DESIGN AND IMPLEMENTATION OF GRID-BASED HYBRID NETWORK FOR ENERGY EFFICIENT WIRELESS SENSOR NETWORKS

MURTADHA ABDULLAH YAS MIHYAWI

JANUARY 2020

DESIGN AND IMPLEMENTATION OF GRID-BASED HYBRID NETWORK

FOR ENERGY EFFICIENT WIRELESS SENSOR NETWORKS

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF NATURAL AND APPLIED

SCIENCES OF

ÇANKAYA UNIVERSITY

BY

MURTADHA ABDULLAH YAS MIHYAWI

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF

MASTER OF SCIENCE

IN

THE DEPARTMENT OF COMPUTER ENGINEERING

INFORMATION TECHNOLOGY PROGRAM

JANUARY 2020

Title of the Thesis: **Design and Implementation of Grid-Based Hybrid Network for Energy Efficient Wireless Sensor Networks**

Submitted by: **Murtadha Abdullah Yas MIHYAWI**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University.

Prof. Dr. Can ÇOĞUN
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Sıtkı Kemal İDER
Department Chair

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Sibel T. ÖZYER
Supervisor

Examination Date: 06 / 01 / 2020

Examining Committee Members:

Prof. Dr. Bülent TAVLI	(TOBB ET Univ.)	
Assoc. Prof. Dr. Çiğdem DİNÇKAL	(Çankaya Univ.)	
Assist. Prof. Dr. Sibel T. ÖZYER	(Çankaya Univ.)	

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Name, Last Name	:	Murtadha Abdullah Yas MIHYAWI
Signature	:	
Date	:	06 / 01 / 2020

ABSTRACT

Design and Implementation of Grid-Based Hybrid Network for Energy Efficient Wireless Sensor Networks

By Murtadha Abdullah Yas MIHYAWI

Master of Science in Information Technology/ Department of Computer Engineering

Supervisor: Assist. Prof. Dr. Sibel T. ÖZYER

January 2020, 47 pages

The Wireless Sensor Networks (WSNs) are consisting of many tiny devices called (sensor nodes) which are distributed spatially in a network, such devices have the ability to sense, process, as well as to communicate. And cooperates with each other to complete specific tasks. Since these nodes have limited energy supplies due to its battery-based nature, a clustering technique is particularly used to overcome the problem of energy consumption in addition to its impact on the network's lifetime.

Grid-Based Hybrid Network Development technique has been provided in this study, such method enabled enhancing the conservation of energy as well as extending the lifetime of networks in the WSNs. By using Matlab tool, this technique showed the throughput that is related to the residual energy as well as the consumed energy for (500, 600) sensor nodes in a specific number of iteration processes (1500 rounds). As a result, we got the optimal solution of how many sensor nodes were kept alive, what was the percentage of dead nodes through that number of rounds, maximum number of rounds resulting in improving the lifetime of network, and overall consumed energy in two energy initial cases (Eini = 1 Joule, Eini = 2 Joules) for our proposed (8 x 8) and (10x10) grid size network.

Keywords: Wireless Sensor Network, Grid-Based Hybrid Network, Base Station, Cluster Head.

ÖZ

Enerji Verimli Kablosuz Sensör Ağları için Şebekeye Dayalı Hibrit Ağın Tasarımı ve Uygulaması

MIHYAWI, Murtadha Abdullah Yas

Yüksek Lisans, Bilgi Teknolojileri/ Bilgisayar Mühendisliği Bölümü

Tez Yöneticisi: Dr. Öğr. Üyesi Sibel T. ÖZYER

Ocak 2020, 47 sayfa

Kablosuz Algılayıcı Ağları (KAA'lar), bir ağda uzamsal olarak dağıtılan algılayıcı düğümleri adı verilen birçok küçük aygıttan oluşur; bu tür aygıtlar algılama, işleme ve iletişim yeteneğine sahiptir ve belirli görevleri tamamlamak için birbirleriyle işbirliği yapar. Bu düğümler pil tabanlı yapısı nedeniyle sınırlı enerji kaynaklarına sahip olduğundan, küme tekniği özellikle ağın ömrü üzerindeki etkisinin yanı sıra enerji tüketimi sorununun üstesinden gelmek için de kullanılır.

Bu çalışmada Şebekeye Dayalı Hibrit Şebeke Geliştirme tekniği sağlanmış, bu yöntem enerjinin korunmasını sağlamanın yanı sıra WSN'lerde şebekelerin ömrünü uzatmıştır. Matlab uygulamasını kullanarak, bu teknik, belirli sayıda yineleme işleminde (1500 devir) (500, 600) sensör düğümü için tüketilen enerjinin yanı sıra enerjiyle ilgili iş hacmini de göstermiştir. Sonuç olarak, kaç sensör düğümünün canlı kaldığına, o sayıda turda ölü düğümlerin yüzdesine, ağın ömrünü iyileştiren maksimum tur sayısına ve iki başlangıç enerjisinde tüketilen toplam enerjinin en uygun sonuçlarını elde ettik (Eini = 1 Joule, Eini = 2 Joule) başlangıç enerjileri için önerilen şebeke boyutları (8 x 8) ve (10x10).

Anahtar kelimeler: Kablosuz Algılayıcı Ağ, Şebeke Tabanlı Hibrit Ağ, Baz İstasyonu, Küme Kafası.

ACKNOWLEDGEMENT

Gratitude to GOD the most merciful, for all of his gifts he who helped me to reach this level in my life, such a level that I am feeling proud of myself. Also, I would like to thank my parents who raised me for the love of learning and continuing my scientific process. Special thanks to my supervisor Assist. Prof. Dr. Sibel T. ÖZYER for her extraordinary efforts that made to improve my skills and abilities in the scientific field and working together in all circumstances.

Finally, I appreciate the full support and cooperation presented by the instructors and academic staff at Çankaya University, especially computer engineering department.

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LIST OF ABBREVIATIONS

GBHND :	Grid-Based Hybrid Network Deployment
WSN :	Wireless Sensor Network
Eini :	Initial Energy
BS :	Base Station
CH :	Cluster Head
ZH :	Zonal Head
ADV :	Average Distance Value
Pos :	Positioning method
SPIN :	Sensor Protocols for Information via Negotiation
TV :	Threshold Value
Z_H :	Zone Height
Z_W :	Zone Width
CV :	Cumulative Value
EL :	Energy Level
TDMA :	Time Division Multiple Access
EFP :	Error Factor Percent

CHAPTER 1

INTRODUCTION

1.1. Background

WSNs becomes vital technique due to its use in several necessary applications, such as weather forecasting, smart industrial technologies, smart cities, wide geographical areas monitoring, medical healthcare and many other commercial services. The principal functions regarding WSNs were data aggregation, data processing and communicating between sensor nodes and transfer this data from source to destination (and vice versa). Wireless sensor networks are designed to work in an extraordinary atmosphere for a long operating time, sensor nodes have latent energy determinants supplied with non-replaceable and non-rechargeable batteries. The inadequate energy resources and the rough environmental circumstances lead to finding solutions to optimize the performance of these batteries for reducing the consumption of energy and increasing the lifetime of network. WSNs consist of three routing types: single-hop transmission approach, multi-hop transmission approach, in addition to the clustering approach.

Since the main cause of losing energy has been associated to distance, a single-hop has been effective with regard to small coverage area networks, yet in large ones, sensor nodes far from the base station are exhausted too quickly, causing a non-monitored area. This is referred to as energy hole problem [1]; At the same time, multi-hop transmission technique sends sensed data from sensor nodes to base station. Sensor nodes near base station act as gateway of remote sensor nodes, thus they have been rapidly exhausting their energy in comparison to distant nodes that resulting in the energy hole problem. In the case when the energy hole problem happens in the multi-hos and single-hop approaches, a few areas related to network couldn’t share the sensed data with the base station. Therefore, the process of sensing this area will not be sustainable for the network lifetime, thus more energy will be consumed.

Whereas clustering is considered as effective approach for minimizing the consumption of energy in WSN. The advantages of applying clustering are indicated in the following way:

- Energy-saving through conducting Cluster Head (CH) selection to all zones.
- CH will gather the data from the adjacent sensor nodes, then transmitting the data to BS.
- Reduce multi-hops. Thereafter, reduce power consumption [2].

The distribution of sensor nodes in WSNs has been considered by classifying these nodes in clusters, whereas the nodes are dynamically allocated in a specific area, without leaving any zone empty in the sensor network area. Therefore, the total amount of sensor nodes must be assigned to each zone randomly, regardless of its density in that zone, high-density zonal areas focus on a specific Cluster Head with the highest energy. Our simulation results show that the energy consumed in a period of iterations could extend WSNs lifetime, and also saving energy [3].

Classical routing protocols don't consider that nodes contain only limited power source. Grid-Based Hybrid approach attempts to increase the duration at which the sensor performance could be reliable and feasible, but it requires improvement in the future, as for scalability and robustness, we draw a practical guideline based on energy consumption and the development of a range of new techniques to improve in sensor networks [4].

The data aggregated by each sensor is transmitted and received over the network by a hybrid transmission technique which applies all the sensed data for determining the environment's characteristics as well as detecting events. The sensor node's energy resources should be kept through the development of communication tools for sending data via CH toward base station. Through grouping the sensor nodes in cluster's shape, such nodes could be directly sending data to CHs, after that CHs sending collected data to base station, such technique will be reducing the consumption of energy. The suggested randomized, hybrid algorithm of clustering utilized for organizing sensors into clusters. After that, extending the algorithm for determining CHs, also this study indicated that the conservation of energy has been high throughout full transmission period. Results in the stochastic geometry have been applied for deriving the solutions for parameter's values in the presented algorithm which reduce total consumption of energy in network in the case when all the sensors are sensing the data via CHs to base station [5].

As we mentioned before, the sensor nodes have been randomly distributed across specific geographic area in wireless network. When this occurs, some areas in the network get intense node concentricity (high-density) while others receive fewer nodes (low-density). To address this problem, the demand of using cluster and grid-based topologies is getting crucial. When cluster-based technology reduces energy consumption and frame out sensor nodes in the form of clusters. This method enhance scalability and durability of the sensor network and also accommodate data aggregation [6].

Meanwhile, the grid-based technology is designed to ensure effective clustering in which entire area has been divided in to geometrical equal-sized areas. In order to be proper for networks of large-scale, election and re-election of the Cluster Head (CH) for each network is determined by the nodes themselves. Grid-based method is recently a common technology because it is comprehensive, non-complexity nature and it is typical to the network's energy consumption [6].

Our thesis focuses on how we can ensure optimal election and determination regarding CH for prolonging the network's lifetime. The major improvement has been developed durable model of WSN which was enhanced for dealing with variations in the network size as well as the sensor nodes density. Grid has been divided in to area of equal-size, also the number of the nodes in all regions has been specified through their coordinates. After the structure is created, the specified Cluster Head (CH) has the maximum Average Distance Value (ADV).

In literature, a lot of routing protocols as well as clustering methods have been suggested with regard to WSNs. However, the majority of these techniques have not addressed the issue of energy efficiency. The major advantage regarding the presented Grid-Based Hybrid Network Deployment approach over the existing algorithms are as follows [7]:

• Dynamically randomized distribution of sensor node reduces calculations and time spent to deploy the nodes, and thus increase the throughput of WSNs.

• Overcome consumption of energy as well as maximizing the lifespan of network.

• By applying our proposed simulation (in Matlab) to this approach, made it possibly suitable for large-scale networks.

1.2. Thesis Motivation

Several studies related to the consumption of energy in WSNs focused on particular aspects, like the must-used number of sensor nodes, grid's size, protocols that used, clustering techniques [6], Load balancing do not usually guarantee by clustering techniques. Our proposed technique illustrated here is used for reducing the power consumption that is related to the sensor nodes. Along with all such facilities, clustering techniques often result in hotspot issue [8] in which number of nodes will be early expired due to incremental use regarding these nodes.

1.3. Thesis Contribution

In order to achieve an optimum solution for our study, a Matlab tool (R2016a/ Win 64) had been used to perform the grid-based hybrid network technique to develop a durable wireless sensor network model.

1.4. Problem statement

Design and implementation of our proposed method primarily consists of two main factors, hybrid topology deployment and the uniform randomly sensor nodes positioning (Pos). Firstly, a hybrid topology is deployed on gird-based WSNs. Secondly, random node positioning method is applied to the mentioned topology as shown below.

$$\mathrm{Pos} = \mathrm{M}\ (1).*\ \mathrm{rand}\ (\mathrm{N}, 2)$$

Where, M indicates dimension regarding the sensor network field, N refers to total number that is related to the sensor nodes, and the formula (*rand (N, 2)) is the sensor nodes' random distribution used in Matlab simulation tool.

1.5. Thesis organization

The presented study contains five chapters. All the necessary information about the design and implementation of Grid-Based Hybrid Network Deployment technique, algorithms were used with regard to energy efficiency, prolong the network lifetime issues.

Chapter 1 is considered to be an introduction to the history regarding WSNs, thesis motivation, thesis contribution, and problem statement.

Chapter 2 includes a background of WSN, an overview of WSN, Routing architectures, and routing protocols. In addition, related work that discussed energy efficiency and network lifetime.

