An Improved Algorithm based on LEACH Protocol for Data Transmission in Wireless Sensor Network

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B.Sc.(Honours) in Statistics\Computer, University of Gezira (2011)

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Department of Computer Science

Faculty of Mathematical and Computer Sciences

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An Improved Algorithm based on LEACH Protocol for Data Transmission in Wireless Sensor Network

Esmat Alameen Ibrahim Ahmed

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DECLARATION

I declare that this thesis satisfies to all requirements as a thesis for the degree of Master of Science in computer science.

This thesis entitled 'An Improved Algorithm based on LEACH Protocol for Data Transmission in Wireless Sensor Network' The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

Signature:........................................
DEDICATION

To My Family
To My parent
To My Brothers
To My Sisters
To My Friends
To Classmates (My batch)
Who always support me
And
Who always stand beside and help me
ACKNOWLEDGEMENTS

First, I thank Allah for guiding me and taking care of me all the time. My life is so blessed because of his majesty.

Thanks to the supervisor Dr. Murtada Khalafallah Elbashir for his advice and He Did not Stingy any information for me, Thanks to Co.supervisor Dr. Sally Dafa Allah Awad Elkarim to help me in this research.

Also, I would like to thank My Family especially My Parents for encouraging and supporting me all the time.

And, I wish to express my considerable gratitude to best Friends, who Always help me, and for their supports.
An Improved Algorithm based on LEACH Protocol for Data Transmission in Wireless Sensor Network

Esmat Alameen Ibrahim Ahmed

ABSTRACT

The Wireless Sensor Networks (WSN) is collection of a large number of sensor devices (nodes) that deployed randomly in geographical area. Each device consists of sensing, processing, communication, and power units. Each component has specific task, a sensing unit for sensing data from the physical surrounding environment, a processing unit for processing data and storage, a wireless communication unit for data transmission, and a power unit for supplying the node with the required power. WSN is applied in wide application area such as health, military, environmental area, Home, office and commercial. WSN suffer from limited power capacity, and it’s not rechargeable or replaceable, so more efforts and techniques are needed in order to save battery lifetime as long as possible. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is hierarchical clustering algorithm for sensor networks that is aimed to minimize the number of node that directly communicates with the base station (BS) to reduce the energy consumption of the network. In LEACH there is the cluster head (CH) nodes compresses data arriving from non-cluster head nodes that belong to the respective cluster, and send an aggregated data to the base station in order to reduce the amount of information that must be transmitted to the base station. The main objective of this research is to prolongate the WSN lifetime, by improving the LEACH protocol and produce new version know as I_LEACH based on energy and distance. So, I_LEACH examine the distance if the CH is close to the BS then the data will be sent to the BS, otherwise in if the distance from the node to base station is greater than the distance from the node to BS through the max_cluster’s cluster head, it selects the cluster head located in the max_cluster that have maximum total energy and minimal distance. MATLAB is used to simulate the I_LEACH protocol. The experimental results show that the proposed protocol outperform the benchmark, hence this will maximize the network lifetime. As for future work, the algorithm can be modified to provide tasks distribution among sensor devices, this will cover the required area and prevent nodes from dies.
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<td>I_LEACH</td>
<td>Improved Low Energy Adaptive Clustering Hierarchy</td>
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<td>CH</td>
<td>Cluster Head</td>
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<td>ADC</td>
<td>Analog to Digital Converters</td>
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<td>BS</td>
<td>Base Station</td>
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<td>BEC</td>
<td>Based Energy Clustering</td>
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<td>Join Request Message</td>
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<td>CSMA</td>
<td>Carrier Sense Multiple Access</td>
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تحسين خوارزمية اعتماداً على برتكول LEACH لرسائل البيانات في شبكات الاستشعار اللاسلكية

عثمان الأمين إبراهيم أحمد

ملخص الدراسة

شبكات الاستشعار اللاسلكية (WSN) هي تجمع لعدد كبير من أجهزة الاستشعار (العقد) التي تنتشر بشكل عشوائي في مساحة جغرافية. يكون أي جهاز من وحدة استشعار، ووحدة معالجة، ووحدة الاتصال، ووحدة الطاقة. لكل مكون مهمة معينة، حيث وحدة الاستشعار للتحسس وقراءة البيانات من البيئة الطبيعية المحيطة، ووحدة المعالجة في معالجة البيانات وتخزينها، ووحدة الاتصال اللاسلكية، ووحدة الاتصال، ووحدة الطاقة تستخدم لتوسيع نطاق الاتصال. يتم استخدام شبكات الاستشعار اللاسلكية في تطبيقات واسعة النطاق مثل التطبيقات الصحية والعسكرية والبيئة والمنازل والمكاتب والتجارة. تعاني شبكات الاستشعار اللاسلكية من قلة أو نفاد الطاقة لأن البطارية محدودة السعة وغير قابلة للشحن ولا يمكن استبدالها، لذا تحتاج لمزيد من الجهود والتقنية لضمان أمان على عمر البطارية لفترة طويلة. بروتوكول تكليف تجمع مرجعي منخفض الطاقة (LEACH) هو خوارزمية التجمع الهرمي لشبكات الاستشعار التي تهدف إلى تقليل عدد العقد التي تتصل مباشرة مع المحطة الرئيسية لتقليل استهلاك الطاقة. في ليتش (LEACH) مقررة المجموعة يقوم بضغط البيانات المستمدة من العقدة الأخرى التي تنتقد لمجموعة، وإرسال البيانات التي تم تصميمها إلى المحطة الرئيسية من أجل تقليل كمية المعلومات التي يتم إرسالها للمحاولة الرئيسية. الهدف الرئيسي من هذا البحث هو نظام شبكة الاستشعار اللاسلكية لتحسين بروتوكول ليتش وأصدار نسخة جديدة تمييزية (LEACH) تراعى الطاقة والمسافة، إذا كان رئيس المجموعة (CH) قريب من المحطة الرئيسية فإنه يرسل البيانات مباشرة للمحاولة الرئيسية Max_cluster، بالإضافة إلى ذلك إذا كانت المسافة إلى المحطة الرئيسية أكبر من المسافة إلى رئيس المجموعة (BS) كان مقررة المجموعة التي تصل مباشرة إلى المحطة الرئيسية، يجب اختيار رئيس المجموعة لضمان الهدف من رئيس المجموعة استخدم لمحاكاة بروتوكول (MATLAB) الذي لديه مجموع طاقة أعلى لمسافة أقل، ماتلاب (LEACH)، الحل المقترح قياساً على بروتوكول ليتش (LEACH)، توضح نتائج التجربة أن البروتوكول المقترح يتفوق على البروتوكول التقليدي بزيادة عمر الشبكة توصي الدراسة بتعديل الخوارزمية من أجل توزيع المهام بين أجهزة الاستشعار، هذا يضمن تغطية المنطقة المطلوبة وينظم بعض العقد من الموت.
CHAPTER ONE
INTRODUCTION

