. 2. Suitable for large number of nodes that face energy constraints. 3. Monitors irregular events occurring in the area and triggers specific nodes to wake up and perform. 4. If event occurs far away, the sensors forward data to nodes near BS, thereby inducing hotspot problem.

Year/Author	Title	CH selection approach	Research Findings
2013 Taruna et al.	Event Driven Hierarchical Cluster based Routing Protocol for Wireless Sensor Network	CH selection based on prediction of energy required for transmission	<ol style="list-style-type: none"> 1. Event driven routing used along with hierarchical approach. 2. Homogenous network with static nodes is considered. 3. Shortest path followed to BS for transmission of data. 4. Network lifetime calculated based on different levels of hierarchy.
2010 Buyanjargal et al.	Adaptive and energy efficient clustering algorithm for event-driven application in wireless sensor networks (AEEC)	CH selection based on residual energy of nodes	<ol style="list-style-type: none"> 1. Modification to the existing LEACH protocol designed for event driven WSNs. 2. Creates a balance between energy consumption of nodes and improves efficiency. 3. Electro node is employed which is responsible for gathering information about energy value of nearest located nodes. 4. Electro node aids in CH selection process.
2009 Buyanjargal et al.	An energy efficient clustering algorithm for event-driven wireless sensor networks (EECED)	CH selection done by elector node based on residual energy of node	<ol style="list-style-type: none"> 1. Event driven protocol used to conserve energy of nodes. 2. Following the basic principle of LEACH, it includes elector node for collecting energy information. 3. Simulation done using equal initial energy of nodes as well as different initial energy. 4. Incurs overhead due to control message exchanges.

Year/Author	Title	CH selection approach	Research Findings
2004 Younis et al.	HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks	Distributed clustering approach, CH selected based on residual energy and minimum distance for communication.	<ol style="list-style-type: none"> 1. Formation of well distributed clusters; every node part of only one cluster. 2. Works well with unsynchronized nodes. 3. Requires only local information to form clusters. 4. High communication overhead due to random election of CH. 5. Rotation of CH incurs extra energy.
2001 Manjeshwar et al.	TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks	Data centric Hierarchical clustering approach that focuses on time critical applications.	<ol style="list-style-type: none"> 1. Suitable for scenarios where user can dynamically control tradeoff between energy and response time. 2. Data transmission done less frequently; energy consumption less. 3. Infeasible for scenarios where periodic reporting is necessary on a frequent basis, as user cannot get any data until threshold is reached 4. Unsuitable for large size networks
2000 Heinzalman et al.	Energy efficient communication protocol for wireless micro sensor networks (LEACH)	Self-organizing, adaptive protocol, that includes randomized rotation of cluster heads.	<ol style="list-style-type: none"> 1. Single hop routing ensures energy saving. 2. Distributed protocol; no global knowledge of network required 3. Data aggregation by CH resulting in less traffic. 4. Number of cluster heads not known; could be less or equal to the optimal number. 5. If CH dies, cluster becomes useless and no link with BS.

2.3 Clustering schemes based on Fuzzy Logic

Energy consumed by intra-cluster and inter-cluster communication is quite high. If the clusters are formed in an effective way, by choosing the most suitable node as CH, then proper utilization of energy can be assured. Several parameters such as battery power, centrality, mobility of nodes etc. can be considered for selecting the most suitable node as CH. Fuzzy Logic system can be used to implement these parameters in an efficient manner and the proper selection of CH can be done.

Indranil Gupta et al. presented a novel approach for CH election for WSNs [13] such that by selecting the appropriate CH can reduce energy consumption drastically. In this paper, three fuzzy descriptors - energy, concentration and centrality have been used to calculate possibility for a node to become the CH. Because of node concentration and centrality used as parameters, evenly distributed cluster heads are guaranteed. The algorithm works in two phases. First phase includes collecting of information by the BS and selecting the appropriate CH based on the chance value. Second phase includes data aggregation and in each round residual energy and location is collected by base station to elect the next cluster head. Simulation results have been derived using three sample networks. Network 1, that has 150 nodes randomly stretching over an area 100x100m. In network 2, each node is supplied with 1J energy at the start of the simulation. In network 3, that is final phase of this algorithm, it is compared with LEACH, and the results indicate a substantial increase in the network lifetime using the proposed algorithm. Along with the various merits, there are some limitations such as it is suitable for medium sized networks. Overhead is more because of periodical collection of information by the BS. Only one CH is selected contrary to the claim made by the author that several CHs can be selected.

CHEF [14], cluster head election based on Fuzzy Logic performs the CH selection on the basis of two various parameters: distance and energy of the nodes. The node with the high amount of residual energy and local optimality is selected as a CH. It has been noticed that the CHEF has 22.7% more efficiency in comparison to the LEACH. In various research works, the parameters like energy, concentration and centrality of the nodes were selected as the input parameters for Fuzzy system. Energy can be used for defining the available energy of the nodes, concentration can be used for measuring the number of connections to the nodes and centrality is a parameter which

is used to measure that how central the nodes is. These parameters can lead to the enhancement to the lifetime of the network. The limitation of this approach is that it uses the GPS system and sometime fails to update the location in some regions.

F-MCHEL [40], is a Fuzzy based master CH election technique based on LEACH that selects the CHs by using the Fuzzy rules which depend upon the idea of energy and distance of the nodes. In this, the node which possesses higher amount of residual energy is selected as a master CH and gets the responsibility to transmit the aggregated data to the BS. It is an improved version of CHEF protocol. Network stability in comparison to the LEACH and CHEF is increased. It works on the consideration of static sink node. Various Fuzzy protocols have been described which can be collaborated with clustering protocols. The Fuzzy based clustering protocols works on the basis of the input parameters and also on the performance parameters such as energy, mobility of the nodes etc. But it lacks at a point where the mobility of the nodes is increased or decreased and the existence of the network remains the same. It is evaluated that the mobility of the network is indirectly proportional to the distance from a node to sink node. This issue can be resolved by considering the centrality as a parameter to perform the fuzzification process.

Seyyit Alper Sert et al. [35], the proposed work deals with the two problems; first called hotspots problem that occurs due to close proximity of the cluster heads to the sink as they die out rapidly due to heavy inter-cluster relay and second called energy hole problem which occurs due to variable locations of node deployment. In order to deal with these problems and to make it optimal in both stationary and changing networks, MOFCA which is a multi objective clustering algorithm using Fuzzy Logic is proposed. Unequal clustering technique is used which helps to reduce the intra cluster delay by generating clusters of smaller sizes nearby the sink. This algorithm is designed keeping two main points in mind, energy efficiency and lightweight for easier implementation. It is a distributed type of unequal clustering algorithm that makes use of fuzzy logic to compute competition radius for selecting a tentative CH and other parameters such as distance to the sink, remaining energy and density of nodes. It does not take Last Node Dies as a metric or a parameter such as if the node location changes intentionally or unintentionally and the energy associated with it could also be considered.

Padmalaya Nayak et al. [24] defined that WSN sets a paradigm for real time based embedded systems along with less complex calculations, communications, storage and power that has been utilized in various application where it is impossible to use or install the traditional network systems. Since the nodes operates on the principle of initial defined energy. Thus, the nodes did not have the capacity for performing any kind of operation if the energy of the nodes gets exhausted once. And these energy batteries are not replaceable and refilled to maintain the longevity of the network. It is considered in this work that the energy is the factor that influences the network's lifetime highly. Thus in order to decrease the energy consumption level, the cluster formation is introduced in the domain of WSNs. For this purpose, LEACH is considered as the most prominent cluster head selection protocol that elects the CH on the basis of the energy. In LEACH a probability threshold is evaluated to select the CH and only CH has the access to transmit the data to the BS. This work proposed a mechanism in which a super cluster head (SCH) is selected out of the available CHs in the network. So, the SCH is the only one which is allowed to communicate with the BS. The proposed mechanism works along with the FIS thus the SCH is selected on the basis of Fuzzy descriptors i.e. remaining energy, mobility of the sink, and centrality factor of the clusters. Then, Mamdani Fuzzy system starts its processing for selecting the SCH. The implementation of the work is done by using the NS2 simulator. After deriving the results it is proved that the proposed work has better results in comparison to the LEACH with respect to the first dead node, half alive nodes, and network stability and enhanced lifetime.

EEFL-CH [10], is an energy efficient CH selection protocol that improvises the LEACH protocol and uses Fuzzy Logic. Selection of appropriate cluster head plays a crucial role which can improve the lifespan of the network. To achieve this goal, three fuzzy parameters are taken in account: residual energy, expected efficiency and closeness to the sink node. Chance for each round is calculated and if the maximum chance value for a node is lower as compared to the calculated threshold value, that node becomes the CH. Communication takes place via CSMA-MAC protocol and CH sends advertisement message to other member nodes declaring that it is a CH. After clusters have been formed and appropriate cluster heads are selected, CH collects information from member nodes and transmits it to base station in the form of a signal packet. Simulation results prove that proposed protocol outperforms LEACH and LEACH-ERE in terms of energy efficiency and maximizes network lifetime. The

main drawback of this approach is that only certain factors have been considered that impact the network lifetime, cluster formation technique can be improvised and a better fuzzy logic based approach can be used for CH selection.

Samayveer Singh et al. [38] proposed a multilevel heterogeneous model for WSNs based on a parameter called model parameter which enables the model to be defined into levels such as level-0, level-1, level-2, level-3 and level-4. The conventional Hybrid Energy Efficient Distributed protocol (HEED) is used which can handle heterogeneous type of network and the approach is called HEED multilevel. Numbers of nodes of each kind are determined using model parameter. Parameters such as node density and residual energy as used in conventional HEED are also utilized. Probability is calculated based on residual energy, distance, and node density, average energy along with weights associated with them and using level values. The nodes with highest probability is chosen as CH. Entire area is covered with clusters, so election of CH is done in non fuzzy environment and also in fuzzy based system. This leads to complexity as not every node may not be that effective as a part of a specific cluster.

Yahya Kord Tamandani et al. [45] proposed SEPFL in which Conventional Stable Election Protocol (SEP) is optimized using fuzzy logic to improvise the process of cluster head election and to improve network lifetime and throughput. Three parameters namely distance from base station, node density and battery level of corresponding nodes is used along with threshold values of SEP. The three parameters stated above are calculated for every node and first probability is computed by entering values into the Fuzzy Inference System (FIS). Second probability is computed using threshold values. Mean of both the probabilities is taken and weighted probability of each node is computed. After sorting the probabilities, the node which possesses the highest weighted probability is selected as the CH. This algorithm can be further optimized using fuzzy Type-2 inference system as it may not be able to handle all types of uncertainties in the network.

Padmalaya Nayak et al. [25] used Type-2 fuzzy logic rather than the traditional Type-1 which has been used widely by researchers. Type-2 fuzzy logic is better at decision making as it can handle uncertainties well as compared to Type-1. The network in this protocol is divided into levels and CH is selected at each consequent level. An RSSI (Received signal strength) indicator is used to compute the distance between the base station and member nodes. To handle energy failure, a new concept of Standby

Cluster Head is introduced which is present at the end of the chain or last level near to the BS, to ensure proper delivery to the BS in case of failure. The node with higher energy value is chosen as the standby CH. CH is selected using Type-2 Fuzzy Logic using parameters remaining battery, distance to BS and concentration. The limitation of this protocol is that data should always come from upper levels and the problem of intra cluster relay is not considered when electing a standby CH for catering to failure at the last cluster head node.

Jung, et al. [16] proposes an adaptive algorithm called FL-TEEN in which selection of CH is done using deterministic method which is based on fuzzy inference system consisting of parameters such as battery level, data frequency and node density. Every node contains location information. First phase include collecting information of own battery level, neighboring node available and data frequency. Probability of a node to become a CH is calculated using information like status of sensor field and indicator of the node lifetime and 'n' CHs are selected using this probability. For the process of filtering data collection, two threshold values are used called hard threshold and soft threshold. These values are broadcasted during the clustering process. If sensed data of nodes is more than hard threshold value, the node saves this data and transmits it based on its own time slot. The soft threshold value comes handy to prevent failure that might be caused during data collection. Energy consumption in FL-TEEN is reduced as compared to conventional TEEN protocol. It ensures uniform consumption of energy by each node.

Manjeet Singh et al. [20] defined that selecting the appropriate cluster head poses to be a challenge in wireless sensor networks. To cater to this challenge, selection of CHs is done using fuzzy logic and then clusters are organized uniformly. Correlation model is used for uniformly distributing the clusters in the network. Correlation of member nodes and sink is done using fuzzy logic and correlation between sensors is utilized for the formation of clusters. The process takes place in two phases, first one being configuration of clusters and second one is collection of data, aggregation and transmission in each cluster. Correlation matrix is calculated and if the distance amid the nodes is greater than or equal to twice the range of the sensing area, correlation value comes out to be zero. Therefore, this ensures that only one cluster head is present within twice the range of sensing area. This approach can be applied to both heterogeneous and homogeneous environments. By organizing the clusters based on spatially close sensors, overall energy consumption reduces for every round. The

limitation for the same is that a better and realistic correlation model can be developed for future research which can be used in three-dimensional environments as well.

Seyyit Alper Sert al. [36] in order to tackle the hotspots and energy-hole problem, a two tier distributed protocol is proposed integrated with fuzzy logic. Efficiency related to clustering and routing stages is taken into account to extend the network lifetime. A two tier distributed fuzzy logic based protocol is proposed that is scalable and adaptive in nature. As it is a two tier model, the first tier includes deciding the CH based on energy and CH is chosen in a probabilistic manner. In the second tier, fuzzy clustering phase comes into action and an optimization framework is also implemented which tunes in two parameters namely Maximum competition radius and threshold rather than using a trial-and-error method. For clustering, three parameters are used namely, node connectivity, distance to the sink node and remaining energy of the node. In order to determine an optimal routing path, parameters such as average link residual energy and relative distance are used. These two tiers help in achieving an efficient data aggregation model. Optimization is done using simulated annealing technique. Due to its scalable nature, it works well in multi hop environments. With the optimization framework, there are no manually assigned parameters or values and also considers any bias caused due to best-case behavior. Other nature inspired optimization techniques can be applied such as Particle Swarm Optimization, Genetic Algorithm etc. which may yield better results.

Summary of various Fuzzy based clustering techniques is presented in Table 2.

Table 2: Literature Review of Fuzzy based clustering techniques in WSNs

Year/Author	Title	CH selection approach	Research Findings
2018 Sert et al.	A Two-Tier Distributed Fuzzy Logic Based Protocol for Efficient Data Aggregation in Multi-Hop Wireless Sensor Networks	Distributed protocol, CH chosen probabilistically and based on energy	<ol style="list-style-type: none"> 1. Tackles hotspot and energy hole problem by implementing a two tier protocol integrated with Fuzzy. 2. First tier incorporates CH selection and in second tier fuzzy clustering phase and optimization framework is implemented. 3. Two parameters used maximum competition radius and threshold for fuzzy evaluation. 4. Works well in multi hop environments and also considers any bias present. 5. Optimization techniques such as PSO, GA etc. can be applied.
2017 Singh et al.	Improving WSN operational lifetime using fuzzy logic and correlation characteristics	CH selection based on Fuzzy Logic	<ol style="list-style-type: none"> 1. Correlation model used for uniform distribution of clusters. 2. Ensures that only one CH is present within twice range of sensing area. 3. Suitable for both homogenous and heterogeneous environments. 4. A better and realistic correlation model can be incorporated for use in 3-D environments.
2017 Jung et al.	Improving adaptive cluster head selection of teen protocol using fuzzy logic for WMSN	CH selection done using deterministic methods based on parameters: battery level, data frequency and node density.	<ol style="list-style-type: none"> 1. Adaptive algorithm and every node contain location information. 2. Works on basic principle of TEEN protocol and uses soft and hard threshold value. 3. Ensures uniform consumption of energy by each node.

