A Major Project-II Report

On

ENERGY AWARE SEP WITH DUAL CLUSTER HEAD AND DUAL SINK APPROACH IN WIRELESS SENSOR NETWORK

Submitted in Partial fulfilment of the Requirement for the Degree of

Master of Technology

in

Computer Science and Engineering

Submitted By

Narendra Singh Harariya

2K16/CSE/08

Under the Guidance of

Mr. Sanjay Kumar

(Assistant Professor)

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahabad Daulatpur, Main Bawana Road,Delhi-110042

June 2018

CERTIFICATE

This is to certify that Project Report entitled **"Energy aware SEP with dual cluster head and dual sink approach in Wireless Sensor Network"** submitted by **Narendra Singh Harariya** (2K16/CSE/08) in partial fulfilment of the requirement for the award of degree Master of Technology (Computer Science and Engineering) is a record of the original work carried out by him under my supervision.

Project Guide
Mr. Sanjay Kumar
Assistant Professor
Department of Computer Science & Engineering
Delhi Technological University

DECLARATION

I hereby declare that the Major Project-II work entitled **“Energy aware SEP with dual cluster head and dual sink approach in Wireless Sensor Network”** which is being submitted to Delhi Technological University, in partial fulfilment of requirements for the award of the degree of Master of Technology (Computer Science and Engineering) is a bona fide report of Major Project-II carried out by me. I have not submitted the matter embodied in this dissertation for the award of any other degree or diploma.

Narendra Singh Harariya
2K16/CSE/08

ACKNOWLEDGEMENT

First of all, I would like to express my deep sense of respect and gratitude to my project supervisor Mr. Sanjay Kumar for providing the opportunity of carrying out this project and being the guiding force behind this work. I am deeply indebted to him for the support, advice and encouragement he provided without which the project could not have been a success.

Secondly, I am grateful to Dr.Rajni Jindal, HOD, Computer Science & Engineering Department, DTU for her immense support. I would also like to acknowledge Delhi Technological University library and staff for providing the right academic resources and environment for this work to be carried out.

Last but not the least I would like to express sincere gratitude to my parents and friends for constantly encouraging me during the completion of work.

Narendra Singh Harariya

Roll No – 216/CSE/08

M. Tech(Computer Science & Engineering)

Delhi Technological University

ABSTRACT

SEP, based on LEACH, focussed on prolonging the stable region - the period before the death of the first node - of the network by taking into consideration a certain level of heterogeneity. We propose a energy aware, dual cluster head approach which improves on SEP in prolonging the stable region. The approach considers the current energy levels of nodes in the election of cluster heads and each cluster has two cluster heads instead of one, with one being used for receiving data from nodes and processing it and the other to send this data to the far-off base station. We also study the effect of introducing dual sink nodes into the network. Compare the performance of the proposed approach with that of traditional protocols like LEACH, SEP, C-LEACH, etc., we found that our approach improves on SEP and other approaches by prolonging the stable region of the network

TABLE OF CONTENTS

List of Figures

List of Tables

List of Abbreviations

1. WSN: Wireless Sensors Network
2. CH: Cluster Head
3. LEACH: Low-Energy Adaptive Clustering Hierarchy
4. PEGASIS: Power-Efficient Gathering in Sensor Information Systems
5. SEP: Stable Election Protocol
6. GAEEP: Genetic Algorithm-based Energy-Efficient Protocol
7. C_LEACH: Centralised LEACH
8. F-LEACH: Frequency based LEACH
9. EAMMH: Energy Aware Multi-Hop Multi-Path Hierarchy
10. TL-LEACH: Two Level LEACH
11. TEEN: Threshold sensitive Energy Efficient sensor Network
12. K-LEACH: K-medoids based LEACH
13. I-LEACH: Improved LEACH
14. V-LEACH: Vice-CH LEACH
15. TDMA: Time Division Multiple Access

CHAPTER 1: INTRODUCTION

1.1 Wireless Sensor Network

Wireless sensor network is an networkment of little battery powered sensors positioned to watch natural or physical conditions or different parameters. A traditional sensors network involves an expansive number of sensor gadgets which are connected to each other wirelessly. The sensors can communicate among themselves using radio transceivers. The sensor gadget is equipped with radio transmitters, computing and sensing extras and power source. The resources in a solitary WSN node are few and limited: they have controlled power supply, constrained radio capacities and restricted on-board computational power. Thus, a WSN framework comprises of an interface that joins wireless network back to the wired system. This gateway is known as the base station or the sink node that additionally performs a large portion of the computational tasks of the system. The base station is expected to have a limitless power supply. The sensor nodes need to exchange their detected information to the sink. They can trade data with the base station directly or through some intermediate sensors.

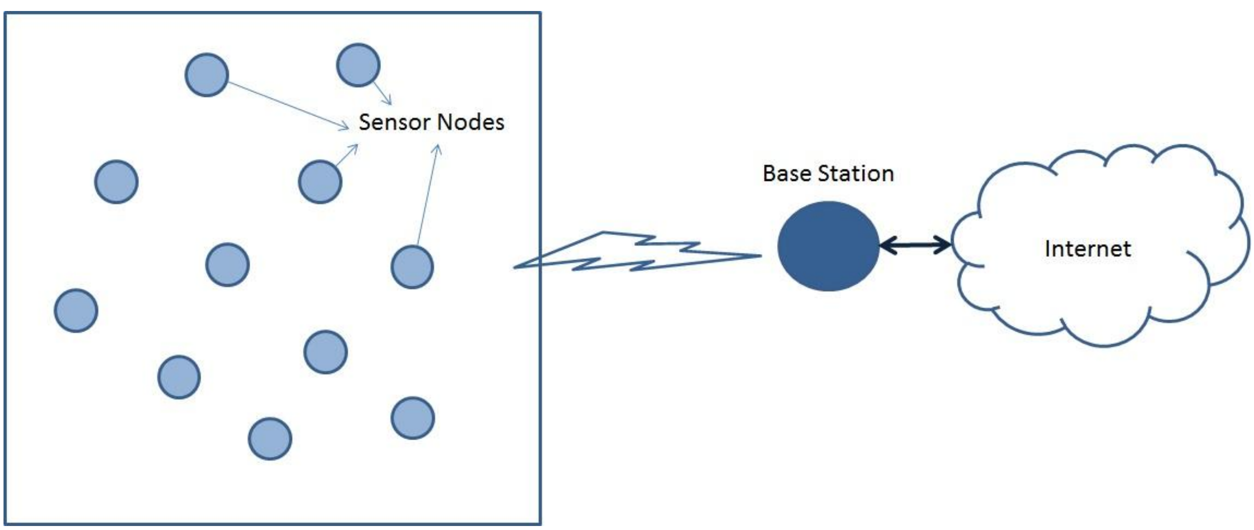

Fig. 1. Wireless Sensor Network

Most of the energy of the sensor nodes is spent on communication among the nodes or with the base station. Thus, the protocols designed for communication is WSNs ought to be energy aware so as to prolong the network lifetime of the system. Different techniques are now available for different applications and implementations of the WSNs. Needless to say, WSNs have a long list of applications now a days as everything eventually is becoming a part of IoT. Most of the time the application of WSN dictates the selection of the wireless model used. Some of the important applications of WSNs are mentioned below.

1.2 Architecture of WSN

The most well-known WSN architecture takes after the OSI engineering Model. It incorporates five layers and three cross layers. For the most part in sensor n/w we require five layers, to be specific application, transport, n/w, information connect and physical layer. The three cross planes are in particular power management, mobility management and task management. These layers of the WSN are utilized to achieve the n/w and influence the sensors to cooperate so as to raise the total effectiveness of the system.

The sensor nodes are generally scattered in the sensor field as exhibited in Fig. 1. All these scattered sensor nodes have the capacities to gather data and course this data to the base station. The traditional stack used by the WSN nodes and the base stations . This tradition stack joins steering and power care, consolidates data with frameworks organization traditions, passes on control adequately through the remote medium and advances supportive undertakings of sensor nodes. The tradition stack includes the physical layer, data link layer, network layer, transport layer, application layer and three administration planes in particular power management, mobility management and task management.

Application layer

The application layer is responsible for traffic management and offers software for various applications that change over the information in an unmistakable frame to discover positive data. Sensor systems orchestrated in various applications in various fields, for example, agrarian, military, condition, medicinal, and so on.

Transport layer

The role of the transport layer is to provide congestion shirking and unwavering quality where a great deal of conventions proposed to offer this capacity are either pragmatic on the upstream. These conventions utilize divergent instruments for misfortune acknowledgment and misfortune recuperation. The vehicle layer is precisely required when a framework is wanted to contact different systems.

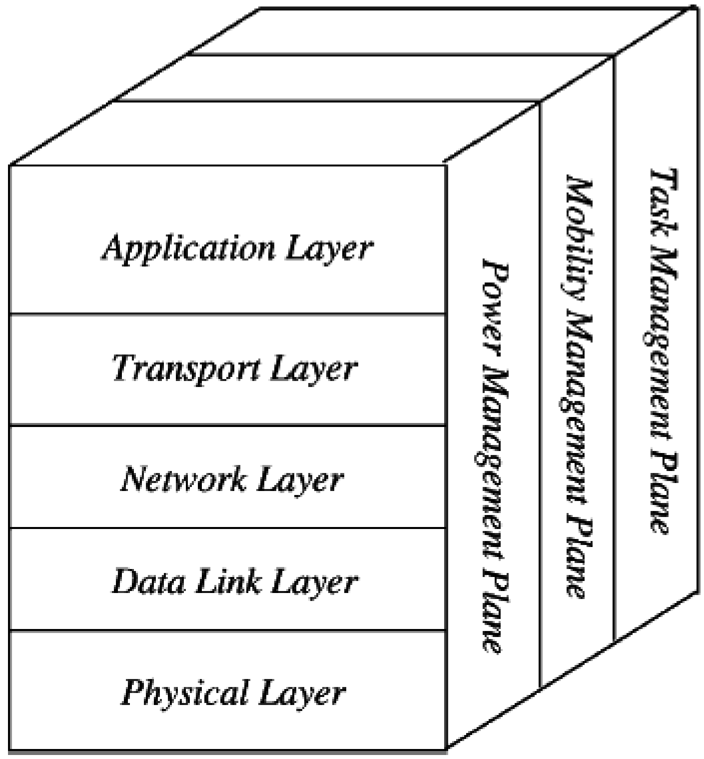

Fig.2. Architecture of WSN

Giving a solid loss recovery is more energy aware and that is one of the fundamental reasons why TCP isn't fit for WSN. All in all, Transport layers can be isolated into Packet driven and Event driven. There are some prominent conventions in the vehicle layer specifically STCP (Sensor Transmission Control Protocol), PORT (Price-Oriented Reliable Transport Protocol) and PSFQ (pump slow fetch quick).

