A Centralized Clustering approach for Wireless Sensor Networks

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Thesis submitted in partial fulfilment
of the requirements for the degree of

Bachelor of Technology

in

Computer Science and Engineering

by

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August 2013

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May 12, 2014

Certificate

This is to certify that the work in the thesis entitled ***A Centralized Clustering approach for Wireless Sensor Networks*** by ***Manisha Choudhury*** is a record of an original research work carried out with my supervision and guidance in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Manmath Narayan Sahoo
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Acknowledgment

I would like to express my earnest gratitude to my thesis guide, Prof. Manmath Narayan Sahoo for believing in my ability to work on the challenging domain of Routing Protocols for Wireless Sensor Networks. His profound insights have enriched my research work. The flexibility of work he has offered to me has been highly influential in producing the research.

I am indebted to all the professors, batch mates and friends at National Institute of Technology Rourkela for their cooperation.

I would conclude with my deepest gratitude to my parents and all my loved ones. My full dedication to the work would have not been possible without their blessings and moral support.

Manisha Choudhury

Authors Declaration

I hereby declare that all the work contained in this report is my own work unless otherwise acknowledged. Also, all of my work has not been previously submitted for any academic degree. All sources of quoted information have been acknowledged by means of appropriate references.

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Abstract

Wireless Sensor Networks consists of hundreds and thousands of micro sensor nodes that monitor a remote environment by data aggregation from individual nodes and transmitting this data to the base station for further processing and inference. The energy of the battery operated nodes is the most vulnerable resource of the WSN, which is depleted at a high rate when information is transmitted, because transmission energy is dependent on the distance of transmission. In a clustering approach, the Cluster Head node looses a significant amount of energy during transmission to base station. So the selection of Cluster Head is very critical. An effective selection protocol should choose Cluster Heads based on the geographical location of node and its remaining energy.

In this work a centralized protocol for Cluster Head selection in WSN is discussed, which is run at the base station, thus reducing the nodes' energy consumption and increasing their life-time. The primary idea is implemented using a fuzzy-logic based selection of Cluster Head from among the nodes of network, which is concluded depending on two parameters, the current energy of the node and the distance of the node from the base station. The protocol is named LEACH-C(ED)-Centralized LEACH based on Energy and Distance, and is run periodically at the base station where a new set of cluster heads are selected at every round, thus distributing the energy load in the network and increasing the network lifetime. The simulation results show that the proposed approach is more effective than the existing LEACH-Centralized protocol.
KEYWORDS: Wireless sensor networks, Cluster Head, micro sensors, network lifetime, LEACH, LEACH-C

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Chapter 1

Introduction

Wireless Sensor Networks (WSNs) are networks that comprise of sensors that are distributed in an ad hoc fashion over a defined geographical area, aimed at sensing some predefined information from the surrounding, processing them and transmitting them to the sink station. The sensors work with one another to capture some physical event. The data assembled is then transformed to get important outcomes. Remote sensor systems comprise of protocols and algorithms with self-arranging capabilities. WSNs can be widely divided into two types-Unstructured WSN and Structured WSN. While Unstructured WSN have a large collection of nodes, put up in an ad-hoc fashion; Structured WSN have few, scarcely distributed nodes with pre-planned deployment. The Unstructured WSNs are difficult to maintain, but it is relatively easy to maintain Structured WSNs.

1.1 Comparison of WSN with ad-hoc networks

i. Wireless sensor networks primarily use *broadcast* form of communication while ad-hoc networks use $point-to-point$ communication.

ii. Wireless sensor networks are *restricted* by sensors limited power, energy and computational capability; whereas ad-hoc networks are not.

iii. Sensor nodes may *not have global ID* owing to the huge volume of overhead, tremendous number of sensors and geographically constrained usage.

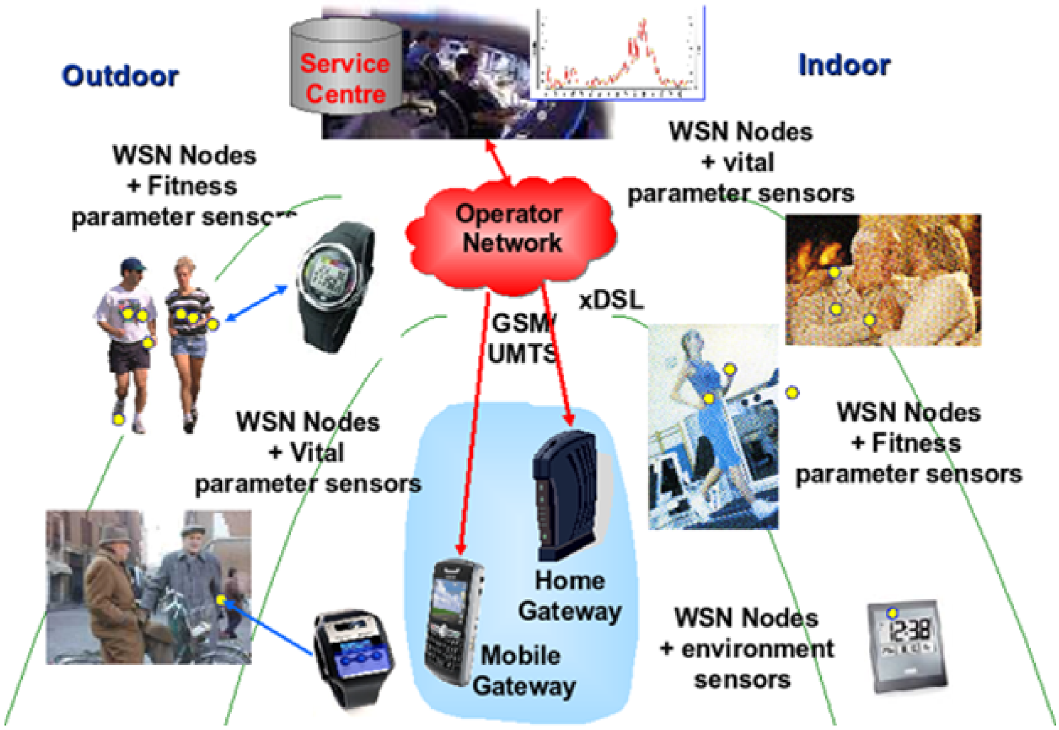

Figure 1.1: Uses of Wireless Sensor Network

1.2 The Sensor Node

Wireless Sensor Networks mainly consists of nodes known as sensors. Sensors are devices with low energy as they operate on battery, having limited memory and processing ability and are designed to survive extreme environmental conditions. These are mostly due to their small size. They are also featured with self organizing and self healing power. Three basic parts of a SENSOR NODE can be seen as:

- A sensing subsystem that is used for data capturing from the real world.
- A subsystem for processing that is used for local data processing and storage.
- A subsystem consisting of wireless communication to be used to for data receiving and transmission.

1.3 Applications of Wireless Sensor networks

The applications of WSN can be categorized in 3 parts:

- Object Monitoring
- Area Monitoring
- Space and objects Monitoring

Object monitoring may be structural monitoring, Eco-physiology based monitoring, condition-based handling, medical diagnostics monitoring and urban terrain mapping. For instance in Intel fabrication plants- sensors collect vibration data, monitor any kind of wear and tear, thus conclude facts in real-time. This reduces the need for a team of engineers and cuts cost in various ways. Monitoring of area may be Environmental and Habitat Monitoring, Precision Agriculture, Indoor Climate Control, Military Surveillance, Intelligent Alarms etc. Interactions between space and objects can be monitored using WSNs such as - Wildlife Habitats monitoring, Disaster managing monitors, Health-Care monitors, etc.

1.4 Communication in WSNs

The communication systems in Wireless Sensor Networks consist of three layered architecture. The three layers are:

i. **Transport Layer** - The main concern of the Transport Layer is *congestion* detection and mitigation. *Reliability* of the network is also checked in this layer. The direction of data communication and packet recovery are important measures taken care by this layer. This layer is also concerned with *energy conservation.*

ii. **Network Layer** - The main concern of Network Layer is to *route* the data-packet in the network. *Data aggregation* and *computational overheads* are taken care by this layer. This is also an energy efficient layer.

iii. **Data-Link Layer** -The main concern of the Data-link Layer is to *transfer data* between two nodes that are physically connected, sharing the same link. *TDMA/CSMA/CA* is carried out by this layer.

1.5 Protocols of WSNs

The different layers of communication use various protocols to accomplish their aims. Some of the protocols of the three layers are mentioned below.

1.5.1 Transport Layer Protocols:

- Sensor Transmission and Control Protocol (STCP)-It is a non specific, adaptable and solid protocol, in which larger part of the functions are executed at the Base Station. STCP offers controlled variable unwavering quality, blockage discovery and shirking, and backings different requisitions in the same system[1].

- Cost-Oriented Reliable Transport Protocol (PORT)-To acquire unwavering quality and minimize vitality utilization, a dynamic rate-control and congestion-avoidance transport plan called PORT is utilized as a part of WSN's Transport Layer. PORT minimizes vitality utilization with two plans. To begin with is focused around the sink's provision-based enhancement approach that bolsters back the ideal reporting rates. Second is a generally ideal directing plan as per the reaction of downstream correspondence condition[2]

- Congestion Detection and Avoidance (CODA)-CODA comprises of three mechanisms to combat with degree of congestion during event impulses: (i) receiver-based congestion detection; (ii) open-loop hop-by-hop backpressure; and (iii) closed-loop multi-source regulation[3].

- Delay Sensitive Transport (DST) - The principle aim of DST protocol is to conveniently and dependably transport occasion characteristics from the sensor field to the sink with least vitality utilization. The convention at the same time addresses blockage control and opportune occasion transport unwavering quality targets in WSNs[4].