1.1 INTRODUCTION

The wireless sensor networks (WSNs) is collection of a large number of sensor devices (nodes) that are deployed randomly in geographical area [1]. Each device consists of sensing, processing, communication, and power units. Each component has specific task, a sensing unit for sensing data from the physical surrounding environment, a processing unit for processing data and storage, a wireless communication unit (transceiver) for communicate with other nodes to send and receive the data, and a power unit for supplying the node with the required power. These sensors have the ability to communicate either among each other or directly to an external base-station (BS). A greater number of sensors allows for sensing over larger geographical regions with greater accuracy. Sensor nodes in wireless sensor networks also can be considered as a collection of low-cost, low-power, and multifunctional wireless sensor nodes. There are wide application area that use wireless sensor networks such as health, military, environmental monitoring, Home, office and commercial smart houses, smart farms, smart hospitals, distributed robotics, and national security [2]. Additionally wireless sensor networks are used in monitoring environmental conditions such as temperature, air pressure, humidity, light, motion or vibration, and so on [3] [4]. WSNs have problem of lifetime of networks because sensors are used in large geographical areas. They are made from several nodes. WSNs suffer from lack of power, because the battery is limited, not rechargeable, not replacement due to the random distribution of sensor nodes [5] and the size of sensor devices is small. Energy conservation is a very important issue in wireless sensor network, so more efforts and techniques are needed to save battery life as long as possible, this can be achieved by reducing the energy consumption of the node to prolong the lifetime of the network as long as possible. To increases the network lifetime of wireless sensors network by using a minimum energy to reducing the amount of data processing. Minimum energy is used by proper grouping of nodes as clusters. Clustering is design method to control the network energy consumption. Clusters make a group of nodes as one and decrease the number of nodes for
communication. In each cluster, one node is selected as a cluster head (CH) on basis of some criteria. Cluster head (CH) receive data from nodes and transfer to base station. Clustering reduce energy consumption. Hierarchical Routing techniques are well known for its scalability and energy efficiency. Algorithm under this category sometimes classified as energy-efficiency routing algorithms. These techniques are also called clustering techniques because nodes within a WSN are divided into different clusters. Examples of hierarchical routing based routing protocol (LEACH, PEGASIS, HEED, TEEN, and APTEEN). LEACH stands fro low-energy adaptive clustering hierarchy, which is very widely known algorithm. In this technique, wireless sensor nodes form clusters based on energy stored. Each cluster has its cluster head (CH) that takes the duty of data transmissions while other nodes of that cluster sense and collect the data, LEACH rotates the role of CHs randomly, and the operation of LEACH is divided into two phase’s set-up phase and the steady-state phase. In the set-up phase, it performs cluster formation and CHs can be selected in it. In the steady-state phase, an actual data transmission takes place in the network to the BS. power-efficient gathering in sensor information system (PEGASIS) was proposed as an enhancement of LEACH protocol. It is an optimal chain-based protocol. It uses a chain-based approach to increase the energy efficiency of the sensor network. Each node in a chain receives data from and transmits data to a closest neighbor, amongst only one node is responsible for transmitting the aggregated data to the BS. Nodes will take turns of being the leader in the chain for the transmission of data to the BS. Due to uniform distribution of load obvious increase in lifetime was observed. The chain formation can either be done through the BS or nodes themselves. If the nodes organize a chain themselves, they must be aware of their position information. Threshold-sensitive Energy Efficient Protocol (TEEN) Routing protocols in sensor networks in another way can be classified into three categories proactive, reactive and hybrid protocols and it depends on how the nodes find a route to the destination. In proactive protocols, for the data to transmit all routes are computed before they are needed. In reactive protocols, routes are compute on request. Hybrid protocol, use up the combination of both reactive and proactive protocols. The TEEN is a reactive protocol specially targeted for reactive networks and to our best knowledge it is the first protocol developed for reactive network. Reactive networks means, nodes will have to respond to the sudden changes in the network such as acoustic changes,
temperature changes, magnetic changes, etc. TEEN follows a hierarchical cluster-based approach along with the use of data-centric approach. Each cluster will have a CH that gathers data from its cluster members; it aggregates the data and sends the aggregated data to the BS or to an upper-level CH node. Adaptive threshold-sensitive energy efficient protocol (APTEEN) is an enhancement over TEEN and is a hybrid protocol that changes the threshold value used in the TEEN according to the type of application and user requirements. It aims at not only getting the overall view of a network but also time-critical data sensing. In APTEEN, after the network is divided into clusters, the CHs broadcast the following messages; attributes (A), thresholds, schedules and count-time (CT). The attributes indicates the set of physical parameters in which the user is interested. The threshold indicates the pair of threshold values called hard and soft threshold values. Schedule indicates the time division multiple access (TDMA) schedule, assigning time slots to each node and the last one, count-time indicates the maximum time period between two successive reports sent by a node. A node sensing the surroundings continuously can transmit the data if they reach threshold value and it transmits data only when the value of an attribute changes by an amount equal to or greater than the soft threshold. Count-time is used to set because if the node does not send data for a period of time, it is forced to sense the environment and retransmit. APTEEN allows users to query a network in three types namely; historical query, one-time query, persistent query. Historical query allows users to query about historical data stored at the BS. One-time query allows querying a particular snapshot of a network and persistent query allows querying future events in the network over a time. Many researchers used LEACH protocol to maximize the network lifetime. In this research LEACH protocol is used to improve the network lifetime based on energy and distance. If the node is close to base station the data will be sent to base station otherwise the data will be sent to the cluster-head and the cluster-head forward it to the base station.

1.2 PROBLEM STATEMENT

The wireless sensor network suffers from some limitations related to the power system such as: Sensor node has limited power source (battery), and battery is not rechargeable, and the replacement of the sensor node battery is difficult operation due
to random distribution of sensor nodes. The major challenge that faces the wireless sensor network designer is the energy conservation and prolongation of network lifetime.

1.3 RESEARCH OBJECTIVES

This research aim to design an improved algorithm to reduce the energy consumption of the nodes to maximize the lifetime of wireless sensor network in order to save power by let the nodes work together formed as cluster and other nodes on sleep mode. The objective of this research is to an improved LEACH (I_LEACH) protocol that reduces the power utilization when the nodes become idle. Use clustering concept, In order to reduce energy consumption of the nodes. I_LEACH protocol which is intended to balance the energy consumption of the nodes and extend the lifetime of the network based on the LEACH protocol [6]. I_LEACH protocol maximize lifetime of WSN based on energy and distance.

1.4 METHODOLOGY

Wireless sensor networks is contains nodes each node has some problems related to power system, the main source of power are battery that is limited power capacity. Intended to innovative solutions to it. I_LEACH protocol let solution based on LEACH protocol. I_LEACH protocol improved the lifetime of network more than LEACH protocol based on energy and distance. I_LEACH protocol selects the cluster head (CH) called Max-cluster that have maximum total energy and minimum distance, figure 1.1 illustrates the clustering architecture.
1.5 DISSERTATION LAYOUT

This thesis contains five chapters, chapter one contains the introduction, problem statement, research objectives, and methodology. Chapter two illustrates background and literature review. Chapter three demonstrates the methodology of the research. Chapter four presents the results and discussion and comparison between two protocols. Finally chapter five presents the conclusion and recommendations.
CHAPTER TWO
BACKGROUND AND LITERATURE REVIEW

2.1 BACKGROUND

Wireless sensor networks (WSN) are very important topics to researchers in modern era. WSN are being used in a wide range of applications such as environmental monitoring, target tracking and surveillance system, military operations, earthquake detection, patient monitoring systems. These networks consist of sensor nodes that deployed in concern area which are capable of sensing and processing the data from the location that will be deployed and send it to remote location called as Base Station (BS) [7], figure 2.1 illustrates the wireless sensor networks architecture.

![Wireless Sensor Networks Architecture](image)

Figure 2.1 Wireless Sensor Networks Architecture [7]

2.1.1 Wireless Sensor Networks

The wireless sensor network is composed of a collection of sensor nodes, the sensor node consist of sensing unit, processing unit, communicating unit, and power unit. They may also have application dependent additional components such as a location finding system, a power generator and a mobilize. The power sources are very important components so that determine the lifetime of network. [8] figure 2.2 illustrates the sensor node component [9].
2.1.1.1 Sensor Node:

Converts physical phenomenon e.g. light, motion, vibration, and sound into electrical signals, figure 2.2 illustrates the sensor node.

Figure 2.2 Sensor Nodes [8]

2.1.1.2 Sensor Node Component:

- Sensing units are usually composed of two subunits: sensors and analog to digital converters (ADCs). The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC, and then fed into the processing unit.
- The processing unit, which is generally associated with a small storage unit, manages the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks.
- Communicating unit connects the nodes to the network to make them sends and received the data from other.
- Power units the source of power that supplying the node by power often consists of a battery.
- Location finding system (optional).
- Power generator (optional).
- Mobilizer (optional) [9].
2.1.2 Routing Protocols:

A sensor node is capable of sensing temperature, air pressure, atmosphere, sound etc. In a WSN a collection of wireless sensor nodes are responsible for gathering data from environment. Gathered data is then sent to the base station for data processing to conclude some information. The process of sending data from all sensor nodes to base station will result in energy wastage due to redundant data transmission. For a large geographical area it may not be possible to transmit data directly to base station. To overcome these issues the protocol adopt some data gathering and data aggregation mechanism to routing algorithms [10].

Routing Protocols [11] in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure [12].

2.1.2.1 Hierarchical-based routing:

Hierarchical or cluster-based routing is techniques to support the concept of scalability and efficient communication, and also utilized to perform energy-efficient routing in wireless sensor network. Hierarchical routing is an efficient way to lower energy consumption that use the clustering techniques to minimize the number of node that directly communicate with the base station (BS). In hierarchical routing, sensor network is divided into segments called clusters, these clusters consists of cluster members and their cluster heads. It randomly selects the high energy nodes for
processing and sending the data while the low energy nodes for sensing and sending the information to the cluster heads. It generates energy efficient clusters for sensor nodes, so, select one of the nodes that have other privileges use as cluster head.

Low energy adaptive clustering hierarchy (LEACH) protocol is hierarchical clustering algorithm for sensor networks [13] [14] [15], it is one of the Hierarchical or cluster-based routing that was proposed for reducing power consumption. LEACH protocol randomly selects a few sensor nodes as cluster heads (CHs) [1]. In LEACH, the cluster head nodes compress data arriving from non-cluster head nodes that belong to the respective cluster, and send an aggregated data to the base station in order to reduce the amount of information that must be transmitted to the base station, so these lead to reduce the energy consumption of node that maximize the life time of network.

2.2 LITERATURE REVIEW:

in 2010 (Linlin Wang, Jie Liu, Wei Wang). Their proposed [16], the new algorithm is different from the LEACH in the method of determining the number of clusters heads and the criterion that chooses cluster-heads. The LEACH determine the nodes that become cluster head based on equation 3.1, and the new improved protocol, Based Energy Clustering (BEC) algorithm determines the number of cluster-heads according to the basic idea as follows:

\[ K = \frac{\sqrt{2\pi M}}{2 \pi r^2 + \pi r^2} \]  

Equation 2-1

Where M is the area of the monitoring region, r is the perceived radius of the nodes, k is the number of cluster-heads

The electing strategy of the cluster-head nodes:

The electing strategy of cluster-heads takes the energy factor into account and the threshold T(n) is defined as

\[ T(n) = \frac{E_i + k}{E_{total}} \]  

Equation 2-2

Where \( E_i \) is the rest energy of the current node, \( E_{total} \) is the rest energy of all the nodes, k is the number of cluster-heads. BEC algorithm uses the same clustering process as LEACH,
Simulation results show that the BEC can prolong lifetime and reduce the energy consuming, it has better performance than LEACH protocol [16].

In 2012 (Reetika Munjal, Bhavneesh Malik). Their proposed [5], by improved ideas to select the cluster head node. The main problem with the LEACH lies in the random selection of cluster heads. The main purpose is to select a cluster head depending upon its current energy level and distance from the sink node. The steps of Algorithm:

i. The first round will be same as normal leach round.

ii. In the second round, each node would send its residual energy along with the sending time stamp T-S and remaining lifetime of battery.

iii. When the base station receives the packet, it will calculate: T-R - T-S (difference between receiving timestamp and current time stamp)

iv. If difference $\geq$ remaining lifetime of node, the node will be non-cluster head.

v. Else If remaining lifetime = max among all nodes of the cluster; choose the node as cluster head [5].

