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An energy saving approach based on a developed optimized technique to prolong WSN lifetime

A Dissertation

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بسم الله الرحمن الرحيم

(قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا
عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ)

صدق الله العظيم

آية (32) من سورة البقرة

Supervisor Certification

I certify that the dissertation entitled (An energy saving approach based on a developed optimized technique to prolong WSN lifetime) was prepared under my supervision at the department of Information Networks/ College of Information Technology/ University of Babylon as partial fulfillment of the requirements of the degree of Doctor of Philosophy in Information Technology/Information Networks.

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In view of the available recommendations, I forward the dissertation entitled "An energy saving approach based on a developed optimized technique to prolong WSN lifetime" for debate by the examination committee.

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Date: /   /2022

Dedication

TO MY LOVELY FAMILY

(My Father, My Mother, My Wife, My Sons, My daughters)

Who have always offered their Patience and prayers

Dheyab

Acknowledgment

First of all, Thanks to Almighty Allah for providing me the great willingness and strength to finish this work.

I would like to express my sincere gratitude and give my deepest thanks to my supervisor Prof. Dr. Saad Talib Hasson for suggesting the research project and for his continuous guidance and support. This work wasn't possible without his guidance and solid knowledge that made me greatly esteemed.

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Abstract

Wireless sensor networks (WSNs) represent an important type of wireless network. WSNs are being applied in various fields such as the industrial, military, agricultural, medical, and other fields civil or military. These networks have characteristics and features such as small size, easily deploy, and cheap. But, they also suffer from different limitations such as limited energy, limited memory, and computation. WSNs also suffer from several challenges including energy consumption. Energy consumption is one of the most important factors affecting WSN efficiency and reliability. One of the most important ways to improve the performance of the WSNs is the clustering approach. Routing protocols in WSNs can be classified based on network structure into flat routing protocols, location-based protocols, and hierarchical routing protocols.

This dissertation focused on the develop hierarchical routing protocols based on clustering by the following contributions.

Proposing and deriving a mathematical model to estimate the optimal number of the created clusters. This optimal number of clusters is the best possible number that can be finally reached iteratively by other clustering methods such as k-means.

Propose and derive another mathematical model to divide the deployed zone into three sectors. The first sector is that surrounding the Base Station (BS) with a diameter equal to the sensors communication range (R), the second sector is the edge or the border of the deployed area with a distance far from the edge equal to R, while the third sector is the rest of the deployed area (area between the two sectors). Propose a hybrid algorithm that combines the Particular swarm optimization (PSO) and the K-mean clustering algorithm in selecting the optimal CHs for the created clusters. This hybrid algorithm is called in this thesis (PSO-K algorithm). PSO-K algorithm selects CH based on the energy residual and the intra and inter-communication distances.

A developed optimal technique to form clusters is proposed in this dissertation. This technique is based on both the Euclidian scales and the optimal number of clusters. An optimal solution to fix the problem of sensors located at the edge of the network is proposed and implemented. This solution prevents these nodes from being CHs. The proposed mathematical model does not give the SNs at the edge of the network any chance to play a CH role.

An optimal solution to the problem of SNs placed at a certain distance near the BS has been proposed mathematically. The sensors near the BS are not able to play the

CH role to according the proposed model. These sensors are allowed to communicate with the BS directly.

The performance of the proposed system was evaluated using a MATLAB simulator. The most important metrics are the energy consumption rate, the number of live and dead nodes per round, and the average number of packets received by the BS. The results of this dissertation were compared with existing protocols such as LEACH, EAMMH, and I-LEACH protocols. The proposed PSO-K algorithm showed an average improvement of about 52% over the LEACH protocol and about 54%, over the EAMMH protocol, and about 10% over the I-LEACH protocol.

Declaration Associated with this Dissertation

Some of the works presented in this dissertation that has been published or accepted are listed below.

A. Published

1. **Selecting an Optimal Cluster Head using PSO Algorithm in WSNs**
   (International Conference on Software, Telecommunications and Computer Networks (SoftCOM2022). It is published in IEEE Explore, 2022)
2. **A New Modeling Approach to Process the Sensors Communication based on their Locations**
   (International Conference on IEEE 8th International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA2022). It is published in IEEE Explore 2022).

B. Accepted

1. **Optimizing LEACH Routing Protocols for WSN: An Analysis Study**
   (2nd International Conference on Modern Applications of Information and Communication Technology (MAICT_2021), IKC College. It has been accepted and will be processed for possible publication in the AIP Conference Proceedings)
2. **LEACH Routing Protocol: A Comparative Study**
   (Accepted in the Indonesian Journal of Electrical Engineering and Computer Science (IJEECS).

C. Submitted

1. **A New Modelling Approach to Optimize Number of Clusters in WSNs**

Table of Contents

List of Abbreviations

Abbreviations	Description
ABC	Artificial Bee Colony
ACO	Ant Colony Optimization
ADC	Analog to Digital Converters
AoI	Area of Interest
BCDCP	Base Station Controlled Dynamic Clustering Protocol
BS	Base Station
CH	Cluster Head
CPU	Central Processing Unit
DBEA-LEACH	Distance-Based Energy Aware -LEACH
DBSCAN	Density-Based Spatial Clustering of Applications with Noise
DC	Direct Communication
EGT	Evolutionary Game Theory
EM	Expectation-Maximization
FA	Firefly Algorithm
FDN	First Dead Nodes
GA	Genetic Algorithm
GMM	Gaussian Mixture Model
GPS	Global Positioning System
GUIs	Guided User Interfaces
HDN	Half Dead Nodes
IoT	Internet of things
LDN	Last Dead Nodes
LEACH	Low-energy adaptive clustering hierarchy
LEACH-C	LEACH-Centralized
MTE	Minimum Transmission Energy
MW-LEACH	Multiple Weight- LEACH
OLE	Optimized Lifetime Enhancement

PEACH	Power Efficient and Adaptive Clustering Hierarchy
PEGASIS	Power-Efficient Gathering Sensor Information Systems
PSO	Particle Swarm Optimization
QoS	Quality of Service
SCH	Secondary Cluster Head
SEP	Stable Election Protocol
SN	Sensor Node
SOP	Self-Organizing Protocol
TDMA	Time Division Multiple Access
TEEN	Threshold sensitive Energy Efficient Sensor Network
W-LEACH	Weight- LEACH
WSN	Wireless sensor network

List of Symbols

Symbols	Description
A	Area of Interest
A_s	Area of the Sensing Node
d	Distance between Node i and BS
K	Number of Clusters
N	Number of Sensor Nodes
P	Coverage Probability
r1	Transmission Range
r2	Threshold Value

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Chapter One

Introduction

1.1 Introduction

A Wireless communications give opportunities to invent this type of network with low power, small size, and low cost called wireless sensor network (WSN). A WSN is a specific type of wireless networks which are used for several application monitoring purposes. SNs are connected to each other by wireless links and setting with a battery, processor, memory, and radio abilities. Then, SNs sense the field and send sensing data to the base station (BS) [1]. BS is the key node that is responsible for gathering information. WSNs comprise a large number of SNs that form the network and the main task is monitoring the interesting area when each SN can sense data from the physical area and send these data to the BS [2].

Many studies focused on energy-efficient algorithms to reduce energy consumption, improve performance and prolong the lifetime of the whole network. Clustering techniques are used to improve energy consumption and prolong the life of the whole WSN by applying clustering techniques including cluster head (CH) selection process and cluster formation process Which significantly affect the WSN performance [3]. This chapter provides a brief description of WSN, motivation, problem statement, aim dissertation, research questions, dissertation contributions, literature review, and dissertation layout.

1.2 Problem Statement

In WSNs, sensor nodes capable of detecting the required information, performing some processing, and communicating with other connected nodes are the main component of these networks. However, the life of these nodes is often restricted by being powered by a battery with a limited life, constraining processing ability, memory, and radio communications. Energy efficiency is one of the most crucial issues for WSNs [4].

Energy is important in WSNs because it must be used in order to guarantee the communication process and data delivery to the user in less period of time. Energy is a key factor to get the best performance for WSNs and increase the lifetime of the network. The key problem here is reducing the energy consumption of SNs and increasing the average energy saving [5].

The big problem is the limits in the power of SNs (the battery) due to the difficulty to change the battery or recharge it in a difficult environment. Energy is important in WSNs because it must be used in order to guarantee the communication process and data delivery to the user in less period of time [6].

Most of the energy is consumed in data processing and transmission. This means it is not rational to energy consumption due to inefficient cluster head selection and cluster formation. Thus, it would be prudent to design and implement systems that are designed to minimize energy consumption, and so increase the node lifetime and thus the life of the overall network [7].

This thesis focuses on the optimization of the WSNs within the context of the sensor network to address a range of challenges, specifically energy efficiency. Energy is a key factor to get the best performance for WSNs and increase the lifetime of the network. The key problem here is reducing the energy consumption of SNs and increasing the average energy saving [8].

1.3 Research Motivation

WSN is becoming ever more pervasive in everyday life, connected to an ever greater array of diverse physical objects. The key vision of the WSN is to bring a massive number of smart objects together in integrated and interconnected heterogeneous networks, making the internet even more useful. It is a futuristic paradigm where all possible devices will interact with each other regardless of their size, compute power, and network connectivity, in a seamless environment. It makes applications smart by sensing, data harnessing, and decision-making towards actions mostly without human intervention [9].

WSN and other enabling technologies will have a significant impact on, for example, information gathering over large geographical areas for applications such as environmental monitoring, agriculture, industry, and surveillance. In such systems, large numbers of connected devices will sense and transmit huge amounts of data, each concerning its local environment and resulting in the realization of connected-device-oriented big data [10].

WSN is the most crucial part of the communication process of IoT networks. It consists of a number of sensor nodes that are responsible for collecting key information, performing some computations, and communicating wirelessly. These nodes can be deployed over a large geographical area and generally configured in a mesh network, ultimately sending a large volume of data to a base station (BS) or a gateway, and are usually forwarded via multiple hops to reach the BS [11]. These nodes are highly constrained devices with strict limitations on battery consumption and processing capabilities. Energy is considered a scarce resource for sensor nodes. Sometimes it can be costly, even impossible, to exchange an energy source, e.g., networks positioned deep in the ocean, near an active battlefield or volcano, or simply because a large number of nodes makes it logistically impossible [12].

In WSNs, SNs are having limitations including power limits, computation limits, and memory limits. These limitations with more requirements motivate for development and building WSNs with efficient- energy. The topic is interesting and many researchers are working on practical applications. There are a number of studies, and research focused on applied clustering techniques in WSNs [13].

1.4 Dissertation Aims

This research aims to investigate and implement routing protocol-based clustering algorithms, cluster head selection techniques, and cluster formation techniques to minimize the number of hops and transmission distances, and thus reduce the energy consumption of WSN devices. This dissertation aims to develop and design a WSN with efficient energy. After studying and comparing different sensor deployment techniques and different clustering techniques in WSNs. This aim can be achieved by the following objectives:

1. Propose a method to find the optimal number of clusters K.
2. Propose a hybrid technique for the CH selection algorithm in WSNs and consider the problem of the SNs that are located at the edges of the network.
3. Propose an efficient approach to cluster formation and find a solution to the sensors located near BS.
4. Propose a developed data routing-based clustering protocol to maximize energy-saving by using hybrid (PSO & K-means) algorithms.
5. Model, simulate and evaluate the performance of the proposed WSN topology.

1.5 Research Questions

There are some important questions that should have been addressed before working to achieve the objectives of this thesis. These questions are:

Q1/ What is the best deployment technique that is suitable for the area of interest?

Q2 / What is the best clustering technique that is suitable for the area of interest?

Q3 / How does one develop new algorithms to increase the lifetime of the WSNs?

Q4 / How does one select a suitable cluster head and form stable clusters?

Q5 / Q/ How to deal with the SNs located on the edges and near the base station?

1.6 Dissertation Contributions

The Dissertation contributes to enhancing the performance of WSNs obtained by decreasing energy consumption and developing and optimizing the routing protocol and evaluating and comparing deployment techniques such as random and regular ways. Also, evaluate and compare Clustering Algorithms such as K-mean, DBSCAN, GMM, Hierarchical and spectral.

Contribution1: Propose a Model to select the optimal number of Clusters in WSNs. Propose an optimal Cluster Formation process based on the optimal number of clusters and less distance.

Contribution2: propose a hybrid technique to select the CH by combining K-mean and PSO algorithms based on high levels of energy residual, the centrality of the SNs, and less distance to BS.

Contribution3: Propose a novel model to prevent SNs that are placed at the edge to become CHs.

Contribution4: Propose a novel model to allow the SNs near BS to communicate with the BS directly.

1.7 Literature review

This section analyses the parts of the literature of the existing and related literature associated with the scope of the dissertation as shown in Table (1.1).

Random selection of CH can be made without any central control of nodes. Low-energy adaptive clustering hierarchy (LEACH) protocol that used a probability equation to select CH [14]. In LEACH-Centralized (LEACH-C) the CH process and cluster formation are done by BS and all nodes send their energy level and their position to the BS. BS selects the CH from the nodes that have greater energy than average energy [15]. Integrated LEACH (ILEACH) is extend the performance of the system by extending the network lifetime by modifying the threshold equation for selecting the CH for every round of clustering [16]. This protocol gives better network performance in terms of lifetime and less amount of power consumption in the network. Improve LEACH (I-LEACH) proposed routing algorithm selects sensor nodes with higher residual energy, more neighbors, and lower distance from the Base Station (BS) as Cluster Head (CH) nodes by modifying the threshold equation for selecting the CH [17].

Some metrics such as residual energy, node degree, and distance to BS are called weight which is computed at each SN. Many studies worked on the select CHs based on these weights by considering the SN with maximum weight is selected as CH.

In multiple weight LEACH (MW-LEACH) protocol [18]. The nodes are selected from the initial set based on the high residual energy closer to the center of the density. This forms an initial set of CH candidates and the candidates then move in different directions to collect data from their members sending it to the BS. This routing protocol selects the CHs based on three parameters: the residual energy, the distances, and an optimal number of member SNs.

In O-LEACH the cluster members will be able to play the role of a gateway. The gateway allows the joining of orphan nodes and the gateway node is considered a CH and it has to connect a number of orphan nodes. The orphan nodes become able to send their data messages to the CH [19].

In Weighted -LEACH (W-LEACH) which is able to handle non-uniform networks as well as uniform networks, while not affecting the network lifetime. W-LEACH increases the network lifetime and the average lifetime for sensors for uniform and non-uniform WSNs [20]. Study and analyzed the measurement parameters of performance of each hierarchical cluster-based routing protocol algorithm. Select hierarchical cluster-based routing protocols in WSNs and compared them with their advantages and disadvantages [21]. Propose a new approach to achieve better enhancement of WSN in terms of network lifetime and data transmission time represented by reducing the packet delay time [22].

This paper Clustering and Neighboring Technique Based Energy-Efficient Routing (CNBEER) proposed by [23]. This approach prolongs the network's lifetime by reducing its total energy consumption. The clustering method divides a network into equal-sized clusters to mitigate inessential energy consumption. This clustering algorithm selects a CH based on the G function which considers the current energy and position of the nodes of a base station. Recently, researchers have tended to solve WSN problems using optimization algorithms including Genetic Algorithm (GA), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO). PSO algorithm and the evolutionary game theory (EGT) algorithm are applied to improve the established clusters and select CHs [24]. Data routing-based clustering was Proposed by [25] to select CHs and cluster formation by using a PSO algorithm. The proposed algorithm selects CHs based on the energy level of the SNs and handles the balancing of energy over the network. Also, this study considers CH failure.

A new algorithm was proposed [26] using the PSO algorithm to determine the optimal number of CHs and achieved maximize the lifetime of the network.
LEACH-P algorithm [27] proposed based on the PSO algorithm for cluster formation of the SNs and CH selection and this algorithm selects the SNs near to the BS as CHs to reduce the power consumption of CH and to prolong the lifetime of the network. A new algorithm using the PSO algorithm was proposed by [28] to select the CHs. This study applied the reselection mechanism. The results of this study show that the proposed algorithm works best than the LEACH algorithm in the stability period. In [29] proposed a new algorithm using the PSO algorithm to select CHs with energy-efficient based on many parameters such as residual energy, inter-cluster and intra-cluster distances of the SNs. Also, this study builds the clusters based on the weight function.
A new algorithm proposed by [30] used the PSO algorithm in order to select the optimal CH algorithm based on node degree, residual energy, distance, and density of SNs in the cluster. This study used the fitness function for PSO in the CH selection process. This study reduces the consumption of energy of SNs and prolongs the lifetime of the network. Proposed select the optimal CH algorithm based on the fitness function and the parameters residual energy level, intra-cluster, and inter-cluster distances [31]. Applied PSO algorithm by [32] in order to select the optimal CH algorithm based on the basis of parameters like residual energy, intra-cluster distance, and inter-cluster distance of the sensor node. This study applied the fitness function for the PSO algorithm in order to reduce energy consumption and improve the lifetime of the network. Proposed Hybrid clustering algorithm based K-Means clustering and Particle Swarm Optimization (PSO) by [33]to achieve efficient energy management and balancing the load distribution in WSN, to make efficient use of the available energy sources, and reduce traffic transmission and find the optimal distribution of sensors and CHs. The improved LEACH (iLEACH)protocol by [34] is based on the initial energy and number of neighbors of the nodes. This protocol is more applicable than any type that assumes a protocol by which each node knows the sum total energy of the network and then adapts its election likelihood of becoming a group head based on its remaining energy.

Table 1.1 Related Work Description

Ref	Clustering Technique	Advantages	Disadvantages
14	LEACH protocol selects cluster heads Randomly using a probability equation.	- Not need any control information. - It saves energy. - It is completely distributed. - Improve the lifespan of wireless sensor networks.	- Do not consider the residual energy when selecting CHs. - Do not consider the location of nodes when selecting CHs. -Unbalanced distribution for CHs. - Direct communication
15	LEACH-C uses a centralized clustering algorithm to select the CH nodes by BS based on higher energy.	- Instead of randomly selecting CHs - Provided better clustering and longer lifetime.	The sensor nodes must send information about their current energy to the BS
17	Integrated Low Energy Adaptive Clustering Hierarchy protocol (ILEACH). The goal of ILEACH protocol is to minimize energy wastage during cluster formation in LEACH by modifying cluster head selection within the setup phase	In ILEACH, the picking of cluster head is based on the residual energy of every node, the number of neighboring nodes, and the minimum distance between the cluster head and sink node. -Network lifetime	The proposed mechanism uses same processes to choose cluster members and data transmission as the conventional LEACH protocol. -It used the initial chosen probability
18	-Multiple weight LEACH (MW-LEACH): select CHs based on 1. Residual energy, 2. Distances between the CHs. 3. The Optimal number of member nodes. -Performance metrics of throughput, energy consumption, packet delivery, network lifetime, and latency.	-Lower complexity in terms of time and message. -It is providing a longer lifetime for the network. -It also provides fault tolerance. -Uniform cluster distribution and locations, the distances for data transmission between the nodes are optimally reduced by the adaptive multi-hop approach. -Reduces the consumption of the energy.	-All the nodes is that they are homogeneous and have limited energy. -Adopts the centralized.
33	Energy optimization in WSN using a hybrid k-means PSO clustering algorithm.	- Achieve efficient energy management and balance the load distribution. - Find the optimal distribution of sensors and CHs.	
34	The improved LEACH (iLEACH) protocol is based on the initial energy and a number of neighbors of the nodes. improved LEACH protocol, based on the initial energy and number of neighbors of the nodes.	Improvement has been done by taking under consideration basically three factors; -Residual Energy in nodes, Distance from BS and number of neighboring nodes	iLEACH assigns a weighting probability to each node.

1.8 Dissertation Layout

This Dissertation is organized into five chapters and these chapters tried to answer the most common research questions. In addition to this chapter, there are other four chapters in this thesis. Thus this section describes briefly the contents of these chapters as follows:

Chapter 2 Displays the ideas, concepts, architecture, applications, types and challenges for WSNs. In the first, it presents the characteristics and architecture of WSNs and their applications and then it discusses categories of routing protocols in WSNs. Then discuss hierarchical protocols such as LEACH and discusses the most common solutions methods to minimize energy consumption.

Chapter 3 introduces the system model and includes determining an optimal number of clusters, hybrid algorithm to select CH, and cluster formation.

Chapter 4 shows the simulation results using the traditional and proposed techniques for the proposed data routing-based clustering protocol in WSNs. And it runs various existing routing protocols to measuring the performance and compares with the proposed algorithm in different environments.

Chapter 5 A summary of the work is presented in the last chapter which displays the conclusions from the results. Recommendations and suggestions are present for future work that would further enhance WSNs. Additional information can be found in appendices A, and B, as a supplement to the main chapters. WSNs applications, WSNs characteristics, challenges of WSNs, challenges of design routing protocols in WSNs, and routing protocols classification in WSNs in detail in Appendix A.

Chapter Two Theoretical background

2.1 Introduction

This chapter presents a momentary description of WSNs and focuses on the energy consumption factor as the biggest challenge facing this type of network as it depends on the battery as the main source of energy, which cannot be charged or replaced in specific applications. This chapter also identifies the sources of energy consumption in these networks and the methods and techniques that have been proposed to reduce energy wastage to give a longer life and better performance for the longest possible period. It also discusses the main categories of data routing protocols in WSNs and presents the problems that face them. Then it focuses on the routing protocols based on clustering and the key advantages, and properties of clustering. The weaknesses of the LEACH protocol are discussed. Deployment and clustering techniques are compared and analyzed. This chapter also displays the main algorithms which are proposed for selecting CH and building the clusters processes.

2.2 WSNs

Advances in computers and wireless communication technologies can build a sensor network with a small size, low cost, and can process and save data. An example of these networks is the WSN which is a special type of wireless network that is composed of a large amount SNs [8]. SNs that are typically working based on battery power with limited energy resources and in some networks replacing the batteries is a difficult task. So, energy efficiency is one of the most important challenges and designing protocols with energy efficiency prolongs the lifetime of the network. WSN has become one of the most common techniques in different applications such as agriculture, factory monitoring, health care, and fire track. WSN has many advantages such as low cost, small size, multifunctional, self-organized, and ability to be routed by WSN protocols. Also, WSN has some limitations such as the low battery, short lifetime, area of sensor deployed, and sensor energy consumption [37].

WSN is formed by the deployment process of sensors in two ways a pre-defined or random process. The main task of SN in WSNs is to sense the AOI and group data and aggregate it and extract useful information. Then, forward this aggregate information to the end destination by a radio link. WSN is commonly applied in military applications including monitoring the battlefields. WSN is an important part of the Internet of things (IoT) networks and it is one of the most promising wireless communication technologies which are enabling IoT applications [38].

Sensors often work based on battery power with limited energy resources and recharging or changing, the battery is a difficult task. So, energy saving is the most important challenge in these networks, and to get this goal must design data routing protocols with energy efficiency in order to prolong the lifetime of the network. Today, this network become the most common wireless communication which is applied in different applications such as agriculture, factory, health care, etc. The most common advantages of the WSN include low cost, small size, and self-organized [39].

2.2.1 WSN Architecture

WSN involves several components that are integrated to create a suitable environment. The following major components of WSN [40-41]:

Sensor Node (SN): A Sensor Node is a small device that has low power signal processing, low power computation, and a short-range communications capability. A sensor node consists sensing unit, a processing unit, a communication unit, and a power unit.

Sink is a sensor node with the specific task of receiving, processing, and storing data from the other sensor nodes. A sink is also known as a data aggregation point.

Base Station (BS): The base station is at the upper level of the hierarchical WSN. It provides the communication link between the sensor network and the end-user. It contains the antennas and other equipment needed to allow wireless communications devices to connect with the network. It is a centralized point of control within the network, which extracts information from the network and it also serves as a gateway to other networks. The BS is either a laptop or a workstation. The Architecture of WSNs includes interested areas, sensor nodes, sink, BS, and user as shown in Figure (2.1).

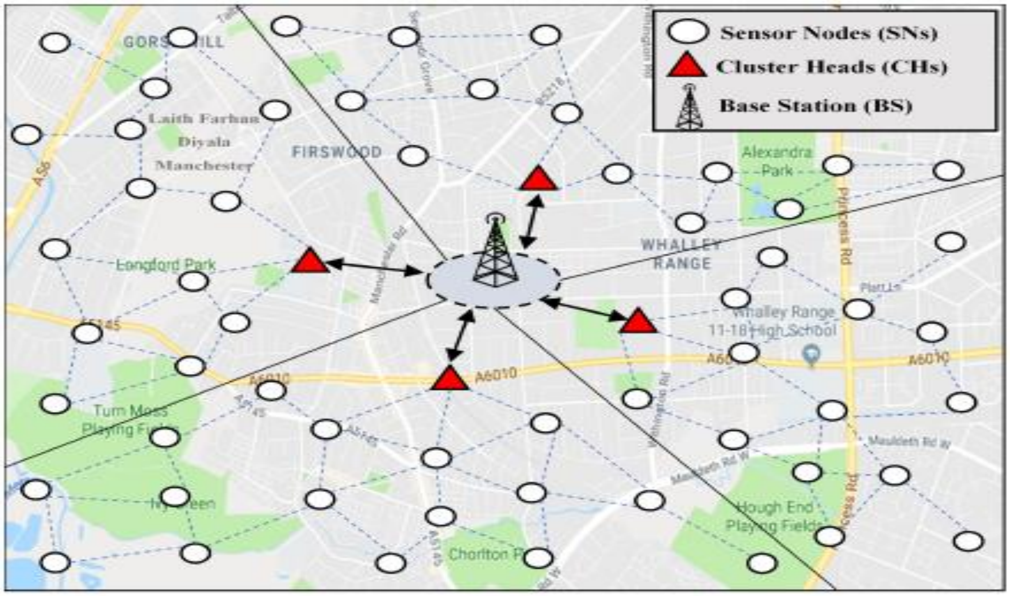


Figure 2.1: Architecture of WSN [38]

2.2.2 Sensor Node Structure

The main parts of any SN are a sensing unit, power unit, transmission unit and processing unit. As shown in Figure 2.2:

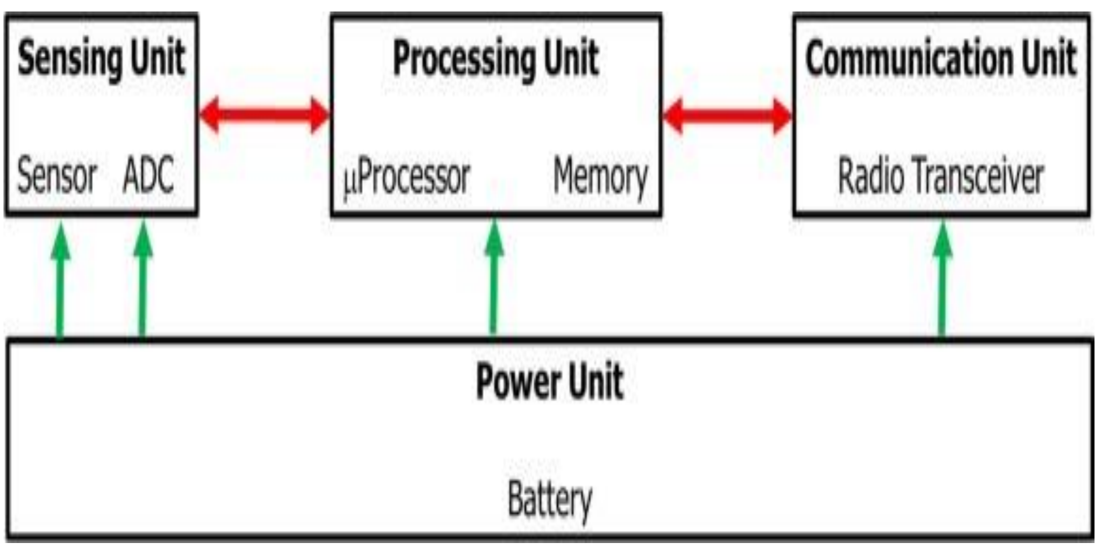


Figure 2.2: Components of Sensor Node [42]

The following simple definition of the main components of each SN in WSNs [42].
Sensing Unit: The sensing unit usually consists of one or more sensors and analog to digital converters (ADCs). The sensors observe the physical phenomenon and generate analog signals based on the observed phenomenon. The ADCs convert the analog signals into digital signals, which are then fed to the processing unit.
Processing Unit: The processing unit usually consists of a microcontroller or microprocessor with memory, which provides intelligent control to the sensor node.

Communication Unit: The communication unit consists of a short-range radio for performing data transmission and reception over a radio channel.

Power Unit: The power unit consists of a battery for supplying power to drive all other components in the system. In addition, a sensor node can also be equipped with some other units, depending on specific applications.

2.2.3 Characteristics of WSNs

WSNs have several features and characteristics which have an important role in SN designing. These features can summarize as follows [43]:

- Static and Mobile WSN.
- Deterministic and Nondeterministic WSN.
- Single Base Station and Multi Base Station WSN.
- Static Base Station and Mobile Base Station WSN.
- Single-hop and Multi-hop WSN.
- Self – Reconfigurable and Non – Self – Configurable WSN.
- Homogeneous and Heterogeneous WSN.
- WSNs can be divided into proactive and reactive networks based on their objectives.
- Scalability; WSNs include a large number of SNs deploying over a wide area and they need to scalable algorithms.
- SN sends data from many-to-one. Send data from multiple sources SNs to BS.

2.2.4 WSN Types and Applications

WSNs are used to track, monitor and other practical applications. These applications include fire prevention, meteorology, earthquake detection, flood, monitoring, and pollution. In all these applications, the sensors are installed over an extensive geographical area and may be in difficult-accessible locations. These networks can be applied in domains like health, agriculture, smart cities, and industry [44]. The major applications of WSNs are categorized below in Figure 2.3.

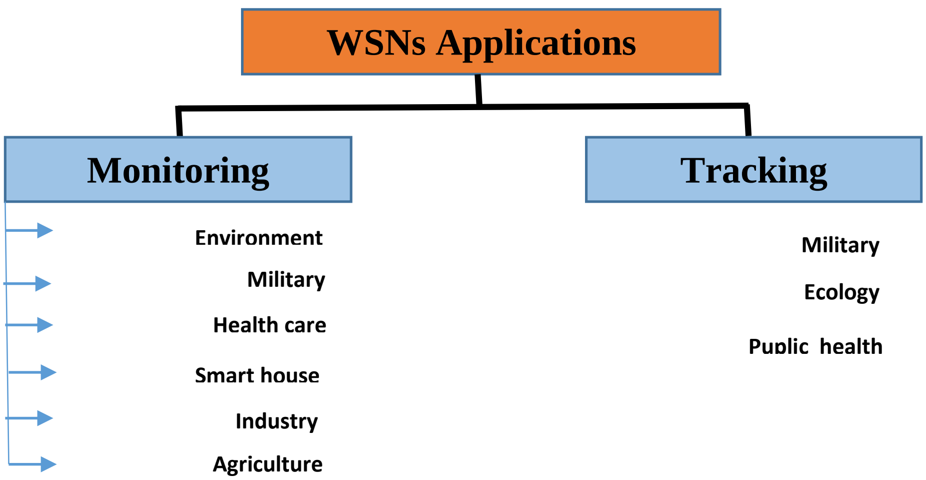


Figure 2.3: WSNs Applications [44]

A WSN can be classified into several types of SNs based on the people, applications, and environment requirements. These types include WSNs terrestrial, WSNs underwater, WSNs underground, WSNs multimedia, and WSNs mobility. The following most common types of WSN are defined below [45]. As shown in Figure 2.4.

- Terrestrial WSNs: In this type, SNs deployed above the ground can be connected with the BS directly and placed either in the structured or unstructured methods.
- Underground WSNs: In this type, SNs can be deployed underground and they are more expensive when compared with terrestrial WSNs.

- Underwater WSNs: they are deploying under the water and the main task for this type of SNs is collecting data underwater.
- Multimedia WSNs: In this type, SNs are designed to monitor multimedia actions such as images, audio, and video.
- Mobile WSN: In this type, SNs have the capability to move from the current place to provide better coverage or energy efficiency.