Network layer

The fundamental role of the network layer is routing, it has a considerable measure of errands in light of the application, in any case, the principle undertakings are in the power rationing, partial memory, buffering, and sensor don't have an all inclusive ID and must act self organized.

The basic thought of the routing protocol is to clarify a dependable path and redundant paths, as per a persuaded scale called metric, which fluctuates from protocol to protocol. There are a great deal of existing protocols for this layer, they can be separated into; flat routing and hierarchal routing or can be isolated into time driven, inquiry driven and event driven.

Data link layer

The data link layer is obligated for multiplexing information, frame detection, information streams, MAC and error control, affirm the unwavering quality of point– point (or) point–multipoint.

Physical layer

The physical layer gives an edge to exchanging a stream of bits over physical medium. This layer is in charge of the choice of frequency, bearer frequency, signal recognition, modulation and encryption. IEEE 802.15.4 is proposed as common for low rate specific zones and Wireless sensor connect with ease, control utilization, density, the scope of communication to enhance the battery life. CSMA/CA is utilized to help star and shared topology. There are a few adaptations of IEEE 802.15.4.V.

Generally, the wireless subsystem needs to work in measuring the energy. Along these lines, information is conveyed via the radio system whenever it is required. A calculation has to be stacked in the node to decide when to send information in view of the detected occasion. Besides, it is essential to limit the power devoured by the sensor. Consequently, the equipment ought to be intended to enable the microchip to wisely control energy to the radio, sensor, and sensor flag conditioner.

1.3 Characteristics and advantages of a WSN

The major characteristics of WSNs incorporate the accompanying,

- The utilization of Power limits for nodes with batteries.
- Ability to deal with node disappointments.
- Some portability of nodes and heterogeneity of nodes.
- Adaptability to substantial size of dispersion (scalability).
- Ability to guarantee strict ecological conditions.
- Ease of use.

- Cross-layer model.

Implementation of WSN comes with a great deal of advantages to the user. Some of the advantages of WSNs are,

- System courses of action can be carried out without immobile infrastructure.
- Suitable for remote places like mountains, oceans, dense forests and remote areas.
- Adaptable if there is a circumstance when an extra workstation is required.
- Execution costs are reasonable and flexible.
- It makes do without the use of a lot of wiring.
- Can provide housing for new devices whenever required.
- Can be accessed using a centralized interface.

1.4 Applications of WSN

Sensor systems have gathered wide recognition due to their flexibility in the handling of concerns in different fields and can improve our livelihood in a number of ways. WSNs have historically been successfully associated with diverse application domains, for example:

- Area Monitoring: For examining an area, the nodes are distributed over a field where some phenomenon is to be observed. The moment of time when the sensors recognise some activity (thermal, environmental, chemical, etc.), it is communicated to the base stations, which then undertakes appropriate action.
- Healthcare/Medical applications: Some of the usages for health monitoring using sensors networks incorporate graphic interfaces for the coordinated patient examining, analysis, and managing medication in medical institutions, assessment of an individual's physiological report and inquiring about physicians or patients within a healthcare facility.
- Military usage: WSNs have a wide range of military applications like war zone tracking, force protection, navigation, communications, figuring insight, war-time reconnaissance and surveillance of the hot zones..
- Nature and natural phenomenon sensing:
    - Observing air contamination
    - Wildfire instrumentation and identification

- Habitat monitoring
- Observation of greenhouse effect
- identification of landslide prone zones

- Architectural Monitoring: WSNs are now also employed to monitor the activities inside structures and foundations, which empowers engineering systems and tools to control and manage resources from a remote base; without physically being present at the site.
- Industrial checking: WS networks provide notable cost saving services for machine control remotely, and there is no need for wired connections during installation of sensor and hence saving the wiring expenditure.
- Highway/Traffic observation: Real-time activity data is gathered by wireless sensors networks to then encourage transportation models and ready drivers of clog and traffic problems. The sensors collect traffic flow statistics, like the volume of traffic, highway densities, vehicle speeds, and then send this information through a wireless network to the base station for further processing.

1.5 Challenges of Wireless Sensor Networks

The WSNs face a considerable number of difficulties owing to the sensor nodes and the wireless setting. There are no reliable lines or foundation for communicating. Sensor node application may suffer from the model used. Sensor nodes convey over remote, unreliable lines with no foundation. With the end goal to prolong the lifetime of the WSN, the conventions should accordingly be planned with the goal of proficient administration of the vital resources.

The challenges faced by a WSN are primarily of two types: *challenges due to design and topology* and *challenges in real time like power management, node management, etc.* Below we describe some of these challenges.

Adaptation to internal failure: Sensor nodes are vulnerable to physical damage as a significant part of the time is passed on in dangerous conditions. Sensors can fall as a result of hardware issues or natural causes or by draining their battery capacity. It is foreseen that the node accidents will be impressively more prominent than what is routinely seen in customary remote frameworks or the wired systems as the sensors are deployed in an uncontrolled environment.

Versatility: Sensor systems may change in scale from a few nodes to conceivably a few hundred thousand. What's more, the sending thickness is likewise a factor. For gathering high determination information, the density of nodes may increase up to a certain height when there are many nodes close to each other in the communication zone. Conventions that are being used in the sensor systems must be adaptable to certain standards and have the capacity for keeping up satisfactory execution.

Production Costs: Because numerous networkment models view the sensor nodes as dispensable gadgets, sensor systems can rival with conventional data collection procedures and hence the nodes could be manufactured efficiently.

Equipment Limitations: At the very least, every WSN node needs a transmission, processing and sensing system, and an energy source. Alternatively, the nodes can have implicit sensing equipment or smart gadgets. Notwithstanding, every extra usefulness accompanies extra cost also, builds the power utilisation and physical size of the node. There should be a proper adjustment between the expense and low-energy specifications as per the changing functionalities.

Communication Medium: The correspondence among the sensors is ordinarily actualized utilising wireless medium in the famous industrial, scientific band. Be that as it may, some sensor systems utilise infrared or optical correspondence and former providing the obstruction free robust path.

WSN Topology: Even though WSN have developed in numerous viewpoints, these systems keep on being with restrained assets as far as energy, processing force, memory, and interchanges capacities are concerned Problems like routing holes, an area where there are no nodes or the nodes can't participate in routing, are caused due to the topology of the network. Topology Route control is a standout amongst various critical concerns investigated for diminishing power utilisation of WSN systems.

Energy Dissipation: As we have observed, large portions of the challenges of sensor systems rotate around the restricted power resources as the nodes are battery enabled. The product and equipment configuration requires the consideration of the concerns of effective power utilisation. Just as an example, information pressure may diminish the measure of energy utilised for radio transmission, however, utilises extra energy for calculation as well as separate. The energy network ment likewise relies on upon the application. Sometimes, it is desired to power off a few nodes with a specific end goal to ration energy while different applications require all nodes working at the same time. Most of the research in this field revolves around minimizing the power expend of the senor networks.

1.6 Energy Dissipation problems in a node

Power dissipation is the most essential part to decide the life of a sensor organize since sensor nodes are driven by the battery. A portion of the time control streamlining is more convoluted in sensor frameworks since it included not simply diminishing of intensity dispersal moreover drawing out the life of the framework much as could be normal. The network is made up of multiple small, battery powered, mobile/static, sensor nodes with limited onboard computing and storage. This limits the performance of the network as the network can only work until the batteries of the sensor node die out. Thus, battery drain of the sensor nodes has to be minimized in order to increase the network lifetime of the system. Network lifetime is defined as the amount of time for which the network is up and running. When all of the nodes die, the network stops or dies.

A sensor node fundamentally comprises of four subsystems:

A computing system: It incorporates a micro-chip which is responsible for the sensors and execution of communication traditions. Microcontroller units generally work under various modes for energy management purposes. As these working styles incorporate dissemination of power, the energy dissipation of the distinctive modes should be taken care while considering the nodes battery remaining limit.

Communication system: In this, the short range radio can converse with outside world through neighbouring nodes positioned in the area. Additionally, such radios gadgets can work under the many modes. Accordingly, there is need to close down the radio gadget when it isn't transmitting the information to some other radio set remotely to preserve the power.

Identifying system: The mix of sensors and actuators for the most part associates the few nodes to the outside world. Power expend ought to be decreased after using low power portions and accordingly sparing the power.

Power source system: This subsystem includes a battery which gives power to the node. It should be comprehended that the measure of power drawn from the battery ought to be viewed over. Since if more energy is expended from a similar power hotspot for a long time, the battery will fail horrendously snappier even despite the way that it could have proceeded for a more drawn out time. Regularly the evaluated current breaking point of a battery limit used by sensor node isn't as much as the base Power expenditure. In this way, there are networkments for expanding life expectancy of battery by diminishing the current persistently or by closing down routinely.

For lessening the power dispersal of WSN systems, unmistakable sorts of traditions and counts are present wherever all through the entire domain. The life expectancy of WSN systems must be extended by and large with working structure identified with the application layer. Moreover, the framework traditions are expected to be control careful. These conventions and computations must think about the gear and prepared to use remarkable components of the little scale processors beside handsets to constrain the sensor nodes' energy dissemination. This method may forward the client characterized respond in due order regarding different sorts of sensor nodes designs. Particular sorts of sensor nodes sent also incite unmistakable sorts of sensor frameworks. This may in like manner provoke the particular sorts of network counts in remote sensor frameworks field.

1.7 Routing of data in WSN and its effect on network lifetime

Remote sensor frameworks have augmented striking acknowledgment in view of their versatility in dealing with issues in different fields and can change our vocation in an across the board scope of ways. Remote sensors systems have been effectively connected with various application spaces. Attributable to a colossal number of nodes in the framework and the complexities of the earth, it is intense and even hard to trade or energize batteries for the sensor nodes. Remembering the true objective to suitably utilize remote sensor network we need to decrease the energy expend while cluster generation and amid the trading of data between the WSN nodes and the sink node.

