DESIGN, IMPLEMENTATION AND EVALUATION OF A LOW ENERGY CONSUMPTION METHOD FOR WIRELESS SENSOR NETWORKS

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DESIGN, IMPLEMENTATION AND EVALUATION OF A LOW ENERGY CONSUMPTION METHOD FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

DESIGN, IMPLEMENTATION AND EVALUATION OF A LOW ENERGY CONSUMPTION METHOD FOR WIRELESS SENSOR NETWORKS

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The aim of this thesis is to save the energy of the nodes. The first goal of this thesis is to reduce the total energy consumption of the wireless sensor network. The second goal is to increase the reliability of the protocol along with improving the network latency as compared with previous cluster-based protocols. The network area is divided to four region. First region send information directly to base station. Second region has cluster heads and this cluster heads collect information and then send to rechargeable sensor and then this sensor send to base station. These cluster heads are selected on the basis of a probability. The third region has rechargeable node and this sensor collect information and then send to base station. Fourth region (same second region) has cluster heads and this cluster heads collect information and then send to rechargeable sensor and then this sensor send to base station. Proposed protocol performance is compared with LEACH (Low Energy Adaptive Clustering Hierarchy). The performance of proposed method is overcome than the previous works.

Keywords: Wireless Sensor Network, Consumption Energy, Clustering LEACH.

ÖZ

KABLOSUZ ALGILAYICI AĞLAR İÇİN DÜŞÜK ENERJİ TÜKETİMİ TASARIMI, UYGULAMASI VE DEĞERLENDİRMESİ YÖNTEMİ

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Bu tezin amacı düğümlerin enerji tasarrufunu sağlamaktır. Bu tezin ilk amacı kablosuz algılayıcı ağlarının toplam enerji tüketimini azaltmaktır. İkinci hedef önceki küme tabanlı protokoller ile karşılaştırıldığında, ağ gecikmesinin iyileştirilmesi ile birlikte protokol güvenilirliğini artırmaktır. Ağ alanı dört bölgeye bölünecektir. Birinci bölge baz istasyonuna bilgileri doğrudan göndermektedir. İkinci bölgede baş düğüm bulunmaktadır. Bu baş düğüm bilgileri toplamaktadır ve daha sonra şarj edilebilir algılayıcı ile bilgileri göndermektedir. Daha sonra bu algılayıcı bilgileri baz istasyonuna göndermektedir. Bu baş düğümler bir olasılık temelinde seçilir. Üçüncü bölgede şarj edilebilir düğüm bulunmaktadır ve bu algılayıcı bilgileri toplayarak baz istasyonuna göndermektedir. Dördüncü bölgede (aynı ikinci bölgedeki gibi) baş düğüm bulunmaktadır. Bu baş düğüm bilgileri toplayarak, şarj edilebilir algılayıcı aracılığı ile bilgileri baz istasyonuna göndermektedir. Sonra DEUKH (Düşük Enerji Uyarlamalı Kümeleme Hiyerarşi) ile protokol performansı karşılaştırılmıştır. Önerilen sistemin performansı önceki çalışmalardan daha yüksek olmuştur.

Anahtar Kelimeler: Kablosuz Algılayıcı Ağ, Tüketim Enerji, Kümeleme DEUKH Protokolü.

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LIST OF ABBREVIATIONS

WSN	Wireless Sensor Network
CH	Cluster Head node
MN	Member Node
LEACH	Low Energy Adaptive Clustering Hierarchy
MANET	Mobile Ad-Hoc Network
DSR	Dynamic Source routing
HEED	Hybrid Energy Efficient Distributed Protocol
PC	Personal Computer
GPS	Global Positioning System
RN	Relay Node
SN	Sensor Node
BS	Base Station
GA	Genetic Algorithm
TDMA	Time Division Multiple Access
LEACH-C	LEACH-Centralized
LP	Low-Power
NP	Nondeterministic Polynomial
BARON	Software Name
IHEED	Improved Hybrid Energy Efficient Distributed Protocol
CPLEX	Software Name

CHAPTER 1

INTRODUCTION

1.1 Introduction

Improvements in technology result in evolution of smart devices. One of such smart devices is wireless sensor nodes, which consist of a sensing board, a battery supply and a wireless antenna to transfer data. We can collect information from the environment by deploying thousands of these tiny smart devices. These devices can also be used to monitor natural habitats or used in giant machine parts for performance evolution. Energy efficient operation is an important issue for WSN design and clustering is one of the most widely used methods for energy efficiency. The sensor network application areas have a wide range, like disaster detection such as forest fire or flood detection, patient monitoring and micro-surgery, home and office accessories communication, military intrusion detection, agricultural crop monitoring, pricing goods in the markets, inventory handling and wildlife habitat monitoring. They can also be used for interaction of cars in traffic for safety, virtual keyboards for PC and musical instruments, commanding industrial robots, making social studies on human interaction, hostile environment exploration, monitoring seismic activity, and the monitoring of freshwater quality. They can be used for: civil engineering; monitoring buildings, urban planning and disaster recovery; for other military applications like military asset monitoring, observation and battle-space checking, urban fighting and self-healing problems [1].

Recent improvements in technology provide us cheap and tiny electronic devices with various sensors on it. These tiny devices are called ’sensor nodes’ and they have great abilities. The aim of using sensor nodes is to sense the environment and process and/or transfer collected information to an analysis center. Sensor nodes are usually battery powered and their transmission range is very low. Therefore, these sensor nodes can establish a network to propagate their data to long distances.

People need to monitor changes in environmental conditions for variety of purposes. Extracting data from changing environment and interpreting that data to gain reasonable information enable people to make meaningful decisions. Today, automation of data collection is facilitated by the improvements in computation and wireless communication technologies. In order to monitor environment or systems, low cost computation and communication devices have been developed. Those devices have sensing ability with built in sensors, basic computational facilities and wireless communication capabilities. With the advances in wireless networking technology, a wireless sensor network can be deployed without a fixed infrastructure. Nodes in the network connect to each other in ad-hoc fashion and they communicate according to wireless communication.

Wireless sensor networks are widely used and preferred for environmental monitoring, military applications, health care, industrial monitoring, etc. Wireless sensor networks consist of different kind of interoperable nodes distributed in an area and those nodes employ wireless communication. By using flexible communication and routing schemes it may also be possible to add/remove nodes into/from the network while it is operating. For example, in order to recover from node failures affecting monitoring quality/coverage, new nodes can be deployed on to the sensing region and after a negotiation phase, new nodes can start to contribute sensing process. This capability adds flexibility to enlarge sensing area and also it contributes to the extending network life time.

Wireless sensor networks idea is envisioned and defined as self-deployed, error prone, long living inexpensive communication devices that are densely deployed to collect data from physical space [2]. Another definition of wireless sensor networks is ”a large-scale, ad hoc, multihop, unpartitioned network of largely homogeneous, tiny, resource-constrained, mostly immobile sensor nodes that would be randomly deployed in the area of interest” [3].

Sensor nodes can be placed regularly or they can be randomly deployed with the help of a plane, simply throwing them from air to inaccessible areas like mountains or forests. These sensor nodes may not be very powerful but they are actually very smart devices. They can establish a sensor network by self-organizing themselves, and they can immediately start transferring data packets as soon as they sense data from their coverage area.

These sensing devices are capable of sensing temperature, humidity, visual, acoustic, location and many more. There are several fields benefiting from sensor networks [2], such as military applications for border control and surveillance, environmental applications [4] for forest fire

detection [5, 6], health applications for patient monitoring [7, 8], home automation and smart homes, and many other fields like agriculture [9], vehicle tracking, inventory management, seismic activity [10] etc.

Since wireless sensor network is a new field in the literature, there are many challenges of using them. Most important challenge is energy consumption. Since these devices are deployed on unattended wide areas, replacing their batteries is not very feasible. With a pair of AA batteries a sensor node can last for 100-120h [11]. Therefore designing an algorithm with a good energy consumption mechanism is very important.

There are several ways to reduce energy consumption in sensor networks. Clustering the network, using sleep/listen cycles, using data aggregation methods, and using data propagation methods are some of them. The impartial of this thesis study is to progress energy efficient clustering algorithms to partition a network into several groups for energy efficient operation.

There are many proposed algorithms and approaches for clustering to achieve energy efficient communication. However, most of these proposed studies have been done with the help of simulations. In these simulations calculations are forming the basis, like energy consumption per data packet, idle listening power consumption, or transmission range etc. Also every possibility of events has a probability of occurrence, like data losses, collisions, etc. However in real life situations we cannot calculate every possibility. Therefore performing experiments with actual sensors becomes very important.

Clustering hundreds of nodes into many controllable smaller groups may eventually increase the performance of the network. Partitioning a network into many clusters will reduce the amount of traffic and the amount of energy consumed in network

[12]. Since energy efficiency is very important for network lifetime, clustering becomes crucial. If a sensor node needs to reduce its energy consumption, it should send its data packets to cluster heads firstly, instead of sending them directly to the sink [11]. There are many efficient proposed ways for selecting cluster heads. However, as a starting point of the selection process, there should be two basic criteria; (1) nodes should have a unique identifier and (2) these identifiers should be uniformly distributed among nodes [12]. Some of the methods used for cluster head selection are; choosing nodes which are closer to the base station, choosing nodes randomly, or choosing the nodes that have highest or lowest parameters than neighbors, in which parameters could be residual energy level, neighbor count, package count, sensed value, unique identifiers etc.