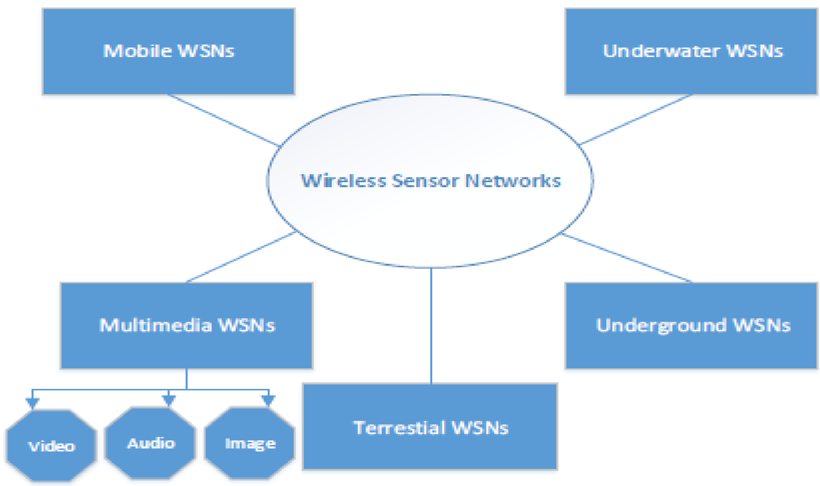


Figure 2.4 Types of WSNs

2.2.5 Challenges of WSNs

The Energy wastage for SNs is a key issue through WSN design. So, determining resources of the energy wastage is significant, and trying to stop these resources is the main goal in order to reduce the energy consumption of SNs and prolong the life of the network. Network lifetime is the most important metrics to evaluate the performance of WSNs.

WSNs challenges during the design and deployment of WSNs are related to be communication and routing protocols used in WSNs. These challenges can have summarized as follows: Limited Battery Power, Noisy Channels, Interference and Quality of Service (QoS) [46]. In WSNs, most of the energy is consumed in the processing, transmitting or receiving of data to fulfill the requirements of the application. It is obvious that reducing data transmissions will save the energy of these constrained devices. In regard to communication, a number of studies have found that a great amount of energy is dissipated in ways that make no useful contribution to the application, such as [47]. Lists some sources of energy wastage:

1. Collision: happens when two or more packets arrived to a SN at the same time. This case causes a need more of energy.
2. Overhearing when the density is high which causes a load traffic. This case need more energy.
3. Distance between SNs means the distance between the source SN and destination SN. This case determines the communication which can be multi-hop or single-hop. The single-hop consumes more energy in large size networks. Multi-hop helps in reducing the transmission distance which resulted in reducing energy. Most of the studies show that multi-hop communication is the best way to reduce the transmission distance between nodes.
4. Non-clustering transmission or direct transmission from each sensor to BS cause more energy consumption.

2.3 Energy Consumption in WSNs

Energy is a big challenge for WSNs and developing an energy-efficient routing protocol is a key task. Routing is a way of choosing a path between source and destination in order to send data [48] Critical problem is to find power efficient route between source and destination nodes. Moreover, if nodes can adjust their transmission power, then the power metric will depend on the distance between nodes [49]. In large networks, data may not reach the BS in a single hop, so, the need to route via multiple hops. An optimized choice of such a routing path is known significantly increases the performance of networks. Routing is the process of selecting paths in a network along which to send network traffic is a key building block in a protocol stack [50].

Energy consumption is an essential design issue for routing, and power management dissemination protocols have been specifically designed for WSNs. Energy consumption is one of the major challenges with WSNs and the largest amount of energy is used for communication. So; the best way to reduce energy consumption is to reduce the number of packets communicated between the sensor and sink node.

The most common definition of energy consumption is the total energy consumed within the transmission, reception, and data aggregation processes. The power metric will depend on the distance between nodes, and in large networks, data may not reach the BS in a single hop, and requires a route through multiple hops. The prime role of the routing protocol is to establish a route between source and BS and enable effective transmission of data along the selected route [51].

2.3.1 WSNs Design and challenges

There are many challenges for WSN designs based on WSN constraints. WSNs suffer from the limitations of several network resources, for example, energy, bandwidth, central processing unit, and storage, and the design challenges in sensor networks. And they involve the following main aspects [52]:

Limited energy: SNs are limited energy due to battery-powered and energy consider a big challenge for designers of the network in hard environments, such as a battlefield, where it is impossible to access the sensors and recharge their batteries. Thus, routing protocols designed for sensors should be as energy efficient as possible to prolong the network lifetime and ensure good performance.

Node Deployment: SN deployment in WSNs is application dependent and can be either manual or random which affects the performance of the routing protocol. In most applications, SNs can be scattered randomly in an intended area and may cause an unbalanced distribution. So, optimal CH selection and optimal cluster formation become necessary to allow connectivity and enable energy-efficient network operation.

Power consumption: this issue changes the lifetime nodes directly. In WSN, sensor nodes are battery-powered and often it is not possible to recharge or change batteries. Efficient energy protocols decrease energy consumption and this leads to an increase in the network lifetime.

Sensor locations: This challenge faces the routing protocols design by managing the location of the SNs. Most of the proposed protocols are based on a global positioning system (GPS).

Data Aggregation: same packets come from multiple SNs and this cause create redundant data. The aggregate process is done to extract useful information and reduce the number of transmissions. This technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols.

Coverage and Connectivity: this means the ability of applications to link with people, the cloud, or with the sensors, and necessary a suitable topology is to cover all the areas of the network.
Scalability: Routing protocols should be able to scale with the network size. The performance of the WSN will be degraded with a large number of nodes and network size must be not affecting the performance of the network.
Throughput: sensor node transfers data to the BS. Throughput is the successful transmission of data packets to/from a specific node with a time.
Security: is an important issue of WSN. Data can be accessed by unauthorized parties and preventing it is an important issue for WSN.

2.3.2 Types of Data Transmissions in WSNs

There are three methods of how WSNs send data to BS using the routing protocols [53-54]:

1. Direct Communication (DC): the SNs can send the data directly to the BS (called a simple protocol).
2. Minimum Transmission Energy (MTE) Protocol: the node acts as a router for the other nodes because the nodes send data to the BS through intermediate nodes.
3. Clustering protocols: the nodes are grouped as clusters and send the data from SNs to their own CH, then CH sends the data collected and processed to the BS.

Data routing-based network organization also can be categorized into three types as shown in Figure 2.5 [56-57]:

- Flat routing protocol: all the SNs are working together based on the same role. This type is not preferred or not used a lot in large-scale networks.
- Hierarchal routing protocols: aim to group the SNs into clusters.
- Location-based protocols: The SNs are addressed based on their locations.

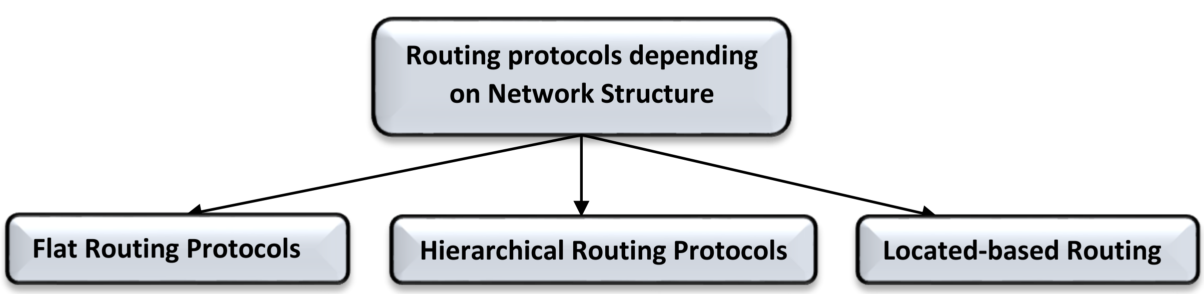


Figure2.5: Routing-based on network organization [58]

Flat routing protocol: all the nodes are working together based on the same role. This type is not preferred or not used a lot in large-scale networks. A flat routing protocol is a network communication protocol implemented by routers. It is distributing information about routing that are connected to each other without any organization. and if any node needs to transmit data, it first searches for a correct route to the BS and then transmits the data.

Hierarchal routing protocols: Hierarchical protocols aim at clustering the nodes so that CHs can aggregate and reduce data in order to save energy and all the nodes work together but in different scenarios by distributing these nodes into groups called cluster heads and each set executing its own tasks. This will provide many useful and supported features to the network such as scalability, energy efficiency, and increased network lifetime [59].

Location-based protocols: In this type of routing, sensor nodes are addressed according to their locations. Location-based protocols use position information to send the data to the wanted areas. The location of nodes may be obtained from a satellite if nodes are equipped with GPS.

Figure 2.6 represents the comparison between hierarchical based routing protocols and flat based routing protocols.

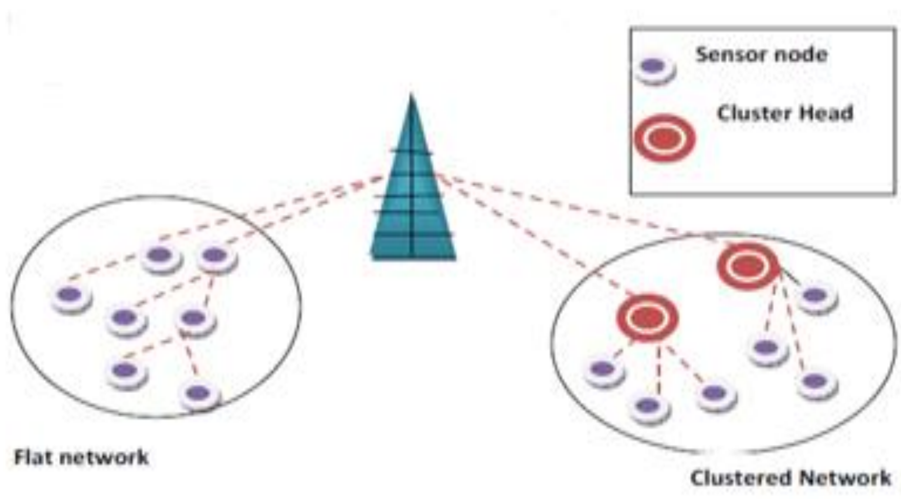


Figure2.6: Flat based and hierarchical based protocols [60]

2.3.3 Hierarchal Routing Protocols

Hierarchical Routing is the method of routing in networks that divide the network into multiple clusters, as shown in Figure 2.7. Every cluster has one CH and many SNs and Each SN gathers information and forwards it to its CH [61]. Then CHs perform aggregation on the collected information and forward aggregated data to the next hop or BS. Clustering in WSNs is still suffering from un-efficient energy management. One of the most well-known distributed clustering algorithms is Low Energy Adaptive Clustering (LEACH) for sensor networks [14].

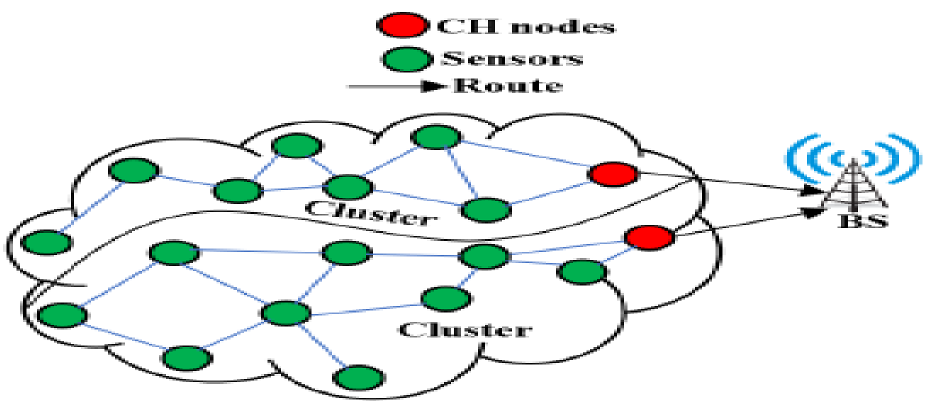


Figure 2.7 Clustering in WSN [62]

Most routing protocols based on clustering work into two steps are setup step and a steady-state step [63]. In the setup step; the network is divided into many areas called clusters and electing a CH for each cluster. In the steady-state step, the member nodes of every cluster send their sensed data to their own CH in order to assign a time division multiple access (TDMA) slot and CHs collect data from member nodes, aggregate it, and send it to BS [64]. They work according to two operations: CH selection, and cluster formation.

Clustering in WSNs has some characteristics including the size of the cluster, the number of clusters, intra-cluster, and inter-cluster communication listed the following [10], [65]:

Cluster count: means the number of clusters established in WSN, which may be predefined or variable that may be subject to application requirements, and it may be a fixed amount of clusters. The numbers of clusters are changeable when the CHs are randomly selected.

Cluster size: In WSN, Cluster size can be different. Many of them can be equal or unequal. In equal cluster size, network area is separated into equal size clusters and in unequal clustering, cluster size can define by the distance of BS and can also depend on other parameters [40].

Intra-cluster topology: Some clustering schemes are based on direct communication between a sensor and its CH. However, multi-hop sensor-to-CH connectivity is sometimes required. The whole communication between member nodes and CH of a cluster is recognized as Intra-cluster communication. It may be direct or multi-hop.

Inter-CH connectivity: When the CH does not have communication capabilities, CHs connectivity to the BS has to be provisioned. In that case, the clustering scheme has to ensure the feasibility of establishing an inter-CH route from every CH to the BS.

All of the clustering algorithms of WSNs can be classified into either Distributed or Centralized Clustering algorithm types [66-67]. Distributed clustering algorithms can be used for location-unaware sensors. These sensors are not aware of their network position and all of their routing decisions have to be made based on their internal information. For example, Low Energy Adaptive Clustering Hierarchy (LEACH), Power-Efficient Gathering Sensor Information Systems (PEGASIS), Threshold sensitive Energy Efficient Sensor Network (TEEN), Self-Organizing Protocol (SOP), and Stable Election Protocol (SEP).

Centralized clustering algorithms can be used for location-aware sensors. That is, sensors that are aware of their network position and all of whose routing decisions can be made in central locations such as the BS. For example, Centralized LEACH (LEACH-C) [15], Base Station Controlled Dynamic Clustering Protocol (BCDCP), Power Efficient and Adaptive Clustering Hierarchy (PEACH), and Optimized Lifetime Enhancement (OLE).

2.4 Cluster Head Selection Techniques

Selecting CHs process has an influential impact on the efficiency of the clustering algorithm and the network lifetime. Optimal CH selection can dramatically decrease energy consumption. The most important ways of CH selection are randomly or deterministically [68]. Optimal CH selection can dramatically decrease energy consumption. The most important challenges of the CH selection process include; CH selection process can be centralized by the BS; The CH selection can be done randomly or deterministically. Higher energy parameters may have a role in the CH selection. The distance parameter may also have a role in the CH selection. The size of clusters or the number of neighbors may affect the CH selection. Un-uniform distribution of the CH leads to more energy consumption.

Cluster formation SNs faced many challenges in clustering algorithms should take into account including; Cluster count, Intra-cluster communications; and Inter-cluster communications [69].

2.4.1 Probabilistic Cluster Head Selection

There are two methods to select CHs probabilistically selects CH randomly and Hybrid algorithms [70].

2.4.1.1 CH Selection Randomly Methods

Select CH without any centralized control nodes that can make decisions. For example, LEACH Protocol. The LEACH protocol is a classical protocol. LEACH is a popular energy-efficient adaptive clustering algorithm that forms node clusters based on the received signal strength and considers the first cluster-based hierarchical routing protocol proposed by [14]. And LEACH assumes:

- Equal residual energy from the sensor when starting the network.
- The life of the network is then divided into rounds and each round consists of two phases: a set-up phase and a steady phase.
- The BS is fixed and is located far from the sensors.
- All nodes can communicate with the BS directly.
- All the nodes can send sensed data to their own CH.
- CH aggregates the sensed data to the BS.

The main aim of LEACH protocol is to improve the lifespan of wireless sensor networks by reducing the energy consumption essential to create and maintain CHs.

The procedure of LEACH protocol consists of several rounds with two phases: The Set-up Phase and the Steady Phase. In the setup phase do the following tasks [71]:
CH selection: Every node takes participates in the cluster election procedure by generating a random value between 0 and 1 and every round begins with a CH selection each node in the network decides whether to become the CH for the current round or not. Depending on the required percentage of cluster heads for the network and the number of times the node has been a CH. For any node *n*, the threshold equation for CH selection. If the value of a random number is less than a threshold value, the nodes are selected as CH. The calculation of the value threshold T(n) value is as follows [14]:

$$T(n)= \frac{\boldsymbol{P}}{\boldsymbol{1-P(r mod\frac{1}{p})}} \qquad \text{if } n \in G \qquad (2.1)$$

T(n)= 0, otherwise

P=Nodes percentage that becomes CH.
r = the round figure.
G = nodes that do not participate in the selection procedure in the last round of 1/p.

Cluster Formation: CH sends a message to all nodes and depending on strength of the received message other nodes are decided to participate in the closed CH by sending a joining request to that CH. Now, as per the threshold equation, a new advertised message has been generated. CH starts to rotate again in each round in order to regularly allocate energy weighted in the sensor nodes. Based on the signal strength, the nodes decide which cluster to join.
In Steady Phase; **Transmission Schedule Creation**: After the formation of the cluster; a TDMA schedule is created based on the number of nodes in the cluster, the CH allots different time slots for each node to transmit by adopting the basic TDMA scheduling and permitted nodes can go to the sleep mode [72].

2.4.1.2 Hybrid CH Selection Methods

The second method applied hybrid CH selection randomly. For example, modified on the threshold T(n) equation, the CH is elected using a modified equation is given as in [14]. It focuses on an efficient CH election scheme that rotates the CH position among the nodes with higher energy levels as compared to others. The algorithm goal is to select the CH such as the initial energy and remaining energy. The modification is done in the classical LEACH algorithm. With the completion of each round, the residual energy of the non-CH nodes is checked, and the one with the higher energy level in comparison to others has a higher probability of CH selection for the current round. There are several studies focused on the modified basic equation (threshold T(n)) for LEACH protocol. For example, [73], Distance-Based Energy Aware -LEACH (DBEA-LEACH) is Based on distance and Deterministic CH Selection energy. DBEA-LEACH, in order to select the appropriate CH nodes in the CH nodes selection phase, the DBEA-LEACH algorithm takes important factors such as the position of the sensor node relative to the BS and the amount of residual energy of each sensor node. Similar to DB-LEACH, DBEA-LEACH establishes a new threshold based on distance as show equation 2. 2.

$$T_{(n)} = \{ C * \frac{\lfloor d_{to\ BS\ avg} - d_{(i,BS)} \rfloor}{d_{to\ BS\ avg}} * \frac{E_i}{E_{init}}, if\ neG \qquad (2.2)$$

Here, E_i is the residual energy of candidate node *i* at the current round. E_{inital} denotes the initial energy of the node before the transmission.

Equation (2.2) shows that the threshold value depends on the geographical distance between the SN and the BS and the residual energy of the candidate node. In addition, it introduces the current energy and initial energy of the node to CH election probability so as to ensure these nodes with higher remaining energy have a greater probability to become CHs than that with low remaining energy. The CH node selection directly affects the performance factors of WSN such as load distribution, energy efficiency, and network lifetime. Figure 2.8 shows the main steps of DBEA-LEACH.

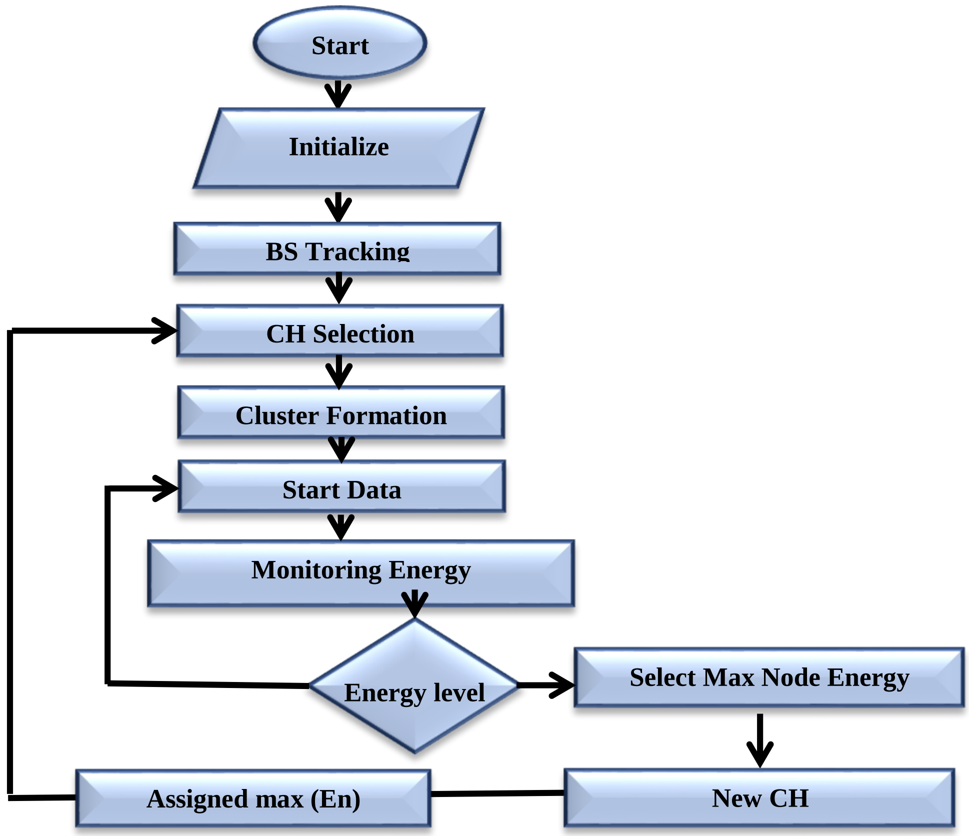


Figure 2.8: DBEA-LEACH protocol [73]

In [74] modified the probability for the selection of CH based on the residual energy of each node. And [75] introduced an algorithm to improve the lifetime of the network by on the threshold T(n) equation for selecting CH and Secondary Cluster Head (SCH) of each round. The SCH becomes a CH at the same time as the death of the previous CH. Also, it modified the threshold T(n) equation to select CH by [17] proposed I-LEACH to select CH based on higher residual energy and SN with high energy has more chance to be selected as a CH node.

2.4.2 Deterministic Cluster Head Selection

Deterministic approaches use standard metrics for selecting CHs such as residual energy, node degree, expected residual energy, distance to BS, node centrality, etc. The deterministic approach is further divided into three types: Weight based and heuristic-based clustering algorithms.

2.4.2.1 Weight-Based Methods

A weight is calculated at each node based on some metrics such as residual energy, node degree, distance to BS, etc. The node with the maximum weight is elected as CH. For example, Weighted Low Energy Adaptive Clustering Hierarchy Aggregation (W-LEACH) selects CH based on the equation by equation (2.3) [20]:

$$W_i = \begin{cases} e_i * d_i & if\ d_i \geq d_{th} \\ d_i & otherwise \end{cases} \qquad (2.3)$$

Where di = (1 + number of alive sensors in range r)/n is the density of the sensor si, r is the range that is reachable by sensor si, ei is the remaining energy in sensor si, and d is a density threshold to define the set of sensors in very low-density areas. A weight is calculated at each node based on some metrics such as residual energy, node degree, distance to BS, etc. The node with the maximum weight is elected as a cluster head. For example, [76] The proposed methodology is based on the idea of multi-hop network for the accomplishment of reduction in energy consumption while implementing communication on long-distance routes. In the proposed network a gateway node is aligned between the CH and BS. The purpose behind using a gateway node is to reduce energy consumption in comparison to previously use single-hop protocols. Gateway node purposefully reduces the distance between cluster heads and main station. Hence by reducing the distance for the communication leads to the reduction in the amount of energy consumption which directly increases or enhances the lifetime and performance of the network.

2.4.2.2 Heuristic-Based Methods

Recently, heuristic-based clustering algorithm is being used in many optimization algorithms [77] such as Ant Colony Optimization (ACO), Artificial Bee Colony Optimization (ABC), PSO, etc., are used in WSN. In [78] PSO-based algorithm is proposed to find the optimal CH selection in the network when all SNs transmit information like residual energy and their location to the BS in each cluster for each round using parameters like residual energy, intra-cluster distance, and inter-cluster distance of the sensor node. The proposed algorithm is split into two stages: Optimal CH selection using the PSO algorithm and cluster formation. [79] introduces an energy-efficient, clustering routing protocol called the PSOLB-EGT protocol. This protocol combines improved PSO and EGT) algorithms to establish clusters and select CHs. [80] Developing a hybrid clustering algorithm: use the K-Means to cluster formation and use PSO and GA separately to select the best CHs.

2.4.3 LEACH Limitations and Versions

The main advantages of the LEACH protocol are [14] clustering idea makes communication very less between the member nodes and the BS and applied single-hop communication and multi-hop communication to efficiently deliver data from CH and BS. But, the disadvantages of LEACH protocol include that more energy is required when the CH is far away from the BS node to transmit data from CH to BS. Another disadvantage is a single- hop communication will need more energy dissipation. And choosing the CH randomly also will cause more energy consumption. The following summary of the disadvantages of LEACH [81]:

1. Select CH randomly based on the threshold equation.

2. The nodes at the edge of the network will be elected as CH.

3. No consideration of the remaining energy of each node after the end of each round.

4. Distribution of the CH is not uniform and the CHs are distributed randomly, near or far from the BS.

5. The randomly situated CH may lead to more energy consumption based on the distance between the CH and BS.

6. No consideration of consumption of the energy and the possibility of selecting a CH is equal to all the nodes.

Therefore, several studies tried to improve LEACH routing protocol. Figure 2.19 shows the main fields for enhancements of LEACH algorithms.

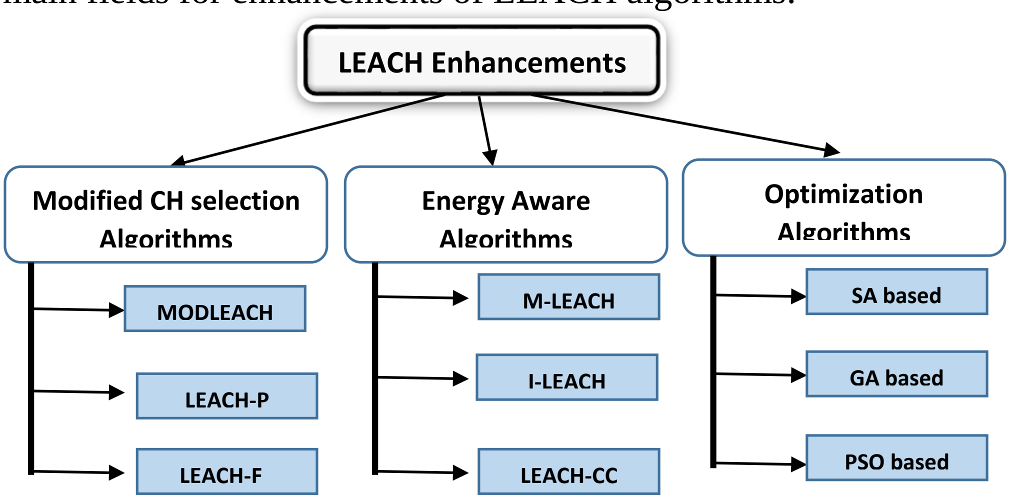


Figure 2.10 Enhancement LEACH Protocols [82]

2.5 Sensors Deployment in WSNs

The sensor' places are affecting the network coverage, connectivity, and reliability as well as other network performance metrics such as energy consumption, throughput, and delay. The major necessary stage in designing any new WSN is affected by SNs deployment. The location of the sensors has a large impact on the WSN and its operation effectiveness. The Sensor's location (position or coordinates) is the most required factor in planning to build or design a new WSN. The performance of a WSNs are effected by the deployment process the SNs. The sensor deployment strategies are classified according to the sensor's roles, the network optimization objectives in deployment, and the methodology of deployment. The deployment and positioning of SNs in WSN is used in defining the number, the position of the SNs, and the topology of the network [84]. Deployment is a planned or random approach to distributing sensors within an interesting environment [83]. There are two types of deployment in WSNs: deterministic and random deployment techniques as shown in figure 2.10.

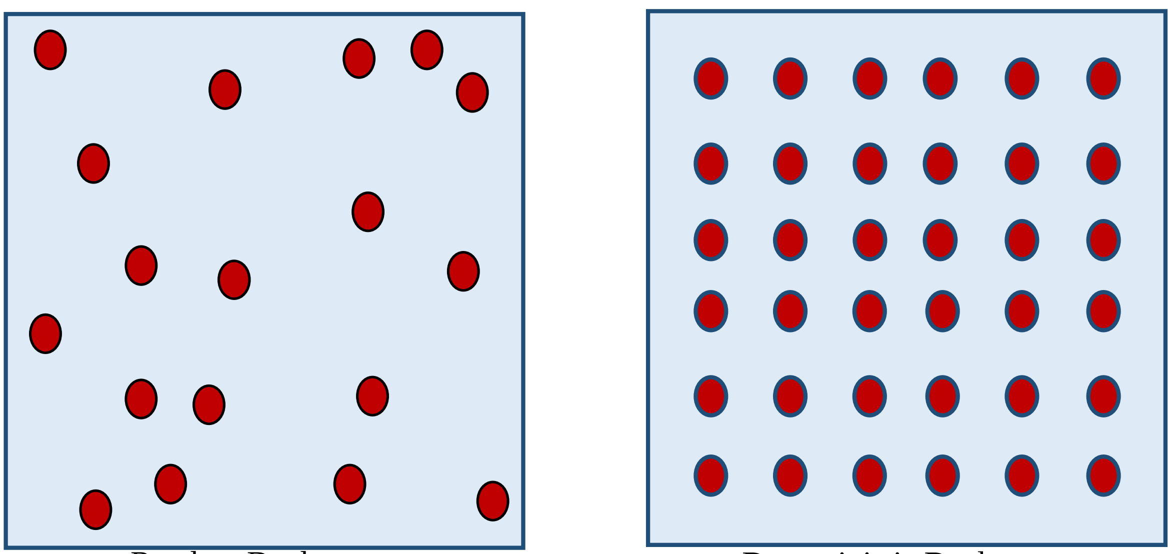


Figure 2.10 Deployment technique types [84]

The main challenges here are to minimize the number of deployed sensors and suitable the connectivity and coverage of the observing zone. In the first step in this thesis system, the deployment techniques are studied in order to select a suitable one for the WSN environment which gives better network performance.

2.5.1 Deterministic Deployment Techniques

A deterministic deployment is how many are required and where the sensors are placed and the placing of the sensors can be applied via controlling deployment. Most of the important WSN optimization techniques are to place the sensors in a deterministic manner to meet the required performance aims. In such case, the sensors' places can be indicated previously [85]. This process represents a careful planning process for the deployment of the sensors. So, the observed area coverage can be certified through the regular sensor distribution, densities, and network topology. In the deterministic deployment, the exact locations of the sensors are determined in order to monitor the area of interest. In this deployment, the SNs are set at exact positions one by one based on the communication range of the nodes. The locations are selected to decrease the number of nodes necessary to succeed the main deployment objectives. The deterministic deployment of sensor nodes can be achieved based on the area of interest [86].

In deterministic deployment, the SNs are deployed by humans and they arrange at exact positions according to the communication range of the SNs and SNs distribute into patterns such as square, triangle, and hexagon. Deterministic deployments are wanted when SN is expensive and also when the location of SNs is affected by the operation [87-88]. A deterministic deployment is how many are required and where the sensors are placed and the placing of the sensors can be applied via controlling deployment. This process represents a careful planning process for the deployment of the sensors.

There are several assumptions when building the deterministic deployment model in the square deployment technique [89-90];

- Similar sensor types are deployed in a square area.
- Calculate the optimum number of required sensors to cover the area as a grid.
- Indicate the optimum sensors positioned at the interested area.
- Define the required coverage and connectivity to reduce the total cost.
- The Square Deployment Technique requires as few sensors as possible.

Show algorithm 2.1 where L is the length of square area, Rs is sensing range of sensors, POS is the position of sensor.