Year/Author	Title	CH selection approach	Research Findings
2017 Nayak et al.	Energy Efficient Clustering Algorithm for Multi-Hop Wireless Sensor Network Using Type-2 Fuzzy Logic	CH selection based on parameters: remaining battery, distance to BS and concentration	<ol style="list-style-type: none"> 1. Type-2 Fuzzy Logic has been implemented instead of Type-1 and is more efficient for decision making. 2. RSSI indicator used to compute distance between BS and other nodes. 3. Energy failure handled well by using standby CH near to BS. 4. Standby CH might lose energy quickly due to hotspot problem.
2016 Tamandani et al.	SEPFL routing protocol based on fuzzy logic control to extend the lifetime and throughput of the wireless sensor network	Node with highest weighted probability is selected as CH	<ol style="list-style-type: none"> 1. Conventional Stable Election Protocol is optimized using Fuzzy Logic. 2. First probability calculated using distance from BS, node density and battery level and are fed into FIS. 3. Second probability computed using threshold values and mean of both the probabilities is taken to select CH. 4. It can be further optimized by using Type-2 FIS.
2016 Singh et al.	Energy efficient clustering protocol using fuzzy logic for heterogeneous WSNs	Node with highest probability is chosen as CH	<ol style="list-style-type: none"> 1. Multilevel heterogeneous model containing model parameter and defined into levels. 2. Probability for CH selection based on residual energy, distance, node density, average energy with weights and level values. 3. Selection of CH for both fuzzy as well as non-fuzzy environment.

Year/Author	Title	CH selection approach	Research Findings
2015 Alami et al.	Energy-efficient fuzzy logic cluster head selection in wireless sensor networks	CH selection based on LEACH and using parameters residual energy, expected efficiency and proximity to BS.	<ol style="list-style-type: none"> 1. Outperforms LEACH and LEACH-ERE in terms of energy efficiency. 2. Nodes send data to CH according to their allocated transmission frame. 3. Cluster formation technique could be improved for better results. 4. Limited factors have been considered that impact the network lifetime.
2015 Nayak et al.	A fuzzy logic-based clustering algorithm for WSN to extend the network lifetime	SCH selection based on remaining energy, mobility of sink and centrality.	<ol style="list-style-type: none"> 1. Concept of SCH used to take load off the CHs. 2. It is based on LEACH and Fuzzy mechanism is used for SCH selection. 3. Performs better in terms of network lifetime, first dead node, half dead and end to end delay as compared to LEACH.
2015 Sert et al.	MOFCA: Multi-objective fuzzy clustering algorithm for wireless sensor networks	CH selected based on competition radius, distance to BS, remaining energy and density of nodes	<ol style="list-style-type: none"> 1. Distributed type of unequal clustering algorithm integrated with Fuzzy Logic. 2. Deals with hotspot problem and energy hole problem. 3. Optimal for both stationary and changing networks. 4. Last dead node not considered as a metric for evaluation.

Year/Author	Title	CH selection approach	Research Findings
2012 Sharma et al.	F-MCHEL: Fuzzy Based Master Cluster Head Election LEACH Protocol in WSN	Cluster head selection by utilizing the Fuzzy parameters i.e. energy and distance of the nodes	<ol style="list-style-type: none"> 1. Improvement to CHEF protocol and a Master Cluster head node is selected. 2. Fuzzy inference system used, which prolongs the network lifetime. 3. Fuzzy parameters like centrality can be used for better results. 4. Network remains constant even when mobility increases or decreases.
2008 Kim et al.	CHEF: Cluster Head Election mechanism using Fuzzy logic in Wireless Sensor Networks	CH selection based on fuzzy parameters such as node concentration, residual energy and node centrality.	<ol style="list-style-type: none"> 1. Elects CH in a localized manner rather than centralized 2. 22.7% more efficient than LEACH 3. Radius is considered due to which less number of CHs might be selected. 4. Non-uniform distribution of CHs.
2005 Gupta et al.	Cluster-head election using fuzzy logic for wireless sensor networks	Centralized clustering in which possibility of a node to become CH is computed using Fuzzy Logic	<ol style="list-style-type: none"> 1. Centralized approach guarantees uniform distribution of CH. 2. Superior to LEACH in terms of efficiency. 3. Applicability limited to small scale networks. 4. BS needs to collect data regularly after a certain period.

Clustering is considered to be an efficient approach in order to reduce energy consumption and maximize network lifetime. Uniform distribution of nodes is achieved with the help of clustering. Finally, the literature has been summarized in Table 1 and Table 2.

CHAPTER 3

Problem Statement

3.1 Problem Formulation

From the literature survey, it has been studied that several protocols have been defined that follow the clustering criteria. But not all the protocols are much effective individually. Similarly in traditional work, it has been stated that LEACH is the most prominent type of hierarchical routing protocol, wherein the CH is selected on a rotational basis depending on a probabilistically computed threshold value and CH is solely responsible to send the aggregated information to the BS. Various other protocols such as HEED, TEEN, CHEF, PEGASIS etc. have been studied and the conclusion has been drawn that energy consumption depends not only on cluster formation but on the cluster head selection technique as well. There are many issues such as hotspots problem i.e. if CH is closer to BS, energy-hole problem etc. that need to be dealt with in order to maximize the lifetime of a network. BS needs to gather information from all nodes at every round, which adds to the overhead of sensor nodes. Communication cost incurred does not depend on the transmission energy but also on various other factors such as distance, reorganization of nodes, and re-election of CH etc. Unequal clusters also pose to be a problem during the deployment of the network that is designed on the basis of BS. Therefore, in order to achieve energy efficiency and maximized lifetime, these issues need to be addressed.

A Fuzzy Logic based clustering algorithm for WSNs to extend the network lifetime is examined in literature survey in which the concept of super cluster head (SCH) is introduced and Fuzzy Type-1 system is implemented. SCH reduces the load on CHs by acting as a mediator between the CHs and BS. There may be situations where it is infeasible to replace the sensor's battery. In this approach, SCH has the sole responsibility to transmit aggregated information to the BS and is selected among the CHs by applying suitable Fuzzy parameters such as remaining battery power (RBP), Mobility of BS and Centrality. Mamdani's rule is applied to compute the chance for a node to be the SCH. Fuzzy logic is beneficial for taking real time decisions without having prior complete knowledge of the environment. The drawback of this work is that the communication criteria between CH and SCH is not very effective, because if the far located CH wants to communicate with the BS, it has to do so by using SCH

even if the sink node is located to near to it. Thus, in this manner high amount of energy is consumed. The other backlog is that the Fuzzy Type-1 is used for electing the SCH. The Type-1 Fuzzy is not capable to handle high level of uncertainties. Uncertainties in inputs [11] to the FIS as there are many factors such as high level of noise that may affect the measurements done by sensors. Uncertainties in control outputs which may arise as a result of change of characteristics due to regular usage, environmental changes etc. Uncertainties arising due to linguistic differences as one parameter may have different meanings for different people. Along with this, the number of parameters considered for SCH selection can also be improved. Thus there is a need to introduce a system for clustering which can handle the high level uncertainties and can also perform energy efficient clustering in WSNs.

3.2 Objectives

The main objectives of the proposed work are:

1. To implement LEACH with Fuzzy Logic for Cluster Head selection.
2. To propose Type-2 Fuzzy System in LEACH for Super Cluster Head selection and optimization.
3. To compare proposed approach with existing approach.

CHAPTER 4

Proposed LEACH – Type-2 Fuzzy Logic based Super Cluster Head Selection

Considering the problem with the existing technique, an energy efficient approach is proposed in which Type-2 Fuzzy Inference System for selecting the SCH is implemented. The basic principle of LEACH is followed for CH selection and formation, and the performance of LEACH is improved by selecting a SCH among the cluster heads by applying appropriate fuzzy parameters. SCH reduces the number of retransmissions done by the CHs, as only SCH can send information to BS, thereby reducing the energy consumption. The load on CH is also reduced and energy efficiency of nodes is increased as SCH does all the work. BS is considered mobile which ensures avoiding of collisions by collecting information from SCH only. All these factors and existence of SCH plays a vital role in the enhancement of energy efficiency. Type-2 FIS is used to calculate the possibility of SCH to be selected. The objective behind using Type-2 Fuzzy system is that it is capable to handle the uncertainties well which Type-1 fails to handle. The fundamental difference between Type-1 and Type-2 is basically two factors namely adaptiveness and novelty [6], which are lacking in Type-1. Adaptiveness means Type-2 fuzzy logic can realize more complex input-output relationships and can be more adaptive in some situations. Novelty means that different membership grades can be used in different rules simultaneously. So, due to this reason Type-2 FIS is used instead of Type-1 FIS. In this approach the criteria for communication between SCH and CH is also updated by using the non-cluster nodes as intermediate nodes. In this way the far located CH can reserve their energy by communicating via intermediate nodes instead of direct communication to the SCH. Along with this, the list of parameters for selecting the SCH is also updated. Figure 7 depicts the architecture of the proposed model.

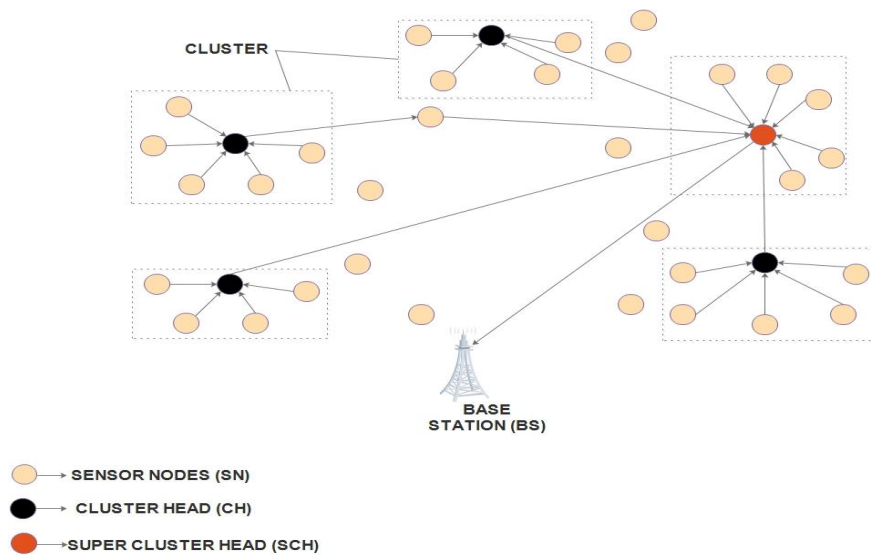


Figure 7: Architecture of proposed model

Nodes are deployed arbitrarily so as to keep track of the environment and following assumptions are made while deploying the nodes:

- Network is considered to be homogenous; all member nodes have the same initial energy.
- Other than the BS, all other member nodes are static.
- Base station is mobile.
- Distance in-between the nodes and BS is computed on the basis of received signal strength.

4.1 Process Flow

Steps of the process flow of the proposed model are discussed. These steps state how the node deployment is done, formation of clusters, selection of CH, selection of SCH and data transmission takes place.

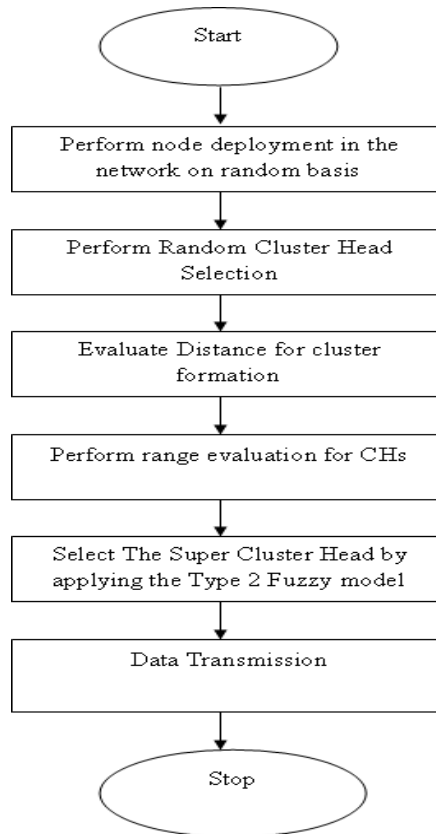


Figure 8: Framework of Proposed Work

The steps of the proposed work as shown in Figure 8 are:

1. Network Creation:

First step is to create the network structure. The network creation is done on the basis of various parameters such as area covered by the network, number of nodes in the network, initial energy of the network etc. These parameters are essential to initialize. The proposed network takes four scenarios into consideration, containing 40, 50, 60 and 70 nodes respectively.

2. Node Deployment

After initializing the parameters, next step is to deploy the nodes in the network. This is done on the basis of the values that are given during parameter initialization.

3. CHs Selection

After creating the network structure, next step is to perform the cluster head selection and this CH selection is done on random basis using LEACH.

4. Cluster Formation

After selecting the cluster heads, the cluster formation is done on the basis of the selected cluster heads. Along with this, distance is also considered as a parameter for cluster formations. The distance from CH and sink is evaluated and the node with minimum distance forms the cluster by using its adjacent nodes.

5. Evaluate the range of CHs

In this step, the range of the CH is evaluated to optimize the energy utilization of the nodes.

6. Apply Type-2 Fuzzy for selecting the SCHs

The super cluster head selection is done by using the Type-2 Fuzzy Inference System. The three input membership function for proposed work are Battery Power, Mobility and Centrality. Battery power refers to the amount of energy that is left in the node after performing various operations i.e. residual energy. Mobility is considered as the mobility of the BS in the network. Centrality refers to the centre position of the SCH with respect to the other clusters. These three membership functions are fed into the Type-2 FIS where the rules are created and applied to the input membership functions. After applying the set of rules a possible output is generated. The output is generated in the form of possibility or chance of a node to get selected as a SCH.

7. Data transmission and Performance Evaluation

After electing the SCH, the data transmission is done between source and destination node. After data transmission, the performance metrics are used to evaluate the performance efficiency of the proposed work.

4.2 Proposed LEACH – Type-2 Fuzzy Logic Model

A network size of 100*100m is considered with BS location at 50*50m. The proposed model considers the network topologies as illustrated in Table 3, based on which performance analysis of the proposed work and LEACH – Fuzzy is made. The process algorithm of the proposed work is shown in Algorithm 1.

Table 3: Network Topologies

Scenario no.	Number of Nodes	Iterations
1	40	1000
2	50	1000
3	60	1000
4	70	1000

Fuzzy Type-2 input parameters are mobility of sink (ms), mean distance point (mdp) and remaining battery power (rbp) based on which a chance value (cn) is computed which is the chance of a node to become a CH. Performance analysis is done based on parameters that evaluate the efficiency of the proposed model which are number of dead nodes in the network (dn), network lifetime (nt), first node dead (fn), half node dead (hn), last node dead (ln) and end-to-end delay (ed).