However, using simple clustering algorithms is not always efficient. If simple clustering algorithms such as selecting nodes with lowest or highest identifiers are applied, same nodes will be selected as cluster head many times. This results in quick energy drain of these selected nodes. Therefore, selection of cluster heads is also crucial to distribute load evenly among other nodes in order to minimize energy consumption.

lists some of the reasons for using clustering in wireless networks such as; to perform data aggregation in order to reduce total energy consumption and reduce the total number of packets transmitted, to disseminate queries to members, or to form an effective routing algorithm for the network. Also, clustering can be performed in single-level, which is the mostly used approach, or multi-level clusters can be performed - which is creating clusters inside a cluster.

Data aggregation is collecting data from member nodes, and transmitting the final data in a single packet to sink node. Data aggregation is widely used in clustering approach, because data from member nodes are collected by cluster heads and sent to the sink in a single packet, in order to reduce network traffic. When a sensor node receives two packets from two different source nodes, it can process incoming data packets and calculate the average readings, in order to send the final value as a single data packet. Another choice for a sensor node to aggregate data is to merge two different readings into same packet and sending the final packet to its destination. Both methods will reduce the energy consumption and network data traffic [13].

Data aggregation models are necessary to avoid redundant data packets, which creates too much traffic, and to minimize energy consumption [14]. Besides, controlling all members in the network is easier when they are controlled as a group. In case of a query based approach, data aggregation algorithms work in the opposite direction to disseminate data query to members, in order to change event thresholds they store or in order to collect different data from network.

Data propagation techniques are also very effective in controlling energy consumption. There are two ways of sending a packet to the sink node. Firstly, node can decide to send its packet directly to the sink, in a single hop fashion, which requires more energy. Secondly, a node can choose one of its neighbors to relay its packets to the sink, in a multi hop fashion. If the second solution is used, energy consumption will be smaller, because the distance is smaller between two nodes. Energy consumption increases incrementally when the distance between a node and sink is increased.

Centralized approach and distributed approach are the most commonly used approaches to form clusters. Distributed approach is more common in large scale networks, because centralized approaches require knowledge of the network topology and that is time and energy consuming [12]. Two alternative ways to form clusters and cluster tree is top-down approach and bottom up approach [15]. In top-down approach root selects its neighbors and they become cluster heads, then they form their own clusters. This method offers more control in creating clusters and cluster tree. Though bottom-up approach forms individual clusters and later try to gather them together. This increases the communication overhead between nodes.

CHAPTER 2

WIRELESS NETWORK CLUSTERING TECHNIQUES

Wireless network clustering has become a popular research area within the increase of applications based on wireless sensor networks. In literature there are different approaches to this problem. The main clustering techniques can be listed as Low Energy Adaptive Clustering Hierarchy and Hybrid Energy Efficient Distributed etc.

2.1 Low-Energy Adaptive Clustering Hierarchy (LEACH)

LEACH [16] is the main clustering protocol projected for periodical data gathering applications in WSNs.

In the LEACH (Low-Energy Adaptive Clustering Hierarchy) [16], [17], [18] algorithm, the sensors organize themselves into local clusters, through one sensor acting as the local BS or CH.

All non-cluster head nodes communicate their data to the CH, though the cluster head node receives data from all the cluster memberships, performs signal processing tasks on the data, and transmits data to the remote BS [17].

LEACH uses a hierarchical network structure and is a source initiated protocol with proactive routing. In addition, LEACH provides an energy adaptive clustering algorithm by a dynamic topology with cluster heads. The process of LEACH is separated into rounds. All of these rounds contains of a set-up and a steady-state phase. During the set-up phase cluster heads are determined and the clusters are prearranged. During the steady-state phase data transfers to the base station arise. With this algorithm cluster heads and clusters change periodically within a time called round. In each round a threshold is determined and with this threshold degree every node decides if they are cluster head or not for that round. In order to do this every node determines a random number for each round and if this random number is smaller than that rounds threshold formerly this node develops a cluster head for that round. In LEACH algorithm p defines the favorite percentage of cluster heads in a single round and due to the aim of energy optimization if a node becomes a cluster head in first round then it will not be selected as a cluster head in the next 1/p rounds. Therefore it is certain that all of the nodes can become cluster head but only once in each 1/p round and only nodes that have not already been cluster head recently will have a chance to develop a cluster head. The node picks a random number; if it is lesser than a threshold T(n), the node becomes a cluster-head for that round. T(n) is the threshold value for each node n. The algorithm of cluster head selection is based on the below formula;

$$T_n = \frac{p}{1 - p\left(r \bmod 1/p\right)} \tag{2.1}$$

After cluster head selection every node determines its cluster according to the closest cluster head. When the nodes take chosen themselves to be cluster heads using the algorithm, the CH nodes need let all the other nodes in the network know that they have chosen this role for the current round. Therefore, every CH node broadcasts an announcement message. [16].

LEACH decreases the communication energy by as greatly as eight epochs compared with straight broadcast and minimum broadcast energy routing. The first node death in LEACH happens over eigth epochs later than the first node death in straight broadcast, minimum-transmission-energy routing, and a stationary clustering procedure, and the last node death in LEACH happens over three times later than the previous node death in the other procedures.

Please note that the energy savings are due to aggregation of data. The problem with LEACH is that it requires direct communication to the sink node; LEACH is not designed for networks where the sink node is to be located outside the communication range of sensor nodes. Another problem is dynamic clustering overheads as head changes and advertisements may consume the energy that is gained from communication.

In case of any communication between two nodes, the transmitter node just needs to send the message to its cluster head and the remaining parts will be completed by the

CH. When the CH receives the message it will send the message to receivers cluster head and this node will send the message to the final receiver node.

Therefore an effective way of energy consumption is provided and moreover since all of the nodes does not need to know whole topology this communication structure will decrease the complexity.

On the other hand in case of direct communication every node needs to send their messages directly to the BS or another receiver. If the receiver is far away from the node then transmission will require higher amount of energy therefore the transmitter and receiver nodes both will lose a large amount of their energy. This will cause nodes to quickly drain their batteries and reduce the networks lifetime. However this type of communication may also be acceptable if the nodes are located close to each other or BS. Although LEACH provides an adaptive energy consumption and it increases the efficiency of wireless sensor networks there are still some problems with energy consumption and data aggregation.

Since every node can become a cluster head in LEACH algorithm it sometimes may result with undesired topologies. In some cases border nodes can become cluster head and in this case the higher distance between cluster heads and cluster heads members increases energy consumption and results an inefficient network. On the other hand distance between the cluster heads also becomes important for efficiency, one of the undesired state in clustering topology is the small distance between cluster heads. In order for efficiency to be higher, distance between the cluster heads should be adequate enough for occurrence of two different clusters.

As a result LEACH provides efficiency for wireless sensor networks however it sometimes may cause inefficient topologies. Some clustering results for good case and bad case are given below in Figure 1 and Figure 2.

In these figures clusters are given with different markers and cluster heads are also marked with square. As it can be seen from Figure 1 there are four different clusters and cluster heads are not border nodes. Additionally the distance between the cluster heads are adequate according to the total size of network. Figure 2 shows the bad case scenario for LEACH. In this case there are six clusters but since two cluster heads are located so close to each other, the selection of these cluster heads may cause inefficiency. Recently there are different research in literature providing different solutions and improvements for LEACH algorithm.

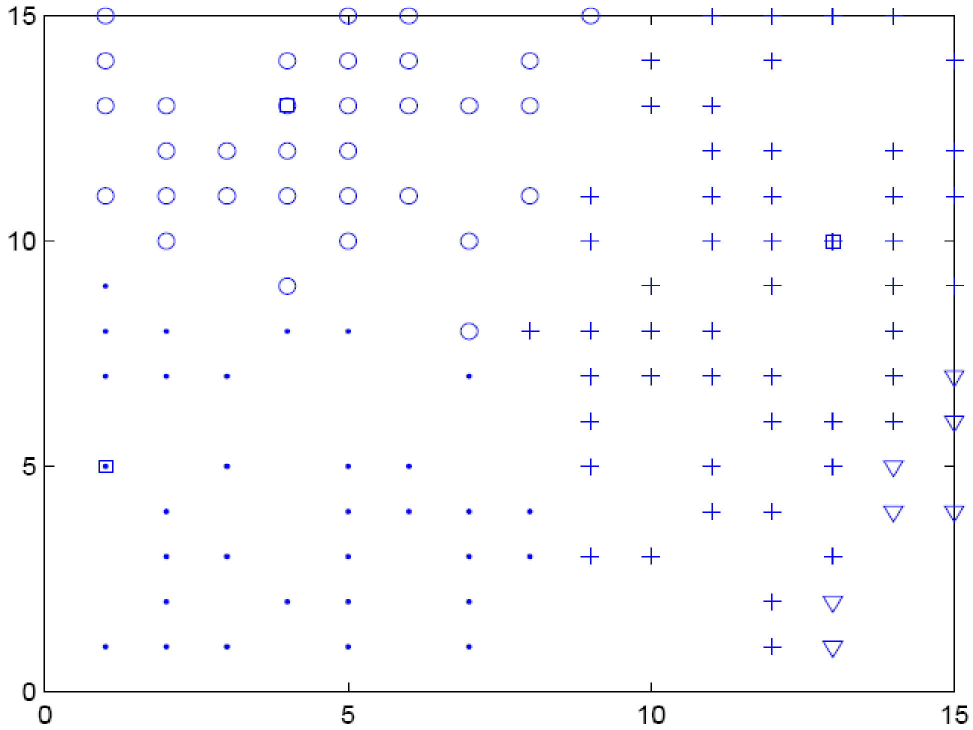

Figure 1 Good case of LEACH.