Algorithm (2.1) Square Deployment

```
Input: L (length of Square area), Rs (sensing range of sensors).

Output: Array containing position of sensor (POS).

Begin {

1.  Calculate the initial coordinates (x,y) for the first sensor
2.  Put sensor in (x,y)
3.  Store (x,y) in the array POS
4.  Calculate dis (distance between sensor and its neighbor)
5.  Do{
6.      y ← y + dis
7.      Do{
8.      x ← x + dis
9.      put sensor in (x,y)
10.     store (x,y) in POS
11.   }While x don't reach the boarder
12.   x ← x (calculated in step 1)
13. }While y don't reach the boarder
14. Return POS
15. } // End Algorithm.
```

2.5.2 Random Deployment Techniques

Randomly deploying the sensors via air is necessary because difficult locations with a number of sensors cannot be prearranged when the size of the network is great. In most WSNs applications sensors are deployed in a random manner. Such randomness deployment produces less control on the network with no coverage guarantee and may achieve a weakly connected network topology. SNs deployment in Random means setting positions of WSN randomly in the area of interest. This method is fast and suitable for distributing with a large number of SNs to complete the network goal. In some applications, random deployment represents a unique choice as a strategy. In random deployment, SNs are randomly distributed in a certain due to human reaching difficulties [91]. In big areas, the suitable deployment is a Random as a cost and time. a larger number of nodes to achieve the same deployment goal and sometimes it is the only feasible strategy when considering an application scenario. random deployment is the only option in some applications of WSN especially due to environments with difficult access in special applications such as harsh environments, disaster region or certain battlefield. Random deployment is easy and fast but, does not guarantee a similar scattering and for this reason, random deployment is often used and the power consumption, connectivity, and quality monitoring are also affected directly by the deployment process or network topology [92].

An important factor in WSNs is deploying the smallest number of SNs that save complete coverage and connectivity. The coverage in the node deployment in WSNs, it is very important and the performance of the WSN is based on the network coverage and improves the network performance. The challenge of SNs deployment is to decrease the number of deployed SNs and maximize the connectivity and coverage of the observing area. To design any new WSN the deployment of the sensor in the first step in this study system, select a suitable way for the interest of area.

2.6 Clustering Techniques

Data mining refers to the process of retrieving data by discovering novel and relative patterns from a large database. Clustering is a distinct phase in data mining that work to provide an established, proven structure from a collection of databases. A good clustering approach should be efficient and detect clusters of arbitrary shapes [93].

Classification and clustering are techniques used in data mining to analyze collected data. Classification is used to label data, while clustering is used to group similar data instances together [94]. The difference between the classification and clustering are shown in Table 2.1.

Table 2.1 difference between classification and clustering techniques

N0	Classification	Clustering
1	The number of classes is known.	The number of classes is unknown
2	Train data is required.	No Train data is required.
3	Popular algorithms include Naïve Bayes classifier, Decision Trees.	Popular algorithms include K-Means, Density-Based Spatial.

Clustering is a division of data into groups of similar objects and each group is called a cluster which consists of items that are related between themselves and unlike compared to items of other groups. Clustering is one of the most popular techniques for WSN topology management by organizing SNs into a set of groups based on a set of pre-defined criteria. SNs are structured into clusters and each cluster must have a CH; the rest of the SNs become cluster members. Numerous advantages of cluster-based WSN are energy efficiency, better network communication, efficient topology management, minimized delay, improved network scalability, and avoid redundant data among SNs [94-95]. Clustering includes models for clustering such as distribution models, density models, hierarchical clustering models, Spectral clustering models, and centroid models, as shown in Figure 2.11.

Distribution models are based on how probable all data points in the cluster belong to the same distribution, for example, the Gaussian Mixture Model (GMM) which uses a probabilistic assignment of data points to clusters. A density model which is searching the data space for areas of the varied density of data points in the data space and it separates various density regions and assigns the data points within these regions in the same cluster such as the DBSCAN algorithm. Hierarchical clustering is also a method of cluster analysis that seeks to build a hierarchy of clusters without having a fixed number of clusters. Hierarchical clustering is a set of nested clusters that are arranged as a tree. In spectral clustering, data points as nodes of a connected graph and clusters are found by partitioning this graph, based on its spectral decomposition, into subgraphs. While centroid models are iterative clustering algorithms work based on the similarity derived by the closeness of a data point to the centroid of the clusters. For example, K-Mean which is run iteratively to find the local optima and needs a number of clusters [96-98].

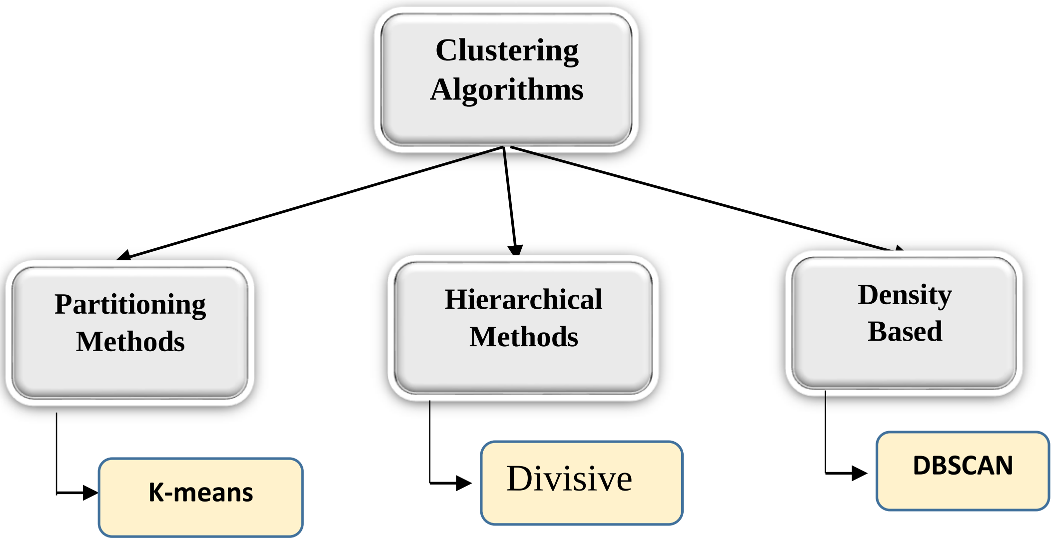


Figure 2.11 Common Clustering Techniques [97]

2.6.1 DBSCAN Clustering Algorithm

This section gives some ideas for the Density-Based Spatial Clustering of Applications with Noise (DBSCAN) algorithm and it can determine clusters of different shapes and sizes of large amounts. The DBSCAN algorithm uses two parameters: a. minimum Points (P) are the mean minimum number of points (a threshold) collected together for the area considered dense. b. neighborhood radius (ϵ-neighborhood) is mean a distance measure that will be used to locate the points in the neighborhood of any point. Density Based Clustering is a well-known density based clustering algorithm which having advantages for finding out the clusters of different shapes and size from a large amount of data, which containing noise and outliers [93].

DBSCAN requires two parameters: (eps) and the minimum number of points required to form a cluster (minPts). It starts with an arbitrary starting point that has not been visited. This point's ϵ-neighborhoods is retrieved, and if it contains sufficiently many points, a cluster is started. Otherwise, the point is labeled as noise. Note that this point might later be found in a sufficiently sized -environment of a different point and hence be made part of a cluster.

If a point is found to be a dense part of a cluster, its -neighborhood is also part of that cluster. Hence, all points that are found within the -neighborhood are added, as is their own -neighborhood when they are also dense. This process continues until the density-connected cluster is completely found. Then, a new unvisited point is retrieved and processed, leading to the discovery of a further cluster or noise [93].

The ϵ-neighborhood of p is the set of points at a distance ϵ or less from p. A core point is one whose ϵ-neighborhood has an overall weight of at least μ. A density area is the union of the ϵ-neighborhoods of core points. A point q is directly reachable from p if q is in the ϵ-neighborhood of p.

Density-based clustering algorithms, which are designed to discover clusters of arbitrary shape in databases with noise, a cluster is defined as a high-density region partitioned by low-density regions in data space. Density Based Spatial Clustering of Applications with Noise (DBSCAN) is a typical density-based clustering algorithm. DBSCAN can discover clusters of arbitrary shape. But it is sensitive to the input parameters, especially when the density of data is non-uniform [99].

There are some drawbacks of the DBSCAN algorithm including [100]:

1. DBSCAN fails to cluster the data points with different densities because the clustering is based on ϵ and minimum Points parameters, and they cannot be selected for all clusters separately.
2. DBSCAN required well-understood data and features in order to set minimum Points and ϵ.

There are three types of points; core, border, and noise. A core is a point that has at least *m* points within distance *n* from itself. A border is a point that has at least one core point at a distance *n*. Noise is a point that is neither a Core nor a Border.

Algorithm 2.2 presents the main steps of the DBSCAN algorithm where ϵ (eps) is the neighborhood radius which mean a distance measure that will be used to locate the points in the neighborhood of any point. (minPts) is a minimum number of points (a threshold) collected together for the area considered dense [101].

Algorithm (2.2): DBSCAN Clustering
Input
Input data to be clustering, the neighborhood radius (ϵ), minimum points (minPts)
Output
Clusters
Process
1. Randomly select a point P
2. Retrieve all points density-reachable from P based on ϵ, minPts
3. If P is a core point, a cluster is formed.
4. If P is a border point, no points are density-reachable from P, DBSCAN selects the next point randomly.
5. Continue the procedure until all points have been processed.
End.

2.6.2 GMM Clustering Algorithm

Gaussian Mixture Model (GMM) is a model as it is a probability distribution and also called Expectation-Maximization (EM) Clustering. GMM is used for representing Normally. A Gaussian distribution is a type of distribution where half of the data falls on the left and the rest half falls on the right. The formula for Gaussian distribution using the mean and the standard deviation called the Probability Density Function used by [102-103].

EM algorithm, which consists of two steps that repeat until convergence following parameter initialization:

1. Expectation: given the current estimate of parameters, calculate the expected value of the log-likelihood of the data samples to assign each sample to a component of the GMM.
2. Maximization: given the expected log-likelihood values and cluster assignments, update the parameters to maximize the complete-data log-likelihood, giving them the value that maximizes the likelihood that the data has the expected labels.

The main steps of the GMM algorithm are:

1. Similar to the K-means cluster, you need to select the number of clusters and randomly initialize the Gaussian distribution parameters for each one of them.
2. Calculate the probability of each data point belonging to a particular cluster. The closer the point is to the Gaussian's center, the better the chances of it belonging to the cluster.
3. Based on these calculations, need to determine a new set of parameters for the Gaussian distributions to maximize the probabilities of data points within the clusters. And use a weighted sum of points positions to compute these probabilities. The points belonging to the particular cluster is the weight factor.
4. Repeat steps 2 and 3 until the entire points are completely clustering.

2.6.3 Hierarchical Clustering Algorithm

Hierarchical clustering is a method of cluster analysis that seeks to build a hierarchy of clusters without having a fixed number of clusters as shown in the algorithm (2.3). This method follows two approaches based on the direction of progress, i.e., whether it is the top-down or bottom-up flow of creating clusters [103].

These two approaches are Divisive and Agglomerative Approaches [104].

1. Divisive: This is a top-down approach, where it initially considers the entire data as one group, and then iteratively splits the data into subgroups. If the number of a hierarchical clustering algorithm is known, then the process of division stops once the number of clusters is achieved. Else, the process stops when the data can be no more split, which means the subgroup obtained from the current iteration is the same as the one obtained from the previous iteration (one can also consider that the division stops when each data point is a cluster.
2. Agglomerative: It is a bottom-up approach that relies on the merging of clusters. Initially, the data is split into m singleton clusters (where the value of m is the number of samples/data points). Two clusters are merged into one iteratively thus reducing the number of clusters in every iteration. This process of merging clusters stops when all clusters have been merged into one or the number of desired clusters

is achieved. The basic algorithm of Agglomerative is straightforward. Compute the proximity matrix, let each data point be a cluster, and repeat: merge the two closest clusters until only a single cluster remains [105].

2.6.4 Spectral Clustering Algorithm

Algorithm 2.3 Spectral clustering Algorithm [108] is a technique with roots in graph theory, where the approach is used to identify communities of nodes in a graph based on the edges connecting them and the data points are treated as nodes of a graph and data points are represent as nodes of a joined graph. Main steps to perform a spectral clustering [106-107]:

- Create a similarity graph between our N objects to cluster.
- Compute the first k eigenvectors of its Laplacian matrix to define a feature vector for each object.
- Run k-means on these features to separate objects into k classes.

Algorithm (2.3): Spectral clustering Technique

Algorithm (2.3): Spectral clustering Technique	
Input	
	Given a data set to be clustered.
Output	
	Clusters of data set
Process	
1.	Start
2.	Form a distance matrix
3.	Transform the distance matrix into an affinity matrix A
4.	Compute the degree matrix D and the Laplacian Matrix L = D – A.
5.	Find the eigenvalues and eigenvectors of L.
6	With the eigenvectors of k largest eigenvalues computed from the previous step form a matrix.
7	Normalize the vectors.
8	Cluster the sensor nodes in k-dimensional space.
End.	

2.6.5 K-Means Algorithm

K-Means Clustering is considered as an automated machine learning that is used in many approaches in data science [109]. The algorithm first selects several categories randomly to use them as centroids and configures their center points. k-means algorithm is based mainly on Euclidian distances and it is calculating the distance between points and group centers. K-Means uses squared Euclidean distance as the similarity measure for cluster membership by an equation in. K means is an iterative clustering algorithm that aims to find local maxima in each iteration by the following 5 steps as shown in figure 2.12 [110-112]:

1. Specify the desired number of clusters K: Let us choose k=2 for these 5 data points in 2-D space.
2. Randomly assign each data point to a cluster.
3. Compute cluster centroids.
4. Re-assign each point to the closest cluster centroid.
6. Re-compute cluster centroids.
7. Repeat steps 4 and 5 until no improvements are possible.

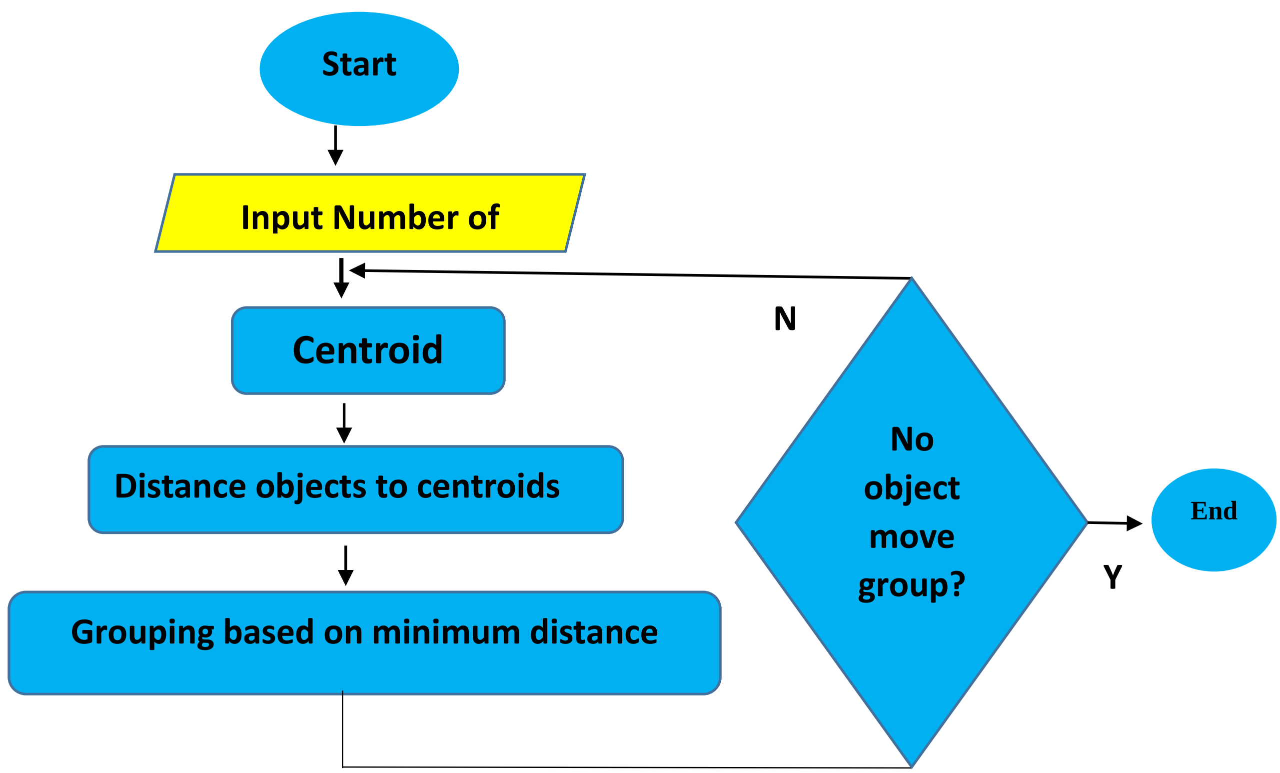


Figure 2.12 K-means algorithm Steps

Algorithm (2.4): K-means clustering

Algorithm (2.5): K-mean clustering Technique	
Input	Given a data set to be clustered.
Output	Clusters of data set
Process	
1. Start	
2. Specify the desired number of clusters K	
3. Randomly assign each data point to a cluster.	
4. Compute cluster centroids.	
5. Assign each data point to their closest centroid clusters.	
6. Re-compute cluster centroid and place a new centroid of each cluster.	
7. Repeat the steps 1 to 3 to get the new closest centroid of each cluster.	
8. If any reassignment occurs, then go to step-4 else go to End.	
End.	

2.7 Meta-Heuristic Algorithms in WSNs

Meta-heuristics is a class of optimizing algorithms to solve difficult optimization problems. Common optimization algorithms are applied in WSNs included: ACO, PSO, GA, ABC, and Firefly Algorithm (FA). A general procedure for a meta-heuristic algorithm can be defined as follows: Initializing, Evaluating, Generating, and Looping [113-118].

PSO is the simplest, nature-inspired, computationally efficient metaheuristic optimization technique. The main goal of using the PSO is to find out the best possible position of the particle which gives the best valuation of the fitness function. During each generation, the velocity of every particle is modified based on the current velocity, the preceding local best, and the global best position of the particle. Updated velocity and position of the particle can be calculated based on these values.

PSO consists of a swarm of particles of a predefined size (NP). Each particle Pi , $1 \leq i \leq NP$ provides a complete solution to a multidimensional optimization problem. The dimension D of all the particles is equal. The particle Pi has position X id, $1 \leq d \leq D$, and velocity V id in the dth dimension of the multidimensional space. Let the i th particle Pi of the population be represented by :

$$P_i = [X_{i,1}, X_{i,2}, X_{i,3}, \ldots \ldots . . X_{i,D}] \qquad (2.4)$$

A fitness function is used to evaluate each particle to judge its quality for the solution to the problem. In order to achieve the global best position, the particle Pi follows its own best, i.e., the personal best called Pbesti and the global best called Gbest to update its own velocity and position. In implementations of PSO, each particle modifies its position using information as: its current position, its current velocity, the distance between the current position and best solution individually found, and the distance between the current position and the best solution found by its neighborhood. Depending on the problem to be solved, a fitness function is used to assess the quality of the PSO solution. The PSO equations are given as follows [32]:

$$v_i^{new} = v_i^{old} + c1 * rand1(\,)(p_{best} - x_i) + c2 * rand1(\,) * (gbest - Xi) \qquad (2.5)$$

$$x_i^{new} = x_i^{old} + v_i^{new} \qquad (2.6)$$

Where...

V_i represent the velocity of particle i in dimension d.

X_i represent the position of particle i in dimension d.

C1, c2 are positive constants.

rand1 and rand2are random numbers.

p_{best} is the best position reached so far by the particle.

gbest is the global best position reached by the neighborhood.

In each iteration, its velocity V_{id} and position X_{id} in the dimension D are updated using the following equations, respectively.

The update process is iteratively repeated until either an acceptable G_{best} is reached or a fixed number of iterations, say t_{max} is reached.

$$P_{bestj} = \begin{cases} p_j & if\ (Fitness\ (p_j) < Fitness\ (P_{bestj}) \\ P_{bestj} & otherwise \end{cases} \qquad (2.7)$$

$$PG_{bestj} = \begin{cases} p_j & if\ (Fitness\ (p_j) < Fitness\ (G_{bestj}) \\ G_{bestj} & otherwise \end{cases} \qquad (2.8)$$

The pseudo-code of the original PSO in algorithm (2.4).

Algorithm (2.4) PSO Algorithm
1. Initialize the population randomly
2. While (Population Size)
3. {
4. Loop
5. Calculate fitness
6. If fitness value is better from the best fitness value (pbest) in history then
7. Update pbest with the new pbest
8. End loop
9. Select the particle with the best fitness value from all particles as gbest on all the receivin antennas
10. While maximum iterations
11. {
12. For each particle
13. Calculate particle velocity by equation (2.5)
14. Update particle position according to equation (2.6) 15.
16. Next
17. }
18. }
End.

The velocity of PSO should not exceed a maximum value, V_{max}, to avoid an unstable state. The performance of PSO search can suffer if the maximum velocity is inappropriately set. If it is too high, the particles can fly past optimal solutions, and if it is too low they can get stuck in local minima. Other models of the velocity equation. The PSO algorithm is straightforward. First, initialize particles with random position and velocity vectors. For each particle: evaluate the fitness and if it is better than the best individual fitness then updates it. After that, update the best global fitness. Then obtain the new velocity and position for each particle. This procedure is repeated for a number of iterations or until convergence is beyond a certain limit.

The velocity in PSO represent each particle and the previous best location saved by the particle memory [118]. This section, present an overview of the PSO Algorithm. PSO combines local and global search methods depends on obtaining a number of particles in the search space and communicating with their neighborhood to find the best solution. Depending on the problem to be solved, a fitness function is used to find the quality goal [119]

The key goal of using the PSO algorithm is to find the best location of a particle that provides the best valuation of the fitness function in order to change the velocity of each particle based on the current velocity. Then, updates the previous local best (p_{best}) position and global best (g_{best}) position of the particle. Then updates the velocity and position of particles [120].

PSO is the best way to find the maximum or minimum of a special function on a multidimensional vector space. Each particle has to maintain its position P_{best} known as the local best position and the g_{best} known as the global best position among all the particles. To improve the performance of PSO, researchers modified the PSO in different ways [121].

The operation of PSO is better than GA in all three parameters. PSO is best than other optimization algorithms. Compared with GA; PSO is easy to implement and used few parameters and could find better solutions when compared to GA [122].

2.8 Energy Consumption Model

In the existing system, the emphasis was mainly on the design, development, and implementation of a network algorithm of high energy-efficiency wireless sensors that form groups containing nodes driven by energy. There is a wide variety of differentiated nodes as homogeneous and heterogeneous sensors capable of collecting accurate information in all types of environments, distant or dangerous. Basically, these sensor nodes work with a DC source that has a low capacity or can be set so that you can't see the replacement of your power source. In general, nodes are implemented ad hoc. The energy is required for the transmitter and the receiver.

In WSNs, most of the energy is dissipated in the process of data transmission. The total energy consumption of a network consists of the energy consumed by non-CH, intermediate and CH nodes for data aggregation and transmission. Figure 3.13 shows the radio energy dissipation model for WSNs. It is a simple model for radio hardware energy dissipation, where the transceiver dissipates energy to run the radio electronics and the power amplifier [14].

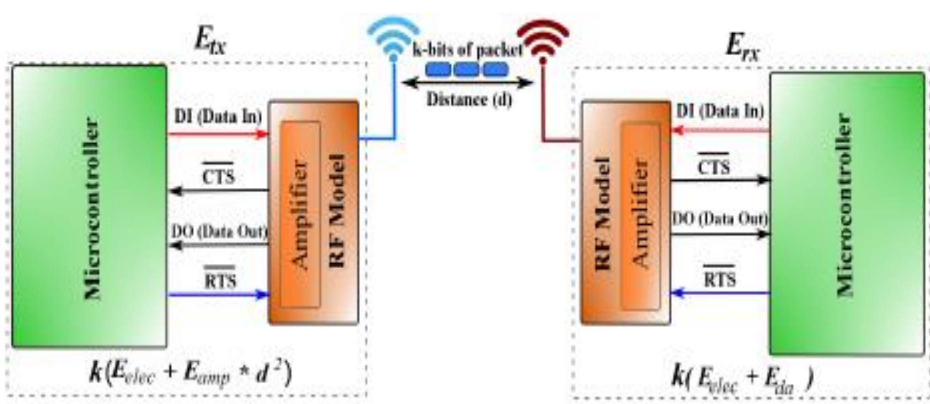


Figure 3.13 The wireless communication power model.

The transmitter utilizes its energy to operate the radio electronics and the amplifier and the receiver utilize its energy to operate the radio electronics. SN wastes its energy based on the number of bits to be transferred through the distance. If the distance d is greater than the threshold distance d_0, the energy consumed by SN is directly to d^4 else energy consumed by SN is directly to d^2. The total amount of energy exhausted for transmission of the n bits' data over distance by each SN in the network field is given by the following equations.

The energy consumed in the model is given as follows [4] :

- To transmit k bits:

$$Etx(k,d) = kEelect + kE_{fs} \times d^2 \qquad (if\ d < do) \qquad (2.11)$$

- To receive k bits:

$$Erx(k,d) = kEelect + kE_{mp} \times d^4 \qquad (if\ d \geq do) \qquad (2.12)$$

Where: E_{elect} is the energy exhausted to operate the receiver or transmitter; ε_{amp} is the energy

Where ε_{fs} and ε_{mp} are the free space propagation (d^2 power loss) and the multipath fading (d^4 power loss) channel models, respectively. These values depend on the distance between transmitter and receiver, d_0 is a threshold value which can be calculated by using Equation 3.13

d_0 specifies the threshold transmission distance which is expressed by the following equation:

$$do = sqrt\ (E_{fs}/\ E_{mp}) \qquad (2.13)$$

And, energy consumed to receive n bits of data by the receiver circuit is expressed by

Another parameter that is also taken into consideration is the data aggregation which is performed by the CH to reduce the total amount of data sent. The data aggregation energy expenditure is set as EDA= 5 nJ/bit/message.

2.9 Performance Metrics for Evaluation

The quantitative metrics are used to measure and evaluate the performance of the simulated routing protocols. Different metrics are used in the simulation phases such as energy consumption, total energy consumption, First Dead Nodes (FDN), Half Dead Nodes (HDN), Last Dead (LDN), Number of Rounds, and Number of SNs. The performance measures that are used to evaluate the process include [123-127]:

1) Network Lifetime: is determined by the time elapsed between FND and LND in the network or lifetime is time spent until the death of all wireless sensor nodes in WSN. Network lifetime: It is considered as the time until message loss rate is above a given threshold. The more complete definition for the lifetime of the network is time to network partition [10]. Network partition occurs when there is a cut-set in the network. It will be introduced as a new metric, which will use energy variance:

Network lifetime = E – (U +a) (2.9)

where $U = \Sigma U_i / N$ (2.10)

E is the total initial energy at each node (full battery charge).

U_i is the average used energy.

N is the total number of nodes in the network.

a is expressed as $a^2 = (U_i - U)^2 / N$

2) Energy Consumption: The energy consumption is the sum of used energy of all the nodes in the network, where the used energy of a node is the sum of the energy used for communication, including transmitting (E_{tx}), receiving (E_{rx}). The total energy consumption is equivalent to the total number of packets sent in the network. The energy metric is taken as the average energy consumption for the network calculated through simulation time.

Energy consumption of the sensor nodes in the sensing field is classified into three types [130]:

- Non-CH nodes: gather, k-bits of data from the environment and transmit them to a next-hop node or direct to the CH node. The energy dispatched by a non-CH node (E_{non}−CH) can be calculated as:

  $E_{non}-CH = E_{Tx}(k,di)+E_{GPS}$ (2.14)

Where EGPS and di are the power dissipations in the global positioning system and distance between non-CH node and its CH node, respectively.

- CH nodes: collect and compress the data that comes from the non-CH nodes, and then forwards them to the BS. Hence, the total energy consumed by each CH node can be calculated using Equation 3.12, where M is the total number of sensor nodes that send their packets to the given CH node and di is the distance between the CH node and the BS:
  $E_{CH} = M(E_{Rx}(k)+E_{Tx}(k,di))+E_{GPS}$ (2.15)

- A hop node (intermediate node): consumed its energy while receiving, processing and transmitting of packets from other nodes. A hop node transmits and receives the information for L number of non-CH nodes. The energy consumption by a hop node Ehop can be calculated as:
  $E_{hop} = L(E_{Rx}(k)+E_{Tx}(k,d_{hop},CH))+E_{GPS}$ (2.15)

3) Stability: means time till the First sensor Node Dead. Network Stability is the time from the beginning of the network till the death of the first node (FND).

4) Packets to BS: This indicates the amount of data transmitted from CH, nodes to BS.

5) Throughput Ratio: Rate of data sent over the network. also, it is defined as the total number of packets successfully delivered at the BS. Network throughput: The end-to-end network throughput measures the number of packets per second received at the destination. It is considered here as an external measure of the effectiveness of a protocol.

6) Network delay: This performance metric is used to measure the average end-to-end delay of data packet transmission. The end-to-end delay implies the average time taken between a packet initially sent by the source, and the time for successfully receiving the message at the destination. It is defined as the average amount of time between the start of disseminating data and its arrival at a node interested in receiving the data.

Latency = Propagation Time + Transmission Time + Queuing Time + Processing Time

Where Propagation time = Distance / Propagation speed

Transmission time = Message size / Bandwidth

Chapter Three

Proposed System

3.1 Introduction

Sensor nodes are usually configured in a mesh network and send their data to the base station (BS) through intermediate nodes and cluster head (CH) nodes. The intermediate nodes are responsible for sensing the nearby environment and forwarding packets received from other nodes towards the BS. These nodes consume most energy during the receiving, processing and forwarding of packets from other nodes. Although WSNs are easy to set up, have low costs, and give good results in collecting information, they face a major challenge as they depend on the battery as the main source of energy. The proposed system helps to save energy and gives a longer life to the network.

This chapter indicates different techniques for deployment and clustering techniques. This chapter presents the most common techniques in CH selection and cluster formation. This chapter describes in detail the proposed system; 1. Propose a mathematical model to select an optimal number of clusters. 2. Propose a mathematical model to divide the interested area. 3. Propose a hybrid algorithm to select optimal CH. 4. Develop an optimal technique to cluster formation. 5. Propose an optimal approach to avoid selecting CH at Edge. 6. Propose an optimal approach to make SNs near BS join BS directly.

Due to challenges in the WSN field, and to reduce energy consumption, many studies present some recommendations for enhancing the performance of the WSNs via different algorithms including; improving sensor deployment techniques, improving clustering techniques, reducing energy consumption, improving cluster head selection techniques, improves data routing protocols. These challenges must be solved in order to achieve maximum energy saving and maximum advantage from the network. This study focused on energy consumption and develop a data routing protocol with efficient energy.

3.2 System Model

We consider a system composed of a number of sensor nodes that are deployed randomly in a large geographic area to monitor and record the physical conditions of the environment. These nodes are connected in a mesh network where the distances (di, j) between any two nodes are based on Euclidean geometry [128]:

$$D_{ij} = \sqrt{((x_i - x_j) + (y_i - y_j))^2} \qquad i, j = 1,2, 3\ldots N$$

Where N is the number of sensor nodes in the system model, and (xi, yi) is the location of each node in the given sensing field.

The sensing field is divided into subgroups using clustering methods, and each group has a different number of sensor nodes that connect to the CH node. All nodes have the same communication range and initial energy level. Each sensor node collects data from the environment and sends it to its CH node with a single hop or via intermediate nodes. The CH node then compresses the data and forwards them to the BS. The BS is fully powered and placed in the center of the sensing field and acts as a gateway between the sensor nodes and the end user. The proposed system work based on the following assumptions included SNs are randomly distributed in an environment of M*M square area. BS node has unlimited power. BS is located at the center of the interest of the area. Each SN has limited power. Each SN has a unique ID. Each SN computes its distance to the BS based on the Euclidian distance. Information is forward to others by neighbor nodes until they reach the BS. The CHs forward the data aggregated to the BS.