Direct communication

In direct communication, every sensor node sends its data straight to the base station. In the case that the base station is far away from the nodes, the data transfer will require a huge measure of transmission energy from each node which will rapidly deplete the battery of the nodes and lifetime of the system. The role of receiving data happens only at the base station, hence if either the base station is near the nodes or the energy required for receiving data is huge, this might be a worthy technique for communication.

Multi-hop communication

Another approach to convey is through multi-hop communication. Multi-hop communication includes transmission of information to the sink node by means of at least one delegate nodes. The nodes that are more noteworthy separation far from the base station transmit their information to some other node which thusly advances it to another node or the base station. Along these lines of correspondence may jump out at have defeated the constraint of the direct communication, however, it likewise has its own restriction. In this strategy, the nodes that go about as mediator nodes deplete out of energy quicker than other nodes. Consequently the nodes closer to the sink node are more plausible to deplete out of intensity than that are at significantly more noteworthy separation from the base station. So there came a requirement for some other technique for data trade between sensor nodes and the sink nodes. Another issue that ascends during trade of data between sensor nodes and the sink node is the exchange of a considerable measure of repetitive information from sensor nodes to the sink node. The greater part of the information detected by sensors that are close to each other are excess, and this information is sent to the sink node. In the event that some way or another this excess can be expelled, network lifetime can be upgraded numerous folds.

Clustering in WSNs

Multi-hop routing solves a lot of problems that were there in Direct communication, but the problem of redundant data being sent over to the base station still persists. Due to the transmission of this redundant data, more energy is wasted in the transfer than expected. Eliminating this problem will extend the network lifetime of the WSN quite a lot.

The answer for these issues is to cluster the sensors into little gatherings. These gatherings are known as clusters. This apportioning of the remote sensors network into clusters is called as clustering. Every one of the clusters has their head called cluster head. Each and every other individual from the cluster sends its information to its cluster head. The cluster heads may straightforwardly forward every one of the information got to the sink node. Else, it can expel the excess from information gathered and afterward forward it to the sink node. Along these lines clustering takes care of the issue of exchange of excess information from the sensor to base station. The issue of the lopsided system remains if static clustering is utilized. Static clustering implies the clusters once shaped are not changed. The cluster head stays same for the lifetime of the system. Presently since the cluster head disseminates significantly more power than the other sensor nodes, it will deplete out of energy substantially quicker than other nodes. Consequently dynamic clustering is utilized as a part of this postulation. In dynamic clustering, the clusters and the cluster heads continue evolving. The cluster head ought to be picked with care. The execution of the calculation basically relies upon the networking of clusters and choosing the cluster heads.

1.8 Major clustering algorithms as base for analysis

LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH [1] is a self-arranging, versatile clustering protocol. It utilizes randomization for disseminating the power stack among the sensors in the system. The accompanying are the suppositions made in the LEACH convention:

a. All nodes can transmit with enough capacity to achieve the base station.

b. Every node has enough computational capacity to help diverse MAC conventions.

c. Nodes found near each other have associated information.

As per this convention, the base station is settled and situated a long way from the sensor nodes and the nodes are homogeneous and energy compelled. Here, one node called cluster head (CH) goes about as the nearby base station. Drain arbitrarily turns the high-energy cluster head with the goal that the exercises are similarly shared among the sensors and the sensors devour battery control similarly. LEACH moreover performs data aggregation, i.e. compression of information when information is sent from the clusters to the base station hence lessening energy scattering and upgrading framework lifetime. LEACH isolates the aggregate activity into rounds—each round comprising of two stages: set-up stage and stable stage.

In the set-up stage, clusters are framed and a CH is chosen for each cluster. The CH is chosen from the sensor nodes at once with a specific likelihood. Every node creates an arbitrary number from 0 to 1. In the event that this number is lower than the edge node [T(n)] then this specific node turns into a CH.

T(n) is given as takes after:

$$T(n) = \frac{p}{1-p*\left(r mod\left(\frac{1}{p}\right)\right)}, if\ n \in G \quad (1)$$

$$T(n) = 0, otherwise \quad (2)$$

where p is the fraction of nodes that are CHs, r is the current round and G is the set of nodes that have not filled in as cluster head in the previous 1/p rounds.

At that point the CH distributes schedule vacancies to nodes inside its cluster. In stable state stage, nodes send information to their CH amid their distributed schedule vacancy utilizing TDMA. At the point when the cluster head gets information from its cluster, it totals the information and sends the packed information to the BS. Since the BS is far from the CH, it needs high energy for transmitting the information. This affects just the nodes which are CHs and that is the reason the choice of a CH relies upon the rest of the energy of that node.

SEP (Stable Election Protocol)

In SEP [2], the impact of heterogeneity of nodes is examined in remote sensors networks that are dynamically gathered. In these frameworks, a part of the nodes advance toward getting to be cluster heads, add up to the data of their cluster people, likewise, transmit it to the sink. We expect that a rate of the masses of sensor nodes is equipped with additional essentialness resources—this is a wellspring of heterogeneity which may happen from the hidden setting or as the task of the framework creates. We in like manner expect that the sensors are aimlessly (reliably) scattered and are not mobile, the bearings of the sink and the estimations of the sensor field are known. We exhibit that the direct of such sensor frameworks ends up being to a great degree problematic once the principle node kicks the basin, especially inside sight of node heterogeneity. Set up gathering traditions expect that every one of the nodes is outfitted with a comparative measure of imperativeness, and therefore, they can't take the full favoured point of view of the closeness of node heterogeneity. SEP is a heterogeneous-careful tradition to drag out the time break before the death of the principle node (we imply as stability region), which is vital for a few applications where the feedback from the sensor network out must be reliable. SEP relies upon weighted choice probabilities of each node to twist up cluster go to whatever is left of the energy in each node. We show up by diversion that SEP constantly drags out the stable time frame appeared differently in relation to (and that the typical throughput is more conspicuous than) the one got using current clustering traditions. We complete up by concentrating the affectability of our SEP tradition to heterogeneity parameters getting imperativeness abnormality in the system. SEP yields longer stable regions for higher estimations of extra energy brought by more extraordinary nodes.

CHAPTER 2: LITERATURE REVIEW

Improvement of network lifetime in WSNs has been researched with different approaches. Multipath based routing, Query based routing, QoS based routing and Clustering based hierarchical routing are some of the examples. The early research on improving the lifetime were LEACH [1], Directed Diffusion [3] and PEGASIS [4].

In [3], the author proposed a data-centric approach. The nodes in DD are application aware enabling them select energy efficient paths by caching and aggregation with the help of diffusion. In [4], the author, motivated by [1], proposed an optimal chain based approach where each node is communicating only with a close node and they take turn transmitting the data to the base station, reducing the energy spent in a round.

This dissertation is focussed on [1], [2] and their developments. In [1], W. Heinzelman proposed LEACH, a low energy clustering based algorithm where the idea was to distribute the energy spent to all the nodes in order to increase the network lifetime. To achieve this, all the nodes were divided into clusters with each cluster having a head. The head is to communicate with the sink. The role of the cluster head was rotated to every node. The Low-Energy Adaptive Clustering Hierarchy (LEACH) clustering framework is upheld by two key assumptions: (1) All nodes transmit their data to a single sink node; and (2) All nodes have the ability to talk particularly with the sink node. Remembering the true objective to adjust the framework power usage, the LEACH tradition realizes a store altering framework that allows the individual nodes to wind up CH at different rounds. For each round, sort out nodes select an random number in the region of zero and one. The node picks itself as a cluster head set out toward the current round if the number is not as much as the threshold. The formula for the threshold is given in equation (1) and (2).

LEACH beats static clustering counts by obliging nodes to embrace to be high energy cluster heads and changing the relating clusters in perspective of the nodes that are cluster heads at a given time. At different circumstances, each node has the heaviness of anchoring data from the nodes in the gathering, joining the data to get an aggregate banner, and transmitting this aggregate banner to the sink node. LEACH is totally distributed, i.e., it doesn't require any control data from the sink node and the nodes require no data about the worldwide system by and large for LEACH to work. Distributing the energy among the nodes in the framework is practical in diminishing energy dispersal from an overall perspective and extending network lifetime.

The main problem with LEACH was that it was developed only for homogeneous systems without any consideration for heterogeneity. This made it impractical for a majority of applications. Also the cluster head selection does not take into account the residual energy in the nodes making the whole process a little unreasonable.

Then came SEP which took heterogeneity into account as to churn out the more practical solution [2]. It assumed that a fraction of the nodes has higher energy than the rest. It also made a change in the election probability formula to make it heterogeneity aware. This resulted in the widening of the stable period making the network more stable and practical as most of the WSNs employed are heterogeneous and even homogeneous networks show heterogeneity after running for a period of time.

In SEP, every sensor node in a heterogeneous two-level orchestrate independently picks itself as a cluster head in perspective of its energy in regard to that of other nodes. SEP is dynamic in that we don't acknowledge any prior spread of the assorted levels of energies in the sensor nodes. Additionally, our examination of SEP is definitely not simply asymptotic, i.e. the examination applies correspondingly well to smaller systems. SEP does not require any overall data of power at every choice round. Finally SEP is flexible as it doesn't require any data of the right position of each node in the field. The makers have proposed to extend SEP to oversee clustered sensor frameworks with in excess of two levels of the chain of significance and in excess of two sorts of nodes.

Further research on LEACH yielded many variants. In [5], author proposed C-LEACH a centralized approach that required the coordinates of the nodes in the network. The base station, with the knowledge of the coordinates, had the role of create better clusters. It would then choose the nodes with enough energy as the cluster heads and broadcast this info. The drawback being that it needed the coordinates of all the nodes to operate. F-LEACH proposed an approach in which clusters are formed only once and only the cluster heads are rotated in each round [6]. This approach flaws when nodes start dying or there are nodes to be added or removed as the clusters need to be flexible for that.

In [7], the author proposed a Multi-hop multi-path approach. EAMMH organizes the nodes into clusters and establishes multiple paths from each node to the cluster head and then chooses the optimal path using an energy aware heuristic function. TEEN is based on threshold sensitivity [7]. TEEN was the first protocol developed for reactive networks. The cluster head in TEEN broadcasts a hard threshold, absolute value of the sensed attribute beyond which the node starts transmitting, and a soft threshold, a small change in the value of the attribute that triggers the node to transmit, to all the nodes.