Chapter 3 focus on the research methodology, algorithms that had been used, and the phases of grid formation, creation of zonal head, and selection and reselection of that ZH.

Chapter 4 designate our proposed technique results and implementation on how the simulation works for minimizing the consumption of energy, dead nodes' percentage, the number of the residual nodes in addition to the overall consumed energy during a full iteration process.

Chapter 5 discuss the conclusion and future work.

CHAPTER 2

BACKGROUND AND RELATED WORKS

2.1. Introduction

In the presented chapter, the main aim has focusing on predefined terms of methods, topologies, tools and techniques that had been applied relevant to our topic, and the effect of these terms to help accomplish our main goals. Furthermore, simplify the understanding of how does WSN work, and confront the obstacles to achieve the optimal solution. On the other hand, we have studied the results of the related work in literature.

2.2. Overview of Wireless Sensor Networks

In this section, the components of wireless sensor networks have been reviewed, as well as the description of each dedicated part.

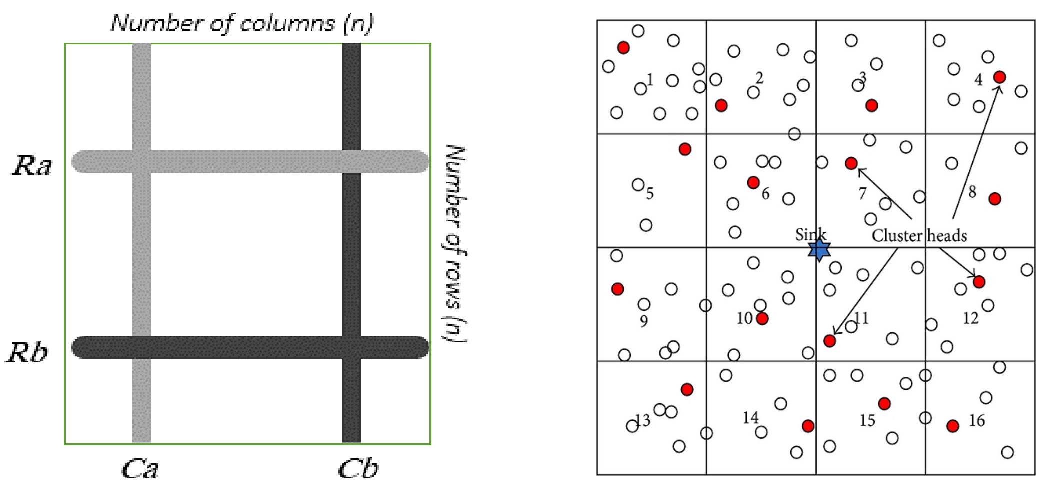
2.2.1. Wireless Sensor Networks

WSNs [9]; are huge number regarding the sensor nodes which are distributed in an area, these nodes are assigned into groups in that area, and have the capability of transmitting and receiving sensed data, communication and computational processing. It is an inseparable part of the real world, wireless sensor network is a useful technique for considering different aspects like science and technologies, monitoring and tracking, et cetera. The principle of sensor nodes in any WSN is to collect and broadcast large sets of the sensed data from covered area.

Whilst in the study of [2], the authors illustrated that WSNs includes set regarding fairly small nodes. These nodes forward and deliver the sensing data constantly. Due to the limited WSN lifetime. Authors tried to lengthen the network's lifetime as well as reducing energy costs in WSNs.

2.2.2. Grid Based in WSNs

A significant grid's characteristic in sensor networks is square formation regarding these grid cells, all grids together forms a cluster shaped area. Here, $Zh \times Zw$ represents the grid cell height and width. This is basically meaning that the grid is constructed by columns as well as rows. Rows are starting from left to right side (Zw), whereas columns will be starting from top and ending at bottom (Zh). Figure 1 (a) is the architecture of the grid-based network model. This architecture shows columns and rows indicated through simple criteria of grid cell formula. In Figure 1 (b), the sensor network field that has been partitioned into grids is presented. A division of the network into equal sized non-overlapping square grids has been done, with each of the grids having one node working at a time. The grid nodes cannot all work at the same time, as such, the nodes work one at a time so that the network lifetime is prolonged. It is expected that each grid will have one head node that will forward information related to routing as well as transmitting the packets of data. Routing take place in grid-by-grid approach. The major goal of applying grid-based hybrid protocol has been for facilitating rapid routing of packets, utilization and extension of sensor nodes energy. More so, this kind of routing protocol is used to hinder the occurrence of network congestion, or even to deal with network congestion if it occurs.



(a) (b)

Figure 1: Grid Topology (a) grid architecture (b) grid based in WSN

The use of clustering method was employed by [7] to arrange nodes in grid. Cluster heads will be selected dynamically, and in the basis of cluster nodes energy dissipation. Afterwards, communication occurs between the head node and base station by a relay node. The algorithm is regarded as an algorithm that is effective in decreasing the consumption of energy by nodes, while increasing the system's lifetime. When the system lifetime is prolonged, network load balance can be achieved.

In a study conducted by [10] a mechanism meant to help in regulating congestion was proposed. The mechanism is proposed to facilitate relieve of congestion in areas that are congested. Through the use of the algorithm, the network lifetime is prolonged, while the available storage can be used.

A survey of extant literature reveals that most of the studies conducted in the past made use of different routing techniques and topologies to proposed methods of addressing congestion and delay problems in WSNs. However, all these techniques have their strengths and weaknesses depending on their applications. Information can be collected by placing the sensors in any part of an environment or a house, even though, the problem of high energy consumption rate remains a significant problem in WSNs. Therefore, it becomes tantamount for reducing the consumption of energy, thus, the network's performance in relation to lifespan prolongation and sensor nodes decongestion can improved. With this, network load balance can be achieved. The sink receives a huge number of packets in mesh and in circular topology, and the most at grid. In theory, grid topology has extra energy efficiency in comparison to other existing topologies [11].

2.2.3. Hybrid Network Approach

The sole aim of using Hybrid Network in WSNs is to gather all the benefits of the two network models (grid-based and cluster based) to reduce energy usage in every dedicated node with regard to energy efficiency as well as load balancing. Hybrid network approach performs the functions of dividing sensing filed into square grids, increasing network lifespan, facilitating energy efficiency and selecting the CH in each grid [12].

There are two main phases involved in the proposed technique, initializing the clustering and the transmission of data. In the initial clustering, the grids are constructed, CHs are selected and reselection phase is scheduled. In the transmission of data phase, packets are forwarded from the Cluster Heads to sink node. Various suggestions related to WSN are provided in the following way:

(a) Random deployment regarding all nodes has been performed and the do not change.

(b) In the grid, every sensor node has similar initial energy.

(c) BS has knowledge regarding location information of all sensor nodes.

(d) CHs will be performing task of sending members to BS.

(e) Communication take place among all nodes via the same radio medium.

(f) By means of a common bidirectional wireless medium, all the nodes communicate with one another.

2.2.4. Network Architecture in WSNs

Particularly there are two primary forms of network architecture in the sensor networks; flat routing architecture and hierarchical routing architecture, which have been discussed separately as shown below.

2.2.4.1. Flat Routing Architecture

With regard to flat routing, network includes a lot of comparable sensor nodes having the same role with regard to sensing as well as sending data to BS or sink. Data is usually flooded in the network and transmitted in a multi-hop way to the sink, as presented in Figure 2.

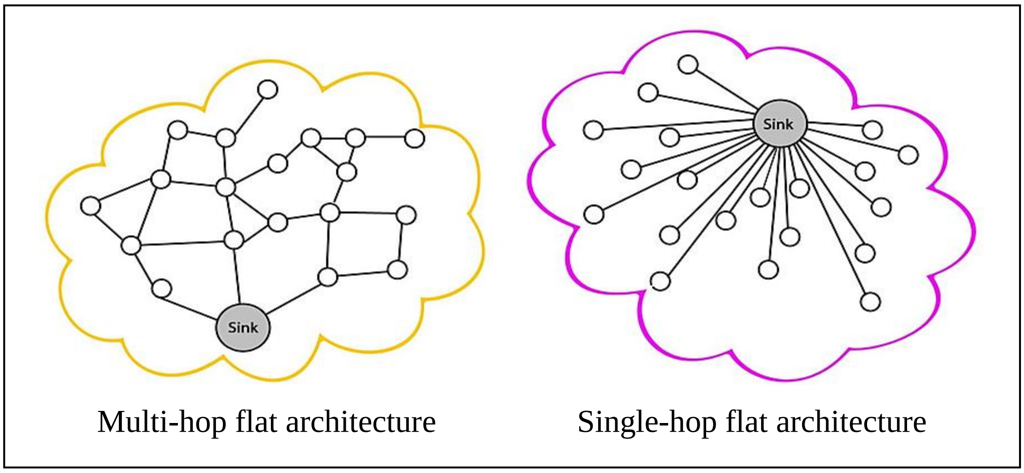


Figure 2: WSNs' (Single-hop and Multi-hop) flat architecture.

Flat routing protocols perform well in small-scale networks but they are not effective for large-scale networks because the whole sensor nodes are generated high data processing in addition to using more bandwidth. Thus, data-centric routing was utilized. An example of flat routing are gossiping, directed diffusion, SPIN protocols (Sensor Protocols for Information via Negotiation), in addition to flooding [13].

2.2.4.2. Hierarchical Routing Architecture

The major aim regarding algorithms of clustering has been reducing amount of data which have been relayed in the packets of data via network for the purpose of reducing costs of energy to transmit the data from source to sink. Said differently, transmission of data has been accomplished by transmitting the data from the source to the destination through specific nodes [14]. With regard to general hierarchical WSNs, sensor nodes are going to be divided in to virtual hierarchy; as shown in Figure 3; which are referred to as clusters in which each one of the nodes belonging to just single cluster, yet a few protocols are accepting the overlapping of clusters, in which the node might be belonging to at more than single cluster [11]; cluster can be defined as group of nodes that has central node referred to as Cluster head (CH), such node receive members' data, conducting data aggregation, and after that aggregated data to Sink. Therefore, fusion as well as data aggregation could be reducing the number of data packets needed for sending sensed data to sink. Furthermore, to distribute the consumption of energy among nodes will extend the lifetime of network.

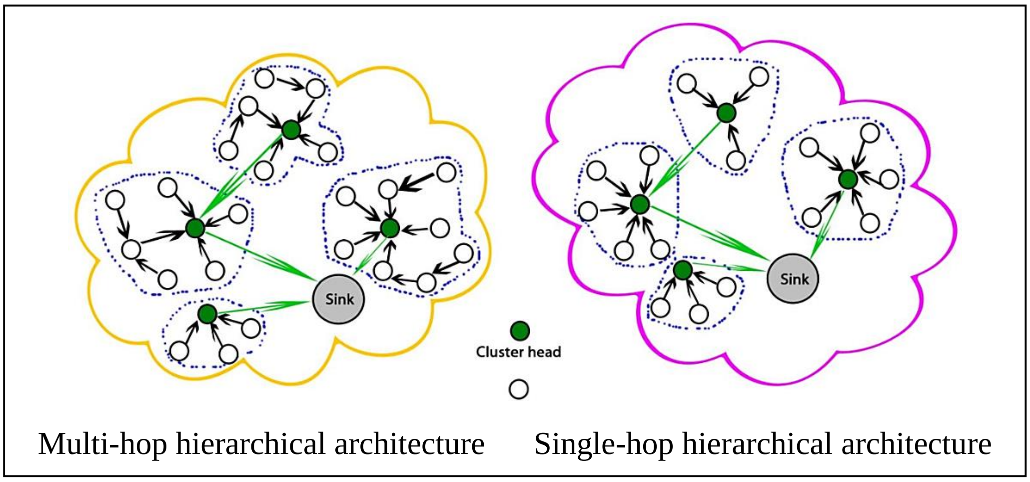


Figure 3: WSNs' (Single-hop and Multi-hop) hierarchical architectures

2.2.5. Routing Protocols

When networks are designed, power utilization becomes one of the critical factors to be considered, because of the problem of power that is related to the sensor nodes. The process of routing includes transmission of sensed data to base station through different paths. A key constraint associated with WSN is to design energy efficient protocol of routing. Generally, the routing protocols have been categorized by 4 groups that are; Reliable Routing Based, Network Structure protocols, Communication and Topology Based [8]. The presented section will provide summary regarding various protocols of routing utilized for WSNs. With uncomplicated overview related to routing, the way that routing in the WSNs could be compared to mobile Ad-hoc networks, review regarding various types related to the WSN routing protocols, as classified in Figure 4.

