

An Energy Efficient Clustering Algorithm for Wireless Sensor Networks (EECA)

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ABSTRACT

Energy conservation has a main priority in all technology and engineering field. Most current applications that consume energy can be customized or optimized in a process resulting less energy consumption. During the rise of wireless sensors field applications, and also, the critical situation of energy consumption, the optimization of energy dispatch becomes a critical and important field of research. Hence, the wireless sensor depends on its internal battery to work its total life time, extending the life time by minimizing the consumption of power is also very important field in current researches. This research aims to optimize the energy consumption of wide scale wireless sensor networks by deploying a novel and adaptive improvement and modification on the traditional clustering of the cells of the network. In this thesis we work on load balancing of each cell in the network, introduce the “Potential” concept which is a measurement of node and cells overall availability and it is related to energy, distance and data transfer, deal with the nodes in between two clusters and finally make all nodes die almost at the same time by using an adaptive system for solving these problems. This research improves the energy conservation with 93% regards to the original LEACH Algorithm. The results are shown and compared to the old LEACH, LEACH-M, and LEACH-L approaches, and this proposed algorithm will be named Energy Efficient Clustering Algorithm “EECA”.

Keywords: Wireless sensors networks, sensors clustering, LEACH, fuzzy logic.

ÖZ

Enerji tasarrufu tüm teknoloji ve mühendislik alanlarında öncelikli bir konu olarak karşımıza çıkmaktadır. Güncel uygulamaların birçoğu ihtiyaca göre uyarlanan, en iyi şekilde kullanılabilen ve daha az enerji tüketimi sağlayacak enerji harcama öğelerini içerir. Kablosuz algılayıcıların alan uygulamalarında olan artış süresince, hassas bir konu olan enerji tüketimi ve enerji dağılımını en iyi şekilde sağlamak önemli ve öncelikli bir araştırma konusu olarak karşımıza çıkmaktadır. Kablosuz algılayıcıların çalışma süresinin içte olan piline bağlı olmasından dolayı, bu algılayıcıların yaşam süresini harcadıkları enerji miktarını azaltarak daha etkili çalışmasını sağlamak güncel araştırma konuları içinde çok önemli bir alanı kapsamaktadır. Bu araştırma her hücrenin yük dengeleme üzerinde çalışmak, düğüm ve hücrelerin genel durumu bir ölçüsüdür "Potansiyel" kavramının tanıtılması ve enerji, mesafe ve veri transferi, iki küme arasında ve nihayet düğümleri ile anlaşma ile ilgilidir bu sorunların çözümü için bir adaptif sistem kullanılarak en iyi duruma getirmeyi amaçlamaktadır. Enerji korumasını yüzde 93 oranında iyileştirmeyi amaçlayan bu araştırma, aynı zamanda ağın farklı hücrelerinin iletişimsel olarak aktarılmasının dengesizliği sorununa da değinmekte ve bu sorunun çözümü için bir sistem önermektedir. Araştırma bulguları önceki LEACH, LEACH-M ve LEACH-L yaklaşımlarıyla karşılaştırılmıştır.

Anahtar Kelimeler: Kablosuz algılayıcı ağları, algılayıcı kümeleri, LEACH, bulanık mantık.

For each and every one whom once was a barrier rock in my life path, for those who made my journey of life complicated, for whom once abused me directly and indirectly, to all those failure, weakness and loss moments, to my dreams that I have always dreamt of achieving and to those times when I touched frustration loneliness and misery.

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LIST OF SYMBOLS OR LIST OF ABBREVIATIONS

WSN	Wireless Sensors Network
LEACH	Low Energy Adaptive Clustering Hierarchy
MAC	Media Access Control
SMAC	Sensors MAC
TMAC	Time-out MAC
DMAC	Data gathering MAC
FIS	Fuzzy Inference System
CH	Cluster Head
J	Joule
W	Watt
AH	Ampere-Hour
MSF	Member Ship Function
FCM	Fuzzy C-Mean
EECA	Energy Efficient Clustering Algorithm

Chapter 1

INTRODUCTION

1.1 Introduction

The wireless sensor networks are an emerging field that performs a comprehensive process of sensing and measurements, measurement logging, data transfer and management via a wireless data network. The wireless sensor is a tiny small device that combines all functions in special measurements and computation. A bulk or set of sensors connected through network in mesh form performing a networking protocol. The hopping data of the sensors from one sensor to another is a major protocol and technique, the sensors that hopping data from one to each other is so called "NODE". The connection and cooperation of large number of nodes makes a rigid network with high capabilities and specifications [1].

The prospective and ability of any wireless sensor networks to deploy a connectivity of large number of nodes, which represents a very small "tiny" devices, represents the power of that network. This networks type is currently deployed to be used in wide range of applications with a suitable cost with respect to its prospective [2].

The wireless sensor networks major rule is to measure specific field and logging its measurements to a host, and this is the most application that known and directly used.

But also, it can be used to control some applications or actuators in that field. It also, reduces the cost of hardware installation and cabling, coming from the fact that, it doesn't need large hardware installation. From the other hand, cancellation of large hardware installations and cabling, reduces significantly the cost of maintenance, neither emergency maintenance nor proactive maintenance. Over that, the outdoor installations, especially cables, almost are subjected to be stableman. This topology of wireless sensors reduces the probability of stalling the equipment and hardware, because of no use of cables [3].

In addition to low installation cost, cheap devices, smaller sensing transducers, longer lasting, it is also, adaptive and can be reconfigured to work in different areas. For example, in a big farm, the same network that measure temperature, pressure, and humidity, also, can be configured to measure the wind speed, also, few configurations can enable that network to sense existence of specific materials in atmosphere. The single device of wireless sensor networks costs less than \$1 in most applications [3].

The wireless sensor nodes also, don't require communicating directly with the nearest control tower which is high power or even don't require directly communicating to the base station. But it communicates with the nodes local peers only. Thus, this connection will be a peer-to-peer connection making a mesh network. The mesh architecture implies a flexible networking of hopping branches. And the system is very adaptive for node failure substitution and compensation [4].

Each sensor node in the wireless sensors networking can perform communication over a range of 50 meters. Thus, to communicate between sensors and transfer the data, no repeaters are needed and no huge number of sensors is required.

Figure 1.1 shows an example of wireless sensor networks applied to a farm. It has a big important in agriculture fields, and such fields are active area for researchers and developers. It's clear that, large number of nodes are distributed throughout the field and connected together. That is establishing what so called "Routing Topology" or "Network Topology". The mount of sensors can be extended from tenth or hundreds to thousands in some cases [5].

1.1.1 Leach Protocol and Energy Optimization

The wireless sensor consumes energy from a battery depends on. The battery is internal structured in the sensors node, and has a specific power consumption period. Whoever, this period depends on the nature of the sensor and the running conditions. The running conditions represents the environmental conditions, data transfer packet, the sequence of transfer, measurement issues, etc. [3].



Figure 1.1: sample wireless sensor networks topology [16]

Hence, the wireless sensor depends on its internal battery; the sensors node life time is limited to battery energy and energy consumption scheme, what so called Power Dispatch or Power Consumption Flow. The computational limitations and also, storage limitations are main bounds of the wireless sensor networks and such systems. Unlike the cell phones or PDA's, the power of the wireless sensor cannot be recharge during its running life. So, the sensor is almost being replaced after its battery died [6].

The communication of wireless sensors via a network is needs specified network to control, and manage the communication, data transfer, and also, measurement logging. Hence, such networks have wide range of applications, that makes developing universal

or single protocol is difficult. Such network topology should provide a complete or enough support of application-specific protocols, that is proving the demands of the sensors and network, specially, power consumption and life time [7].

This thesis, concerns on energy optimization protocol for a large scale wireless sensors network. This protocol enables to cluster and distribute sensor nodes in optimal topology and communication specs in order to get maximum energy conservation and better communication management scheme [8].

1.2 Problem Definition and Motivation

The wireless sensor depends on its battery to run along its life time, thus, the life time depends on the consumption of the power. This is related to many variables, including the distance between the sensor and the head of cluster, the transfer packet size, the energy slope of that sensor which is related to its physical measuring structure, and other effects.

In the wireless sensors network, once the first sensors battery consumed, the sensor is considered to be died. Not all sensors in the wireless network are being died in the same moment. So, once the first one died, the network and/or the cell will be unbalanced. In this case, if the network continues to running – collecting data, logging, and transferring the data to base station – the overall data will have a shortage. The dead sensor(s) couldn't send any data, so, the data is missing.

Whereas, if the network stopped and replacement process is manipulated, this will comprise replacing batteries that not been died yet. Replacing non-empty batteries is the

enemy of battery and energy saving. It causes to lose an interested amount of energy, that – if could to save – can save a non-negligible amount of energy, maintenance cost and time, wasted running time, chemical material, and sensors / battery cost.

The maintenance cost is an issue in any engineered system, so, it is important to make the period between each replacement of the sensors to be longest. During the replacement time, the wireless network will be malfunctioned, and cannot collect data or transfer, thus, all measurements will be disabled in this time.

The chemical materials that are the building components of the batteries and sensors are in most cases dangerous to the environment and human. From these points, it's important to minimize the use of those materials. The energy optimization, of course, minimized the use of that material by minimizing the amount of batteries and other materials that used in wireless sensor networks over the time. Also, the cost of sensors, power and batteries represent a big problem for all users and manufacturers [1].

From that, the problem of energy optimization in wireless sensor networks is important case for the modern researchers, and taken into place for all manufacturers and developers of such systems. Whereas, the main issue of this problem - from computer systems and information technology side – is the clustering of the wireless sensors network.

By developing a good new adaptive clustering algorithm of the network, it can be save energy by 93% or more in large scale wireless sensors network related to the original LEACH Protocol.

1.3 Research Objective

This thesis focuses on adaptive energy conservation and optimization in the wireless sensors networks. Hence, the wireless sensor depends on its battery, the energy and power consumption is so critical in such applications.

The power flow of the wireless network should be balanced in order to get symmetrical power dispatch in the overall transfer period. This research focuses on making the energy losses in all sensors approximately equals. This is done by balancing the transfer and introducing new clustering technique.

When clustering and dividing the sensors of the wireless network into clusters, some sensors can be added to more than one cluster without damage the cells and with correct clustering processor.

Thus, this research developed a new methodology and technique of wireless sensor networks clustering. This clustering is fuzzy-clustering based. And comprise variable clusters every transfer process. Where, the clusters and also, the head of cluster, are being changed every transfer process. And this thesis also, introduces a new concept in distributing sensor (nodes) on the cells (clusters), depending on the potential of the cluster. The potential of the cluster is an introduced and adapted variable that included

implicitly all physical variables those affect the energy dispatch and transfer of the network.

Finally, this research in determined concept, concentrate on deploying wireless sensor networks clustering procedure that ensures all nodes to be dead in a time limit approached to zero.

The result of the introduce protocol will be compared to LEACH, LEACH-M, and LEACH-L methodologies.