M. J. Handy, et all has published a paper about an improved version of LEACH algorithm. They point out some disadvantages of LEACH such as the probability of the nodes with lower level energy becoming cluster heads. Their first approach for increasing the lifetime of the network is taking into explanation the remaining energy of nodes in CH assortment. In case of this calculation a node has to have enough energy to become a cluster head therefore low energy nodes will not have the right to become cluster head. In order to apply this approach to the algorithm they modified

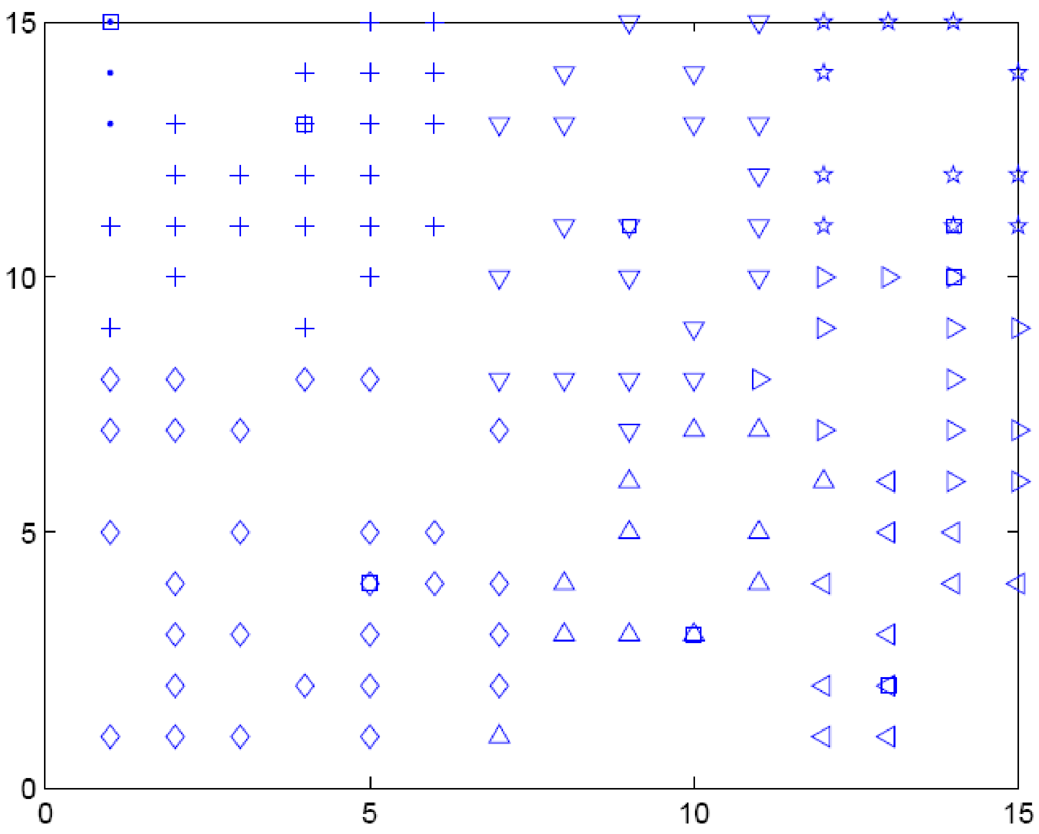

Figure 2 Bad case of LEACH.

LEACH formulation as below;

$$T_n = \frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)} \frac{E_{ncur}}{E_{n\max}} \qquad (2.2)$$

E_{ncur} is the existing energy of the node and $E_{n\max}$ is the preliminary energy of that node. Therefore they represent the energy level with the coefficient $E_{ncur}/E_{n\max}$. This approach leads higher energy level nodes to become cluster heads and simulation results show that improvement in efficiency can be provided. However there are still some disadvantages also in this case, after certain number of rounds network becomes stuck. Since after some certain rounds most of the nodes will have low level of energy, the threshold for becoming a cluster head will become too low. Although there will be still some nodes which have enough energy to send data due to the low energy level of threshold the network will already become stuck.[19] The equation is modified as in 2.3 with a coefficient for the nodes that has not become a cluster head in 1/p rounds.

$$T_{n_{new}} = T_{n_{LEACH}} \left(\frac{E_{ncur}}{E_{n\max}} + r_s p - \frac{r_s p E_{ncur}}{E_{n\max}} \right) \qquad (2.3)$$

In equation 2.3 rs is the amount of rounds for a node that had not become a CH, if this number reaches 1/p then the formula will be modified the older version as in LEACH then $T_{n_{new}} = T_{n_{LEACH}}$. Therefore remaining nodes will have chance to become cluster head and in other cases r_s will be set to 0 in order to achieve modified formula.

By this modification authors has solved the problem of stuck network and also they have reached a more effective energy consumption than LEACH. With these alterations a thirty percent of increase in lifetime of micro sensor networks can be talented.

The authors in [19] has deliberated two modifications of LEACHs CH selection procedure. The nodes themselves define whether they develop CH. A message with the base station or an arbiter-node is not essential.

Once the clusters and cluster heads are determined cluster heads select a predefined number of head set nodes according to the signal strength of acknowledgement messages. At the finish of round, completely the clusters are not demolished; though, each cluster is reserved for the number of rounds equivalent to the head set extent [20]. Therefore nodes of the clusters with the head set extent one can become candidate for the next round however the nodes of cluster whose head set size is bigger than one do not participate in the next selection. This clustering structure decreases the number of elections and provides more efficient clustering.

2.2. Hybrid Energy Efficient Distributed (HEED)

The authors in [21] has approached a new clustering algorithm based on some probabilistic equations. In this algorithm it is assumed that nodes have no specialties such as having a GPS. The main approach is to cluster all the nodes in an equal way which is based on probability. As the other clustering techniques HEED algorithm also aims to prolong the network lifetime and increase the efficiency. In order to compare network time they defined a certain value as the first or last node depletes its energy. The main factor in the probabilistic approach is the residual energy of nodes.

In HEED algorithm every node is exactly mapped to one cluster and this node has to be able to interconnect with the CH via lone hop. The transmission ranges and energy levels are classified and defined as inter-cluster transmission range, inter-cluster power, intra-cluster transmission range and intra cluster power. Inter cluster transmission range is higher and inter transmission requires more energy than intra cluster transmission as expected.

Cluster head selection is mainly based on two different approaches that are about energy level and cost. In order to consider the energy levels of nodes for cluster head selection authors define an initial set including high energy level nodes. Therefore it is prevented for low energy nodes to become cluster head. The second parameter cost is used to break ties between nodes. If two different nodes in the same intra cluster transmission range sends their willingness to become a cluster head a tie occurs between these two nodes.

The HEED algorithm is mainly based on probability of being a cluster head which is given with the following equation 2.4, all the nodes set their initial probability to become a cluster head as $C_{h_{prob}}$;

$$C_{h_{prob}} = \frac{C_{prob} E_{res}}{E_{\max}} \tag{2.4}$$

$C_{h_{prob}}$ is the likelihood of a single node to develop a cluster head, $C_{h_{prob}}$ is the small constant that is defined by algorithm.

HEED provides an efficient clustering algorithm based on probabilistic to increase the network lifetime. There are some different approaches on HEED to increase efficiency. O. Younis et all has provided an improved algorithm IHEED which is mainly based on HEED. This algorithm integrates node clustering and multi hop routing in order to increase efficiency of network.

One of the most important challenge in IHEED is addition of clusters in data collection trees without degrading path superiority [22]. In this topology only cluster heads are used to construct the aggregation tree, since cluster heads will be distributed well even if the nodes are not well distributed path quality will be higher inter cluster level. Figure 3 shows the general structure of aggregation tree with IHEED clustering.

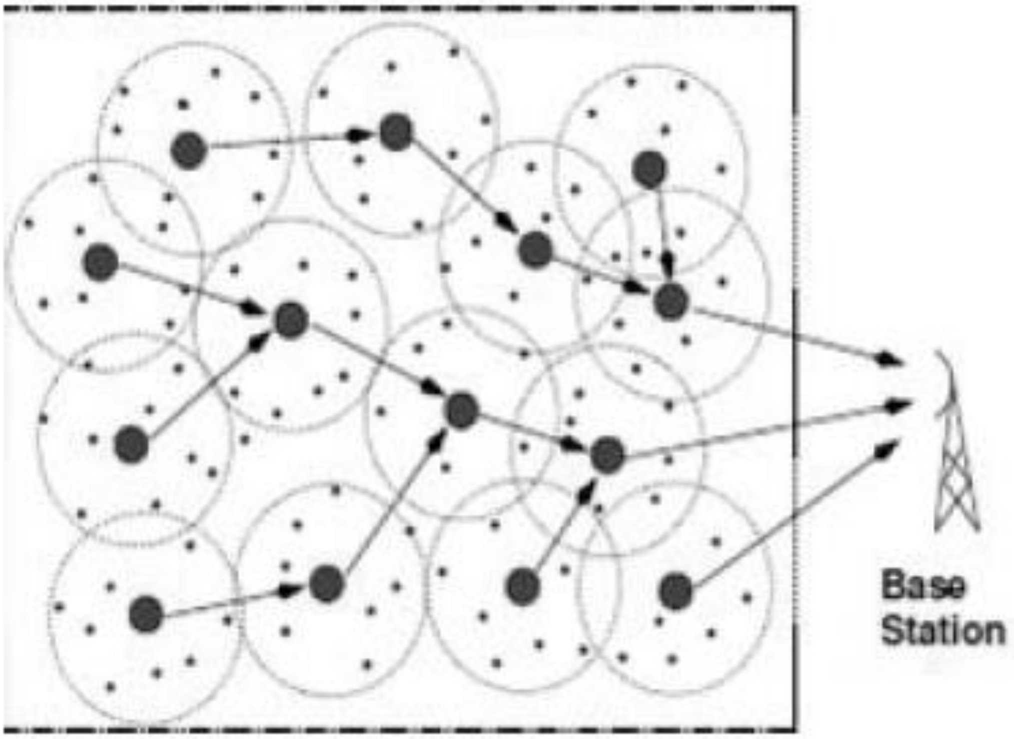

Figure 3 Spanning tree of cluster heads in IHEED [19].