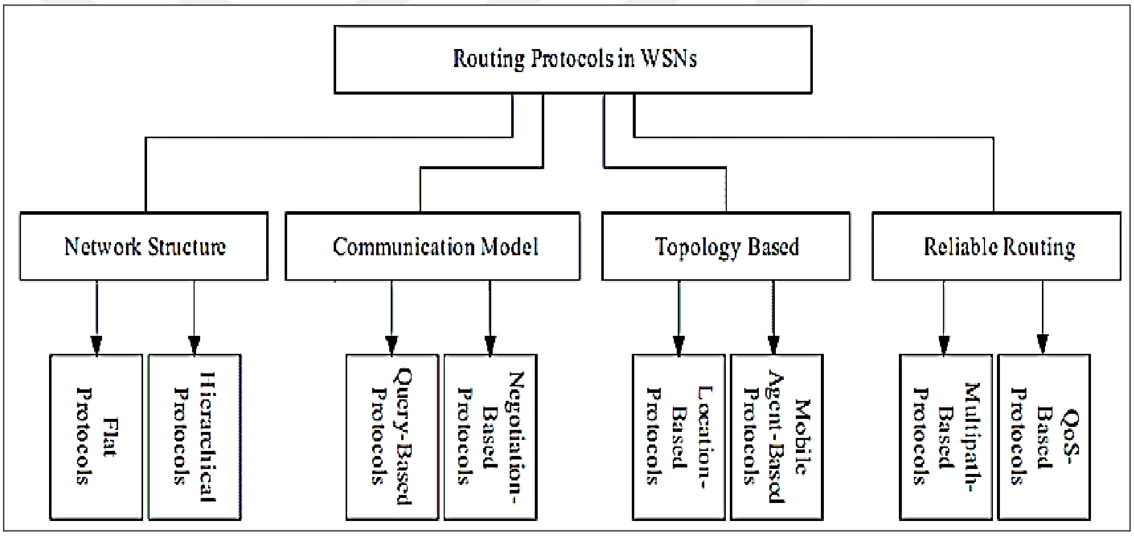


Figure 4: Routing protocols in WSNs

Low-Energy Adaptive Clustering Hierarchy (LEACH): [15] LEACH can be specified as main protocol of routing with regard to the cluster-based WSNs. The major aim of LEACH is that the algorithm of clustering suggests reducing the consumption of energy utilizing through the data forwarded from the sensor node to BS, also the lifetime of network has been divided in to rounds. Each one of those rounds has 2 phases, which are the Steady State Phase (data transmission) and the Setup Phase (Cluster formation). With regard to the second one, decisions of being CH will be locally made at the node level. Each one of the nodes will be selecting a number randomly between 0 and 1. In the case when the random number is considered to be below threshold value, node will be selecting itself as CH as well as announcing itself as CH. Or else, node is going to be regular one and is going to be waiting for the advertisements of CH. After that, following receiving the message of advertisement and on the basis of signal strength that is related to the advertisement messages, regular node will be electing a CH for joining and it will be sending join message. Following receiving joining messages, CH will create and broadcast transmission (TDMA) schedule. TDMA schedule consists of time slot with regard to each one of the nodes for communicating with CH. In the case when node will receive schedule table, after that it will have the ability of obtaining time slot, also it will be sleep to wait for its assigned time for communicating to its CH.

Low Energy Adaptive Clustering Hierarchy-Density (LEACH-D): With regard to a study assigned by [16], cluster diameter has been applied as metric along with the multi-hop routing, considered that distance from BS as well as energy level of nodes have been applied to select CH along with multi-hop, and a 2-layer multi-hop routing approach has been suggested, in which sensing coverage has been specified in the selection of CH. So as, the selection of CH consider the density of nodes over certain area, also the transmission of data has been accomplished through multi-hop, and rotation of CH in same cluster consider the energy level of node.

Low Energy Adaptive Clustering Hierarchy-Centralized (LEACH-C): A study illustrated by [17] indicated that the LEACH-C can be defined as one of the centralized cluster-based protocols. The process of cluster formation has been achieved through centralized algorithm which is performed at BS. Furthermore, the BS itself will be selecting a few of the nodes to be considered as CHs taking into account each node’s residual energy. With regard to setup phase that is related to the LEACH-C, all the nodes have been sending their location, also the current energy level to BS. On the basis of current energy level of the node, BS will be electing set which might be acting as CHs for next round. After that, BS will apply the algorithm of simulated annealing for the purpose of partitioning the network to pre-defined number of cluster, which is considered to be 5% regarding total number of the nodes. As soon as identifying the clusters, BS will be broadcasting clustering information message which consists of the ID of CH with regard to each one of the nodes. In the case when a message is received via the node, when the ID of CH in message will be matching its ID, the node will take the CH's task, and change its status to wake up as well as waiting for the data of members; or else it will determine its time slot, and after that entering the sleep mode. With regard to steady state in the LEACH-C as in LEACH, clusters have been created a temporary CHs that are specified for each one of the clusters, temporary CH cause the selection of CH for next round, on the basis of energy level of nodes, yet the issue regarding static clustering is that there is no possibility for adding new nodes to network for replacing the dead nodes, also the robustness will be decided through the capability of temporary CH to occur, therefore in the case when temporary CH dies under any circumstances, in case of battery exhaustion or physical damage, members of cluster are going to have loss of communication with BS.

A study described by [18] suggested centralized fixed ring approach. Initially, network will be divided via BS to set of clusters, in which the nodes are using ring-based with regard to the intra-cluster data disseminations, cluster sender role has been rotated periodically, yet in the fixed networks [14], there is no possibility for adding new nodes, also in the case when CH is being died, all members of cluster are going to suffer loss of communication with BS. Furthermore, the ring-based communication has been impacted through all the members.

Hybrid Energy-Efficient Distributed clustering (HEED): A study represented by [19], [20] specified that HEED can be defined as self-organizing clustering routing protocol, the major aim of HEED has been prolonging the lifetime of network. HEED will start selecting set of nodes as CHs on the basis of node's residual energy as primary parameter in addition to the intra-cluster communication costs as secondary parameter with regard to selecting CHs. The process of clustering in initialization phase: each will determine if tentative CH or not, this will be on the basis of its current residual energy, secondly node will be entering repetition phase in which each one of the nodes attempt on selecting a tentative CH, the selection of head is on the basis of intra-cluster communication costs, following selecting CHs, the non-cluster heads nodes (normal members) deciding on joining CH with not much communication costs, after that the operational phase will start.

Threshold Sensitive Energy Efficient Sensor Network (TEEN): [11] TEEN can be defined as one of the cluster-based routing protocols on the basis of LEACH. The major aim of TEEN has been reducing the consumption of energy with the use of Hard

Threshold (HT) as well as Soft Threshold (ST) [14] for controlling the number of forwarded readings. In the case when the sensor node has new reading, sensed value (SV) is going to be forwarded to cluster head in the case when cluster head is greater in comparison to HT or different from preceding (SV) through (ST). The performance of the network is based on threshold values- small (ST) is going to provide more precise view with regard to the network; yet, there will be more transmission of data, and thus more consumption of energy. Due to the fact that sensor might be spending more period to sense, yet not forwarding with the use of big (ST) or (HT), this will make TEEN not adequate for certain applications in which the periodic reports have been required.

Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network Protocol (APTEEN): In [11] as well, APTEEN can be considered as hybrid routing system which applies 2 policies of communication; proactive and reactive. For the purpose of avoiding the issue regarding possible long time period which the node might be spending on sensing, but still not sending, the node is going to forward its data in the case when it is exceeding value of the Count Time (TC), that is controlling the duration in the interval of two sequential reports. Furthermore, APTEEN will be supporting various query types: persistent, one-time, as well as historical queries for responding to the requests of user. Hereafter, the major drawback regarding APTEEN and TEEN is the complexity regarding implementing threshold values and overhead [14], in addition to the complexity to create multi-hop clustering.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS): In [18] PEGASIS is illustrated as one of the chain-based protocols which forms as node just requires communicating with the nearest node. For the purpose of building the chain, greedy algorithm will be used by PEGASIS, start from farthest node from BS, as well as attempting on finding neighbor which is close to BS. After that, each one of the nodes will be sending advertisement to the closest neighbor till all data has been aggregated at chain leader. Then, aggregated data will be sent via chain leader to BS on account of the other chain members. PEGASIS will be reducing total consumption of energy through reducing transmission distance, due to the fact that each one of the nodes will be sending the data just to the closest neighbor. Yet, PEGASIS will be assuming that each one of the nodes has global knowledge with regard to all locations of nodes, yet it has not been referenced by which techniques nodes might be obtaining such locations. Furthermore, there is extreme delay with regard to the distant nodes on chain. The important overhead with regard to the topology adjustment needs knowledge regarding the status of node's neighbors, particularly for extremely used networks.

Geographical and Energy Aware Routing (GEAR): A study by [11] suggested that the major aim of GEAR has been reducing the amount of interest in the directed diffusion, instead of flooding the interests to whole network. GEAR applies heuristic approach [14] to select a neighbor which have lowest cost for the purpose of forwarding packet to targeted region. Furthermore, recursive geographic approach has been applied to forward packets in region.

Sequential Assignment Routing (SAR): In a study conducted by [11] specified maintaining multi-path routes from sensor node to sink. With regard to the construction of route, SAR will be constructing a tree rooted at source, in which regarding the nodes, QoS and energy will be defined whereas adding node to path. In the case when generating a packet, the node should be deciding the path that should be followed via the packet for reaching the sink, whereas taking into account the priority of packet, amount of required energy along the path, as well as the delay. For instance, packet that has high priority should be forwarded via minimum delay path that might be consuming more energy, thus the node must be deciding the path that must be selected for packet forwarding. A few of the paths might be changing due to certain node's failure in enforcing consistency, thus, a procedure of recovery with the use of handshakes between down and upstream node might be achieved.

Stateless Protocol for Real-Time Communication (SPEED): A study declared by [21] indicated that SPEED can be defined as stateless protocol of routing used for the soft real-time communications; each one of the nodes will be maintaining information regarding its neighbor, also path finding will be accomplished with the use of geographic forwarding method. End-to-end delay [14] is on the basis of distance between source and destination. Such delay could be determined through application regarding provide packet prior to taking route decision for calculating end-to-end delay. Distance between sink and node will be divided through the determined SPEED. Furthermore, to the support of QoS, load balancing as well as congestion management will be given via SPEED, and still SPEED doesn't take into account further energy metrics.

MMSPEED (Multiple Multi-SPEED): A study described by [21] focused on definite delivery of packets instead of consumption of energy. Localized decision with regard to the forwarding of packet will be conducted, utilizing just the information of local-node neighbor, thus no previous route setup or route state will be required. MMSPEED will offer options of QoS reliability as well as timeliness domains. With regard to timeliness domain, multiple network-wide speed options exist [14], thus, intermediate node could be selected between elevated speed of packet for fulfilling delay deadline or accomplishing reliability requirements with the use of probabilistic multi-path forwarding.

2.3. Related Work and Literature Review

This section presents a discussion of previous work that have been carried with the aim of addressing issues related to the prolonged lifespan of the network, while balancing the consumption of energy in wireless sensor networks.

A description of WSN depicted by [15] as a set regarding many devices which are cheap, small and self-powered. According to these researchers, the WSNs have the ability to sense, compute, as well as communicate with other devices so as to gather local information which can facilitate an inclusive decision-making about a physical environment. Limitations such as storage capacity, processing capacity and transmission power are common among Wireless Sensor Networks. This implies that resources must be used prudently. The popularly types of protocols are, LEACH and PEGASIS protocols. Despite being the most popular kinds of protocols, LEACH does not support the optimal distribution of cluster heads, and PEGASIS is limited by overhead delay problem. The aim of the approach that is proposed in this study is to improve the network lifespan by means of efficient routing path and less energy consumption.

According to [22] cluster head selection is dependent on location in an event that the use of dynamic clustering is employed. The implication of this is that the cluster is unequally distributed with significant variation in the number of the nodes within clusters. Furthermore, when clusters have been distributed over huge areas in network, constricted spatial correlations between the related sensor nodes occurs. Such inequalities negatively affects the efficiency of the WSN negatively. For example, one of the requirements for the aggregation of cooperative data is packets of large size. The exploitation of aggregations depending on the spatial correlation sensor nodes has been tricky. In this regard, Distributed Uniform Clustering Algorithm (DUCA) was developed by the authors for cluster based WSN. The mechanism used to form clusters in DUCA depends on decrease in energy consumption, a virtual grid system, uniform homogenized cluster sizes and nodes sensing range that is capable of providing the uniform cluster distribution. The result of DUCA is an algorithm that is efficient enough to improve the distribution of cluster head by over 2 times while decreasing energy consumption by 15% to 50% as compared with available protocols.

In a study provided via [23], nodes were suggested near sink in WSN, while featuring heavy loads of transmission. With this prolonged network lifespan and energy is hindered. Routing tactics have made remarkable contributions to the improvement of energy consumption and transmission performance. Classic sources of routing tactics in grid topology consist of; Destination-Zigzag Forwarding and Balance Forwarding, Random Equal Probability Forwarding, Source-Zigzag Forwarding and Line Forwarding. Traffic load distribution within nodes for such routing tactics, as well as calculating the load related to performance bottleneck nodes as well as the transmission delay in one phase of data collection cycle. The model of energy consumption has been used to compare the consumption energy during transmission and in stand-by mode for such tactics. Numerical results reveal that in terms of energy consumption minimization in nodes, tactics of Balance Forwarding outperforms that of others. On the other hand, the energy that is consumed by Random Equal-Probability and Line Forwarding is high.