- Pump Slowly, Fetch Quickly (PSFQ)-An easy, expandable, and reliable transport protocol that is modifiable to meet the requirements of emerging dependable data applications in sensor networks,PSFQ is designed to send data from a source node by sending data at a slower velocity (”pump slowly”), but permitting nodes that encounter data loss to regain any missing data from their local immediate neighbors aggressively (”fetch quickly”)[5].

- Event-to-Sink Reliable Transport (ESRT)- It is a solution for transport developed to accomplish dependable event detection in WSN with least energy expenditure. It contains a congestion control module that does the dual purpose of accomplishing dependability and preserving energy. The algorithms primarily work on the sink, with minimum requirement of resource constrained sensor nodes[6].

1.5.2 Network Layer Protocols:

- Geographical Routing-Geographic routing depends on geographic location information. It is primarily put forth for wireless networks and based on the concept that the source sends a message to the geographic position of the destination rather than using the network address.The protocols like Geographic Routing Algorithm (GERA), is evaluated in terms of end to end delay and routing load management done by the protocol[7].

- Anchor Location Service (ALS)-This is a protocol based on grid that supplies sink position data in a extensible and optimal fashion and therefore bears location-based routing in large-scale wireless sensor networks.Location-based routing is one of the most widely used routing strategies in large-scale WSNs[8].

- Secure Routing-All the luster based protocols like LEACH, LEACH-C, LEACH-E, LEACH-A, Multi-hop Routing, etc. are secured routing protocols Their efficiency is being constantly improved by researchers.

- Secure Cell Relay (SCR)-This is a routing protocol, immune to various types of attacks on sensor networks, including selective forwarding, sinkhole, wormhole, Sybil, hello flooding attacks, etc. SCR is also an optimal energy utilization routing protocol with affordable security overhead[9].

1.5.3 Data-link Layer Protocols:

- Z-MAC-This protocol aggregates the strengths of TDMA and CSMA. Z-MAC accomplishes high channel usage as in CSMA and low delay under low contention as of TDMA. It also attains high channel usage under high contention and lessens collision among two-hop neighbors at a minimal cost[10]
- CC-MAC (Spatial Collaboration based Collaborative MAC)-CC-MAC protocol has two parts: Event MAC (E-MAC) and Network MAC (N-MAC). E-MAC strains out the relation in sensor records while N-MAC gives priority the transmission of route-through packets[11].
- Low Power Distributed MAC-This design is mostly for multi-hop WSNs. A set of low power MAC design principles are proposed in the work[12], and a new uber-low power MAC is developed to be broadcast in nature to support extensible, survivable and adaptability requirement of WSNs.

1.6 Clustering based Protocols for WSNs

Grouping calculations for WSNs could be isolated as Centralized cluster calculations and Distributed grouping calculations. Distributed clustering systems are again isolated into four sub segments relying upon the sort of cluster, necessity for clusters and parameters utilized for CH determination. The four sub-sections are - Identity based grouping, Iterative, Neighborhood information based and Probabilistic individually [13]. Probabilistic systems for framing clusters in Wireless sensor systems relies on attributed likelihood values for sensor hubs. Low-Energy Adaptive Clustering Hierarchy convention proposed in [14] is such a protocol, giving offset of vitality utilization by arbitrary turn of group heads then ensuring equivalent burden adjusting in one-bounce sensor systems. LEACH-C is focused around transmission of position subtle elements and vitality levels of every sensor hub to base station (BS) and sensor hubs with vitality level above decided beforehand edge are chosen for getting to be cluster heads by the base station (BS) itself[14].

Chapter 2

LITERATURE REVIEW

2.1 Literature Survey

- In designing routing protocols for WSNs, it is necessary to deploy advanced routing algorithm for decreasing the consumption of any node's energy, thus be able to extend network life. Wireless Sensor Network routing algorithms are primarily classified as follows - hierarchical protocols protocols and flat routing. While flat protocols employee an overhead of delay and management complexity which leads to excess power consumption, in hierarchical protocols-node that is the cluster head is selected, that are responsible towards handling all nodes contained in the cluster and establishing communication with the Base Station. This prolongs the network life [15].

- A hierarchical clustering based architecture has many advantages. The network is scalable and components are task oriented. The algorithms are of distributed type, light weight and energy efficient; which makes the network reliable and less granular with clusters. Every node also has data aggregating capability [16].

  The advantage of this architecture[16] are as follows:

  i. The cluster membership change is limited to atmost two clusters. Thus the clustering algorithm is not processed for entire network. This is an important feature for sensor networks, which will help in scaling the network.

  ii. Sensor networks, unlike general internet networks, are task specific at a

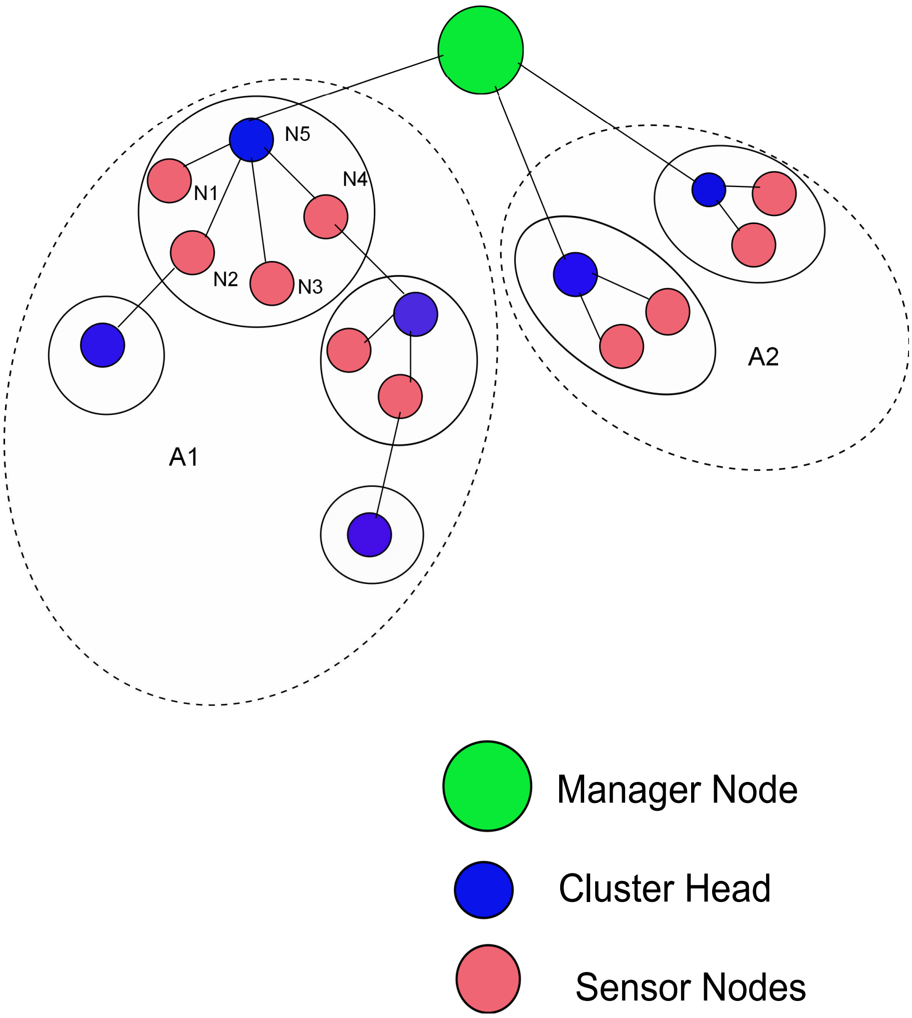

Figure 2.1: Hierarchical Management Architecture

time. The architecture is based on combining neighbor list information. The task data object helps in choosing the cluster data, based on the task. Thus network performance is optimized for specific task.

iii. In this clustering algorithm, the nodes furnish the information, does the complicated computation, while clustering algorithms run on the base station (BS). Also cluster algorithm runs at the start of/updation of the cluster.

The dis-advantage of this architecture[16] are as follows:

i. The architecture does not take care of algorithm for hierarchy one level above, that is, it is single hierarchy design.

ii. The task orientedness of the algorithm, does not allow it to distinguish on incoming data/input of the nodes.

iii. The algorithm does not mention of fault detection and recovery methods in WSNs.

- The architecture of WSNs should to accommodate three features:

  i. **Scalability:** Bigger area based Wireless Sensor Networks depend on hundreds of small sensor nodes for collecting data from the physical world[17]. All the sensor nodes may not be required to be working continuously, so addition of sensors and removal of sensors from the network can be done dynamically [18]. A long term and extensible design enables alteration in the topology with a reduced of updating of transmitted messages.

  ii. **Task Orientation:** The WSNs correlate with assigned operations at present stage. The operations of WSN vary from the simple data collection, static nodes to complex collection of data, using mobile-node sensor network [19, 17]. The structure of the program must be made efficient and enhanced, based on specified task-set of every node, to be adjusted to this specification.

  iii. **Light Weighting:** The processing power and memory - which enables storing data for sensor nodes are very restricted. Tasks like data collection, reducing size of the message, acknowledgement using piggyback, etc. that are lightweight, must be incorporated in the architecture design.

- Study of Ad-Hoc Mobile Networks

  A protocol, that is suitable with SNMPv3-simple network management protocol, version 3; known as Ad-hoc network management protocol (ANMP), is discussed here. It uses same PDU-protocol data units for data collection. This protocol also integrates sophisticated security mechanisms that is improved to fulfill specific requirements[20].Certain properties of ad-hoc networks pose challenge to manage them. Some of their properties are as following:

– Nodes range in complexity, from simple sensor nodes to complex laptops as nodes.

– In mobile networks, topology changes very frequently.

– Network management overhead should consume minimum energy, as ad-hoc networks run on battery.