In the proposed system, the search area was reduced to select CHs using the area condition where the area close to the BS and the far area at the edge of the network were excluded from the search area. The proposed system reduces the time to search for the best node to choose CH and reduces energy expenditure by choosing the nodes with the least distance from BS. Also, choosing an ideal CH gives a longer life for the CHs and thus a longer life for the network, and this is reflected in the improvement of network performance.

The proposed System Phases can be shown in figure 3.1:

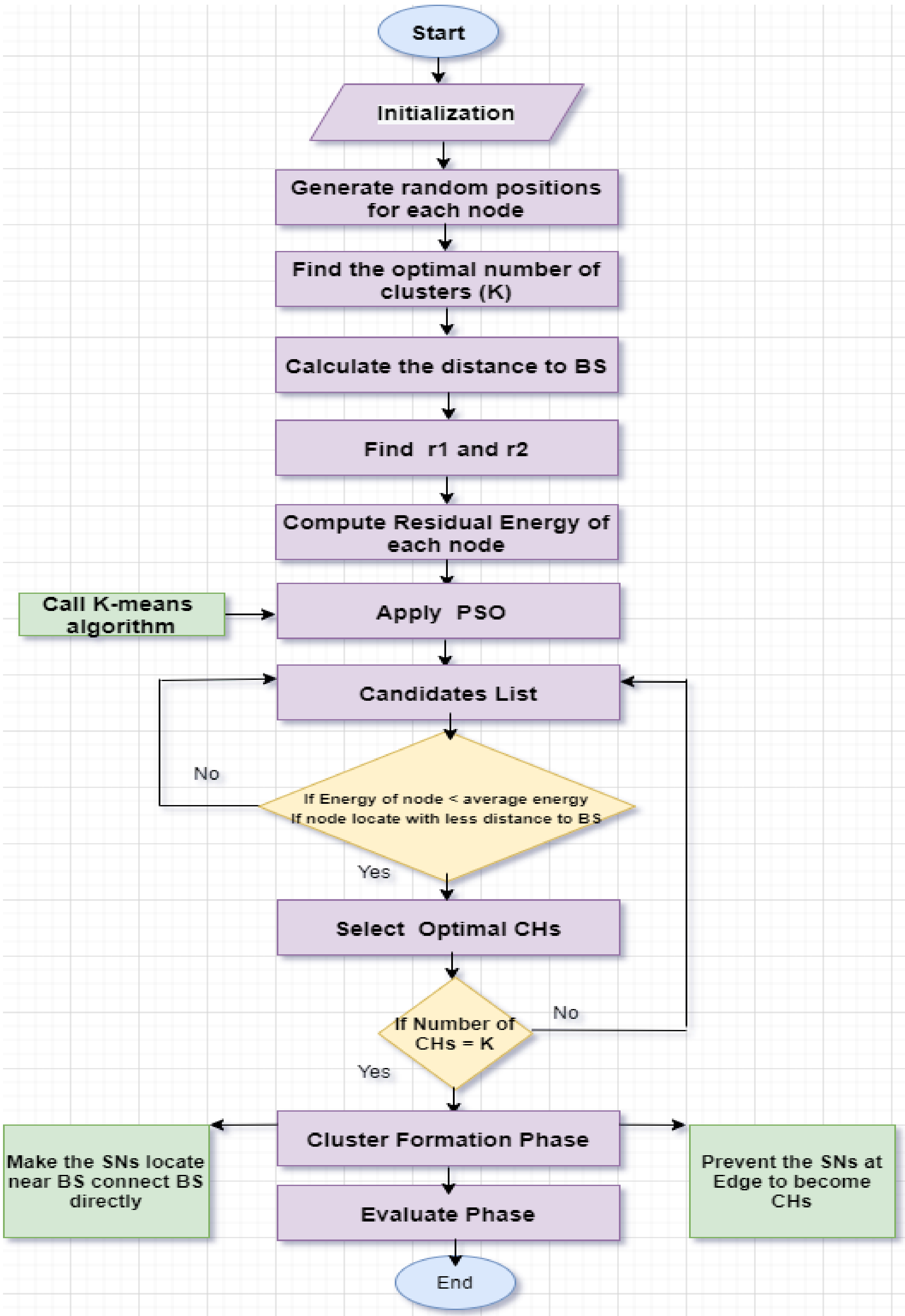


Figure 3.1 Flowchart of the Proposed System

Before a sensor network is deployed, it is important to determine how many sensors are required to achieve a certain level of coverage. The number of sensors required for maintaining k-coverage depends on the area of the monitored region, the probability that a node fails or powers off (to save energy), and the deployment strategy. The sensor's places are affecting the network coverage, connectivity, and reliability as well as other network performance metrics such as energy consumption, throughput, and delay. The major necessary stage in designing any new WSN is the SNs deployment. It powerfully influences the network performance in its effective communication and precise detection. The main challenges here are to minimize the number of deployed sensors and suitable the connectivity and coverage of the observing zone. In the first step in this thesis system, the deployment techniques are studied in order to select a suitable one for the WSN environment which gives better network performance.

A deterministic deployment is how many are required and where the sensors are placed and the placing of the sensors can be applied via controlling deployment. This process represents a careful planning process for the deployment of the sensors. The deterministic deployment of sensor nodes can be achieved based on the area of interest see section (2.5.1).

Randomly deploying the sensors via air is necessary because difficult locations with a number of sensors cannot be prearranged when the size of the network is great. In most WSNs applications sensors are deployed in a random manner. SNs deployment in Random means setting positions of WSN randomly in the area of interest. As mentioned in section (2.5.2).

The main limitation of the non-clustering method is that it does not reduce energy consumption and it causes end-to-end delay. Clustering can reduce overhead of the communication for both single and multi-hops networks and this can be reducing the number of access to the channel. Also, in clustering information can extracting and updating at the CHs. Clustering has many advantages such as grouping SNs, reducing the number of SNs that receiving data, aggregating data, and reducing the number of the transmission to BS. And then increase energy saving. Therefore, to solve this problem, the clustering technique is applied to achieve energy efficient clustering protocol. There are several models for clustering which were mentioned in section (2.6).

As mentioned in section (2.6.1), the major steps of the DBSCAN. This algorithm begins with a random point. And when this point has "*MinPts*" with "ϵ" cluster start build starts. Else the point is noise. continues until the cluster is finish. The steps of the DBSCAN algorithm are summarized in the following:

1. The algorithm starts with an arbitrary point that has not been visited and its neighborhood information is retrieved from the ϵ parameter.
2. If this point contains *MinPts* within the ϵ neighborhood, cluster formation starts. Otherwise, the point is labeled as noise.
3. If a point is found to be a core point, then the points within the ϵ neighborhood are also part of the cluster.
4. The above process continues until the density-connected cluster is completely found.
5. The process restarts with a new point that can be a part of a new cluster or labeled as noise.

The Gaussian Mixture Model is a model as it is a probability distribution and is also called Expectation-Maximization (EM) Clustering. GMMs are used for representing Normally Distributed data. The main steps of the GMM algorithm that are applied in WSNs shown in section (2.6.2).

As mentioned in (2.6.3), the key phases of the Hierarchical Clustering Algorithm are summarized in the algorithm (3.3). This algorithm starts by handling each one as an isolated cluster. Then, it repeated the following two steps:

1) define two clusters that are nearest together.

2) Combine the two greatest alike groups. And continues until all the groups are merged together.

As mentioned in section (2.6.4), The following are common steps of a spectral clustering algorithm. As shown spectral algorithm (3.4) that suitable for the WSN environment.

After studying clustering methods and the possibility of their compatibility with the environment of wireless sensor networks, we said that each of the above methods has advantages and disadvantages in using it with this type of network. Therefore, a compromise must be taken and the method that is most useful and most appropriate for the proposed work must be taken. Through the study, analysis, and comparison of the results by calculating the energy expenditure for each method and through the method of distributing the nodes, we found that the k-means method is the most acceptable, even if we found in some of the results that other methods are distinguished in certain circumstances.

3.3 K-Means Algorithm

As mentioned in section (2.6.5), K-mean is an algorithm that is needed to predict a number of clusters called K. The K-means guaranteed and group points in clusters with different sizes and shapes. K-means has disadvantages such as that is difficult to predict K-Value. Algorithm (3.1) and figure (3.2) show the general algorithm steps of the K-mean clustering algorithms that are suitable for the WSN environment.

Algorithm (3.5): K-means clustering Technique
Input
Number of SNs
Output
Clusters of SNs
Initialization
Set the number of the SN
Coverage area (100*100)
Process
1. Start
2. Input the number of clusters K.
3. Select centroid points randomly.
4. Put each SN to closest centroids.
5. Re-compute a new centroid of each cluster.
6. Repeat step 3.
7. End if no any change happens. Else go to step-4.
End.

3.3.1 Propose a Model to Find Optimal Number of Cluster

There are important parameters which are cause more energy consumption and decrease the quality of the performance of WSNs including the number of clusters, number of CHs, number of SNs, number of rounds, size of the field, initial energy of SNs. In the first part of a new modified algorithm, compute the number of clusters. Next, the K-mean algorithm is applied to divide the interest of an area into an optimal number of clusters. Also, prevent inputting the number of clusters according to the user's desire. A k-mean algorithm was created to work with the database environment, but we want to adapt this algorithm to work in the environment of the wireless sensor without changing the core of the algorithm. The k-mean algorithm begins by defining the number of clusters in the network.

Several previous types of research and studies relied on several techniques to select K. Some previous studies relied on probability in determining the number of clusters called probability P. Some previous studies relied on mathematical equations in determining the number of clusters. Common centroid clustering ways have drawbacks including empty clusters, input random K, and unbalanced CHs distribution.

K-Means Algorithm has some disadvantages. To exceed these disadvantages and to adapt the K-means algorithm for WSN, the following suggestions are proposed. A proposed approach is implemented in this thesis to select k based on the suggested WSN environment. K can be determined based on a set of factors that affect the environment of WSNs. The sensing (coverage) area of any SN can be represented by a circle with a radius R (sensing radius).

SN sensing the area indicated by equation (3.1).

$$A_s = R^2 * \pi \qquad (3.1)$$

Where A_s represent the area of the sensing node, and R, the sensing radius. Figure (3. 2) present the sensing (coverage) area of any Sensor can be represented by a circle with a radius R. Where r is communication range of the sensor.

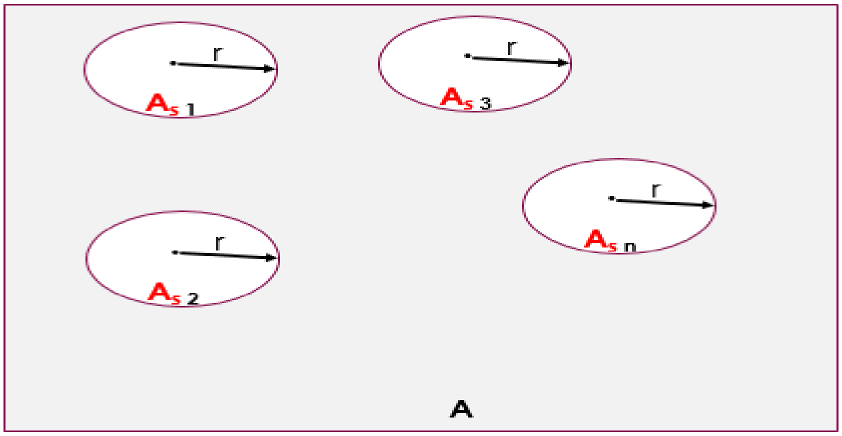


Figure 3.2 Compute sensing area for

To estimate the coverage probability, equation (3.2) is suggested.

$$P = \frac{A_s}{A} \qquad (3.2)$$

Where A is the area of interest, and P is the coverage probability. To select the optimal number of SNs (N) require to cover a certain area, equation (3.3) is developed.

$$N = A/A_s \qquad (3.3)$$

N is very important because deploying more sensor nodes leads to high costs but using fewer sensor nodes may cause bad coverage. The basic input to the K-means (K) that can be estimated using equation (3.4).

$$K = N * P \qquad (3.4)$$

The proposed mathematical model by applying equations (3.1), (3.2), (3.3), and (3.4) results in a modified K-mean algorithm. These modifications represent determining the number of clusters that are suitable for the WSN environment. The selection process is based on important factors especially the area of interest and the optimal number of SNs (N) require to cover a certain area. After selected the optimal number of clusters K, then entered this number when run K-mean algorithm. Figure (3.3) present the main steps for K-means Algorithm with the proposed mathematical model to determine optimal number of clusters K.

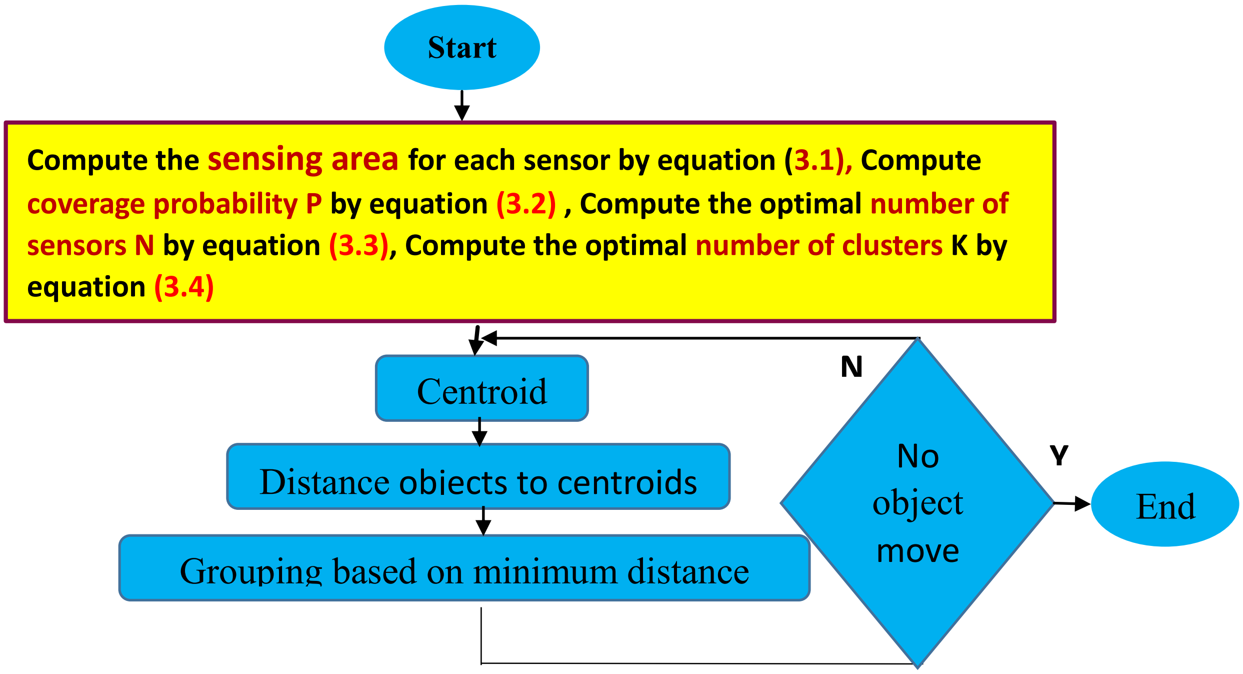


Figure 3.3 Apply K-means with proposed model to find optimal number of clusters k

3.4 Proposed Methodology

In this section, the Proposed key model (Proposed Approach) that can be used to implement this dissertation is stated. The schematic diagram to represent the general view of the proposed approach which can divide the interested area into three parts. First part represents the area near or around BS. Second part represents the suitable area that includes the candidate sensor nodes to become CHs. Third part represents the area that includes the sensor nodes located at the edge of the network. The following conditions that are divide the area into three part are:

- If the distance d between SN i and BS is less or equal to r1 then this node has no chance to become CH, it joins the BS directly as indicated in equation (1):

$$d \leq r1 \qquad (3.5)$$

- If the distance d between SN i and the BS is greater than r1 and less or equal to r2 then the node has a chance to become a CH as defined in equation (2):

$$r1 < d \leq r2 \qquad (3.6)$$

- If the distance d between SN i and BS is greater than r2 then the SN location is on the edge of the network and it has no chance to become CH as defined in equation (3):

$$d > r2 \qquad (3.7)$$

Where

d is the distance between SN i and BS. r1 = communication rang of sensor node. r2 is threshold value.

Figure 3.4 presents the red nodes are located near BS which are computed by r1. The green nodes are located in suitable area to select CHs which are computed by r2 minus r1. The black nodes indicate to the sensor nodes that located at the edge of the network.

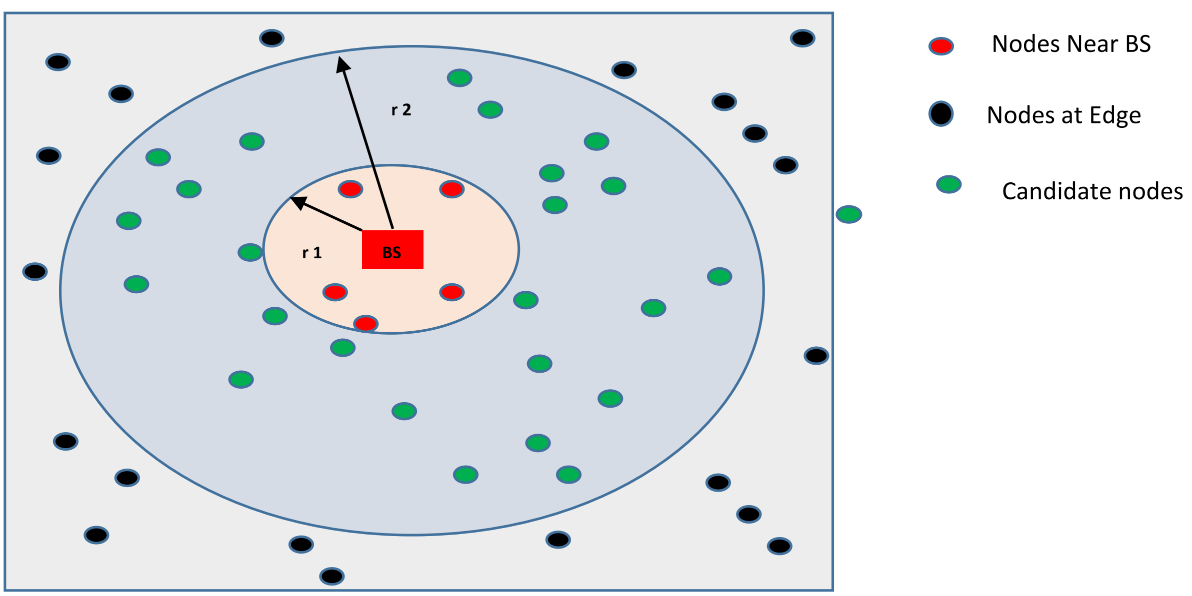


Figure 3.4 Proposed Methodology

Figure 3.5 explain compute r1 and r2 where L represent length. L / 2=half value.

r1 represents the transmission range (or distance d). r2 is represents L / 2 – r1.

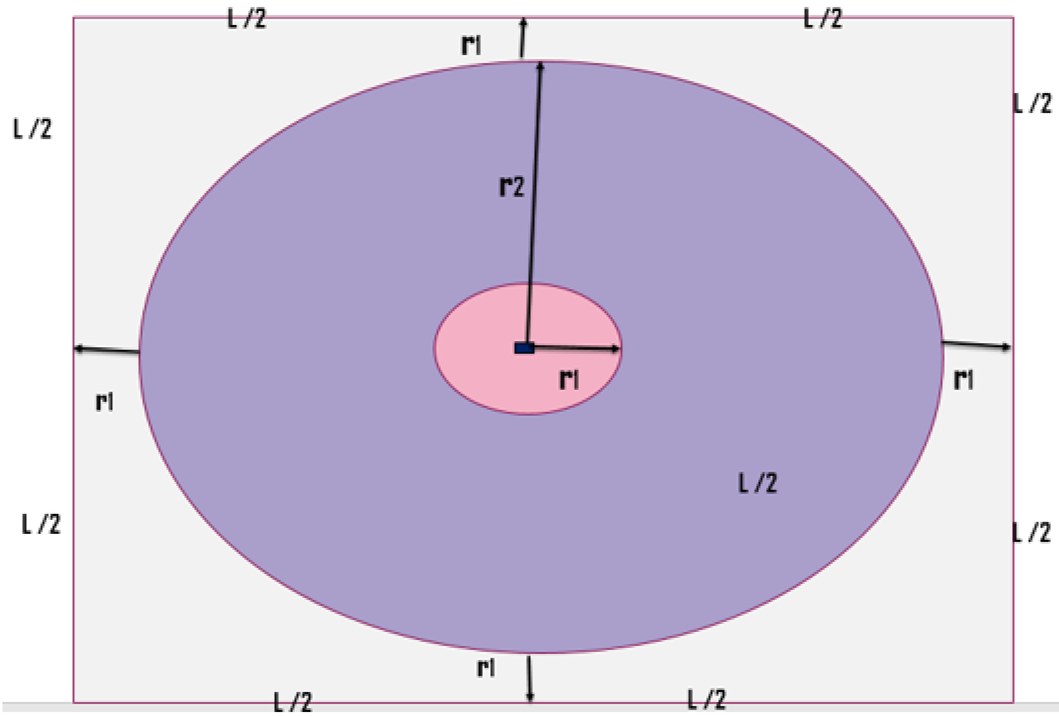


Figure 3.5 Explain compute r1 and r2

3.5 Proposed Hybrid Algorithm

Clustering mechanisms have four phases, namely the network deployment phase, neighbor discovery phase, CH selection, cluster formation phase, and communication phase. This thesis mainly focuses on CH selection and cluster formation. The CHs are not changed in every round; CH changes are dependent on the threshold value. If the threshold value is less than the other member, neighbor nodes, then re-clustering is occurring and changes CH.

As mentioned in section (2.4), the CH selection can be done randomly or deterministic technique. There are two techniques to select CHs probabilistically. The first way is CH selection in random techniques and the second way is select CHs using Hybrid algorithms. The random techniques of CH selection are done without any interference or control from the SNs or without any centralized from SNs to make to make a decision. For example, LEACH Protocol applied the threshold T(n) equation as mentioned in section (2.4.1).

The second way is the deterministic techniques which is use some important metrics such as residual energy, node degree, distance to BS, and node centrality. deterministic techniques can be categories into Weight based and heuristic-based clustering algorithms as mentioned in section (2.4.2). For example, CH selection based weight applied the equation (2.3) as mentioned in section (2.4.2.1).

Meta-heuristics represent a category of promising algorithms to solve difficult optimization problems. Many algorithms used for the optimization goals such as GA, ACO, and PSO. As mentioned in section (2.4.2.2) and in section (2.7).

Critical problem is to find power efficient route between source and destination nodes or in other words, to find optimized energy consumption in the WSN using routing-based on clustering protocols via how to select suitable CHs, how to build clusters, and how transmission packets from source to destination efficiently with fewer amount of energy consumption. Increasing the lifetime of a sensor network is one of the most important research works for researchers in this field.

The literature on CH selection algorithms infers that in order to prolong the network lifetime, appropriate CHs need to be selected among the network nodes. The number of data transmissions to BS is increase if the number of CHs is more, and this will increase the energy consumption of the network. If the number of CHs is very few, this will increase the intra-cluster communication distances and the energy consumption also increases. So, require to select the smallest and enough number of CHs to reduce energy consumption.

One of the ways in which we can increase the lifetime of the sensor network is by optimizing the CH selection. The unsuitable selection of CHs may lead to the death of the CHs which weakens the performance of the network. Therefore, the proper selection of CHs becomes important for the energy conservation of sensor nodes and to maximize the lifetime of the network. CH selection plays a very important role in ensuring a longer network lifetime for a WSN. Many routing algorithms have been designed that consider more than one factor of sensor node such as residual energy, number of sensors present in each sensor, probability to become CH, and to ensure a longer network lifetime.

In proposed Algorithm, the process of searching for candidates to be CH in all interested areas is based on the PSO algorithm with a K-mean algorithm and the CH selection process based on the residual energy level, the distance between SNs and CH, and between CH and BS, and node centrality. The operation of the proposed scheme is composed of two major phases: set-up phase and steady-state phase.

• Set-up phase: after the sensor nodes are deployed in the sensing field and assigned with the unique ID numbers. The BS sends hello message to discover all nodes that are located in the sensing field. Sensor nodes receive the BS message and send a response message back to the BS. The message contains a unique ID number and positional information of each node. The BS gets the sensor nodes information and broadcasts the routing information table to all nodes in the sensing field that are related to it and then, the tree-based clustering is created. Based on the received information from the BS, each node knows the length of the path and the number of hops to the BS through the assigned CH node. Based on these steps, the nodes and BS can communicate and share the data with each other.

• Steady-state phase: the performance of any transmission is negatively affected by the transmission distance. Therefore, selecting CH with a shorter transmission distance leads the lower energy consumption.

The process of data aggregation within the different clusters of the network Compression of the sensed information that is being sensed by the sensor node into its different CH within the cluster only and Transmission of the compressed data to the sink via different CHs.

With the effective scheme of particle encoding and fitness function, the proposed PSO algorithm is implemented for reducing energy consumption and improving the lifetime of the network.

As mentioned in section (2.7.1) PSO is the simplest, nature-inspired, computationally efficient metaheuristic optimization technique. The main goal of using the PSO is to find out the best possible position of the particle which gives the best valuation of the fitness function. During each generation, the velocity of every particle is modified based on the current velocity, the preceding local best, and the global best position of the particle. Updated velocity and position of the particle can be calculated based on these values.

PSO consists of a swarm of particles of a predefined size (NP). Each particle Pi , 1≤ i ≤ NP provides a complete solution to a multidimensional optimization problem. The dimension D of all the particles is equal. The particle Pi has position X id, 1 ≤ d ≤ D, and velocity V id in the dth dimension of the multidimensional space. Let the i th particle Pi of the population be represented by :

$$P_i = [\, X_{i,1}, X_{i,2}, X_{i,3}, \dots \dots .. X_{i,D}] \qquad (3.8)$$

A fitness function is used to evaluate each particle to judge its quality for the solution to the problem. In order to achieve the global best position, the particle Pi follows its own best, i.e., the personal best called Pbesti and the global best called Gbest to update its own velocity and position. In implementations of PSO, each particle modifies its position using information as: its current position, its current velocity, the distance between the current position and best solution individually found, and the distance between the current position and the best solution found by its neighborhood. Depending on the problem to be solved, a fitness function is used to assess the quality of the PSO solution. The PSO equations (2.5) and (2.6). In each iteration, its velocity V_i and position X_i in the dimension D are updated using the equations (2.7) and (2.8).

The velocity of PSO should not exceed a maximum value, V_{max}, to avoid an unstable state. The performance of PSO search can suffer if the maximum velocity is inappropriately set. If it is too high, the particles can fly past optimal solutions, and if it is too low they can get stuck in local minima. Other models of the velocity equation. The PSO algorithm is straightforward. First, initialize particles with random position and velocity vectors. For each particle: evaluate the fitness and if it is better than the best individual fitness then updates it. After that, update the best global fitness. Then obtain the new velocity and position for each particle. This procedure is repeated for a number of iterations or until convergence is beyond a certain limit.

Figure 3.6 presents the main steps for applied the PSO algorithm in WSNs environment to find the optimal CHs and suitable cluster formation.

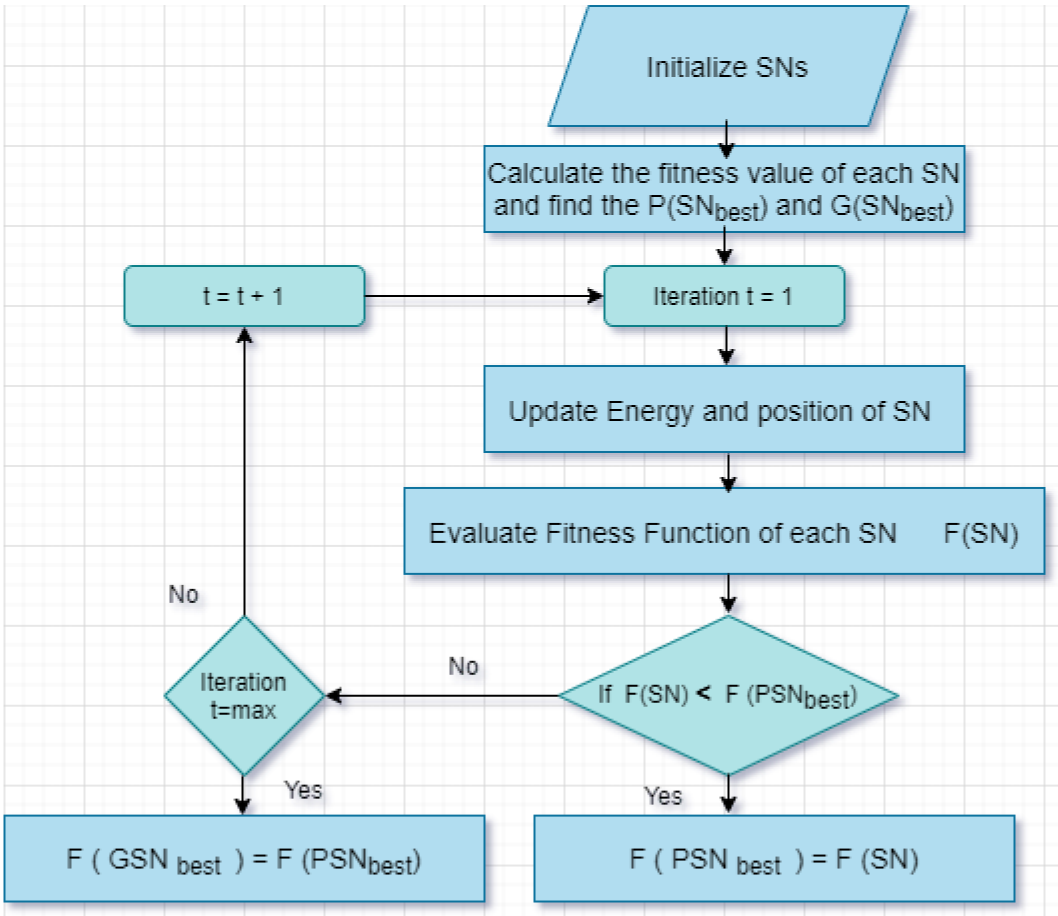


Figure 3.6 Flowchart of applied PSO in WSN

We consider number of birds as sensor nodes (SNs) and consider all birds (SNs) are closed to each other and are placed on interest of area. The objective of the PSO algorithm is to minimum the fitness function in order to find optimal CH. The proposed fitness function is given in Equation 3.9.

$$F = \begin{cases} SN \;\; become\ CH\ if\ SN\ has\ \max(Energy) \& \min(distance) \\ Normal \;\; SNs \qquad\qquad otherwise \end{cases} \qquad (3.9)$$

Where

F represents the fitness function to select the optimal CH node.

SN represents the sensor node.

CH is a cluster head.

Max energy is the highest residual energy for each SN.

distance represents less distance between the candidate SN and BS.

t represents iteration.

F (SN) represents the fitness function of the sensor node.

P (SN_{best}) represents the local best SN candidate with high energy and less distance.

G (SN_{best}) represents the global best SN candidate with high energy and less distance.

The following main steps of the proposed PSO-K algorithm.

Step 1: Find Optimal K by equation (3.4).

Step 3: Applied PSO at the BS to select CHs.
Step 4: Applies the K-means algorithm to partition the network into k clusters.

Step 5: PSO create list of candidates that are have energy residual and less distance to BS.

Step 6: PSO selects optimal CHs based on residual energy and distance. And applied equation (3.6).

Step 7: SNs placed at the edge of the network cannot become CHs.
Step 8: After selecting CHs, clusters are formed based on the optimal number of clusters (K) and the applied Euclidian distance.
Step 9: SNs join the nearest CH except for SNs near BS and connect to BS directly.
Phase 5: SNs location is on the edge of the network has no chance to become CH by equation (3.7).

Phase 6: SNs near BS has no chance to become CH, it will have join the BS directly by equation (3.5).

PSO used to solve the WSN CH selection and gives promising results, developing a low computational and high performance clustering algorithm. Now, we present our proposed algorithm by use the particle representation for SNs and the velocity representation for energy. The main objective of our proposed WSN clustering algorithms is to group the SNs into optimal number of clusters by call K-mean in order to partition n nodes into k clusters, and find the optimal CHs. We propose a Hybrid PSO and K-means called (PSO-K) Algorithm to solve the energy consumption problem based on clustering. PSO-K algorithm consists of two main phases: the initialization phase and the transmission phase.