Authors in [24] posits that WSN applications require data communication that is reliable together with maximum network lifetime. According to these authors, these requirements are the most critical requirements of Mobile Wireless Sensor Networks (MWSN) than they are in static WSN. The reason behind this is that it is challenge for data to be reliably received at the cluster head in MWSN that is cluster based. To address this issue, energy conservation becomes crucial, and there must be a reliable connection between sensor nodes and CHs. The majority of cluster-based MWSN protocols could be obtaining reliable data, yet utilizing more power, that will be reducing the lifetime of network. The authors here suggested virtual grid-based distributed clustering (VGDC) as a means of solving the issue of data reliability; their solution is capable of providing 30% reliability of data at the cluster-heads of WSN. The proposed VGDC is capable reducing the consumption of energy.

Furthermore, in different research provided via [9], the aim was for providing solution to the problem of energy consumption in WSN; therefore, they proposed techniques that are effective enough to tackle the problem. There is evidence that grid-based clustering is highly efficient in high dynamic networks. In their study, they implemented the grid strategy on dense network, after that divided the network area in to numerous grid cells with different densities (Empty, Low, and High). Subsequent to this, grids were integrated to facilitate the formation of advanced and normal cluster. The CH regarding each one of the clusters was chosen based on high energy. To test and implement the novel strategy which they proposed, they used MATLAB. Results revealed that proposed strategy is more effective in 150 nodes WSN and grid size between 5- 10 units, in which the network lifetime is approximately 633 seconds.

Authors in [12],[25] asserted the sensing and transmission of data is a continuous process. The lifespan of the WSN is limited by the wireless nature of the WSN. Hence, it is important to put into consideration ways through which the lifespan of network can be increased while cost of energy is reduced. In response to this need, different techniques are proposed and used. In the work by these authors, a comparison of the grid based cluster network and grid network is done on the basis of energy consumption so as to provide a comparison result. The use of QualNet tool were used in the simulation. The sole aim of the approach is to integrate the benefit of both networks. With regard to such approach, the network area has been first of all divided into grids using grid’s structure. Subsequent to this, the CH creates the basis of Reduced Function Device (RFD) and Fully Functional Device (FFD). The chain that is forwarded to the sink node via other intermediate coordinator nodes is responsible for taking the information that has been collected other related nodes. The routing protocol of DSR is utilized in routing information from source to the destination nodes.

Authors in [26] asserted that current problems affecting the environment are pollution and increase in carbon footprint. They stated that these problems can be truncated through early detection by means of sensors and sensor networks. For the veracity of the data to be guaranteed, WSNs must be deployed with high level of security and energy efficiency. Replacing the sensor batteries can be more difficult if the environment in which ESNs are deployed is unsuitable. So, it is very important that the network's lifespan be increased. Since WSN are usually left in unmonitored environments they tend to be more prone to several kinds of attacks. As such, efficiency and security must be given priority when routing protocols for WSNs are developed. The researchers made efforts to tackle the aforementioned issues by proposing a novel Secure and Low-energy Zone-based Routing Protocol (SeLeZoR). In this routing protocol, WSN nodes are divided into zones, and the zones are further partitioned into clusters. Each one of the clusters will be controlled through CH. In first stage, information is sent to the zone-head securely by using a secret key. Subsequent to this, the data has been sent through zone-head to BS using the secure and efficient mechanism. The performance of the (SeLeZoR) was found to be better than that of the existing protocols of WSN in terms of security and energy efficiency.

In the study conducted by [8]; authors highlighted the key factors that must be considered when WSN is designed, and the factors are load balancing and energy conservation. By means of the clustering approach, the energy consumed by nodes is reduced, which in turn increases the network lifespan. It was indicated that in several multi-hop cluster-based protocols of routing, rapid exhaustion of energy occurs in nodes that are located close to BS than other nodes. This is caused through forwarding regarding data from the entire network through them. This results in network portioning and a shorter lifespan for the nodes that are nearby. This problem is regarded as a hot problem. In their work, this group of researchers proposed Energy Efficient Uneven Grid Clustering-Based Routing (EEUGCR) protocol that is energy efficient. The protocol is to be used for large network areas. The suggested protocol depends on centralized method that applies fixed clustering. Such protocol involves dividing the whole network through BS in to clusters of fixed rectangular shapes as well as unequal sizes. The cluster's size has been decided through distance between BS and cluster. The proposed protocol presents a clustering approach of an unequal size grid with the aim of overcoming the energy loss which takes place in the clusters which are found close to the BS. The cause of this energy loss is the increase in data handling. Through the use of the proposed approach, the transmission distance that is related to any network's communication is not exceeding the threshold model regarding energy consumption. It has been indicated that the suggested method has the ability of achieving load balancing with regard to data traffic, but with increase in energy consumption. The proposed approach is also capable of solving hotspot problem, which in turn increases the network lifetime as compared with other extant routing protocols.

According to [7] sensor nodes energy conservation can be considered as significant problem in designing WSN that has received great attention. The nodes that are located close to the sink have been found to have overloading issue with the overload being caused by heavy traffic because it is through those nodes that the data from every part of the region is forwarded to the sink. This causes the occurrence of network portioning because of rapid energy exhaustion. This kind of problem is called hotspot problem. In addition, there are a lot of factors like battery exhaustion, hardware damage, as well as environmental hazard that could cause sensor node failure. The grid-based clustering as well as the routing algorithms can be used in solving the problem of hotspot. The authors who proposed an approach known as Grid-Based Fault Tolerant Clustering and Routing Algorithms (GFTCRA) Protocol, intended for providing solutions to the CHs failure problem. The algorithms are based on distributed approach. More so, distributed runtime management has been suggested for all the member sensor nodes regarding any one of the clusters was proposed. This was proposed in case of an event whereby the CHs fail. The proposed routing algorithm tolerates the unexpected failure of CHs. The algorithms were simulated through the use of different scenarios. On the basis of simulation results, the performance of the proposed method better in relation to energy consumption, network lifespan and number of dead sensor nodes; the performance is better than that of two other grid-based algorithms.

Authors in paper [2] provided a discussion on the inadequacy of energy associated with sensor nodes of WSNs, due to the fact that it is currently of high importance for the studied for developing various routing protocols which can facilitate the usage of minimum power. Cluster size in Cluster-Based Routing Protocols (CBRP) has a significant influence on the conservation of energy and prolongation of network lifespan. With a decrease or increase in cluster size, an increase occurs in the consumption of energy. Therefore, to improve the performance related to CBRP, the cluster's optimum size must be ascertained. Hence, a mathematical analysis was provided by the authors in this study for the calculation of the ideal size of cluster, which till this time is not understandable. More so, Balanced Energy Efficient Grid-Based Clustering protocol (BEEG) was introduced by the study as a solution to the optimum cluster size problem. Clustering is known to be one of the best ways to decrease the energy consumption regarding the sensor nodes.

An article conducted by [17] asserted that clustering hierarchical schemes can enable the reduction of energy consumption. In their study, they gave a broad classification of hierarchical schemes as grid-based in addition to cluster-based approaches. On the basis of their classification, cluster-based approaches focus on the grouping of nodes in to clusters, with relevant sensor node have been selected as CH. In the grid-based approach the network has been divided through BS into confined virtual grids. In their article, they outlined the issues related to designing cluster-based schemes, and as well discussed them. The main parameters for the formation of clusters were discussed, alongside the importance of these techniques. More so, in their article they discussed the different classes of hierarchical clustering protocols. The grid-based and cluster-based techniques were evaluated using certain parameters with the aim of helping users make a selection of most appropriate techniques. They also gave an extensively summarized these protocols, and their applicability in given scenarios, as well as the advantages and disadvantages.

Authors in [27] asserted that Clustered regarding WSN is considered as hierarchical network structure which is conserving energy through distributing sensing tasks as well as transferring data tom among non-CH and CH node in cluster. With regard to Mobile WSN, the maintenance of cluster will be increasing at reception at destination throughout the operation of communications is complex because of the movement regarding non-CH and CH nodes in and out of cluster. For the purpose of conserving energy as well as increasing transfer of data to destination, there is a requirement for finding duration after which the role of sensor node must be changed from CH to non-CH and conversely, suggested energy independent round time approach for identifying duration after which the procedure of re-clustering must be invoked for the changing roles regarding sensor nodes as CHs and related nodes for conserving energy as well as increasing the delivery of data. This is on the basis of dissemination interval with regard to sensor nodes instead of energy of sensor node. The researchers offered total analytical estimate regarding the energy consumption of network as the energy is consumed in each one of the phases of around.

Authors in [7], [13], [20] suggested algorithm for CH selection in WSNs. A node could be CH in the case when it is connecting to one or more distinctive neighbor node in which the distinctive neighbor is defined as the one which isn't connected to other nodes. In the case of non-existence regarding non-connect unique nodes, cluster head will be chosen based on residual energy as well as how many neighbor nodes. As the clusters are increasing, network's processing energy will also be increased; thus, such algorithm suggests lowest number of clusters that additionally result in more lifetime of network. The main new contribution regarding the suggested study is an algorithm which ensure totally connected networks with least isolated nodes. Furthermore, the isolated node is going to remain just in the case when it isn't within other node's transmission range. With maximum connectivity, network's coverage will be maximized automatically. The major advantage regarding the suggested design has been proved via results of simulation achieved in MATLAB, in which it is clearly depicting that the total numbers of rounds prior to the network dying are maximum in comparison to other current protocols.

The consumption of power can be defined as important challenge in WSNs. The authors in [28] examined the consumption of power which is achieved through comparing dynamic as well as static WSNs. Furthermore, the researchers put to comparison the results related to static network with results related to dynamic networks. Dynamic and static WSNs have comparable architecture (Homogenous) as well as suggested protocol. On the basis of the proposed protocol, simulation results will be showing that the consumption of energy in static WSN has been less in comparison to dynamic ones. Yet, to move sensors in dynamic WSN show real improvements when delivering packets to BS. With regard to the suggested protocol of routing, the process of transmitting data has been achieved in hierarchal manner. Inexpensive sensors have been provided and used for improving the network's QoS. The final results as well as conclusions have been indicated.

In a bid to minimize and balance the consumption of energy, authors in [29] provided grid-based multi-hop routing technique that is trustworthy for WSNs. Through the use of the proposed protocol the CH selection process is optimized through integrating individual capabilities. The constituents of the individual ability are residual energy and location of node, alongside the local cognition that have the ability of balancing the consumption of energy among nodes using consultative approach. The consultative mechanism is on the basis of lifetime expectancy regarding CH. As observed from the simulation results, the routing protocol was able to improve the stability period as compared with other protocols. In addition, it was also observed that in terms of reliable data transmission, energy efficiency and data forwarding delay.

A comparison of the performances of three different routing protocols in grid based clustering for WSN was done [30]; authors found that the sensor network maintains limited energy as well as power of battery. With regard to sensor networks, sensor node's energy will be consumed. Additionally, the functioning of grid based sensor is dependent on the locations which are divided into several portions. The function of the cluster head in grid based wireless sensor is serving as BS, the cluster zones collect every information that passes through sensor nodes. The 3 protocols of routing which were evaluated and compared in their study include this study analyzed and compared three routing protocols which include; Dynamic MANET on demand routing (DYMO), Dynamic source routing (DSR) and Ad-hoc On-demand Distance Vector routing (AODV).

A study conducted by [31] explained that in the design of WSN, energy consumption is a major problem that can be tackled by using clustering method to reduce the energy that is consumed by each node. The major goal of this study is prolonging the lifetime of network. In their work, they also aimed at addressing the issue of energy loss that is present in clusters that are positioned near the BS due to handling of more data. In order to ensure transmission distance regarding all communications in network remain in threshold distance which the energy consumption model is recommending, the authors introduced the grid clustering approach. Load balancing with regard to data traffic as well as energy consumption is also increased through the use of the new approach. Additionally, the proposed approach is capable of solving hotspot problem, thereby improving the network's lifetime in comparison to other extant routing protocols. Furthermore, the proposed system integrates the concept of hierarchal clustering

2.4. Summary

In this chapter, more insight was given among all the theoretical concepts that are discussed in literature associated with WSNs. Some failures of WSN routing protocols and approaches may come from; either the small-scale coverage area, deficiency in energy consumption, incompetence of other tools and techniques to accommodate a huge sensor nodes' grid size and number, or even the problem of evaluation the distance from selected node as (CH) and the sink node (BS), and the power consumed by (CH) to be residual for a long period of time in the sensor network. As compared with other routing protocols in WSN, the performances of the algorithms that been utilized in our presented Grid-Based Hybrid Network Deployment approach are more comprehensive and superior, in the sense that it is adaptable with large-scale areas, meanwhile using a numerous sensor nodes and selecting the most efficient (CH) in terms of highest energy and nearest to the sink node (BS). As a result, the energy efficiency will be higher.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 . Introduction

With regard to the presented chapter, the aim is suggesting GBHND approach that have variable grid size. The suggested hybrid method will be distributing the load evenly across network, enhancing the management of network, as well as extending the lifetime of network. Often, random deployments will be resulting in un-even node distribution. The suggested approach will be overcoming such challenge through using merge and split approach. Such approach will be overcoming the problem of hotspot as well as improving the management of network in the case when nodes have been distributed evenly. Figure 5 shows the suggested approach. The process will be divided in to the next major phases:

3.1.1 . Deployment Phase

Total number regarding nodes N (in which N = 1, 2, 3, n) has been deployed randomly in square targeted area ($A = FH \times FW$), in which FW and FH are field width and height respectively. Some default node parameters will be assumed, for example, energy level, node ID, as well as coordinates. As soon as constructing the topology and deploying the nodes, they will be sharing such configuration information with BS. Such information will be used later through BS to more effectively conduct the procedure of grid formation.