In 2013, (Yong-Zhen Li, Ai-Li Zhang, Yu-Zhu Liang). Their proposed [17]. Many researchers have proposed many improved algorithms based on LEACH. This study solved the problem of LEACH that each node is frequently repeated several times elected cluster-head and consumed some energy. The proposed protocol that In order to reduce the energy consumption of cluster heads, firstly, the way of selecting clusters and building cluster heads uses LEACH protocol, secondly, the cluster head itself don’t hand over the right in the next round, which will take on several times . Based on these, an improved cluster head reappointment algorithm (i.e., LEACH-R), combined LEACH, use optimization threshold model. LEACH-R is classified into three steps: selecting cluster head, transmission and cluster reappointment. Selecting cluster heads and clustering. LEACH-R’s principle is similar with LEACH. so add , the base station assigned different sequence to each cluster, and then cluster-head assigned the corresponding Time Division Multiple Access (TDMA) gap to its own nodes, the nodes transmit message in the respective allocated time, can avoid conflicts [17].
in 2014, (Layla AZIZ, Said RAGHAY and Abdellah JAMALI). Their proposed. In the original LEACH, after receiving data from cluster members, the CH aggregates these data and then sends it to the BS that might be located far away from it. The CH will die earlier than the other nodes in the cluster because of its operation of receiving, sending and overhearing. When the CH dies, the cluster will become useless because the data gathered by the cluster nodes will never reach the Base Station. The proposed work, this study is tried to improve the network life on the basis of two parameters: distance and energy. Initially when the cluster heads formed based on their energetic value; if the CH is close to the BS then the data are directly sent to the BS. But if $d_{toBS}$ is greater than $d_{toMaxCLCH} + d_{maxCLCHtoBS}$. Also selected the Cluster Head located in the Max_Cluster which is a cluster having a maximum total energy and if there are a two clusters with the same energetic total then choose the one that will will keep the minimum distance. This will minimize the energy consumption of the network [18].

In 2014, (Lalita Yadav). Their proposed, this study proposed a new improved cluster algorithm of LEACH protocol which is intended to balance the energy consumption of the entire network and extend the lifetime of the network. Used the clustering algorithm based on LEACH protocol. LEACH protocol is the first protocol of hierarchical routing which proposed data fusion, it is of milestone significance in clustering routing protocol. The LEACH Network is made up of nodes, some of which are called cluster-heads. The election of the cluster-head based on equation 3-1. used LEACH is able to distribute energy dissipation evenly throughout the sensors, doubling the useful system lifetime for the networks [6].

In 2014, (Lanying Li, Changdong Liu). Their Proposed, this study proposed an improved algorithm of LEACH. The main idea of the improved algorithm is to consider the current position and the current energy of the node, which can be more evenly distributed cluster head, in order to prolong the life time of the node. These algorithms take into consideration the Cluster head election according to distance. So Choosing different models in different conditions, making the nearly distance between the base station have a greater chance to be elected as the cluster head. Improved cluster head election is shown as equation 2-3 this improved call NEWLEACH protocol. The algorithm have the same steps of original LEACH protocol, and
calculation of the threshold according to equation 2-3 show below.

\[ T(n) = \left\{ \frac{p}{1-p*\left\lfloor r \mod \left(\frac{1}{p}\right)\right\rfloor} \times \left[ 1 + \alpha \times k * \frac{E_{\text{current}}}{E_{\text{total}}} + \beta * \frac{d_2^2}{d_1^2 + d_2^2} \right] \right\} \quad \text{Equation 2-3} \]

So, \( \alpha \) represents energy factor, \( E_{\text{current}} \) represents node of current residual energy, \( E_{\text{total}} \) represents current round all the nodes residual energy (total of residual energy of all nodes in the current round), \( \beta \) represents distance factor, define \( \beta = 1-\alpha \), \( d_2 \) represents distance of the node to the cluster head, \( d_1 \) represents distance of the node to the base station, \( k \) represent the number of cluster head [19].

In 2015, (Alhag Alsayed Mohammed Ali). Their proposed, The main objective of this study is to prolong the life time of the sensors nodes by using clustering algorithm. Low-Energy Adaptive Clustering Hierarchy- Centralized (LEACH-C) protocol can be used for cluster head selection by rotation based on a desired percentage value in the cluster and the remaining energy of the node. The LEACH-C protocol initial technique enhancing the life span of a LEACH network is the addition to the remaining energy level existing in every node. It can be accomplished by decreasing the threshold \( T(n) \), comparative to the node’s left out energy. \( T(n) \) is multiplied with an aspect representing the remaining energy level of a node:

\[ T(n)_{\text{new}} = \frac{p}{1-p \times \left\lfloor \frac{r}{p} \right\rfloor} \times \frac{E_{\text{current}}}{E_{\text{max}}} \quad \text{if } n \in G \quad \text{Equation 2.4} \]

Where \( P \) is the desired percentage of CHs, \( r \) is the current round, and \( G \) is the set of nodes that have not been elected CHs in the last \( 1/P \) rounds, \( E_{\text{current}} \) indicates the current energy and \( E_{\text{max}} \) indicates the initial energy of the node [2].

### 2.2.1 Summary of literature review:

<table>
<thead>
<tr>
<th>NO</th>
<th>Author</th>
<th>Methodology</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Linlin Wang, Jie Liu, Wei Wang</td>
<td>An Improvement and Simulation of LEACH Protocol for Wireless Sensor Network</td>
<td>An improved protocol based on LEACH, Based Energy Clustering (BEC) protocol is presented in this paper. BEC protocol indicates the optimal number of cluster-heads in a network and considers residual energy in</td>
</tr>
<tr>
<td></td>
<td>Number of clusters heads and the criterion that chooses cluster-heads</td>
<td>The stage of cluster-heads selection.</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Yong-Zhen Li, Ai-Li Zhang, Yu-Zhu Liang</td>
<td><strong>Improvement of Leach Protocol for Wireless Sensor</strong>&lt;br&gt;the shortcoming of LEACH that each node is frequently repeated several times elected cluster-head and consumed some energy.</td>
<td>This paper proposes a cluster-head reappointment routing algorithm, it solves the disadvantage that cluster-head frequently built cluster and consumes lots of energy.</td>
</tr>
<tr>
<td>3</td>
<td>Reetika Munjal, Bhavneesh Malik</td>
<td><strong>Approach for Improvement in LEACH Protocol for Wireless Sensor Network</strong>&lt;br&gt;The main problem with the LEACH lies in the random selection of cluster heads. Here our main purpose is to select a cluster head depending upon its current energy level and distance from the sink node.</td>
<td>Simulation results show that our algorithm is much more efficient and indicate that this algorithm can balance nodes’ energy consumption and prolong the network’s life span.</td>
</tr>
<tr>
<td>4</td>
<td>Lalita Yadav</td>
<td><strong>Low Energy Adaptive Clustering Hierarchy in Wireless Sensor Network</strong>&lt;br&gt;LEACH protocol is the first protocol of hierarchical routing which proposed data fusion, it is of milestone significance in clustering routing protocol used the clustering algorithm based on LEACH protocol to distribute energy dissipation among the nodes.</td>
<td>Improve of LEACH is able to distribute energy dissipation evenly throughout the sensors, doubling the useful system lifetime for the networks.</td>
</tr>
<tr>
<td>5</td>
<td>Layla AZIZ, Said RAGHAY, Abdellah JAMALI</td>
<td><strong>A New Improved Algorithm of Leach Protocol for Wireless Sensor Networks</strong>&lt;br&gt;we propose a new improved algorithm of LEACH protocol for WSN based on distance and the total energy of clusters to minimize the energy consumption of nodes and extend the life of the network.</td>
<td>This paper proposes a new improved algorithm of Leach protocol based on total energetic of clusters and distance between the CH and the BS, which is aim at improving the network life and total communicated over the network.</td>
</tr>
<tr>
<td>6</td>
<td>Alhag Alsayed Mohammed Ali</td>
<td>LEACHC protocol can be used for cluster head selection by rotation based on a desired percentage value in the cluster and the remaining energy of the node.</td>
<td>The results of simulation show the LEACH-C protocol improves the life time of the wireless sensor network compared to LEACH protocol.</td>
</tr>
</tbody>
</table>
CHAPTER THREE
RESEARCH METHODOLOGY

3.1 INTRODUCTION

Low-Energy adaptive clustering hierarchy (LEACH) is hierarchical protocol which allows the nodes to transmit data to the cluster heads. Hierarchical (cluster-based routing) protocol whose main aim is to increase the lifetime of the wireless sensor network. The cluster head node is randomly selected, and aggregate the data received from the other nodes (non-cluster heads nodes) and forward it to the Base Station. LEACH adapts the clustering concept to distribute the energy consumption among the sensor nodes of the network. By LEACH protocol that improves the energy-efficiency of wireless sensor networking model based on energy and distance. I.LEACH protocol used clustering concept based on the LEACH protocol idea to improve the network lifetime based on distance between nodes and cluster head, and energy of nodes, figure 3.1 illustrates clustering structure.

![Figure 3.1 Cluster Structure](image-url)
3.2 LEACH PROTOCOL:

The main objective is to design LEACH protocol to minimize the energy consumed by the network by divide the wireless sensor network into several clusters [20] [21] [22]. The LEACH protocol reduces the number of nodes that directly communicate with the base station. LEACH is dynamic because the job of cluster-head is rotates. LEACH protocol operation based on rounds. In each cluster a dedicated node with other privileges called cluster head (CH). The operation of LEACH is separated into two phases, the setup phase and the steady state phase [18], the steady state phase must be much longer than the setup phase figure 3.2 illustrates the LEACH phases.