The proposed PSO-K algorithm based on a centralized clustering at the BS and consider that each SN knows its position. In order to join SNs to a cluster in cluster formation process, the BS, consider the energy level and the Euclidean distance between a sensor and selected CHs. The PSO-K protocol operates in rounds and each round starts with a setup phase at built of clusters, and followed by a steady-state phase. During the setup phase, SNs send information about their current levels of energy and their positions to the BS. And the BS calculates the average energy level of all SNs. Only SN has energy level highest than the average and less distance to BS are suitable to be candidates for a CH for the next round.

In proposed (PSO-K) algorithm, the K-means clustering algorithm is used to divide the network based on the proposed model to determine the optimal number of clusters K. The BS will select SNs as CHs that equal to K, then other SNs joins its nearest CH expect the SNs near BS which are communicate to BS directly. A new CH is chosen as the middle of the cluster and prevent the SNs at the edge of the network become CH. These steps are repeated until no new CH is selected.

Figure 3.7 shown the PSO is applied for select CHs in the network. In this phase, each SN in the network send its information such as residual energy and their location in the cluster and the distance to the BS. PSO call K-mean in order to select center points and to select set of SNs as candidates which are placed in the center of the network. To find best CHs, proposed algorithm using PSO is runs at the BS and the optimal CHs depend on residual energy and distance. Prevent select SNs at edge of the network as CH by select CH from the set of the candidates in the center of the network. PSO will search the space of all possible CHs which save energy and provide best solution.

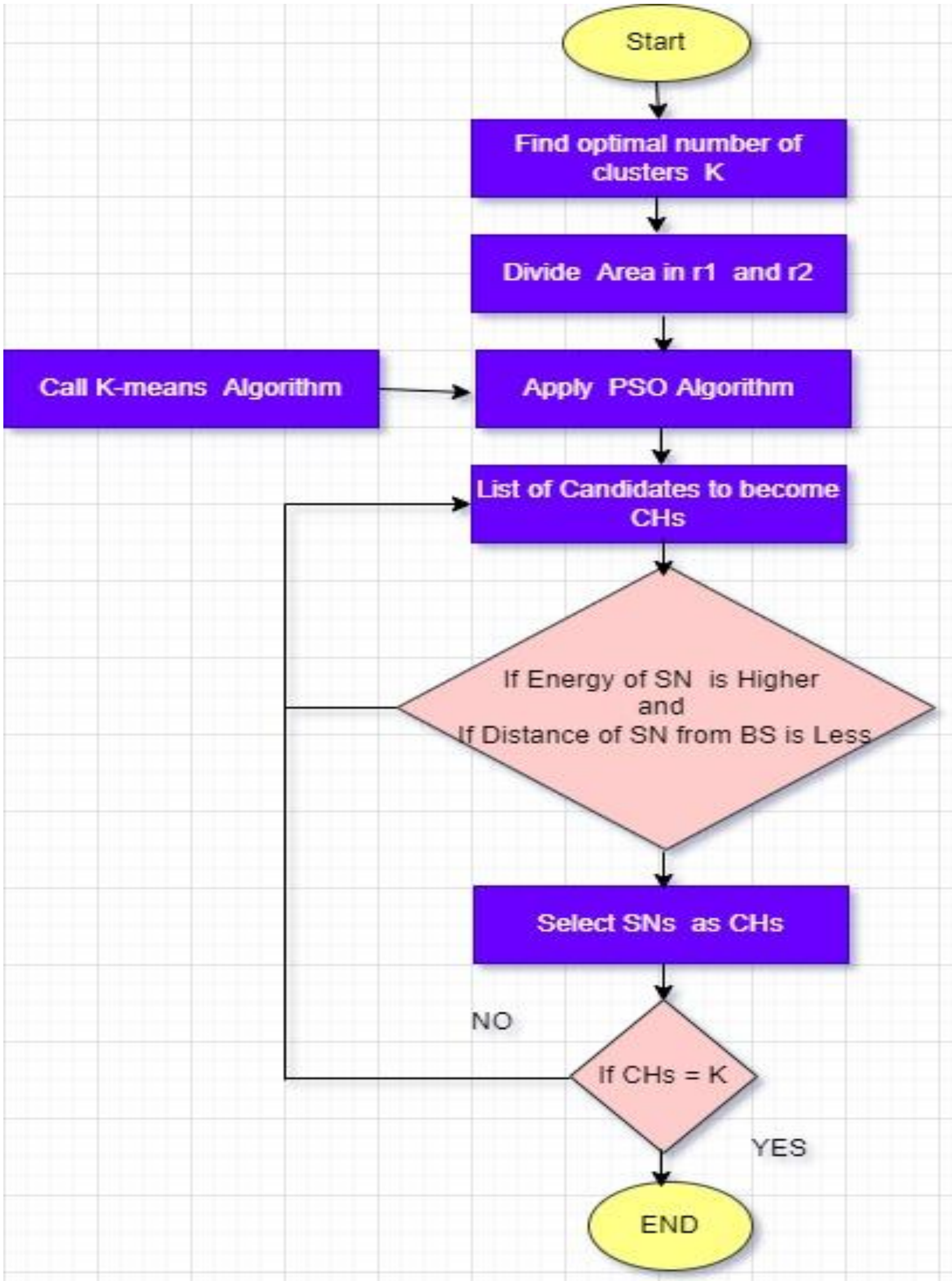


Figure 3.7 Flowchart of Proposed PSO-K Algorithm

3.6 CH Selection problem at the edge of the network

One of the main challenges in routing protocols based on clustering is the distribution of the CH is not uniform and all SNs have the same chance to become CH without considering the SN position. If SN is located at the edge of the network and chosen as CH may cause more energy consumption, for example, LEACH protocol [14].

As shown in figure 3.8 present the edge problem in LEACH protocol. Some nodes were chosen to be CH that they lose their energy quickly, and lead cut the communication. Therefore, will not serve the network optimally.

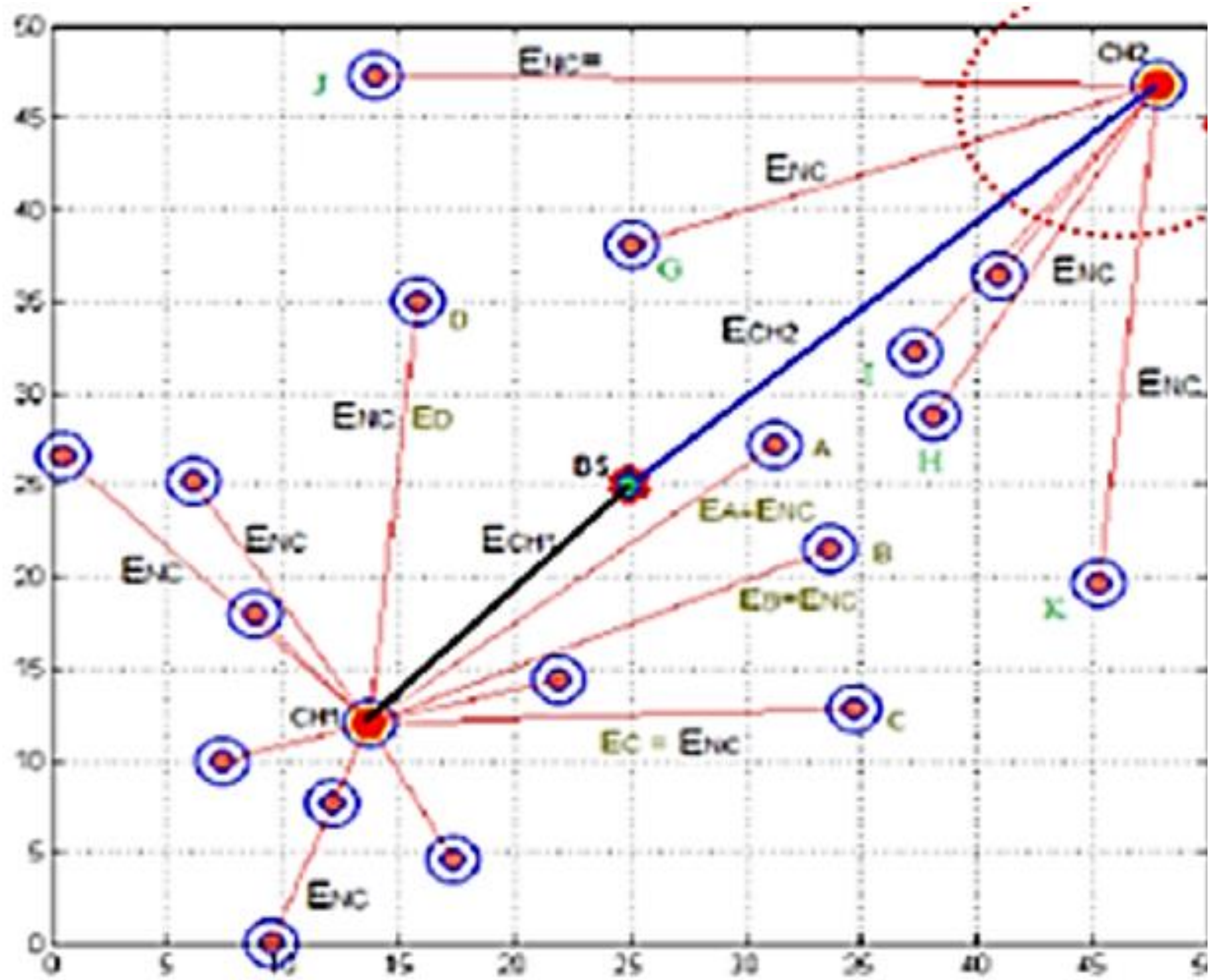


Figure 3.8 Nodes at edge Problem in LEACH Protocol

For the purpose of solving the problem in the previous section, we will avoid selecting a CH at the edges of the network. In Mathematics, the Euclidean distance is applied to measure the distance between two points or the straight line distance.

The problem solved through applied new model by equation (3.7) and used K-mean algorithm to select center points and generate a list from sensor nodes as candidates to become CH. So, all SNs selected by the PSO-K algorithm located near the center and far from edge of the network. As show figure 3.9.

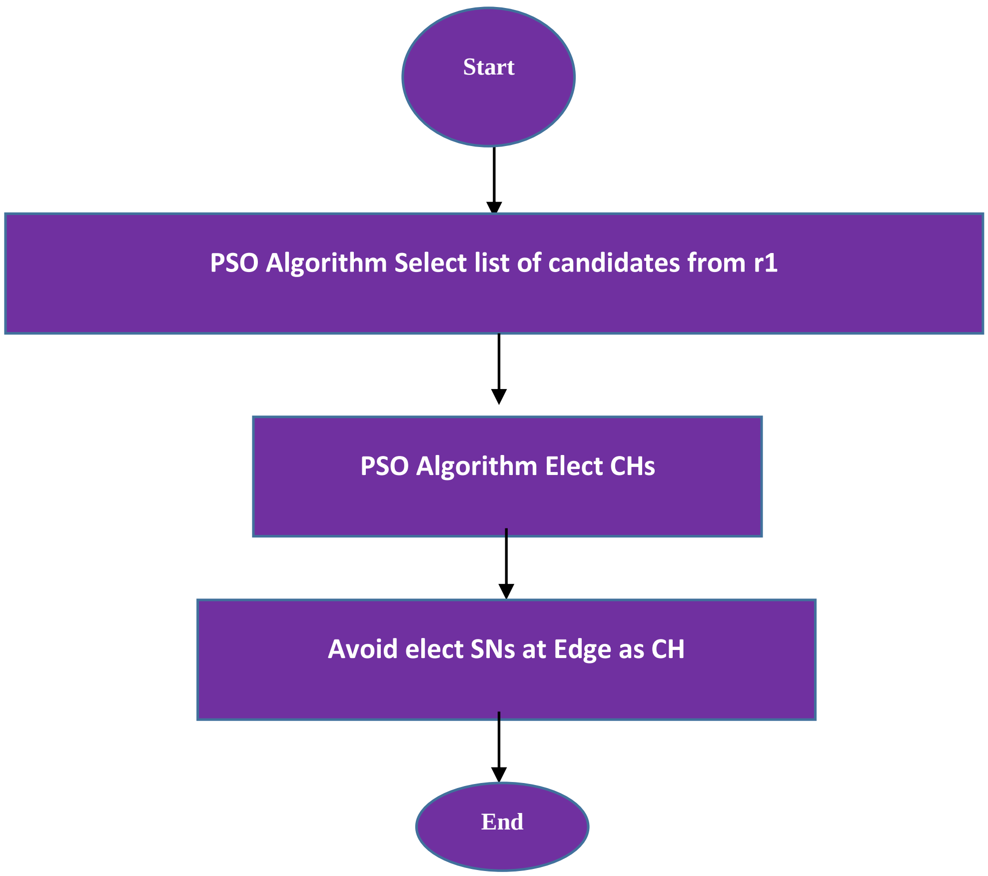


Figure 3.9 Flowchart for Solve Edge problem

3.7 Cluster Formation Techniques

After complete CHs election, the clusters are formed based on the distance between SNs and CH. Classically the SN joins to its nearest CH. This is critical problems in LEACH protocol are generated due the forms process for clusters based on the received signal strength. The randomly situated CH may lead to more energy consumption based on the distance between the CH and BS. And select CHs randomly may form more clusters that leads more energy consumption or less clusters leads bad coverage for field.

3.7.1 Proposed optimal method to Cluster Formation

PSO-K Algorithm applied to solve number of clusters that are suitable for particular environment using optimal K with distance factor using Euclidean distance. As shown the figure 3.10.

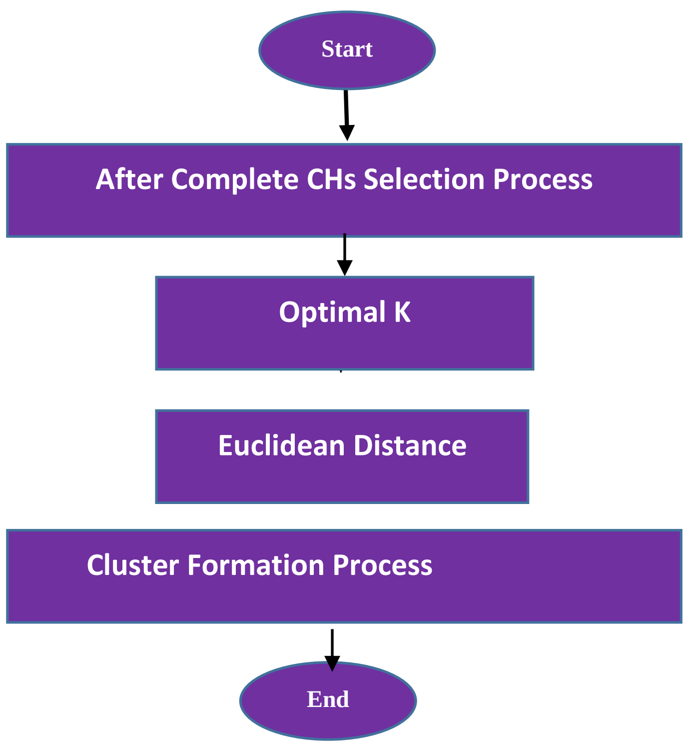


Figure 3.10 Build the clusters in PSO-K Algorithm

3.8 Sensor Nodes near Base Station Problem

There are several problems related to cluster formation that caused more energy consumption. One of these problems is the normal SNs join to nearest CH. This is a critical problem in LEACH protocol due data will be sent to its CH while the distance between these SNs and the BS is less than the distance between these SNs and their own CH.

The other problem that occurs after the network formation process, this problem causes the nodes to drain energy, and the reason is the link of the node with the head of a cluster and the distance of this link is longer than the link of the nodes with the base station and close to it. As shown figures 3.11 and 3.12.

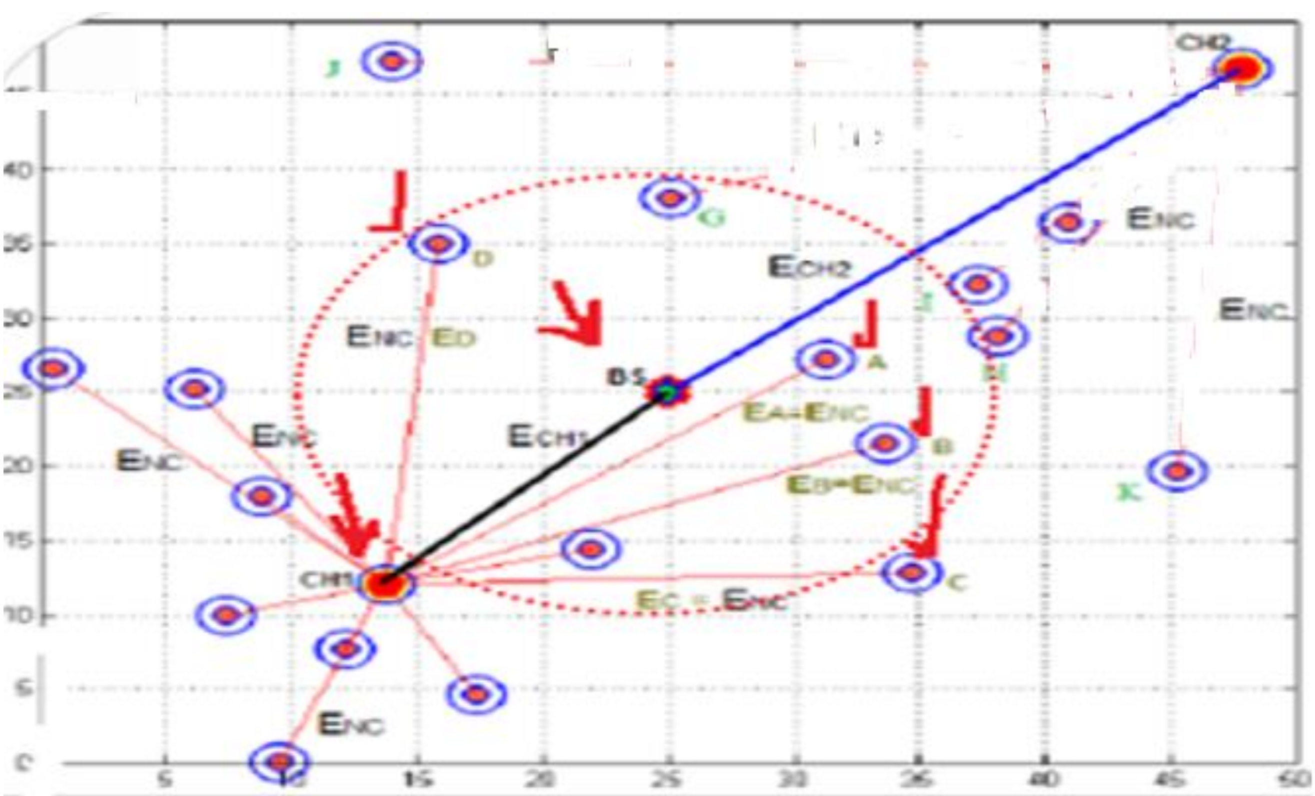


Figure 3.11 display SNs near BS

As see from figure 3.11 and 3.12. SNs join CH while the distance between these SNs and the BS is less than the distance between these SNs and CH. PSO-K algorithm solved this problem using a new model applied equation (3.5). So, the SN joins with the nearest CH, if the distance between the SNs and the CH is less than the distance between that SNs and the BS and data will be transmitted to CH.

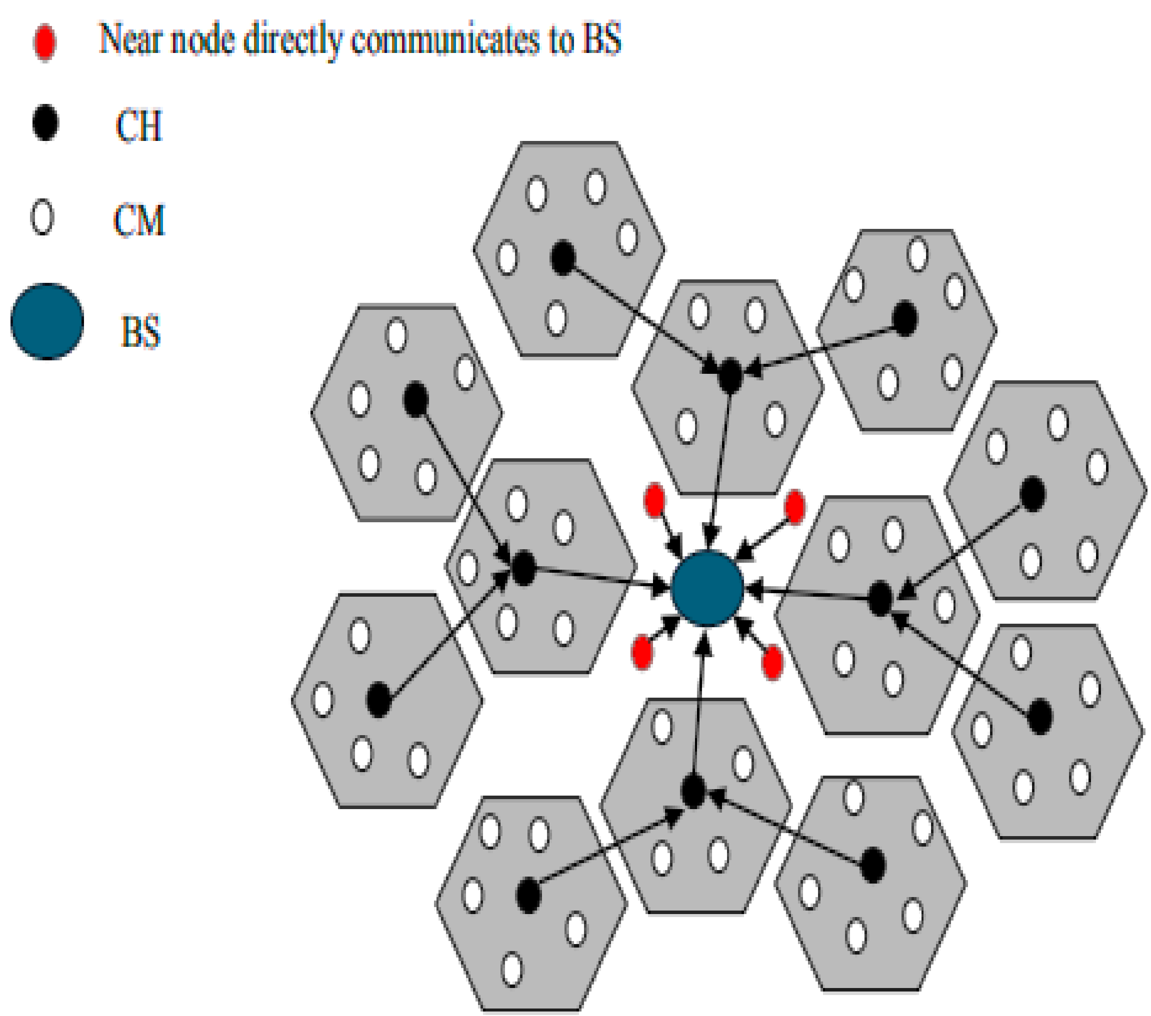


Figure 3.12 describe nodes near BS Problem

Chapter Four

Simulation Results and Performance Evaluation

4.1 Introduction

The WSN's performance in terms of an average lifetime has been studied by developing a MATLAB code that simulates all previous equations in detail. This chapter is divided into several sections; A brief introduction in the following by Assumptions and Parameters in the first stage, and the second stage contains the simulation process and the programs used for simulation, evaluating and comparing the performance of WSNs for several deployment techniques. In the third stage, study and evaluate the effect of clustering techniques on the system and compare it with the proposed technique developed to extend the lifetime of WSN. In the fourth stage, determine the optimal number of clusters via a new mathematic model. In the five-stage, evaluating and comparing the performance of WSNs for different CH selection methods with a newly proposed technique. In the six-stage, evaluating and comparing the performance of WSNs for different cluster formation methods with a newly proposed technique. The seven-stage is related to the position of SN at the edge of the network which is selected as CH in some algorithms such as LEACH protocol. The eight-stage is related to the cluster formation process when SNs near BS join to CH even if they are nearest to BS.

This chapter includes the simulation results for the proposed system compared with different algorithms via some metrics such as average energy consumption, FDN, HDN, and LDN. These simulations were applied within the same environment where Area 100*100 or 200*200 or (N*M). The number of sensor nodes is 100, 200, ….,1000, 2000. The number of rounds is 100, 200, …, 1000, and 2000.

4.2 Result Layout

The proposed system model solves some problems in WSNs and decrease the energy consumption to enhance the performance and prolong lifetime of the network. Figure 4.1 shows a schematic diagram of all work and results achieved. The results of the work are divided into seven stages.

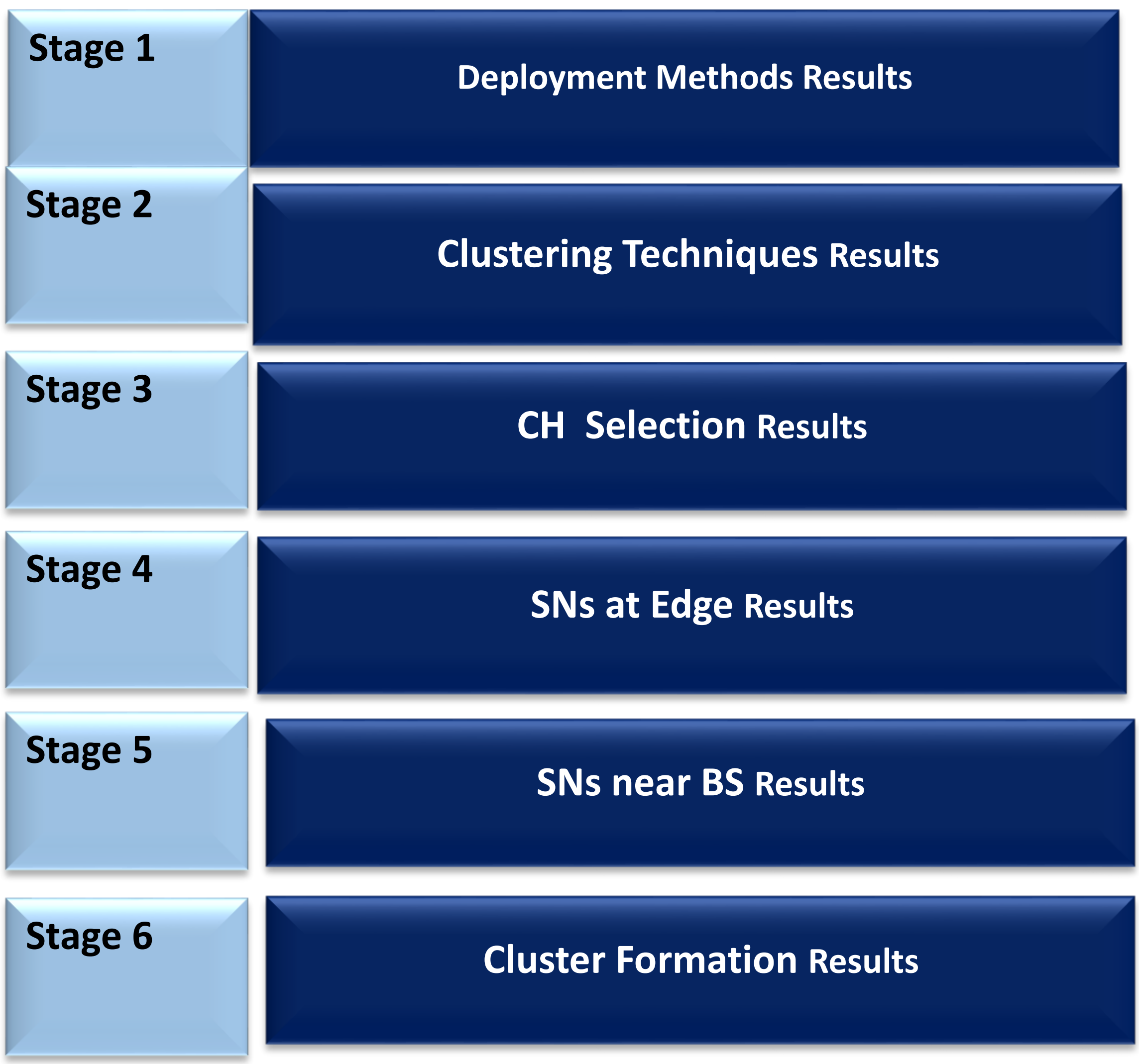


Figure 4.1 Result Stages of Proposed System Model

4.2.1 Simulation Assumptions

The beginning with the simulation results of the system model used the results of deployment results, clustering results and the proposed algorithm. This section will start with the basic assumptions for proposed network structure works with Node Numbers 100, 500, 1000, and 2000. The round numbers 100, 500, 1000, and 2000. Deployment Methods (randomly and regular), Clustering Techniques (K-mean, DB-SCAN, Hierarchical, spectral, and GMM). The CH Numbers 0.01, 0.02, 0.03, 0.04, 0.05. Area field 100*100, 200*200, or M*N. The BS is placed in the middle of the network. Each node contains a unique ID. The initial energy of all the sensor nodes counts as 0.1, 0.0.2, or NJ. BS has information about the location of the node and there are no communication problems between the nodes and their CHs and between nodes and BS. Assumed the communication between the nodes and the BS using the RF model. The proposed procedure was implemented in MATLAB. Table 4.1 shows simulation parameters.

Table 4.1 shows simulation parameters

Parameter	Value
Network Area	N x M m^2 such as 100*100
Number of Nodes	100, 500, 1000, 2000
BS	X,Y such as 50*50
Initial Energy (E_0)	0.1, 0.2, or N J
Energy dissipation: receiving (E_{amp})	0.0013 pJ/bit/m4
Energy dissipation: free space model (E_{fs})	10 pJ/bit/m2
Energy dissipation: power amplifier (E_{amp})	100 pJ/bit/m2
Energy dissipation: aggregation (EDA)	5 nJ/bit
Electronics energy (E_{elec}) per bit	50 nJ
Number of round	1000, 2000 or N rounds
Number of CH (Probability of number of CH)	0.01, 0.02 , 0.03, 0.04 and 0.05
Message size	4000 bits
r1	Transmission range
r2	Threshold

4.2.3 Guided User Interfaces (GUIs)

Guided User Interfaces (GUIs) in Figure 4.2 showing run and implement the comparison for deployment, and clustering techniques. Figure 4.3 show the main window to evaluate and compare the deployment, and clustering techniques. These GUIs are samples from several forms created by the Matlab simulator to show the processing results of simulation performance.