3.1.2 . Grid Formation

With regard to this phase, information which is obtained from various nodes will be applied for creating zones as well as constructing topologies as provided by Algorithm 1. This study suggested new approach with regard to grid formation that will be more divided into three major steps.

3.1.2.1 Zone Formation

BS will be dividing the whole network in to virtual grids depending on these parameters:

Z will be representing the number of grids/zones

Zn will be representing the zone number

N_Z will be representing number of nodes for each zone

ZH_T will be representing the number of zone heads

F_H will be representing the field's height

F_W will be representing the field's width

Z_H will be representing the height related to each one of the grids/zones

Z_W will be representing the width related to each one of the grids/zones

R represent the rows

C represent the columns

M will be representing the field's dimension

Zxs, Zys will be representing the zone's starting coordinates

Zxe, Zye will be representing the zone's ending coordinates

n_Z represent the neighboring zone

(n_x, n_y) represent the node's coordinates

(ZC_x, ZC_y) represent the zone's centroid coordinates

Each one of the grids will be representing single zone which is specified through distinctive zone ID. As soon as completing the zone formation phase, BS will be determining the number of nodes for each zone through estimating starting and ending point regarding each one of the zones as can be seen in the Algorithm 1.

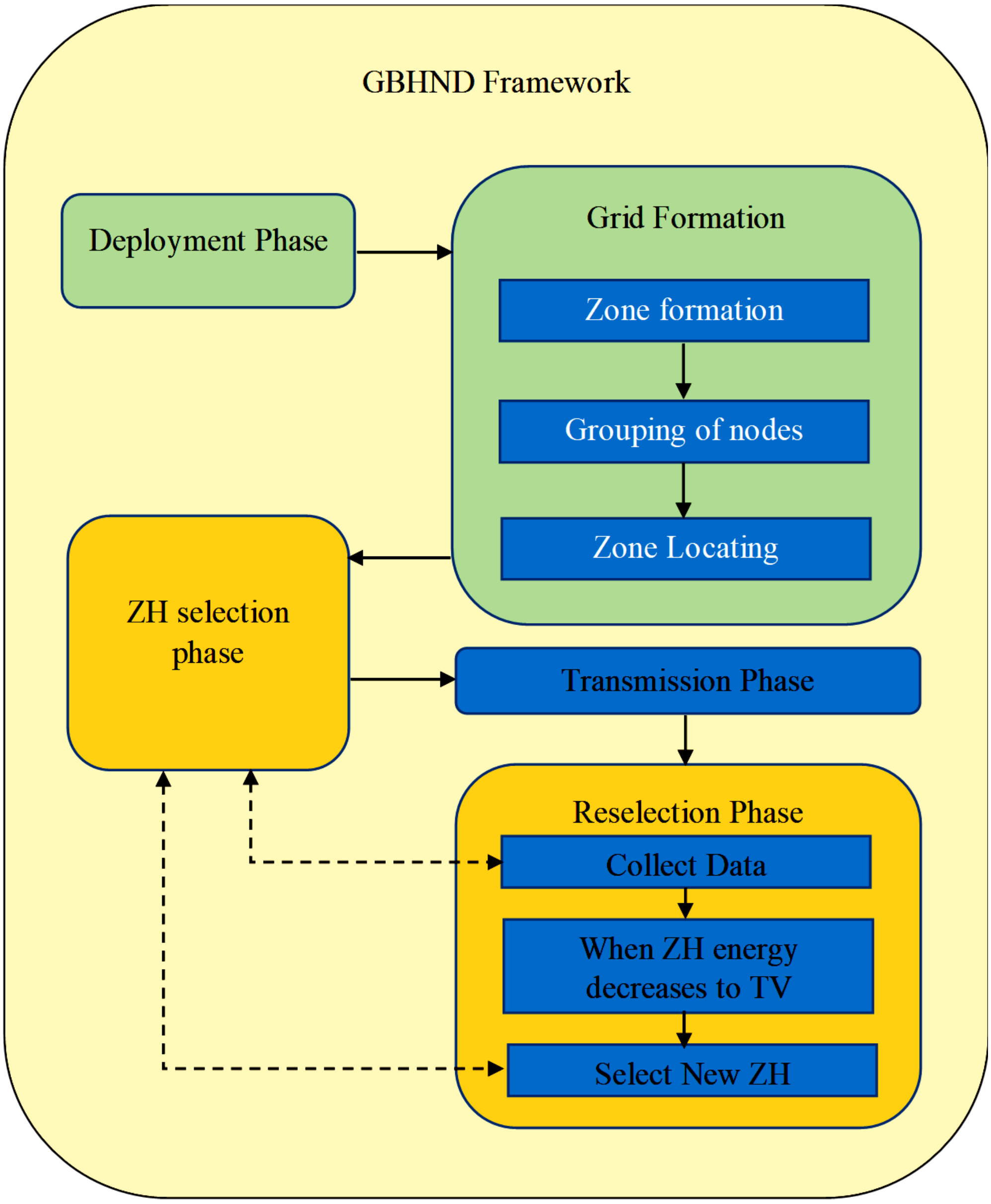


Figure 5: Framework of GBHND

(1) **Procedure** Grid Formation by Zones
(2) **Input**: number of zones, Z; height and width of deployment area, M; Zone width, ZW; zone height, ZH;
(3) **For** Zn = 1 to Z **do**
(4) R = [(Zn)/M]
(5) C = [(Zn − 1) mod M] + 1
(6) Zxs= $C*$ ZH – ZW
(7) Zys= $R*$ ZW − ZH
(8) Zxe= Zxs+ ZW
(9) Zye= Zys+ ZH
(10) **For** n = 1 to N **do**
(11) **If** ($nx \geq Zxs$ & $nx < Zxe$ & $ny \geq Zys$ & $ny < Zye$) **then**
(12) IncrementZD (Zn)
(13) NodeInZone (n) = Zn
(14) **End if**
(15) **End for**
(16) **End for**
(17) **End procedure**
(18) **Output**: Zone formed, Zn.

Algorithm 1: Grid Formation by Zones [6]

Figure 6 will show zone formation in which the nodes have been deployed randomly across $M \times M$ grids. With regard to this figure, C_0 to C_{m-1} are considered to be columns and R_0 to R_{m-1} are representing the rows. (Z_x, Z_y) and (Z_{xe}, Z_{ye}) representing start and end regarding each one of the zones. Zone height (Z_H) as well as the zone width (Z_W) regarding each one of the grids will be determined as follows [6]:

$$Z_H = \frac{F_H}{M}, \qquad Z_W = \frac{F_W}{M}. \tag{3.1}$$

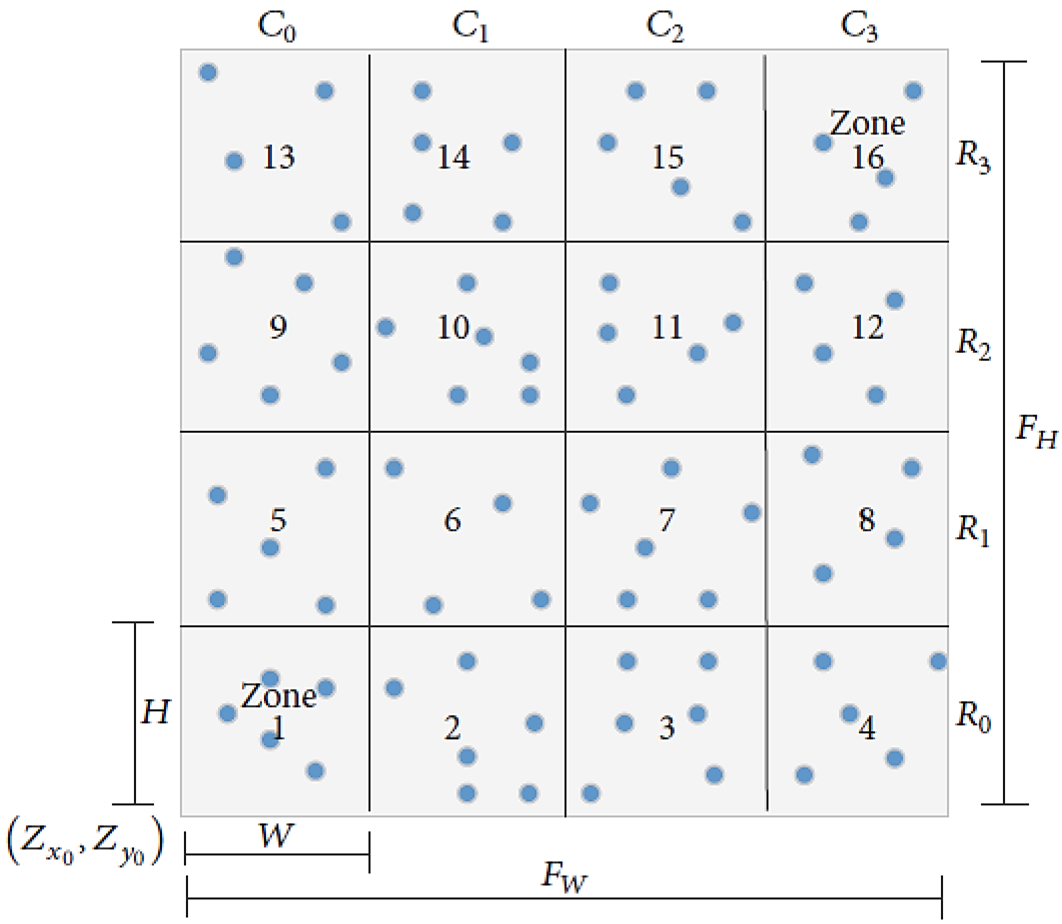


Figure 6: Grid Formation by Zones

3.1.2.2 Zone Head Selection Phase

This is of high importance in energy efficient protocol. ZH is accountable for the aggregation of data before forwarding data to the base station for more processing or to make decisions upon received data. The ZH selection is considered to be a process of high importance; thus, it is needed for defining standards prior to selecting ZH.

3.1.2.3 ZH Selection Criteria

Zone's performance will be directly dependent on ZH; thus, it is of high importance to select optimum node as ZH among available ones. With regard to the suggested method, there are 2 parameters (1) energy level (EL) and (2) Average Distance Value (ADV) have been aggregated for coming up with Cumulative Value (CV) regarding single node i in the following way [6]:

$$CVi = Aggregate\,(ELi + \frac{1}{ADVi}) \tag{3.2}$$

The node's i energy level is represented through EL; at first, it is going to be the same for each one of the nodes. High EL value will be increasing the possibility of candidate node to become ZH, in which ADV can be considered as ADV regarding each one of the individual nodes in such certain zone as can be seen in (3.5). ADV can be defined as the distance of node from all the other nodes in zone in addition to from center of zone as can be seen in the (3.3) and (3.4), respectively. ADV's minimum value, determined through base station, is going to be increasing the possibility of node to be ZH. The BS is going to get ADV regarding all nodes in network, which is going to be determined as follows [6]:

$$d\,(i,j) \;=\; \sqrt{(ix \,-\, jx)2 \,+\, (iy \,-\, cy)2} \tag{3.3}$$

In which $d\ (i,\ j)$ represent distance regarding the node from other nodes in its zone. For the purpose of recognizing how far node is from the other ones that are in direct transmission with it [6], assume

$$cent\,(i,c) \;=\; \sqrt{(ix \,-\, cx)2 \,+\, (iy \,-\, cy)2} \tag{3.4}$$

In which cent $(i,\ c)$ represent zone's center. For the purpose of recognizing the node's position in its zone [6], assume

$$ADVi = \alpha \,*\, cent\,(i,c) + \frac{\beta}{n-1} \sum_{j=1}^{n} d\,(i,j)\,,\ j \neq i \tag{3.5}$$

In which α and β have been weighted indices allocated to the centroid as well as the distance from other nodes [6].

3.2 . Zone Head Selection

As soon as ZH standard have been set as well as zones being created, ZH will be selected for each one of the individual zones based on (3.2). BS is going to have collection list which is going to have CV regarding all nodes against each one of the zones in network. The node that has maximum CV is going to be chosen as ZH regarding that certain zone as can be seen in the Algorithm 2.

The major benefit to have collection list has been avoiding broadcasts as well as communications regarding maintenance messages throughout the process of reselecting ZH. The process of reselection has been decentralized in which BS isn't included. Such method considerably decreases the number of exchanged messages (unicast of broadcast) in the ZH reselection process in zone ultimately decreasing the consumption of energy and therefore increasing the lifetime of network. The ZH lifetime regarding one complete iteration has been specified through Threshold Value (TV). More specification related to TV will be provided in reselection phase.