Apart from that, there is I-LEACH which proposes the theory of twin nodes, geographically very close nodes [8]. It stated that in the cases of twin nodes, which are frequent in random deployment, one of the nodes should remain off until the energy of the twin goes down. This helps the target area remain under sensing for a longer time. TL-LEACH, on the other hand, employs a two-level hierarchy in that there is an extra cluster head with a sole purpose of collecting the aggregated data from all the cluster heads and then sending it to the sink node [9].

A new research on LEACH followed the path of data fusion [10]. It employed their own data fusion algorithm during the data aggregation in addition with two cluster heads for each cluster. First, the network was divided into cluster by the use of k-medoids technique, then the first cluster head was selected following a procedure similar to that of [1]. The second cluster head was selected as the one nearest to the centroid of the cluster. This approach required the coordinates of the node to be known beforehand making it less suitable for a number of applications. The work depicted in [11] proposed V-LEACH (Vice-CH LEACH) tradition. In V-LEACH, other than having a CH in the gathering, the sensor network also comprises of a vice-cluster head that fills the role of the cluster head and makes the cluster reliably connected with BS when the CH terminates. The LEACH tradition requires the customer to show the liked probability of CHs for use with the edge work in choosing if a node transforms into a CH or not.

The homogeneity of LEACH algorithm is a very major drawback now-a-days. That's why we were motivated for SEP which is heterogeneous aware.

In [12], the K-medoids LEACH (KLEACH) protocol was depicted to upgrade the gathering and CHs assurance procedure. For the first round of communication, in setup stage, the K-medoids estimation was used for cluster improvement, which ensures uniform gathering. In [13], a Genetic Algorithm-based Energy-Efficient Protocol (GAEEP) has been displayed to capably intensify the lifetime and consistent quality time of remote sensor network. GAEEP uses genetic estimation to gain ground the framework lifetime and stable region of the remote sensor network by finding the perfect number of gathering heads and their zones in light of restricting the power usage of the sensor nodes.

TSEP (Threshold SEP) is a protocol that utilizes three levels of heterogeneity [14]. It is a reactive protocol, meaning it responds when changes to relevant attributes occur. The election of the cluster heads is based on a threshold. This protocol increases the stability region of the WSN.

CHAPTER 3: PROPOSED WORK

Research on wireless sensor network has been carried out many times to improve the network lifetime of the network so that the network may sense the target region for longer. However, there are applications that require the sensing feed to be on and reliable all the time, i.e., they require that all the nodes should sense the field for a longer time. This would require the batteries of the nodes to be updated. SEP also worked to improve the stable region, period before the death of the first node, in order to extend the network lifetime.

The proposed work has been detailed in this section with simulation and experimental results being provided in the next. The results have been compared with other algorithms and indicate the better performance of as compared to other algorithms.

3.1 Problem Statement

After a comprehensive survey of available clustering algorithms, it has been found that less focus is made on extending the stable region of the network. There are a lot of application like surveillance that require all the nodes be up and running for a long period of time. They require avoiding any blind spots. Therefore extending the stable region of a network is the way to go also because in hierarchical clustering like in [1] and [2], the network is seen to die out rapidly after the death of the first node anyway.

3.2 SEP as the base for analysis

SEP was a product of the research on the impact heterogeneity has, energy wise, on hierarchically clustered WSNs. It focussed on prolonging the stable region, before the death of the first node, so that the feed is reliable and stable. It took advantage of the heterogeneity present in the network as it is based on weighted probabilities for election of cluster head by taking into account the remaining energy of the nodes.

Working

SEP is based on LEACH, i.e., it is based on clustered hierarchical networks. It assumes that a certain fraction, m, of the total nodes, n, have α times more energy than the rest and are referred to as *advanced nodes*. The other $(1\text{-}m) * n$ nodes are called *normal nodes*. Also, the nodes are randomly distributed across the field. That is how it is heterogeneous aware.

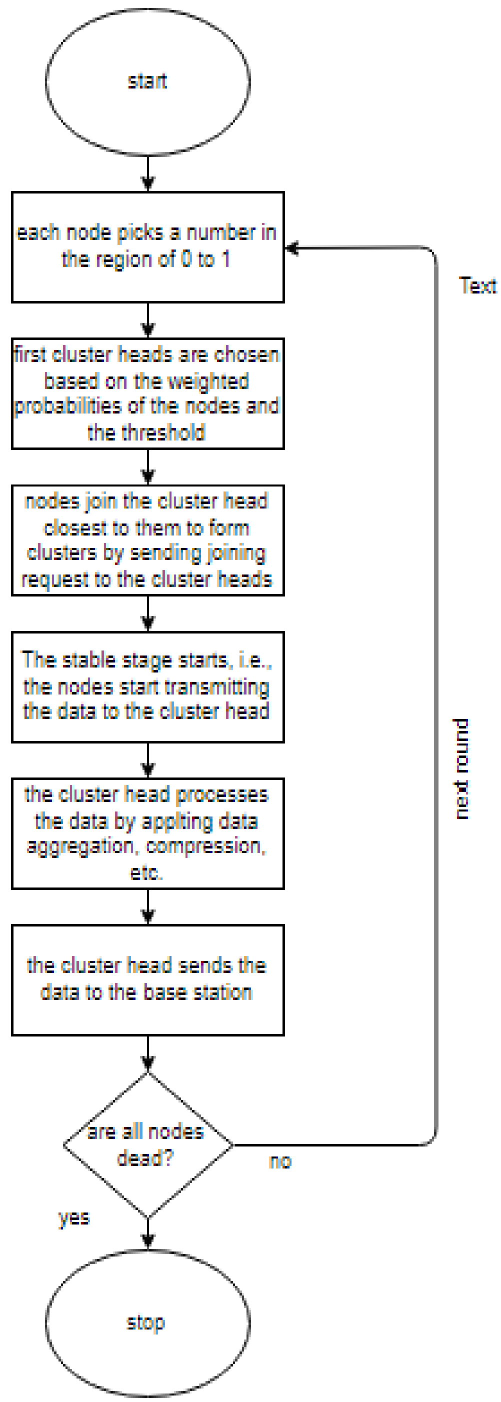

Fig.3. Flowchart for SEP

For the prolonging of the stable region, it is clear that advanced nodes will have to take the role of cluster head more often. In LEACH, a fraction *p* of the total nodes would become cluster head in a round. It guarantees that each node becomes cluster head every *1/p* rounds. SEP refers to this period as *epoch*. Nodes that are selected cluster heads cannot take the role again in the same epoch. Nodes that haven't become cluster heads in an epoch belong to set *G*. In each round, every node belonging to *G* is given a random number in [0,1] and then is compared with a threshold, *T(s)*. If the random number is less than this threshold, the node is made a cluster head. As each round passes, election probabilities of nodes in *G* increase.

SEP works on weighted probabilities which means weight is added to the probabilities according to the heterogeneity. Both the *advanced nodes* and the *normal nodes* have different weighted probabilities.

In SEP the probabilities *p* are weighted. Let p_{nr} be the election probability for *normal nodes* and p_{ad} be the election probability for advanced nodes. In a way, we have $n*(1+\alpha.m)$ normal nodes. The weighted selection probabilities, thus, for the two nodes are given by,

$$p_{nr} = \frac{p}{(1+\alpha.m)}$$

$$p_{ad} = \frac{p}{1+\alpha.m} * (1+\alpha)$$

Equations (3) and (4) respectively.

In eq. (1) and (2), the value of p is replaced with these weighted probabilities and the new equations for calculating threshold are,

$$T(s_{nr}) = p_{nr}/(1 - p_{nr}.\left(r \, mod \frac{1}{p_{nr}}\right))$$

If s_{nr} belongs to G', the set of normal nodes not yet selected as cluster heads in this epoch, and,

$$T(s_{nr}) = 0$$

Otherwise (5).

Similarly,

$$T(s_{nr}) = p_{ad}/(1 - p_{ad}.\left(r \, mod \frac{1}{p_{ad}}\right))$$

If s_{ad} belongs in G'', set of advanced nodes not yet cluster head in the current epoch,

$$T(s_{ad}) = 0$$

Otherwise (6).

Now instead of using p in (1), *pn* is used for *normal nodes* and *pa* is used for *advanced nodes.* Because of the different probabilities, the sets of non-cluster head nodes in the epoch is also changed. *G'* becomes the set of *normal nodes* that haven't been cluster heads in the last *1/pn* rounds. *G''* is now the set of *advanced nodes* that haven't been cluster heads in the last *1/pa* rounds.

Once the cluster heads are decided, the feild is then divided into clusters and each node in the cluster sends its data to its cluster head. The cluster head then aggregates the data from all the nodes in the cluster and sends it to sink. This sums up the working of SEP. Now let's look at the proposed scheme.

3.3 Proposed Scheme

The proposed work is closely based on SEP. All the stages are similar to SEP and includes changes inside those stages. It involves incorporating 2 cluster heads instead of one. The roles of the cluster heads are also modified. The *second cluster head* has the role of collecting the data from the other nodes in the cluster and processing this data which it then sends to the *first cluser head.* The *first cluster head* has the role of forwarding this data to a far-off sink and thus the energy dissipated by the heads is now divided into two. Like [1] and [2], the operation of proposed work is also broken down in rounds. Each round starts with the setup phase followed by the steady phase, also called stable region.

The assumptions made in SEP are also carried forward.

Working

In the proposed scheme, each round consists of two phases like that in [1], set-up phase where the clusters are formed and the two cluster heads are chosen.

Setup phase

Initially, each node is assigned a random number between 0 and 1. This random number is then compared to the threshold in (1). If the random number assigned is less than the threshold, the node is made a cluster head for the round.

To add energy awareness into the picture, we have added relative energy weights into the threshold. The relative weight, *E(n)/Eo*, was added to the threshold. The new equation for calculating the threshold *T(s)* is,

$$T(s) = \frac{p}{1 - p.\left(r \, mod \, \frac{1}{p}\right)} * \frac{E(n)}{Eo}$$

(7) where *E(n)* is the current energy of the node and, *Eo* is the initial energy of the node.

Note that *Eo* is the initial energy of the *normal nodes*. This means that initially, when the energies of *advanced nodes* are higher than that of the *normal nodes.* Once the energy levels are comparable, the proposed works very much like [1].