Algorithm 1: Proposed LEACH – Type-2 Fuzzy Logic based SCH selection

```

#Network Initialize()
{
    Area=a;
    Nodes=N;
    Packets=P;
    NodeE(1 to N)=e;
    EnergyModel;
    NodesLocation=nl(with limit a);
    SinkinitLocation =a/2;
}
#Fuzzy 2 Model Creation(Input,Output)
{
    Input=(ms, mdp, rbp);
    Output= cn;
}
# Selection of Super Cluster Heads
For R=1 to round
    If R==1
    {
        CH=randomSelection();
        where CH is clusterhead node numbers;
    }
For i=1 to Count of CH
    X1 = nl(CH(i),1);
    Y1 = nl(CH(i),2);
    For j=1 to nodes
        X2 = nl(i,1);
        Y2 = nl(i,2);

```

```

        DistMat(j)= $\sqrt{(X1 - X2)^2 + (Y1 - Y2)^2}$ 
    End
    NodeAllotmenttoCH=min(Distmat);
    End
    mdp(1 to CH)=mean(Distmat)/ N;
    # Location updation of sink
        SinkNewLocation=RandomMobilityModel();
        ms=SinkinitLocation- SinkNewLocation;
    # Fuzzy 2 System evaluation
    For i= 1 to Count SCH
        rbp=NodeE(SCH(i));
        cn(i)=eval([ms,mdp,rbp]);
    End
    SCH=max(cn);
    CommunicationNodetoSink();
    # Calculate Performance Parameters
    {
    performance=eval([dn,nt,fn,hn,ln,ed])
    }
    End

```

Type-2 Fuzzy Logic model:

According to the fundamentals of Fuzzy Logic explained in [6], implementation of Type-2 Fuzzy Logic consists of the following steps as shown in Figure 9. Fuzzification converts crisp data i.e. 0 or 1 into fuzzy data or membership functions such as Low, Medium, High etc. Fuzzy inference process combines membership functions with fuzzy if-then rules to derive the desired fuzzy output. In Defuzzification, the resultant fuzzy output is arranged in a lookup table. Furthermore, an output is selected from the lookup table and is converted back into the crisp value. Membership functions can have different shapes such as trapezoidal form, triangular, Gaussian, bell shaped, sigmoidal etc. and usage differs depending on the application. For applications where there are dynamic changes in a short period of time, triangular or trapezoidal form is suitable whereas for high control accuracy, gaussian form is suitable.

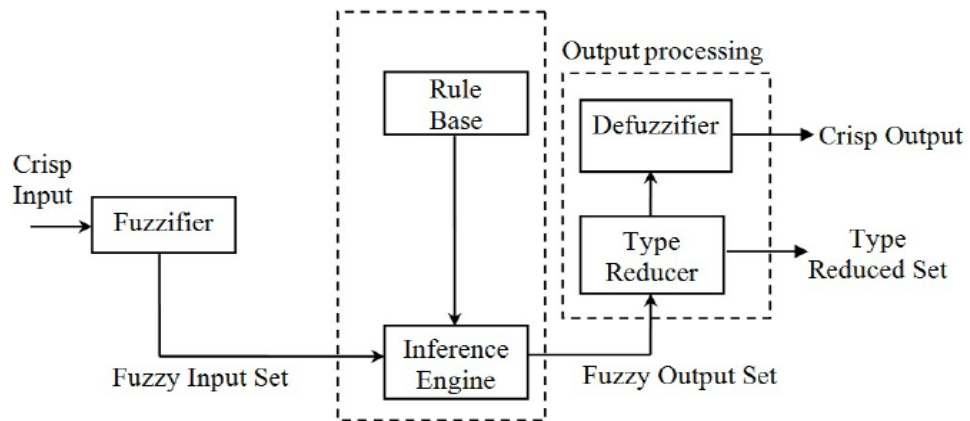


Figure 9: Schematic representation of Type-2 FIS

In the proposed work, Sugeno system has been used as it is much more compact and representation provided is computationally effective as compared to the Mamdani system. Sugeno system uses adaptive techniques for establishing fuzzy models. It is a very well suited technique for mathematical analysis. The three input parameters - Battery Power, Mobility and Centrality have their corresponding membership functions are shown in Table 4. Battery power is considered after each consecutive round. As the base station is considered mobile, so mobility factor is considered as distance of BS from SCH increases or decreases. Centrality considers that when SCH transmits data to BS, how central it is with respect to the other clusters.

Table 4: Input Membership Functions

Input Membership Function		
Battery Power	Mobility	Centrality
LessL/LessU(0)	LowL/LowU (0)	CloseL/CloseU (0)
MediumL/MediumU (1)	ModerateL/ModerateU (1)	AdequateL/AdequateU (1)
HighL/HighU (2)	FrequentL/FrequentU (2)	FarL/FarU (2)

Figure 10, shows the membership function for battery power. The degree of membership function is within 0 and 1. The X-axis shows the range of battery power function i.e. from 0 to 2. As per this range 0 depicts the less, 1 depicts the medium and 2 depicts the high range.

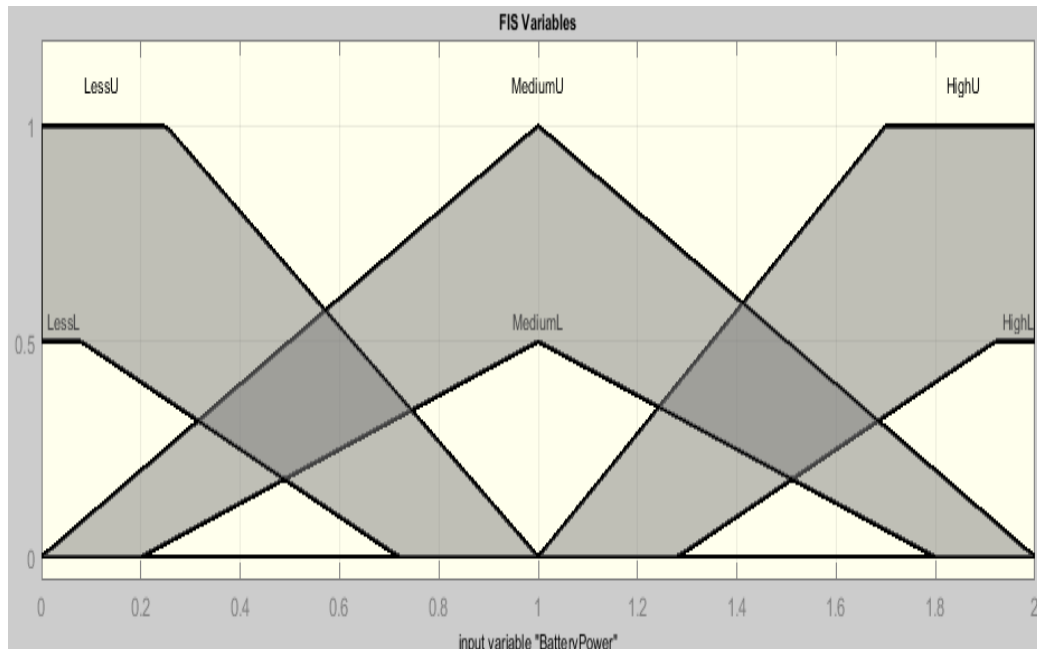


Figure 10: Input Membership function - Battery Power

The graph in Figure 11, depicts the input membership function mobility.

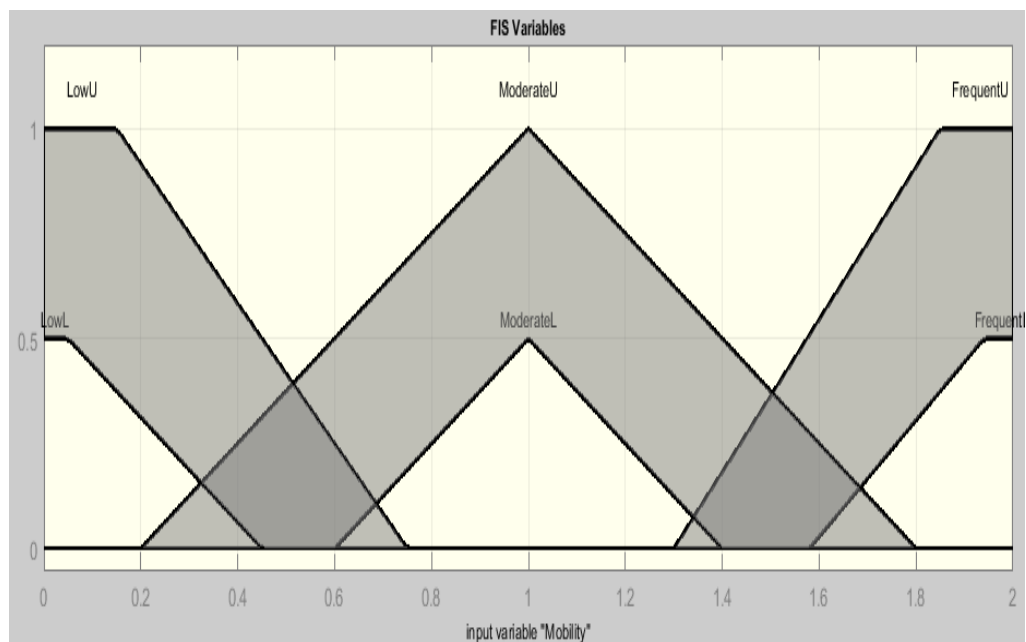


Figure 11: Input Membership function – Mobility

Similarly, Figure 12, shows the input membership function centrality. The degree of both membership functions lies with in 0 and 1. The X-axis in both graphs depicts the range of the membership functions and it ranges from 0 to 2.

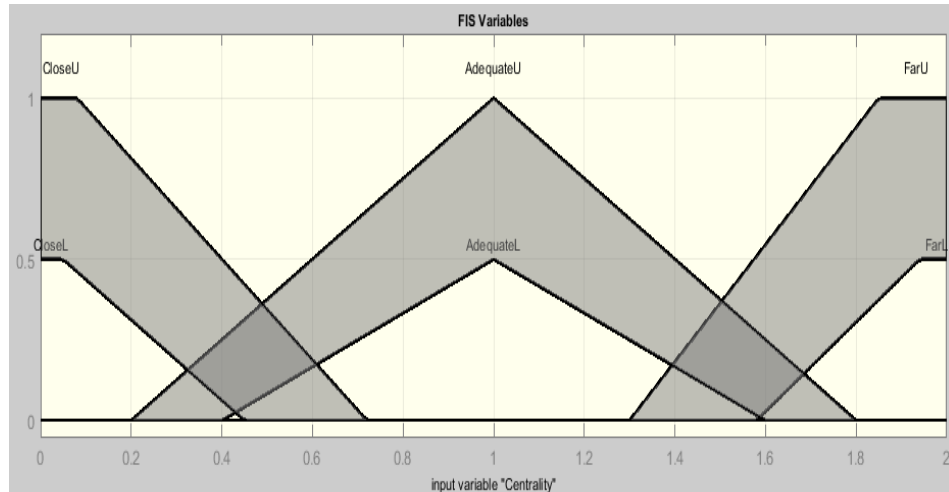


Figure 12: Input Membership function - Centrality

Figure 13, shows the Type-2 Fuzzy Inference system for proposed work. The model depicts the three input membership functions for proposed work i.e. Battery Power, Mobility and centrality. After applying the set of rules a possible output is generated. The output is generated in the form of possibility of a node to get selected as a SCH.

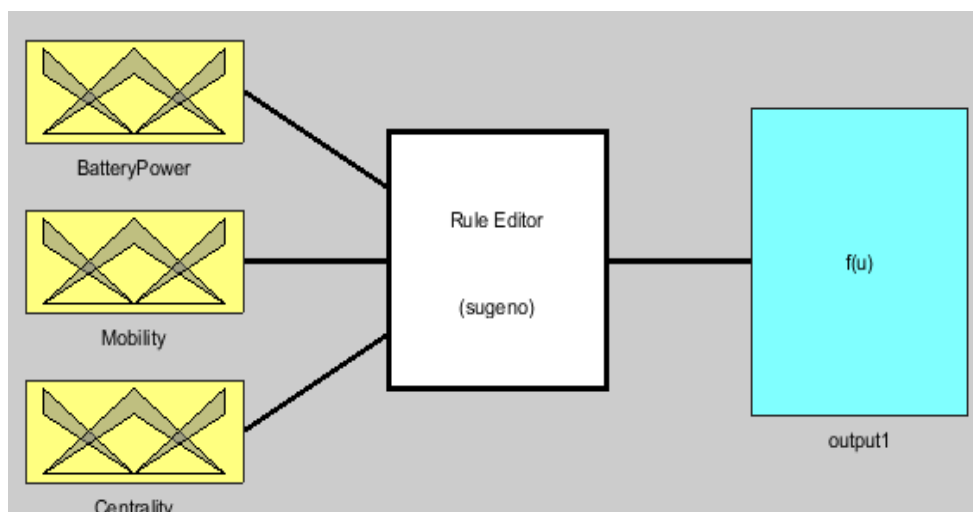


Figure 13: Proposed Type-2 FIS

The chance value for a node to be selected as SCH is computed using the three fuzzy parameters. Fuzzy rules and chance are given in Table 5.

Table 5: Rule set for Proposed Type-2 Fuzzy system

Battery Power	Mobility	Centrality	Chance
LessL/LessU(0)	LowL/LowU (0)	CloseL/CloseU (0)	Very Weak (-1)
LessL/LessU(0)	LowL/LowU (0)	AdequateL/Adequate U (1)	Weak (0)
LessL/LessU(0)	LowL/LowU (0)	FarL/FarU (2)	Lower Medium (1)
LessL/LessU(0)	ModerateL/ModerateU (1)	CloseL/CloseU (0)	Weak (0)
LessL/LessU(0)	ModerateL/ModerateU (1)	AdequateL/Adequate U (1)	Lower Medium (1)
LessL/LessU(0)	ModerateL/ModerateU (1)	FarL/FarU (2)	Medium (2)
LessL/LessU(0)	FrequentL/FrequentU (2)	CloseL/CloseU (0)	Lower Medium(1)
LessL/LessU(0)	FrequentL/FrequentU (2)	AdequateL/Adequate U (1)	Medium (2)
LessL/LessU(0)	FrequentL/FrequentU (2)	FarL/FarU (2)	Higher Medium (3)
MediumL/MediumU (1)	LowL/LowU (0)	CloseL/CloseU (0)	Weak (0)
MediumL/MediumU (1)	LowL/LowU (0)	AdequateL/Adequate U (1)	Lower Medium (1)
MediumL/MediumU (1)	LowL/LowU (0)	FarL/FarU (2)	Medium (2)
MediumL/MediumU (1)	ModerateL/ModerateU (1)	CloseL/CloseU (0)	Lower Medium (1)
MediumL/MediumU (1)	ModerateL/ModerateU (1)	AdequateL/Adequate U (1)	Medium (2)
MediumL/MediumU (1)	ModerateL/ModerateU (1)	FarL/FarU (2)	Higher Medium (3)
MediumL/MediumU (1)	FrequentL/FrequentU (2)	CloseL/CloseU (0)	Medium (2)
MediumL/MediumU (1)	FrequentL/FrequentU (2)	AdequateL/Adequate U (1)	Higher Medium (3)
MediumL/MediumU (1)	FrequentL/FrequentU (2)	FarL/FarU (2)	Strong (4)
HighL/HighU (2)	LowL/LowU (0)	CloseL/CloseU (0)	Lower Medium (1)
HighL/HighU (2)	LowL/LowU (0)	AdequateL/Adequate U (1)	Medium (2)
HighL/HighU (2)	LowL/LowU (0)	FarL/FarU (2)	Higher Medium (3)
HighL/HighU (2)	ModerateL/ModerateU (1)	CloseL/CloseU (0)	Medium (2)
HighL/HighU (2)	ModerateL/ModerateU (1)	AdequateL/Adequate U (1)	Higher Medium (3)
HighL/HighU (2)	ModerateL/ModerateU (1)	FarL/FarU (2)	Strong (4)
HighL/HighU (2)	FrequentL/FrequentU (2)	CloseL/CloseU (0)	Higher Medium (3)
HighL/HighU (2)	FrequentL/FrequentU (2)	AdequateL/Adequate U (1)	Strong (4)
HighL/HighU (2)	FrequentL/FrequentU (2)	FarL/FarU (2)	Very Strong(5)

Energy Model Description

The radio model in [24] is used and shown in Figure 10.