1.4 Thesis Organization

The thesis scope is to demonstrate the main issues that are related to the wireless sensors network, including the application, main duties, etc. In addition to mention and illustrate important theoretical background about it and related to this research. Then, the methodology that followed in this research should be illustrated followed by the simulation results. The conclusion will be at the end.

Chapter one, introduces the wireless sensor networks and general issues about that. It illustrates the basics of this thesis, and defining the problem and the motivation of this research. The objectives is illustrated in this chapter, it represents the main aims and points of modification, followed by the contributions that added. Short illustration of the proposed Energy Efficient Clustering Algorithm “EECA” system is described.

Chapter two demonstrates main theoretical topics and illustrations. It is a summary for the material related to clustering and protocols of the wireless sensors network, in addition to major structure.

The methodology of the work is shown in Chapter three in details. It illustrates the main steps of work, diagram of development process and program running, also, the program flow in details.

Chapter four shows the results of simulation for two different sizes networks, with different measurements. The results are compared with the most common protocols LEACH and LEACH-M, also, it is compared to LEACH-L algorithm.

Finally, chapter five summarizes the conclusions and discussion of this work and results. It discusses the work that can be done in future researches to develop the Energy Efficient Clustering Algorithm “EECA”.

1.5 Contribution

This research depends on [Fengjun, 2010] paper, it introduces and developed the LEACH-L algorithm in order to optimize the energy of wireless sensor networks adaptively. This research start from [9] and developed a new contributed algorithm that save energy in percent better than LEACH-L, with some other benefits.

The main contributions of this research are:

1. Increasing the energy saving in percent more than 93% with related to the original LEACH Protocol.
2. Balancing the running and transfer load of each cell in the network.
3. Introducing the “Potential” concept. The potential is a measurement of node (sensor) and cells overall availability. It is related to energy, distance, data transfer, etc.
4. Making all nodes died almost at the same time (that means the interval becomes near to zero)

Those contributions add a good value to the previous protocols LEACH, LEACH-L, in addition to LEACH-M. Furthermore, it prepare for more development and modification in dealing with control transfer.

Chapter 2

THEORETICAL REVIEW

2.1 Literature Review

Many researches were submitted in the past few years concerning the wireless sensor networks issues, and specially, communication and control protocols. Those researches include energy management and power consumption, optimal clustering, communications structure and topology, etc. Here down, major researches, those with core related to this proposed thesis.

The researchers in [3] proposed and developed algorithm which investigates building an on-demand protocol for wireless sensor networks routing. That protocol subjected to be quickly adapted to the changes of the topology. This important problem, come from the fact that, the protocols those use route caches to execute routing; it was a good contribution because of the changes of the topology which is considered to be frequent [3].

The researchers have been proposed a proactive disseminating of information broke-linked information for caches of sensors that have it. The proposed updating of the proactive cache is a major point of making quick adaptation of route caches to topology changes. Also, informing the nodes that have broken link cash important is important to avoid unnecessary overhead. So, if detection of link failure is happened, then, the target

of the algorithm is requesting nodes that can communicate with which cached it for the failure of the link. A modified cache structure of cache has been defined and called “cache table”. Its task is keeping the necessary information for updates of the cache [3].

In paper [8] the researchers have developed an approach related to life time of the network, and power consumption minimization. It was done by suggestion of the geographical efficient routing of the power. Whether both the network has uniformly distributions of nodes or non-uniform, if it is GPER-based, then, the consumption of the power may be minimized. The old algorithms stick to minimal power consumption path that may leak sensors on paths and then, the network life time will be short if the distribution of the network communication is uneven. This algorithm uses multi-paths for power drain elimination. Multiple paths approach is improving the balancing of load; the data line between the initial node point and destination pair is separated via multi-paths, thus, the utilization of energy is spread to the network nodes [8].

In researcher in [1] has been introduced a randomized and fast algorithm for distributing and organizing of the sensors in the wireless sensor networks based on hieratical form of clusters. This optimizes the energy consumption during the communication. In contrast, this algorithm faces a problem that it assumes the environment of communication to be condensational and without any error (typical environment). So, it doesn't deal or handle nay error of data transmission or even retransmit case. This protocol has no redundancy structure or mechanism. Thus, even though, this algorithm reduces the power consumption but it comprises more weakness in the system's structure [1].

In [4], the researchers suggest a new modified algorithm for fault handling of the requirements of reliability and tolerant in wireless sensor networks. This algorithm performs that, all nodes have maximum range of transmitting for any node dependently in order to avoid the failure of a link in sensors power limitations of sensors, which is mainly the battery. Moreover, this algorithm uses Total Time to Live (TTL) in order to modify the data reliability level, thus, it comprises the data use more possible path and more robustness. The TTL is higher than the network diameter for the necessary redundant packet sake [4].

In paper [9], the researchers introduced a query-based sensor system's protocol. In such protocol, a specified query with QoS is issued by the user's requirements. The terms of timeliness and reliability are manipulated. The expectation of the response is done in this algorithm within a specified time, where that time is predefined to be the "deadline. In such system, the fault-tolerant is being achieved by path and source redundancy, thus, selecting the redundancy of the source and the optimal path depending on this algorithm [9].

The author of [2] developed a hop-by hop paradigm of dissemination of the data to form the data delivery multiple path. That introduced depending on constrained resources of wireless networks. This algorithm helps to use an alternative of incurring of extra overhead in multiple paths formulation [2].

In [10] the LEACH protocol has been proposed. This thesis considers the LEACH to be major algorithm and protocol in wireless sensor networks and energy optimization. The

term LEACH regards Low Energy Adaptive Clustering Hierarchy. This algorithm based on clustering (making data in cells) of the nodes in which each cluster has a head of that cluster, where that head is communicating directly to the base station and all other cell's nodes is communicated to the heads of cluster (CH) [10].

The overall tasks which are that related to communicating and transfer of the data to / from the mobile base station are being tasked to the head of cluster, which can be dialed as the center of the cluster in clustering criterion. The LEACH protocol is considered as an important and efficient solution for power conservation and energy optimization. In such, the clusters are passing all data from the head of cluster before send / receive from / to the base station. But the problem of LEACH protocol is the random selection of the head of cluster. This thesis is a novel modification on the LEACH concepts [10].

In [11] the PEGASIS protocol is introduced. It used to deal with optimal chain or nodes, where the node communicated with its neighborhood node only. This topology minimizes the actual distance of communication between the transmit sensor and the receive one. In traditional clustering, each node communicates with the head of cluster, and that comprise long distance between the most of nodes and the cluster center (head of cluster). Where, in this proposed algorithm, the distance is the closest between each two nodes. This approach minimizes the energy consumption, especially for far nodes from the head of cluster. Even though, this protocol is very weak, due to any failure of any node, the failure specified node means that all pervious nodes will be dead because of missing the communication line [11].

2.2 Wireless Sensor Networks

As a special purpose and new version of ad-hoc, the wireless sensor networks have many of applications in many areas, like agricultural, animal monitoring application and large factory area monitoring applications. All such networks are implemented in ad-hoc conditions and specifications. The wireless sensor networks consist of nodes and base station, each node is a representation of wireless sensor tag. The sensor's energy comes from internal battery that built in the sensors case, and thus, it has a limited life time depending on the battery used, sensor's design, and the applications. The criticality of power saving and energy consumption in wireless sensor networks make this field important and rich for modern researcher, weather software or hardware researchers.

The power saving using topology management has main role and can save energy in better way that MAC layer protocol for example. This thesis concerns in proposing and developing a new topology [8].

2.3 MAC Protocol

The MAC protocol of wireless sensor networks coordinates and manages the access of the sensors node to the communication field or area. The efficient MAC protocol for efficient power management is important methodology for life time extend. Also, the latency is important feature in MAC protocol for specified design of sensors network [12].

A special type of MAC protocol that is specially designated for wireless sensors networks is the SMAC. The SMAC operates the sensor's node at cycle with low duty; it

commands the sensors to sleep periodically. This saves more power. The protocols that use a fixed duty over all running time aren't energy efficient. This also, minimizes the traffic load, and saves the power of the sensor with low traffic. And this is much reliable than other protocols such as 802.11 [12].

The improvement of SMAC protocol is the TMAC, which regards "Time-out MAC". It developed to adapt the duty cycle of sensors running. The sensors node enters the sleep mode when no task attached to it. And thus, the sensor will consume power only when requested to measure, calculate, or transfer data neither in nor out. So, the TMAC protocol saves more energy than SMAC protocol, due to dealing with variable traffic [13].

The policy or aggressive power conservation is a side of TMAC protocol. That policy implies that each node can enter the mode of sleep early; this will result in latency increasing and lower throughput. Another issue in booth TMAC and SMAC protocols is the communication grouping during the activity of small periods. So, these protocols are collapsing under any high load of traffic.

DMAC is another type of MAC protocol with is "Data gathering MAC protocol", it also, uses adaptive variable duty cycle and ensures latency of low node-to-sink in the communication of converge, that done by wake-up time staggering of the sensors node in converge cast tree. Thus, the DMAC implies the SMAC task in terms of throughput, energy and latency. But it supports the communication paradigm more than convergence cast [14].

There are a more modifications and extensions of MAC protocol such as PMAC, all those modifications supports the basic MAC functionality and modify some specifications in order to solve specific inertia in a side of work or enhance the performance [15].

2.4 LEACH

LEACH is acronym regards “Low Energy Adaptive Clustering Hierarchy”. The hierarchal clustering was introduced by Heinzelman. It clusters all nodes of the network into clusters (cells) where each cell has center called “head of cluster”. In such protocol, each node transmit its information to the head of cluster, and it collects the data from all cluster’s nodes, then, it compress and format the data before sending it to the base mobile station [2].

The cluster’s head consumes more power than other sensors, because of the load on it. The load is subjected to collecting data from all nodes, formatting data, sending and receiving data from base station. This needs to make the CH to have max power or energy than other sensor nodes. The LEACH, uses random selection of the head of cluster, so, it may not be the maximum energy node. The LEACH protocol rotates the node that is selected as head of cluster when its energy becomes low after a threshold value [16].

Heinzelman simulation results show that the nodes that can be considered the head of cluster is not exceed than 5% of the total wireless sensor networks nodes. Where the LEACH, uses a specified MAC protocol in order to minimize inter or intra cluster

collision, such as DMAC. Also, this algorithm supposed the head of cluster to be centralized or semi-centralized node in the cluster. Figure 2.1 shows a sample hierarchically clustered network [17].