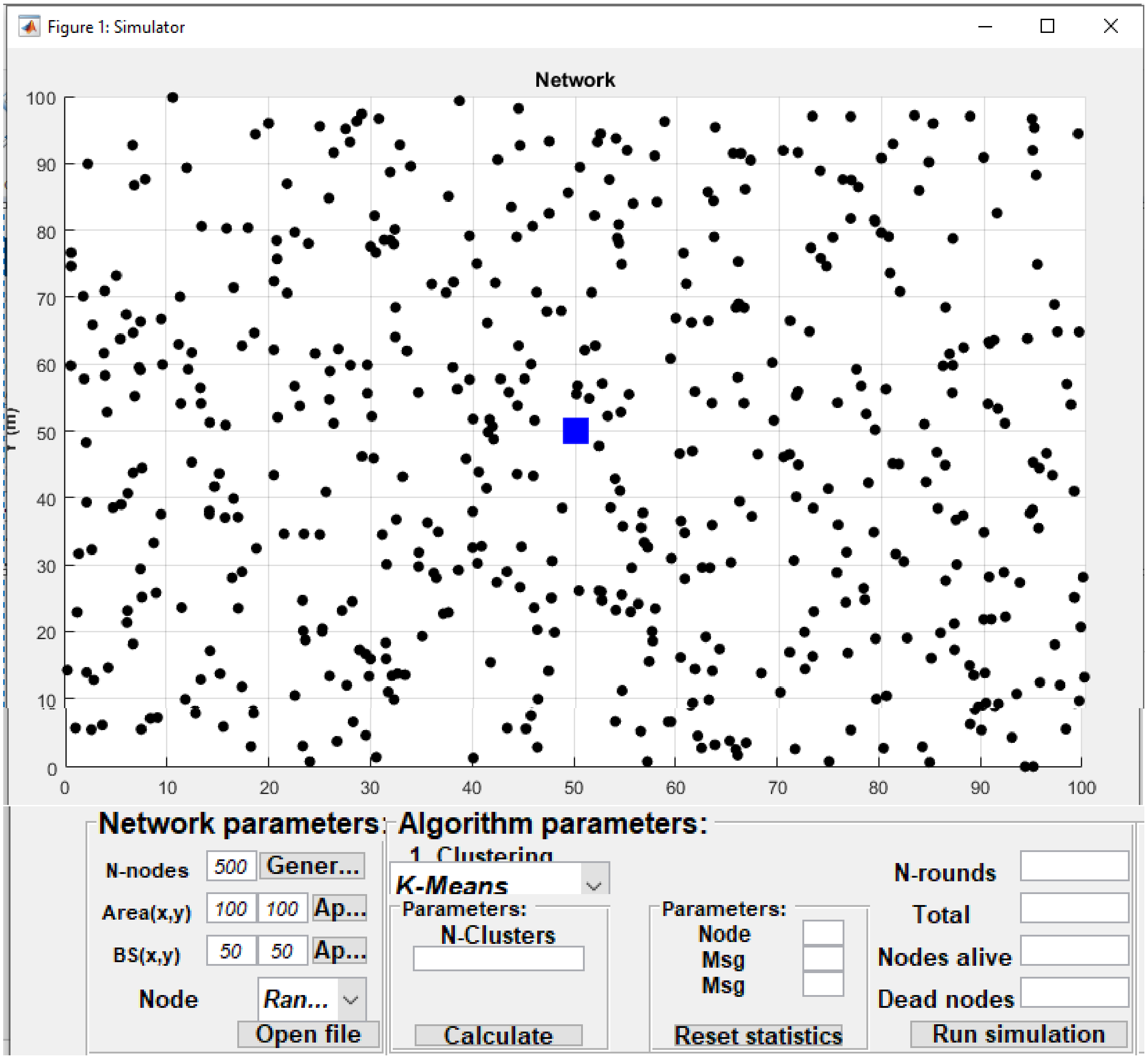
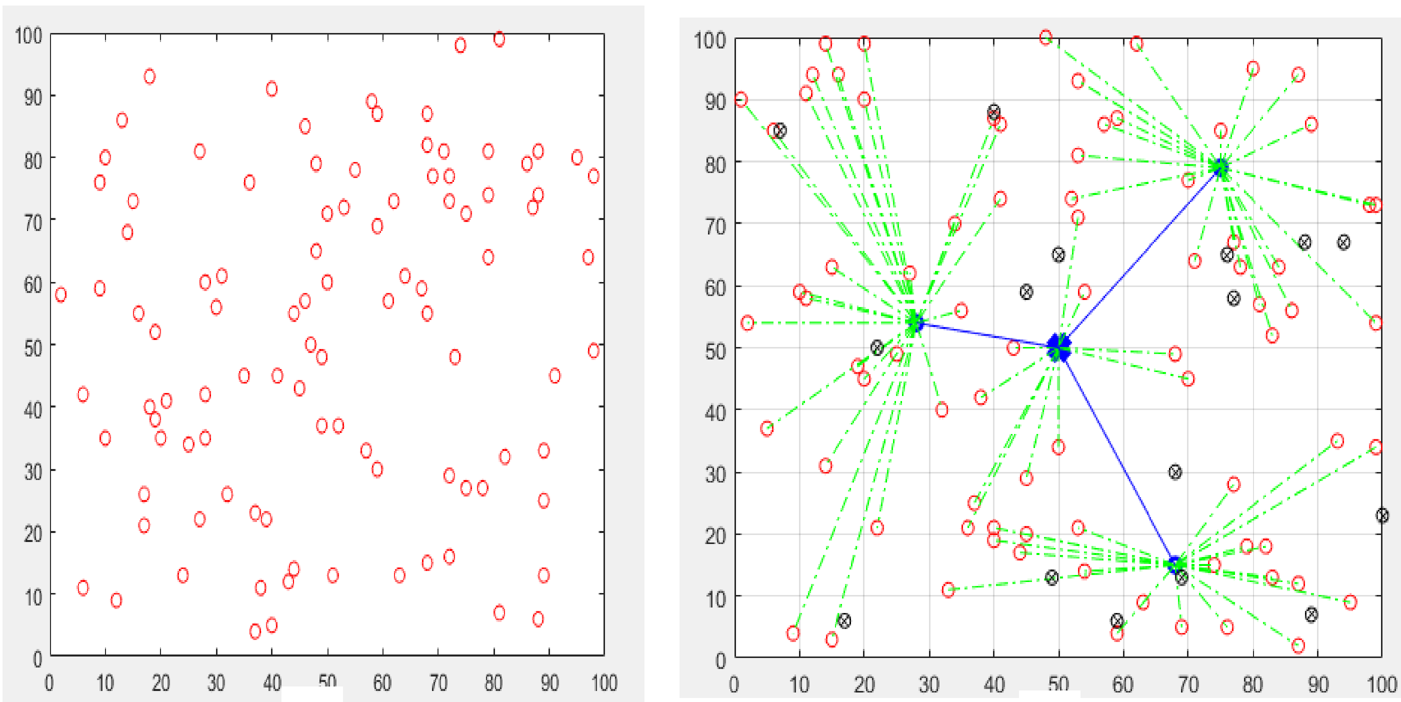


Figure 4.2 GUI for Comparison for Deployment and Clustering techniques

Figure 4.3 (a) shows the deploy the sensors randomly in the proposed algorithm. Figure 4.3 (b) shows run the PSO-K Algorithm.



a b

Figure 4.3 illustrate the runnig proposed PSO-K algorithm

4.3 Results of Deployment techniques

Before a sensor network is deployed, it is important to determine how many sensors are required to achieve a certain level of coverage. The number of sensors required for maintaining k-coverage depends on the area of the monitored region, the probability that a node fails or powers off (to save energy), and the deployment strategy. The sensing coverage of the field of interest is an important function of the sensor nodes in connected WSNs. It is to be covered if each point in the field is monitored by at least one sensor node. Targets or physical stimulus in WSNs can be deterministic located inside the field of interest, randomly scattered in the field of interest. Although random deployment is widely used in theoretical analysis of coverage and connectivity, and evaluation of various algorithms, it has often been considered too expensive as compared to optimal deterministic deployment patterns when deploying sensors in real-life.

Two types of random and deterministic deployment were carried out in an environment of 100 * 100 and 200 * 200 square meters and the number of nodes that were deployed were 100, 500, 1000, and 2000 in different rounds 100, 1000 and 2000 and the energy consumption rate was calculated in each experiment. In deterministic deployment applied four types: square, triangle, hexagon, and tri-hexagon. Figure 4.4 present GUI for deployment techniques comparison.

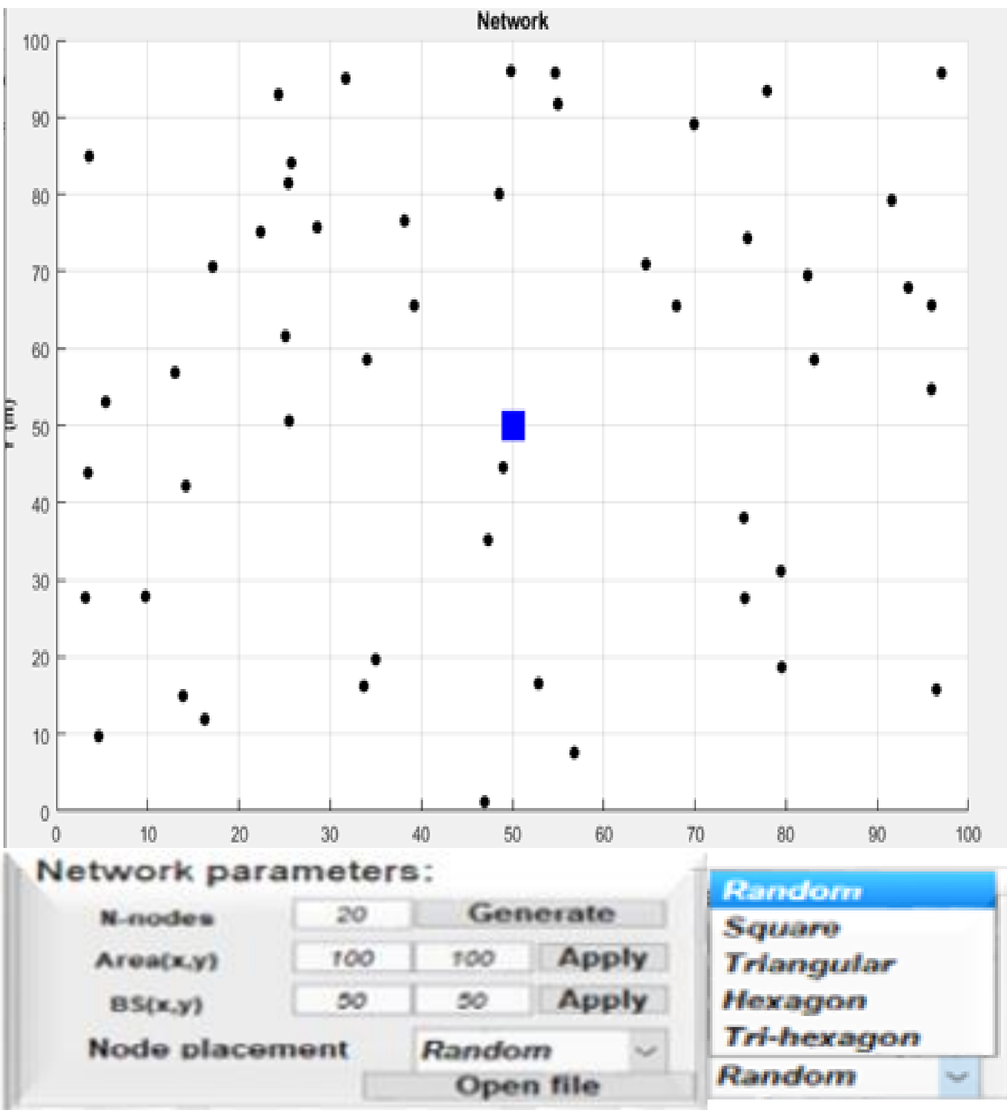


Figure 4.4 GUI for deployment techniques comparison

Table (4.2) offers information on the numerical comparison between the five deployment techniques at 500 and 1000 nodes. 500, 1000 and 2000 rounds. The comparison process is done according to effect the number of nodes and rounds on the energy consumption.

Table (4.2) Comparison among deployment techniques

Number of Nodes	Number of Rounds	Deployment Method	Energy Consumption in joules
500	500	**Random**	7.1439
		Square	7.1492
		Triangular	7.1504
		Hexagon	7.1498
		Tri- Hexagon	7.1479
	1000	**Random**	14.2877
		Square	14.3364
		Triangular	14.2928
		Hexagon	14.3024
		Tri- Hexagon	14.2987
	2000	Random	28.3263
		Square	28.7089
		Triangular	28.5897
		Hexagon	28.6074
		Tri- Hexagon	28.5984
1000	500	Random	14.3011
		Square	14.3195
		Triangular	14.3096
		Hexagon	14.3119
		Tri- Hexagon	14.6788
	1000	Random	28.6115
		Square	28.6349
		Triangular	28.6237
		Hexagon	28.6332
		Tri- Hexagon	28.6168
	2000	Random	57.1836
		Square	57.2935
		Triangular	57.2567
		Hexagon	57.2403
		Tri- Hexagon	57.2424

Many experiments have been conducted in the number of different numbers of nodes and rounds within five methods of deployment and it was found that random deployment in an WSN environment is the least in energy consumption.

After proposing a mathematical model to determine the number of nodes and clusters, this model is appropriate with the deterministic deployment, as it gives a clear vision of the requirements for WSN after analyzed this environment and study the most important factors affecting it.

But from an economic point of view, the application of the model of determining the number of nodes and number of clusters can be applied in random deployment also, and the challenges of random deployment and its determinants are taken into account, such as the fall of a number of nodes in one place, which affects coverage and connectivity. Therefore, such a problem must be avoided by doubling the number of nodes twice. Or more.

4.4 Results of Clustering Techniques

The main limitation of the non-clustering approach in WSNs is that it does not reduce energy consumption and it does not provide energy efficiency to the network and it causes end-to-end delay. So, to overcome the problems and decrease energy consumption; clustering techniques are applied.

Because clustering algorithms are many and differ in the way they are classified, we have studied and analyzed the most common clustering algorithms, namely K-means, DBSCAN, GMM, Hierarchical, and spectral algorithms. We tried to highlight the most important advantages and the most important disadvantages of each method and the proportion of its suitability to work with the WSN environment. This study displays the most properties and Adjectives for each algorithm.

Table 4.3 comparison among clustering algorithms

Adjective	DBSAN	GMM	Hierarchical	Spectral	K-means
Metric	density	Gaussian	distance	spectrum	distance
High Dimensional	does not operate well for high dimensional data.	Complex algorithm with high dimensional	Recommended for a small dataset	Recommended for lower-dimensional	Recommended for high dimensional data
Measure	Density	Probabilistic assignment	Agglomerative and Divisive	Eigenvalues and eigenvectors	Median or mean
Parameter	eps and minPts	EM algorithm	Need K	Need K	Need K
Cost	Expensive	Expensive	Expensive	expensive	cheap
Speed	slow	slow	slow	slow	fast
Varying densities.	Affected	Effected	doesn't affect	Affected	doesn't affect
Cluster	discards objects as noise.	clusters all the objects	clusters all the objects	clusters all the objects	clusters all the objects
Outliers and noisy	efficiently	Very sensitive	Very sensitive	efficiently	not work well
Computationally	Easy to implement.	Flexibility	Easy	very efficient	Easy

From the above study, it is clear to us that each algorithm has advantages and disadvantages for working with the wireless sensor network environment. The k-means algorithm was chosen to work in the proposed system because it has features that suit the work environment such as its simplicity in processing, ease of application, the possibility of determining the number of clusters. And its most important characteristic is its ability to work in a different density environment, unlike the DBSCAN algorithm. Also, K-means algorithm is acceptable from other clustering algorithms in energy consumption metrics. Figure 4.5 present GUI for clustering techniques comparison.

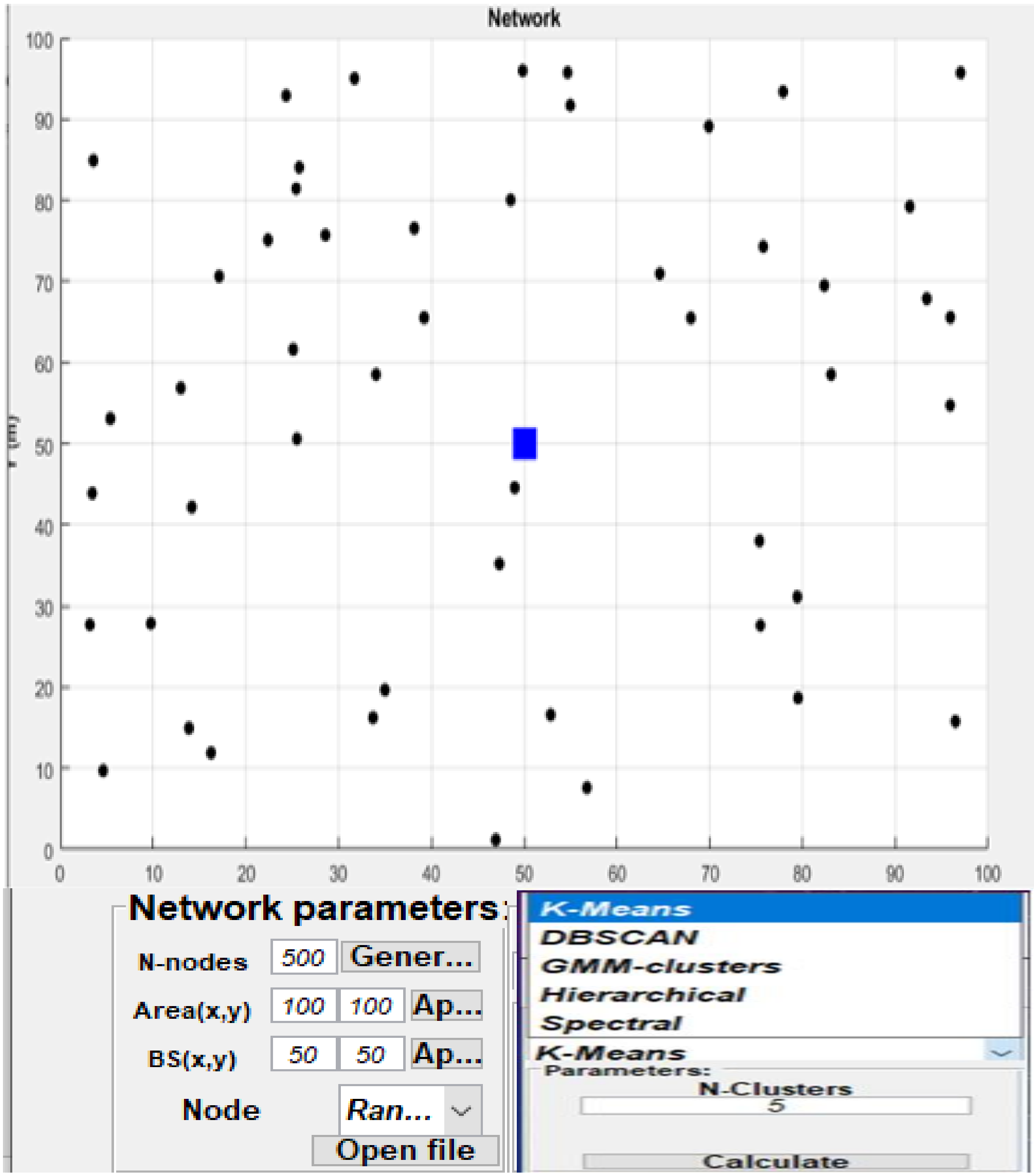


Figure 4.5 shows the main window for cluster formation

Table 4.4 affect different rounds for 100 nodes with different clustering techniques. Using three parameters: total energy consumption, number of alive nodes and number of dead nodes. Show Figure 4.6.

Table 4.4 comparison among different clustering techniques

N0 of nodes	Deployment Technique	Clustering Technique	N0 of Rounds	Total energy consumption In Jules	N0 of alive nodes	N0 of dead nodes
50	Random	K-mean	100	0.141	50	0
			200	0.281	50	0
			300	0.421	50	0
			400	0.505	8	42
			500	0.509	8	42
		GMM	100	0.142	50	0
			200	0.284	50	0
			300	0.427	50	0
			400	0.509	6	44
			500	0.513	6	44
		Hierarchical	100	0.142	50	0
			200	0.286	50	0
			300	0.429	50	0
			400	0.511	3	47
			500	0.515	2	48
		Spectral	100	0.148	50	0
			200	0.294	50	0
			300	0.431	50	0
			400	0.513	2	48
			500	0.514	0	50

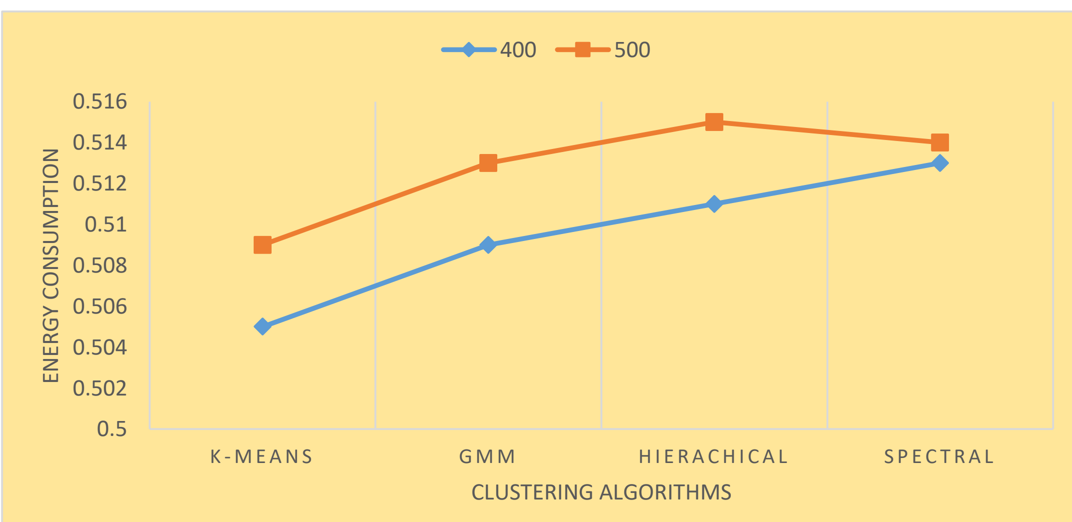


Figure 4.6 Comparison among different clustering techniques

Table 4.5 affect different rounds for 500 nodes with different clustering techniques. Using three parameters: energy consumption, number of alive SNs and number of dead SNs. As show Figure 4.7.

Table 4.5 affect different rounds on the energy consumption

N0 of nodes	Deployment Technique	Clustering Technique	N0 of Rounds	Total energy consumption	N0 of alive nodes	N0 of dead nodes
500	Random	K-mean	100	1.425	500	0
			200	2.958	500	0
			300	4.309	500	0
			400	5.075	45	455
			500	5.125	30	470
		GMM	100	1.442	500	0
			200	2.877	500	0
			300	4.314	500	0
			400	5.179	57	443
			500	5.128	41	459
		Hierarchical	100	1.445	500	0
			200	2.883	499	1
			300	4.311	496	4
			400	5.104	40	460
			500	5.144	34	466
		Spectral	100	1.509	493	7
			200	2.983	482	18
			300	4.431	444	56
			400	5.320	23	377
			500	5.459	30	470

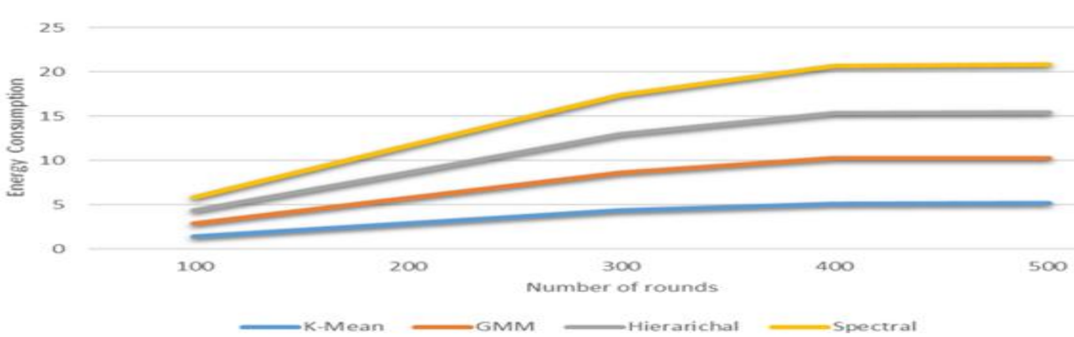


Figure 4.7 Comparison among different clustering techniques

Tables (4.4), (4.5) and Figures (4.6) and (4.7) presents that the number of round effect on the energy consumption and k-mean is the accepted in energy consumption.

Table (4.6) present the effects of the number of CH with different clustering techniques on total energy consumption. Number of CHs is the important factor for energy saving in clustering techniques in WSNs due it increasing the number of CHs can be increase energy consumption. As shown in Figure (4.8).

Table (4.6) CH numbers effected on the energy consumption

Number of Nodes	Number of Rounds	Clustering Method	Probability P of the number of CH	Total Energy Consumption in jule
100	1000	K-mean	0.02	2.5498
			0.03	2.6714
			0.04	2.8770
			0.05	2.8788
		DBSCAN	0.02	2.6412
			0.03	2.7714
			0.04	2.8770
			0.05	2.9788
		GMM	0.02	2.8006
			0.03	2.8767
			0.04	2.8828
			0.05	2.8843
		Hierarchal	0.02	2.6663
			0.03	2.7912
			0.04	2.8752
			0.05	2.8799
		Spectral	0.02	3.0002
			0.03	3.2577
			0.04	3.3854
			0.05	3.5989

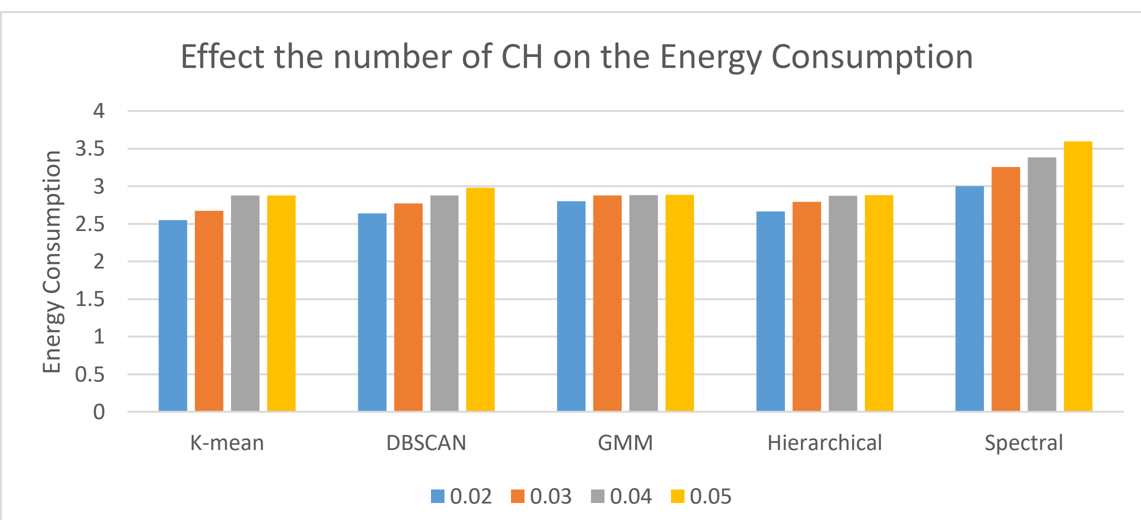


Figure 4.8 Comparison among different clustering techniques

Table (4.6) and Figure (4.8) present that the number of CH is effect on the energy consumption and k-mean is acceptable in energy consumption.

Table (4.7) present the effects the number of CH with different clustering techniques on total energy consumption. As shown in Figure (4.9).

Table (4.7) affects the number of CH on the energy consumption

Number of Nodes	Number of Rounds	Clustering Method	Probability P of the number of CH	Total Energy Consumption in jule
100	2000	K-mean	0.02	5.7102
			0.03	5.7112
			0.04	5.7557
			0.05	5.7289
		DBSCAN	0.02	5.4102
			0.03	5.6112
			0.04	5.7557
			0.05	5.8289
		GMM	0.02	5.7472
			0.03	5.7512
			0.04	5.7720
			0.05	5.7859
		Hierarchal	0.02	5.7319
			0.03	5.7473
			0.04	5.7508
			0.05	5.7788
		Spectral	0.02	5.7350
			0.03	6.0627
			0.04	6.0330
			0.05	6.1393

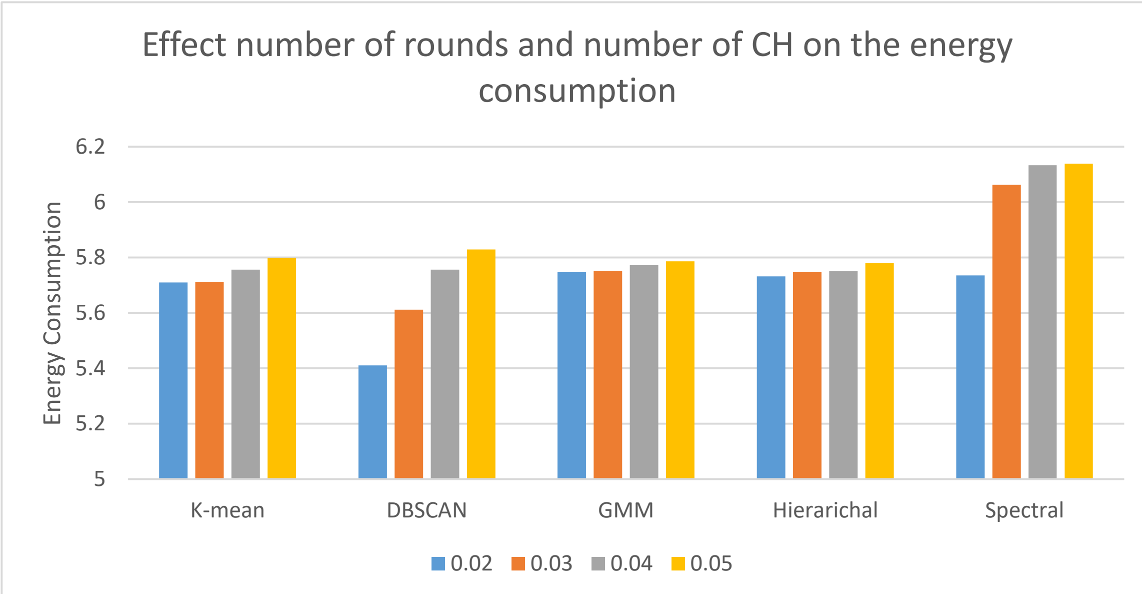


Figure 4.9 Effect the number of CH on the energy consumption

Table (4.7) and Figure (4.9) present the number of round effect on the energy consumption. Probability of CH number effect on the energy consumption. And k-means is the acceptable in energy conservation among the four clustering methods.

K-Means performs the division of objects into clusters that share similarities and are dissimilar to the objects belonging to another cluster. The term 'K' is a number. You need to tell the system how many clusters you need to create. For example, K = 2 refers to two clusters. There is a way of finding out what is the best or optimum value of K for a given data. K-Means clustering is used in a variety of examples or business cases in real life, like: Academic performance, Diagnostic systems, Search engines, Wireless sensor networks.

Table (4.8) comparison among different clustering techniques with 50 nodes deployment randomly. Measuring the total energy consumption, alive and dead nodes.

Table (4.8) different clustering with total energy consumption

Node Number	Round	Deployment Method	Clustering method	Total Energy consumption		
				T. energy	**live**	**dead**
50	**100**	**Random**	**K-means**	**0.14176**	**50**	**0**
	200			**0.28152**	**50**	**0**
	300			**0.42134**	**50**	**0**
	400			**0.50517**	**8**	**42**
	500			**0.50903**	**8**	**42**
	100	**Random**	**GMM**	**0.14235**	**50**	**0**
	200			**0.28474**	**50**	**0**
	300			**0.42711**	**50**	**0**
	400			**0.50792**	**6**	**44**
	500			**0.51165**	**6**	**44**
	100	**Random**	**Hierarchal**	**0.14288**	**50**	**0**
	200			**0.28635**	**50**	**0**
	300			**0.42983**	**50**	**0**
	400			**0.50757**	**3**	**47**
	500			**0.51191**	**2**	**48**
	100	**Random**	**Spectral**	**0.14856**	**49**	**1**
	200			**0.29421**	**48**	**2**
	300			**0.4319**	**48**	**2**
	400			**0.51329**	**2**	**48**
	500			**0.51372**	**0**	**50**

Table (4.8) comparison among different clustering techniques with 500 nodes deployment randomly. Measuring the total energy consumption, alive and dead nodes.

Table 4.9 Effect Round Number for energy consumption for WSN.