![LEACH Phases](image)

Figure 3.2 LEACH Phases [18]

3.2.1 Setup phase:

Each node decides whether it should be the cluster head or not (non-cluster heads). Sensor nodes generate a random number between 0 and 1, if it is less than threshold $T(n)$ the nodes becomes a cluster head. Each node becomes a cluster-head at least once. Equation 3.1 illustrates the computation of $T(n)$ ("the threshold value given by threshold function $T(n)$").

$$T(n) = \frac{P}{1 - P \times \left(\frac{r \mod \frac{1}{p}}{p}\right)} \quad \forall n \in G \quad \text{Equation 3-1}$$

Where $P$ : is the cluster head probability

$n$ : is a random number between 0 and 1,

$r$ : is the current round,

$G$ : is the set of nodes that have not been cluster heads in the last $\frac{1}{p}$ rounds.
After cluster-head is selected all cluster heads sends advertisement messages (ADV) to non-cluster-head nodes to allow them to choose the appropriate cluster head. This message is a small message containing the node's ID and a header that distinguishes this message as an announcement message.

Non-cluster-head nodes sends join-request message (Join-REQ) to choose cluster heads that requires the minimum communication energy, based on the received signal strength, in order to allow them to create the transmission schedule.

Cluster-head sends time division multiple access (TDMA) schedule to the active member nodes. Figure 3.3 illustrates the flowchart of LEACH protocol in Setup Phase [3].

![Flowchart of Setup Phase](image)

Figure 3.3 Flowchart of Setup Phase [18]
3.2.2 Steady state phase

This phase is divided into two steps schedule creation and data transmission [18]. The steady operation is broken into frames where nodes send their data to the cluster-head at most once per frame. The cluster-head nodes send the advertisement message (ADV) to inform all the other nodes in the network that they have chosen this role for the current round, this is doing by using a non-persistent carrier sense multiple access (CSMA). Each nodes reply by send join request message (Join-REQ) to near cluster head using a non-persistent CSMA to inform the cluster head node it will be become a member's of the cluster. The objective of this step the cluster head know the number of their member nodes. The second step data transmission, the nodes sends the data during their allocated TDMA slot to the cluster head. so use minimal amount of energy base on signal strength. Each non-cluster head node can be asleep until the nodes allocated TDMA slot. This will minimize energy dissipation in nodes. after all the data has been arrived from the node, the cluster head aggregate it and sent to base station as illustrated in figure 3.5.

From setup phase

Yes

Node I
cluster head

Announce cluster-head status

Wait for join-request messages

Create TDMA schedule and send to cluster members t=0

Steady-state operation for t = T_{round} Seconds

No

Wait for cluster-head announcements

Wait for schedule from cluster-head t=0

Send join-request message to chosen cluster-head

Figure 3.4 Flowchart of Steady State Phase [18]
3.3 PROPOSED ALGORITHM:

The LEACH protocol extends the lifetime of the network by minimizing the energy consumption of nodes using clustering technique. This research aims to develop a new technique based on LEACH that improves the lifetime of the network more than it. The I_LEACH protocol improves the lifetime of network more than LEACH protocol, I_LEACH protocol use the same steps of LEACH protocol and select the cluster head based on residual energy, equation 3-2 their calculate the threshold \( T(n) \) value to select cluster head has more energy of other nodes.

\[
T(n) = \frac{P}{(1-P \times \left( \frac{r \mod \frac{1}{P}}{P} \right))} \times \frac{E_{\text{current}}}{E_{\text{max}}} \quad \forall \ n \in G \quad \text{Equation 3-2}
\]

\( P \): is the cluster head probability

\( n \): is a random number between 0 and 1,

\( r \): is the current round,

\( G \): is the set of nodes that have not been cluster heads in the last \( 1/p \) rounds.

\( E_{\text{current}} \): is the current energy of the node

\( E_{\text{max}} \): is the initial energy of the node.

The I_LEACH protocol improve lifetime of the WSNs depend on two parameters. The first one is the distance, if the cluster head is near to base station then sends the data aggregation directly to base station. The second parameter is the energy, if the distance to base station is greater than the distance to max_cluster's cluster head then add to distance max_cluster's cluster head to base station, it selects the cluster head located in the max_cluster that have maximum total energy and minimal distance, equation 3-3 illustrates these. These minimize the energy consumption of the network and prolong the lifetime of the wireless sensor network this are objective of research.

\[
\text{If} \quad d_{\text{toBS}} > d_{\text{toMaxClCH}} + d_{\text{MaxClCHtoBS}} \quad \text{Equation 3-3}
\]

Where \( d_{\text{toBS}} \) distance between the nodes and base station, \( d_{\text{toMaxClCH}} \) distance between the nodes and Max_cluster's cluster head, \( d_{\text{MaxClCHtoBS}} \) distance between the Max_cluster's cluster head and base station.
3.3.1 Flowchart Diagrams of I_LEACH protocol:

Start

Sensor node generates a random number $n$ between 0 and 1

Calculate the threshold $T(n)$

If $n < T(n)$

Choose as cluster head

If $d_{iB} > d_{iM} + d_{MiB}$

Select the cluster head located in the max_cluster

Send data to BS

End

Choose as non-cluster head node

If $d_{iB} > d_{iM} + d_{MiB}$

Send data to BS

Send data to CH

End

Figure 3.5 Flowchart of I_LEACH protocol
3.4 COMPRESSION BETWEEN I_LEACH AND LEACH-C:

Compression Between (An Improved Algorithm based on LEACH Protocol for Data Transmission in Wireless Sensor Network) and (Optimizing Energy Consumption in Wireless Sensor Networks Using Clustering Algorithm)

- If the nodes are near to base station then send the data aggregation directly to base station, otherwise send the data to cluster head, in both protocol.
- I_LEACH improved the network life time based on the energy and distance , after select the cluster head , LEACH-C [2] continues in the basic task (the non-cluster nodes aggregate data and sends it to cluster head nodes that forward it to base station), the base station might be located far away from it, I_LEACH adds other feature, as the cluster head after receiving data from non-cluster head nodes checks the distance and energy of node (after receiving data from the non-cluster head nodes the cluster head aggregates data and might be dies before send it to base station) in this case Max-cluster cluster head that have maximum total energy and minimal distance will be selected. this lead to minimize energy consumption of nodes that maximize lifetime of network. in the I_LEACH the data send to cluster head, if the distance to base station is greater than the distance to max_cluster's cluster head then add distance max_cluster's cluster head to base station equation 3-3 illustrate, it selects the cluster head located in the max_cluster that have maximum total energy and minimal distance ( select other cluster head to insure maximum life time of network), otherwise send the data to base station directly.
3.5 COMPRESSION BETWEEN I_LEACH AND NEW_LEACH:


This study proposed an improved algorithm of LEACH. The main idea of the improved algorithm is to consider the current position and the current energy of the node, which can be more evenly distributed cluster head, in order to prolong the life time of the node. This algorithm takes into consideration the cluster head election according to distance, so choosing different models in different conditions, making the nearly distance between the base station have a greater chance to be elected as the cluster head. Improved cluster head election is shown as equation 3-4 this improved call NEWLEACH protocol [19]. The algorithm have the same steps of original LEACH protocol, and calculation of the threshold according to equation 3-4 show below.

\[
T(n) = \left\{ \frac{p}{1-p\cdot \text{round}(1/p)} \right\} \left( 1 + \alpha \cdot k \cdot \frac{E_{\text{current}}}{E_{\text{total}}} + \beta \cdot \frac{d_2^2}{d_1^2 + d_2^2} \right)
\]

so \( \alpha \) represents energy factor, \( E_{\text{current}} \) represents node of current residual energy, \( E_{\text{total}} \) represents current round all the nodes residual energy, \( \beta \) represents distance factor, define \( \beta = 1 - \alpha \), \( d_2 \) represents distance of the node to the center(cluster head), \( d_1 \) represents distance of the node to the base station, \( k \) represent the number of cluster head.
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 SIMULATION RESULTS

The main aim of these experiments is to increase the network lifetime by reducing energy consumption of the nodes. by simulating LEACH and I_LEACH protocols using MATLAB. The following figures illustrating the various options of LEACH and I_LEACH protocols, figure 4.1 illustrates the distributed of sensor node

![Figure 4.1 Distributed Sensor Network](image)

- **X**: represent base station
- **O**: represent normal node (non-cluster-head node)
- **�性**: represent cluster-head
- **♣**: represent the dead node

Figure 4.1 Distributed Sensor Network
4.1.1 Test (1)

I_LEACH and LEACH of 100 nodes and 100*100 M dimensions, randomly distributed in a geographical location of X and Y coordinates measured in meters, table 4.1 illustrate the simulation parameters, figure 4.2 illustrate the results of simulation.