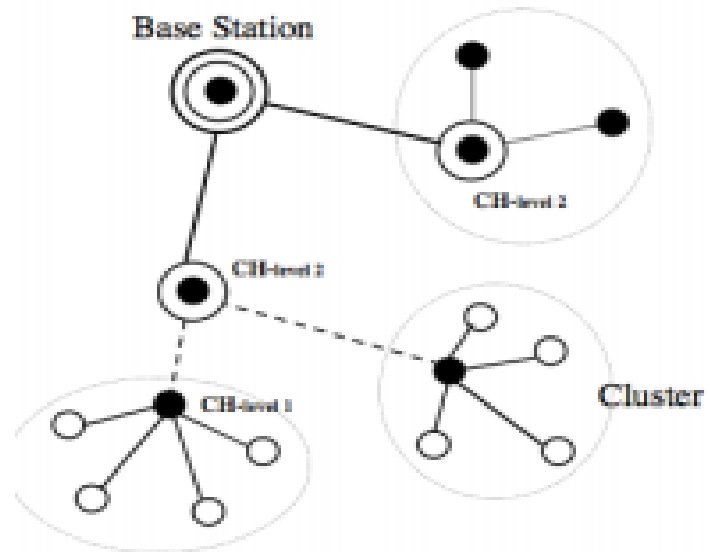


Figure 2.1: Sample Hierarchically Clustered Wireless Network [35]

The operation of LEACH consists of two stages; step stage and steady running phase. In the first stage, the networks are being clustered and select the cluster-head (CH) for each cluster. In the next stage, the sensing and measurement data transfer is being done. The data is transferred to the base station. The first stage is the configuration phase, while the steady running is the normal run phase [17].

In the setup / configuration stage, a predefined nodes part is being chosen as cluster heads. This is done according to a threshold value where this value deepens on the percentage that enables the node to be head of a cluster. The node requests to become a cluster head by chosen a value between 0 and 1. The cluster head may be changed in

rounds. Each new head of cluster will notify all cluster nodes to deal with it as head. The acknowledge message will be submitted from the non-head of cluster nodes.

The LEACH protocol attack is very difficult in comparison with the conventional protocols of multi-hop networks. The conventional protocols of multi-hop imply all nodes to be surrounding to the base station, so, this is attractive to compromise. But, in the LEACH protocol, the heads of clusters are communicates directly with the base station while the other nodes are not.

The head of cluster can be located anywhere in network irrespective of the mobile base station. Also, the heads of clusters (CH) can be changed randomly. This makes head cluster to be difficult to be spotted. Hence, the wireless sensor networks based on a negligible memory sensors and low computational power, thus, the security of the network is a key management of improving the networks [18].

LEACH protocol assumptions may cause a lot of real-time system's problems. The main assumptions are [19]:

- If needed, all nodes can transmit to the base station with enough power.
- Each node can supports different MAC protocols, so it should have enough computational power.
- The nodes always have data that is waiting to be sent.
- The nodes that are located close to each other have data correlation.
- Since the first node dies, the system becomes unbalanced.

- In each selection round, the rest of nodes have the same energy capacity amount, assuming that being a head of cluster will drain the same energy value that is for each node approximately.

2.5 Wireless Sensor Networks Applications

Applications of wireless sensors networks are various, but the most direct application is monitoring the low frequency data of remote environments, Such as, manufacturing of plants, demining, farms, long distance oil and gas lines, etc. [9].

In long distance oil and gas lines, it's very difficult or even impossible to detect the leakage point or spot points in traditional inspection methodologies and techniques. The overall measurements of such lines are capable to be done using the wireless sensor networks protocol and technology. The use of WSN enables to detect all variables and measurements of such long distance line with high security and reliability instead of uncertainty problems solving, cost, difficulty of installations, and other problems in wired and traditional measurement procedures [20].

The main categories of wireless sensors networks applications can be divided into three categories and any application will fall into one of these categories; those are:

1. Data collection for environmental applications.
2. Security, surveillance, and monitoring.
3. Object tracing.

The applications of data connection of canonical environments are a main field that software engineers and scientist researchers are interested in. In such, the researchers

need to collect the readings of several sensors from sets of environmental points in a specific timer interval, to detect the physical interdependencies and trends. Normally, the collection of data is the most scientists interested field where it done across months and may extend to be years to measure or study long term trends. Such environments have large number of nodes that sense the environments and send data to the base station [19].

The applications of controlling and monitoring the environmental variables, comprises no essentiality of developing strategies of optimal nodes routing. The topology of optimized routing could be calculated instead of that, in the network outside, after that, the necessary information will be communicated and transferred to the target node. What makes this strong possibility is that, the network's physical distribution and routing is constant relatively, whereas, the communication of radio frequency has features stated as time-variant and it makes the connection ability of two different sensors or nodes to be intermittent. The networks general topology will be highly stable [1].

Normally, the interval between each data transmissions period could be in the order of few minutes. The period is being expected in typical condition to locate from 1 to 15 minute. But, it is possible to be less. Although, the parameters of typical environment which are monitoring, for example, pressure, humidity, light intensity, temperature, etc. are being changed very slow, so, it doesn't require reporting with high rates [8].

The security monitoring wireless sensor networks application includes anomaly, illegal entrance, surveillance, etc. it is related to composing nodes that are placed throughout

fixed locations environment. This differs from environment data collection sensors, the security monitoring check its sensor's status and transmit a report when a security violation is happened. So, no data collection is happened in security monitoring sensors network.

Each node should confirm its existence and functionality continuity. When node starts to die or fail, it will send a violation of security report. The sensor nodes are being configured to be responsible for status confirmation of all other nodes. A specific approach or algorithm states that, assigning every single node to a peer, and if the sensor has a function, then, a report will be generated [21].

The node tracking scenario is introduced for tagged object tracking through a space region that is needed to be monitored by an amount of sensors. Different situations where the valuable assets or personnel are located would be tracked.

The traditional tracking of objects has many specs and methodologies, but the determination of current position is very difficult. For example, every shipment can be scanned with bar-coded UPS, any time it is passed within a center of routing. Thus, when an object do not flow form check point to check point it will break down. And the assumption of object to pass through the check points continuously is wrong assumptions.

Simply, the tracking of the objects is being done by getting small sensors that tag the object in WSN node points. The tracking of the sensor node is done as it moves along of

sensor nodes field. This is deploying at known location environment. Improving any node will be done in order to sense and detect the radio frequency message of sensor's node. The nodes are represented in tracking applications as like active tags which announces the device presence. Where, the locations of tracked objects are saved in a database with respect to set of known locations of nodes.

2.6 Communication

The communication rate, power consumption, and transmission range are the key evaluation metrics in the wireless sensor networks. The range of transmitting has nodes density that is accepted with respect to sensors and data measuring in addition to other criteria, while, the coverage argument is not transmitting range limited by individual nodes. When placing the node too far; then the connection to the network may not be possible to establish and maintain a high reliability with enough redundancy [22].

When demanding higher density of node by the radio communications, the system should be add more additional nodes to increase the density of node to tolerable level. Also, the rate of communications has a performance that significantly considerable in nodes. The more transmission and speed communication is being translated in ability of achieving higher effective rates of sampling and lower consumption of network's power. The transmission takes less time as increasing of the bit rates and then the bit rate requires less potentially energy. Always, the increasing in the rate of radio bits is accompanied by the consumptions of radio power increasing [23].

All things being equal, a higher rate of the transmission will result in higher performance of the system. So, the increase of bit transmission rate of the communication has a non-negligible importance on the computational requirements and consumption of energy of each node. Totally, the increase in the rate of bits has a benefit that can be offset by several other factors.

In communicating procedure, the conventional steps starting transmission data encoding / decoding, where the structure of decoding data design, is capable for probability increasing to ensure completely succeeded communication transition that ensures the light errors to be corrected or even filtered. The process of data encoding is being pipelined within the process of real transmission, whereas that increase and ensures more efficiency and reliability [6].

The structure of coding has a range from simple schemes of DC-balancing to complex CDMA schemes, i.e. Manchester encoding or 4b-6b. When one data bit or more symbols are coded into radio transmission collection, it will be called chips. There are two chips in Manchester coding per symbol, they represents a 1 data bit. 15 to 50 chips per each symbol often exist in CDMA and direct sequence spread spectrum.

Chapter 3

METHODOLOGY

3.1 Proposed System

Figure 3.1.a shows the general mode of the Energy Efficient Clustering Algorithm “EECA” adaptive software system. Starting by network data collection, it includes the calculation, determining the energy of each sensor and the initial nodes clustering (distributing on the cells) over the measurement space and initialization.

The initialization is plotting the location of each sensor in measurement space and applying (FCM) traditional clustering algorithm to get the starting location of the head of each cluster. That done after receiving the number of clusters that is needed to be used for cells from the base station.

The next is to start the EECA clustering procedure, which is continue overall running period of the network. During this mode, the network is re-clustered every transfer time and re-localizes a new head of cluster and new distribution of nodes (sensors) in the cells (clusters). When the nodes start to die, the base station should stop collecting data from the network and generates the decision and command to replace the sensors.

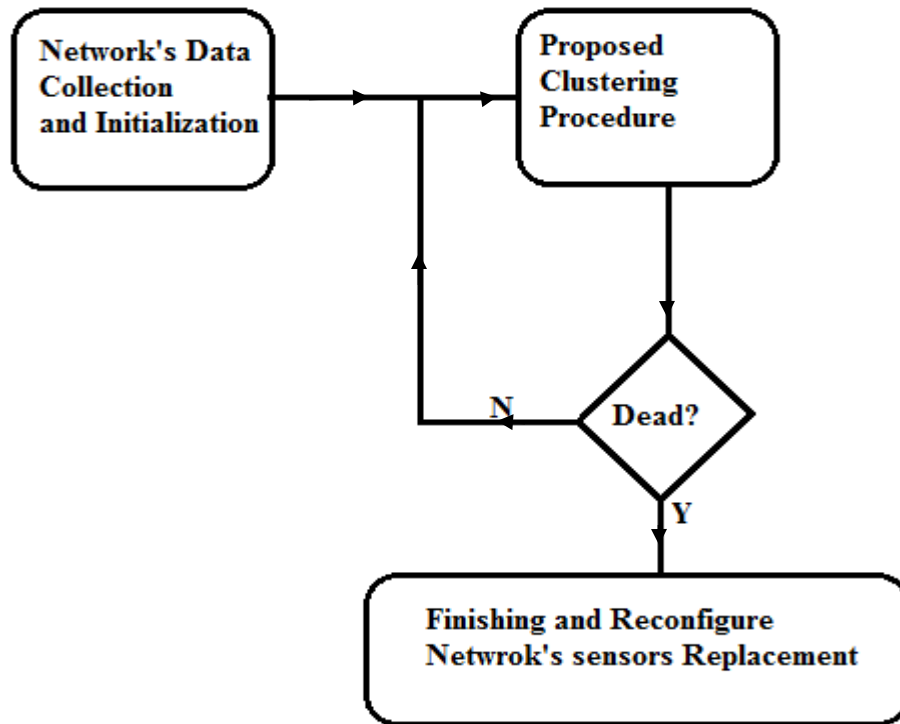


Figure 3.1.a: The EECA system's initial diagram

General scheme of the adaptive EECA is being illustrated in Figure 3.1.b and the details will be described as following; the process starts by data collection from the network. Then, the initial fuzzy clustering algorithm FCM is applied. After that, the normal running mode is entered, it consists of two phases those are consequent. The first is adaptive clustering which is described in details in Section 3.6, and the second is data transfer. This is still running until the network becomes idle, either by nodes death or by the base station commands. While Figure 3.1.c illustrates the original LEACH algorithm flow. It is summarized as following; the process starts by data collection from the network. Then traditional clustering is applied at startup which means that the cluster head is going to be fixed forever. A normal running mode is entered, it consists of only data transfer and this is still running until the network becomes idle, either by nodes death or by the base station commands.