Node Number	Round	Deployment Method	Clustering method	Total Energy Consumption		
				T. energy	**live**	**dead**
500	100	Random	K-Mean	1.4259	500	0
	200			2.8581	500	0
	300			4.3099	500	0
	400			5.0792	45	440
	500			5.1251	33	458
	100	Random	GMM	1.4423	500	0
	200			2.8771	500	0
	300			4.3142	500	0
	400			5.1793	57	453
	500			5.1288	41	465
	100	Random	Hierarchal	1.4459	500	0
	200			2.8833	499	1
	300			4.3117	496	4
	400			5.1047	40	460
	500			5.1448	34	476
	100	Random	Spectral	1.5097	493	7
	200			2.9834	482	18
	300			4.4312	444	56
	400			5.3202	123	377
	500			5.4590	36	466

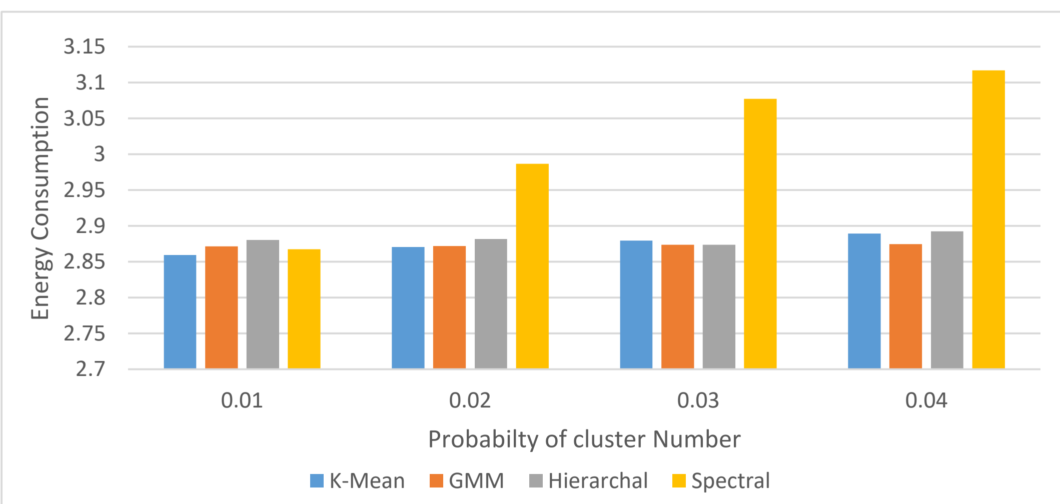


Figure 4.10 display number of CH with different clustering algorithms. Round=1000

Tables (4.8) and (4.9) and Figure (4.10) present:

- Number of round effect on the energy consumption. And in round 400 to 500 increase the energy consumption and leads to increase the dead nodes.
- k-mean is the best clustering algorithm in energy conservation among the clustering methods.

4.4.1 Optimal Number of Clusters K

After applying different deployment techniques and different clustering techniques and notes clear that the K-mean algorithm is a more suitable WSNs environment. There are critical factors that affect the performance of WSN including the number of clusters, number of CHs, number of SNs, number of rounds, size of the field, and initial energy of SNs. This section presents the results of the proposed modified K-mean algorithm. A proposed approach is implemented in this thesis to select k based on the suggested WSN environment. K can be determined based on a set of factors that affect the environment of WSNs.

Table (4.10) Comparison between classic K-Mean algorithm and modified K-mean algorithm based on equation (3.4) and compute the energy consumption metric. Where rounds are 1000 and nodes are 500. The classic K-Mean algorithm to calculate the energy consumption metric. With different rounds are 100 to 500 and a select a number of nodes randomly such as 500. And select the number of clusters randomly based on the probability P=0.5 that K=25.

Table (4.10) Applied the classic K-means algorithm

Number of Nodes	Clustering method	Number of Rounds	Total Energy Consumption
500	Classic K-Mean	100	1.434
		200	2.871
		300	4.301
		400	5.759
		500	7.171

Table (4.11) applied K-Mean algorithm with optimal N and K. With different rounds are 500 and 1000. Optimal number of nodes=100 and optimal K=5.

Table 4.11 K-mean algorithm used optimal K.

Node Number	Clustering method	Number of Rounds	Total Energy Consumption in jule
100	K-Mean with optimal N and K	100	0.28637
		200	0.57439
		300	0.8658
		400	1.1483
		500	1.4379

Figure (4. 11) presents the comparison between the classic K-mean algorithm and K-means with optimal N and optimal K.

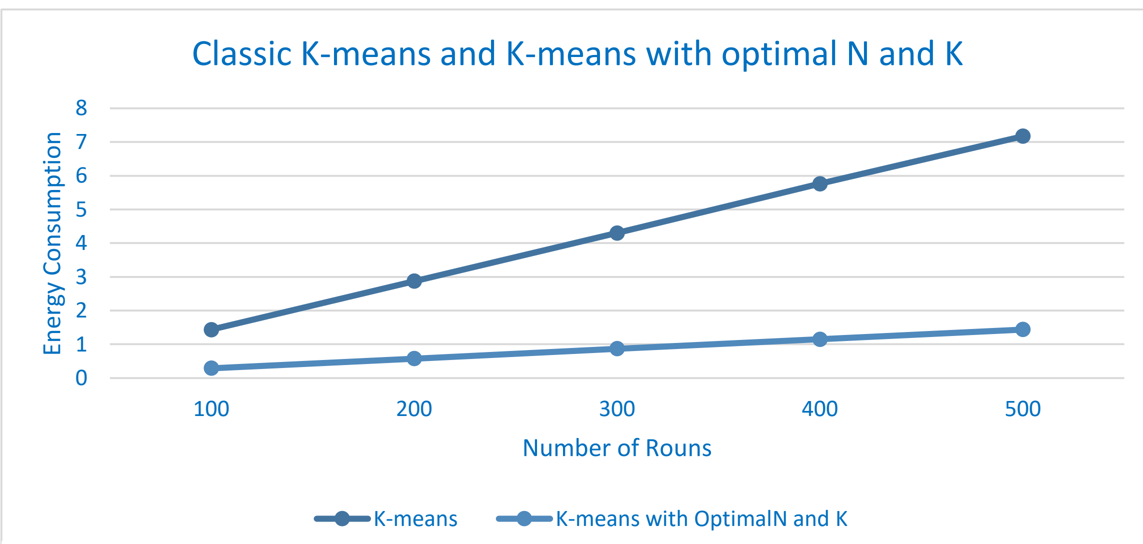


Figure 4.11 comparison between applied classic k-means and K-means with optimal K

Table (4.10) and (4.11) and Figure (4.11), present that the K-mean with optimal N and K is less energy consumption.

4.5 Proposed PSO-K Algorithm Results

The proposed algorithm moved away from using random methods in selecting CHs, as in leach algorithms and their versions, and turned to using deterministic methods in selecting CHs, where we used optimization methods and some characteristics such as residual energy and distance. Table (4.12) shows a comparison between the algorithms used to select the CH and form clusters and shows the advantages and disadvantages.

Table (4.12) Comparison among existing Algorithms

Protocol	Proposed improvement	Results of improvement
LEACH-C	Centralized clustering approach with the known location of member node	Reduce data transmission cost and increase lifetime
LEACH-B	Number of CHs kept optimum	Low energy consumption
MR-LEACH	Multi-hop routing and hierarchy of CHs	Better network lifetime
LEACH-GA	Use GA to find CHs	Prolong lifetime
V-LEACH	Use of vice CHs	Prolong lifetime
Improve V-LEACH	Maximum residual energy, minimum energy and minimum separation distance for vice CH selection.	Improve network lifetime
MEDC	Mutual exclusion used for CHs selection. One CH with one sensor range	Better network lifetime
LEACH-B	Proposed a new adaptive strategy to choose CHs	Improve network lifetime
EWC	Use residual energy, distance and node degree	Improve network lifetime
LEACH-M	Use residual energy and node mobility	Improve network lifetime
TL-LEACH	Primary CH and secondary CH	Send information to BS over two levels to get better energy
Multi-hop LEACH	Improve CH selection and determine the number of CHs.	Energy minimum
E-LEACH	Use residual energy, determine the number of CHs and total number of sensor nodes to scale	Enhance lifetime
FL-LEACH	Apply fuzzy logic on LEACH to determine	Enhance lifetime

The proposed algorithm was implemented in MATLAB. The proposed area size is 100 × 100 m. The initial energy of each sensor is settled as 0.1, 0.2, and 0.3 J. The Simulation experiments were executed by varying the number of sensors from 100 to 1000 with 2%, 3%, 4%, and 5% as CHs. The deployed sensors are static (not mobile) and homogeneous. Deploying the smallest number of nodes is an important issue. This study focuses on random deployment which is setting positions of WSNs randomly and independently in the target area. The first step is the sensors deployed randomly as shown Figure (4.12).

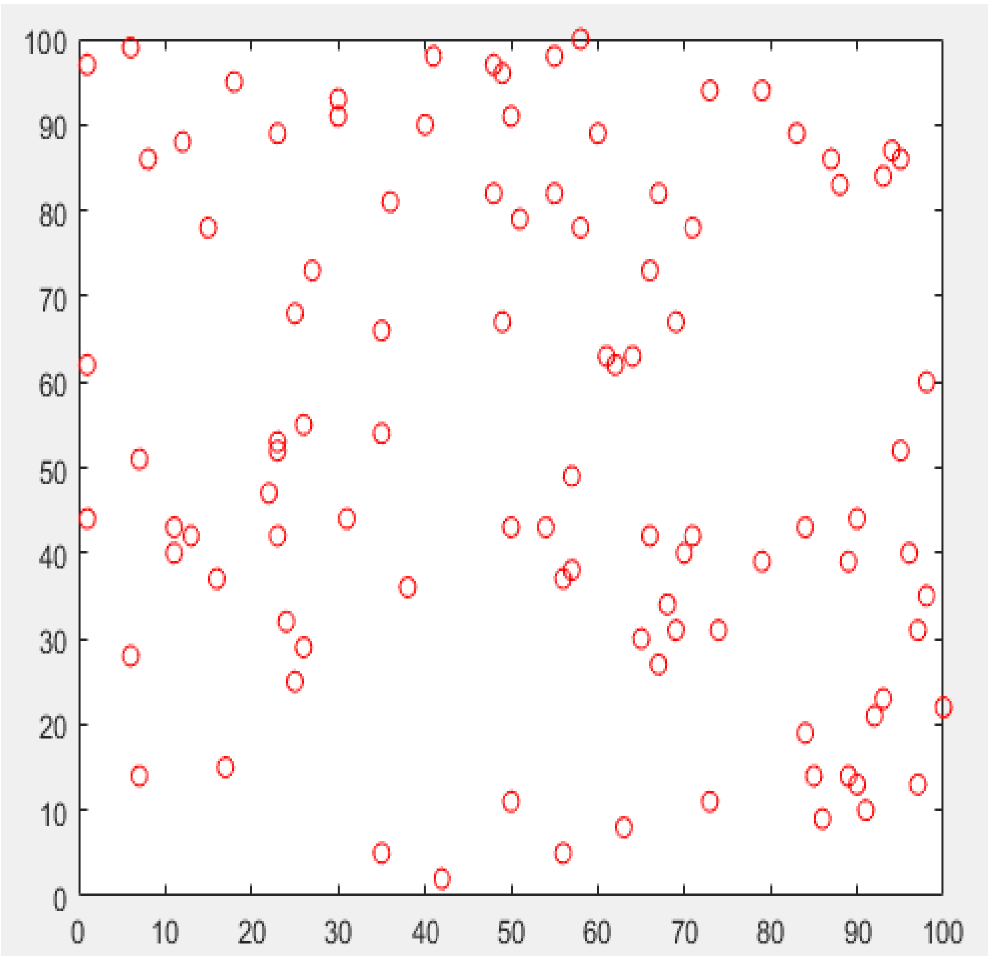


Figure 4.12: Deployment sensor nodes randomly

4.5.1 Evaluating the stability and lifetime network metrics

The simulation result was compared with the existing protocol: LEACH, EAMMH, and I-LEACH. Three performance metrics are used to evaluate the performance of the proposed algorithm: First Dead Nodes (FDN), Half Dead Nodes (HDN), and Last Dead Nodes (LDN). FDN is the death of the first node. HDN when half nodes are dead. LND means death of the last node in the network. The proposed PSO-K algorithm uses these metrics in order to evaluate the performance and compare the proposed PSO-K algorithm with existing algorithms: LEACH, EAMMH, and I-LEACH when the area is 100 * 100 and the number of nodes is 100. The initial energy is 0.1 J and the probability P is 0.02. Round is 1000.

Table (4.12) comparison among proposed PSO-K protocol and existing common protocols includes LEACH, EAMMH, I-LEACH protocols in same environment of WSNs. The comparison process is done based on a different number of rounds, 100 nodes, and computes FDN metric. As shown Figure 4.13.

Table (4.13) comparison among PSO-K and LEACH, EAMMH, I-LEACH Protocols by

Round	Metrics	LEACH	EAMMH	I-LEACH	Proposed
100	FDN	7	23	35	37
500		6	22	41	43
1000		13	23	40	41

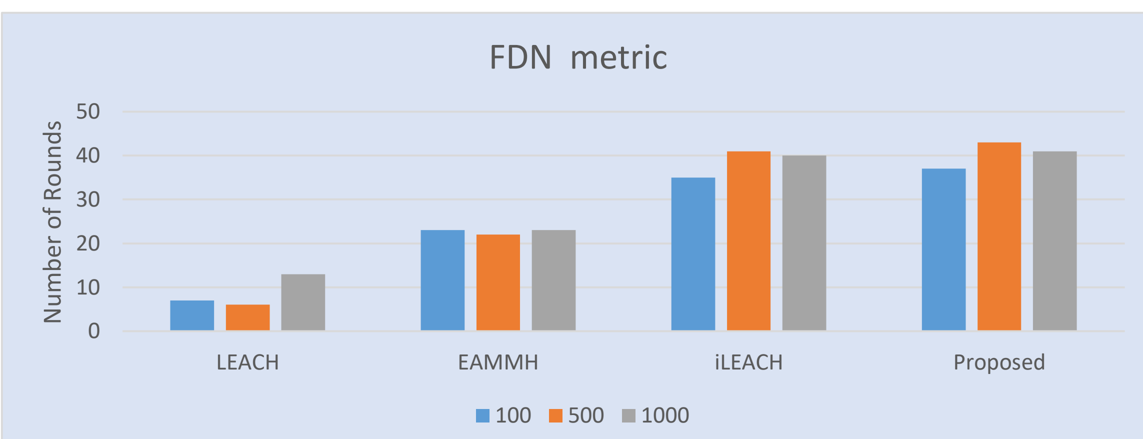


Figure 4. 13 Applied FDN metric

Table (4.13) and Figure (4. 13) display that FDN in round 1000 is dies at 13 rounds in LEACH whereas for EAMMH is at 23 rounds. I-LEACH is at 40. PSO-K is at 41. Proposed PSO-K algorithm is the best.

Table (4.14) comparison among proposed PSO-K protocol and existing common protocols includes LEACH, EAMMH, I-LEACH protocols in same environment of WSNs. The comparison process is done based on a different number of rounds, 100 nodes, and computes HDN metric. As shown Figure (4.14).

Table (4.14) comparison among PSO-K and LEACH, EAMMH, I-LEACH by HDN

Round	Metrics	LEACH	EAMMH	I-LEACH	Proposed
100	HDN	50	60	100	100
500		95	100	250	285
1000		90	112	260	278

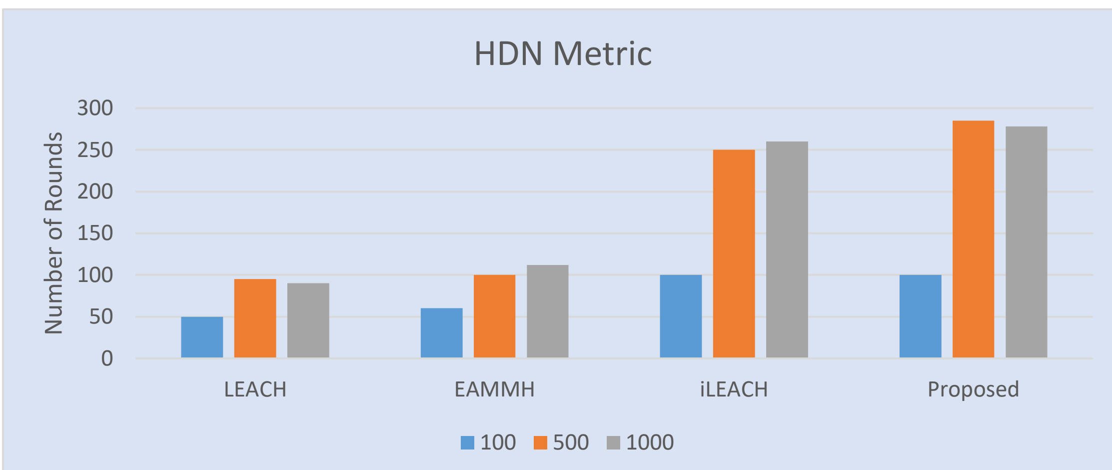


Figure 4.14 HDN metric

Table (4.14) and Figure (4.14) present comparison used HDN metric. If round is 500, HDN in LEACH is done in round 95 and in EAMMH in round 100 whereas I-LEACH in round 250. So, HDN with proposed PSO-K is done in round 285.

If round is 1000, HDN in LEACH is done in round 90 and in EAMMH in round 112 whereas I-LEACH in round 260. So, HDN with proposed PSO-K is done in round 278. The proposed PSO-K is accepting.

Table (4.15) comparison among proposed PSO-K protocol and existing common protocols includes LEACH, EAMMH, I-LEACH protocols in same environment of WSNs. The comparison process is done based on a different number of rounds, 100 nodes, and computes LDN metric. As shown Figure (4.15).

Table (4.15) comparison among PSO-K and LEACH, EAMMH, I-LEACH by LDN

Round	Metrics	LEACH	EAMMH	I-LEACH	Proposed
100	LDN	50	60	100	100
500		497	500	500	500
1000		500	345	956	978

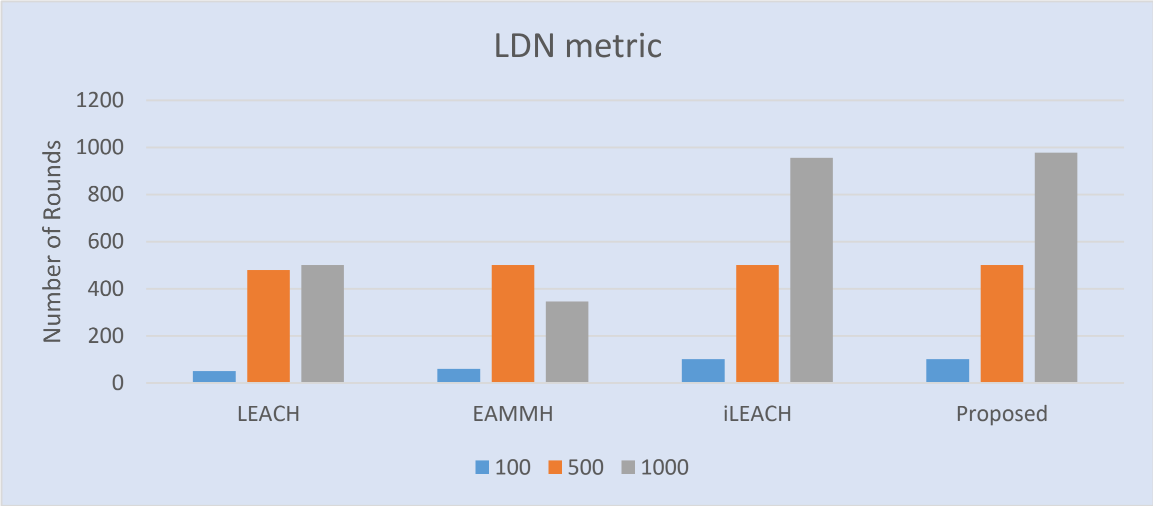


Figure 4.15 comparison among PSO-K and LEACH, EAMMH, I-LEACH by LDN

Table (4.15) and Figure (4.15) present comparison used LDN metric. If rounds are 500, LDN in LEACH is done in round 497 and in EAMMH in round 500 whereas I-LEACH that 21 alive nodes and 79 dead nodes at end of 500 round. So, LDN with proposed PSO-K is 38 alive nodes and 62 dead nodes at the end of 500 rounds. When rounds are 1000, LDN is done in LEACH at round 500 when EAMMH at 345 round whereas 6 alive nodes and 94 dead nodes in I-LEACH at end of round 1000. But, LDN with proposed PSO-K alive nodes are 10 and 90 dead nodes in proposed PSO-K at end of round 1000. The proposed PSO-K is accepting.

Figure (4.16) shows that the proposed algorithm is more stability and prolong lifetime.

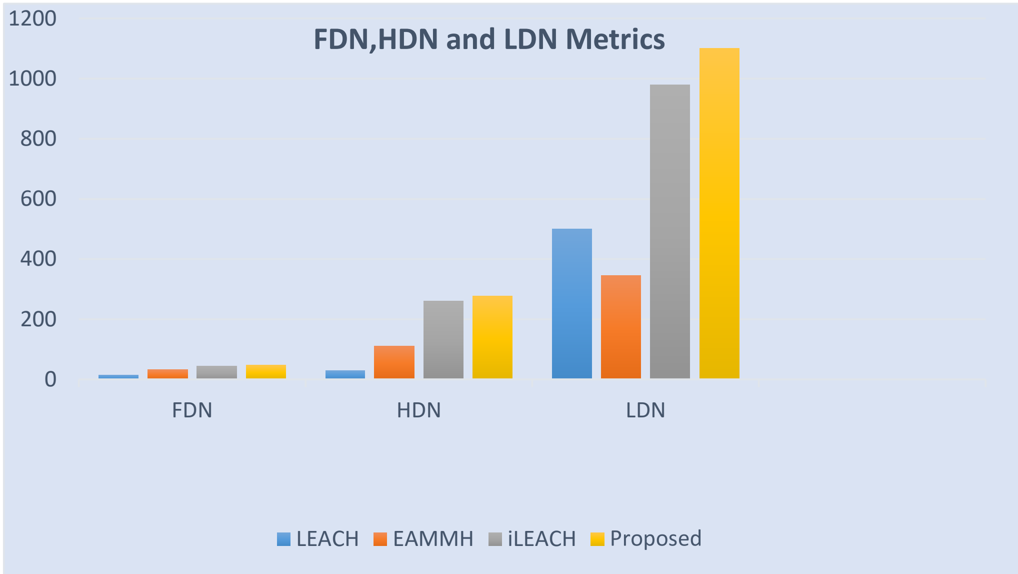
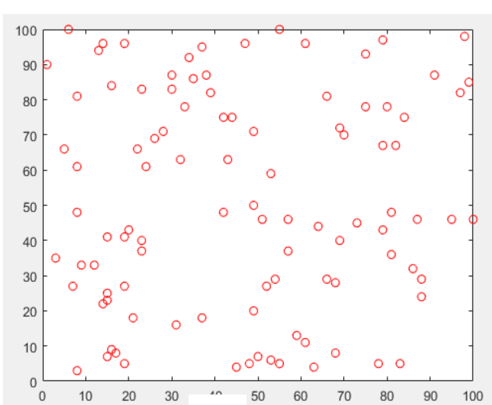


Figure 4.16 FDN, HDN, and LDN metrics

The performance of PSO-K is compared with LEACH, EAMMH, and I-LEACH in terms of stability period, network lifetime. The proposed PSO-K has higher stability (FND) and longer lifetime (HND and LND) compared to LEACH, EAMMH, and I-LEACH .

4.5.2 Evaluating Energy Consumption Metric

CH selection algorithms are important to prolong the network lifetime and appropriate CHs selection process is more required among the network nodes. Optimal CHs selection mean energy saving while CHs selection randomly may cause more energy consumption. Figure (4.17) (a) and (b) present the deployment 100 and 200 nodes randomly in proposed PSO-K algorithm. Area is 100*100.



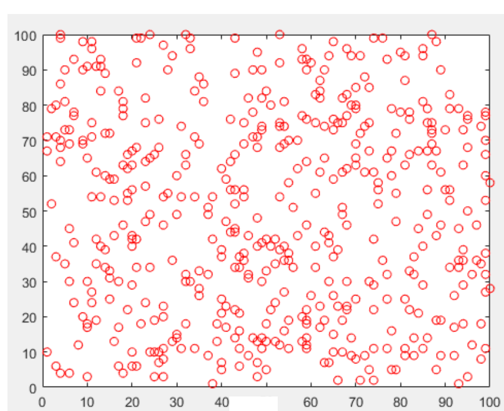


Figure 4.17 (a) and (b) main window for deployment 100, 200 nodes randomly in PSO-

Number of CHs (K) in clustering protocols is important factor that effect on the energy saving. Figure 4.18 (a) clustering when K=2. In Area is 100*100 and (b) clustering when K=3 in proposed PSO-K algorithm. In Area is 200*200

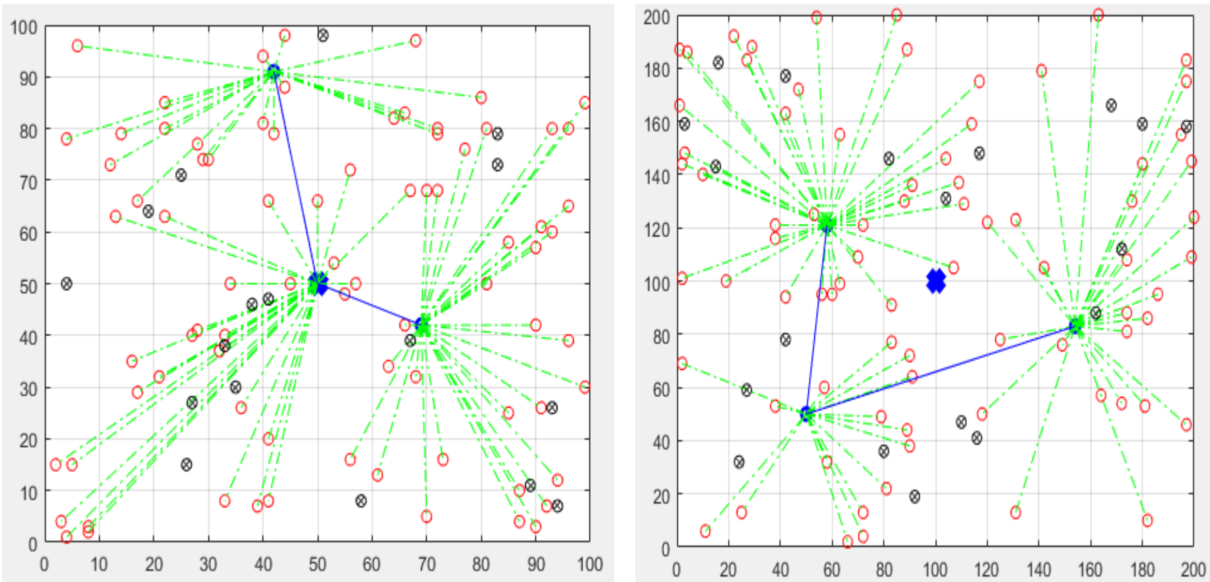


Figure 4.18 (a) and (b) present the clustering by PSO-K algorithm used k =2 and 3

Figure (4.19) present clustering technique in proposed algorithm when (a) K=5 and (b) K=6.

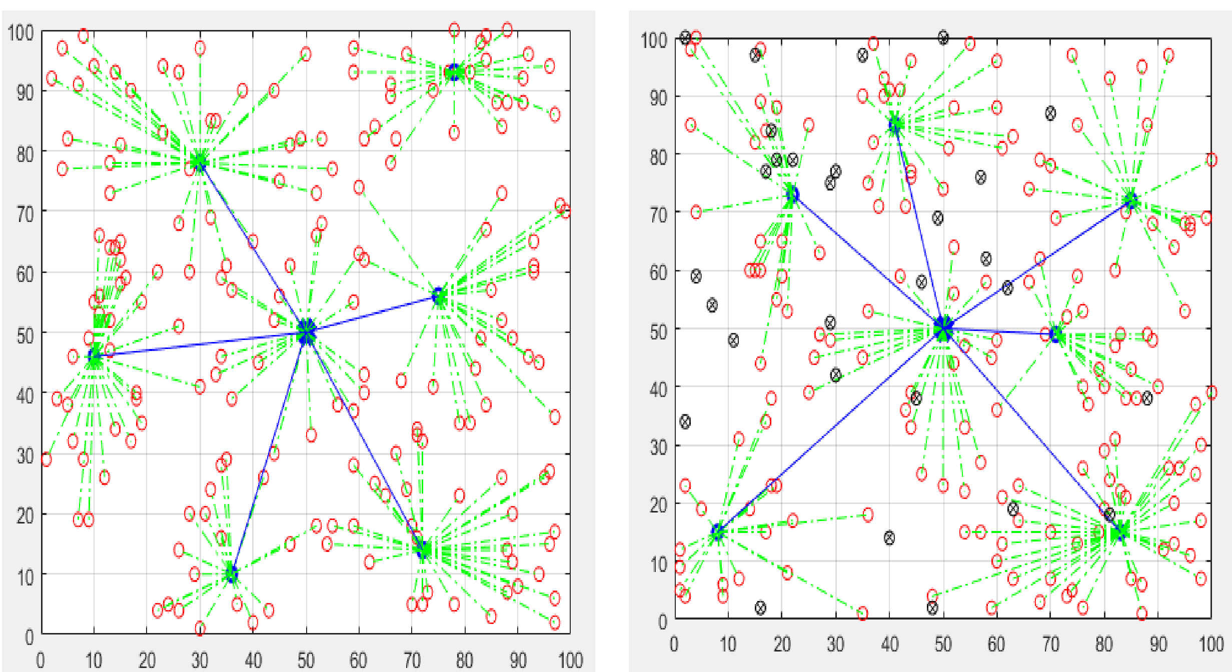


Figure 4.19 (a) Clustering with K=5 and (b) Clustering with K=6 in PSO-K algorithm.

Figures (4.18) and (4.19) present that:

- The proposed PSO-K algorithm is best in distributed nodes in the interest of area.
- The proposed PSO-K algorithm select optimal CH far from edge and far from BS.

Table (4.16) compute the average energy consumption with different rounds for LEACH, EAMMH, I-LEACH and PSO-K Protocols. As shown Figure (4.20).

Table (4.16) compute the average energy consumption with different rounds

Protocol	Round=100	Round=500	Round=1000
LEACH	**0.015**	**0.049**	**0.051**
EAMMH	**0.013**	**0.038**	**0.049**
I-LEACH	**0.013**	**0.036**	**0.045**
Proposed	**0.012**	**0.034**	**0.041**

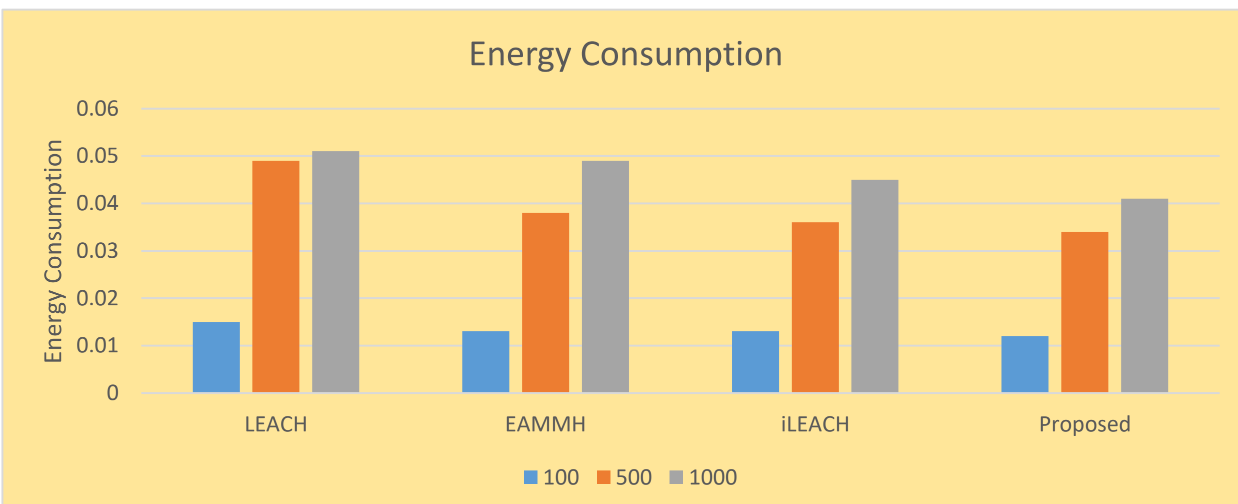


Figure 4.20 Energy consumption with different rounds

Table (4.16) and Figure (4.20) presents that the average energy consumption the proposed algorithm is less.