Table 4.1 Simulation Parameters in 100 nodes and (100*100) dimensions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sensor Nodes in the networks</td>
<td>100</td>
</tr>
<tr>
<td>Network Dimension in two coordinates (X,Y) in</td>
<td>100 m x 100 m</td>
</tr>
<tr>
<td>Base Station location</td>
<td>(0.5<em>X, 0.5</em>Y)</td>
</tr>
<tr>
<td>Nodes initial energy (EO )</td>
<td>0.5J</td>
</tr>
<tr>
<td>Transmitter circuitry dissipation (Eele)</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Amplifier dissipation free state( fs)</td>
<td>10pJ/bit/m^2</td>
</tr>
<tr>
<td>Amplifier dissipation multipath (amp)</td>
<td>0.0013 pJ/bit/m^4</td>
</tr>
<tr>
<td>Energy of transmit(ETX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Energy of receive(ERX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Data aggregation energy consumption (EDA)</td>
<td>50nJ/bit/signal</td>
</tr>
<tr>
<td>Probability of a node to become cluster head(P)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Figure 4.2 Simulation results in 100 nodes and (100 *100) dimensions

Figure 4.2 shows the results of simulation comparison between LEACH protocol and I_LEACH protocol for 100 nodes and 100*100 M dimensions. The figure 4.2 illustrated that there are initially 100 nodes in the network before starting of execution. After 900 rounds of execution, the number of alive nodes for the LEACH and
I_LEACH are same i.e., 100. At 1177 rounds of execution, the first node dies in the I_LEACH protocol. At 984 rounds of execution, the first node dies in the LEACH protocol, at 2000 round, the number of dead nodes are 65 in I_LEACH protocol and 90 in LEACH protocol, at 3500 round, the number of dead nodes are 87 in I_LEACH protocol and 99 in LEACH protocol. The I_LEACH saves more energy by reducing energy consumption, it also improves the life time of the network. Table 4.2 illustrate the comparative result between LEACH and I_LEACH protocols.

Table 4.2 The Comparison of Simulation Results

<table>
<thead>
<tr>
<th>Number of round</th>
<th>Number of dead nodes in LEACH protocol</th>
<th>Number of dead nodes in I_LEACH protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>984</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1177</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>1500</td>
<td>90</td>
<td>26</td>
</tr>
<tr>
<td>2000</td>
<td>90</td>
<td>65</td>
</tr>
<tr>
<td>2500</td>
<td>96</td>
<td>76</td>
</tr>
<tr>
<td>3000</td>
<td>98</td>
<td>83</td>
</tr>
<tr>
<td>3400</td>
<td>99</td>
<td>87</td>
</tr>
</tbody>
</table>

4.1.2 Test (2)

I_LEACH and LEACH of 200 nodes and 100 * 100 M dimensions, randomly distributed in a geographical location of X and Y coordinates measured in meters. Table 4.3 illustrate the simulation parameters, figure 4.3 illustrate the results of simulation.

Table 4.3 Simulation Parameters in 200 nodes and (100*100) dimensions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sensor Nodes in the networks</td>
<td>200</td>
</tr>
<tr>
<td>Network Dimension in two coordinates (X,Y) in</td>
<td>100 m × 100 m</td>
</tr>
<tr>
<td>Base Station location</td>
<td>(0.5<em>X,0.5</em>Y)</td>
</tr>
<tr>
<td>Nodes initial energy (EO )</td>
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<td>Amplifier dissipation free state (fs)</td>
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</tr>
<tr>
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<td>0.0013pJ/bit/m4</td>
</tr>
<tr>
<td>Energy of transmit(ETX)</td>
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</tr>
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<tr>
<td>Probability of a node to become cluster head(P)</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Figure 4.3 Simulation results in 200 nodes and (100*100) dimensions

Figure 4.3 shows the results of simulation comparison between LEACH protocol and I_LEACH protocol for 200 nodes and 100*100 M dimensions, illustrated that there are initially 200 nodes in the network before starting of execution. At 976 rounds of execution, the first node dies in the I_LEACH protocol. At 992 rounds of execution, the first node dies in the LEACH protocol, at 1500 round, the number of dead nodes are 93 in I_LEACH protocol and 176 in LEACH protocol, at 2000 round, the number of dead nodes are 166 in I_LEACH protocol and 187 in LEACH protocol, at 3000 round, the number of dead nodes are 185 in I_LEACH protocol and 198 in LEACH protocol. The I_LEACH saves more energy by reducing energy consumption, it also improves the life time of the network, Table 4.4 illustrate the results of simulation.

Table 4.4 The comparison of Simulation results in 200 nodes and (100*100) dimensions

<table>
<thead>
<tr>
<th>Number of round</th>
<th>Number of dead nodes in LEACH protocol</th>
<th>Number of dead nodes in I_LEACH protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1100</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>1500</td>
<td>176</td>
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<tr>
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<td>195</td>
<td>180</td>
</tr>
<tr>
<td>3000</td>
<td>198</td>
<td>185</td>
</tr>
<tr>
<td>3500</td>
<td>198</td>
<td>189</td>
</tr>
</tbody>
</table>
4.1.3 Test (3):

I_LEACH and LEACH in 100 nodes and 200 * 200 M dimension, table 4.5 illustrate the simulation parameters, figure 4.4 illustrate the results of simulation.

Table 4.5 Simulation Parameters in 100 nodes and (200 * 200) dimensions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sensor Nodes in the networks</td>
<td>100</td>
</tr>
<tr>
<td>Network Dimension in two coordinates (X,Y)</td>
<td>200 m × 200 m</td>
</tr>
<tr>
<td>Base Station location</td>
<td>(0.5<em>X,0.5</em>Y)</td>
</tr>
<tr>
<td>Nodes initial energy (EO )</td>
<td>0.5J</td>
</tr>
<tr>
<td>Transmitter circuitry dissipation (Eele)</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Amplifier dissipation free state( fs)</td>
<td>10pJ/bit/m2</td>
</tr>
<tr>
<td>Amplifier dissipation multipath ( amp)</td>
<td>0.0013pJ/bit/m4</td>
</tr>
<tr>
<td>Energy of transmit(ETX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Energy of receive(ERX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Data aggregation energy consumption (EDA)</td>
<td>50nJ/bit/signal</td>
</tr>
<tr>
<td>Probability of a node to become cluster head(P)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Figure 4.4 Simulation results in 100 nodes and (200 *200) dimensions

Figure 4.4 shows the results of simulation comparison between the LEACH protocol and I_LEACH protocol for 100 nodes and 200*200 M dimensions. The figure 4.4 illustrated that at 602 rounds of execution the first node dies in the I_LEACH protocol and at 727 rounds of execution the first node dies in the LEACH protocol. at 1500 rounds of execution the number of dead nodes are 59 of I_LEACH protocol, at 1500 rounds of execution the number of dead nodes are 91 of LEACH
protocol. The number of dead nodes are 89 in 3500 rounds of I_LEACH protocol, the number of dead nodes are 100 in 2823 rounds of LEACH protocol (all nodes are dead after 2823 rounds of execution in the LEACH protocol). The number of dead nodes in I_LEACH protocol are less than the number of dead nodes in LEACH protocol per round (see the figure 4.4), these lead to minimize the energy consumption of nodes and increasing the life of the network, table 4.6 illustrate the results of simulation.

Table 4.6 Comparison of Simulation results in 100 nodes and (200*200) dimensions

<table>
<thead>
<tr>
<th>Number of round</th>
<th>Number of dead nodes in LEACH protocol</th>
<th>Number of dead nodes in I_LEACH protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1000</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1100</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>1500</td>
<td>176</td>
<td>93</td>
</tr>
<tr>
<td>2000</td>
<td>187</td>
<td>166</td>
</tr>
<tr>
<td>2500</td>
<td>195</td>
<td>180</td>
</tr>
<tr>
<td>3000</td>
<td>198</td>
<td>185</td>
</tr>
<tr>
<td>3500</td>
<td>198</td>
<td>189</td>
</tr>
</tbody>
</table>

4.1.4 Test (4)

I_LEACH and LEACH in 200 nodes and 200 * 200 M dimensions, table 4.7 illustrate the simulation parameters, figure 4.5 illustrate the results of simulation.

Table 4.7 Simulation Parameters in 200 nodes and (200 * 200) dimensions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sensor Nodes in the networks</td>
<td>200</td>
</tr>
<tr>
<td>Network Dimension in two coordinates (X,Y)</td>
<td>200 × 200 M</td>
</tr>
<tr>
<td>Base Station location</td>
<td>(0.5<em>X,0.5</em>Y)</td>
</tr>
<tr>
<td>Nodes initial energy (EO )</td>
<td>0.5J</td>
</tr>
<tr>
<td>Transmitter circuitry dissipation (Eele)</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Amplifier dissipation free state( fs)</td>
<td>10pJ/bit/m2</td>
</tr>
<tr>
<td>Amplifier dissipation multipath ( amp)</td>
<td>0.0013pJ/bit/m4</td>
</tr>
<tr>
<td>Energy of transmit(ETX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Energy of receive(ERX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Data aggregation energy consumption (EDA)</td>
<td>50nJ/bit/signal</td>
</tr>
<tr>
<td>Probability of a node to become cluster head(P)</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Figure 4.5 Simulation results in 200 nodes and (200 * 200) dimensions

Figure 4.5 shows that the result of simulation comparison between LEACH protocol and I_LEACH protocol for 200 nodes and 200*200 M dimension. The figure 4.5 illustrated that at 622 rounds of execution the first node dies in the I_LEACH protocol, at 881 rounds of execution the first node dies in the LEACH protocol, at 1130 rounds the number of dead nodes are 100 in I_LEACH protocol, at 1130 rounds the number of dead nodes are 121 in LEACH protocol, at 2000 rounds the number of dead nodes are 175 in I_LEACH protocol, at 2000 rounds the number of dead nodes are 188 in LEACH protocol, at 3500 rounds the number of dead nodes are 190 in I_LEACH protocol, at 3500 rounds the number of dead nodes are 199 in LEACH protocol. I_LEACH protocol reduces energy consumption of the nodes and improves life time of the network, table 4.8 illustrate the results of simulation.