– Frequent partitioning of networks, due to switching off/moving out of region should be taken care off.

– Signal quality varies dynamically.

– Frequent attacks from hostile agents - eavesdropping, penetration, snooping, etc. need to be handled.

Properties	**Implications in ANMP**
Variability in node capability:	Inherently heterogeneous network
Nodes are mobile:	Need for topology update
Battery operated:	Minimized message and processing overhead
Possibility of partition:	Partitioned sub-network need to operate autonomously
Variable link quality	Robust to high packet loss
Inherently insecure network:	Encryption needed
Potential for node tampering:	Build trust in untrustworthy environment

Table 2.1: Implications in ANMP for respective properties of Ad-Hoc network

- LEACH (Low-Energy Adaptive Clustering Hierarchy)Protocol [14]

  LEACH is an application-specific protocol architecture[21, 22]. It is designed to supports application that are based on microsensor networks, used for monitoring remote physical environment. Each nodes' data are often redundant and co-related in such networks, while the end user does not desire the repetitive elaborate data. Thus the nodes are featured with data aggregation and compression techniques, utilized to aggregate multiple correlating signals of data into tinier sized sets of data that maintain the effectiveness of data (i.e., the content of information) of the original signals[23]. The correlation is the most firm in between signals from sensor nodes that are positioned near each other. Thus it is a logical choice in LEACH to adapt clustering of nodes as infrastructure. This enables much less data that is needed to be transferred from the cluster head to the Base Station.

LEACH works with the principle that all the nodes arranges itself into smaller clusters on a local scale and a single sensor node pretends to be the CH. All the other non-CH nodes need to communicate their information to the CH. The CH accepts information from entire cluster, that is the other nodes, it performs data collection,and then sends the information to the sink, the Base Station. Hence, becoming a cluster head (CH) is lot more energy consuming than a non-CH node. When the CH exhausts it energy and it cannot operate any longer, then it affects whole of the network as all the nodes that are belonging to that cluster donot have any means to communicate. So in LEACH there is a system of random rotation of high-energy nodes, the CH's position among other sensor nodes, to prevent the emptying the energy of any one node in the entire network. Thus the energy overhead in acting as a CH is uniformly divided between all the sensor nodes. LEACH operates by dividing the functioning into rounds. The round in LEACH initiates with a set-up phase. This consists the formation of clusters by selection of cluster head and assignment of each node to a definite CH in the network. This is accompanied by a steady-state, in which information is transmitted from sensor nodes to Cluster Head and then to the Base Station by the Cluster Head.[14]

According to LEACH Protocol for WSNs, the chance of being selected as a Cluster Head is dependent on a node's energy level which is compared proportional to the total remaining energy of the network. The choice of probabilistic method for choosing a CH is developed on the claim that all the sensor nodes will begin operation with same value of energy, and also every sensor node is having information to transmit to CH while each and every frame of a round. In case sensor nodes differ in amount of total energy (or in case an event-driven model is utilized, in which sensor nodes will transmit information only when an event shall happen in the physical surrounding), then the node with extra residual energy can be selected as the CH, more often than the nodes with less amount of total energy. This will take care that all the sensor nodes run out their total energy more or less at the same time, thus the network will last for longer time. The aim is accomplished by using the chance of a node becoming a Cluster Head, as a function of a node's remaining energy in comparison to the total energy leftover in the network, instead of it being a function of the count of the sensor node already being the Cluster Head. Thus the formula is given as[14]:

$$P_i(t) = \left\{ \frac{E_i(t)}{E_{total}(t)} k \right\} \tag{2.1}$$

where $E_i(t)$ is the current energy of node i and

$$E_{total}(t) = \sum_{i=1}^{N} E_i(t) \tag{2.2}$$

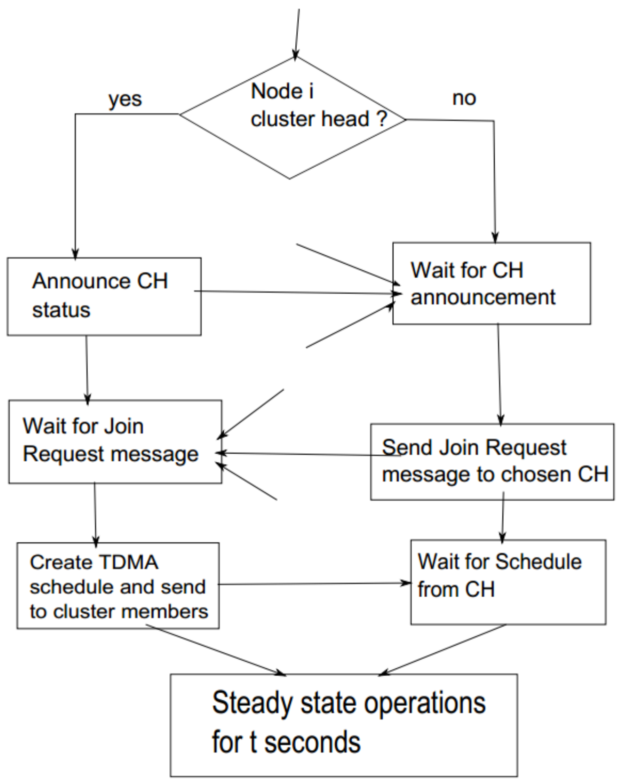

Figure 2.2: Cluster formation in Leach

LEACH has a few drawbacks as mentioned:

- The time duration of setup-phase cannot be determined. The collisions cause too much delay, therefore the sensing service is interrupted.This may cause LEACH to be unstable during the setup phase.
- LEACH Protocol cannot be applied to networks that are used in a gigantic field area, as it utilizes one hop routing in which each sensor node transmits information immediately to the CH, that in turn transfers to the BS.
- The CH nodes in a LEACH round use up a big volume of energy if the locations are far from the BS.
- Leach cannot give a assure that CH will be distributed uniformly.
- Leach makes use of dynamic clustering, thus resulting in added overhead such as the CH change,Ch advertising, etc. which increases the energy expense.

- LEACH - C (Low-Energy Adaptive Clustering Hierarchy - C)[14] In the *Set-up phase* of LEACH-C - every node transmits data regarding its present position (mostly established throguh a GPS receiver) and its energy level to the BS. The BS calculates the mean node energy, and any nodes that have energy greater than mean is a candidate for CH selection. Using these "candidate CH" nodes, the BS finds k-optimal clusters by simulated annealing algorithm [24]. BS distributes data comprising of the ID of cluster head for every node. The *Steady-state* phase of LEACH-C is similar as the *Steady-state* phase of LEACH.

- Appropriate choosing of CH can decrease energy usage significantly and prolong the life of the networks. A few clustering algorithms make use of fuzzy logic to manage expected states in network, where fuzzy logic is employed to blending different clustering parameters, thus enable selection of CHs. To combat the defects of LEACH, Gupta et al. [25] has proposed the use of three fuzzy descriptors namely - centrality, concentration, and residual energy for choosing the CH, where concentration means the count of node sensors lying in the neighborhood. Centrality here means a measure which will classify the nodes depending on how near to the center, the node lies. For each round, each node passes its cluster data to the BS for whom the Cluster Heads have been elected centrally. But this is a centralized mechanism. A similar kind of approach CHEF-Cluster Head Election mechanism using Fuzzy logic was proposed by Kim et al. [26] but it works in a distributed fashion, in which it uses two fuzzy descriptors namely-*residual energy* and *local distance*. The total distance between the temporary Cluster Head and the nodes in the considered competition diameter is the Local distance. This reduces the burden of the BS of collecting cluster data among every other node. Choosing a CH is not an easy job in various physical environments which have varied characteristics. Thus Annoet al.[27] deployed various fuzzy descriptors such as battery energy remaining, neighboring sensor nodes count, cluster centroid distance and network traffics. Using these metrics the performance is evaluated. The sensor nodes close to the BS consume significantly more energy because of the significantly more traffic close to the BS. Therefore the nodes near the BS drain out of battery faster. Along with residual energy, Bagci et al.[28] also took into consideration a fuzzy descriptor, *distance* from the BS, for choosing of the CH.

- LEACH-ERE (Expected Residual Energy) proposes that Cluster Head can also be selected based on Expected Residual Energy (ERE) of a node after the current set-up(round) has been . Thus it uses the below mentioned formulas to approximate the *expected consumed energy* and *expected residual energy* respectively:

$$E_{expConsumed}(l, d_{toBS}, n) = N_{frame} * (E_{Tx}(l, d_{toBS}) + n * R_{Rx}(l)) \tag{2.3}$$

$$E_{expResidual}(l, d_{toBS}, n) = E_{residual} - E_{expConsumed} \tag{2.4}$$

  The chances of becoming a CH for a node is evaluated on the basis of fuzzy logic table for ERE and Residual energy [29].

- Multi-hop LEACH-The physical distance among the CH and the BS increases enormously when the network radius increases many-fold. In this case, energy efficient output of the network can be significantly raised by using multi-hop system for communication in the clustered network. Multihop-Leach being a clustering algorithm for completely distributed system and design, multi-hop approach is deployed inside as well as outside of the cluster network [30].