Another challenge that IHEED provides is the estimation of remaining energy of a node. Although this estimated energy level is not always guaranteed it results more efficient clusters. The method is used to estimate energy level is credit point system which is already used in previous applications. It is a simple method that compiles identified physics formula, and converts Joule feeding into point inference for simpler calculations.

Simulation results show that IHEED reaches its goal of prolonging the network life time by integrating clustering to data aggregation [21].

CHAPTER 3

LITERATURE REVIEW

3.1 Properties of Wireless Sensor Networks

Design space of the wireless sensor networks is very large since applications and systems differ much with varying requirements and characteristics. Taking this fact into account, [3] try to point out the design issues in wireless sensor network design. A similar discussion is also made by [2].

Interaction among users, request domain experts, hardware designers and software designers is needed for an effective design. They complete their analysis with the following dimensions.

3.1.1. Deployment

Deployment of the sensors may take different forms. Sensor nodes can be located at predetermined locations or they can be dispersed randomly, e.g. dropping from aircraft on to a disaster area. This can be a onetime activity (sensor nodes are deployed only once) or a continuous process (after first batch is deployed, additional nodes are deployed to replace failed ones or to improve coverage during monitoring). Type of deployment affects the decisions that will change the performance of the network.

3.1.2. Mobility

The initial location of the sensor nodes can change because of several factors. Sensor nodes can be carried by mobile devices or they may have capability to move themselves. In addition to these, environmental factors, like wind or water flow, can change the initial position of the sensor nodes. Mobility has an important impact on the network subtleties and henceforth effects the networking procedures and algorithms proposed for the design of the sensor network. Sensor nodes can be mobile or immobile considering the equipment and requirements of the sensor network.

3.1.3. Cost, Size, Resources, and Energy

Size of the sensors changes depending on the actual needs of the application; it varies from the extent of a shoebox to a minutely small particle. Costs of the sensors can vary widely considering their properties. Powerful nodes can be required for small sized networks and these cost hundreds of Euros whereas the cost can be only a few cents for very simple sensors. Energy availability and resources for computing, storage and communication are directly related to the size and the cost of the sensor.

3.1.4. Heterogeneity

Nodes might change in the type and number of involved sensors; some computationally influential nodes might collect, procedure and route data from many more imperfect sensing nodes; selected nodes may act as rechargable to extensive range data announcement networks. Heterogeneity is important since it affects the organization of the entire system.

3.1.5. Communication modality

Public modality is radio waves since they don’t require free line of vision, and communication over average ranges can be implemented with comparatively small antennas. Light beams and sound are also used for communication in different applications.

3.1.6. Infrastructure

There are two common forms for infrastructure of the wireless sensor network design which are infrastructure based or ad hoc. In infrastructure based networks, nodes can communicate with only a BS. In the ad hoc form, nodes can communicate with every extra also that they can send data to the base station (or sink) over extra nodes. Deployment of the former has higher cost therefore ad hoc networks are generally preferred.

3.1.7. Network Topology

There are several network topologies like star, tree and mesh considering the design of a sensor network. Topology is very crucial since network characteristics like capacity, latency, and robustness are directly affected by the choice of topology. Moreover, important decisions such as routing and processing of the data sensed should be made according to the network topology.

3.1.8. Coverage

Coverage is about the sensing capability of the wireless sensor network. Therefore it is related with the sensing ranges of the sensor nodes used for monitoring. In a monitoring area, only some regions may be of interest or some specific locations need to be sensed by the sensor nodes. In some cases, area of interest may have to be completely covered by sensors. There are different coverage models discussed by [23]. These are blanket coverage, barrier coverage and sweep coverage. In barrier coverage, a static preparation of the sensor nodes which reduces the probability of undetected diffusion is tried be achieved. In blanket coverage, the aim is to arrange the sensor nodes so that total detection area is maximized. Sweep coverage is the dynamic arrangement addressing a balance among maximizing the detection rate and minimizing the number of missed discoveries per part zone.

3.1.9. Connectivity

The nodes of the sensor network consume to be connected in directive to forward the sensing information to a base station or a sink node. A network is said to be connected if each sensor can interconnect with at least one extra sensor and there exists at least one node that can communicate with a sink node. Communication ranges of the sensors are important for the design of a connected network, as they determine the connectivity. In general, two sensors are connected if the distance between the two is fewer than the smallest of their communication ranges.

3.1.10. Network Size

Size of the network is resolute by the size of the area of interest, the number of nodes, sensor characteristics and sensing requirements such as coverage and connectivity.

3.1.11. Lifetime

Lifetime of the network is determined by the properties of the sensor nodes. It can change from hours to years for different applications. Energy efficiency is an portant issue for network lifetime. Sources of energy consumption are discussed in detail by [16].

3.1.12. Quality of Service Requirements

Quality of service aspects to be considered are real time constraints (degree of coverage, required time for reporting data etc.), robustness, resistance and other issues.

3.2. Design Issues in Wireless Sensor Networks

Studies in the literature generally concentrate on the deployment of the sensor nodes. The problem of deployment in wireless sensor networks emerged as the base station location problem for cellular phone networks in early 1990s, as stated in [24]. Sensor nodes in WSNs can also transmit the data to other nodes in addition to their own sensing tasks, therefore sensor nodes need to communicate with each other (connectivity). Base station location problems are similar to facility location network design problems, where location of each facility needs to be determined and the network connecting the facilities must be optimized. In this type of problems, sensors are manually deployed across the monitoring area. The sensors are deployed over the monitoring area without human, e.g. by dropping from aircraft.

Data routing is another decision in WSN design. Obviously, connectivity is a requirement for data routing. This assumption is not realistic since area to be covered can be disjoint, some physical obstacles like mountains and buildings can block communication. In the literature there are different objectives considered in the optimization of data routing, which are also discussed by [25]. Algorithms for connectivity are discussed [26]. Another important concept for WSNs is energy efficiency. Sensor nodes are often little devices fortified with one or more sensors, one or more transceivers, processing and storing resources. [2] State that sensors have a small and finite source of energy, and they are incomplete in computational capacity and memory, therefore it is important to take wireless channel bandwidth limitations and sensors' processing capacities into consideration while minimizing the energy consumed in communication. This is directly related with efficient routing of the data.

Taking all of these into account, we categorize the related studies according to decisions considered. To start with deployment, sensor nodes may be deployed manually or randomly. If the sensor nodes are deployed randomly, there is not a location decision to make. Most of the studies considering given or random deployment deal with energy efficiency problems. Data routing is another decision that must be taken into account. In the literature there are some studies that determine the data flow between sensor nodes. Hence, studies are also categorized as "no routing" and "routing" according to determination of data flows between sensor nodes.

3.3. Given or Random Deployment - No Routing

Potkonjak and Slijepcevic [27] consider energy efficiency problem for stochastically placed sensor network. They present a experiential that selects equally exclusive sets of sensor nodes, anywhere members of every set together totally cover the monitoring area. Significant energy savings is achieved by allowing only one of the sets to be dynamic at any time. The study of [28] is very similar to [27]. In this study, the objective is to maintaining coverage of the targets as long as possible. Their approach is based on finding maximum number of sets as in [27]. The difference is that a sensor node can be included in different sets for different time intervals. Their approach is to schedule the node activation times so that lifetime of the network is maximized. They proposed an integer programming formulation for finding the schedule and a greedy approach using LP relaxation of this integer program.

Cardei and Wu [28] provide a survey on offerings addressing energy effective coverage problems in static WSN. They describe coverage formulations for different network requirements such as connectivity and minimum energy together with assumptions and solution approaches.

3.3.1. Deployment Decision - Only Location

Chakrabarty et al. [29] address the grid attention strategies for actual surveillance and target location in dispersed sensor networks. Monitoring area is divided into grids and they are referred to as targets to be detected at any time. A digit linear programming model is proposed for lessening total cost of sensors for complete attention of the monitoring area. Large problems are tried to be solved by a divide-and-conquer approach.

Ke et al. [30] try to solve the sensor deployment problem by dividing sensor field into grids containing of squares or regular triangles. By this format, they find the minimum amount of sensors prerequisite to be deployed on grid points in order to concept a WSN that fully covers the chosen critical grids. Connectivity is also considered in this paper. They conclude that the critical grid coverage problem is NP-Complete.