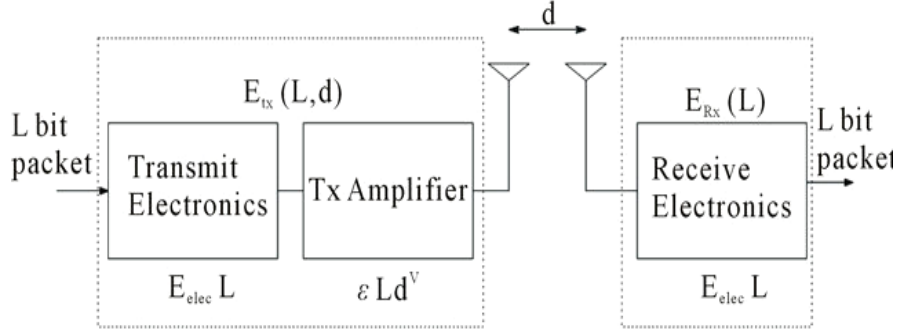


Figure 14: Radio model

During the transmission and reception phase, for ‘l’ bits and a distance ‘d’, the energy expended from the transmitter to the receiver is given in Equation 4.1.

$$\begin{aligned}
 E_{Tx}(l, d) &= E_{Tx-elec}(l) + E_{Tx-amp}(l, d) \\
 &= l * E_{elec} + l * \epsilon_{fs} * d^2 \text{ if } d < d_0, \text{ else} \\
 &\quad l * E_{elec} + l * \epsilon_{mp} * d^4 \text{ if } d \geq d_0
 \end{aligned} \tag{4.1}$$

E_{elec} is the energy dissipated per bit to operate the transmitter/receiver. It depends on parameters such as digital coding, filtering, spreading the signal, modulation etc.

ϵ_{fs} & ϵ_{mp} are characteristics of transmitter where ϵ_{fs} represents free space model and ϵ_{mp} represents multipath model.

If the distance between the transmitter and receiver is lower as compared to d_0 (threshold value), free space model is used yielding d^2 power loss. Else, multipath fading model yielding d^4 power loss is used.

Equation 4.2 represents the energy consumed to receive ‘l’ bit of data.

$$E_{Rx}(l) = E_{elec} * l \tag{4.2}$$

The threshold value is calculated by taking ratio of ϵ_{fs} & ϵ_{mp} and is given in Equation 4.3.

$$d_0 = \sqrt{\varepsilon_{fs} / \varepsilon_{mp}} \quad (4.3)$$

4.3 Summary

This section proposed a LEACH-Type-2 Fuzzy Logic based Super Cluster Head Selection technique. The basic functionality relies on LEACH protocol for CH selection and various Fuzzy parameters are used in order to select the suitable SCH. With the integration of SCH in this work, the load is lifted off the CHs for transmitting the information to the BS. SCH is solely responsible for the communication and acts as a central gateway between the CHs and BS, thereby improving energy efficiency of nodes as most part of the energy is consumed in transmission. Type-2 FIS is used to select the appropriate SCH and this is a promising technique for the purpose of selection. Further improvements have been made by considering non-cluster nodes for the purpose of communication between the CH and SCH, if CH is far located. The overall network lifetime improves when compared with the traditional work and it also guarantees a more stable network.

CHAPTER 5

Results and Discussion

Simulation in accordance to proposed LEACH - Type-2 Fuzzy Logic based SCH selection has been implemented in MATLAB [31].

5.1 Simulation Environment

The proposed approach is developed to achieve an energy efficient WSN. In order to attain the defined goal, this study implements the Type-2 Fuzzy inference system (FIS) to select the SCH to accomplish the successful data delivery to the BS. Table 6 depicts the network parameters that are used for simulating the proposed work. These are the major parameters that are necessary to initialize for creating a network. Along with this, three input parameters are fed into the Type-2 FIS i.e. Battery Power, Mobility and Centrality.

Table 6: Simulation Parameters

Simulation Parameters	Values
Network Area	100×100 m ²
Number of Nodes	40
Number of Clusters	5
BS position	50×50 m
Node Distribution	Random
Sink Mobility	Random
Channel	Wireless
Channel Type	Bi-Directional

5.2 Experimental Results

Results have been computed by comparing LEACH – Fuzzy and proposed LEACH – Type-2 Fuzzy model. Comparison is done using four topologies which contain 40, 50, 60 and 70 nodes respectively on the basis of various parameters to evaluate energy efficiency of proposed work.

5.2.1 Network Analysis for 40 nodes

The graph in Figure 15, depicts the network structure created by the proposed work. As per the graph the network covers the area of 100*100m and has 40 nodes. The nodes in red color depict the cluster member nodes, the node in green color is a SCH node and the node shown in black cross is the sink node or BS in the network.

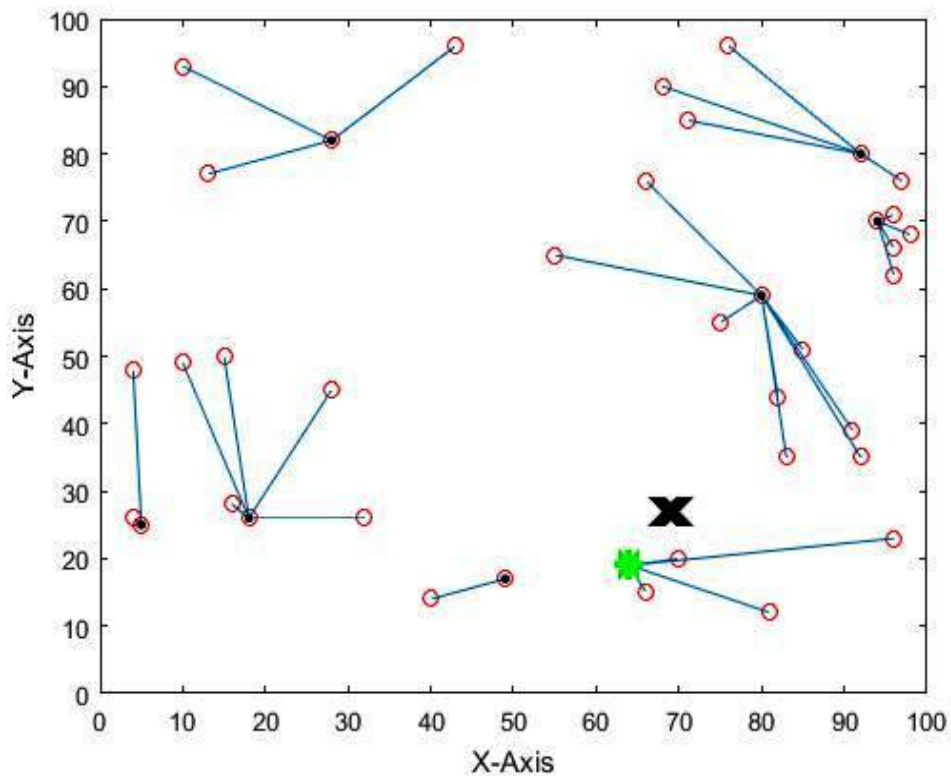


Figure 15: Proposed Network Structure for 40 nodes

The dead nodes in the network depict the nodes that run out of energy and are not capable to perform any of the operations in the network. Higher the number of dead nodes in the network, less energy efficient the network is. The number of dead nodes in the network should be low and this can be achieved only by utilizing the energy of the nodes in an effective manner. The graph in Figure 16, shows the number of dead nodes in the network with respect to the time when compared with LEACH - Fuzzy.

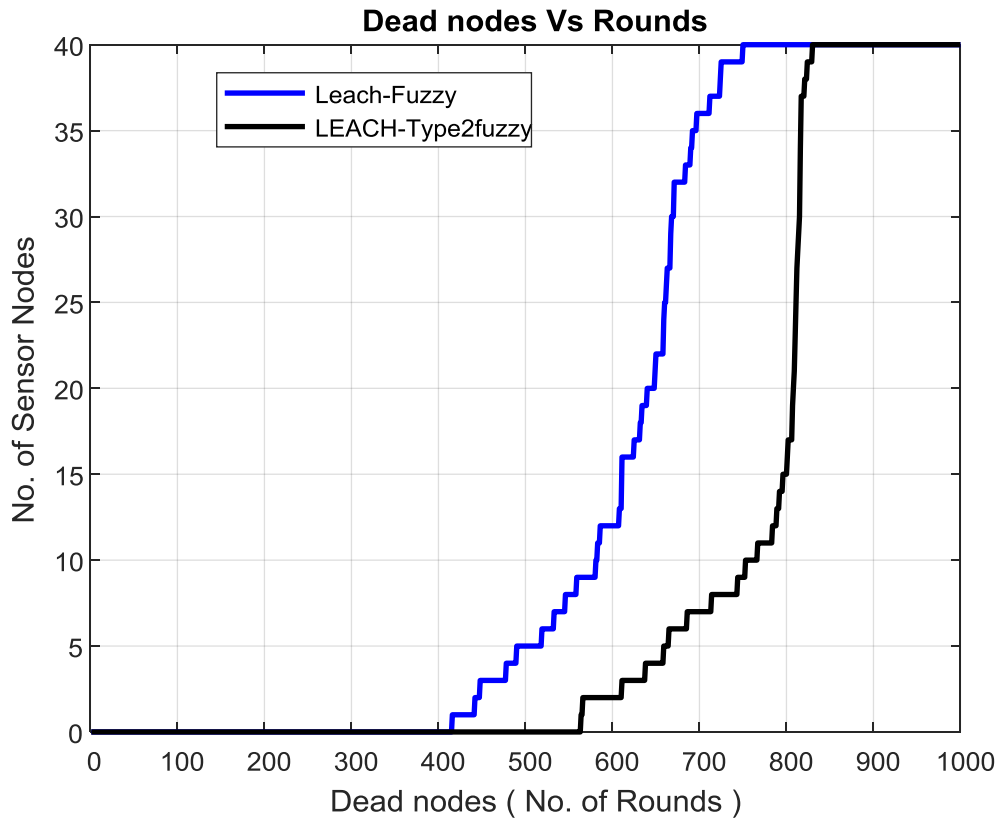


Figure 16: Dead nodes analysis for 40 nodes

The graph in Figure 17, delineates the comparison of proposed LEACH-Type 2 FIS and LEACH-Fuzzy model. The comparison is done on the basis of the network lifetime. The traditional work had implemented the LEACH CH selection protocol by using Fuzzy inference system and in proposed work the Type-2 FIS is applied to replace the traditional FIS. Thus, in order to assure the performance of the proposed work in terms of network lifetime a contrast analysis is derived in the following graph. The graph proves that the network lifetime of the proposed work is higher in comparison to the traditional work. In LEACH Fuzzy, the nodes started falling at initial stage whereas in proposed work it happens after the completion of 656 rounds. Therefore, in this way it is proved that the proposed work outperforms the traditional work and leads to the improvement in the network lifespan.

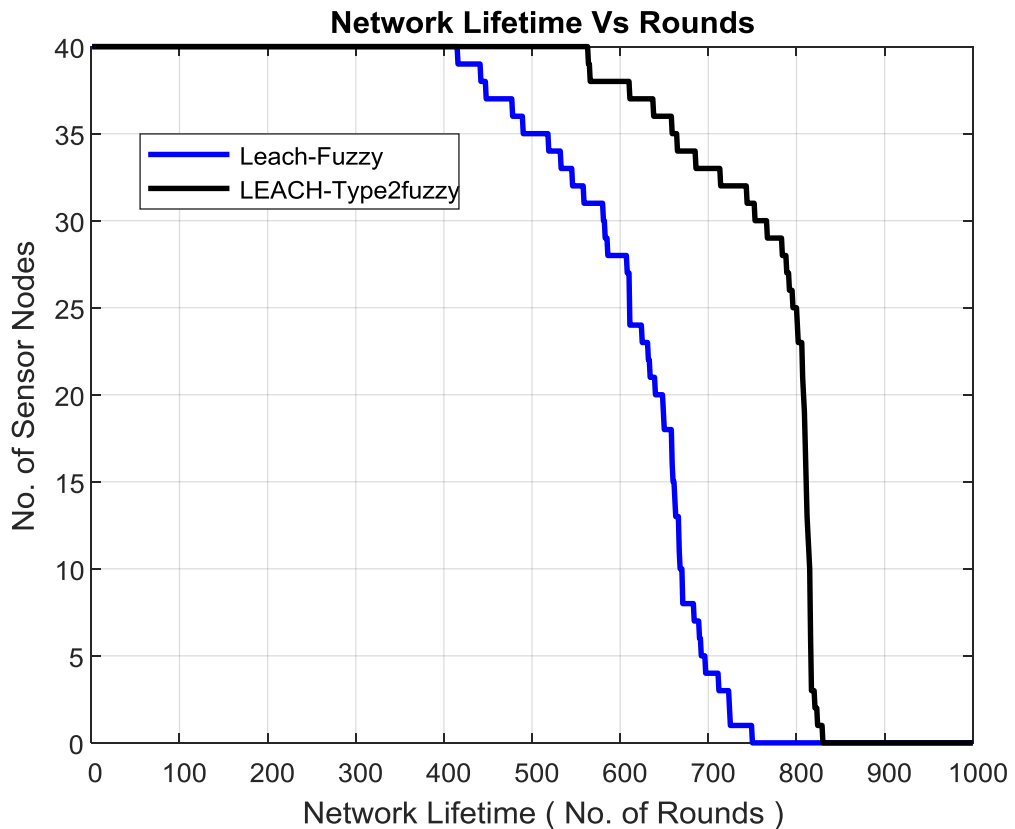


Figure 17: Network Lifetime analysis for 40 nodes

The graph in Figure 18, shows the comparison of LEACH Fuzzy and LEACH Type-2 Fuzzy in terms of First Node Dead in the network. This parameter is evaluated with respect to the time factor. The bar in blue color shows the performance of LEACH-Fuzzy and bar in black color shows the performance of the proposed work. The first node dies in the traditional work quite earlier as compared to the proposed work.