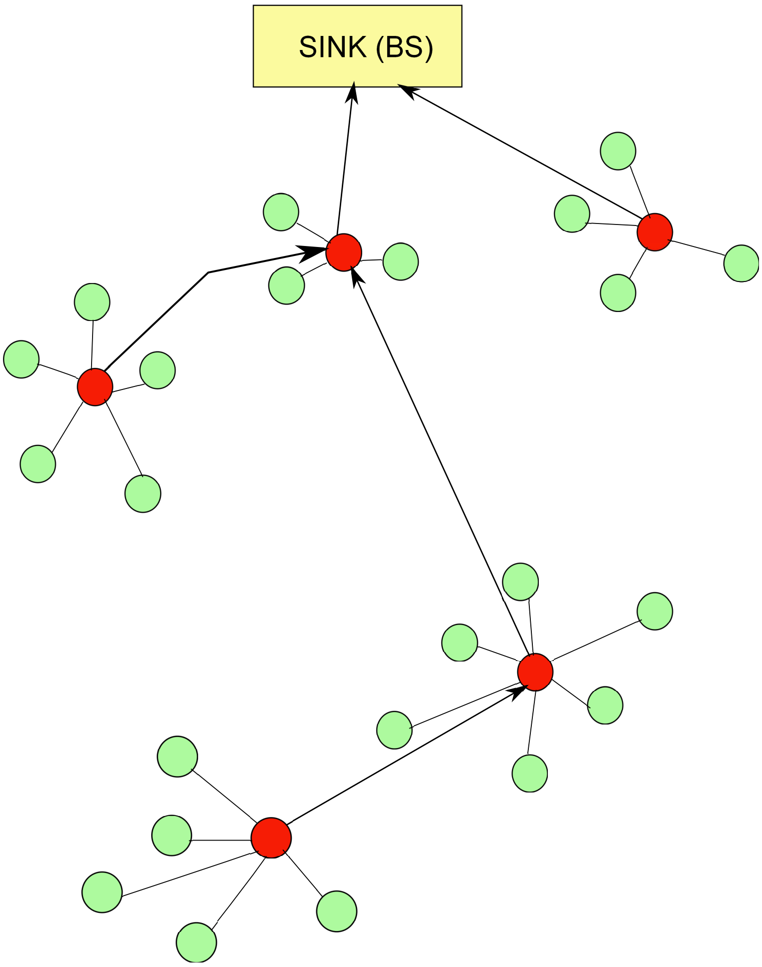

Figure 2.3: Topology for Multi-hop LEACH

- LEACH-F(Fixed number of clusters Low Energy Adaptive Clustering Hierarchy)In LEACH-F, the clusters are formed only one time in whole life time and are made fixed. Thus the setup overhead at the starting of every round is eradicated.The protocol uses that centralized cluster formation algorithm which is used in Leach-C in selecting the clusters.For the Leach-F protocol ,adding new sensor nodes to the network is not possible as they do not adjust with the increasing number of dying nodes. Even LEACH-F cannot manage the mobility of sensor nodes. The position of the CH is put under rotation with the other nodes in the cluster. LEACH-F can or cannot be energy optimizing. LEACH-F uses a stable cluster concept with rotation of CH in which the cluster once formed is constant all through the life of sensor network[31].

- LEACH-E-(Energy Low Energy Adaptive Clustering Hierarchy-Enhanced) It is an improvement for the existing LEACH. In this algorithm, there is a CH selection process where nodes are given unequal initial energy. The node sensors have global info on the location of other nodes so that they can reduce to minimum the total consumption of energy. The demanded number of CHs needs to be scaled to *square root of total number of sensor nodes* which may be decided by LEACH-E. By considering residue energy for sensor node as the prime factor, the algorithm decides if the node can be CH or not in the following round[31].

- LEACH-B-(Balanced Low Energy Adaptive Clustering Hierarchy)makes use of a decentralized algorithm of cluster formation so that each node knows its own location but receiver node is not aware of the location of every node. Leach-B includes - formation of Cluster and transmission of data with multiple access, evaluation of the energy exhausted in route to final receiver and selection of CH for each node by itself. Leach-B is more efficient than LEACH[31].

- LEACH-A(Advanced Low Energy Adaptive Clustering Hierarchy)
  In LEACH the CH expends greater amount energy than any other node of the cluster. Therefore, energy conservation and reliability of transfer of data is improvised in LEACH-A. Here the data is worked on using a mobile agent strategy which is derived from LEACH. It is a heterogeneous energy protocol, which is suggested to reduce the node's failure rate and to elongate the life of the first sensor node. This is called stability period[32]

- LEACH-M-(Mobile - Low Energy Adaptive Clustering Hierarchy) Mobility support is quite significant matter in LEACH. In Leach-M, the algorithm solves this problem by involving the mobile non-CH nodes and CH nodes for the steady

Table 2.2: Comparison of Performance LEACH & LEACH−C Protocols

state and setup phase. Sensors of Leach-M are presumed to be homogeneous, having their position data, with the help of a GPS system. The least mobility and least attenuation mode is chosen as cluster head. This elected CHs broadcast their status to all sensors in their transmission range[31].

2.2 Background

Research being done in the area of WSNs focus mostly on energy aware computing and distributed computing for the sensor nodes. Routing in WSNs differs from conventional routing in fixed network in various ways: Infrastructure is not available in WSNs, links are not reliable as they are wireless, sensor nodes fail frequently, light weight independent modular algorithm should be designed and routing protocols should combat with strict saving energy efficiency of the network. The protocols for routing in WSNs have to ensure distributed execution and reliability in multi-hop system in such conditions.

The substantial distributive routing protocol, based on clusters-LEACH has a few short comings when compared to LEACH-C [13]:

2.3 Design Challenges

- **Heterogeneous Nodes:** The sensor devices deployed in area maybe of various types and they need to collaborate with each other.

- **Distributed Algorithms:** The algorithms should be of distributed type as they are executed on different nodes.

- **Low Bandwidth Communication:** The data should be transferred with least possible bandwidth, between sensor nodes.

LEACH	**LEACH-C**
It is a distributed clustering algorithm.	It is a centralized clustering algorithm
Any node can choose itself as a cluster head independent of other nodes.	Cluster heads are elected by base station
Cluster heads are elected based on Probabilistic threshold that is randomly chosen by the node.	BS runs centralized cluster formation algorithm to elect CHs based on energy level of a node and its distance from BS
It is neither guaranteed that desired number of cluster heads will be formed nor even distribution of cluster heads in the network.	It is guaranteed that desired number of cluster heads will be created and evenly distributed among the nodes in the network.
Set up phase consists of choosing cluster heads randomly, such that every node becomes cluster head at least once.	Every node may not get a chance to become CH, and same node may become CH for the next rounds as BS takes control of network.
Life time of network will be less compared to that of LEACH-C	Life time of network will be more compared to that of LEACH
Start up energy dissipation will be less compared to that of LEACH-C	Start up energy dissipation will be more compared to that of LEACH
Data signals received at BS will be less compared to that of LEACH-C	Data signals received at BS will be more compared to that of LEACH
Total energy dissipation will be more compared to that of LEACH-C	Total energy dissipation will be less compared to that of LEACH

- **Coordination:** The sensors should coordinate with each other and the Base Station to produce required results.

- **Utilization of Sensors:** The sensors should be utilized in a ways that they give maximum performance with least energy consumption.

- **Real Time Computation:** The computation should be done in real-time and fast as new data is being continuously generated.

2.4 Motivation

- The energy expense of a node is dependent on the distance to which the node transmits its energy, because when the distance of transmission is greater than a factor d_0 then the energy consumption grows by a factor d^4.

- LEACH-C is more energy efficient than LEACH [30], primarily because LEACH does not generate uniformly distributed clusters in every round and does not consider the nodes' distance from BS.

- In LEACH-C the Cluster Head selection process is run at Base Station, which is assumed to have infinite energy as compared to nodes' energy. Thus any WSN process run at the BS does not generate energy overhead to the network nodes, except the minimal node information that is communicated to BS by node.

2.5 Objective

- To develop an effective selection protocol that chooses Cluster Heads based on the geographical location of node and its remaining energy.

- The algorithm is a centralized protocol for Cluster Head selection in WSN, which is run at the base station, thus reducing the nodes' energy consumption and increasing their life-time.

- Improvement on centralized LEACH based on Energy and Distance, which is run periodically at the base station where a new set of cluster heads are selected at every round, thus efficiently distributing the energy load in the network.

Chapter 3

PROPOSED WORK

A Wireless sensor network is a set of affordable battery-powered devices- the sensors which are deployed to detect events which are of a predefined manner and sending sensed information to the BS for even more introspection. They have integrated computing, sensing, and wireless communication capabilities[33]. It has been observed that WSNs have huge potentials for quite a range of applications like - military monitoring, monitoring the surrounding, infrastructure and facility diagnosis, etc.[17]. It is expected that WSNs have least possible total energy consumption and that they balance energy consumption for individual sensor nodes. For Wireless Sensor Networks, the most important design task is to increase the life of network without sacrificing sensing and other network goals.

The entire life of a wireless sensor network may be determined as the time started from the first sensor node in the network consumes its energy, because when one sensor node goes off, the sensing capacity of the network begins to degrade [34]. To help maintain maximum life for a network , an energy-efficient routing algorithm has to be utilized for the purpose of communicating data. The algorithm should have the these three primary characteristics [35]:

i. minimum usage of total energy

ii. balanced consumption of energy

iii. characteristics in a distributed manner

For energy efficient information collection and transmission, wireless sensor networks (WSNs) use routing techniques, such that networks are partitioned into clusters.

This enables the network to have a prolonged life.

Clustering approaches that are presently being uses make use of 2 methods: selection of a CH with more left over energy, and rotation of CH periodically so that the energy consumption among nodes is distributed and thus the lifetime of network is extended.

The work done is the output of three observations. Firstly the energy expense of a node is dependent on the distance to which the node transmits its energy, because when the distance of transmission is greater than a factor d_0 then the energy consumption grows by d^4, the details of which is in the Radio Energy Dissipation model. The second observation is that LEACH-C is more energy efficient than LEACH[13], primarily because LEACH does not generate uniformly distributed clusters in every round and does not consider the nodes' energy and distance from BS. The third observation is that LEACH uses dynamic clustering which results in extra overhead such transmission of advertisement and receiving join requests that reduces the energy consumption gain; whereas this overhead is curbed in LEACH-C in which the Cluster Head selection process is run at Base Station, which is assumed to have infinite energy as compared to nodes' energy. Thus any WSN process run at the BS does not generate energy overhead to the network nodes, except the minimal node information that is communicated to BS by node.