3.3.2. Deployment Decision

Jourdan and Weck [24] work on the optimization of WSN layouts. A multi impartial GA for sensor deployment problem is proposed where two opposing objectives are total sensor coverage and epoch of the sensor network. It is assumed that the number of sensors to be deployed is given and each gene in a chromosome represents the coordinates of each sensor. Routing of the data is done by using Dijkstra’s shortest path algorithm. They state that if this ratio is lower than ½, layout is formed of polygons and crowded whereas hub-and-spoke type layouts become optimal in the opposite case.

Wang et al. [31] discuss relay node deployment in WSNs. They develop a formulation in which the number and position of sensing points are known. Three kinds of devices, SN, relay nodes and BS can be installed at chosen points. Given sensor node locations, they concentrate on connectivity oriented deployment. They solve this problem by considering it as a minimum set covering problem. In the second case, they assume that RNs have a limited energy and fixed transmission range. They pose a two phase RN deployment approach. In the first stage, minimum amount of RNs are placed to confirm the connectivity of SNs. In the second stage, additional relay nodes are placed to provide the connectivity of the previously placed RNs to the sink node. For the second phase they present three heuristics based on load balancing considering the capacity of RNs and distance to the sink. In the first algorithm, starting from the RN farthest from a BS, data is routed to closest existing the RN. When existing neighboring RNs cannot handle the traffic load, a new RN is added. In the second algorithm, two different approaches are proposed. In the first one, starting from the RN farthest from the sink node. In the second approach, workload of a given RN is distributed starting from the one with the maximum residual capacity. In the last algorithm, when a new RN is added, the workload is distributed to other RNs and the newly added node whereas it is only distributed to newly added RN in the previous algorithms. Moreover the location of a new RN is chosen as close to the BS as possible. They conclude that the last algorithm performs best considering their metrics which are the number of RNs added, energy cost and average capacity utilization.

Hou et al. [32] talks the problem of energy provisioning and transmit node deployment for a two-tiered wireless sensor network. For some applications, even under optimal stream routing, it may not be able to meet the assignment supplies. In such cases energy provisioning may solve the problem of the network lifetime. They propose a mixed integer nonlinear programming model to solve the joint problem of energy provisioning and relay node deployment. In addition to flow decisions, decision of deployment of relay nodes over the monitoring area is also considered. The deployment is done in the continuous manner meaning that a relay can be located at any location on the monitoring area. A decision variable is introduced for energy provisioning so that the energy of a certain number of relay or sensor nodes can be increased during monitoring. Total energy available is known and the aim is to distribute this energy to the nodes in order to increase the lifetime. The model is solved using BARON for small instances, but it is not computationally efficient for larger problems. A two phase heuristic algorithm is proposed. In the first phase, locations of the relay nodes are found by a heuristic algorithm. In the second phase an LP is solved for the energy provisioning problem since the energy provisioning problem turns out to be an LP with given locations of relay nodes.

Pan et al. [34] consider a two-tiered WSN containing of sensor clusters organized around strategic locations. The aim is to locate base stations in a continuous manner over the monitoring area. The authors propose methods to maximize network lifetime, by placing the location of the base station and relaying between sensor nodes and base station. After locating base station, flow assignments are determined.

Krause et al. [33] focus on a unified approach for deploying sensor nodes. They try to optimize location of sensor nodes using expert knowledge obtained by initial deployment. They propose a polynomial time algorithm which deploys sensors at informative and cost effective locations. They introduce a temperature measurement example where the quantity of information is taken as the expected amount of temperature change that cannot be sensed.

3.3.3. Given possible locations

Zongheng et al. [36] address the problem of constructing a minimum size connected network with K -coverage. This means selecting a set of sensors such that each point is covered by at least K different sensors and sensors are connected. The idea is to keep the minimum set of sensors active to provide the necessary coverage and connectivity, resulting in an energy conservation technique. They propose a greedy algorithm considering the number of times each point is covered by the same sensors in the selected set. The greedy algorithm returns a connected set. A distributed version of the algorithm provides larger size solutions.

Quintao et al. [35] address the problem of activating the minimal number of nodes for maintaining coverage and connectivity with network lifetime consideration. They state that this problematic is identified as the attention and connectivity problematic in WSN and can be demonstrated as a mixed number linear programming. They propose a mathematical model but try to solve it by a two phase heuristic solution method because the exact solution requires high computational effort. They pose the problem as follows: assumed a monitoring area, a set of request points, a set of sensor nodes and a basin node, assure that at least n sensor nodes cover each demand point in the monitoring area, there is a path among these nodes and the basin node, and battery energy of the activated sensor nodes is not depleted. Connectivity is taken into consideration as stated in the second part of the problem but data routing is not considered. It is assumed that energy consumption for receiving and transmitting is independent of the data amount.

Quintao et al. [35] decompose the problem into two sub problems. The first problem, definition the minimal number of nodes required to cover all demand points, is solved by a genetic algorithm. In the second phase the best solution originate in the first phase is adapted to ensure the connectivity among active nodes. In the genetic algorithm, binary encoding is used to represent the activated nodes. Fitness is taken as the number of uncovered points together with total cost of the paths from all nodes to the sink node. They try to consider both energy efficiency and coverage. Using solutions obtained from the genetic algorithm, they apply Prim’s minimum spanning tree algorithm. The condition for connectivity is taken as follows: two nodes can communicate with each other which is not generally the case for WSN applications. Given this condition, some active nodes may be disconnected from the tree constructed. Some inactive nodes on the path found are also activated. They compare their results with optimal results obtained by solving the mathematical model using CPLEX. The deviation of their heuristic approach from optimal is nearly 20% with better run times. Important issues like sensor capacities and data routing are not considered in this study.

Cheng et al. [39] express a constrained nonlinear software design problem to determine both places of the sensor nodes and data flow between the nodes considering two objectives: maximize network lifetime and minimize total application cost. A heuristic approach is proposed to solve this nonlinear program with single objective. They claim that for a given time horizon, both objectives can be considered by minimizing the total power consumption.

Pandey et al. [37] consider the problem of placing the minimum number of relay nodes to handle the traffic of previously deployed sensor nodes. The problem is formulated as an optimization problem and three different approaches are proposed to solve the problem. In the first one, the problem is modeled as a binary integer linear programming model without connectivity constraints, and the solution is modified by a greedy Steiner tree algorithm to have a connected network. A greedy deployment algorithm based on clustering and a genetic algorithm are also proposed. The constraint violations are penalized in the fitness calculation. They have also considered hybridizing these algorithms.Chang and Chang [38] propose efficient node deployment, topology is first constructed based on grid based WSNs. Then, two different sensor node deployment schemes trying to balance the power consumption of sensor nodes are applied. Finally, a scheduling protocol is used to avoid packet collision.Ferentinos and Tsiligiridis [40] focus on a multi-objective optimization method for self-organizing, adaptive wireless sensor network design and energy management. They propose a genetic algorithm with a fitness function incorporating different objectives of the network optimization problem. The decision is the status of the sensor nodes deployed (active or inactive) and the signal range of the active sensors (high or low). Their GA tries to optimize sensor activation and range selection from the set of distributed sensor nodes on the given grid layout of the monitoring area. Although this seems to be a problem where sensor locations are given, activation decision and range selection are analogous to deployment of two types of sensors. They also consider the dynamic version of the problem. In the dynamic case, sensor nodes activated in GA solution work for some time and then battery energy of the sensor nodes are updated. Then a new GA run provides a new solution which will work for some given period.

3.4. Discussion

Connectivity and coverage requirements together with application specific constraints are not taken into consideration explicitly in most of the studies. In Patel et al. [41], it is emphasized that wireless channel capacity and finite sensor capacities should be taken into consideration in order to prevent routing of the data packets over highly congested links and paths since congestion increases the delay and packet losses, which will increase the energy consumption because of retransmission of the packets. Moreover most studies deal with homogeneous wireless sensor network design. In our study, we consider heterogeneous wireless sensor network design by taking application specific constraints such as connectivity, coverage, node capacity and link capacity into account.

Our study takes all of these aspects into account simultaneously for WSN design.

As stated by Cheng et al. [39], we try to investigate the tradeoff between cost and lifetime objectives while deciding on sensor deployment and data routing. We use a probabilistic coverage model for the detection of the targets. We consider locating sensors at given possible locations resulting in an ad hoc network and try to model the data communication under the connectivity, coverage, node capacity and link capacity constraints.

CHAPTER 4

PROPOSED METHOD

4.1 Network model

In this section, we tend to assume N sensors that remain deployed arbitrary in a very field to observe setting. We denote the i^{th} sensor element by n_i and resultant sensor element node set N= n_1, n_2.., n_n .We suppose the network model shown in figure 4.