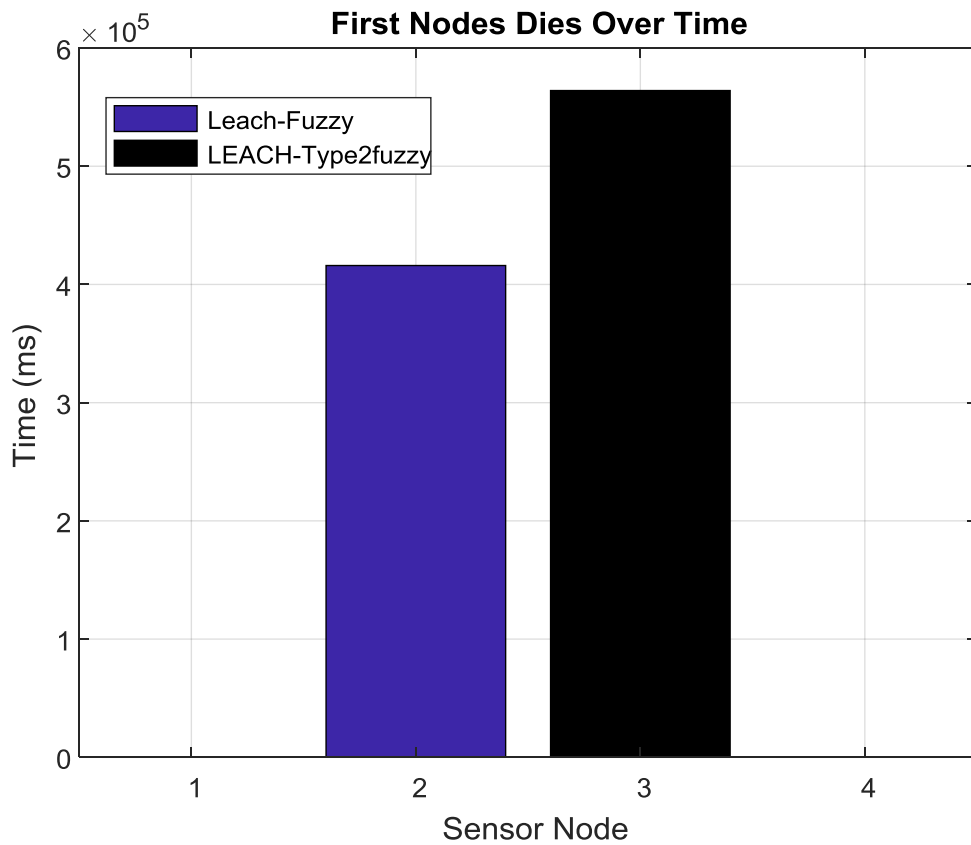


Figure 18: First Node Dead analysis for 40 nodes

The graph in Figure 19 and 20, shows the comparison of half node dead and last node dead in the proposed work and traditional work. The comparison is evaluated in the terms of time factor.

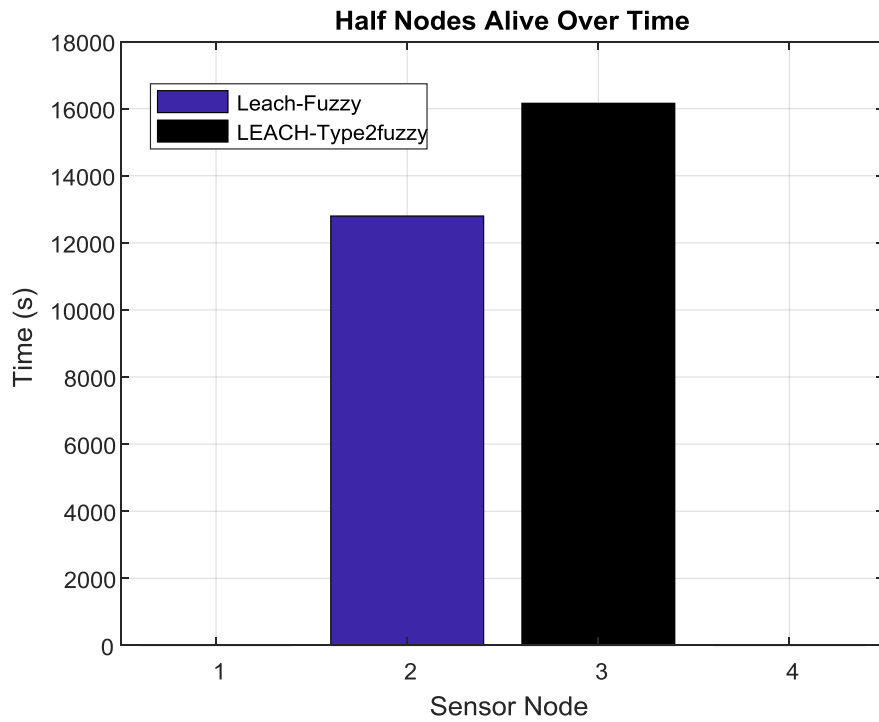


Figure 19: Half Dead Node analysis for 40 nodes

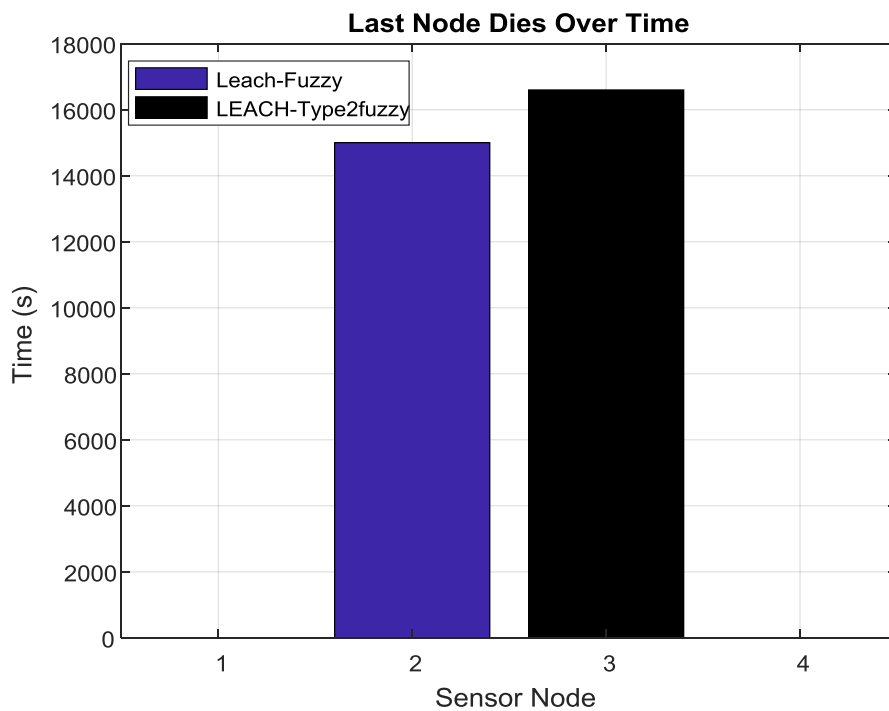


Figure 20: Last Node Dead analysis for 40 nodes

As per the observations, it is concluded that in the traditional work, half of the nodes in the network die earlier and same goes for the last dead node whereas in the proposed work, half of the nodes and last node die quite late. Thus, it leads to the enhancement of the network lifespan.

The comparison graph of proposed work and traditional work in terms of the end-to-end delay is depicted in Figure 21. The end-to-end delay is a parameter that is used to evaluate the delay that happens to deliver the data or information from sender to receiver. The end-to-end delay reduces if the number of hops in a communication is less and if the number of hops is higher than the end to end delay enhances and in this way the quality of the network degrades. Therefore, it is suggested that the end-to-end delay of a network should be low. The graph concludes that the end-to-end delay in traditional work is higher and in proposed work it is quite low.

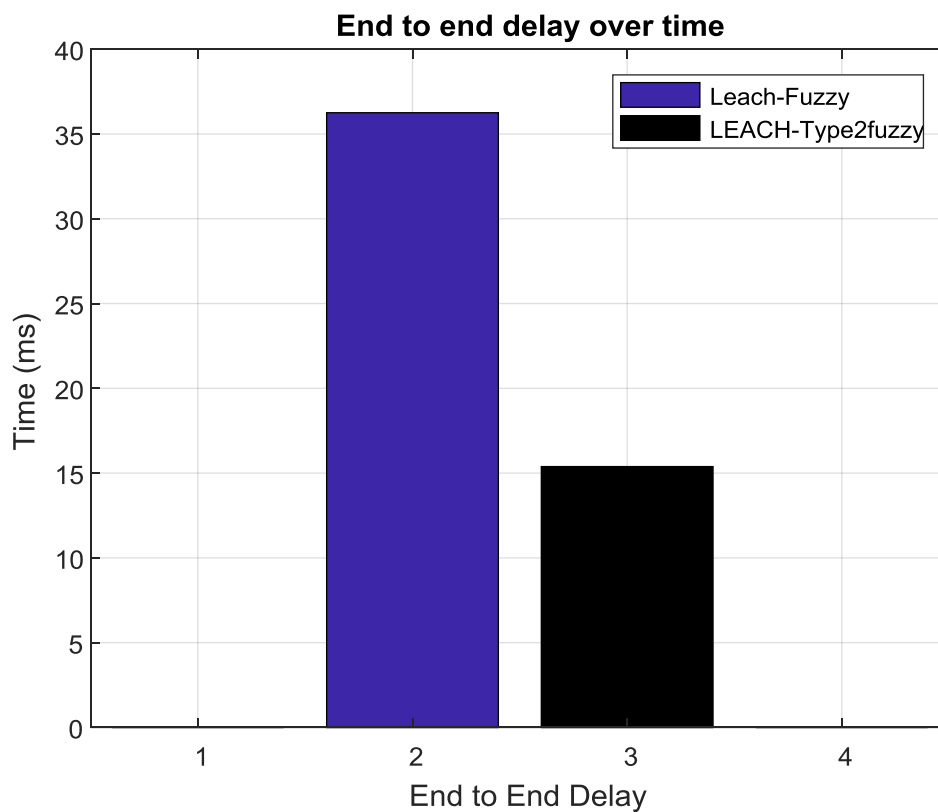


Figure 21: End-to-end delay analysis for 40 nodes

5.2.2 Network analysis for 50 nodes

In this case, a total of 50 nodes are deployed in the network. The number of iterations is 1000. The network structure of the respective topology is given in Figure 22.

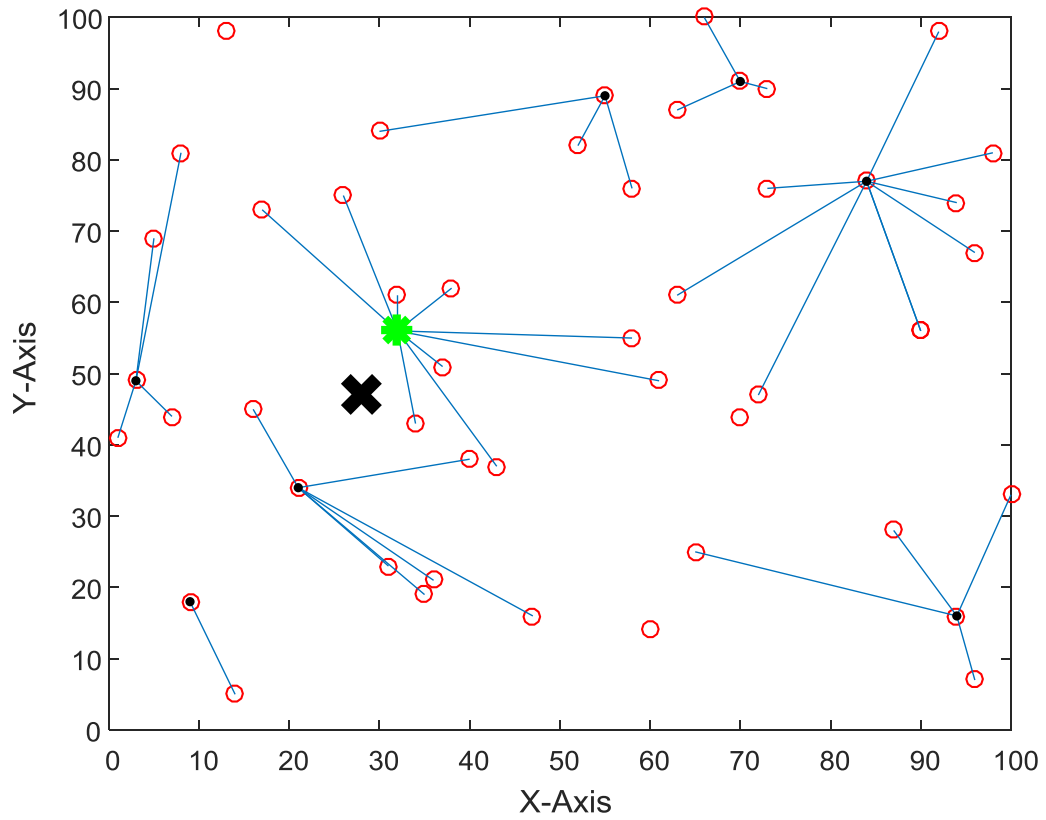


Figure 22: Network structure for 50 nodes

The graph in Figure 23, depicts the number of nodes that are found to be dead in the proposed work in contrast to LEACH-Fuzzy.

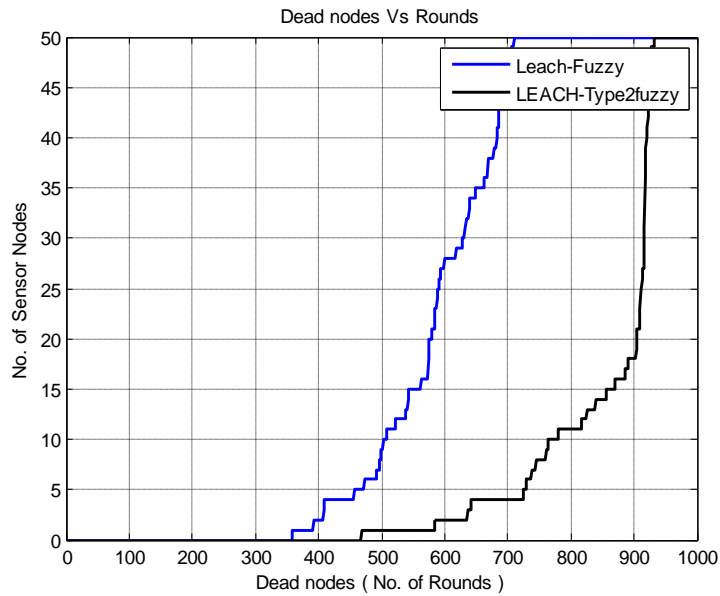


Figure 23: Dead Nodes analysis for 50 nodes

The graph in Figure 24, shows the network lifetime of proposed work in contrast to LEACH-Fuzzy. The graph explains that the initially all the nodes are alive till the completion of the 470 rounds in the proposed work as compared to 360 rounds for LEACH-Fuzzy technique.