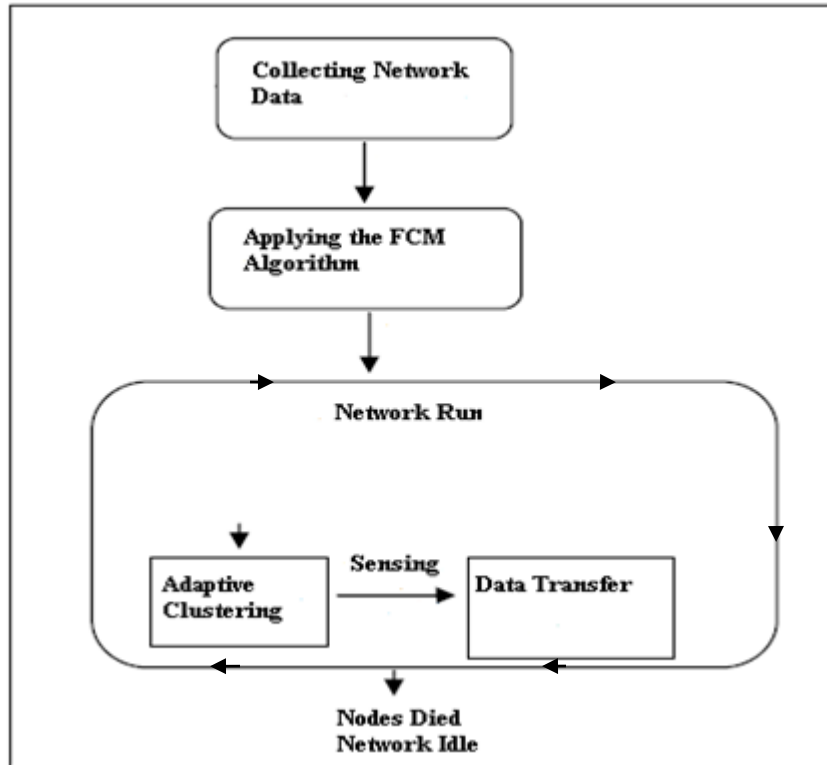


Figure 3.1.b: Basic Block Diagram of the EECA System

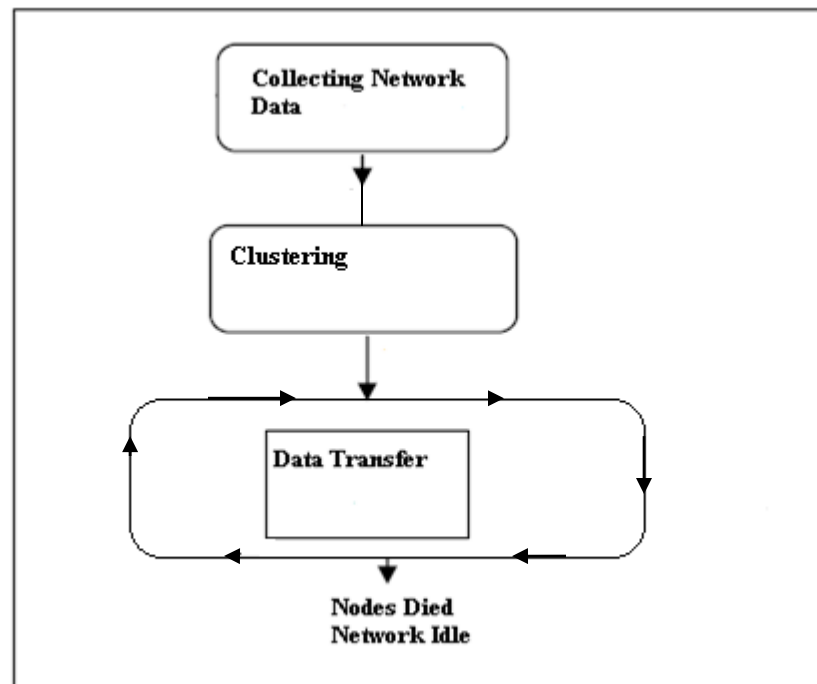


Figure 3.1.c: Basic Block Diagram of the Traditional LEACH Algorithm

3.2 Energy

The power consumption of any device can be represented in many ways. Actually, the energy is being measured in “Joules” and has the “J” abbreviation. The power consumption is measured in “Watts” and is abbreviated as “W”. Watt is the energy consumed in one time unit. Usually, the system’s power is represented by the manipulated variables – not direct variable – like voltage and current. The voltage is not changes depending on the load, the manipulated variable of batteries become the current and time.

Batteries in general are being rated as “Amp-hour” or “mAH” regards to milliamp hour. Milliamphour means by theory that, i.e. if the battery is being rated as 50mAH, if the load consumes 50mAmp, then, the battery can run this load for one hour. If the load consumes 20mAH, then, the battery can be operated on this load for 2.5 hours. But from practical view, this is not completely true, due to the chemical structure of the battery [24].

In wireless sensors network, the battery is fixed and wouldn’t be replaced until the sensor is replaced. The sensors are designated for a long time operation of its internal battery. The life time of battery may extend to 5 or more years.

This thesis aims to optimize the energy consumption of the wireless sensors nodes by optimizing the protocol of LEACH introducing a new terms and algorithms of nodes clustering in order to make the network to be adapted to the work conditions.

3.3 Evaluation Metrics

The evaluation metrics is the measurements and criteria that are being used to evaluate and test the wireless sensor networks quality and operation. It implies a high level criteria and network aimed functionality in addition to long time running period. These metrics will be met at optimal value to ensure the benefits of the wireless sensor networks in comparison with other technologies [25].

The evaluation metrics includes a key variables that should be monitored and recode its validity. Those variables describe the capabilities of the wireless sensor networks and include

- Cost.
- Power dissipation.
- Coverage.
- The ease to use and deploy.
- Life time.
- Security.
- Accuracy.
- Effective sampling rate.
- Response time.

Sometimes, those metrics are dependent to other, so, in order to increase one metric variable, another variable should be changed. For example: in order to increase the life time, the power dissipation should be minimized.

This work proposes the distance between the nodes to be measured by the Euclidean distance. The straight line distance between two points is mathematically known as “Euclidean distance” (or Eq.Dist). The points those subjected to calculate the Eq.Dist may be placed with respect to two dimensional or three dimensional spaces, or even on a dimension of line. Equation 3.1 is the mathematical representation of Eq.Dist in two dimensional x-y coordinate plans. Here, the Eq.Dist will be calculated between two points named p, q respectively [9].

$$d(p, q) = d(q, p) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \dots + (q_n - p_n)^2} \quad \dots(3.1)$$

3.4 Fuzzy Logic

To illustrate the concept of fuzzy logic, consider for example the tall of human. When it should be decided that, one person is tall or short? In digital concepts and digital decisions, if the person is taller than threshold value, then he will be tall, otherwise he will be short. For example, if 175 cm considered being the threshold value of tall people, the digital concepts consider the 175 cm tall person to be tall whereas, the 174 is being considered to be short. Is that right? Definitely it is not [26].

The fuzzy logic introduces the concepts of fuzzy sets and fuzzy decision where the tall is represented in waiting function that is so called Member Ship Function “MFS”. The membership function is a mathematical representation curve that represents the weight of the decision. Figure 3.2 shows the most commonly used membership functions [27].

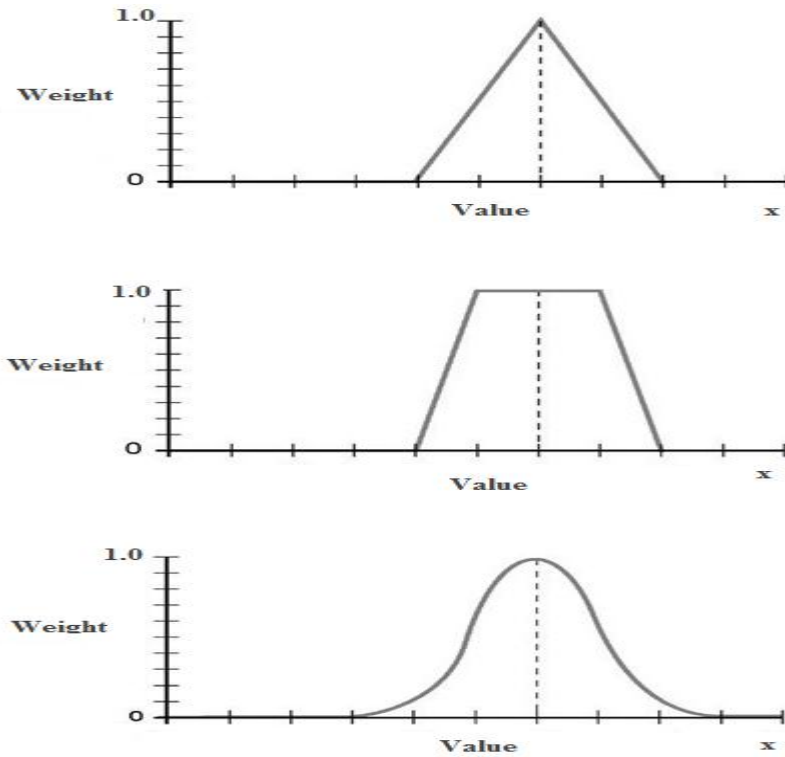


Figure 3.2: Different Types of Commonly used Member Ship Functions [27]

For such weighted functions, the decision will be if the person's tall being 200cm then this person is tall in 1.0 percent while if his tall being 165cm, then it will be tall in 0.55 percent for example, while, the 155cm person is tall with 0.2 percent.

Also, fuzzy logic introduces multi decisions for the same variable. For example, the person of 170cm tall would have the following decisions:

- TALL with 0.7 percent.
- MEDIUM with 0.95 percent.
- SHORT with 0.15 percent.

This is being done by using three membership functions for the same variable which is “tall”. The first “MSF” is “TALL”, the second is “MEDIUM”, and the third is “SHORT”.

Figure 3.3 shows a variable that is being represented by fuzzy membership functions. The y-axis represents the weight value where the x-axis represents the measured or estimated value of that variable. In such, there are six membership functions those are: “Remote”, “Very High”, “Low”, “High”, “Moderate”, “Very Low”. That variable is being built with a modified “Gaussian” membership function.