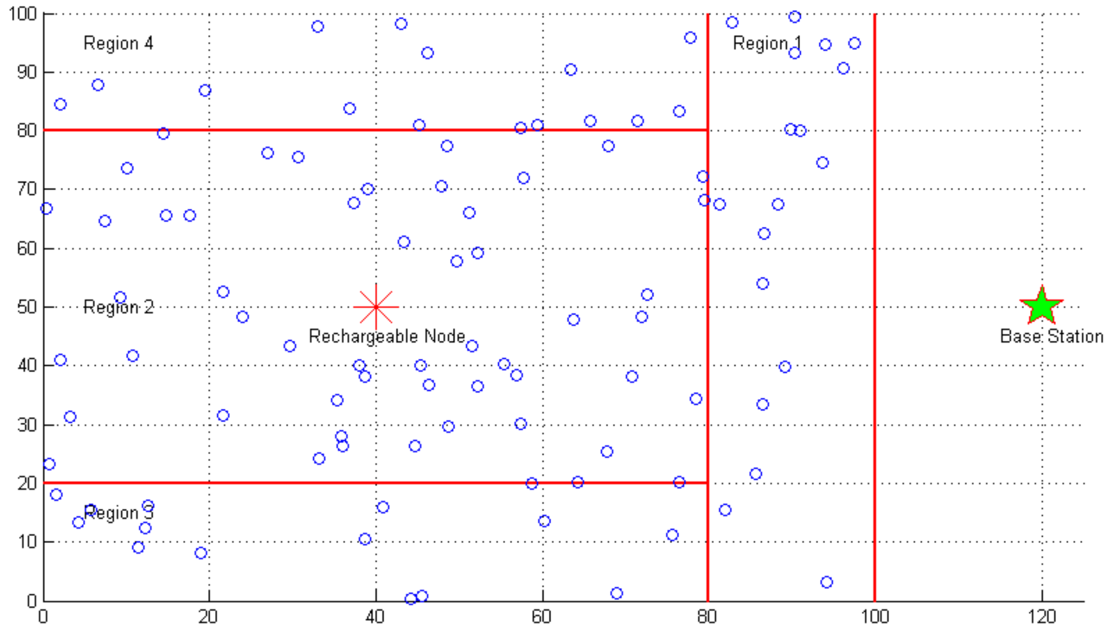

Figure 4 Our proposed network model.

We spread the base station away from the sensing field. Sensor element nodes and also the base station are stationary later positioning.

Whole of sensor element node is allocated with a particular symbol.

We used radio model as employed in [42, 43]. Figure 5 shows this model.

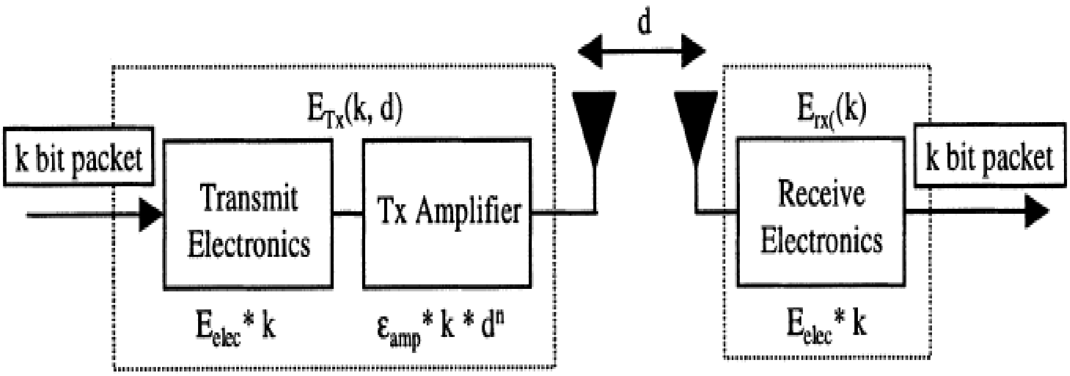

Figure 5 Radio model

Whole of sensors need energy to transmit packet of k bits information to a distance d and to receive an information packet of k bits, is given as:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec} \times k + E_{amp} \times k \times d^2 \tag{4.1}$$

$$E_{Rx}(k) = E_{Rx-elec}(k) E_{Rx}(k) = E_{elec} \times k$$
$$E_{Rx}(k) = E_{elec} \times k \tag{4.2}$$

4.2. THE PROPOSED METHOD

In this section, we render detail of our method. Sensor element nodes have an excessive amount of sensed information for base station to method. Therefore, self-acting technique of joining or collect the information into a little set of important information is required [44] and [45]. The method of information collect aggregation additionally termed as data fusion. So as to boost network life and output, we have a tendency to deploy a rechargeable sensor node at the center of the network area.

4.2.1. Initial Phase

After initialization of nodes and simulation environment, sink node creates the first advertisement message which consists of message ID, sender, query, send list. After producing advertisement message, sink node creates the first entry which is located at the first place of the time line with time stamp 0.0.
This entry consists of sender node, list of nodes that message is sent to, message and time stamp. The first entry's type is set as send type. This is the first entry to be processed in starting phase of simulation. Task list is the container of the entries created by nodes and entries are ordered in time of creation.

4.2.2. Setup Phase

In setup phase, we divide the network area to four region. The first region send information directly to base station. Other two region send to cluster heads and cluster heads send information to rechargeable sensor and this sensor send information to base station. The other region is near to rechargeable node and this sensor send their data directly to rechargeable node and this node send this information to base station. The nodes in region two that are close to rechargeable sensor, send their information on to rechargeable sensor that aggregates information and this sensor send information to base station. The first region and last region is without any cluster head.

4.2.3. Cluster Head Selection

In LEACH algorithm nodes select their respective CHs according to the probability value from the node that announces itself as CH. Data aggregation and fusion and TDMA schedule is executed by CH, thus CH nodes consumes relatively much more energy than member nodes. In every round of the clustering process CH role have to be rotated among all nodes in order to obtain load balancing. LEACH algorithm runs in distributed manner, every node decides autonomously to become a CH without any centralized control. Every nodes determines a random value between 0 and 1, and compares this random value with the threshold T(i);

$$T(i) = \begin{cases} \dfrac{p}{1 - p \times \left(r \bmod \left(\frac{1}{p} \right) \right)} & if \quad i \in G \\ 0 & otherwise \end{cases} \tag{4.3}$$

Where r is the current round number, p is the percentage of cluster head which determined for whole network before and G is the set of sensor nodes which are not become CH in the last 1/p round. If random value is less than threshold T(i) node becomes a cluster head for the current round.

This method is probabilistic and nodes in the network have to be CH without looking their energy level. Thus in the data gathering phase if node dies, whole cluster connectivity is affected until new clustering round would start.

Besides, authors of the LEACH proposed a centralized method LEACH-C to control clustering process by remote base station. Each node sends information about its current location and energy level to the BS. In order to obtain load balancing and select node with high energy level as CH, BS computes average energy of the network and decides that nodes have energy below this average cannot be cluster heads for the current round. The data gathering phase of LEACH-C is identical to that of LEACH. LEACH-C performs better than LEACH on energy consumption but needs node position information and centralized control.

4.2.4. Generating Scheduling

Scheduling is an iterative process started by finding a cluster head node in the nodes in simulation. In algorithm, cluster head nodes are found in the node list. Clusters node count is calculated by adding cluster head node's child nodes and their child nodes up to the third level of depth. Last task's time stamp is taken as the start time of the TDMA scheduling. Slot time is calculated as (round_time / cluster node_count +1). Total slots are distributed to the all child nodes in the cluster with three iterative loops. Each loop finds the child nodes and slots are assigned to the nodes calculating the child nodes of child nodes. Each parent node assigned slots according to their number of child nodes.

4.2.5. Steady-State Phase

In region two and four whole of sensors send their sensed information to cluster heads and this clusters analyzed this information and send to rechargeable nodes. Then this sensor send this information to the base station.

4.3. EVALUATION of PERFORMANCE

We compare our results with results of LEACH (Low Energy Adaptive Clustering Hierarchy). We expect the performance of our algorithm system will overcome the previous works.

4.3.1. Performance Parameters

In this subdivision, we have a tendency to exhibit performance metrics. During this work, we have a tendency to evaluated 3 performance parameters given below.

Table 1 Parameter

Parameter	**Value**
E_0	0.5 J
E_{elec}	5 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
E_{da}	5 pJ/bit
Base station position	(150, 50)
x	[0 100] ^{m}
y	[0 100] ^{m}
N (number of nodes)	100
Message Size	4000 Bit

4.3.2. Simulation Results and Analysis

In this section, we tend to show the simulation results. We tend to run comprehensive simulations and compare our results with LEACH. Next subsections provide detail of every metric.

4.3.3. Network lifetime

When we make simulations, we should define what the network lifetime is. System lifetime can be considered as the time passed before the death of the first sensor in the network. Although this can be a metric, it should not be the only criterion to decide if one algorithm is better than another algorithm. Since the sensor networks consist of many sensors, they are robust to single or few sensor failures. For dense networks, few failures do not affect operation. Let us assume that in Network A, α number of sensors can monitor an area sufficiently. Assume another deployment is made in Network B in a similar area with $2*\alpha$ number of sensors, with two sensors in the same position instead of one sensor in Network A. Network B can continue its operation as good as A even after one of the double sensors die. Therefore, networks can continue their operations even if a big number of their sensors die, if they were deployed densely enough. Figure 6 shows the life time of sensors. As shown in this figure we can see that the proposed method is very good in dead of sensors and this sensors is dead after 1800 round but in LEACH algorithm sensors are dead after 1200 round.