3.3 . Data Transmission Phase

As soon as nodes joining ZH, they will be start sending their sensed data to ZH according to their allocated transmission schedule. Nodes are going to be sharing their date with their respective ZH on the basis of data transmission schedule. The member nodes are going to be transmitting the obtained data regarding ZH throughout their allocated time slot. This will enable the nodes for keeping their radio off till the occurrence of transmission time. Node energy will be saved via the sleep periods. With regard to the wakeup periods, ZH is going to be aggregating as well as compressing received data as well as forwarding it to base station.

```
(1) Procedure Zone Head selection
(2) Input: Cumulative Value of node, CV; Threshold Value, TV;
    Calculate CV of all Nodes
    Zone (i) = [CVs of all nodes in ZH(i)]
    /∗ select node with maximum CV ∗/
    ZH (i) = CVmax (i)
    BS exchange Collection list and TV with ZH (i)
    Member nodes register with ZH (i)
(3)     If CVZH (i) > TV then
(4)             Remain ZH
(5)     Else
(6)             Reselect ZH
(7)     End if
(8) End procedure
(9) Output: Zone Head, ZH.
```

Algorithm 2: ZH selection [6]

3.4 . Reselection Phase

In such phase, the main aim is minimizing the consumption of energy in the process of reselection related to ZH. Rather than implementing periodic reselections related to ZH which will result in additional overhead of network as well as consumption of energy, GBHND will be dynamically initiating the reselection process on the basis of energy level (EL) regarding zone head. With regard to certain iteration, in the case when EL value has been below or equal TV (EL $\leq$ TV), corresponding zone head is going to be changed as can be seen in the Algorithm 3. Number of iterations is considered to be independent of zone, also the process of reselection will be implemented for each zone when needed. The number of iterations could be distinctive for each one of the zones for minimizing created traffic in network, also for not disturbing the overall network.

```
procedure Zone Head Reselection
Input: Energy Level of Current Zone Head, old EL_ZH; Threshold Value, TV;
   Cumulative Value of each node, CV; Candidate Zone Head, CZH;
   Difference of Initial and updated CV, X;
    If (newELZH = oldELZH – oldELZH × 0.1) then
        If ELZH ≤ TV then
            Ask first CZH to send updated CV
            If first CZH reply exceeds timer then
              Fetch CV from second CZH
            Else
              Compare updated CV and initial CV
              If difference < X then
                  Select first CZH as new ZH
                  ZHcurrent ← member node
                  ZHnew ← first CZH
             Else
                  Fetch CV from second CZH
             End if
            End if
        Else
            Remain as ZH
        End if
    Else
        Continue Transmission
    End if
End procedure
Output: New Zone Head, ZHnew.
```

Algorithm 3: Zone head reselection process [6]

With regard to Algorithm 3, value regarding X has been determined as follows [6]:

$$X = (initial\_CVi - updated\_CVi) - EFP \tag{3.6}$$

EFP (Error Factor Percent) is representing the marginal error's percentage. The value that is related to TV isn't fixed, yet it is changed depending on generated traffic through ZH. Fixing TV to specific value, situation will emerge in the case when all the candidate nodes are failing to be elected as ZH resulting in scenario of flat network. For the purpose of preventing this, TV value will be changed in terms of reducing EL and thus periodically monitored through ZH. Therefore, each ZH will be maintaining 2 lists, un-trusted and trusted. The nodes in trusted list can be considered as normal ones, also could be competing for the process of ZH selection, while un-trusted list consists of black listed nodes that have been eliminated from the process. All drastic changes in EL are going to put the node in untrusted list and is going to be shared with the base station.

CHAPTER 4

RESULTS AND IMPLEMENTATIONS

4.1 Introduction

For starting with simulation setup, some assumption has been made in the study as follows:

(1) All BSs as well as sensor nodes are considered to be static following using.

(2) BS will be located out the field boundary, also it will be recognized for each one of the network nodes.

(3) The sensor nodes will be having information regarding initial energy and location.

(4) Nodes already are having their distinctive IDs.

The performance related to the suggested algorithm has been determined for conducting detailed simulations. The results of simulation indicated that the overall consumption of energy throughout transmission, selection of ZH, zone formation, as well as ZH reselection was decreased. All simulations have been conducted with the use of (MATLAB R2016a).

4.2 Simulation Setup

The performance results with regard to various metrics were acquired through changing specific parameters: total consumed energy, size of grid, initial energy, number of nodes, in addition to the lifetime of network. Such parameters will be discussed as follows:

4.2.1 Effect of Initial Energy

The initial energy related to all nodes will be fixed to 1 J, 2 J with regard to estimating our suggested GBHND approach for determining the number of rounds in the case when the percentage of dead nodes regarding network are from (0-10%). Figures 7 and 8 show that the suggested approach has large number of rounds in comparison to the other approaches. This is due to the fact that control messages are decreased in selection and reselection processes of ZH. This will be increasing the number of rounds as well as maximizing the lifetime of network as can be seen in the Figures 7 and 8.

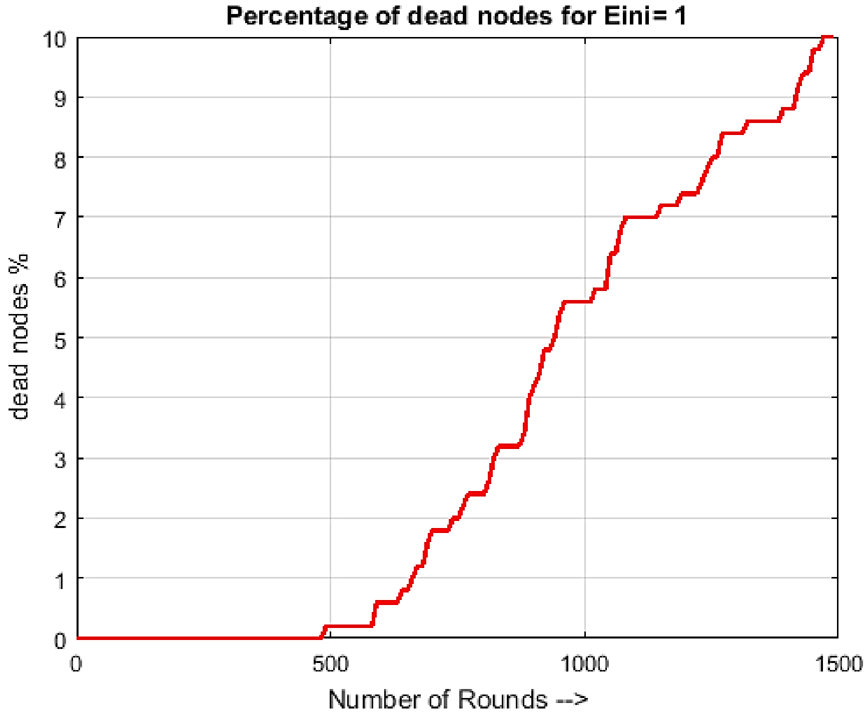


Figure 7: determining the number of rounds when nodes being died while E_{ini} = 1 J

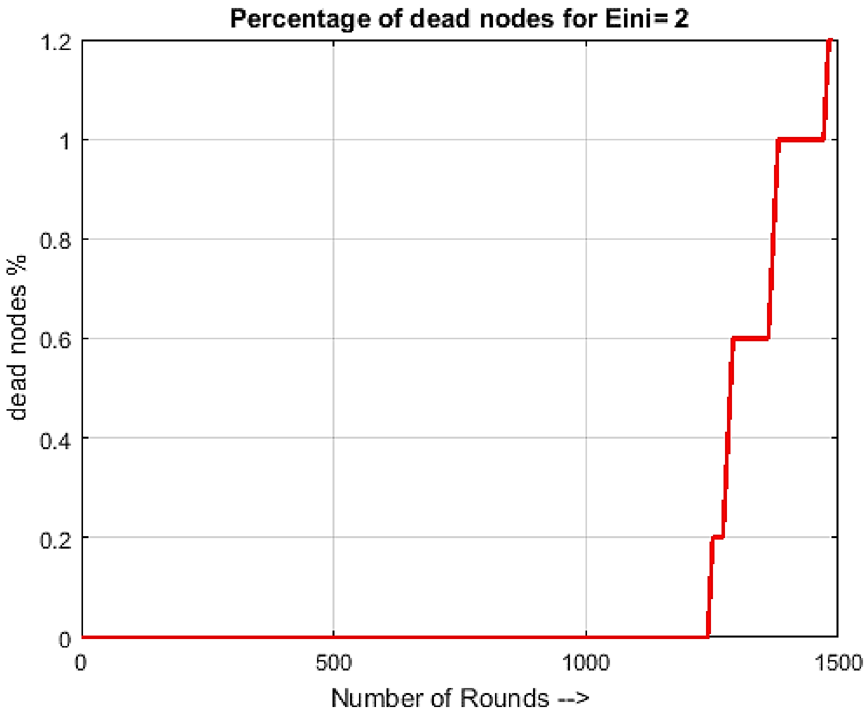


Figure 8: determining the number of rounds when nodes being died while E_{ini} = 2 J

4.2.2 Effect of Grid Size

To evaluate the impact of grid size, whole sensor network area will be divided into grid sizes of (8 × 8) and (10 × 10) as illustrated in Figures 9 and 10. The proposed technique accomplished maximum number of rounds this enhancing the lifetime of network. In comparison, grid size 10 × 10 has the maximum number of rounds than grid size 8 × 8 through keeping the same parameters like number of nodes (600 node) initial energy (Eini= 2 J) and number of rounds (1500).

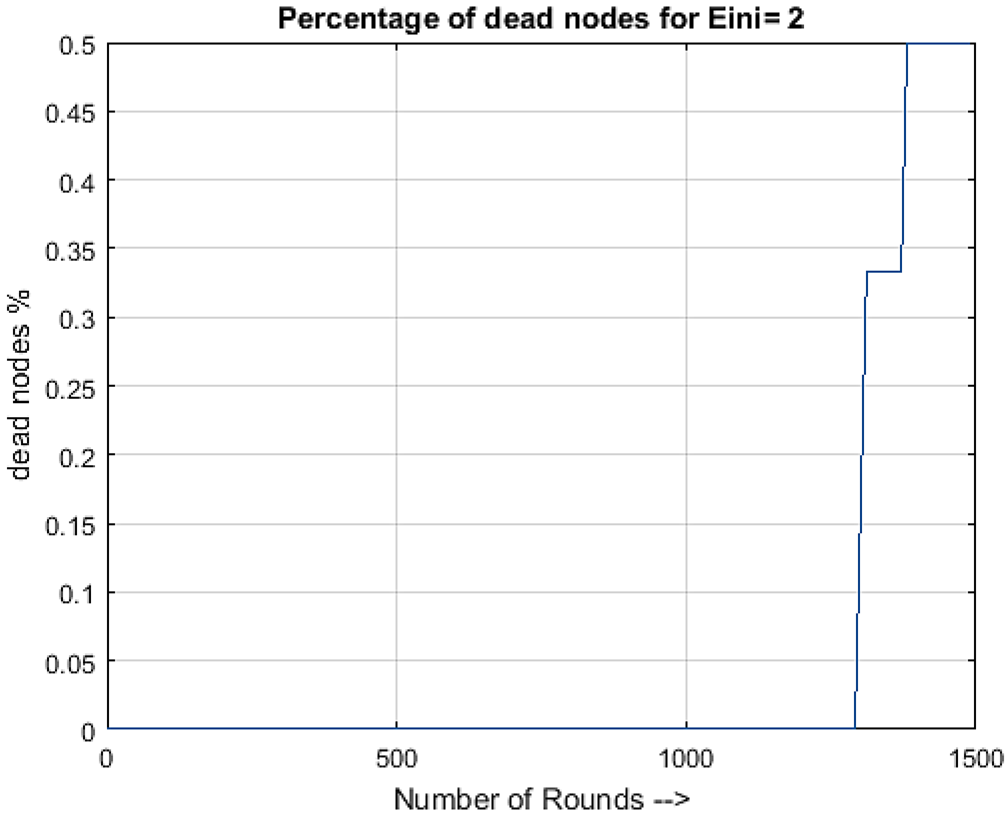


Figure 9: 10 x 10 grid size and number of nodes = 1389 rounds at 0.5%

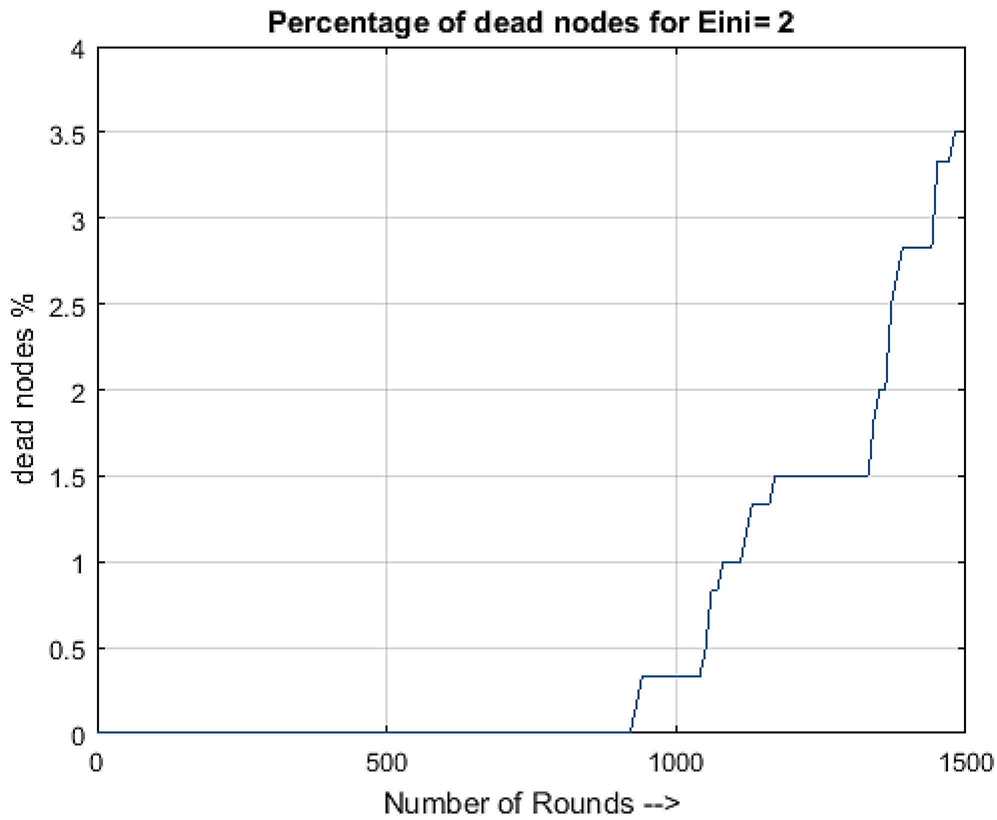


Figure 10: 8 x 8 grid size and number of nodes = 1091 rounds at 0.5%

4.2.3 Lifetime of the Network

For the purpose of analyzing the lifetime of network, two simulations have been used by various initial energy values (1 J and 2 J) with regard to 600 nodes. In Figures 11 and 12, our approach has the maximum number of rounds leading to lengthy the lifetime of network. This will indicate that the suggested approach will be surpassing other methods in terms of lifetime prolonging, energy efficiency, as well as load balancing.