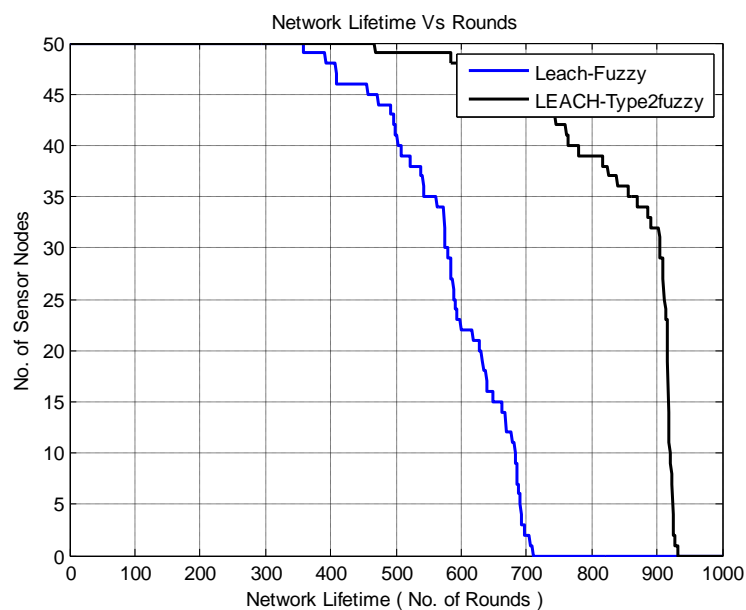


Figure 24: Network Lifetime analysis for 50 nodes

The graph in Figure 25, Figure 26 and Figure 27 comprises of comparison analysis of First Node Dead (FND), Half Node Dead (HND) and Last Node Dead (LND) respectively for LEACH-Fuzzy and proposed LEACH-Type-2 Fuzzy mechanism.

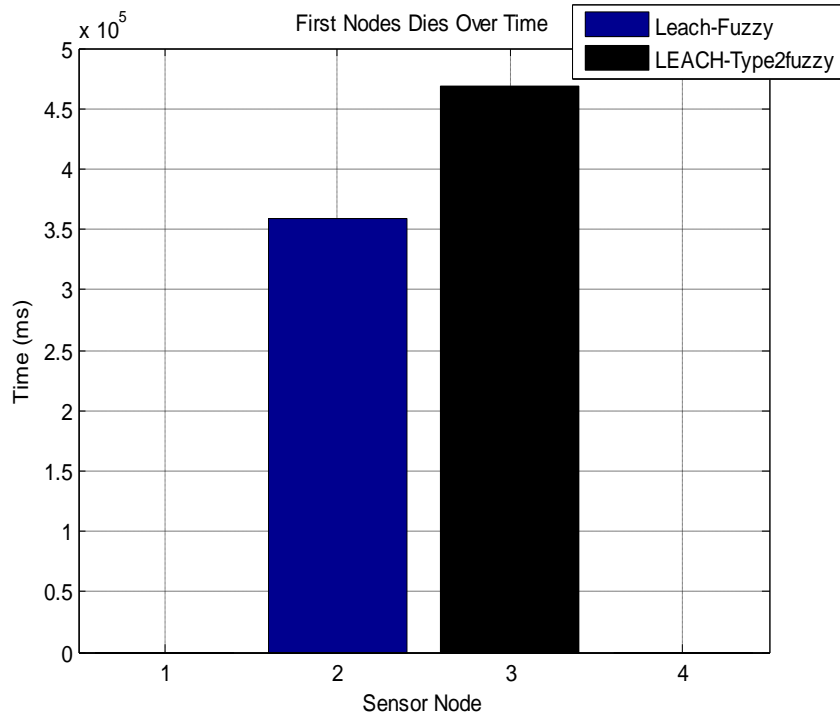


Figure 25: FND analysis for 50 nodes

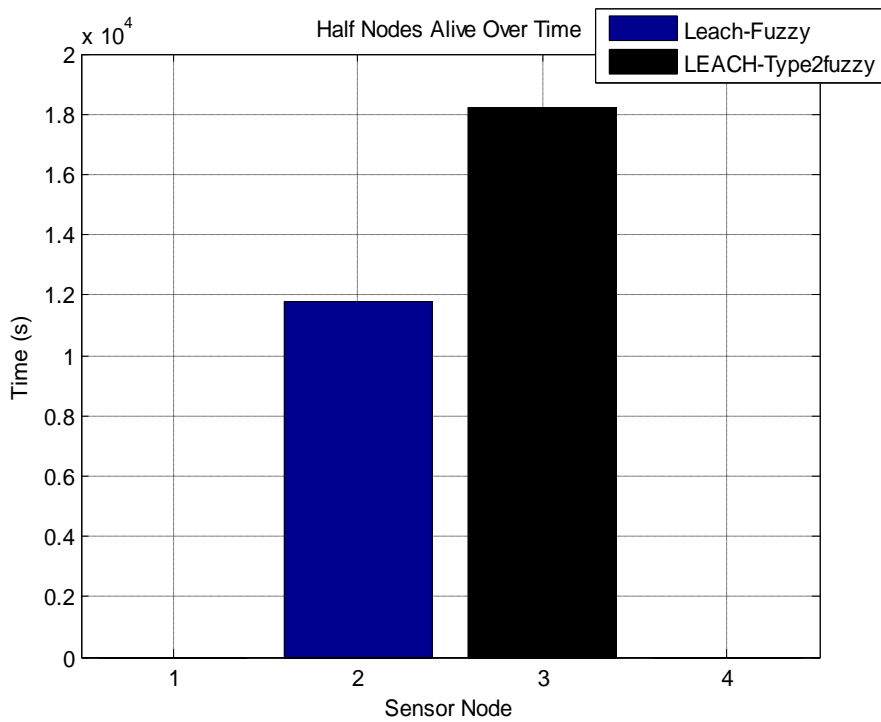


Figure 26: HND analysis for 50 nodes

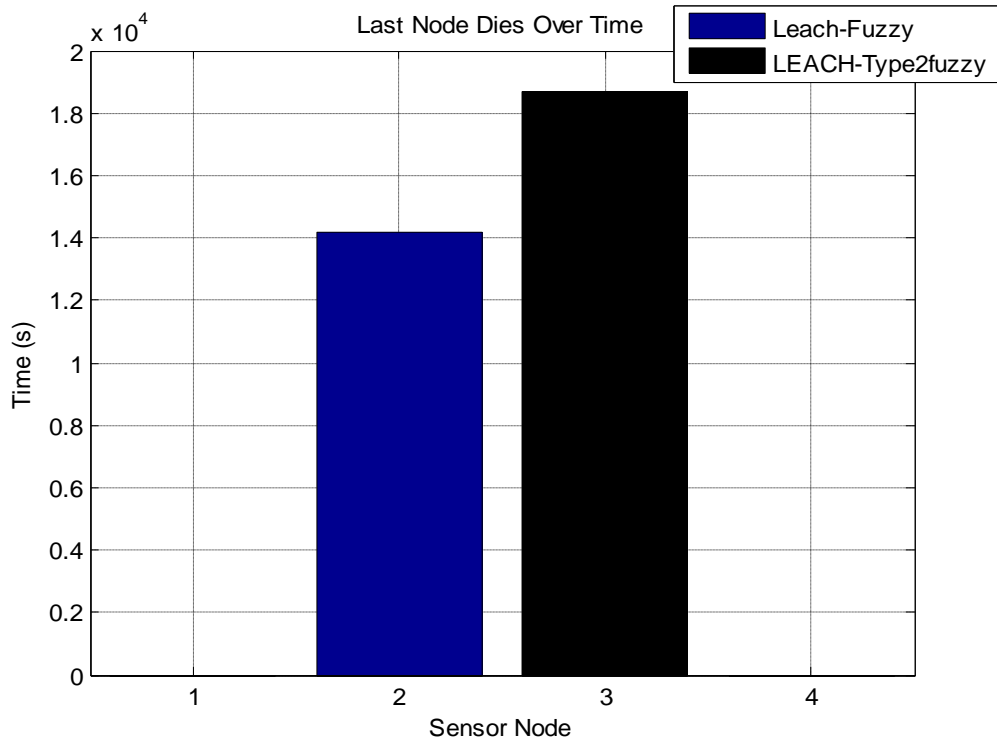


Figure 27: LND analysis for 50 nodes

The end-to-end delay comparison for LEACH-Fuzzy and proposed LEACH-Type-2 Fuzzy is depicted in Figure 28.

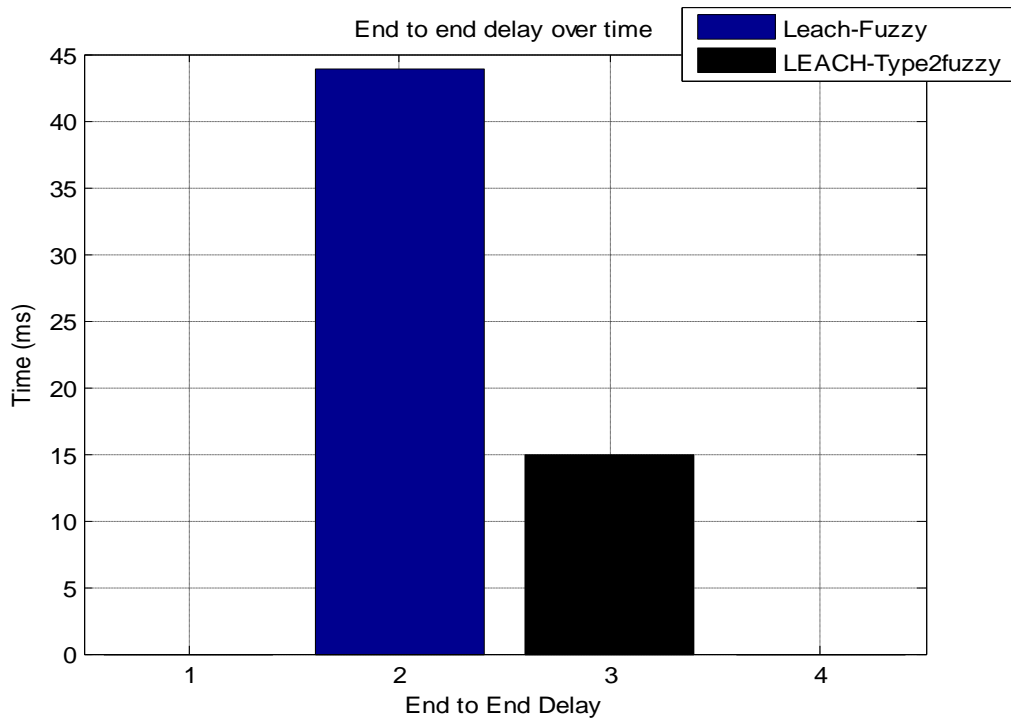


Figure 28: End-to-end delay analysis for 50 nodes

5.2.3 Network analysis for 60 nodes

The results are generated by using the proposed work and LEACH-Fuzzy in which the number of nodes is 60 and the rounds for communication is 1000. The graph in Figure 29, illustrates the number of dead nodes in the network in the proposed work in contrast to LEACH-Fuzzy.

No. of nodes = 60

No. of iterations = 1000

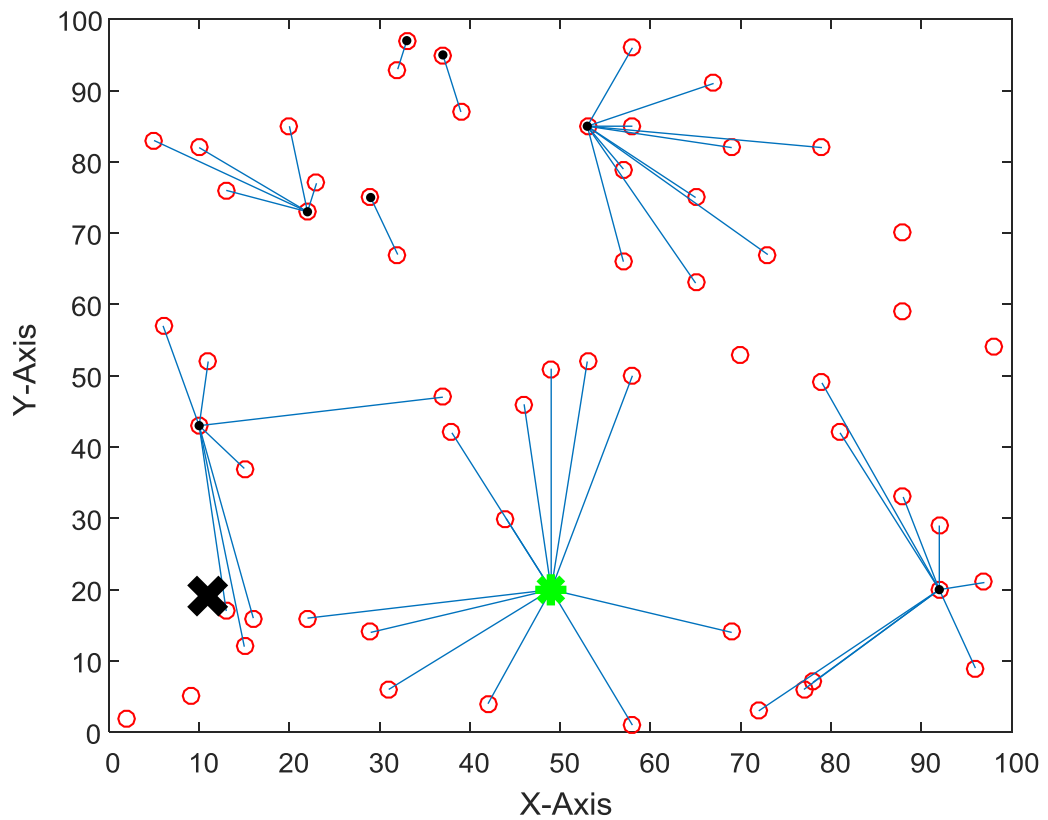


Figure 29: Network structure for 60 nodes

The graph in Figure 30, depicts the number of nodes that are found to be dead in the proposed work in contrast to LEACH-Fuzzy.

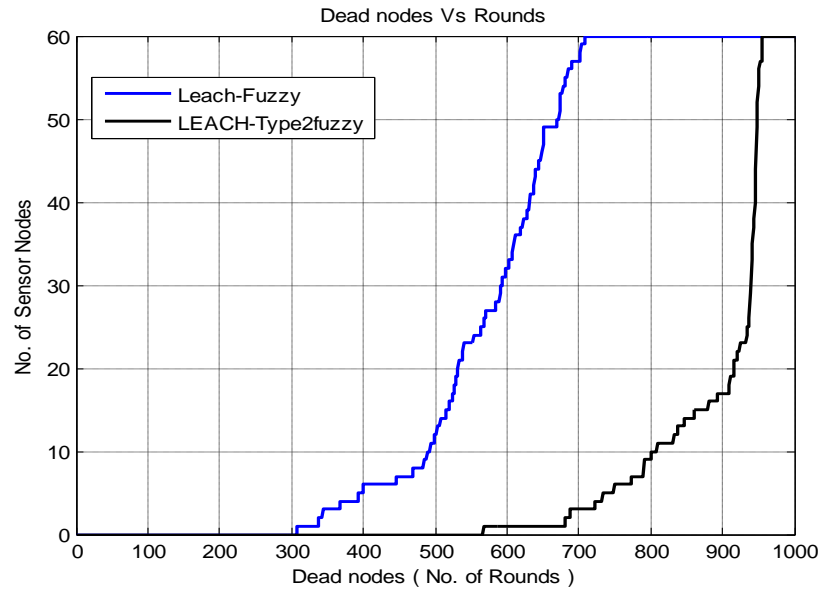


Figure 30: Dead nodes analysis for 60 nodes

The graph in Figure 31, network lifetime of proposed work with regard to 60 nodes is compared with LEACH-Fuzzy. As per the graph the nodes start running out of energy after completing 550 communication rounds as compared to 310 rounds in LEACH-Fuzzy approach.