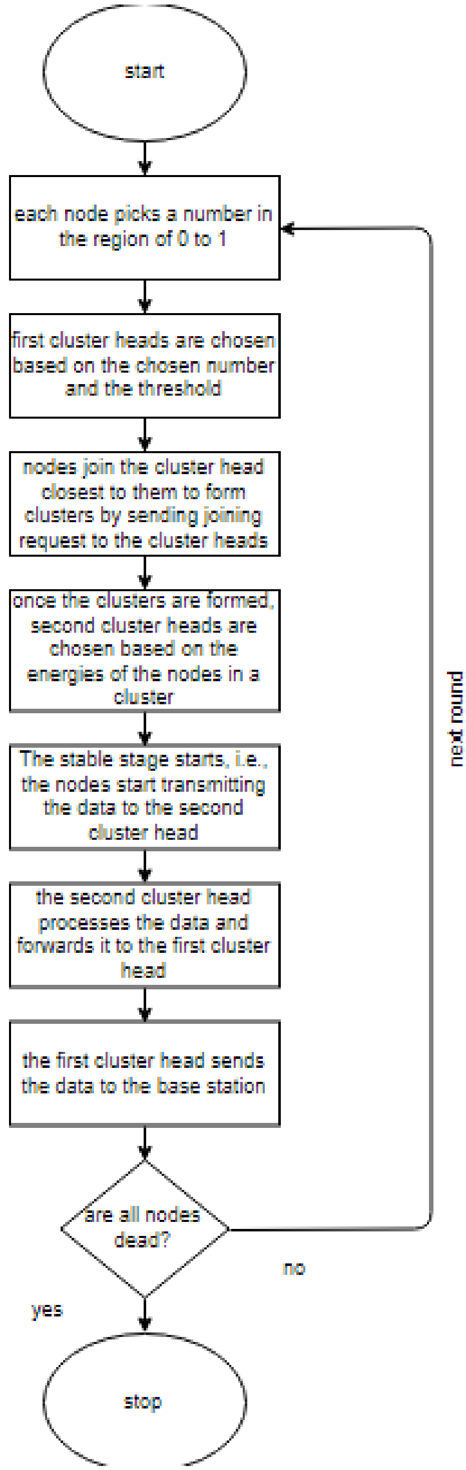

Fig.4. Flowchart of the proposed scheme

After the selection of cluster heads, the clusters are created based on the *Euclidian distance* of the nodes from the cluster heads. Once the clusters are formed, the node with the highest energy in the cluster, apart from the cluster head, is made the second cluster head. The roles of both cluster heads are different. The *first, main, cluster head* has the role of receiving the data from the *second cluster head* and forwarding it to the sink node. The second cluster takes on the role of receiving the data from the nodes in the cluster, and sending it to the *first header node,* which is very close to the *second cluster head* than the sink node. This way the high energy expenditure of the *cluster head* is further divided among two nodes. This technique is somewhat similar to the one in [11], but it employed *k-medoids* for clustering, the *second cluster head* was chosen as the one nearest to the centroid and the use of the nodes was also varied.

The nodes inform the *second cluster head* about the inclusion in the cluster which then creates a TDMA schedule for each node to transmit their data based on the number of nodes in the cluster. This schedule is then broadcasted back to the nodes.

Stable phase

After the *setup phase* is over, the operation of transmitting of data by the sensor nodes can begin. If a node has data to send, it will only transmit during its TDMA schedule. The transmitter of the nodes is off at times other than allotted. This minimizes energy expend of the nodes.

The *second cluster head*, however, has to keep its receiver on at all times. All the data is compressed into a single signal once collected which is then sent to the *first cluster head* to be processed upon and finally sent to the *sink.*

After a certain amount of pre-determined time, the next rounds begins and it done all over. This pre-determined time, in which the data transmission occurs, is called the *steady phase.* This is determined to be longer than the *setup phase* to reduce the overhead of clustering and head selection and to improve efficiency.

At last, we test a double sink approach in which 2 sink nodes are placed in he sink for the cluster heads to send their data. The *cluster heads* transmit the data to the sink that is closer to them according to the Euclidian distance. This approach has the downside of including the additional sink which is not that common and practical but we were motivated to test it nonetheless.

3.4 Energy model for analysis

The work is based on the same radio energy dissipation model as the one used in [1] and [2] which is illustrated in Fig. 2.

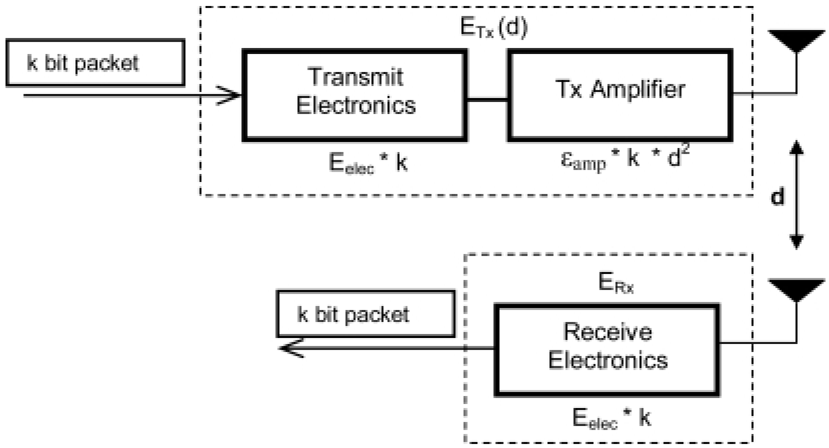

Fig.5. Radio model

According to this model, the energy expended by the radio while achieving acceptable SNR in transmitting a k-bit message over *d* distance is given by,

$$E_{Tx}(k,d) = k.E_{elec} + k.\epsilon_{fs}.d^2$$

If d<do and

$$E_{Tx}(k,d) = k.E_{elec} + k.\epsilon_{mp}.d^4$$

When d>=do.

where E_{elec} is energy spent on running the transmitter or receiver circuit per bit, $\epsilon_{fs}$is the energy spent while on free space model and $\epsilon_{mp}$is the energy used while on the multi-path model of transmission.

By solving the above two equations for $d=d_o$ we get $d_o = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$. Also, the receiving cost of the radio for a k-bit message is $E_{Rx}=k.E_{el}$.

Let us assume that *n* nodes are distributed uniformly across a field and that the sink is located at the centre of the field and the distances of all nodes from the sink is $<d_o$. The energy spent by the *second cluster head* in a round is given by,

$$E_{SH} = k.E_{elec}\left(\frac{n}{c} - 1\right) + \frac{E_{da}n}{c} + k.E_{elec} + k.\epsilon_{fs}d_{toFH}^2$$

where E_{da} is the data aggregation cost, c is the cluster count and d^2_{toFS} is the square of the distance between the *second cluster head* to the *first cluster head.* Similarly, the energy spent by the *first cluster head* is given by,

$$E_{SH} = k.E_{elec} + k.E_{elec} + k.\epsilon_{fs} d^2_{toBS}$$

where d^2_{toBS} is the square of distance between the *first cluster head* and the *base station.*

The energy used by the non-head nodes in a round is given by,

$$E_{NCH} = k.E_{elec} + k.\epsilon_{fs} d^2_{toSH}$$

where d^2_{toSH} is the square of distance between the node and the *second cluster head.*

CHAPTER 4: SIMULATION AND RESULT

For the purpose of the performance analysis, we use MATLAB. For the sake of simplicity, the following assumptions are made in the model,

- The nodes are randomly distributed across the field.
- The nodes in the field are heterogeneous with some nodes having higher energy than others.
- The sink, *base station*, is not power limited.
- The nodes are not mobile.

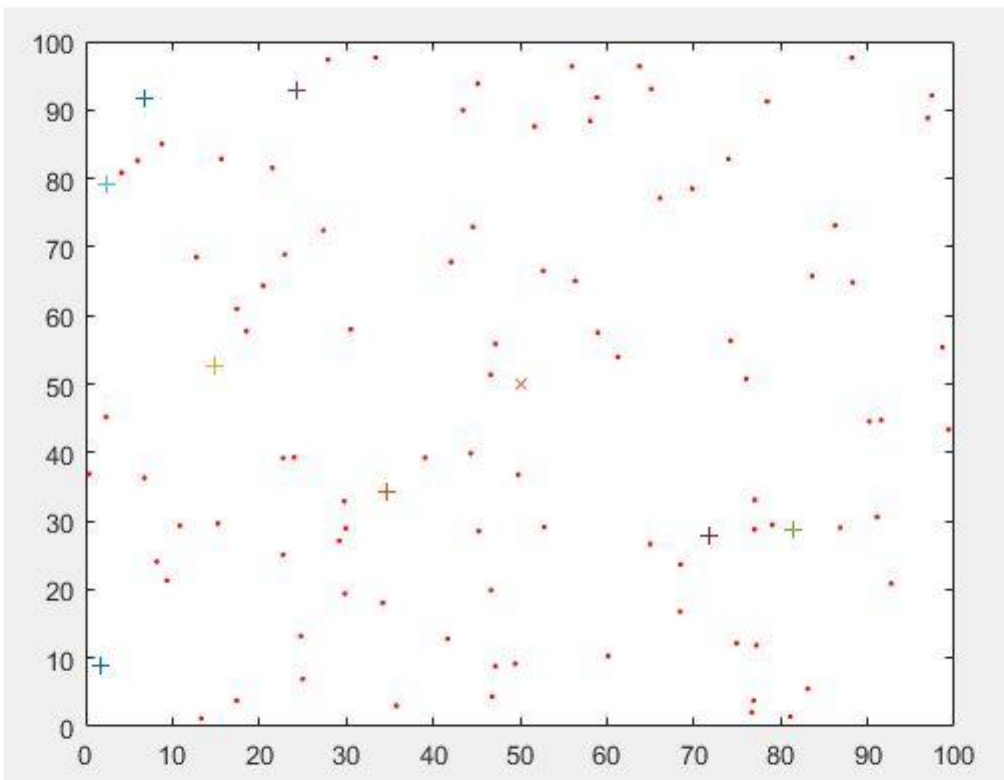

Fig.6. Random Sensor Network

The following values were set as the simulation parameters,

- Percentage of header nodes per round, p=0.1
- Percentage of advanced nodes, m =0.1.

- α=1.
- Number of nodes, n=100.
- Dimensions of field, 100m*100m.

The energy levels considered for the simulation are described in table 1.