4.2.4 Total Energy Consumed

Figure 13, 14, 15, and 16 will be showing the total consumed energy (communication, computation, as well as sensing) will be plotted against number of rounds for the total nodes of (500, 600) nodes. Graphs will show that the consumption of energy regarding the suggested approach is less. This is because of the node's even distribution across network leading to steady consumption of energy.

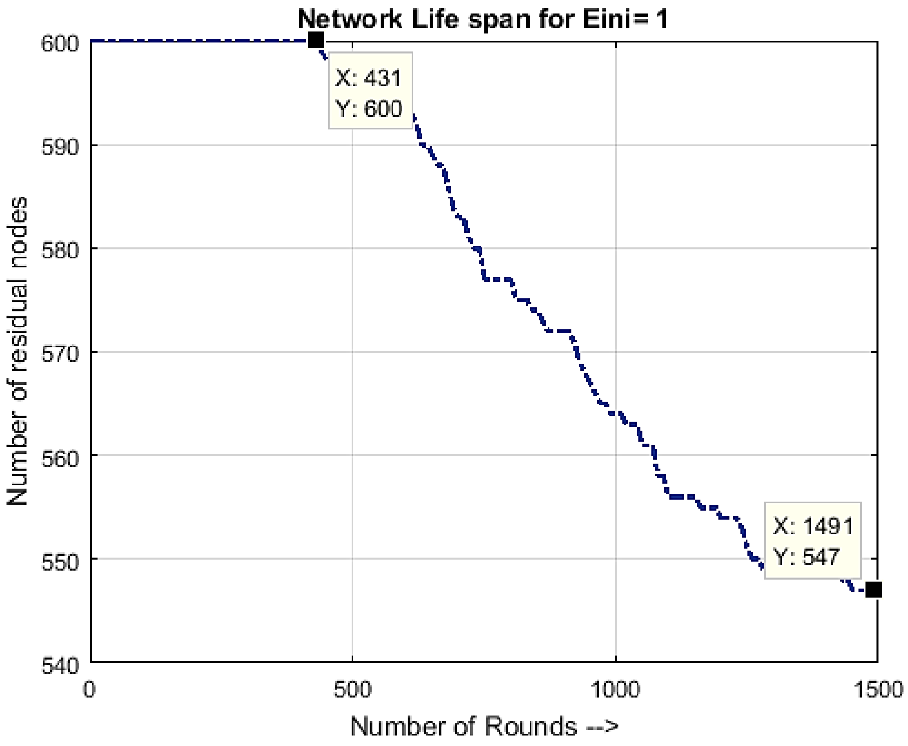


Figure 11: network lifetime for 600 nodes and Eini=1 J.

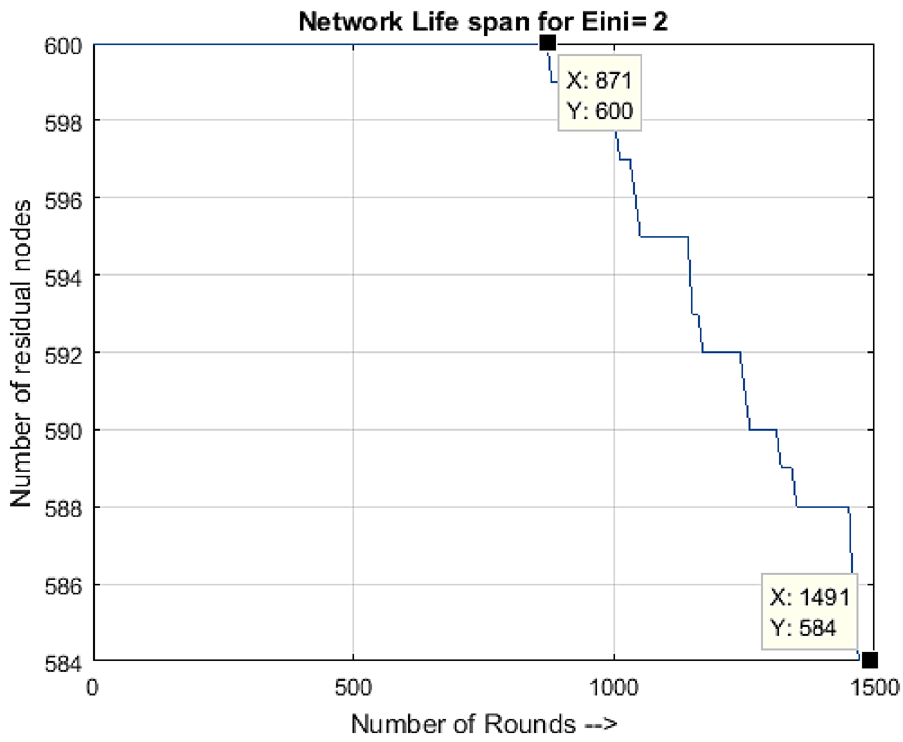


Figure 12: network lifetime for 600 nodes and Eini=2 J.

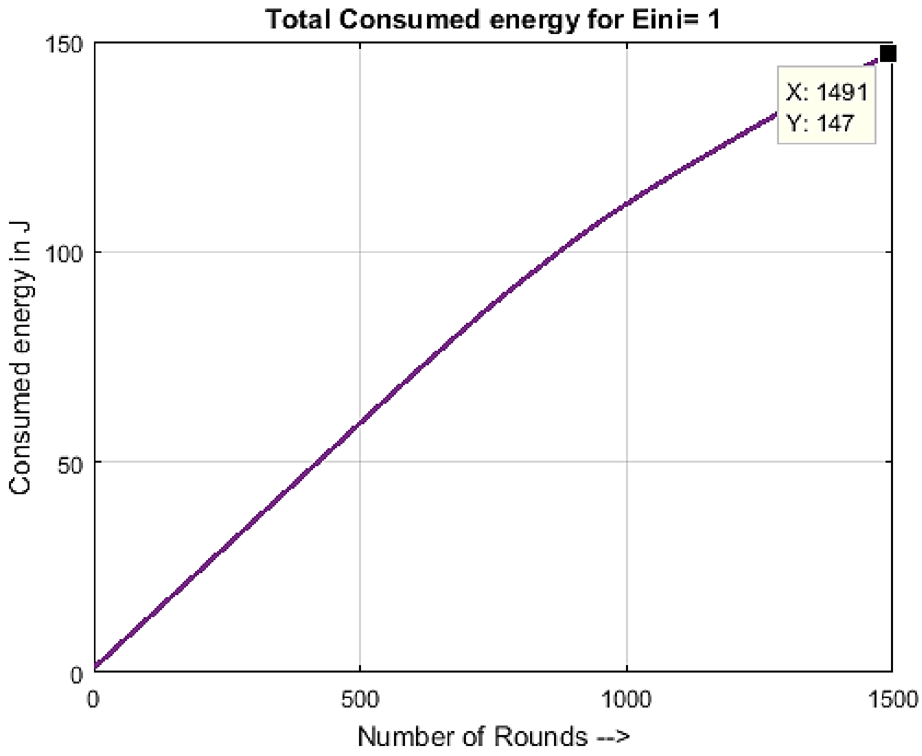


Figure 13: Total consumed energy for 500 nodes and Eini=1 J.

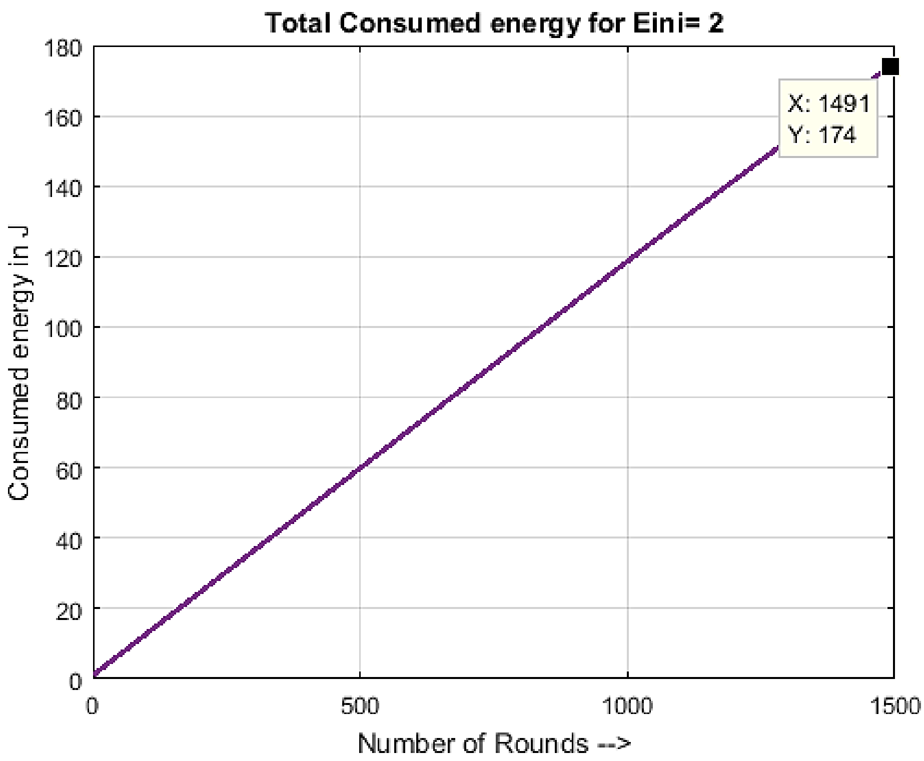


Figure 14: Total consumed energy for 500 nodes and Eini=2 J.

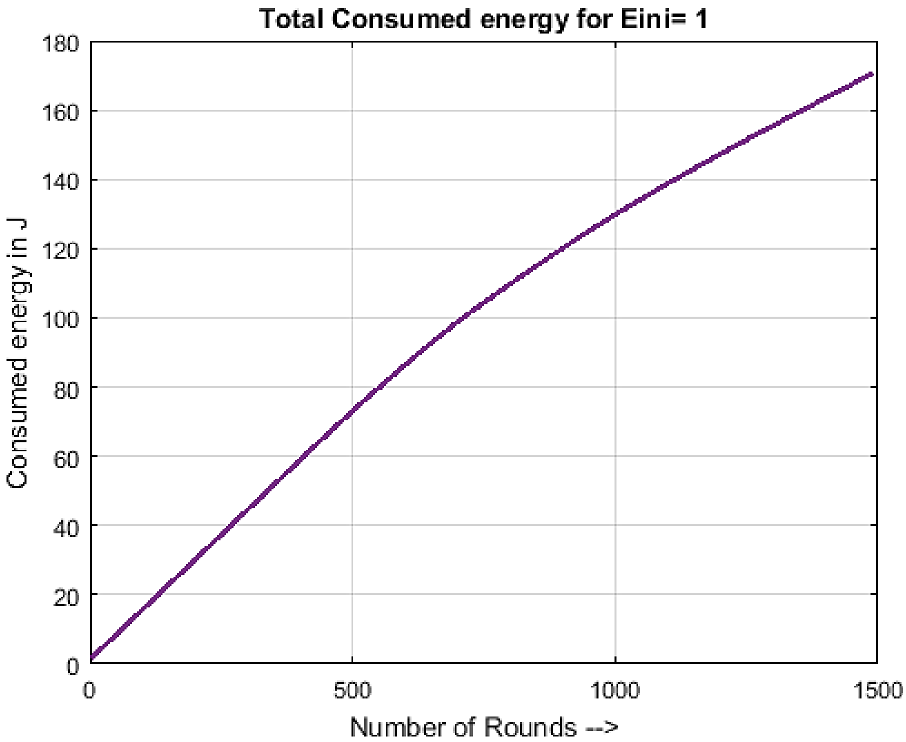


Figure 15: Total consumed energy for 600 nodes and Eini=1 J.