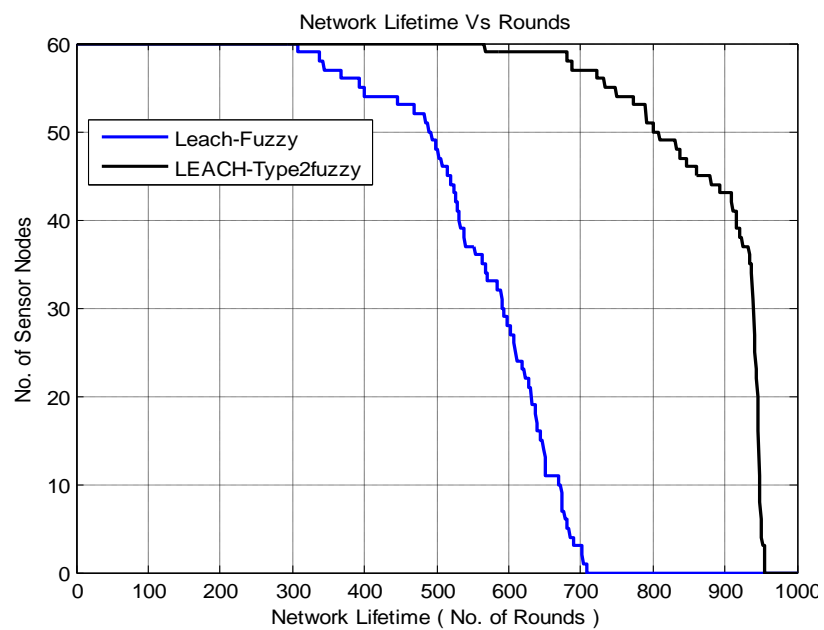


Figure 31: Network Lifetime analysis for 60 nodes

Similarly, the graph in Figure 32, Figure 33 and Figure 34 calibrates the FND, HND and LND respectively for proposed work and LEACH-Fuzzy mechanism.

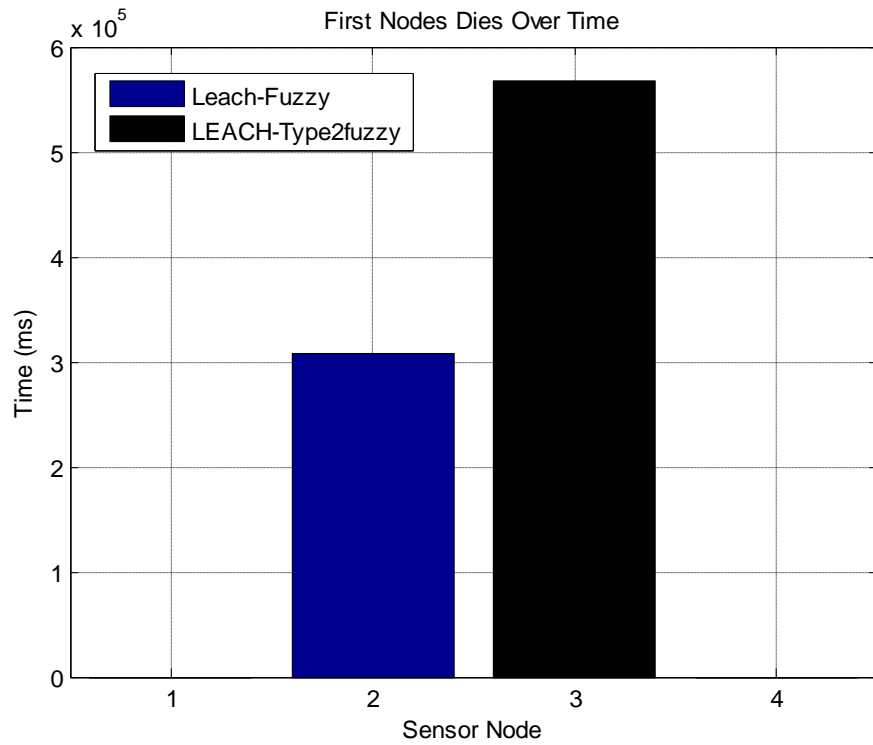


Figure 32: FND analysis for 60 nodes

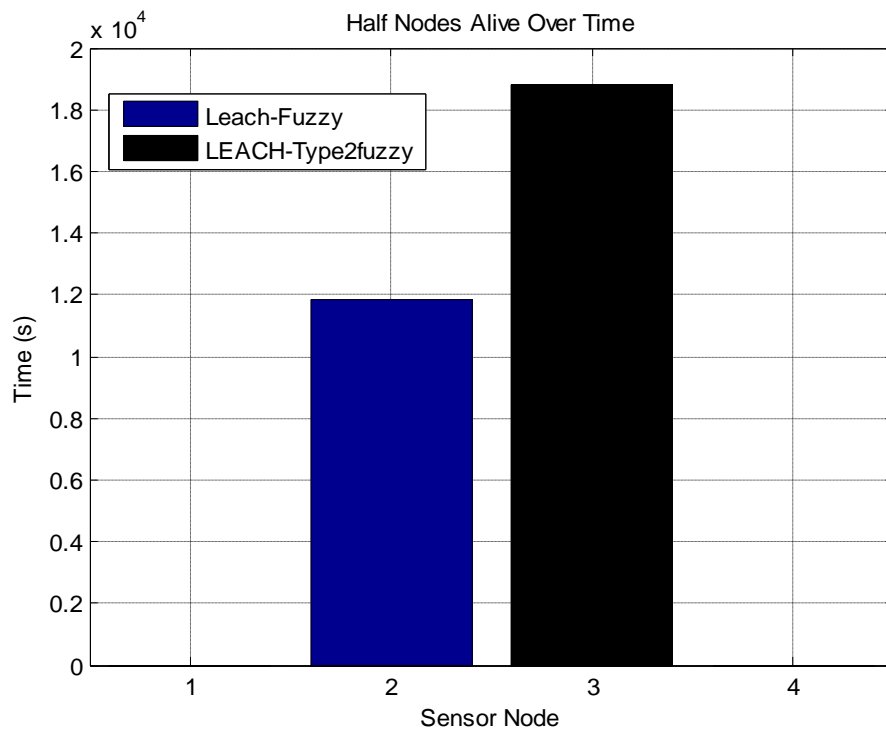


Figure 33: HND analysis for 60 nodes

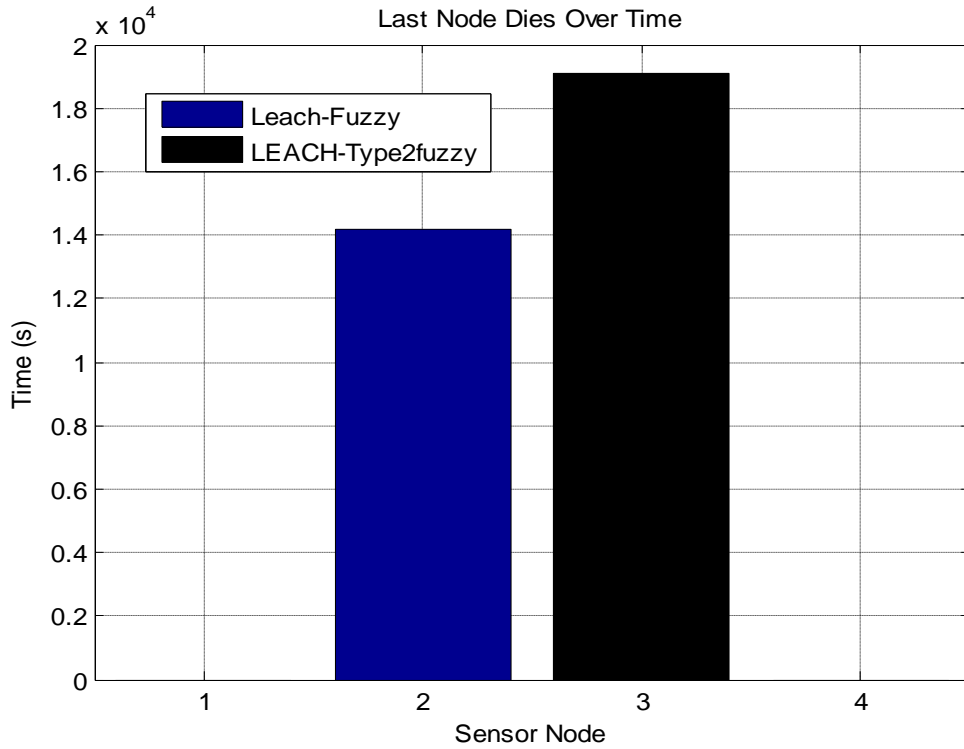


Figure 34: LND analysis for 60 nodes

The end-to-end delay comparison for LEACH-Fuzzy and proposed LEACH-Type-2 Fuzzy is depicted in Figure 35.

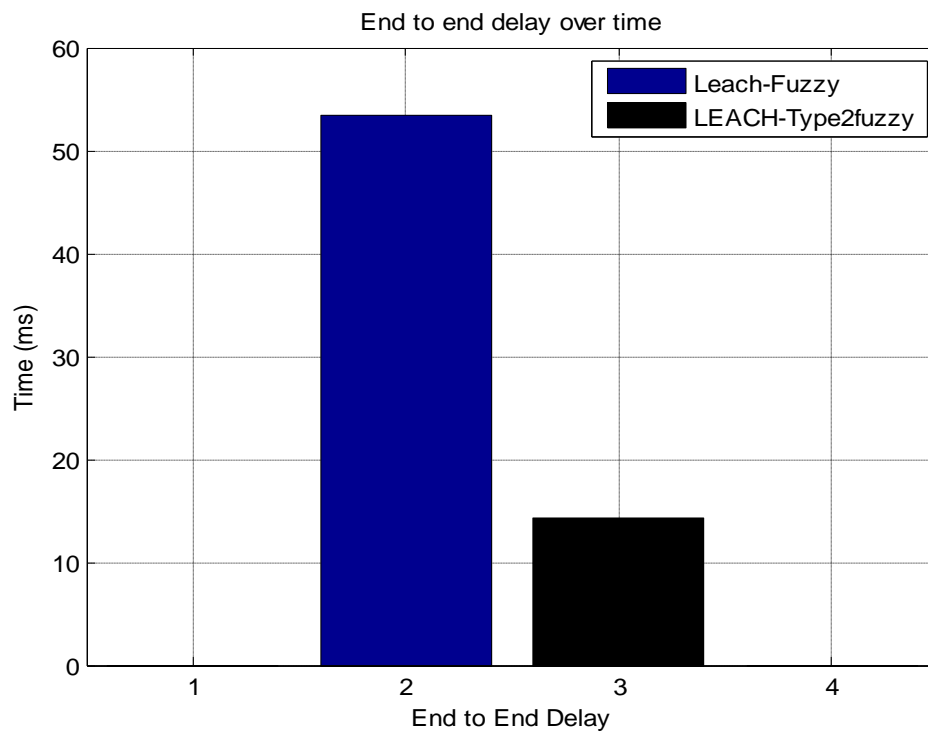


Figure 35: End-to-end delay analysis for 60 nodes

5.2.4 Network analysis for 70 nodes

The results are generated on the basis of 70 nodes in the network. The Figure 36, shows the number of dead nodes for proposed work and LEACH-Fuzzy mechanism.

No. of nodes = 70

No. of iterations = 1000

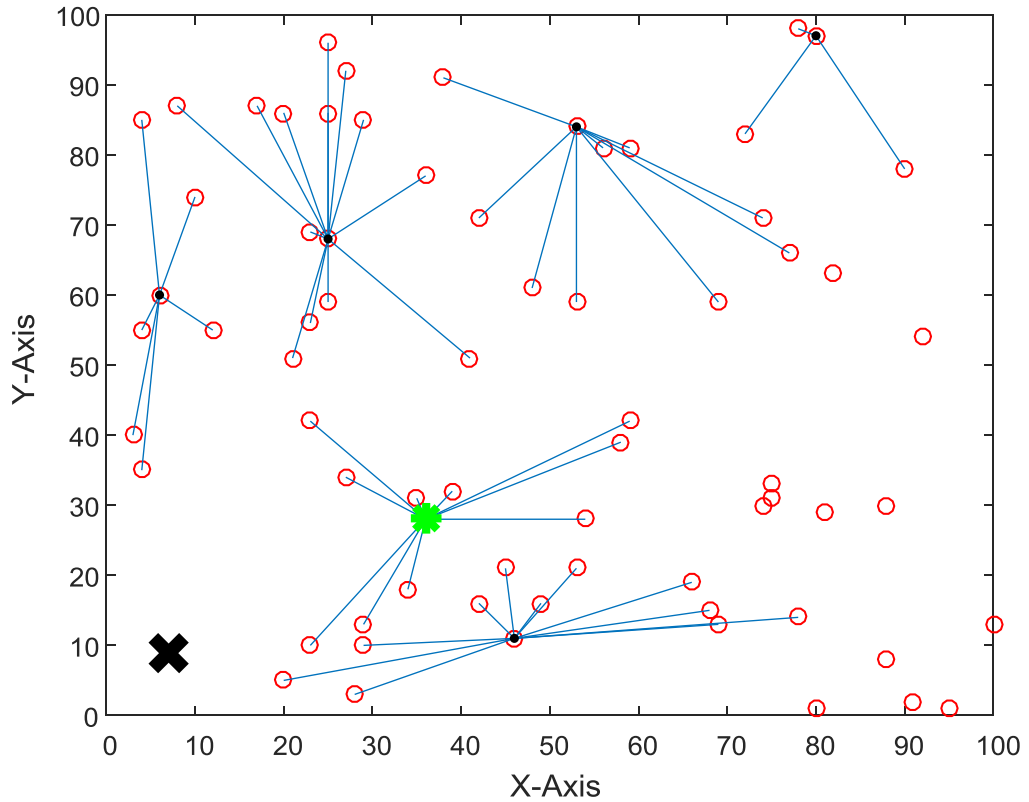


Figure 36: Network structure for 70 nodes

The graph in Figure 37, depicts the number of nodes that are found to be dead in the proposed work in contrast to LEACH-Fuzzy.