Table 4.8 Comparison of Simulation results in 200 nodes and (200 * 200) dimensions

<table>
<thead>
<tr>
<th>Number of round</th>
<th>Number of dead nodes in LEACH protocol</th>
<th>Number of dead nodes in I_LEACH protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>900</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>1000</td>
<td>19</td>
<td>58</td>
</tr>
<tr>
<td>1200</td>
<td>157</td>
<td>118</td>
</tr>
<tr>
<td>1500</td>
<td>179</td>
<td>159</td>
</tr>
<tr>
<td>2000</td>
<td>188</td>
<td>175</td>
</tr>
<tr>
<td>2500</td>
<td>197</td>
<td>182</td>
</tr>
<tr>
<td>3000</td>
<td>198</td>
<td>184</td>
</tr>
<tr>
<td>3500</td>
<td>199</td>
<td>190</td>
</tr>
</tbody>
</table>
4.1.5 Test (5)

I_LEACH and LEACH in 100 nodes and 500 * 500 M dimensions, table 4.9 illustrate the simulation parameters, figure 4.6 illustrate the result of simulation.

Table 4.9 Simulation Parameters in 100 nodes and (500 * 500) dimensions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sensor Nodes in the networks</td>
<td>100</td>
</tr>
<tr>
<td>Network Dimension in two coordinates (X,Y)</td>
<td>500 × 500 M</td>
</tr>
<tr>
<td>Base Station location</td>
<td>(0.5<em>X,0.5</em>Y)</td>
</tr>
<tr>
<td>Nodes initial energy (Eo)</td>
<td>0.5J</td>
</tr>
<tr>
<td>Transmitter circuitry dissipation (Eele)</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Amplifier dissipation free state (fs)</td>
<td>10pJ/bit/m2</td>
</tr>
<tr>
<td>Amplifier dissipation multipath (amp)</td>
<td>0.0013pJ/bit/m4</td>
</tr>
<tr>
<td>Energy of transmit (ETX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Energy of receive (ERX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Data aggregation energy consumption (EDA)</td>
<td>50nJ/bit/signal</td>
</tr>
<tr>
<td>Probability of a node to become cluster head (P)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Figure 4.6 shows the results of simulation comparison between LEACH protocol and I_LEACH protocol for 100 nodes and 500*500 M dimensions. The figure 4.6 illustrated that at 26 rounds of execution the first node dies in the I_LEACH protocol, at 42 rounds of execution the first node dies in the LEACH protocol ,at 1312 rounds the number of dead nodes are 83 in I_LEACH protocol and at 1312 rounds the
The number of dead nodes are 95 in LEACH protocol, at 2000 rounds the number of dead nodes are 86 in I_LEACH protocol, at 2000 rounds the number of dead nodes are 96 in LEACH protocol, at 3500 rounds number of dead nodes are 92 in I_LEACH protocol, at 3500 rounds the number of dead nodes are 99 in LEACH protocol. I_LEACH protocol reduces energy consumption of the nodes and improves lifetime of the network, table 4.10 illustrate the results of simulation.

Table 4.10 The comparison of Simulation results in 100 nodes and (500 * 500) dimensions

<table>
<thead>
<tr>
<th>Number of round</th>
<th>Number of dead nodes in LEACH protocol</th>
<th>Number of dead nodes in I_LEACH protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>43</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>250</td>
<td>63</td>
<td>70</td>
</tr>
<tr>
<td>500</td>
<td>83</td>
<td>79</td>
</tr>
<tr>
<td>700</td>
<td>86</td>
<td>83</td>
</tr>
<tr>
<td>1000</td>
<td>92</td>
<td>83</td>
</tr>
<tr>
<td>1200</td>
<td>95</td>
<td>83</td>
</tr>
<tr>
<td>1500</td>
<td>96</td>
<td>86</td>
</tr>
<tr>
<td>2000</td>
<td>96</td>
<td>86</td>
</tr>
<tr>
<td>2500</td>
<td>99</td>
<td>88</td>
</tr>
<tr>
<td>3000</td>
<td>99</td>
<td>91</td>
</tr>
<tr>
<td>3500</td>
<td>99</td>
<td>92</td>
</tr>
</tbody>
</table>

### 4.1.6 results of simulation comparison between I_LEACH protocol and LEACH-C protocol:-

The simulation using MATLAB to show the results of comparison between I_LEACH protocol and LEACH-C protocol. Assume the parameters as the same into two protocols, table 4.11 illustrate the simulation parameters, figure 4.7 illustrate the results of simulation.

Table 4.11 Simulation Parameters comparison between I_LEACH and LEACH-C in 100 nodes and (100 * 100) dimensions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sensor Nodes in the networks</td>
<td>100</td>
</tr>
<tr>
<td>Network Dimension in two coordinates (X,Y)</td>
<td>100 m × 100 m</td>
</tr>
<tr>
<td>Base Station location</td>
<td>(0.5<em>X,0.5</em>Y)</td>
</tr>
<tr>
<td>Nodes initial energy (EO)</td>
<td>0.5J</td>
</tr>
<tr>
<td>Transmitter circuitry dissipation (Eele)</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Amplifier dissipation free state( fs)</td>
<td>10pJ/bit/m^2</td>
</tr>
<tr>
<td>Amplifier dissipation multipath (amp)</td>
<td>0.0013pJ/bit/m^4</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Energy of transmit (ETX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Energy of receive (ERX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Data aggregation energy consumption (EDA)</td>
<td>50nJ/bit/signal</td>
</tr>
<tr>
<td>Probability of a node to become cluster head (P)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Figure 4.7 shows the results of simulation comparison between I_LEACH protocol and LEACH-C protocol for 100 nodes and 100 * 100 M dimensions. The figure 4.7 illustrated that there are initially 100 nodes in the network before starting of execution. After 800 rounds of execution, the first node dies in the LEACH-C protocol. After 1200 rounds of execution, the first node dies in the I_LEACH protocol. At 1585 rounds of execution, the number of dead nodes are 35 in I_LEACH protocol, at 1585 round, the number of dead nodes are 82 in LEACH-C protocol, at 2289 round, the number of dead nodes are 76 in I_LEACH protocol, at 2289 round, the number of dead nodes are 95 in LEACH-C protocol, at 2993 round, the number of dead nodes are 83 in I_LEACH protocol, at 2993 round, the number of dead nodes are 98 in LEACH-C protocol. The I_LEACH conserve more energy than LEACH-C by reducing energy consumption. It also improves the life time of the network, table 4.12 illustrate the results of simulation.
Table 4.12 The comparison of Simulation results between I_LEACH and LEACH-C in 100 nodes and (100 * 100) dimensions

<table>
<thead>
<tr>
<th>Number of round</th>
<th>Number of dead nodes in I_LEACH protocol</th>
<th>Number of dead nodes in I_LEACH protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>872</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>900</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>1177</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>1500</td>
<td>26</td>
<td>81</td>
</tr>
<tr>
<td>2000</td>
<td>65</td>
<td>92</td>
</tr>
<tr>
<td>2500</td>
<td>76</td>
<td>95</td>
</tr>
<tr>
<td>3000</td>
<td>83</td>
<td>97</td>
</tr>
</tbody>
</table>

4.1.7 Results of simulation comparison between I_LEACH protocol and NEW_LEACH protocol:

The simulation using MATLAB to show the results of comparison between I_LEACH protocol and NEW_LEACH protocol. Assume the parameters as the same into two protocols, table 4.13 illustrate simulation parameters, figure 4.8 illustrate the results of simulation.

Table 4.13 Simulation Parameters between I_LEACH and NEW_LEACH in 100 nodes and (100 * 100) dimensions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sensor Nodes in the networks</td>
<td>100</td>
</tr>
<tr>
<td>Network Dimension in two coordinates (X,Y)</td>
<td>100 m × 100 m</td>
</tr>
<tr>
<td>Base Station location</td>
<td>(0.5<em>X,0.5</em>Y)</td>
</tr>
<tr>
<td>Nodes initial energy (EO)</td>
<td>0.5J</td>
</tr>
<tr>
<td>Transmitter circuitry dissipation (Eele)</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Amplifier dissipation free state( fs)</td>
<td>10pJ/bit/m2</td>
</tr>
<tr>
<td>Amplifier dissipation multipath (amp)</td>
<td>0.0013pJ/bit/m4</td>
</tr>
<tr>
<td>Energy of transmit(ETX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Energy of receive(ERX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Data aggregation energy consumption (EDA)</td>
<td>50nJ/bit/signal</td>
</tr>
<tr>
<td>Probability of a node to become cluster head(P)</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Figure 4.8 Simulation results between I_LEACH and NEW_LEACH protocols in 100 nodes and (100 *100) dimensions

Figure 4.8 shows the results of simulation comparison between I_LEACH protocol and NEW_LEACH protocol for 100 nodes and 100*100 M dimensions. The figure 4.8 illustrated that there are initially 100 nodes in the network before starting of execution. After 496 rounds of execution, the first node dies in the NEW_LEACH protocol. After 1178 rounds of execution, the first node dies in the I_LEACH protocol, at 1190 rounds of execution, the number of dead nodes are 25 in NEW_LEACH protocol, at 1190 rounds, the number of dead nodes are 1 in I_LEACH protocol, at 1600 round, the number of dead nodes are 56 in NEW_LEACH protocol, at 1600 round, the number of dead nodes are 37 in I_LEACH protocol, at 2000 round, the number of dead nodes are 93 in NEW_LEACH protocol, at 2000 round, the number of dead nodes are 65 in I_LEACH protocol, at 2612 round, the number of dead nodes are 99 in NEW_LEACH protocol, at 2612 round, the number of dead nodes are 79 in I_LEACH protocol. The I_LEACH protocol conserve more energy than NEW_LEACH protocol by reducing energy consumption. it also improves the life time of the network, table 4.14 illustrate the results of simulation.
Table 4.14 Comparison of Simulation results between I_LEACH and NEW_LEACH in 100 nodes and (100 * 100) dimensions