3.1 The Radio Energy Dissipation Model

This work adopts the first-order radio model to calculate the energy dissipation. For transmitter circuit, when the distance between the transmitter and receiver is less than the threshold value d_0, the free space (fs) model is employed, in which the energy consumption is proportional to d^2 . Otherwise the multipath (mp) fading channel model is used, where the energy consumption is proportional to d^4. Equation (4.1) shows the volume of energy expended for sending l bit data to d distance, where (4.2) shows the volume of energy spent for accepting l bit data.

$$E_{Tx}(l,d) = \begin{cases} l * E_{elec}^{Tx} + l * \epsilon_{fs} * d^2 & d < d_0 \\ l * E_{elec}^{Tx} + l * \epsilon_{mp} * d^4 & d \geq d_0 \end{cases} \quad (3.1)$$

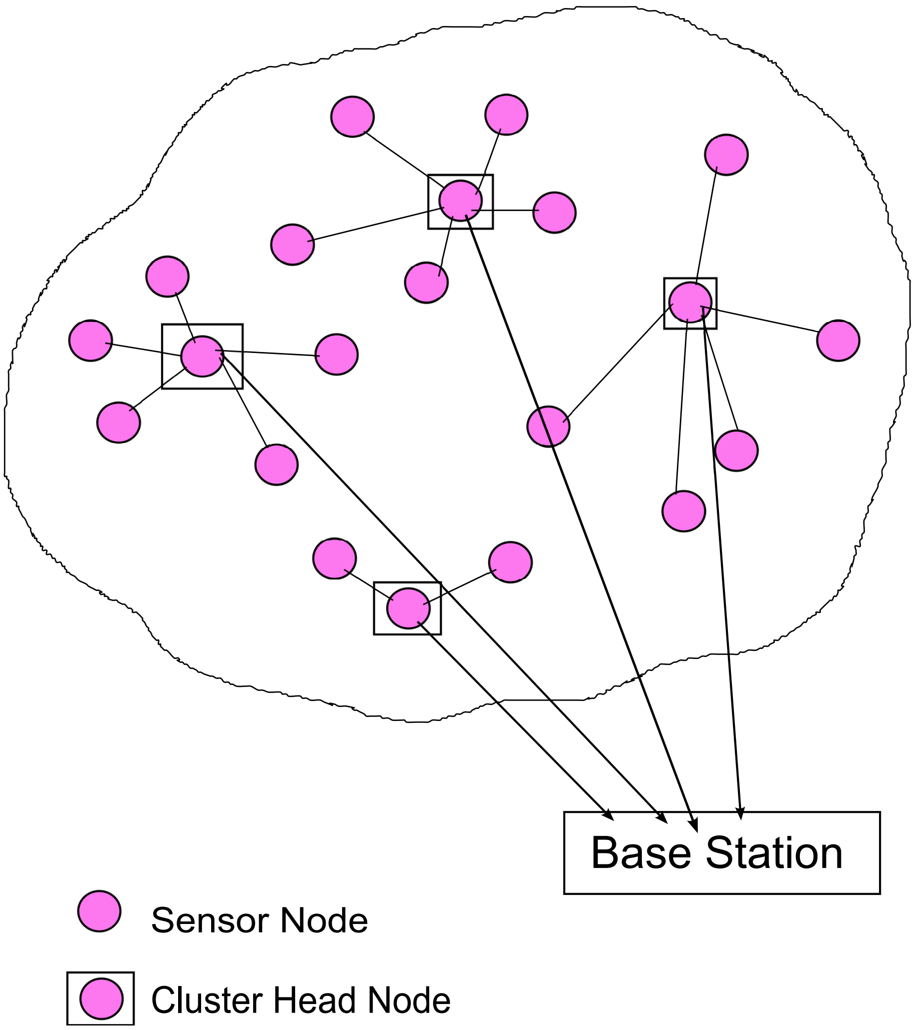

Figure 3.1: Topology Structure for LEACH-C(ED)

$$E_{Rx}(l) = l * E_{elec}^{Rx} \tag{3.2}$$

where $d_0 = \sqrt{\frac{\epsilon fs}{\epsilon mp}}$, ϵfs and ϵmp are the energy usage factor of amplification for - free space and multipath radio models, respectively; which depends on the distance of the receiver and the acceptable bit-error rate.

In the transmitter and receiver circuit E_{elec}^{Tx} and E_{elec}^{Rx} are the electronics energy consumptions per bit respectively, which relies on characteristics like the modulation, digital coding, spreading of the signal, and filtering. [36]

3.2 System Assumptions

We consider WSN implementations in where sensor nodes are put up in a random order so that the environment is monitored continuously. The data accumulated by sensor nodes is transmitted to a BS situated in exterior of the chosen area. Every sensor node can function either in sensing mode to check the surrounding and send it to the allotted CH or in Cluster Head mode to collect data, squeeze it and send it to the BS. The additional presumption are as follows:

- The sensor nodes and BS are immobile.
- All the nodes possess the equal energy initially.
- All nodes are given unique identifier.
- The distance among nodes is calculated depending on the received strength of signal.
- All nodes have ability to compute their respective distance from base-station, based on GPS or other location detection scheme.
- All nodes are part of event driven WSN model.

3.3 Fuzzy Inference System for the Protocol

The work has used the Mamdani Fuzzy Inference Systems (FIS) to calculate the chance for each node, which is the chance of the node to become the Cluster Head in that particular round. As depicted in Fig.3.2, two variables are input for the FIS, which are the $CurrentEnergy$ of the node and the $Distance$ of the node from base station, and the one and only output parameter for the node is the probability for being selected CH for the round. This is named chance. Higher the value of chance, the more is the node's chance to become CH.

The fuzzy membership set describing the CurrentEnergy input variable is depicted in Fig.3.3. Here the linguistic variables used for describing the fuzzy set are as follows: *high*, *ratherhigh*, *medium*, *ratherlow* and *low*. Trapezoidal membership functions

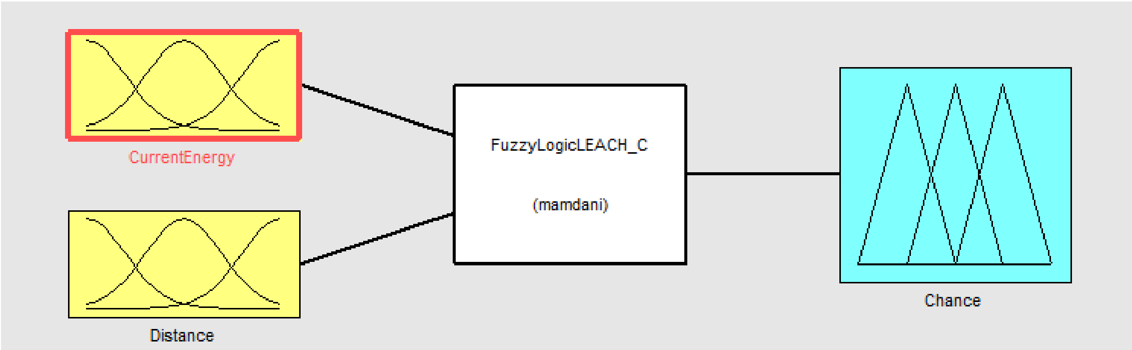

Figure 3.2: Fuzzy Inference System for LEACH-C(ED)

are used for high variable and low variable,whereas triangular membership functions are used for each of the other linguistic variables in the input set. The second input variable is the Distance of the node from BS. The fuzzy membership set that chalks the Distance input variable is shown in Fig.3.4. *High* and *low* linguistic variables are used for this set. For both of high and low a trapezoidal membership function is utilized. The the chance of a CH candidate is the only fuzzy output variable. The fuzzy membership set defined for the output-chance, is shown in Fig.3.5. There are seven linguistic variables used in this set. They are *veryhigh*, *high*, *ratherhigh*, *medium*, *ratherlow*, *low* and *verylow*. Very high and very low are represented by trapezoidal membership function while the other linguistic variables are shown with the help of triangular membership functions. Triangular and trapezoidal membership functions are purposefully chosen here to reducing the cost of computation.

The calculation of chance is done using fuzzy if-then mapping rules, that is defined in the fuzzy tool box, so that the uncertainties are handled. On the basis of the two fuzzy input variables, 10 fuzzy mapping rules are declared in Table 3.1. The fuzzy rules define and derive the chance variable. This fuzzy output variable has to be converted into a crisp values to be used in practice. This approach uses the center of area (COA) method for defuzzification in the chance variable. The fuzzy rules are derived either from the heuristics of problem or from the experimental observable data available.