Parameter	**Value**
Node initial energy, Eo	0.5 J
ϵ_{fs}	10 Pj.(bit.m^2)$^{-1}$
E_{mp}	0.0013 Pj.(bit.m^4)$^{-1}$
E_{da}	50 nj.bit^{-1}
E_{rx} , E_{tx}	50 nj.bit^{-1}
Packet size	4000 bits

TABLE 1. Energy level parameters

With these parameters set, we analysed our work with a span of 2000 rounds. The random node distribution is shown in Fig. 6.

We then compare the performance of the algorithm with that of LEACH [1], SEP [2] and C-LEACH [8]. The performance of the algorithm is shown in Fig. 7. Fig. 8, 9 and 10 show the performance of LEACH, SEP and C-LEACH respectively.

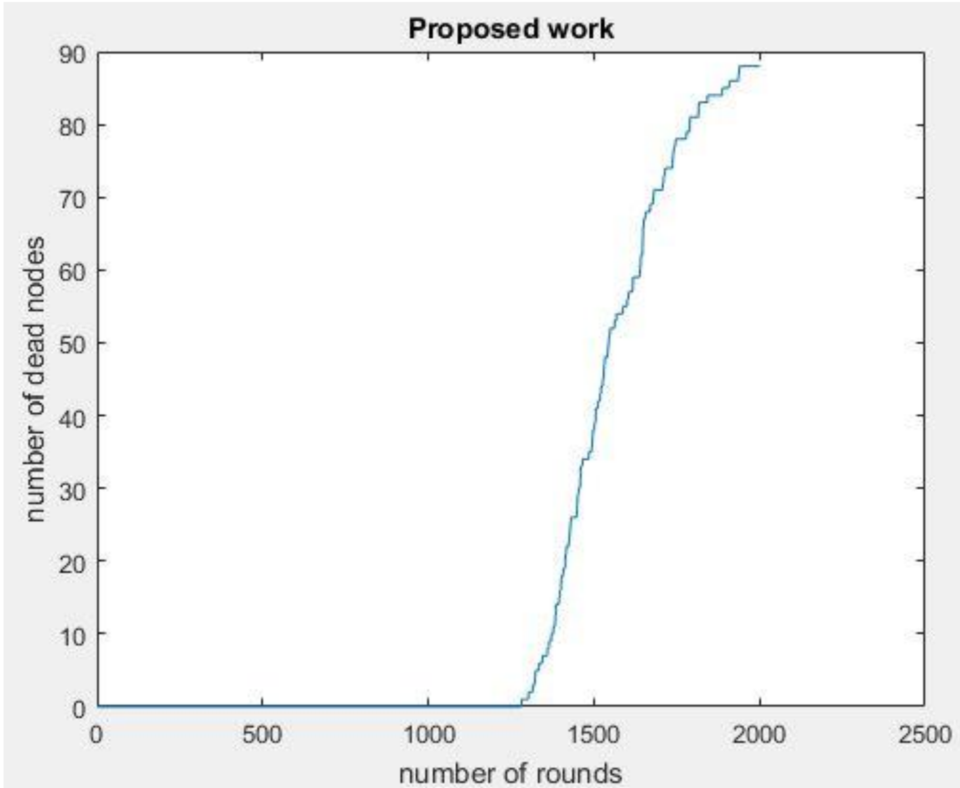

Fig.7. Performance of proposed work

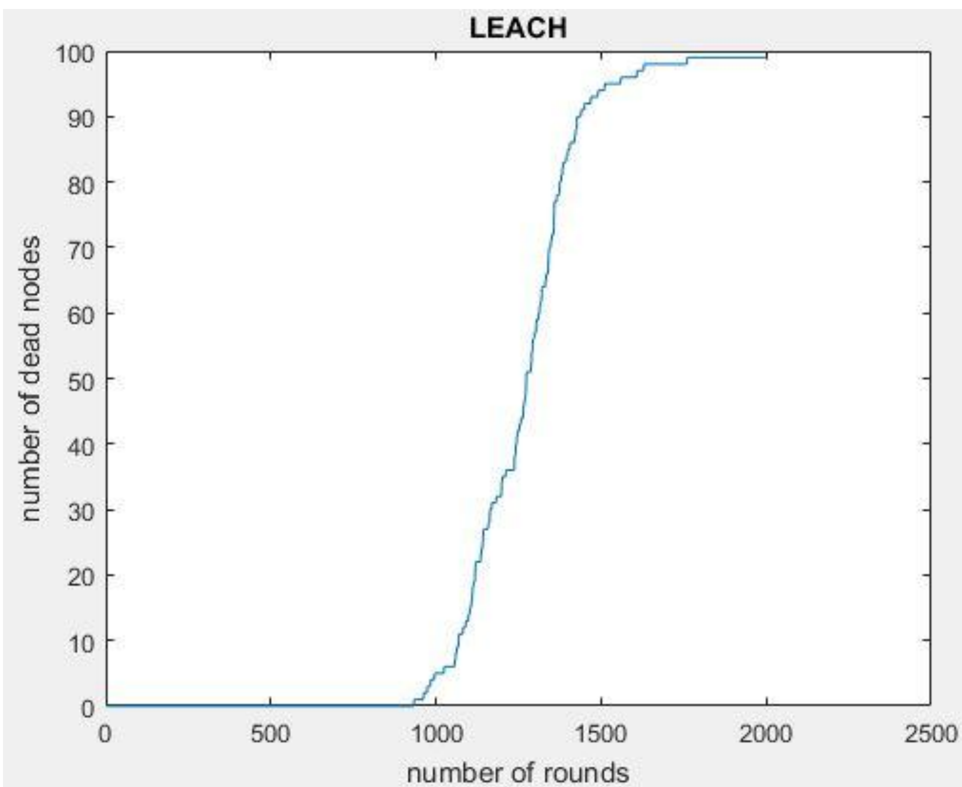

Fig.8. Performance of LEACH

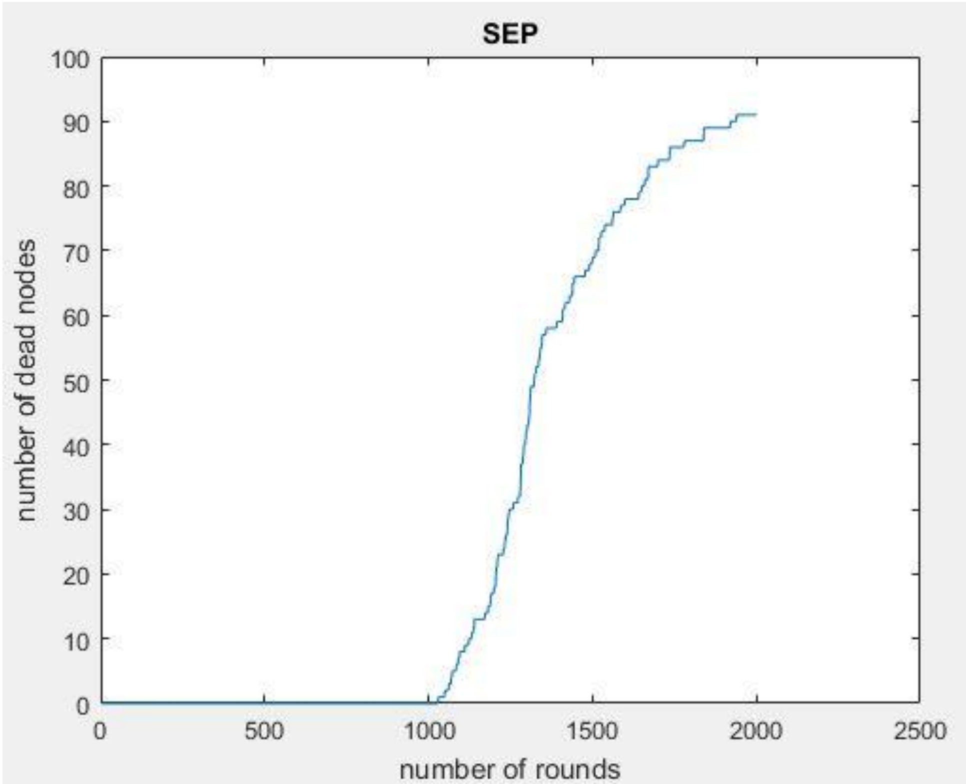

Fig.9. Performance of SEP

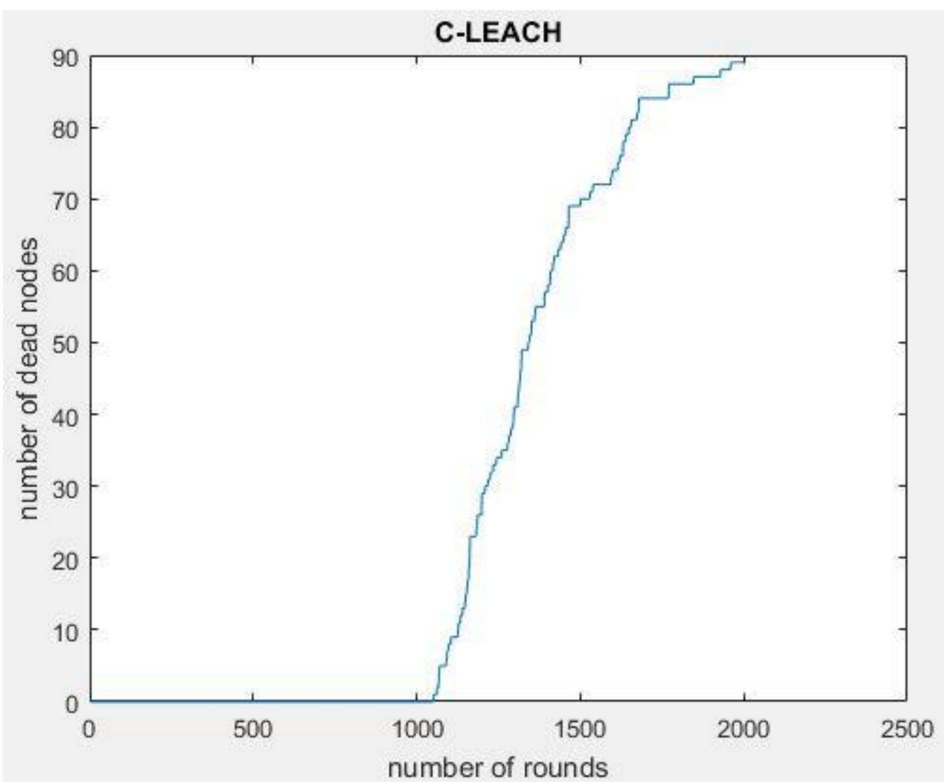

Fig.10. Performance of C-LEACH

Comparison Factor	LEACH	SEP	C-LEACH	Proposed work
First Node Die	933	1029	1098	1245

TABLE 2. Comparison of LEACH, SEP, C-LEACH and proposed work

We can see from the graphs that the performance of LEACH is the worst with the first node dying at round 933. SEP improves on LEACH as the stable region is long in SEP with the first node dying around the 1030 round mark. C-LEACH performs respectably and further improves upon the performance of SEP with its last node dying at around 1100 round.