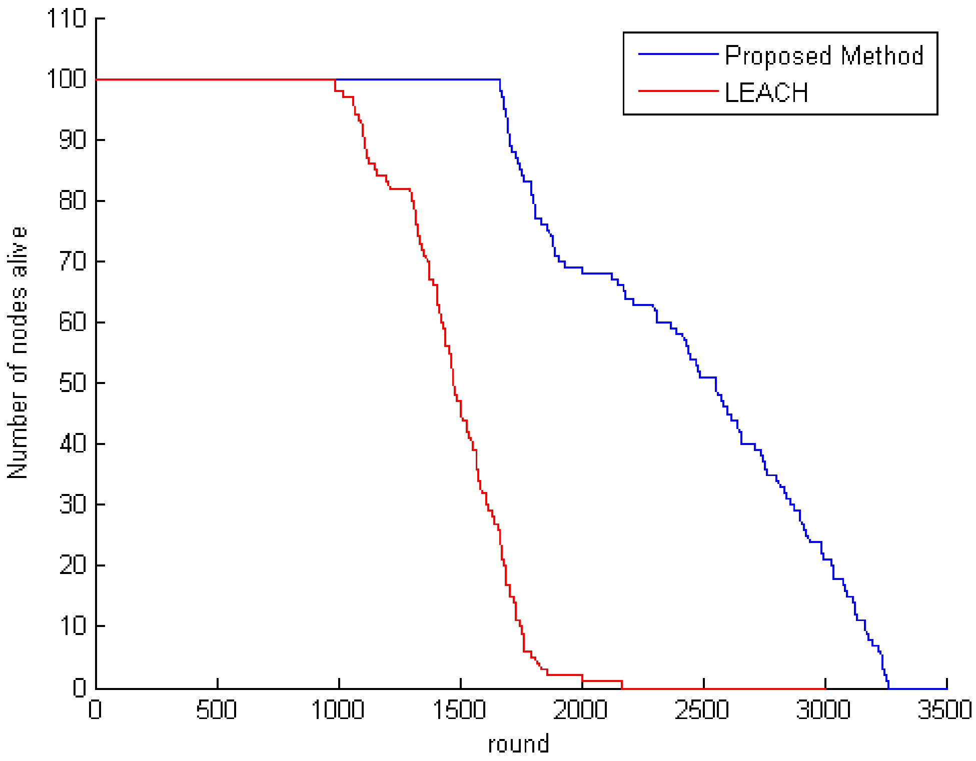

Figure 6 Result of simulation, number of nodes alive vs round

4.3.4. The parameter describing service speed

Whole of packets sent to base station are evaluation through simulations. Simulation results of proposed method show increased output. Interval designs of method and LEACH in figure 7 obviously shows performance of each protocols.

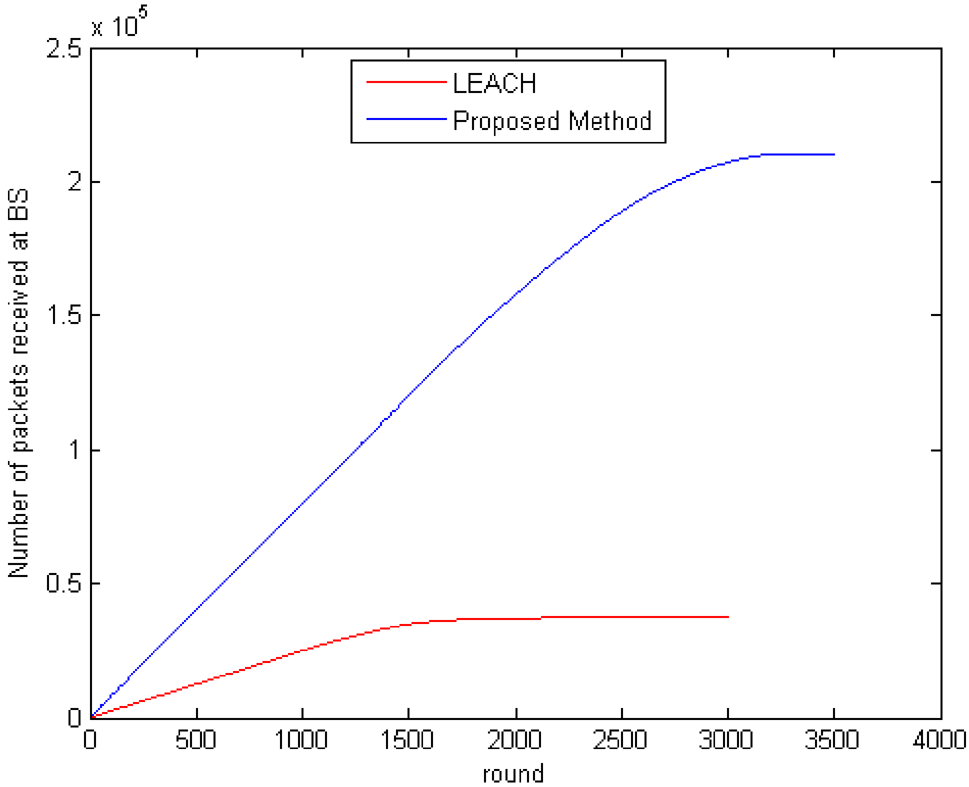

Figure 7 Number of packers received at base station vs round

To compute output, we tend to assume that cluster heads will communicate freely with rechargeable sensor node. Simulation results illustration a rise output of five times then LEACH. Sensor nodes close to rechargeable sensor send their information on to rechargeable sensor equally nodes close to base station transmit information on to base station. Sensor nodes in each areas consume less transmission energy so, nodes keep not dead for extended period. A lot of alive nodes contribute to transmit a lot of packets to base station.

Meaning energy residual of network per round is illustrated in figure 8. The whole sensors have 0.5 joule. Proposed method produces lowest energy usage than LEACH algorithm. Figure 8 shows this result.

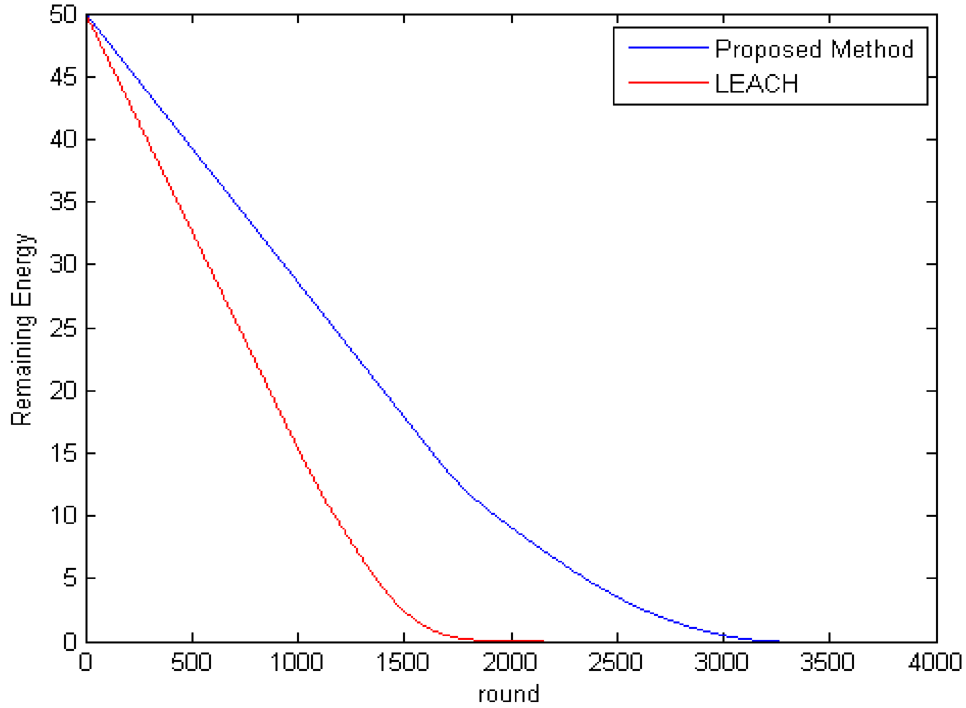

Figure 8 Simulation result for remaining energy vs round

Here we used some other scenario for our proposed. We changed the position of Base Station. This schematic is iluustrated in figure 9.

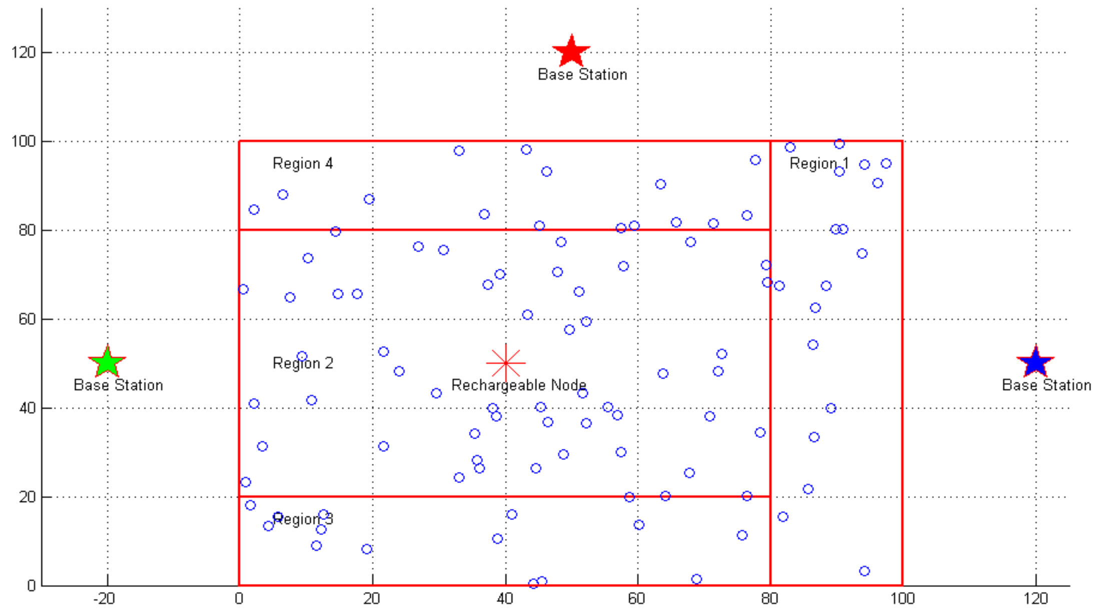

Figure 9 Some other scenario for our proposed method

If the Base station is to be the other where the result is changed because the nearest sensor send directly communication sending data for BS, at now they have to send far a way. The result of scenario is illustrated in figure 10, 11 and 12.