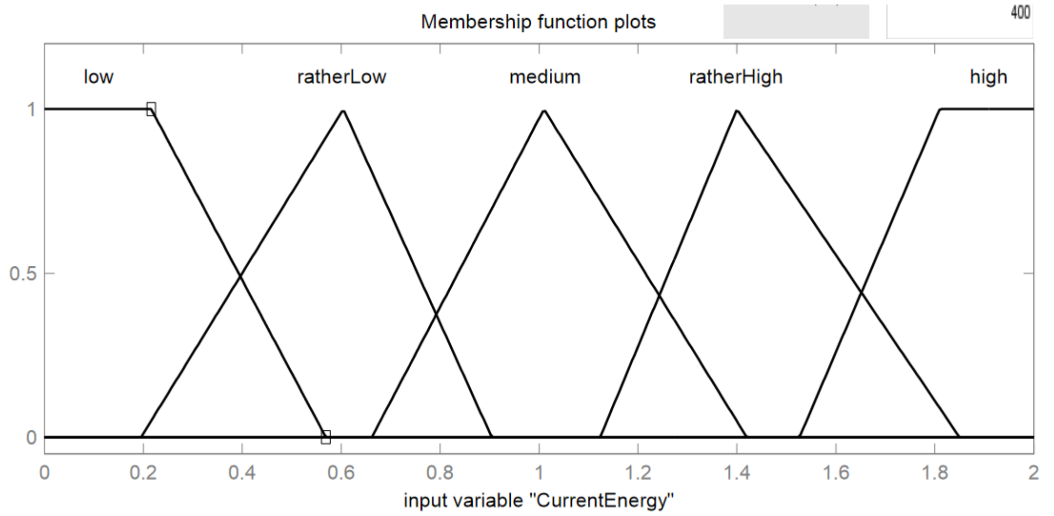

Figure 3.3: Fuzzy Membership set for Current Energy

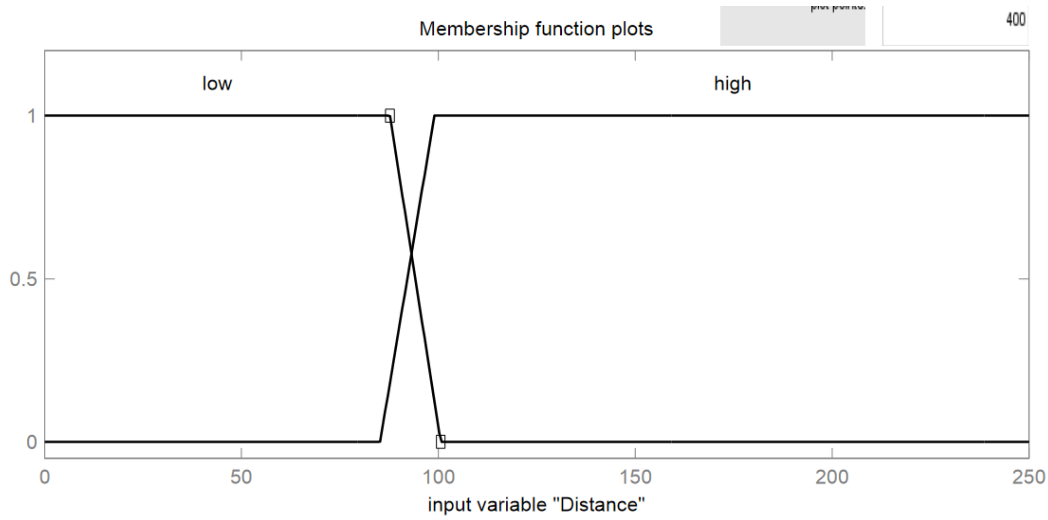

Figure 3.4: Fuzzy Membership set for Distance

In this work, heuristic based fuzzy logic rules are generated. the principle used is: A node whos Current Energy is more and who's Distance from BS is lesser(less than d_0) gets a greater chance to become Cluster Head.

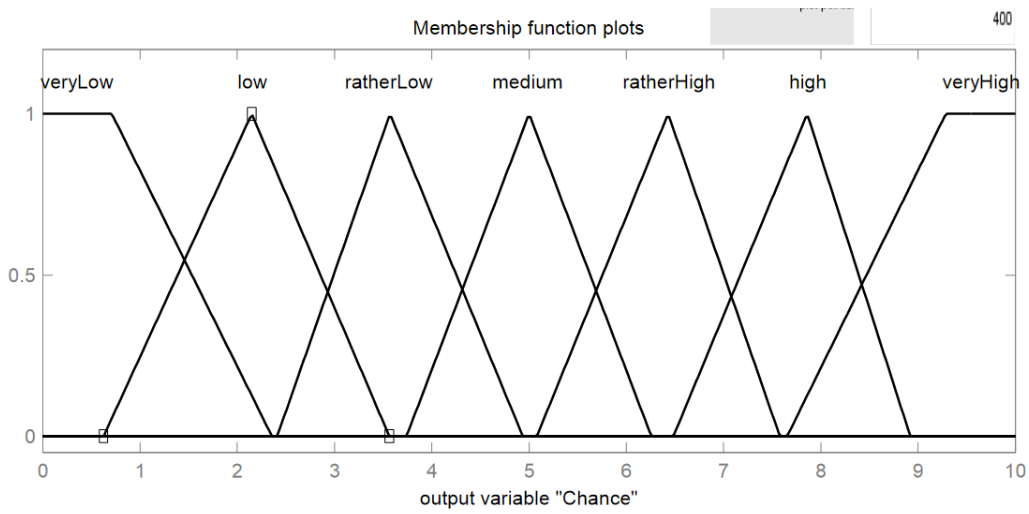

Figure 3.5: Fuzzy Membership set for Chance

	CurrentEnergy	Distance	Chance
1	high	low	veryHigh
2	ratherHigh	low	high
3	medium	low	ratherHigh
4	ratherLow	low	medium
5	low	low	ratherLow
6	high	high	medium
7	ratherHigh	high	ratherLow
8	medium	high	low
9	ratherLow	high	veryLow
10	low	high	veryLow

Table 3.1: Fuzzy Mapping Rules

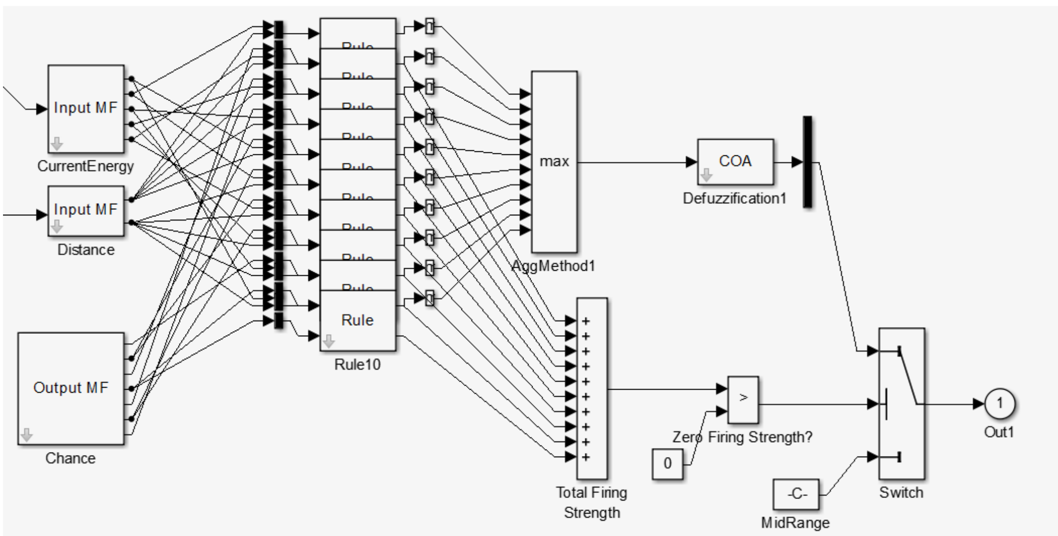

Figure 3.6: FIS Operational Diagram

3.4 Proposed Algorithm

Algorithm 3.1: The Proposed Cluster Head Selection Algorithm

Input:
N: the wireless sensor network
nn: the total number of nodes in N
k: the expected number of clusters for each round
a : a node in N
T: a randomly selected value for becoming a CH candidate
chance(a): the chance of the node to be CH, calculated based on currentEnergy and distance from BS
probability(a): true for the node which has chance(a) value above threshold
bucket(a): the node a is a member for random selection of CH
candidate(a): a is a candidate for cluster head
Output:
cluster(a): the CH of the node, which is a node from among nn nodes
Function:
broadcast(data, range of distance);
send(data, receiver);
fuzzylogic(currentEnergy, distance);
findMinDist(nodesX1[], nodesY1[], nwSize1, nodesX2[], nodesY2[], nwSize2, nodeIndex, clusterIndex) ;

```
/* FOR EVERY CLUSTERING ROUND */
/* SET-UP Phase */
/* AT NODE */
```

```
send(data[currentEnergy, distance], BS);
/* AT BASE-STATION                                                  */
foreach node nn do
    chance(a) < − fuzzylogic(currentEnergy, distance);
    probability(a) ¡- false;
    if (chance(a) > T) then
        probability(a): true;
        count++;
        bucket(a);
    else
        probability(a):false;
    end
end
candidate(a) = random(bucket);  /* k unique nodes are selected
    randomly from "count" number of nodes in "bucket[]", as
    candidate for CH                                                */
cost = findMinDist(nodesX1[], nodesY1[], k, nodesX2[], nodesY2[], nn,
nodeIndex, clusterIndex);
minCost = cost;
itr = count*count;
while itr do
    candidate(a) = random(bucket);  /* k unique nodes are selected
        randomly from "count" number of nodes in "bucket[]", as
        candidate for CH                                            */
    cost = findMinDist(nodesX1[], nodesY1[], k, nodesX2[], nodesY2[], nn,
    chIndex, clusterIndex);
    if (cost < minCost) then
        minCost = cost;
        cluster(a) = clusterIndex(a);
    end
    itr−−;
end
broadcast(cluster[], N);
```

Chapter 4

ANALYTICAL STUDY

As in LEACH and LEACH-C, this proposed cluster head selection method configures clusters in each and every round. The algorithm outlines a new cluster head selection technique, which will be executed at the base station, on receiving the data of nodes' energy and distance from BS. The pseudo code for the Set-up Phase is described in the Algorithm. The Steady Phase will be same as LEACH or LEACH-C. For a given static WSN-N, having nn number of nodes, the expected number of clusters is k. The chance(a) of a node of becoming cluster head is evaluated based on fuzzy logic rules. If the chance of a node is greater than the defined threshold value T, then probability of a node to be CH is true. All the nodes with probability true are put together in the array named bucket.