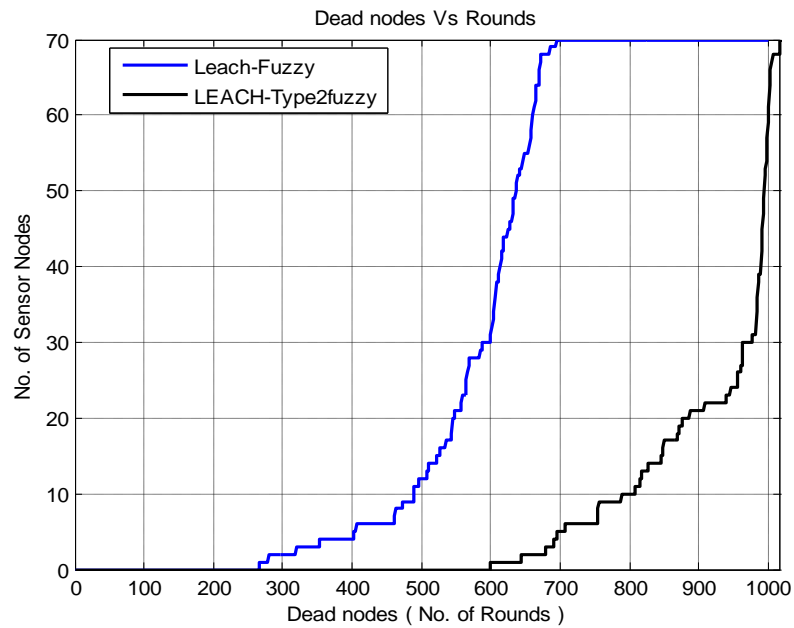


Figure 37: Dead Nodes analysis for 70 nodes

The graph in Figure 38, shows the network lifetime of the proposed work and LEACH-Fuzzy mechanism.

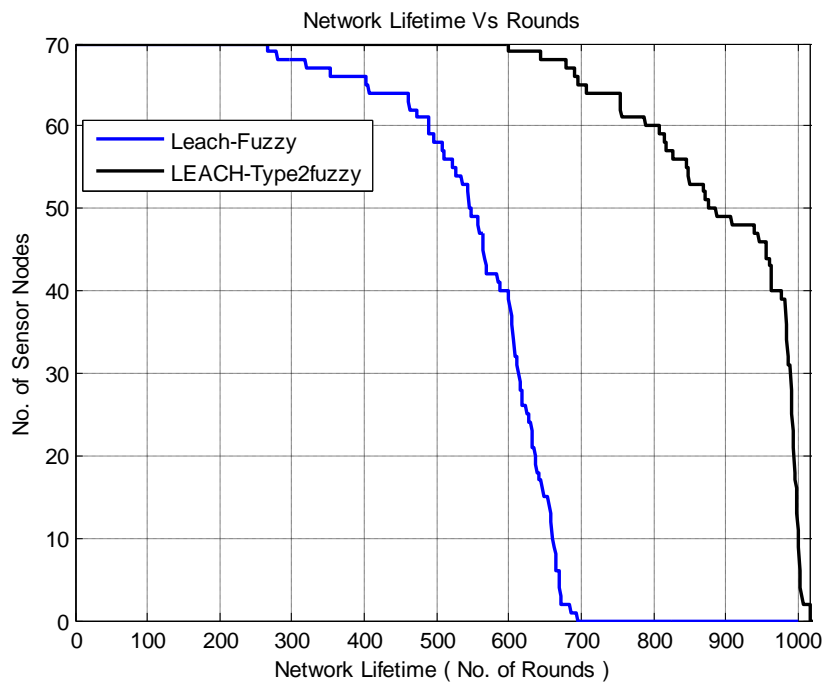


Figure 38: Network Lifetime analysis for 70 nodes

The graph in Figure 39, Figure 40 and Figure 41, depicts the FND, HND and LND respectively for proposed work and LEACH-Fuzzy approach.

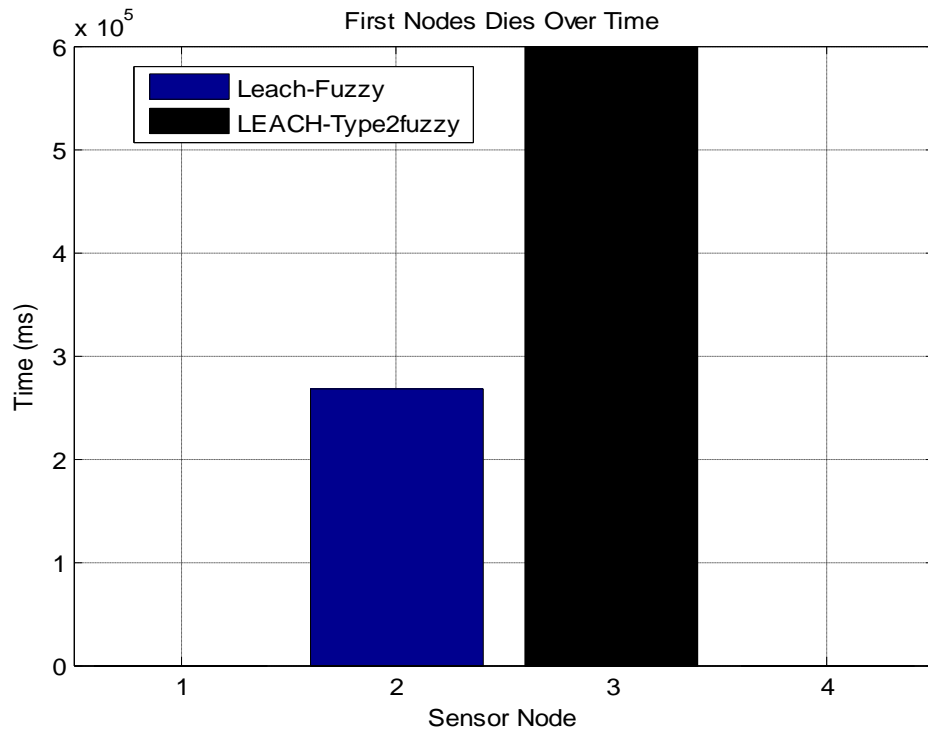


Figure 39: FND analysis for 70 nodes

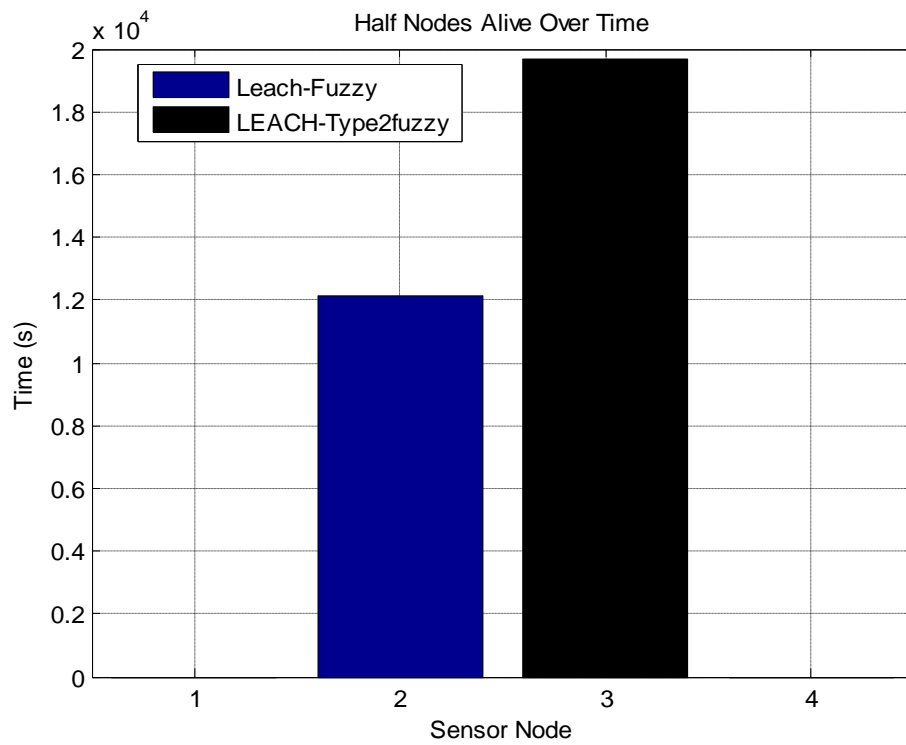


Figure 40: HND analysis for 70 nodes

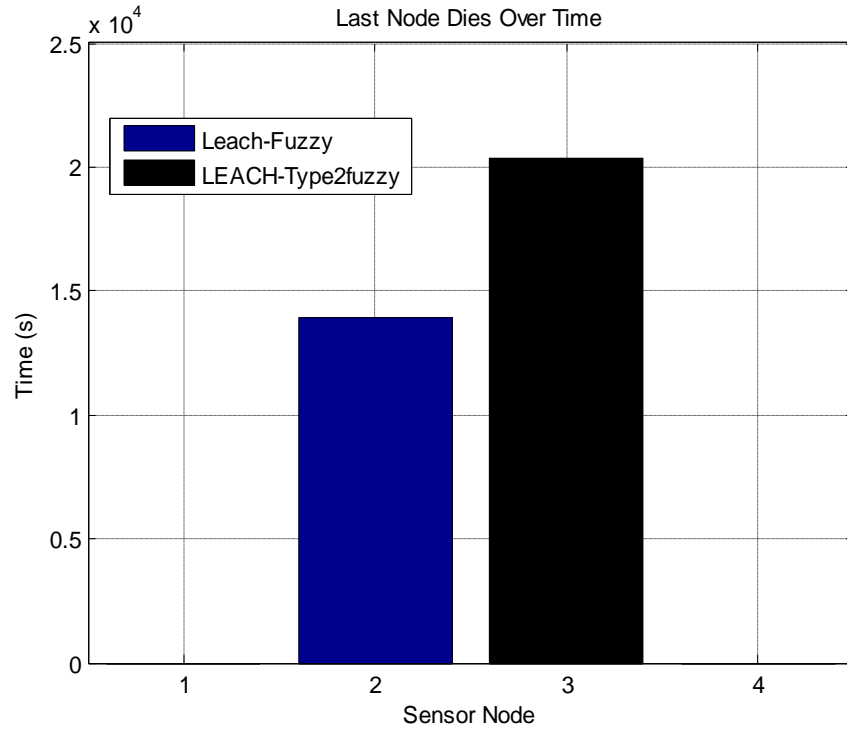


Figure 41: LND analysis for 70 nodes

The end-to-end delay comparison for LEACH-Fuzzy and proposed LEACH-Type-2 Fuzzy is depicted in Figure 42.

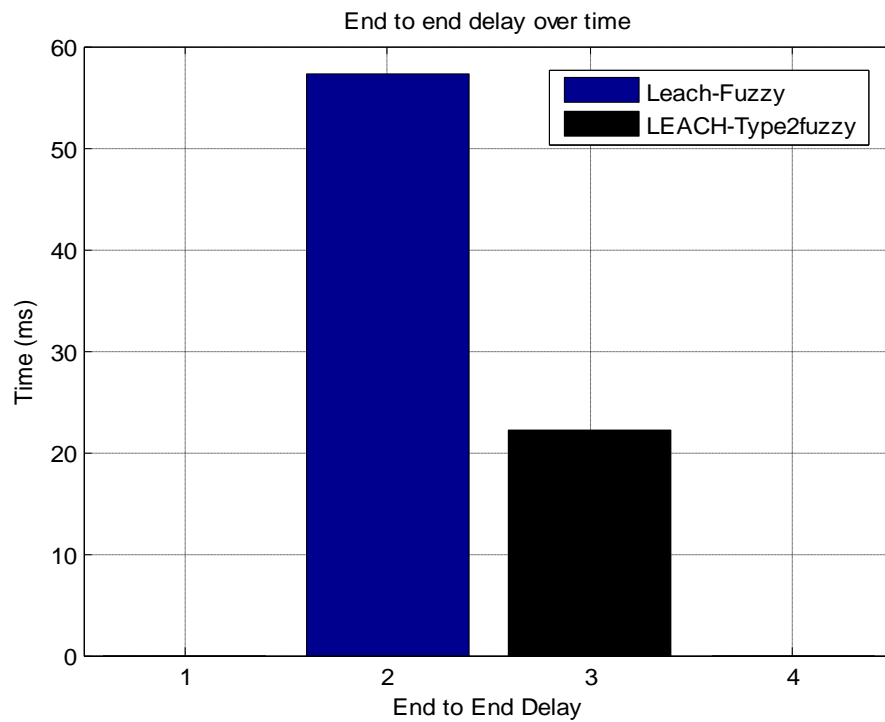


Figure 42: End-to-end delay analysis for 70 nodes

We summarize the results of all the four topologies with respect to first node dead, half nodes dead and last node dead in Table 7.

Table 7: Comparative analysis of the topologies

S. NO.	NODE COUNT	NO. OF ITERATIONS	LEACH-FUZZY (Time in seconds)			PROPOSED WORK (Time in seconds)		
			FND	HND	LND	FND	HND	LND
1	40	1000	8400	12400	15000	10800	16200	16600
2	50	1000	7200	11800	14000	9400	18200	18800
3	60	1000	6200	12000	14200	11400	18800	19400
4	70	1000	5400	12200	13500	12000	19800	21000

By observing the results, we can say that in each and every case the lifetime of the proposed work is found to be enhanced in comparison to the traditional work. Number of dead nodes is evaluated with respect to the number of rounds of communication in the network. The number of dead nodes in the proposed work is also found to be lower than that of the traditional work. The number of FND, LND and HND is also found to be prominent than the traditional LEACH-Fuzzy technique. The percentage gain in terms of FND for 40, 50, 60 and 70 nodes is 22.22%, 23.40%, 45.61% and 55% respectively. The percentage gain in terms of HND for 40, 50, 60 and 70 nodes is 23.45%, 35.16%, 36.17% and 38.38% respectively. The percentage gain in terms of LND for 40, 50, 60 and 70 nodes is 10.63%, 25.53%, 26.8% and 35.71% respectively. The end-to-end delay of the proposed work is also found to be less in comparison to the traditional work.

CHAPTER 6

Conclusion and Future Scope

This study is organized to develop an energy efficient approach for clustering in wireless sensor networks. Clustering is quite an important and difficult task to perform in sensor network. If the clustering and Cluster Head Selection is not done in an effective and smart way then the network's performance can be degraded and in this way it would become difficult to achieve an energy efficient network. The cluster formation and CH selection can be done effectively by managing the various factors such as energy of the nodes, distance, mobility, centrality, hop counts etc. Along with this a concept of Super CH is also implemented in which a node is selected as a SCH and it has all the responsibility to transmit the data from CH to the sink node. Thus, in this way the number of hops is reduced in the communication. The SCH is selected on the basis of three major parameters i.e. Battery Power, Mobility and Centrality. Then a Type-2 FIS is applied to these input parameters and the SCH is selected on this basis. The results are simulated and it is observed that the LEACH - Type-2 FIS outperforms the LEACH-Fuzzy in terms of end to end delay, dead nodes, network lifetime, first node die, half node die and last node die.

In future, the performance of the present approach can be enhanced by using another variant of LEACH protocol. The presented protocol can be compared with various advanced optimization algorithms such as PSO (Particle Swarm Optimization), Firefly, ANN (Artificial Neural Network) etc.

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APPENDIX

Paper published:

- [1] Japman Kaur, Sharad Saxena, "Optimization of Cluster Head Selection in Hierarchical Clustered Sensor Networks", *7th International Conference on Reliability, Infocom Technologies and Optimization*, 29-31st August 2018, Amity University Noida, IEEE [Accepted].