The proposed work however performs very well and prolongs the stable region for the longest time with the last node dying at round 1245 mark. This simulation solidifies the position of the work that it does indeed prolong the stable region of the network. We do not focus on the death of the last node aspect of network lifetime as after the death of the first node, the network degrades quickly and is not reliable towards the end when there are only a few nodes left. Which is why this paper focuses on prolonging the stable region of the network.

We now change the degree of heterogeneity by changing *m*, the percentage of nodes that have higher energy than the rest to see the results.
Here , the value of m is taken as 0.2, a 0.1 increase from the previous simulations.
The simulation results for m=0.2 can be seen in table 3.

Comparison Factor	LEACH	SEP	C-LEACH	Proposed work
First Node Die	927	1070	1156	1270

TABLE 3. Comparison of LEACH, SEP, C-LEACH and proposed work with m=0.2

It is quite evident that all the algorithms except for LEACH [1] show increased stable region on increasing the percentage of advanced nodes which means that all the other three algorithms are energy-aware in some sense and that they will benefit from the increased heterogeneity.

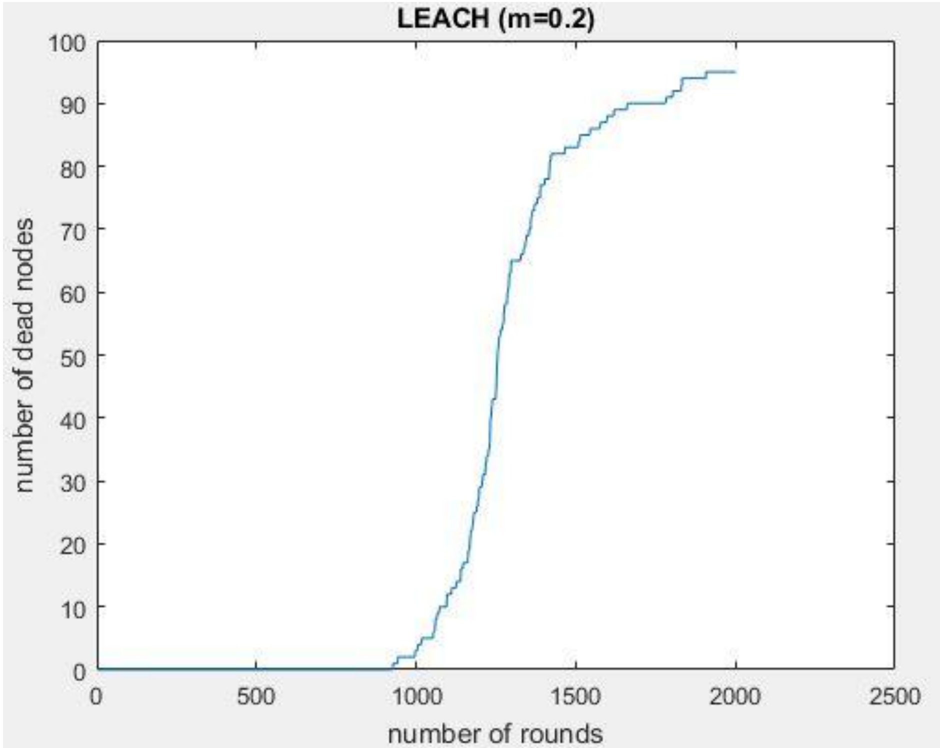

Fig.11. Performance of LEACH with m=0.2

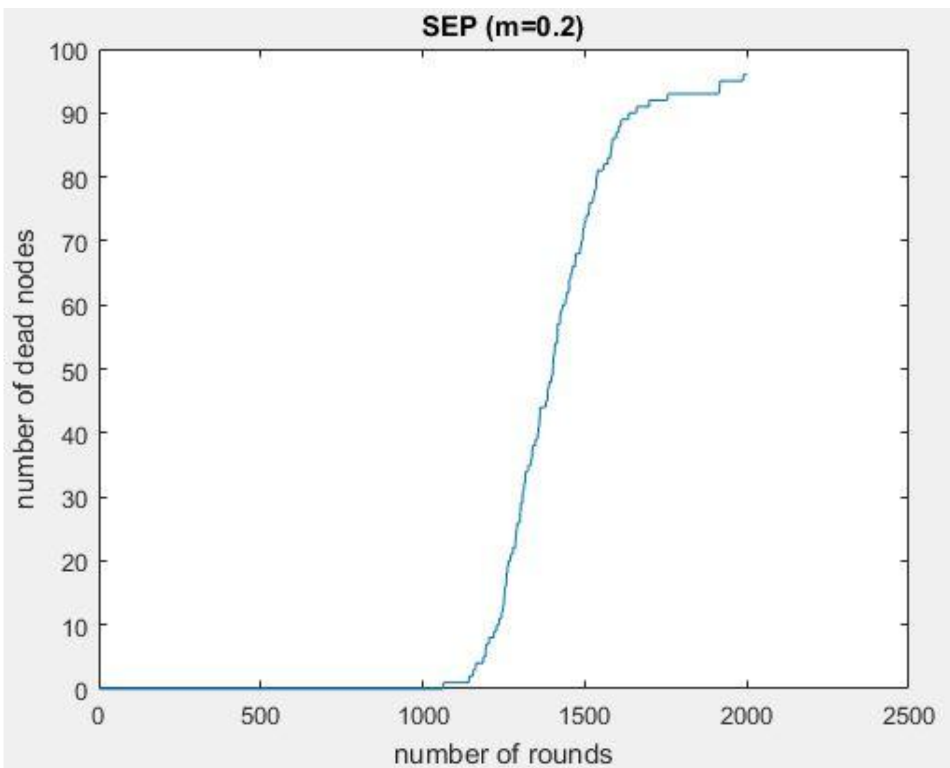

Fig.12. Performance of SEP with m=0.2

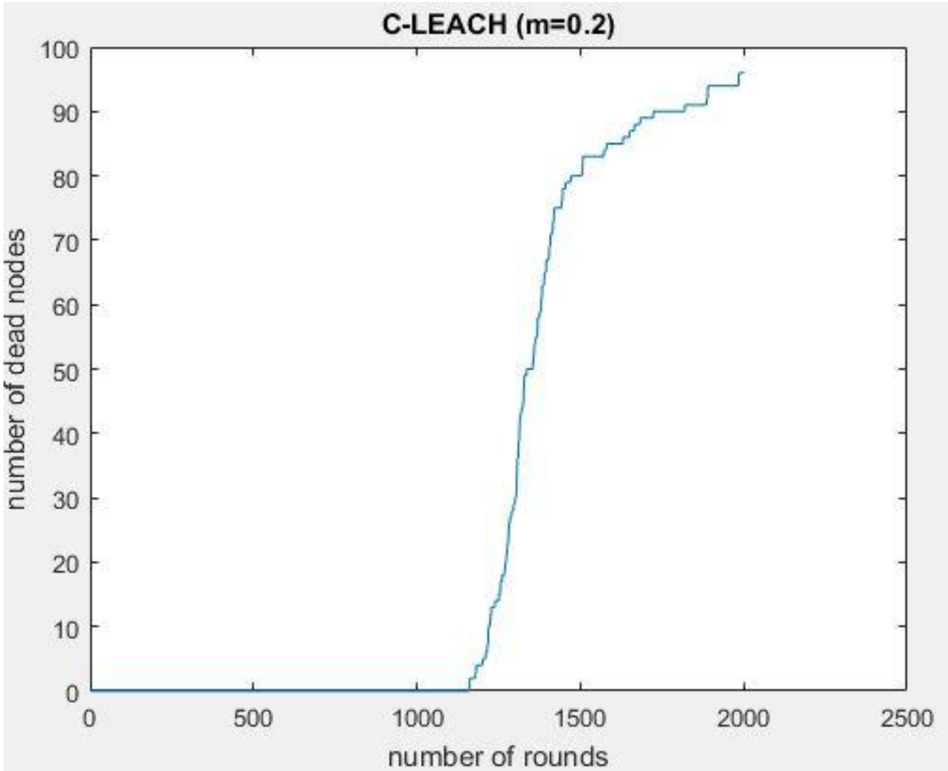

Fig.13. Performance of C-LEACH with m=0.2

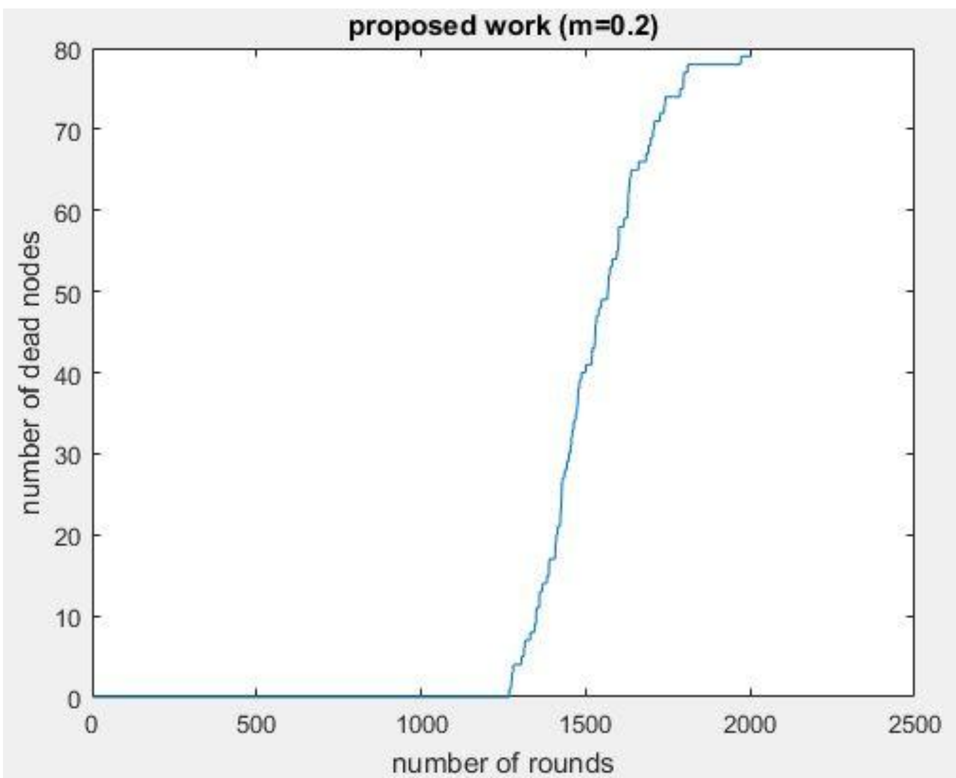

Fig.14. Performance of proposed work with m=0.2

We also tested the dual sink node approach and found that it has no visible advantage in terms of the first death round and also adds to the cost of the system. The performance of dual node system is shown in Fig. 15.