<table>
<thead>
<tr>
<th>Number of round</th>
<th>Number of dead nodes in I_LEACH protocol</th>
<th>Number of dead nodes in NEW_LEACH protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>872</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>900</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>1177</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>1500</td>
<td>26</td>
<td>81</td>
</tr>
<tr>
<td>2000</td>
<td>65</td>
<td>92</td>
</tr>
<tr>
<td>2500</td>
<td>76</td>
<td>95</td>
</tr>
<tr>
<td>3000</td>
<td>83</td>
<td>97</td>
</tr>
</tbody>
</table>

4.2 SUMMARY OF THE RESULT:

I_LEACH protocol makes butter improvement of network energy's lifetime than LEACH protocol in all the previous cases. In other experiments, the I_LEACH protocol improves the network lifetime more than LEACH-C and NEW_LEACH protocols. These result make the I_LEACH protocol prolong the lifetime of network butter than LEACH, LEACH-C and NEW_LEACH protocols.
CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

This research presents an improved algorithm based on LEACH protocol for Data Transmission in wireless sensor networks. Wireless sensor networks are composing of huge number of sensor devises call nodes that are deployed in wide area. WSNs have many constraints like the small memory, computational of power, and limited energy, each node has the four components, sensing unit, processing unit, communication unit, and power unit. A power unit often consists of the battery. Each node has the main problem of the WSN and that is the limitation of energy because of the small size of batteries. Must be find solutions to these problem. LEACH protocol used the clustering Technique to distribute the energy consumption between the nodes, make the nodes work together, select few nodes as cluster head and let other nodes in sleep mode. So select few nodes as a cluster head that has other privileges that save energy of the nodes and prolong lifetime of the network based on LEACH protocol. I_LEACH protocol improve lifetime of WSNs based on the LEACH protocol. I_LEACH protocol improved the lifetime of the network based on energy and distance. So if the cluster head is close to the base station then the data are directly send to the BS. Otherwise, it selects the cluster head located in the max_cluster that has maximum total energy and minimal distance.

The results of simulation illustrate, the I_LEACH protocol improve the lifetime of the network more than LEACH LEACH-C and NEW_LEACH protocol.

5.2 RECOMMENDATIONS:

As a future work, the algorithm can be modified to provide tasks distribution among sensor devices to minimize the variation in energy level or power consumption in order to guarantee continuous full area covering. This will prevent some areas of network not to die whilst the other areas still have considerable amount of energy.
REFERENCES


clear;

% PARAMETERS

% Field Dimensions - x and y maximum (in meters)
xm=100;
ym=100;

%s and y Coordinates of the Sink
sink.x=0.5*xm;
sink.y=0.5*ym;

% Number of Nodes in the field
n=100

% Optimal Election Probability of a node
to become cluster head
p=0.1;

% Energy Model (all values in Joules)

% Initial Energy
E0=0.5;

% Eelec=Ex=Er
Emax=0.5;

ETX=50*0.000000001;
ERX=50*0.000000001;

% Transmit Amplifier types
Efs=10*0.000000000001;
\[ \text{Emp} = 0.0013 \times 0.000000000001; \]

\[ \% \text{Data Aggregation Energy} \]

\[ \text{EDA} = 5 \times 0.000000001; \]

\[ \% \text{Values for Heterogeneity} \]

\[ \% \text{Percentage of nodes than are advanced} \]

\[ m = 0.1; \]

\[ a = 1; \]

\[ \% \text{maximum number of rounds} \]

\[ r_{\text{max}} = 3000 \]

\[ \% \text{END OF PARAMETERS} \]

\[ \% \text{Computation of do} \]

\[ do = \sqrt{E_{\text{fs}}/\text{Emp}}; \]

\[ \% \text{Creation of the random Sensor Network} \]

\[ \text{figure(1);} \]

\[ \text{for } i = 1:1:n \]

\[ \text{S(i).xd} = \text{rand(1,1)} \times x_{\text{m}}; \]

\[ \text{XR}(i) = \text{S(i).xd}; \]

\[ \text{S(i).yd} = \text{rand(1,1)} \times y_{\text{m}}; \]

\[ \text{YR}(i) = \text{S(i).yd}; \]

\[ \text{S(i).G} = 0; \]

\[ \% \text{initially there are no cluster heads only nodes} \]

\[ \text{S(i).type} = 'N'; \]

\[ \text{temp_{md0} = i;} \]

\[ \% \text{Random Election of Normal Nodes} \]

\[ \text{if (temp_{md0} >= m \times n + 1)} \]

\[ \text{S(i).E} = E_{0}; \]
S(i).ENERGY=0;

plot(S(i).xd,S(i).yd,'o');

hold on;
end

% Random Election of Advanced Nodes
if (temp_rnd0<m*n+1)
    S(i).E=Eo*(1+a)
    S(i).ENERGY=1;
    plot(S(i).xd,S(i).yd,'+');
    hold on;
end
end
S(n+1).xd=sink.x;
S(n+1).yd=sink.y;
plot(S(n+1).xd,S(n+1).yd,'x');

% First Iteration
figure(1);

% counter for CHs
countCHs=0;

% counter for CHs per round
rcountCHs=0;

cluster=0;

countCHs;

rcountCHs=rcountCHs+countCHs;

flag_first_dead=0;
d_to_bs=0;
d_to_max_clch=0;
\begin{verbatim}
d_max_clch_to_bs=0;
for r=0:1:rmax
    r
    \%Operation for epoch
    if(mod(r, round(1/p)) == 0)
        for i=1:1:n
            S(i).G=0;
            S(i).cl=0;
        end
    end
end
hold off;
\%Number of dead nodes
dead=0;
\%Number of dead Advanced Nodes
dead_a=0;
\%Number of dead Normal Nodes
dead_n=0;
\%counter for bit transmitted to Bases Station and to Cluster Heads
packets_TO_BS=0;
packets_TO_CH=0;
packets_TO_BSi=0;
packets_TO_CHi=0;
\%counter for bit transmitted to Bases Station and to Cluster Heads
\% per round
PACKETS_TO_CH(r+1)=0;
PACKETS_TO_BS(r+1)=0;
PACKETS_TO_CHi(r+1)=0;
\end{verbatim}
PACKETS_TO_BSi(r+1)=0;

figure(1);

for i=1:1:n

% checking if there is a dead node

if (S(i).E<=0)
    plot(S(i).xd,S(i).yd,'red .');
    dead=dead+1;
    if(S(i).ENERGY==1)
        dead_a=dead_a+1;
    end
    if(S(i).ENERGY==0)
        dead_n=dead_n+1;
    end
    hold on;
end

if S(i).E>0
    S(i).type='N';
    if (S(i).ENERGY==0)
        plot(S(i).xd,S(i).yd,'o');
    end
    if (S(i).ENERGY==1)
        plot(S(i).xd,S(i).yd,'+');
    end
    hold on;
end
end

plot(S(n+1).xd,S(n+1).yd,'x');
STATISTICS(r+1).DEAD=dead;

DEAD(r+1)=dead;

DEAD_N(r+1)=dead_n;

DEAD_A(r+1)=dead_a;

% When the first node dies

if (dead==1)
    if(flag_first_dead==0)
        first_dead=r
        flag_first_dead=1;
    end

end

countCHs=0;

cluster=1;

for i=1:1:n
    if(S(i).E>0)
        temp_rand=rand;
        if ( (S(i).G)<=0)
            % Election of Cluster Heads
            if(temp_rand<= (p*S(i).E/(1-p*mod(r,round(1/p)))*Emax))
                d_to_bs= sqrt( (S(i).xd-(S(n+1).xd) )^2 + (S(i).yd-(S(n+1).yd) )^2 );
                d_to_max_clch=max(d_to_bs,sqrt(((S(i).xd-(S(n+1).xd) )^2) + ((S(i).yd-(S(n+1).yd) )^2 )));
                if(d_to_bs > d_to_max_clch + d_max_clch_to_bs)
                    cluster = max(cluster);
                    countCHs=countCHs+1;
                end
            end
        end
        packets_TO_BSi=packets_TO_BSi+1;
    end
    PACKETS_TO_BSi(r+1)=packets_TO_BSi;
    S(i).type='C';
S(i).G=round(1/p)-1;
C(cluster).xd=S(i).xd;
C(cluster).yd=S(i).yd;
plot(S(i).xd,S(i).yd,'k*');
distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 + (S(i).yd-(S(n+1).yd) )^2 );
C(cluster).distance=distance;
C(cluster).id=i;
X(cluster)=S(i).xd;
Y(cluster)=S(i).yd;
cluster=cluster+1;

%Calculation of Energy dissipated
distance;
end

countCHs=countCHs+1;
packets_TO_BS=packets_TO_BS+1;
PACKETS_TO_BS(r+1)=packets_TO_BS;
S(i).type='C';
S(i).G=round(1/p)-1;
C(cluster).xd=S(i).xd;
C(cluster).yd=S(i).yd;
plot(S(i).xd,S(i).yd,'k*');
distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 + (S(i).yd-(S(n+1).yd) )^2 );
C(cluster).distance=distance;
C(cluster).id=i;
X(cluster)=S(i).xd;
Y(cluster)=S(i).yd;
cluster=cluster+1;
% Calculation of Energy dissipated

distance;

if (distance>do)
    S(i).E=S(i).E - ((ETX+EDA)*(4000) + Emp*4000*(distance*distance*distance*distance));
end

if (distance<=do)
    S(i).E=S(i).E - ((ETX+EDA)*(4000) + Efs*4000*(distance*distance));
end

end end end

STATISTICS(r+1).CLUSTERHEADS=cluster-1;