Then k number of nodes is randomly selected from the bucket. These are the elected CHs. Using the function findMinDist(); which takes as parameter the location co-ordinates of nodes and elected CHs, the cluster head for each of the nn node is decided. The CH for each node is that elected CH, the distance to which from the node is the shortest. Then the sum of distances of all the nodes to their respective CHs is calculated in this function and this sum is returned as the cost.

This process is repeated for predefined *itr* number of times and the minimum cost cluster is saved. Here cluster(a) is an array that stores the CH index of the node *a* from the minimum cost cluster already found. This Cluster Head information is broadcasted in the network by the BS. In the Steady-Phase, as in LEACH and LEACH-C, the CH implements the TDMA schedule for the cluster's member nodes; receives data, aggregates and compresses them and transmits to the sink (BS).

Chapter 5

SIMULATION AND RESULTS

Here in simulation and results section, we present the output of experimental simulations to prove the effectiveness of the proposed approach. The proposed clustering algorithm LEACH-C(ED), is compared with the basic Centralized Cluster-Head selection algorithm LEACH-C. The simulation results prove that the approach selected in the work reveals better performances.

5.1 Simulation Environments

This simulation was deployed using the standard network simulator NS-2.34. There are 100 nodes. They are spread in a random order in a 100 x 100 area. The values that are used in the first order radio model are shown in Table 5.1.

5.2 Simulation Results

Given a fixed Base Station and a 100 nodes fixed topology of Sensor nodes, the number of nodes alive during the time of simulation is compared for LEACH-C and LEACH-C(ED)in the following Fig.5.1 and Fig.5.2.

Fig.5.2 also shows similar characteristics of LEACH-C(ED)in comparison to LEACH-C in Fig.5.1, when BS is at (100,175).

In Fig.5.1, at any point of time during the simulation, the number of nodes alive for LEACH-C(ED)network is more than that of LEACH-C network. It can also be observed that the network for LEACH-C(ED) and LEACH-C die at almost same time.

Type	Parameter	Value
Network topology	Number of nodes	100
	Expected number of clusters	5
	Network coverage	(0, 0) (100, 100) m
Radio Model	Startup energy	2 J
	E^{Tx}_{elec} / E^{Rx}_{elec}	50 nJ/bit
	ϵ_{fs}	10 pJ/bit/m^2
	ϵ_{mp}	0.0013 pJ/bit/m^4
Application	Packet header size	25 bytes
	Data packet size	500 bytes

Figure 5.1: Configuration Parameters used

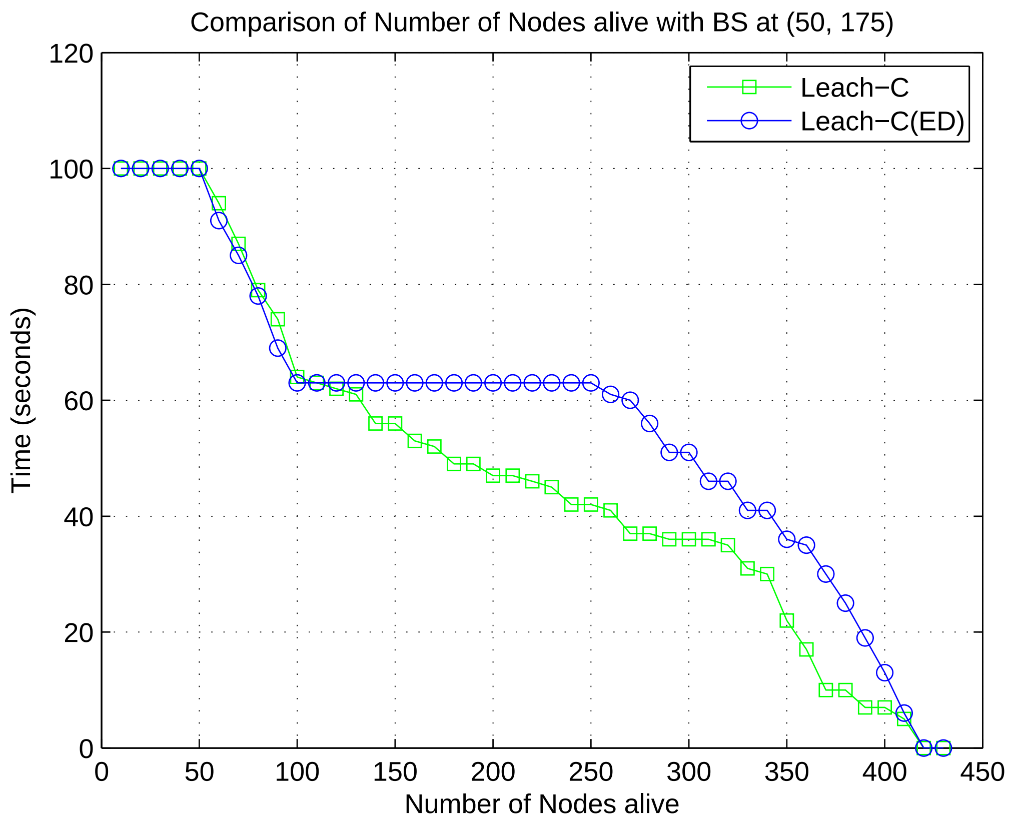

Figure 5.2: Nodes alive when BS is at (50,175)

Handy et al. [37] in their paper, have proposed a metric called *Half* of the *Nodes Alive* (HNA) that describes an approximate value for *time* by when fifty percent of the nodes deplete their full energy content and die. The metric is quite useful for

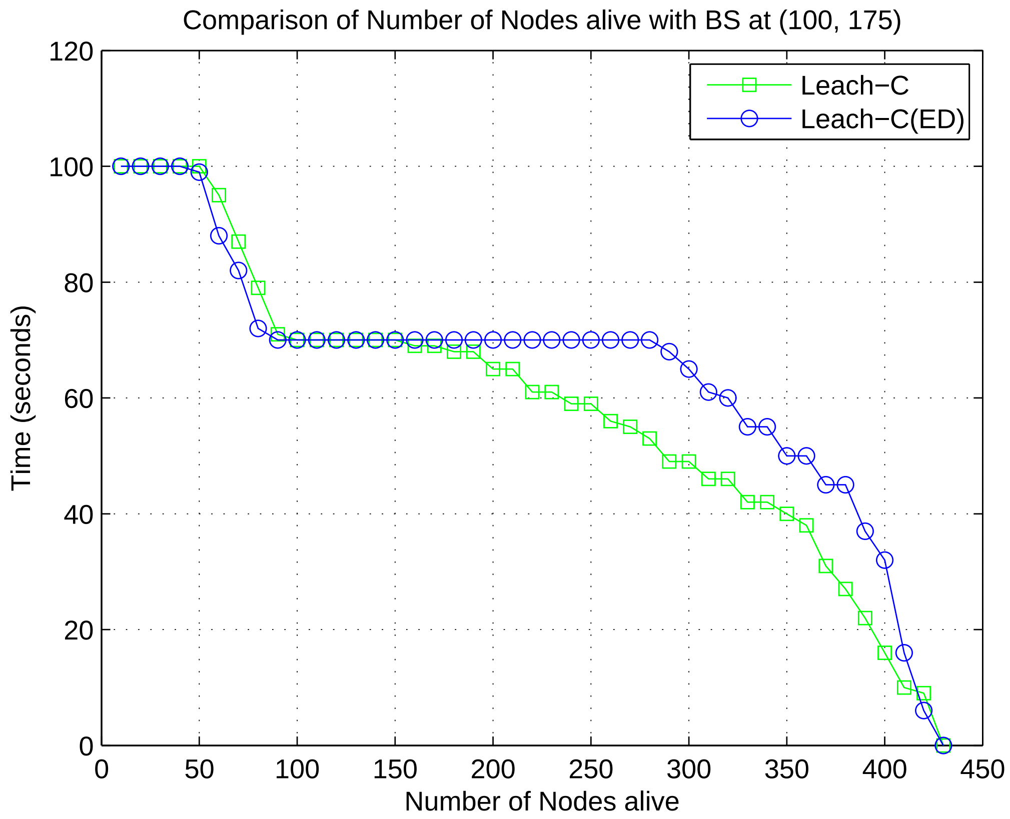

Figure 5.3: Nodes alive when BS is at (100,175)

evaluating sensor networks and comparing WSN algorithms. As shown in Fig.5.3, the proposed LEACH-C(ED) method performs better than LEACH-C.

When the BS is at (50,175)the HNA(Half Node Alive) efficiency of LEACH-C(ED) is 41.71 % more than LEACH-C, and when the BS is at (100,175)the HNA efficiency of LEACH-C(ED) is 20.27 % more than LEACH-C; whereas the total energy consumption of the network under each of the two protocol is almost equivalent.

Fig.5.5 shows that the Half Node Alive(HNA) status of a network under LEACH-C(ED) is always better than LEACH-C, when compared on basis of increasing average distance of Base Stations from the sensor nodes of network.