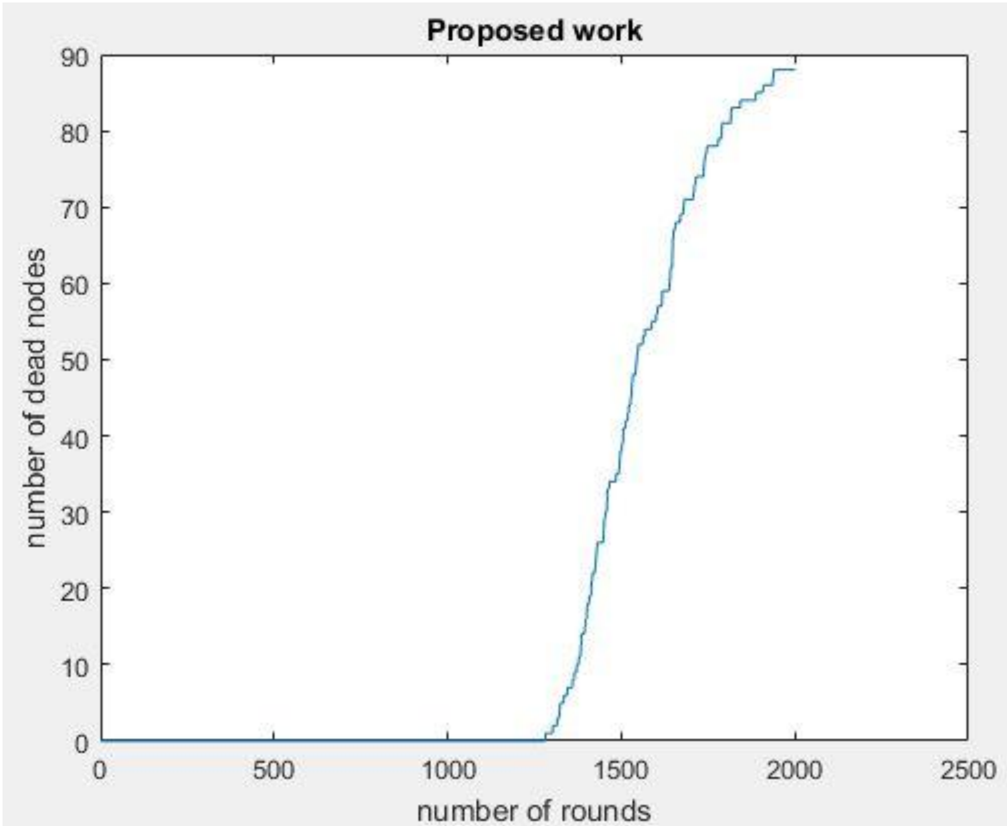

Fig.15. Proposed work with dual-sink approach

For reasons unknown, the dual-sink approach seems to have no to little effect in the performance of the proposed scheme. We tested the dual node approach with all the assumptions and same parameters and it gave us a first node death of 1254, which is very close to the normal value and the improvement, if any, is negligible.

CHAPTER 5: CONCLUSION AND FUTURE DIRECTIONS

Improving the network lifetime of a Wireless Sensor Network (WSN) is a frequently researched topic as the advantages are numerous. LEACH and SEP proved that hierarchical routing can save energy and extend the lifetime of a network. This paper describes an Energy-aware, Dual Cluster Head approach to SEP to address the problem of improving the *stable region* for greater stability and reliability. We introduced weighted thresholds that take into account the current energy levels of the nodes as well as the heterogeneity among the nodes. We tested a dual cluster head approach in the work in which each cluster head has a separate role. The second head collects the data from the nodes and forwards this data to the first head node, which then forwards this data to the base station. In this way the energy consumption of the cluster head is divided between two nodes reducing the pressure on a single node. Simulation results show that our work effectively improves the stability region when compared to the likes of LEACH, SEP and C-LEACH. This improvement will help applications that depend on reliable sensing of the target area for a longer period of time. The work will be further beneficial when the sink is far from the target field.

Future directions include better use of the dual cluster head technique probably by better selection criteria for the second header node to ensure less energy consumption by reducing overheads. Also, the concept of dual sink nodes can be wisely applied for better results. Election thresholds can also be researched upon for better results.

CHAPTER 6: REFERENCES

[1] Wendi Rabiner Heinzelman, AnanthaChandrakasan and HariBalakrishnan, “Energy-Efficient Communication Protocol for Wireless Microsensor Networks”, Hawaii International Conference on System Sciences, January 4-7, 2000.

[2] G. Smaragdakis, I. Matta and A. Bestavros, “SEP: A stable election protocol for clustered heterogeneous wireless sensor networks”, in Technical report BUCS-TR-2004-022.

[3] C. INTANAGONWIWAT, R. GOVINDAN, D. ESTRIN, “Directed diffusion: a scalable and robust communication paradigm for sensor network,” Proceedings of the 6th ACM/IEEE International Conference, Boston, IEEE, pp. 56-57, 2000.

[4] B. S. Lindsey and C. S. Raghavendra, "PEGASIS: Power-efficient gathering in sensor information systems," *Proceedings, IEEE Aerospace Conference,* 2002, pp. 3-1125-3-1130 vol.3.

[5] W. Heinzelman, A. Chandrakasan and H. Balakrishnan., "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", IEEE Trans. Wireless Communications, Vol. 1, No.4, October 2002, pp.660-670.

[6] W. Heinzelman, Application-Specific Protocol Architectures for Wireless Networks, Ph.D Thesis, Massachusetts Institute of Technology, June 2000.

[7] A. R. Khan, N. Rakesh, A. Bansal and D. K. Chaudhary, "Comparative study of WSN Protocols (LEACH, PEGASIS and TEEN)," *2015 Third International Conference on Image Information Processing (ICIIP)*, Waknaghat, 2015, pp. 422-427.

[8] Z. Beiranvand, A. Patooghy and M. Fazeli, “I-LEACH: An efficient routing algorithm to improve performance and reduce energy consumption in WSNs”, Irwine association of information and communication technology, 2015.

[9] V.Loscri, G.Morabito, and S.Marano, “A Two-Levels Hierarchy for Low-Energy Adaptive Clustering Hierarchy (TL-LEACH),” in 62nd Vehicular Technology Conference, IEEE, vol.3, 2005, pp.1809-1813.

[10] H. Wang, H. Chang, H.Zhao and Y.Yue, “ Research on LEACH algorithm based on double head cluster clustering and data fusion”, International conference on mechatronics and automation, IEEE, aug 6-9, 2017.

[11] M. B. Young, A. Al-zou'bi, Y. Khamayseh and W. Mardini, “Improvement on LEACH Protocol of Wireless Sensor Network (VLEACH)”, International Journal of Digital Content Technology and Its Applications, vol. 3, no. 2, (2009), pp. 132-136.

[12] P. Bakaraniya and S. Mehta, “K-LEACH: An improved LEACH Protocol for Lifetime Improvement in WSN”, International Journal of Engineering Trends and Technology (IJETT), vol. 4, no. 5, (2013) May, pp. 1521-1526.

[13] Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Shigenobu Sasaki, “A New Energy-Efficient Adaptive Clustering Protocol Based on Genetic Algorithm for Improving the Lifetime and the Stable Period of Wireless Sensor Networks”, International Journal of Energy, Information and Communications Vol.5, Issue 3 (2014), pp.47-72.

[14] A. Kashaf, N. Javaid, Z. A. Khan and I. A. Khan, "TSEP: Threshold-Sensitive Stable Election Protocol for WSNs," *2012 10th International Conference on Frontiers of Information Technology*, Islamabad, 2012, pp. 164-168.

[15] A. Braman and Umapathi G.R, “A Comparative Study on Advances in LEACH Routing Protocol for Wireless Sensor Networks: A survey,” International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE), vol. 3, issue 2, pp. 5683-5690, February 2014.

[16] P. Manimala and R. Senthamil Selvi, “A Survey on LeachEnergy Based Routing Protocol,” International Journal of Emerging Technology and Advanced Engineering (IJETAE), vol.3, issue 12, pp. 657-660, December 2013

[17] W. Liu and L. Wang, “An improved algorithm based on LEACH protocol”, Journal of Applied Mechanics and Materials, vol. 347, (2013), pp. 2725-2727..

[18] L. M. Sun, J. Z. Li and Y. Chen, “Wireless sensor networks,” Tsinghua University Press, 2005.

[19] W. S. McCulloch, “ Pitts W. A Logical Calculus of the Ideas Immanent in Nervous Activity,” Bulletin of Mathematical Biophysics, vol. 5, pp. 115-133, 1943.

[20] H. B. Wang, X. J. Xiao and X. J. Yan, “Wireless sensor monitoring network information processing technology,” National Defense Industry Press, 2010.

[21] LEACH Algorithm - MATLAB - leach, Mathworks, https://www.mathworks.com/matlabcentral/fileexchange/44073-low-energy-adaptive-clustering-hierarchy-protocol--leach-.

[22] SEP algorithm – MATLAB – sep, Mathworks, “https://www.mathworks.com/matlabcentral/fileexchange/46199-comparison-of-leach-eammh-sep-teen-protocols--contact-for-codes-in-wsn-“