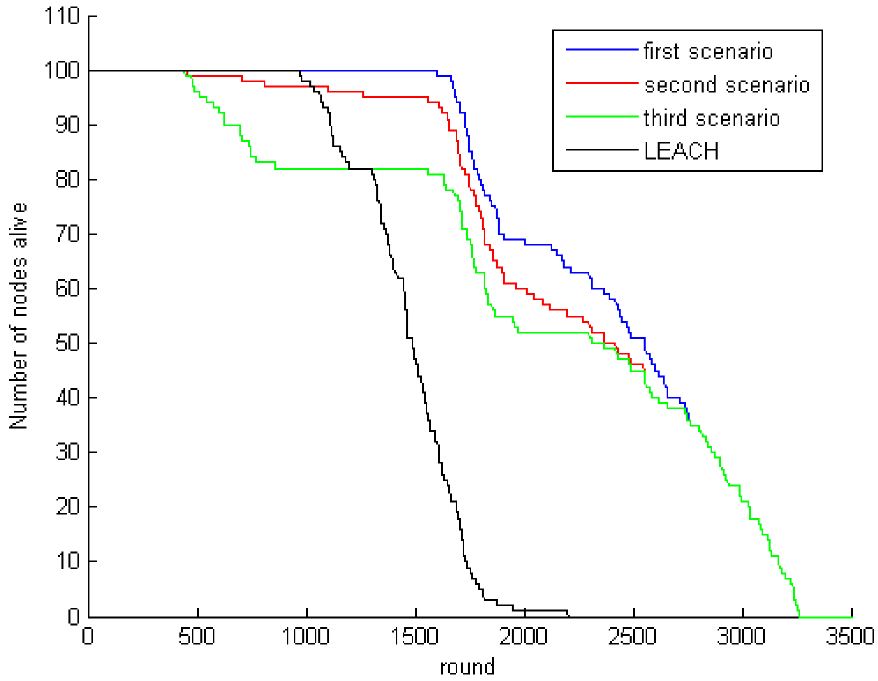

Figure 10 Result of simulation, number of nodes alive vs round

This figure shows if we select the BS near to region one we can to save a lot of energy for sensors. The blue color is show about first scenario. The red color is upper position of BS, and the green result is left position of BS.

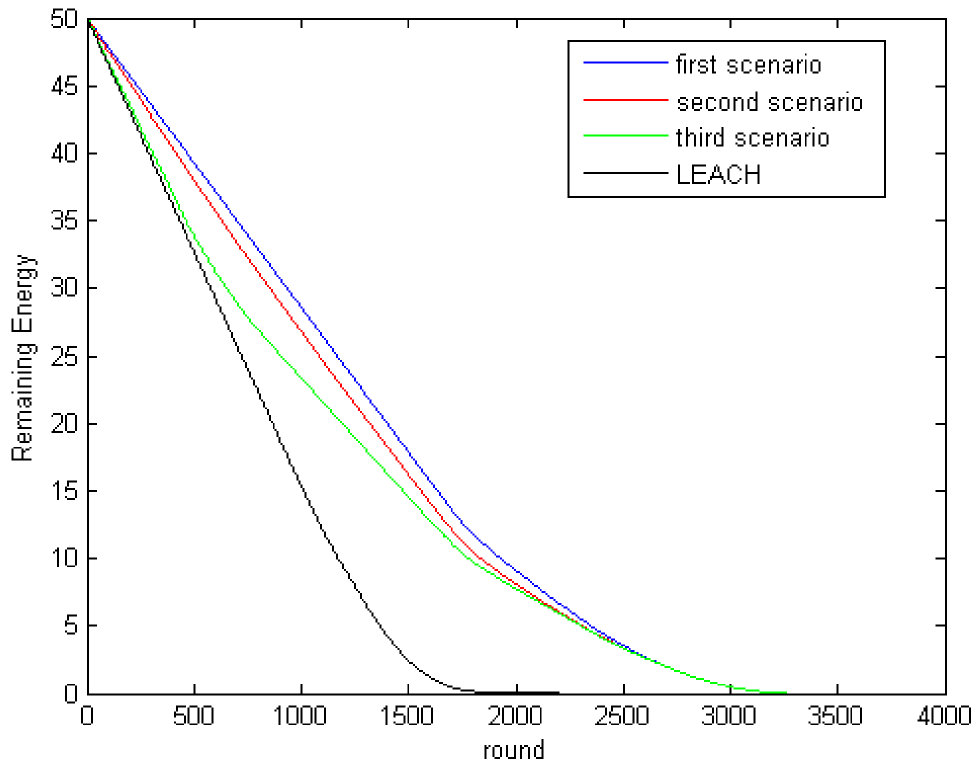

Figure 11 Simulation result for remaining energy vs round

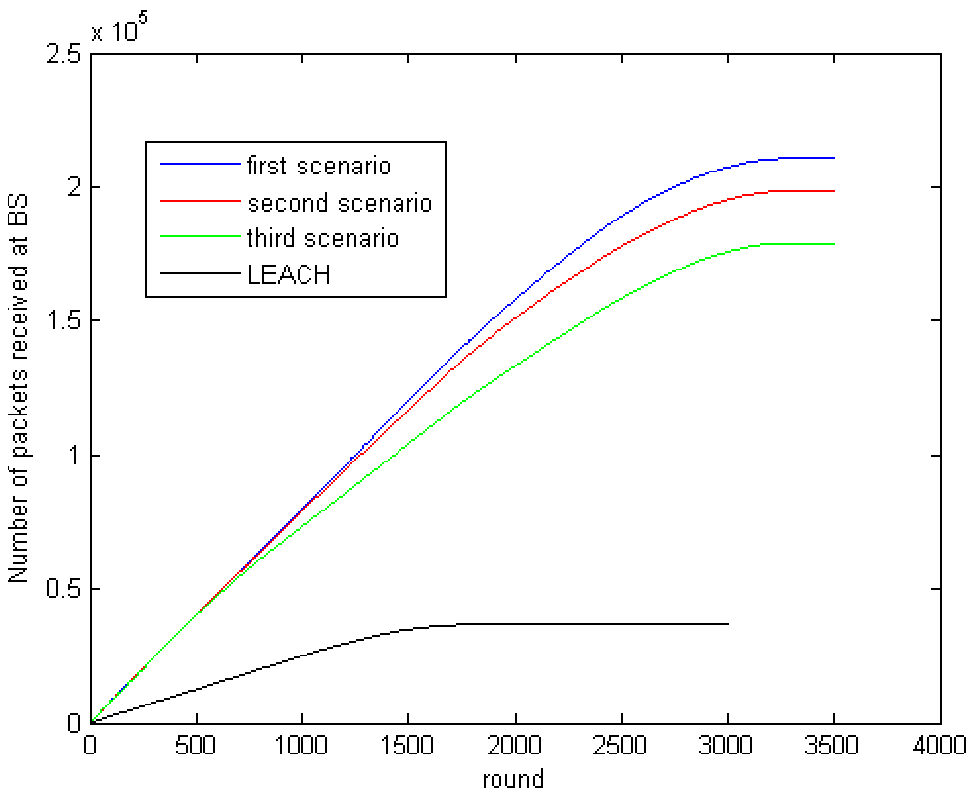

Figure 12 Number of packets received at base station vs round.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The algorithms considered have been evaluated over regular and random topologies on 100x100 sensing region. For the simulations, locations and sensor measurements of the nodes are saved in a file and a predefined set of queries are applied during simulation. Therefore, all clustering models are evaluated under the same conditions. The aim of this thesis is to save the energy of the nodes. The first goal of this thesis is to reduce the total energy consumption of the wireless sensor network. The second goal is to increase the reliability of the protocol along with improving the network latency as compared with previous cluster-based protocols. We divide the network area to four region. First region send information directly to base station. The energy consumption for transmitting a message is directly proportional to length of the message. Two other region has cluster heads and this cluster heads send information to rechargeable sensor and then this sensor send to base station. These cluster heads are selected on the basis of a probability. The area covered by the cluster is chosen as the cluster head. With such a cluster head selection method, the average hop count for child nodes to reach and deliver their messages to the cluster head decreases and this leads to reduced energy consumption for intra cluster communication phase. Each parent node receiving data from its children aggregates those messages and send aggregate to its parent node. Therefore, increase in the hop count also increases message sizes and so energy consumption increases. The last region has rechargeable node and this sensor collect information and then send to base station. Then we are going to compare our protocol performance with LEACH (Low Energy Adaptive Clustering Hierarchy). In order to, prove and compare efficiency of proposed algorithms, a computer simulation software has been developed. We expect the performance of our proposal system will overcome the previous works.

As results, the proposed method is very good in dead of sensors and this sensors is dead after 1800 round but in LEACH algorithm sensors are dead after 1200 round. The whole sensors have 0.5 joule. Proposed method produces lowest energy usage than LEACH algorithm. To compute output, we tend to assume that cluster heads will communicate freely with rechargeable sensor node. Simulation results illustration a rise output of five times then LEACH.

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APPENDICES A

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