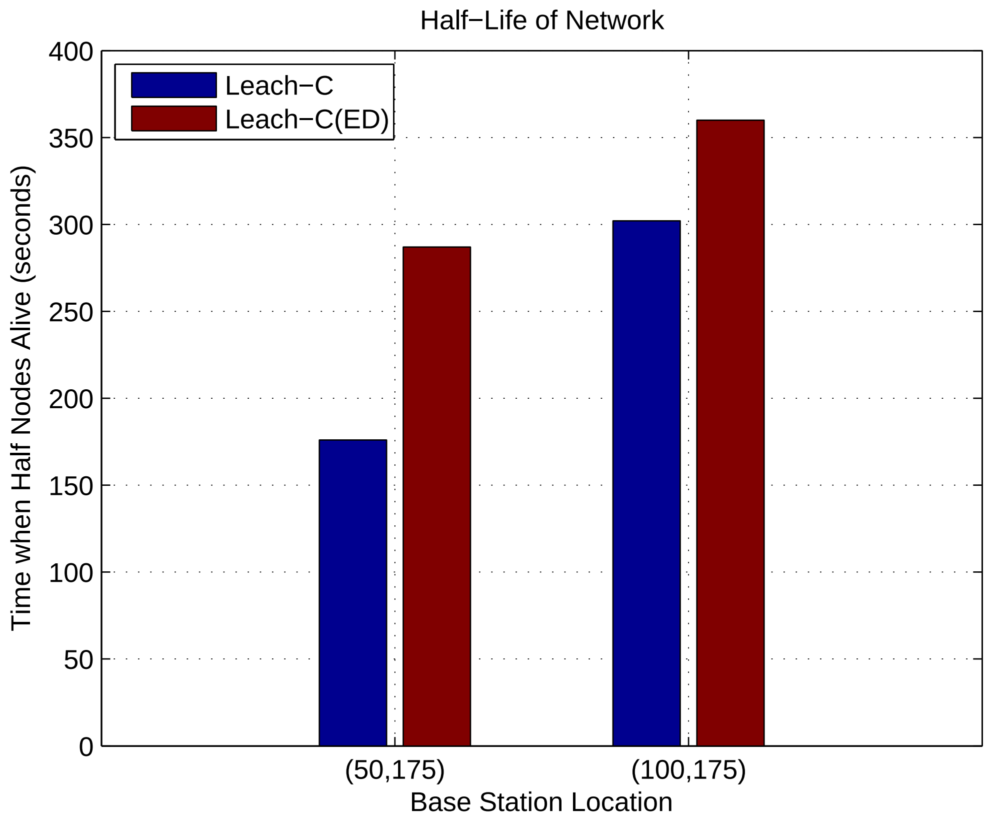

Figure 5.4: Comparison of Half Node Alive(HNA) of the Network under both Protocols

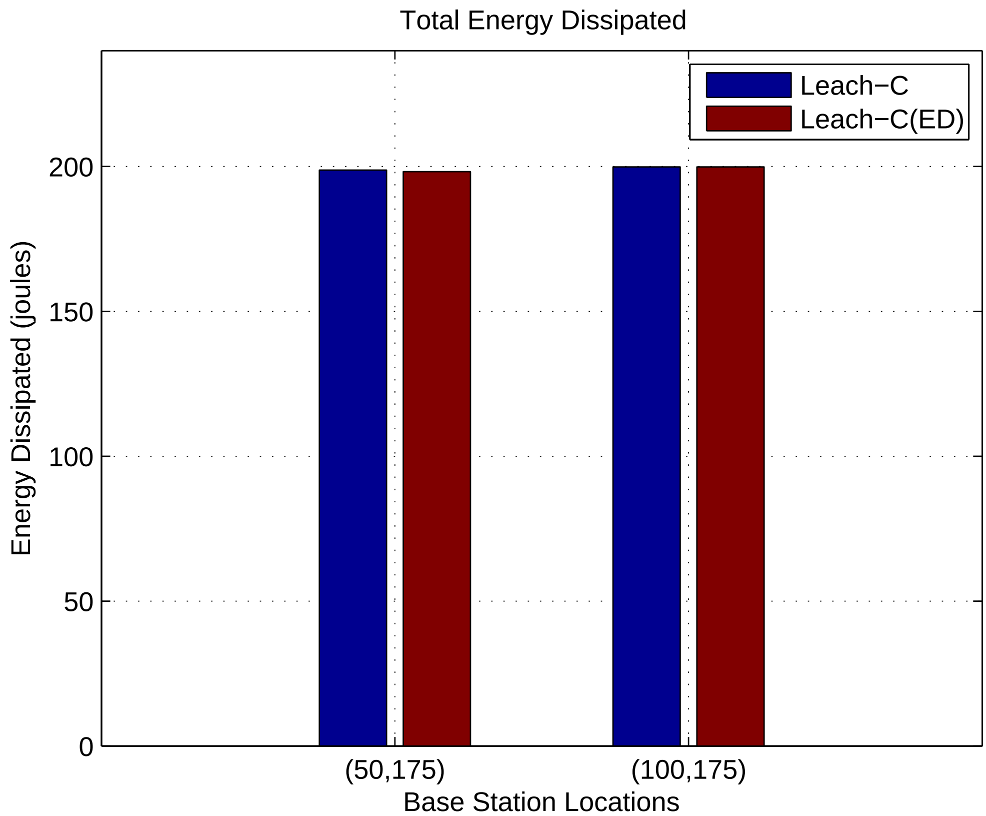

Figure 5.5: Comparison of Total Energy dissipated for same network under both Protocols

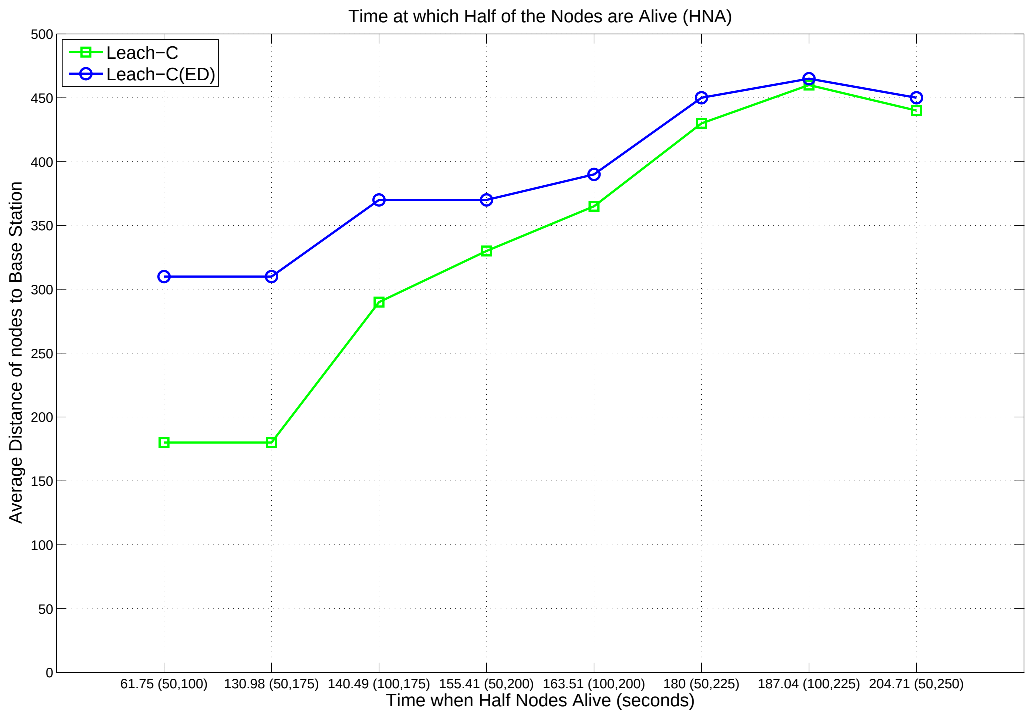

Figure 5.6: Time at which half of the nodes are alive for each of the Base Stations locations

Chapter 6

CONCLUSION AND FUTURE WORKS

6.1 Conclusion

The network life-time, which is dependent on energy remaining in the sensor nodes, is a major factor to be considered when designing WSNs. For an energy efficient WSN, many WSN architectures and clustering algorithms have been proposed among which Leach is a mile-stone. LEACH makes use of the probabilistic model for distributing energy consumption of the CHs among the nodes. The protocol does not guarantee for the placement and count of number for CH nodes. Thus a poor cluster if set-up for a round, may effect the all over performance[38]. LEACH-C is a centrally controlled protocol and produces better cluster forms by spreading the CH nodes all through the network. Along with determining better clusters, the BS also ensures that energy distribution is equally divided among all the sensor nodes.

This work, named LEACH-C(ED) proposes a centralized approach for Cluster Head selection based on fuzzy rules for energy and distance. The main aim of the proposed algorithm is to extend the lifespan of the Wireless Sensor Network by uniforming dividing and spreading the load and to improve the NP hard annealing algorithm, to reduce the execution time at the base-station. To accomplish this target, we have concentrated on predicting the set of nodes eligible for CH selection based on current energy and distance of node from BS, thus reducing the number of iteration and random CH selection steps in LEACH-C algorithm.

At any point of time, the overall number of nodes not dead in the WSN of LEACH-

C(ED) is greater than number of nodes not dead in LEACH-C, for a fixed Base Station.The Half Life of Network under LEACH-C(ED) is much better than LEACH-C.For a network of 100 nodes with Base Station at (50,175), LEACH-C(ED)'s efficiency is 42.72 % better than LEACH-C, when HNA is compared.It is also observed the while the HNA status of LEACH-C(ED) is much better than LEACH-C, the total energy consumption of both the networks is equivalent.The comparison of HNA Status of LEACH-C(ED) with LEACH-C shows that LEACH-C(ED) performs better than LEACH-C for various Base Station locations taken into consideration. Thus the simulation outputs present that the proposed LEACH-C(ED) is more efficient than the centralized algorithm LEACH-C.

6.2 Future Works

This LEACH-C(ED) algorithm is developed and designed for the Wireless Sensor Networks having stationary sensor nodes. As a future work, this protocol can be extended for dealing mobile sensor node networks. Also, future improvements for this work is to integrate this Cluster Head selection approach with multihop Leach[30] which overcomes the scalability limitation of LEACH and LEACH-C. The Algorithm may require improvement for an event driven network scenario, in which the frequency of event is very low.

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