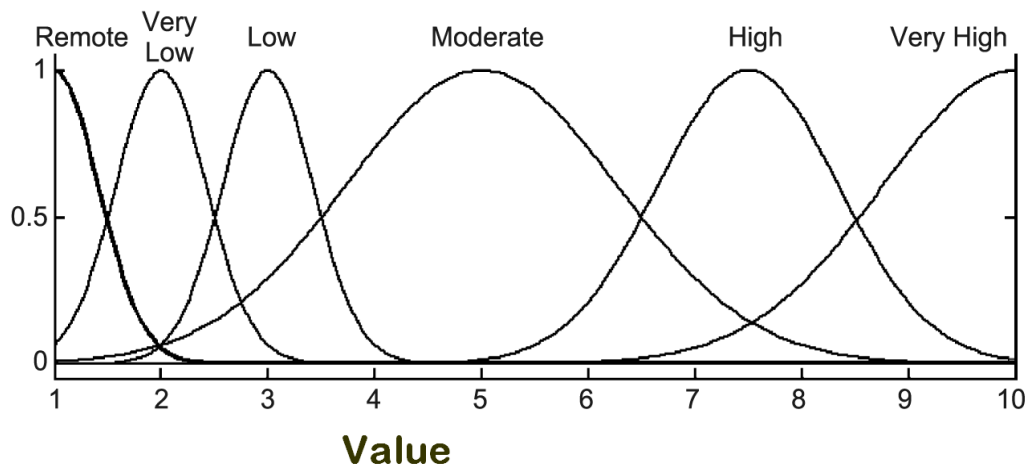


Figure 3.3: An example of a variable that represented in fuzzy form with six member ship functions [27].

3.5 Clustering

Nodes classification in clusters (cells) is the core of the LEACH protocol and its extensions (i.e. LEACH-M, LEACH-L). In general, grouping a set of points (nodes) into cells or clusters is interested methodology in modern applications and researches, especially, in networking and scalability of the networks.

The grouping a bulk of nodes into clusters is highly dependent on the deployment specifications, system's architecture, scheme of bootstrapping, cluster characteristics, etc. The center of the cluster is commonly known as Head of Cluster "CH". The head of cluster is one of the cluster's nodes. The number of nodes in one cluster is almost differs from it in the other clusters. Where the head of cluster can form in some systems a second tier of the network and thus, another hieratical level can be formed, or it may be just the data to another point [28].

The clustering in theory has many advantages in addition to the network scalability support. Also, it minimized the routing table's size that stored at individual nodes, and allows to safe the bandwidth of the communication because it limits the cluster interactions scope to the head of clusters, the redundancy avoiding would result and change among nodes is being enabled.

Figure 3.4 shows a sample of bulk data clustering in the left, and that is being clustered in the right side. The Figure shows two dimensional distributed nodes, then, it classified into four clusters. Each cluster is colored with unique color.

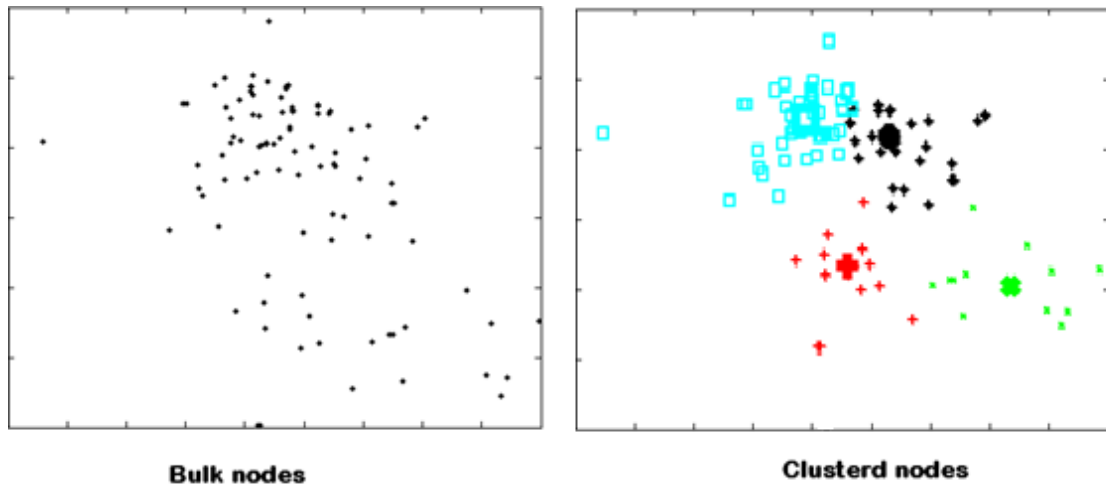


Figure 3.4: Sample of data clustering

Different methodologies are being used in data clustering, some of them are numerical or analytical, and the most intelligent methodology is the fuzzy clustering method. The most common, efficient, and reliable fuzzy clustering method is the Fuzzy C-Mean “FCM” algorithm.

In wireless sensors network, the clustering process isolates the nodes of changes at the tier of inter-cluster heads level, thus, reducing the maintenance topology overhead. Optimized techniques can be implemented by the head of cluster in order to enhance the operation of the network and extends the battery life of the nodes. So, the heads of clusters schedules the overall activity of the clusters, thus, the nodes switch the sleep modes at the most of the time. That reduces the consumption of energy.

To minimize or even cancelation the redundancy of the data in the clusters, the use of data aggregation or similar techniques is being taken a place. In addition, the clustering increases the connectivity of nodes to the head of cluster and center all cluster nodes on

the cluster head. This reduces the delay of measurement transfer and communicating to the base station. It comprises the maximum network longevity.

3.6 The Proposed Clustering Algorithm

The EECA is an adaptive developed structural algorithm that locates the head of cluster by cluster centroid localization of data set that consists of geometric distribution of sensor-nodes in x-y plan or even capable to be used in 3-D space of sensing. EECA is based on the original Fuzzy C-mean algorithm of clustering data in 2-D plan, and improving it that by the use of “Potential” concept of the networks nodes and clusters. When calculating the overall sensor-nodes potential to the centroid that is being obtained from FCM, the nodes will be distributed into clusters easily by the mean of its potential not Euclidean distance.

In the contributed EECA algorithm, once the potential of each node is calculated, the head of cluster (CH) will be localized via the traditional FCM algorithm. The clustering process will follow the last centroid (head of cluster) determination phase. This will be determined and localized using the current suggested modification (addition) to the fuzzy approach of clustering. The developed procedure in this thesis will generate clusters that are equivalent in potential. Equation 3.2 expresses the contributed potential mathematical form.

$$P = \frac{1}{E_q} + \frac{1}{E_r} - d \times Tq - k \quad \dots (3.2)$$

Where: P is the Potential.

Eq: is the Euclidian distance.

Er: is the total remaining energy in the sensors battery.

D is the transmission data cost function.

Tq is the energy slop of transmission data.

K is the battery self-leakage.

This equation calculates the potential of the node, and it represents a non-linear relation between the Euclidean distance (see Equation 3.3 above), and the sensor's current working energy (which is the maximum initial energy minus the running cost energy), in addition to the energy cost (assumption) of each data bit; the energy consumption is known as (energy slope).

When the potential is taken into consideration, the specification of internal battery surely has leakage. Its leakage is represented by the Equation 3.3 [9].

$$d(p, q) = d(q, p) = \sqrt{\sum_{i=1}^n (q_i - p_i)^2} \quad \dots (3.3)$$

The above equation illustrates how to calculate the Eq.Dist between target point “q” and destination pint “p”. Here the distance is “d”. The destination point may be the head of cluster or normal node [9].

For communication purposes with the BS (Base Station), various or different frequency levels and gaps may differ from area to area or from sensor to sensor. This thesis focuses on clustering energy optimization, so, the frequency and communication power is being expressed by the mean of slope of the energy for each sensor's-node. This work implements MATLAB procedures and functions to simulate the contributed EECA and comparing it with the well-known LEACH algorithm and its extensions. The prolonging of the overall time that the network can work in is clear from the result of the simulation.

The proposed methodology of the thesis consists of three phases. The bulk network of sensors should be divided into clusters and that process is so called "Clustering". The thesis assumed to use the fuzzy logic approach of clustering by what is called C-mean. The phase one distribute the sensor points into separate clusters, each cluster has its own head. That clustering is potential-based as illustrated in this chapter above. Equation 3.2 is being used to calculate the contributed potential.

The data transfer (protocol data, measurement physical variables data, and status) will proceed starting from each node in the cell or cluster to communicate with the base station. This communication doesn't pass directly, the node communicates with CH (cluster head), and all heads will transfer data directly to/from the main unit (base station). After each single transmission round, the sensor loses a part of its energy. The power consumption is named above to be named as (slope of the energy).

Communicating was the second phase, while in the last phase, the cluster head will be changed continuously with every communication round process. The contributed

adaptive EECA assumes the CH (head of cluster) to be changed in order to save it the maximum power node. Equation 3.4 shows the mathematical expression that is being used to calculate the commutative head of cluster. Once, a new cluster head is being selected; all nodes will be re-clusters again. That will keep all clusters to be saved or got similar energy levels.

$$P_c = \min(P_{co} \sum(P_{co} - 1) + (P_{co} + 1)) \quad \dots (3.4)$$

The new heads of the clusters will be determined by their potential (p_c), with respect to the old potential of the heads of clusters (p_{co}).

Those operational processes should continue running and re-selecting the clusters and head of clusters. This proposed scheme will be active and running during all the time of network run. The calculating of new suitable heads will be localized at every round.

Bellow the next Figure (3.5), displays a topology of clustered WSN in 2-D. In such Figure, there are three types of nodes, the first those is bold and big which is the head of clusters. The second has a single color, where those are node related to a cluster head that has the same color. Whereas, the bi-colored points, is a sensor-nodes those has a mid-potential between two clusters.

Those nodes can be categorized in each of the two clusters without a significant change in the cluster itself. In the fact, these small changes could be used to balance the potential of clusters. The points that are located potentially between two heads will be

named in this thesis as “In-Between Nodes”. Figure 3.5 categories the network into four cells.

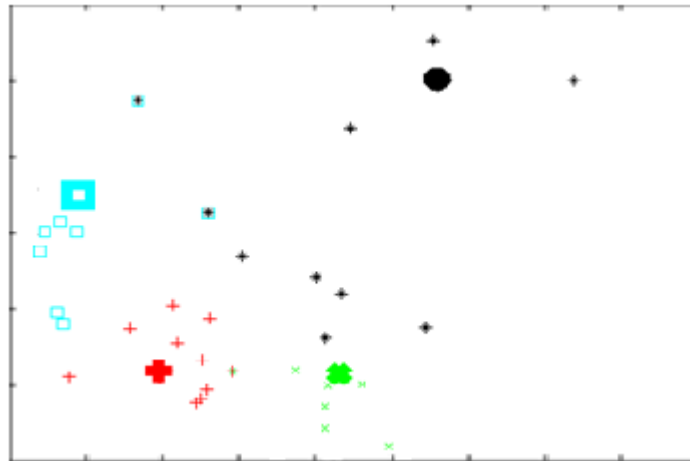


Figure 3.5: Sample scheme of clustered WSN for the nodes in between two clusters- depending on the potential of the each cluster.