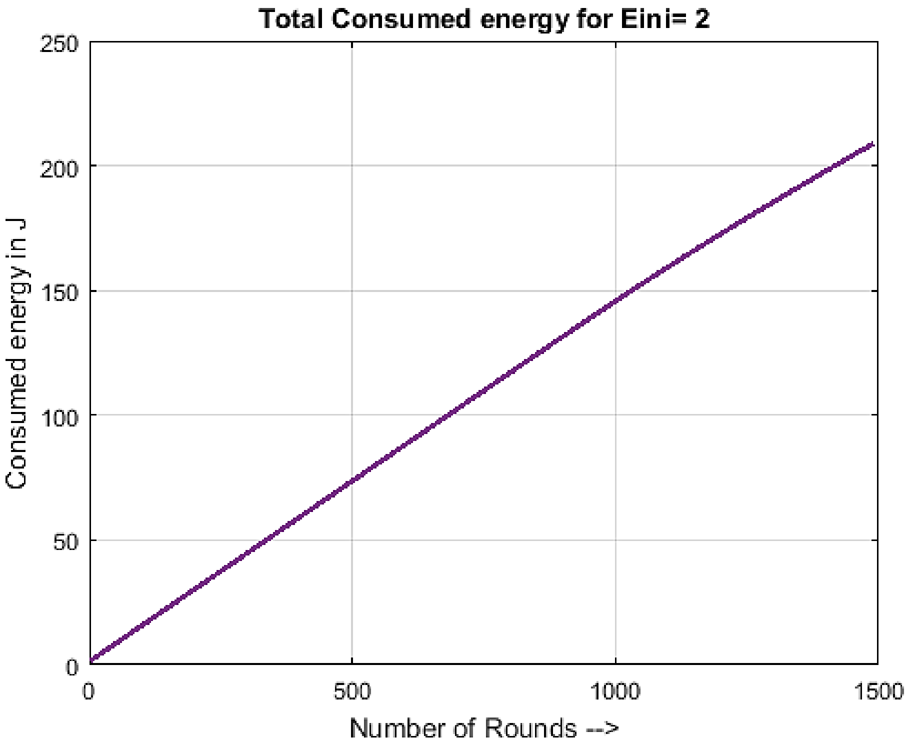


Figure 16: Total consumed energy for 600 nodes and Eini=2 J.

4.2.5 Effect of Nodes Density

With regard to our method, the impact regarding initial energy as well as node density has been indicated in a grid area of (8x8). With regard to such case, the number of nodes will be changed from 500 to 600 with various initial energy values 1 J and 2 J. Figures 17, 18, 19 and 20 are showing the number of rounds from nodes 500 as well as 600 with initial energy values 1J and 2J, respectively. Graphs in such figures are showing that there will be increase in the number of rounds through the increase of node density in GBHND approach. The lifetime of the resulting network is superior, due to the fact that after the increase in node density, each zone head's responsibility will be distributed.

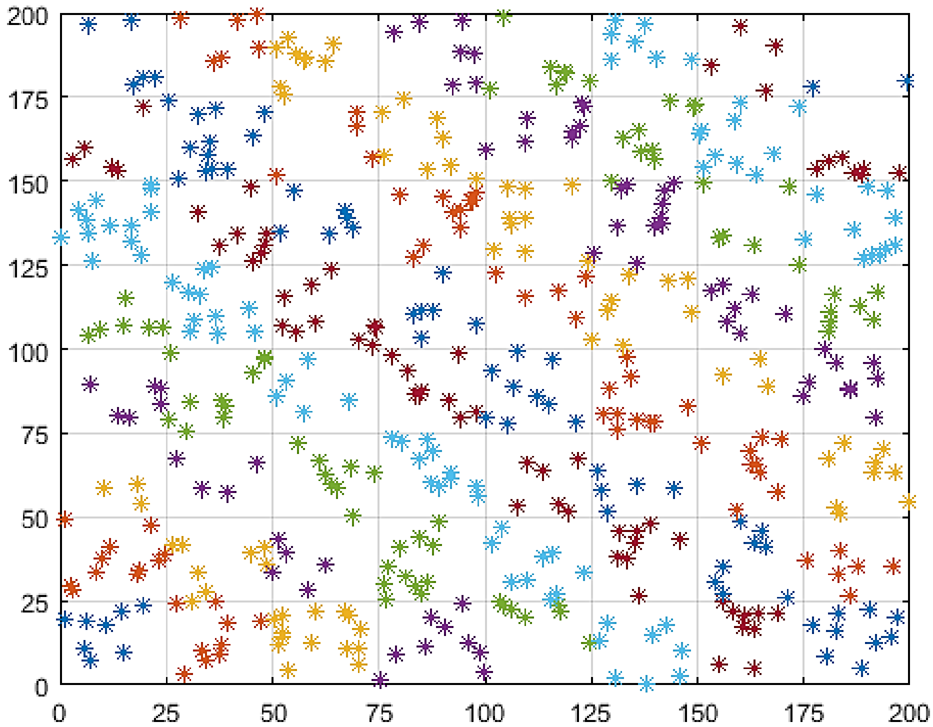


Figure 17: Node Density in grid size (8x8) for 500 nodes and Eini=1 J.

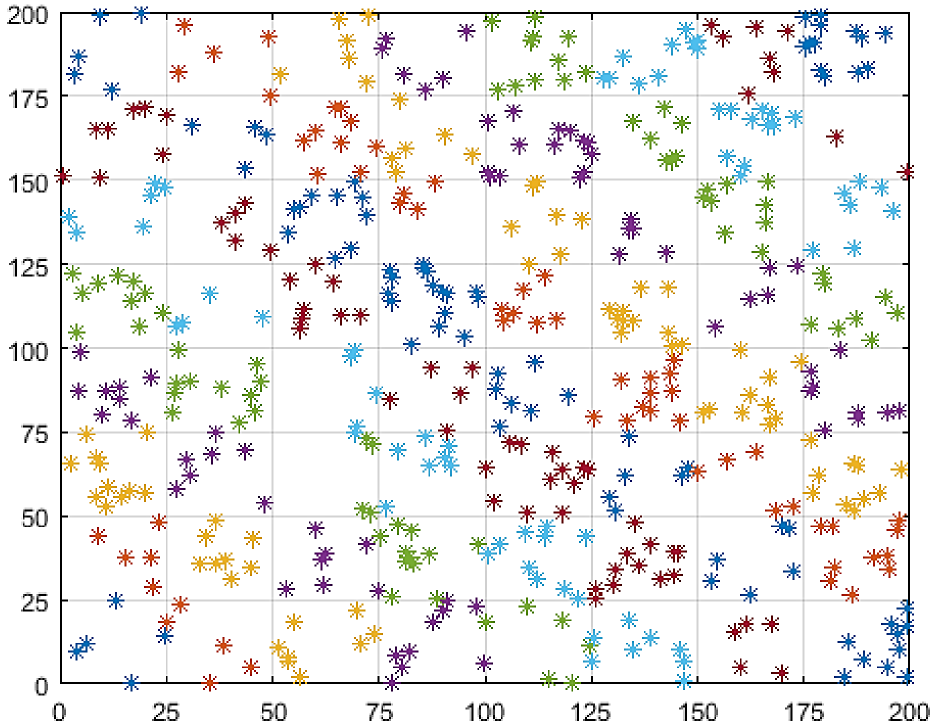


Figure 18: Node Density in grid size (8x8) for 500 nodes and Eini=2 J.

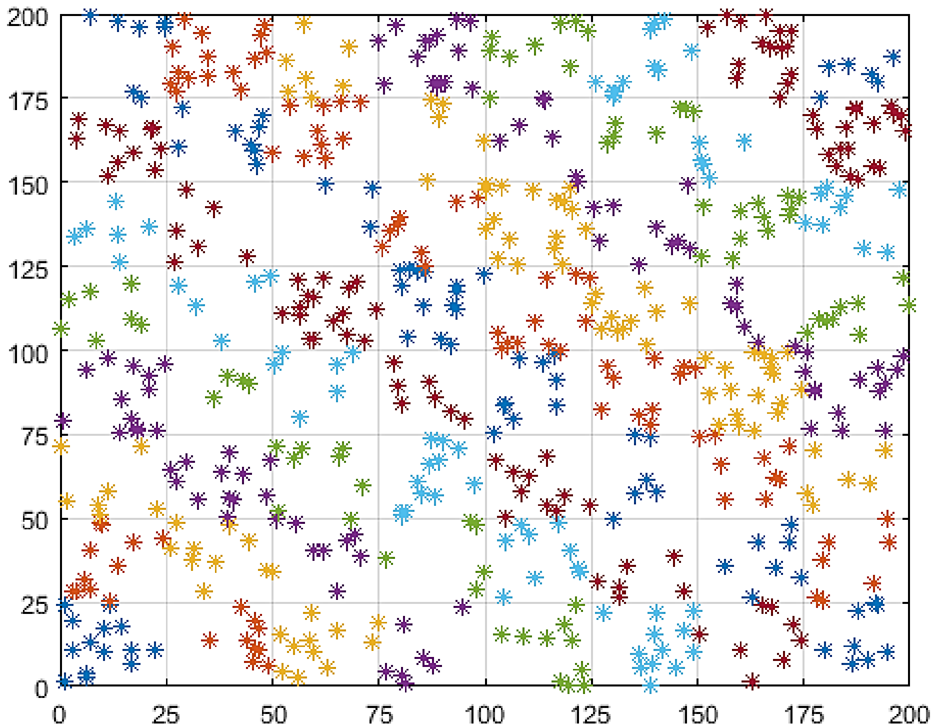


Figure 19: Node Density in grid size (8x8) for 600 nodes and Eini=1 J.

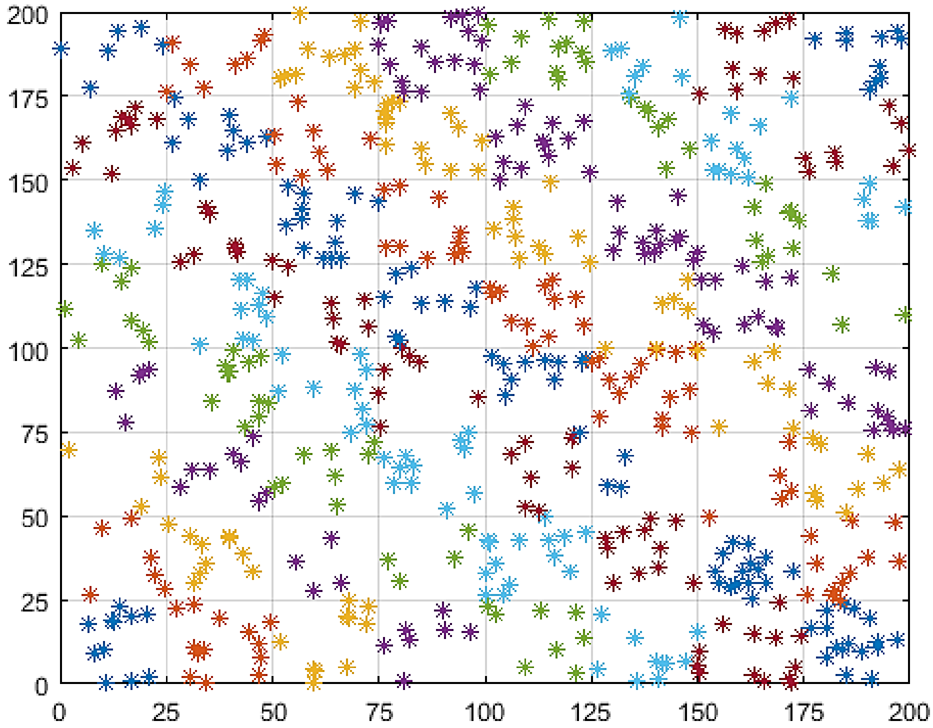


Figure 20: Node Density in grid size (8x8) for 600 nodes and Eini=2 J.

CHAPTER 5

CONCLUSIONS AND FUTURE WORKS

The presented study provided GBHND approach with regard to load balancing for ensuring WSN’s energy efficiency. With regard to certain random node deployment state, the suggested approach constructed grid through partitioning the deployment area to zones. All nodes have been related to their corresponding zones through BS. As soon as constructing the network topology, the node that has maximum CV will be selected and specified as ZH across every zone. Reselection process as well as overhead messages will be simplified the presented method and that will enable maximizing the lifetime of network. The results of simulation are showing that the suggested approach is more effective in comparison to other routing current approach through placing ZH evenly across the field as well as balanced grid formation.

Furthermore, the implemented algorithm is outperforming this method with regard to changing total consumption of energy, dimensions of grid, initial energy, lifetime of network, as well as density of node. Also, the proposed study could be developed as underlying topology with regard to the other energy efficient load balancing as well as routing protocols. Furthermore, more studies are required for making the framework of network adaptive through enhancing a predictable criteria to specify a number of nodes automatically to specific region of sensor network, especially for large-scale WSNs, as well as the number of grids for that nodes in the network area.

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