CLUSTERHS(r+1)=cluster-1;

%Election of Associated Cluster Head for Normal Nodes

for i=1:1:n
    if ( S(i).type=='N' && S(i).E>0 )
        if(cluster-1>=1)
            min_dis=sqrt((S(i).xd-S(n+1).xd)^2 + (S(i).yd-S(n+1).yd)^2 );
            min_dis_cluster=1;
            for c=1:1:cluster-1
                temp=min(min_dis,sqrt((S(i).xd-C(c).xd)^2 + (S(i).yd-C(c).yd)^2 ));
                if ( temp<min_dis )
                    min_dis=temp;
                    min_dis_cluster=c;
                end
            end
        end

%Energy dissipated by associated Cluster Head

min_dis;

if (min_dis>do)
S(i).E=S(i).E- (ETX*(4000) + Emp*4000*( min_dis * min_dis * min_dis * min_dis));
end

if (min_dis <= do)
  S(i).E=S(i).E- (ETX*(4000) + Efs*4000*( min_dis * min_dis));
end

% Energy dissipated
if (min_dis > 0)
  S(C(min_dis_cluster).id).E = S(C(min_dis_cluster).id).E- ((ERX + EDA)*4000);
  PACKETS_TO_CH(r+1)=n-dead-cluster+1;
end

S(i).min_dis=min_dis;
S(i).min_dis_cluster=min_dis_cluster;
end end

hold on;
countCHs;
rcountCHs=rcountCHs+countCHs;

% Code for Voronoi Cells
% Unfortunately if there is a small
% number of cells, Matlab's voronoi
% procedure has some problems
% [vx,vy]=voronoi(X,Y);
% plot(X,Y,r*;vx,vy,b-);
% hold on;
% voronoi(X,Y);
% axis([0 xm 0 ym]);
end
LEACH PROTOCOL:

clear;

%%PARAMETERS

%mField Dimensions - x and y maximum (in meters)
xm=100;
ym=100;

%x and y Coordinates of the Sink
sink.x=0.5*xm;
sink.y=0.5*ym;

%Number of Nodes in the field
n=100

%Optimal Election Probability of a node
to become cluster head
p=0.1;

%Energy Model (all values in Joules)

%Initial Energy
Eo=0.5;

%Eelec=Etx=Erx
ETX=50*0.0000000001;
ERX=50*0.0000000001;

%Transmit Amplifier types
Ef=10*0.000000000001;
Emp=0.0013*0.000000000001;

%Data Aggregation Energy
EDA=5*0.0000000001;

%Values for Heterogeneity
% Percentage of nodes than are advanced
m=0.1;

% alpha
a=1;

% maximum number of rounds
rmax=100

%%% END OF PARAMETERS %%%

% Computation of do
do=sqrt(Efs/Emp);

% Creation of the random Sensor Network
figure(1);
for i=1:1:n
    S(i).xd=rand(1,1)*xm;
    XR(i)=S(i).xd;
    S(i).yd=rand(1,1)*ym;
    YR(i)=S(i).yd;
    S(i).G=0;
    % initially there are no cluster heads only nodes
    S(i).type='N';
    temp_rnd0=i;
    % Random Election of Normal Nodes
    if (temp_rnd0>=m*n+1)
        S(i).E=Eo;
        S(i).ENERGY=0;
        plot(S(i).xd,S(i).yd,'o');
        hold on;
    end
%Random Election of Advanced Nodes

if (temp_rnd0<m*n+1)
    S(i).E=Eo*(1+a)
    S(i).ENERGY=1;
    plot(S(i).xd,S(i).yd,'+');
    hold on;
end

eend

S(n+1).xd=sink.x;
S(n+1).yd=sink.y;
plot(S(n+1).xd,S(n+1).yd,'x');

%First Iteration
figure(1);

%counter for CHs
countCHs=0;

%counter for CHs per round
rcountCHs=0;

cluster=1;

countCHs;

rcountCHs=rcountCHs+countCHs;

flag_first_dead=0;

for r=0:1:rmax
    %Operation for epoch
    if(mod(r, round(1/p)) == 0)
        for i=1:1:n
            S(i).G=0;
            S(i).cl=0;
        end
    end
end
end
end
hold off;

% Number of dead nodes
dead=0;

% Number of dead Advanced Nodes
dead_a=0;

% Number of dead Normal Nodes
dead_n=0;

% counter for bit transmitted to Bases Station and to Cluster Heads
packets_TO_BS=0;
packets_TO_CH=0;

% counter for bit transmitted to Bases Station and to Cluster Heads
% per round
PACKETS_TO_CH(r+1)=0;
PACKETS_TO_BS(r+1)=0;
figure(1);

for i=1:n

  % checking if there is a dead node
  if (S(i).E<=0)
    plot(S(i).xd,S(i).yd,'red .');
dead=dead+1;
  end
  if(S(i).ENERGY==1)
    dead_a=dead_a+1;
  end
  if(S(i).ENERGY==0)
dead_n=dead_n+1;
end
hold on;
end
if S(i).E>0
    S(i).type='N';
    if (S(i).ENERGY==0)
        plot(S(i).xd,S(i).yd,'o');
    end
    if (S(i).ENERGY==1)
        plot(S(i).xd,S(i).yd,'+');
    end
    hold on;
end
end
plot(S(n+1).xd,S(n+1).yd,'x');
STATISTICS(r+1).DEAD=dead;
DEAD(r+1)=dead;
DEAD_N(r+1)=dead_n;
DEAD_A(r+1)=dead_a;
%When the first node dies
if (dead==1)
    if(flag_first_dead==0)
        first_dead=r
        flag_first_dead=1;
    end
end
countCHs=0;
c Cluster=1;
for i=1:1:n
    if(S(i).E>0)
        temp_rand=rand;
        if ( (S(i).G)<=0)
            % Election of Cluster Heads
            if(temp_rand<= (p/(1-p*mod(r,round(1/p)))))
                countCHs=countCHs+1;
                packets_TO_BS=packets_TO_BS+1;
                PACKETS_TO_BS(r+1)=packets_TO_BS;
                S(i).type='C';
                S(i).G=round(1/p)-1;
                C(cluster).xd=S(i).xd;
                C(cluster).yd=S(i).yd;
                plot(S(i).xd,S(i).yd,'k*');
                distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 + (S(i).yd-(S(n+1).yd) )^2 );
                C(cluster).distance=distance;
                C(cluster).id=i;
                X(cluster)=S(i).xd;
                Y(cluster)=S(i).yd;
                cluster=cluster+1;
                % Calculation of Energy dissipated
                distance;
                if (distance>do)
                    S(i).E=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*( distance*distance*distance*distance ));
                end
            end
        end
    end
end
if (distance<=do)
    S(i).E=S(i).E- ((ETX+EDA)*(4000) + Efs*4000*( distance * distance ));
end
end
end
end

STATISTICS(r+1).CLUSTERHEADS=cluster-1;

CLUSTERHS(r+1)=cluster-1;

}%Election of Associated Cluster Head for Normal Nodes
for i=1:1:n
    if ( S(i).type=='N' && S(i).E>0 )
        if(cluster-1>=1)
            min_dis=sqrt( (S(i).xd-S(n+1).xd)^2 + (S(i).yd-S(n+1).yd)^2 );
            min_dis_cluster=1;
            for c=1:1:cluster-1
                temp=min(min_dis,sqrt( (S(i).xd-C(c).xd)^2 + (S(i).yd-C(c).yd)^2 ));
                if ( temp<min_dis )
                    min_dis=temp;
                    min_dis_cluster=c;
                end
            end
%Energy dissipated by associated Cluster Head
    end
    min_dis;
    if (min_dis>do)
        S(i).E=S(i).E- ( ETX*(4000) + Emp*4000*( min_dis * min_dis * min_dis * min_dis ));
    end
end
if (\text{min\_dis} \leq \text{do})
\begin{align*}
S(i).E &= S(i).E - (\text{ETX} \times 4000 + \text{Efs} \times 4000 \times (\text{min\_dis} \times \text{min\_dis})); \\
\end{align*}
end

\text{% Energy dissipated}

if (\text{min\_dis} > 0)
\begin{align*}
S(C(\text{min\_dis\_cluster}).id).E &= S(C(\text{min\_dis\_cluster}).id).E - (\text{ERX} + \text{EDA}) \times 4000; \\
\text{PACKETS\_TO\_CH}(r+1) &= n \text{-dead\_cluster} + 1; \\
\end{align*}
end
\begin{align*}
S(i).\text{min\_dis} &= \text{min\_dis}; \\
S(i).\text{min\_dis\_cluster} &= \text{min\_dis\_cluster}; \\
\end{align*}
end
end
end
hold on;
countCHs;
rcountCHs = rcountCHs + countCHs;
\text{% Code for Voronoi Cells}
\text{% Unfortunately if there is a small}
\text{% number of cells, Matlab\'s voronoi}
\text{% procedure has some problems}
\text{[vx\_vy]=voronoi(X,Y);} \\
\text{% plot(X,Y,'*',vx\_vy,'b-');} \\
\text{% hold on;} \\
\text{% voronoi(X,Y);} \\
\text{% axis([0 \text{ xmin} 0 \text{ ym}]);} \\
end