This contributed algorithm, doesn't generate exactly a cells those has typically the same potential, but the difference of potential between them has a limit may reaches to zero or near to zero, and thus, that difference will be neglected. The EECA aims to generate such equi-potential cells. This contribution saves 3% or more for the total cells energy. This result (3%) is gotten by simulating the network with and without the process of managing the “In-Between Nodes”.

The LEACH algorithm extensions (either M or L) aim to make the life time of the nodes to be maximum, but in both, once the first node is dead, a problem occurs. The problem is that, the dead sensors will not be able to measure the physical data and cannot transfer any data to the head of cluster node. So, it should be imagined that, one of the two scenarios may happen once the first node is dead. The first scenario is that, the network still working as it is, thus, one node cannot log the measured data. While the process

continues, more nodes will start dead and thus, a non-negligible data will be loosed, and the network becomes un-useful. The second scenario is that, the network sensor nodes are being replaced in the start time of nodes death, thus, a high cost will be achieved. Then, the contributed EECA aims to minimize the period between the first and last node death. This will keep the network running in balance measurements and data collection, and also, it saves more power.

Many researchers performed experiments and researches to save network energy, specially the energy between the first and final node death. This thesis, implements a very effective and adaptive approach, that minimizes significantly the energy lose and cost.

The best algorithm that saves the energy in interval of nodes death is LEACH-L before testing the EECA approach. It increases the balancing in the nodes, thus, the use of low power nodes converted to high power nodes. This contributed thesis increase the efficiency to 90% rather than LEACH-L.

In this thesis, the key point in the developed EECA is making all nodes died in the same time (that means the interval becomes near to zero) that why it is an efficient clustering procedure for cells. The adaptation means that, the cluster head will not be fixed – even it is still has large power in the cell -. It will be changed to keep on the balancing of the cluster. Thus, the nodes distribution will be balanced with respect to its potential, and it results the balance energy slope and power consumption of all nodes. The generated clusters will be symmetrical along the overall running period.

Furthermore over that, the head of cluster should be kept as it is the larger potential node over all running time. This requires re-clustering all of the data at each round. This makes a benefit of decreasing the power consumption of the leave nodes where that is considered to be head in the traditional LEACH procedure or its extensions. The wrong cell center (Head of clusters) is almost leaks a big value of energy. On the other hand, the contributed Energy Efficient Clustering Algorithm “EECA” contributes intelligent solutions for that problem, and thus, saves an interesting value of the cell’s power.

Chapter 4

RESULTS

4.1 Performance Evaluation

This Thesis developed MATLAB program to experiment and simulate EECA algorithm and getting the results. In such, two assumed areas are used for testing the protocol. The wireless sensor networks are distributed in the two scope areas individually and both are tested, and the parameters measured individually.

The “round” concept represents a complete transmission process over running of the wireless sensors network.

The first scope is 300 by 300 m, where the second is 500 by 500 m. Initial conditions and test conditions are illustrated in Section 4.2. The test will consider almost on the energy optimization measurements with respect to a LEACH, LEACH-M, and LEACH-L protocols. The result will be compared and discussed in Section 4.3.

Table-4.1 bellow illustrated the assumed parameters that have been implemented in simulation for testing purpose. Those parameters are selected in order to make the comparison between the EECA protocol and the other LEACH protocols more meaningful. Thus, the new modifications, improvements, and optimization – especially in energy – are clearer in the Figures.

The trends and Figures illustrated the energy scope and performance. The energy consumption will be shown in Figures to show how the energy is being consumed. The dead node trends show the node activity until it died. The overall nodes death displays the performance of the network optimization.

The testing of EECA is done in two topological scenes; the first is over 500 by 500 meters, while the other comprises 300 by 300 meters.

Table 4.1: Simulation Parameters [9]

Parameter	Test conditions 1	Test conditions2
Network validity scope “m”	300 by 300	500 by 500
No# of wireless sensors	900	2500
Energy at Starting	0.5 J	0.5 J
E (J)energy parameter	1	1
Transmission packet length “bits”	4000	4000
$E_{(DA)}$ (Energy required for data aggregation)	5×10^{-9}	5×10^{-9}
P(cluster-head section probability used during cluster creation)	0.1	0.1
M (Multipath-Fading)	0.1	0.1
D (distance between transmitter and receiver)	70 m	70 m
Transmission-Distance(m)	30	70

4.2 Experimental Result

From the Figures bellow, it's easily and clearly to see that, the contributed Energy Efficient Clustering Algorithm "EECA" comprises the minimized power consumption via time unit. So, the backup power of the sensors will be saved for longer time.

The cycle across the total running time of the network of 300X300 m results are displayed in Figure 4.1. From the Figure, it's clear that, the nodes using the EECA algorithm are running for more number of cycles than the others and the death of the nodes is very balanced in the contributed EECA algorithm. While in comparison to other LEACH schemes, there is a larger interval. Again, that cause to save more power and energy by prolong the nodes running time.

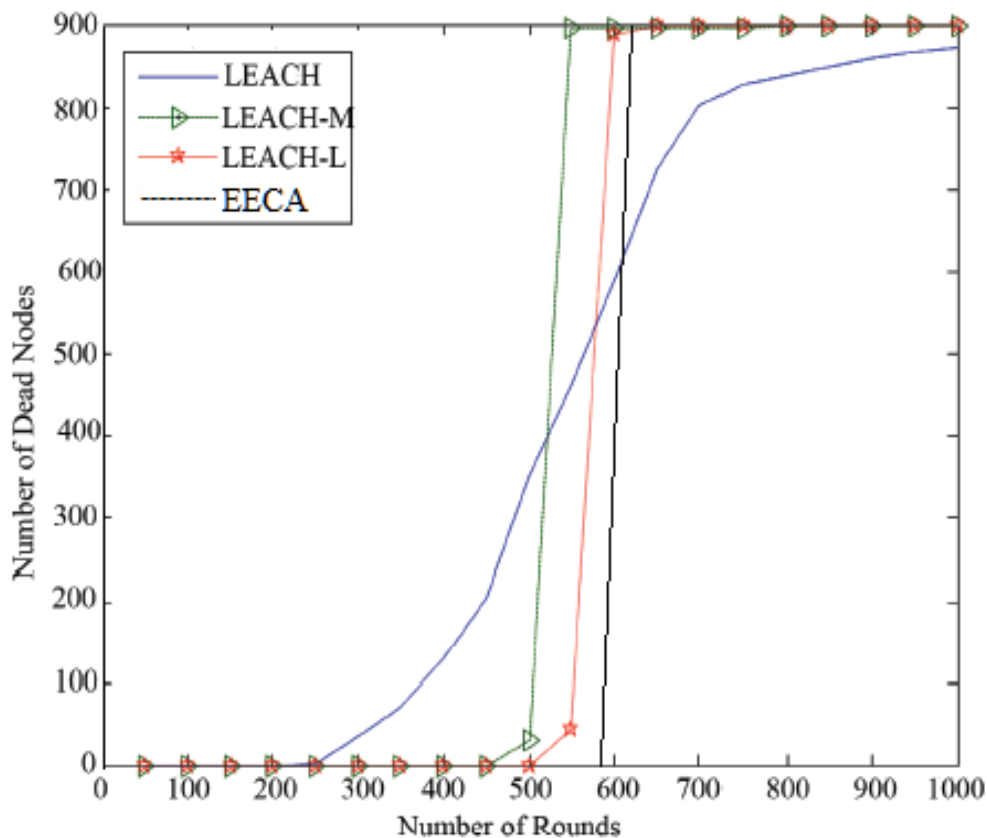


Figure 4.1: Nodes Death over 300 x 300 round in different protocols.

Whereas Figure 4.2 displays the nodes death scheme for an area of 500 by 500m. It can be shown that EECA algorithm has two benefits: The system is running for more number of rounds than using other LEACH protocols and the time death interval between the first and last node is the shorter than others. So EECA system can minimize the death nodes interval, reduce the power consumption, save more energy and prolong the lifetime of the nodes.

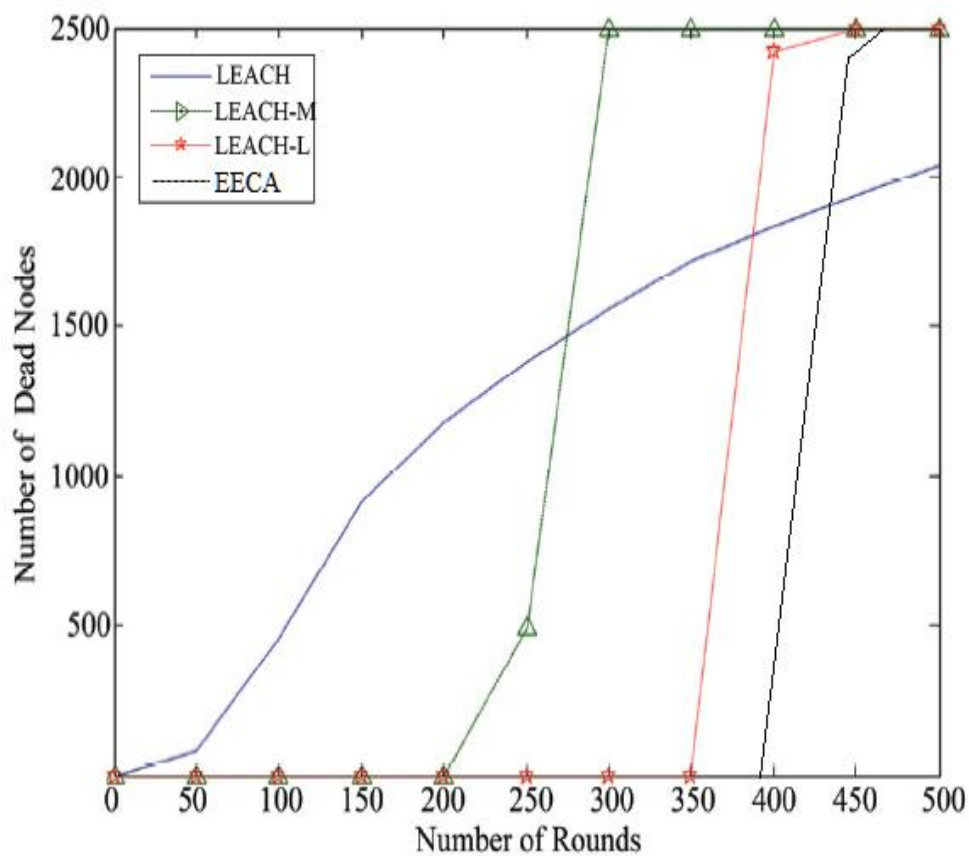


Figure 4.2: Dead Nodes over a round of 500 x 500 in different protocols

The next two Figures show the received packet number in time interval of all LEACH protocols in addition to the EECA protocol tested in 300x300m WSN space, and 500x500m WSN space respectively.

Figure4.3 displays the relation of the amount of sent packets during their life interval in an area of 300 by 300m. It shows that EECA system can transmit more number of packets than other LEACH protocols for a longer period of time and can clarify the very helpful linearity implementation that ensures the progress of data packet communicating plus the increasing in number of transmitted packets.

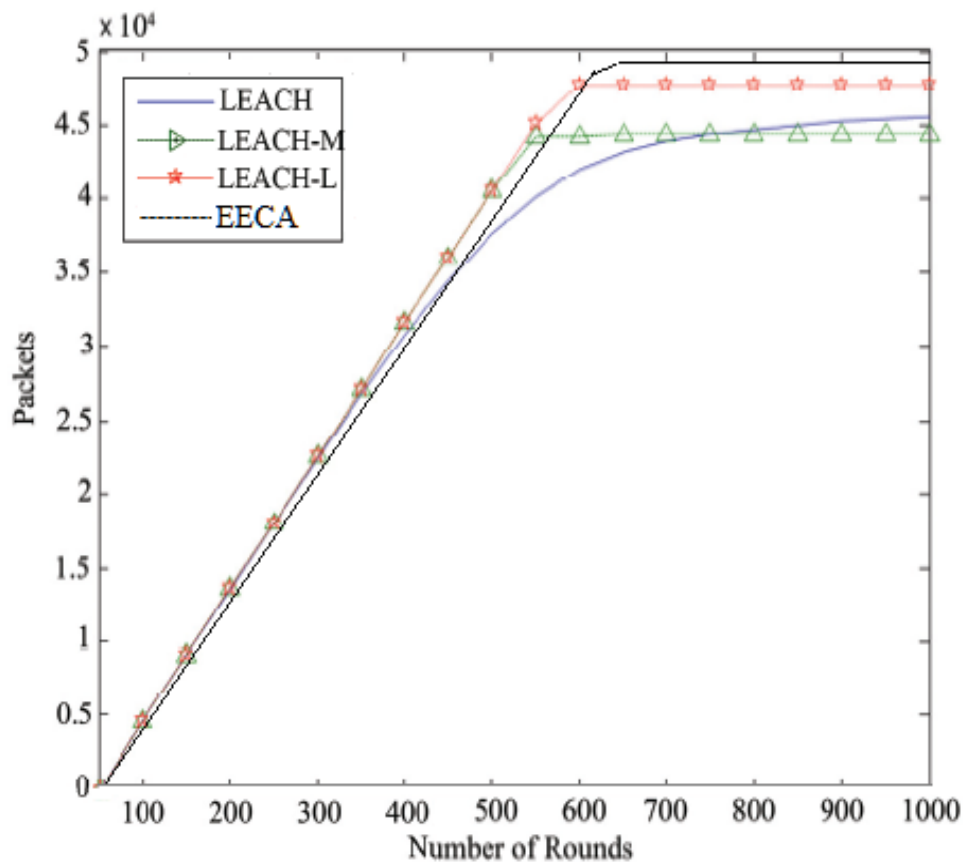


Figure 4.3: Received packets over round of 300 x 300 in different protocols

While Figure 4.4 displays the transmitted packets number in time interval for an area of 500 by 500m. It can be noticed that the EECA system increases the amount of transmitted packets, keep on communicating for more number of cycles and minimize the time death interval between the whole nodes which leads to improve the performance of the system.

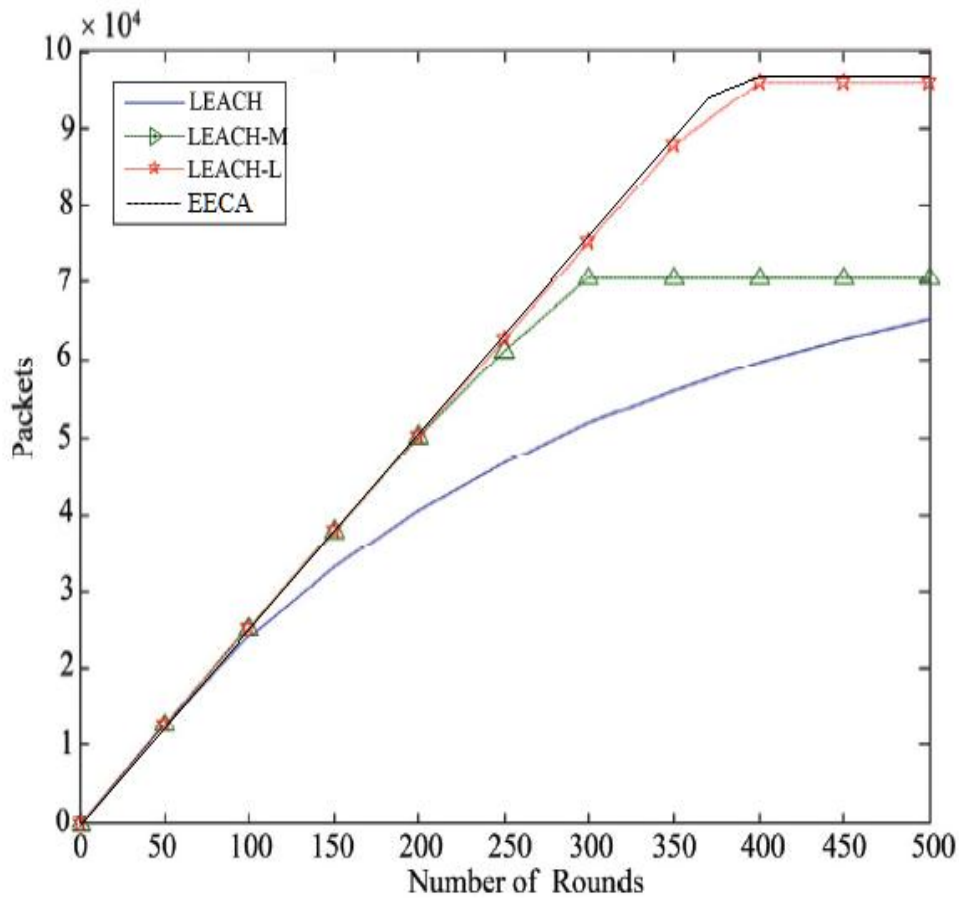


Figure 4.4: Received packets over round of 500 x 500 in different protocols

The next two Figures show the direct relation between the power consumption with the number of cycles for an area of 300 by 300m and 500 by 500 m respectively.

The power consumptions (energy drain) of different LEACH protocols are compared to the contributed EECA protocol in the next two figures. Figure 4.5 represents a 300 by 300m space WSN space. In the same conditions, this figure shows the amount of energy consumptions over a time, the total sensor's energy value is adopted to keep the network running in long period of time. So, the capacity of the battery is enough to run the sensor in normal operation using EECA algorithm rather than old methodology as in old LEACH protocol.

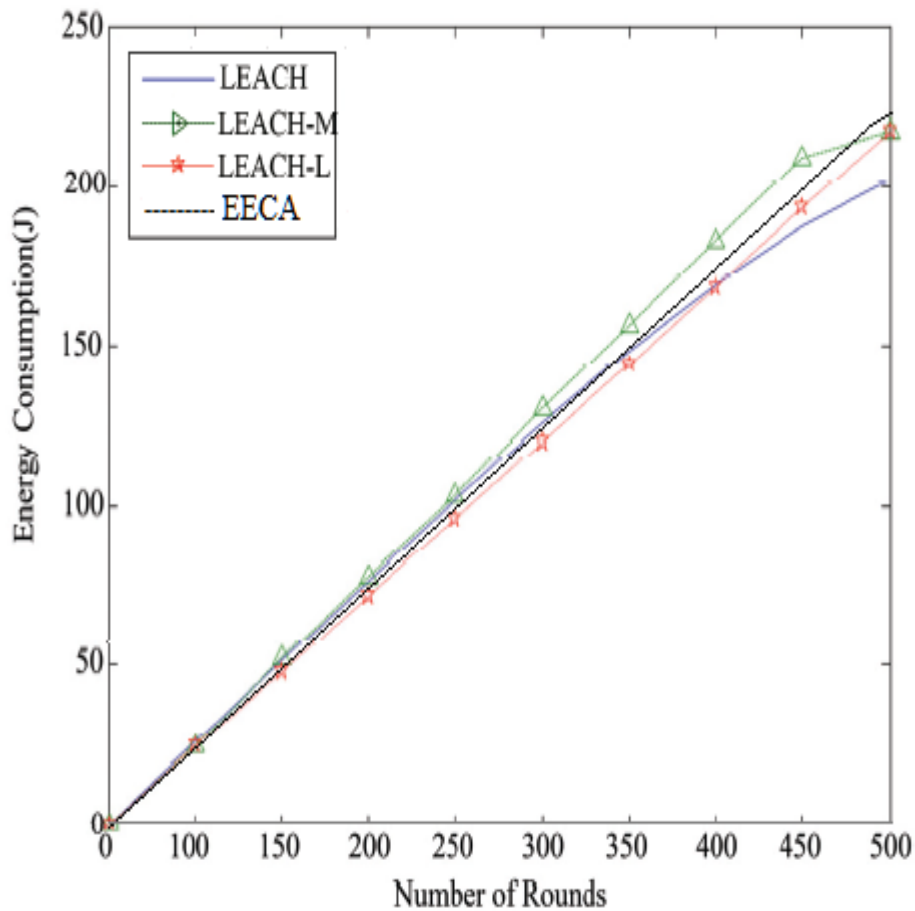


Figure4.5: Energy Consumption over round of 300 x 300 in different protocols

The power consumption of the contributed EECA protocol is compared to the old LEACH protocol in the next figures. Figure 4.6 is representing a 500 by 500m WSN space. In the same conditions, this figure shows the amount of energy consumptions over a time, EECA algorithm adopted the total sensor's energy value to keep the network running in long period of time. So, the capacity of the battery is enough to run the sensors in normal operation rather than old methodology.

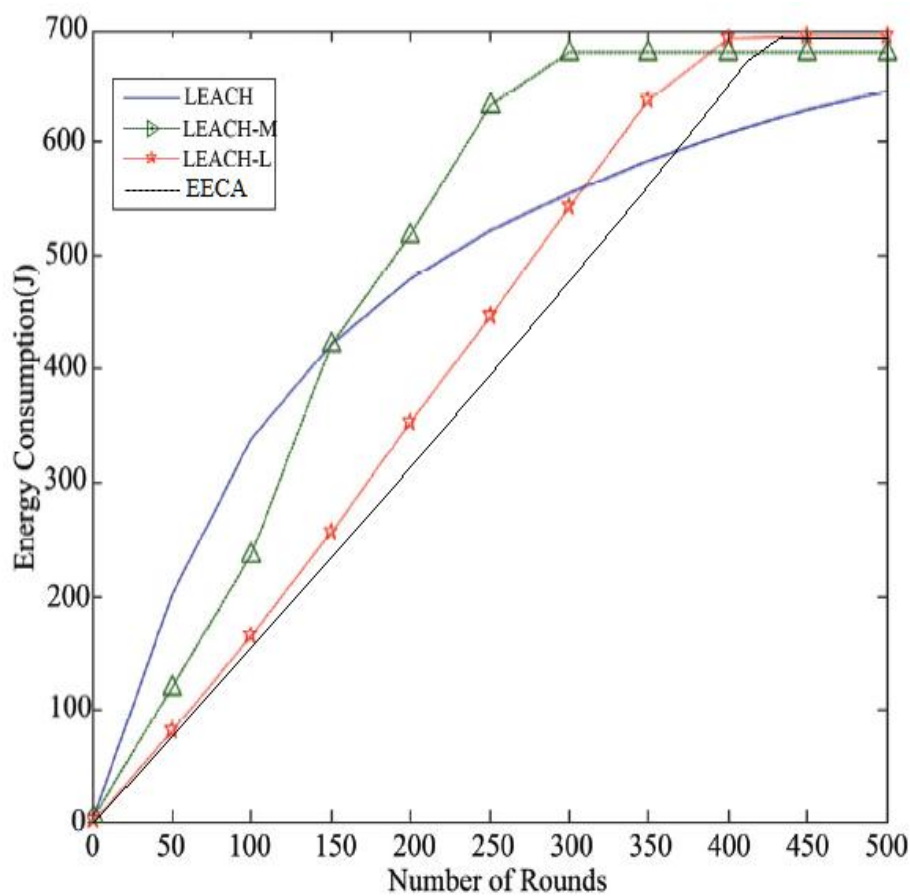


Figure 4.6: Energy Consumption over round of 500 x 500 in different protocols

Table 4.2 shows the energy optimization efficiency that is achieved using the EECA algorithm of variable clustering of the wireless sensor networks comparison with the different algorithms that is used.

Table 4.2: Energy optimization of different clustering algorithms

Algorithm	Energy Optimization Percent
EECA	93%
LEACH-M	80%
LEACH-L	65%

Chapter 5

CONCLUSION

This research concerns to implement a new methodology for wireless sensors adaptive clustering in order to optimize energy and power consumption in the network. Many researches in past and current information systems world are concerning in the energy optimization. The optimization of wireless network energy researches either concerns on hardware modification and optimization or either software management.

The past researches on clustering of wireless sensor networks got a result of saving an interesting amount of energy and sensor's life.

This research added a value of saving more energy and power, and building adaptive algorithm. This algorithm as shown in chapter four, was been tested on different scopes of wireless sensors networks in different conditions. From that point the following conclusions have been got:

- The energy of wireless sensor networks is important issue and needs more hardware and software solutions to get good optimization methods.
- Energy optimization can significantly be done by a suitable clustering algorithm.

- This research is a novel clustering algorithm for improving the conservation of energy in WSN's.
- Hence, the asymmetry of clusters (cells), the nodes will consume asymmetrical power, due to the asymmetrical structure, design, and packet data transfer. While, it can be managed to balance the cluster's load by introducing a specific variable or concept that can express the overall load of the cluster and also node. Whereas this variable or concept should be mathematically and physically meaningful for all conditions and variables that affect the sensors battery and cluster communication transfer. This variable or concept is so called in this thesis "POTENTIAL".
- This thesis, introduces the "POTENTIAL" concept of the wireless sensors network. The potential of the node represents the availability of that node (sensor) to transfer data and for how long a time.
- The POTENTIAL of the cell is the availability of the cluster of sensors to measure and send data for a how long time.
- In thesis, the symmetry of all clusters (Cells) enables all clusters to work in the same time long. Thus, all clusters will start to die at the same time. This ensures that, no cluster work and other die.
- Also, the symmetry inside the cluster, make to whole network nodes work in the progress together for a time long, and the all nodes will start in death in the same moment. This ensures a time interval for nodes death to be approaches zero.

- The symmetry of the clusters and nodes can be achieved in different methodologies. This paper use three methodologies and techniques to perform this approach. The first one is to re-cluster all networks continuously after each transfer process. Although, this will increase up the computational power, but this rise is always negligible with comparison of optimization. The second technique is to make the head of clusters to be variable, and all heads of clusters are being changed continuously over the time after each data transfer process seemingly.

While, the third technique is to deal with specific sensor nodes, whose represents sensors located in between two – or more – clusters. Those sensors can be added in clustering process to any one of the clusters those the nodes located near to it without any big change in cell load. The “in between” nodes is a good concept to handle. The calibration of cluster balance can be done by controlling those nodes in order to fine tune the POTENTIAL of the clusters. The small change of cluster’s potential can be tuned using those nodes interestingly.

- Fuzzy logic clustering is an intelligent method to distribute the nodes over the cells or clusters, but its result is always generated Not-Equal sizes clusters and also, Not-Equal Potentials.
- This thesis introduced and implemented a new modification on the fuzzy C-mean clustering algorithm. This modification uses the POTENTIAL to distribute the nodes over the cells (clusters). The fuzzy C-mean clustering is used to determine the initial nodes those can be represented as “head of clusters” and the modification of the

algorithm is to retest each node and add it to the appropriate cluster by POTENTIAL.

- The fact that, if we got symmetrical clusters by POTENTIAL over the time of data transfer, then all nodes and clusters will start to die and die in the same time, leads to implement the variable clustering algorithm. This clustering includes re-locating the head of cluster after each transfer of data process, and then re-clustering all data.

5.1 Suggestions for Future Work

Many researches related to wireless sensor networks energy optimization are being introduced in this time. The research that can achieve a good score and add an important contribution is the research that solves the important problematic issues. Those include energy optimization and power dispatch, data transfer, security, hardware reliability, and management.

This research is concerning in software for energy optimization, it is a first stage of performing energy and data saving across a total network running period or life. That is including managing the measurements, data logging, transfer, energy optimization, and replacement.

The future work that is closely related to this thesis is concerns in two axes. Those axes should be implemented and developed to complete the full system optimization. Those are:

1. Adapting management protocol that manages both, the data transfer and clustering algorithm. This protocol is the main control protocol of base station.

2. Implementing measurement, data logging, and transfer protocol that comprises the energy and performance saving.

Ongoing, the PhD of mine will be a completion work on this side of researches. The problems that should be solved and dealing with in PhD thesis are the following:

- Handling the control and management protocol of the EECA directly from the base station, while it was automatic in this thesis.
- Dealing with the In-Between nodes automatically.
- Handling the far nodes, where those were excluded from this research.
- Dealing with tracking applications and real-time physical data measurements and logging.
- Contributing an intelligent technique for activation / deactivation of nodes depending on area of interest for measurement.

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APPENDIX

Simulation Code

```
Function drawResults
```

```
figure(1); title('500x500 round node death')
```

```
loadEECARec.mat
```

```
hold on
```

```
plot(Rmea1(1,:),Rmea1(2:),'g-','LineWidth', 2.1)
```

```
plot(RLa1(1,:),RLa1(2:),'r-','LineWidth', 2.3)
```

```
plot(RLLa1(1,:),RLLa1(2:),'b-','LineWidth', 2.2)
```

```
plot(RLMa1(1,:),RLMa1(2:),'k-','LineWidth', 2.4)
```

```
hold off
```

```
clear;clc
```

```
loadLchRec.mat
```

```
figure(2); title('300x300 round node death')
```

```
hold on
```

```
plot(Rmeb2(1,:),Rmeb2(2:),'g-','LineWidth', 2.1)
```

```
plot(RLb2(1,:),RLb2(2:),'r-','LineWidth', 2.3)
```

```
plot(RLLb2(1,:),RLLb2(2:),'b-','LineWidth', 2.2)
```

```
plot(RLMb2(1,:),RLMb2(2:),'k-','LineWidth', 2.4)
```

```
hold off
```

```
clear;clc
```

```
figure(3); title('energy consumption')
```

```
hold on
```

```

loadLcLRec.mat

plot(Rmec2(1,:),Rmec2(2,:),'g-','LineWidth', 2.1)

plot(RLc2(1,:),RLc2(2,:),'r-','LineWidth', 2.3)

plot(RLLc2(1,:),RLLc2(2,:),'b-','LineWidth', 2.2)

plot(RLMc2(1,:),RLMc2(2,:),'k-','LineWidth', 2.4)

hold off

clear;clc

figure(4); title('round numb paket number')

loadLcMRec.mat

hold on

plot(Rmed1(1,:),Rmed1(2,:),'g-','LineWidth', 2.1)

plot(RLd1(1,:),RLd1(2,:),'r-','LineWidth', 2.3)

plot(RLLd1(1,:),RLLd1(2,:),'b-','LineWidth', 2.2)

plot(RLMd1(1,:),RLMd1(2,:),'k-','LineWidth', 2.4)

hold off

clear;clc

%=====

```

```

functionfiras(n)

% set of points arrangement and plotting
loaddatasample.mat
fcmdata = scho;

fcmdata = abs(randn(40,2))*10;
fcmdata(:,3)=100;           %starting battery energy of each sensor's node -
potential 1
fcmdata(:,4)=rand(40,1);   %energy consumption slope - potential 2
                           % potential 3 = Euclidean distance value

[r0 c0]=size(fcmdata);
figure;plot(fcmdata(:,1),fcmdata(:,2),'k')
title('Data Set')

%=====
%getting cluster centers from fuzzy logic clustering
[allcenters, U, obj_fcn] = fcm(fcmdata, n);           %fuzzy c-mean
clustering
maxU = max(U);

plotstyle=['bo'; 'gx'; 'r+'; 'k*'; 'cs'; 'yv'];      %array of plot style and colors
pause
figure(2)
for k=1:n
hold on
%=====
plot(allcenters(k,1),allcenters(k,2),plotstyle(mod(k,6)+1,:),'markersize',14,'LineWidth',6)
%plotting the colored centers of clusters
end
%=====

```



```

for j=1:r0-1
if(conx(j,1)>conx(j+1,1))
sorx=conx(j,:);
conx(j,:) = conx(j+1,:);
conx(j+1,:) = sorx;
end
end
end
conx;
count=ceil(r0/n)

clust{k}=conx(1:count,:);
clustx =conx(1:count,:);
context(:,1:3)=conx(1:count,2:4)
allclusters(:,k) = clustx;

clusmin=min(context(:,3));
[u0 p0]=size(context);
for w=1:u0
if(context(w,3)==clusmin)
break;
end
end
newcenters(k,:)=context(w,1:2);

if(tyt>1)
for i=1:count
text(context(i,1), context(i,2), num2str(context(i,3)));
end
end

```