4.6 Proposed optimal Cluster Formation

After the success of the process of selecting the CH in each cluster, normal nodes must join to best CH this process called "Cluster formation" which is a key challenge in the clustering technique in WSNs. Most existing routing-based clustering protocols are suffering from some problems within cluster formation. LEACH for example is works based on strongly a signal to join the suitable cluster. Often protocols based on clustering build a cluster depend on Euclidian distance. Number of clusters and unbalancing distribution in cluster formation are most problems. Cluster formation is a key challenge in the clustering technique in WSNs as shown in Figure (4.21). Most existing routing-based clustering protocols are suffering from some problems includes:

1) Unbalancing distribution in cluster formation.
2) SNs at the edge of the network have the same chance to become CH.
3) SNs position near BS cannot join to BS directly.

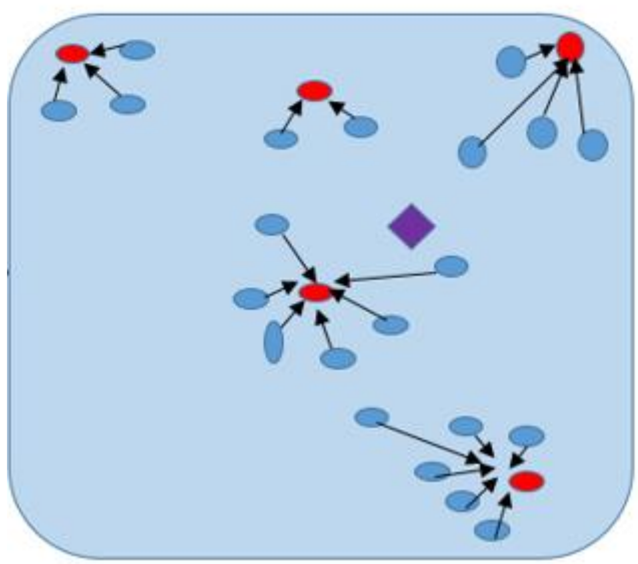


Figure 4.21 Problems with existing protocols

The proposed algorithm build a cluster based on the proposed hybrid method to determine the optimal number of cluster (K) and Euclidian measure in order to suitable cluster formation and balance distribution. As shown Figure (4.22).

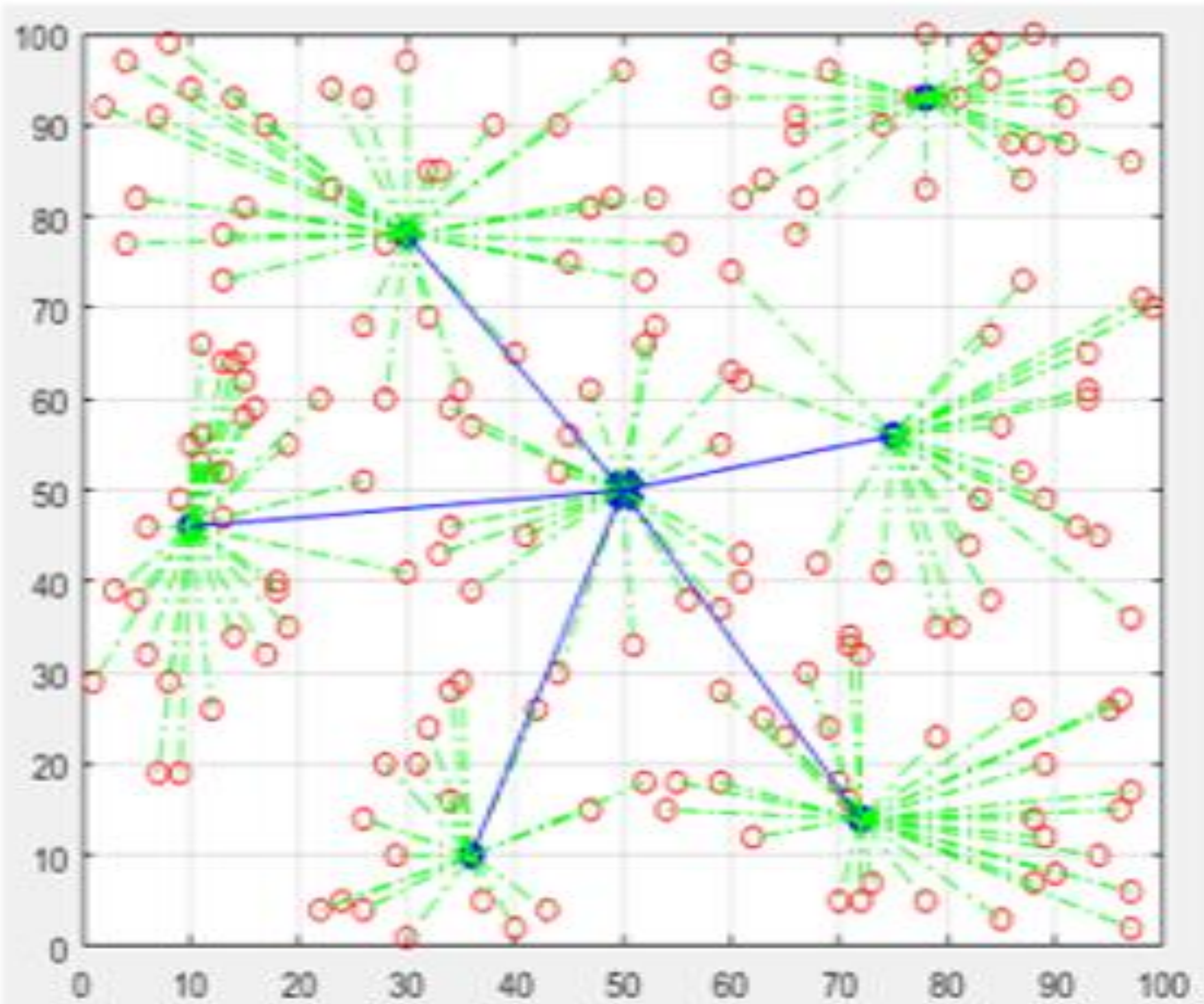


Figure 4.22 Solving the problems by PSO-K algorithm

Figures (4.22) present that the proposed PSO-K algorithm improve the cluster information process via applied both optimal number of cluster (K) and Euclidian distance.

4.7 Nodes at Edge Results

With most common routing protocols which are based on clustering techniques suffers from a key problem when the all sensor nodes in network have the same chance to become CH. If SNs at the edge of the network have chance to become CH leads to more energy consumption, for example; LEACH protocol as shown Figures (4.23).

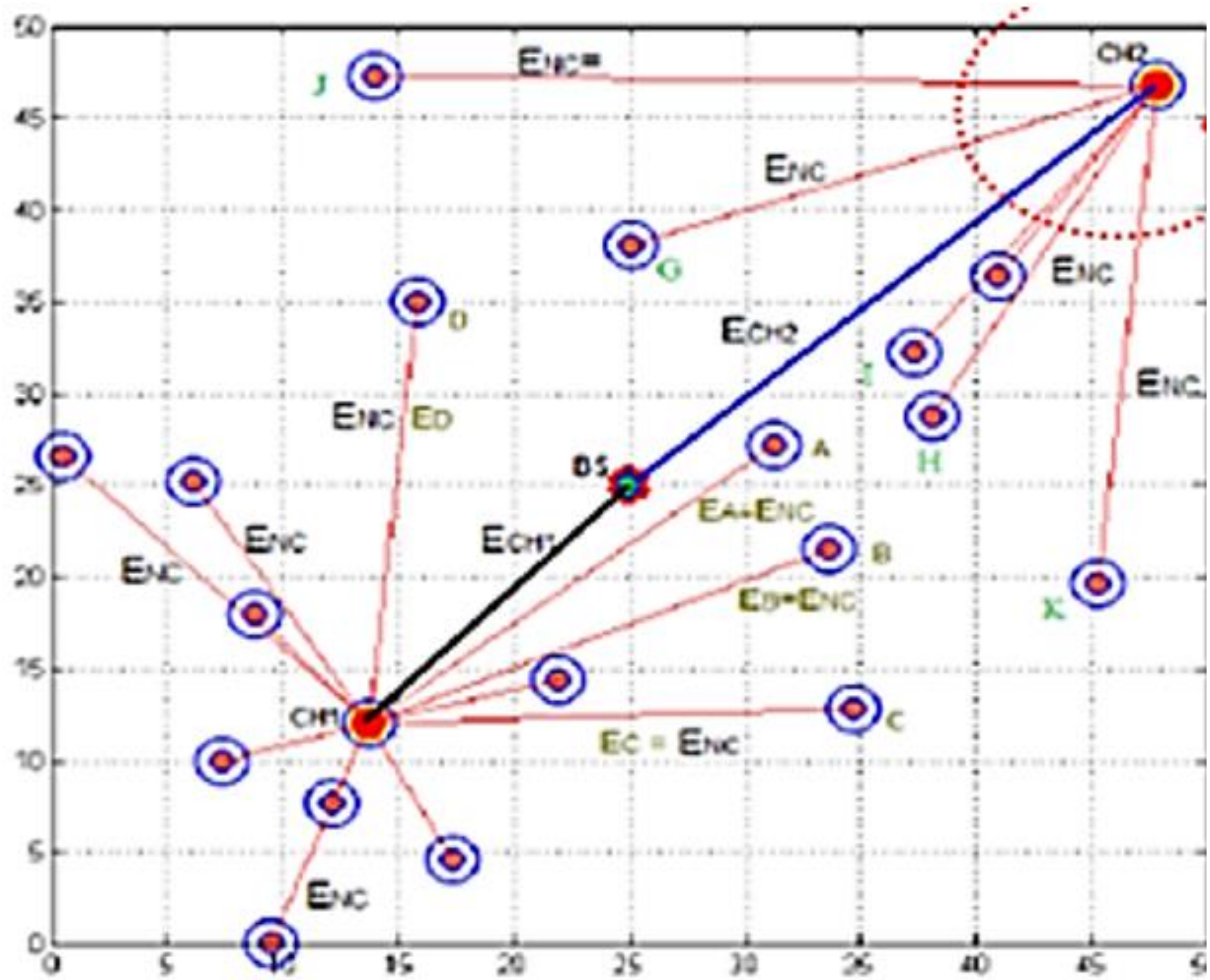


Figure 4.23 Nodes at edge Problem in LEACH Protocol

PSO-K algorithm solving edge problem by prevent the SNs located at the edge of the network become CHs applied the proposed equation (3.7). As shown Figures (4.24), (4.25) and (4.26).

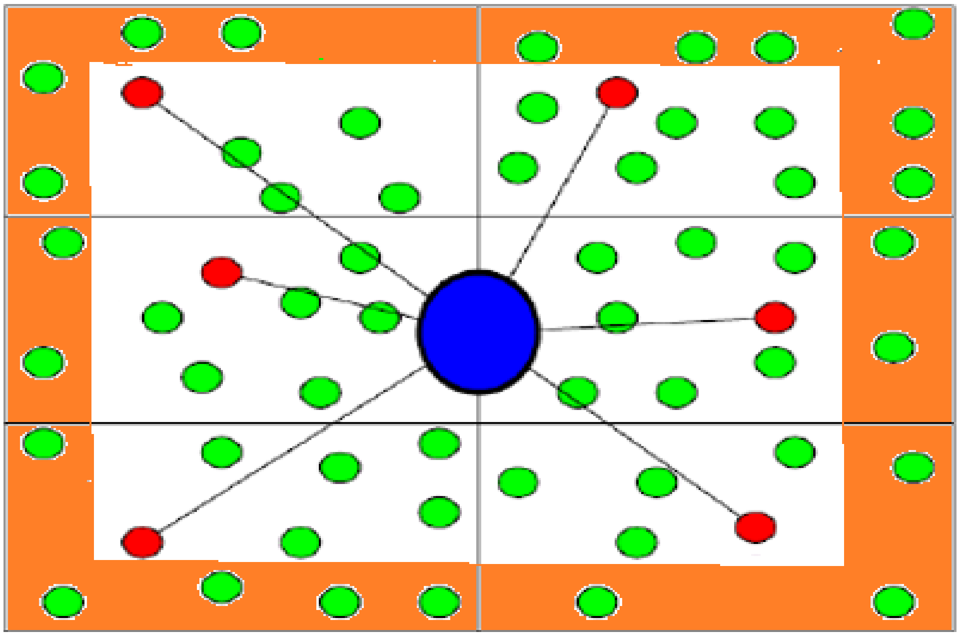
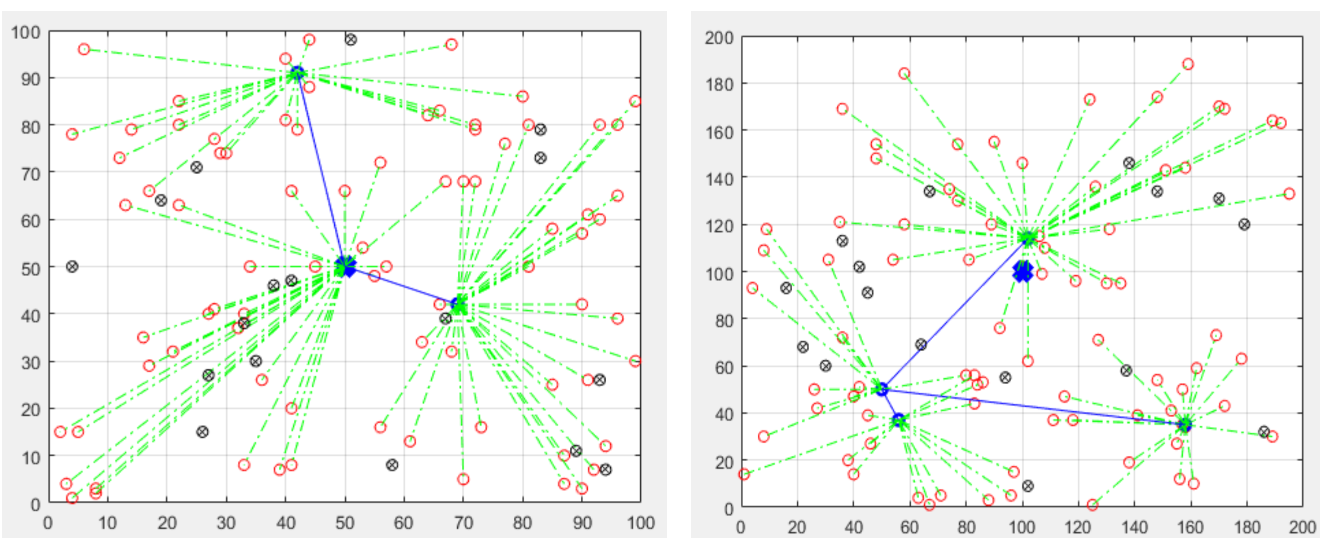


Figure 4.24 display the solution of the edge problem



(a) (b)

Figure 4.25 Solve edge problem

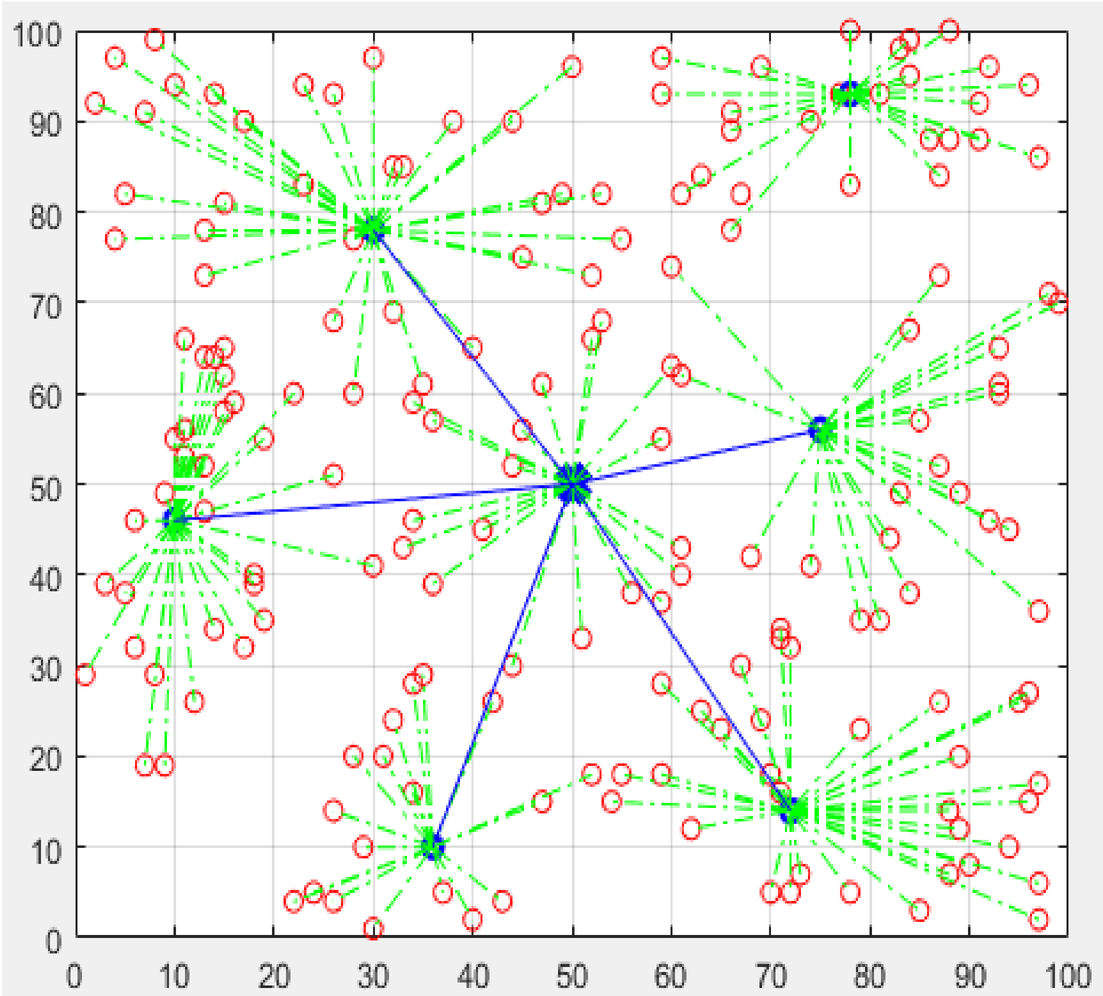


Figure 4.26 Run proposed algorithm

Figures (4.24), (4.25) and (4.26) present that the proposed PSO-K algorithm solve the sensor nodes at edge problem by prevent them become as CHs.

4.8 Node near BS Results

Most common routing protocols which are based on clustering techniques suffer from a key problem when the SNs located near BS cannot join to BS directly. This problem causes more energy consumption when SNs join to nearest CH even BS is nearest to them. This problem is found in several routing protocols which are based on clustering techniques such as LEACH protocol. As shown Figures (4.27) and (4.28).

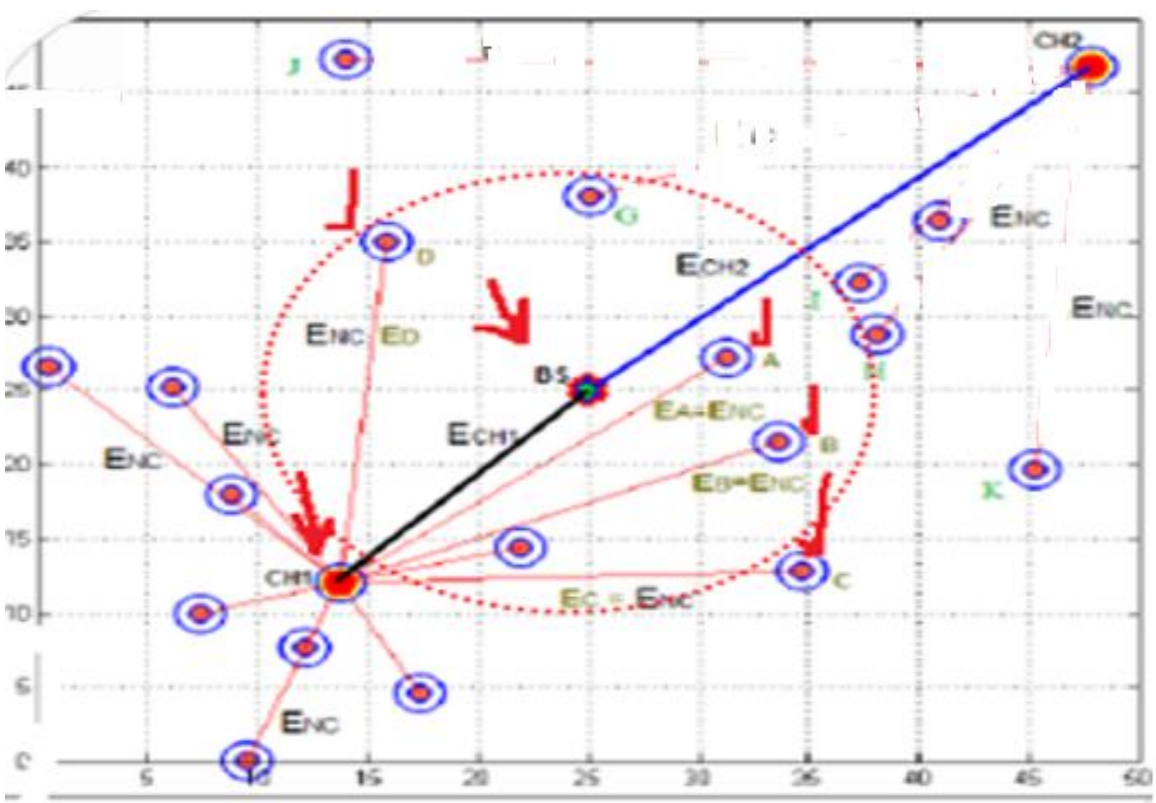


Figure 4.27 display SNs near

Proposed PSO-K algorithm solve SNs near BS Problem applied the proposed equation (3.5). Show Figures (4.29) and (4.30).

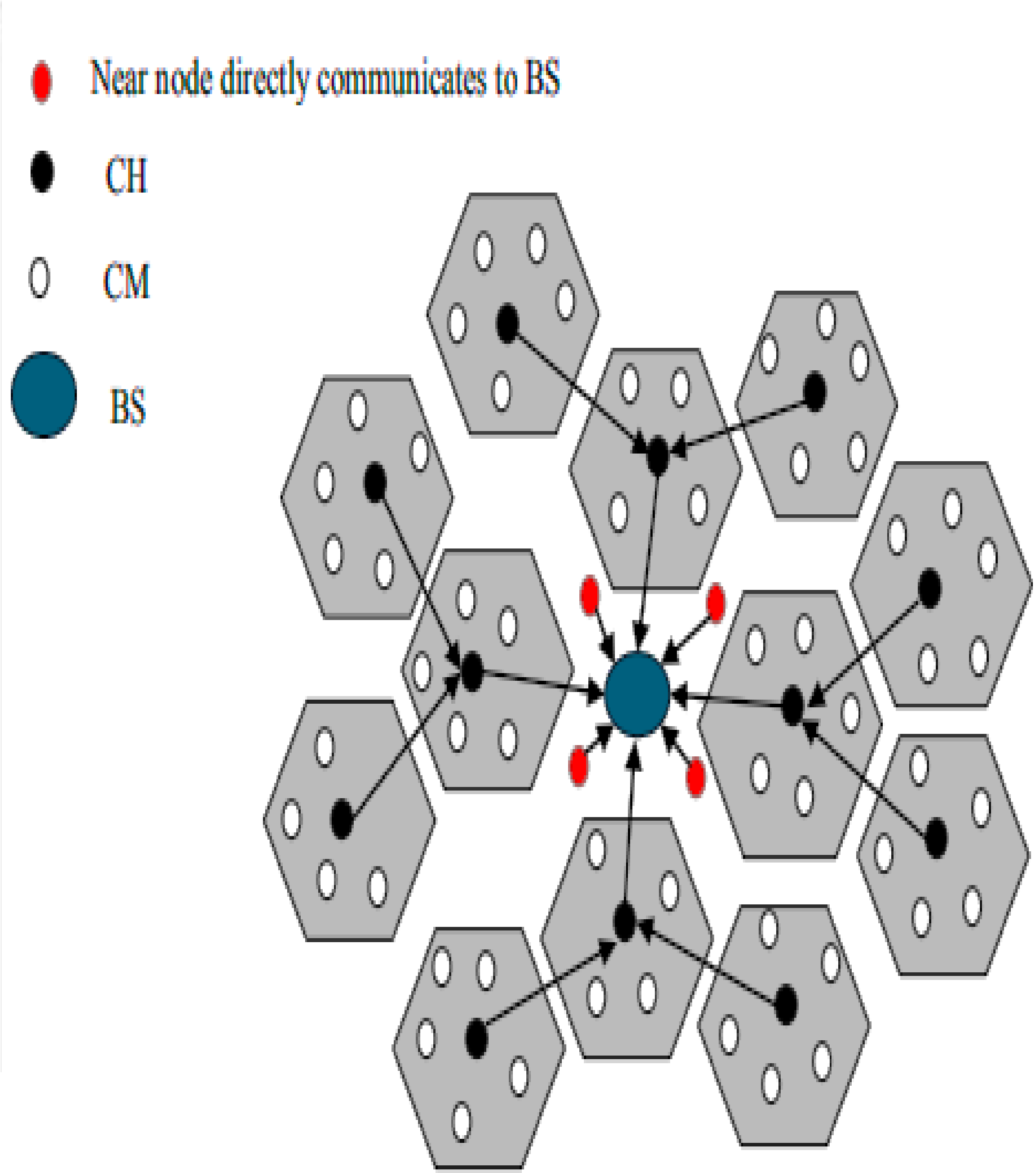


Figure 4.28 PSO-K Algorithm solve sensor nodes near BS

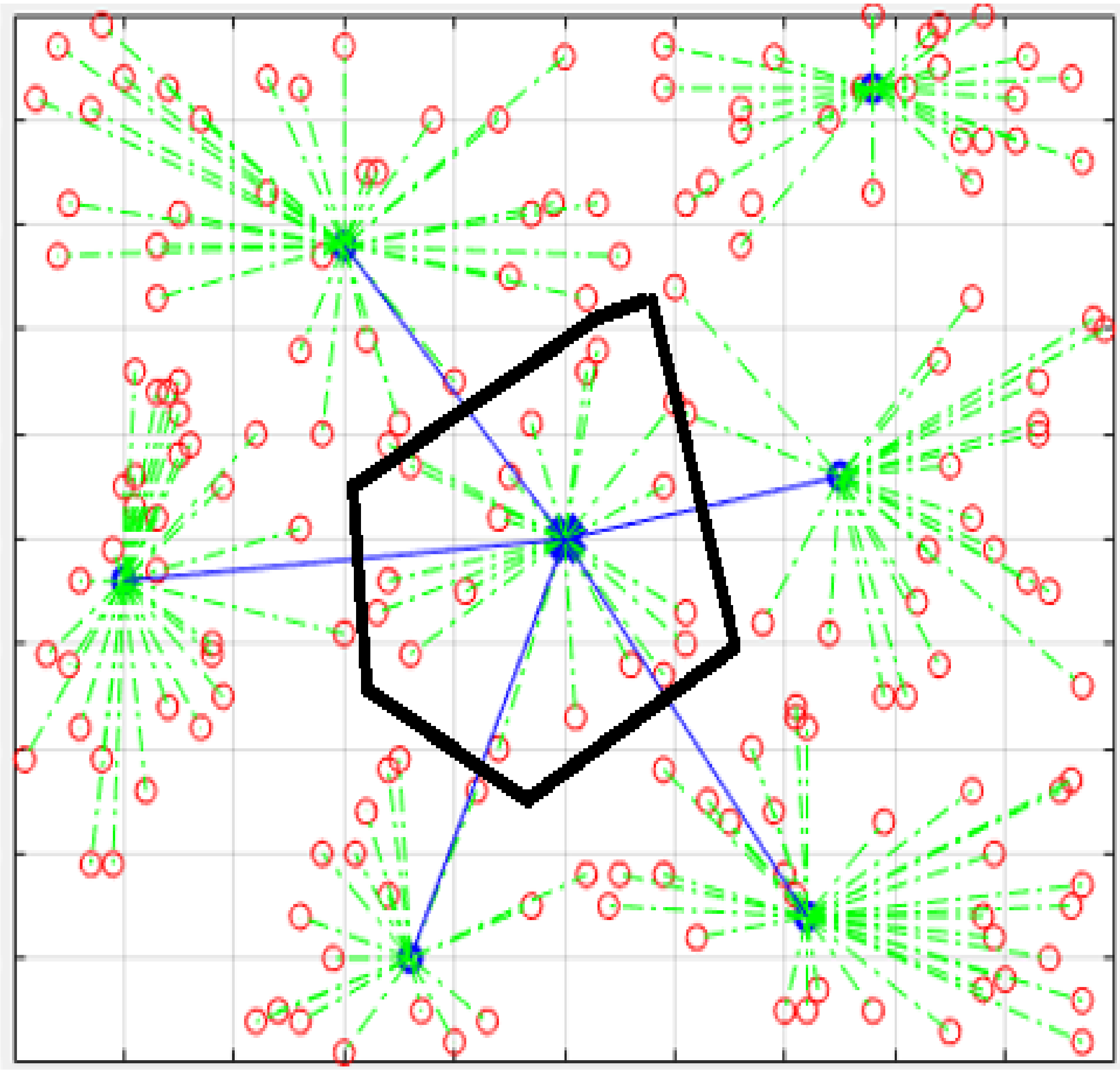


Figure 4.30 PSO-K algorithm solve the SNs near BS problem

Figures (4.29) and (4.30); present that the proposed PSO-K algorithm solve the sensor nodes near BS by make them communicate BS directly.

Chapter Five

Conclusions and Future Directions

5.1 Introduction

A hybrid PSO and K-means (PSO-K) clustering algorithm was proposed and implemented called the PSO-K algorithm. The proposed algorithm consists of Three steps; step1: The K-means algorithm is used to partition the WSN into a number of clusters based on the optimal number of clusters and generate a candidate list of SNs. Step2: the PSO algorithm selects the best CH with the highest residual energy, centrality, and less distance from BS for each cluster. Step3: executes the simulator tool in order to evaluation of the performance of the proposed system. The proposed PSO-K algorithm showed an average improvement of about 52% over the LEACH protocol and about 54%, over the EAMMH protocol, and about 10% over the I-LEACH protocol.

5.2 Conclusion

This study focused on selecting suitable deployment and clustering techniques with a WSN environment. Also, this study focused on CH selection and cluster formation via optimization algorithms. This study also focused on the problem related to the placed a CH at the edge of the network cause more energy consumption. Another problem related to build clusters when SNs located near BS and connected with far CH. Matlab simulator is used for simulating the proposed protocol and compared the results with LEACH, EAMMH, and I-LEACH with energy consumption terms and the improvement in lifetime. All results show that the network performance of the proposed scheme is better than previously proposed clustering techniques.

The major necessary stage in designing any new WSN is deploying the SNs in suitable techniques in order to decrease the number of deployed SNs and maintain the connectivity and coverage of the interest of the area.

1) The simulation results prove that the random deployment technique is less energy consumption as shown Table (4.2).
2) The simulation results prove that the K-mean algorithm is the acceptable as show Tables (4.3), (4.4) and Figure (4.6) which are present that energy consumption is less among others.
3) Tables (4.5) and Figure (4.7); present the number of round effects on energy consumption.
4) Table (4.6) and Figure (4.8) present that the number of CH is effect on the energy consumption and k-mean is acceptable in energy consumption.
5) Table (4.7) and Figure (4.9) present the number of round effect on the energy consumption. Probability of CH number effect on the energy consumption. And k-means is the acceptable in energy conservation among the four clustering methods.
6) Tables (4.8 and 4.9) and Figure (4.10) present that the number of round effect on the energy consumption. And in round 400 to 500 increase the energy consumption and leads to increase the dead nodes. And k-mean is the best clustering algorithm in energy conservation among the clustering methods.
7) Table (4.10) and (4.11) and Figure (4.11), present that the K-mean with optimal N and K is less energy consumption.
8) Table (4.13) and Figure (4. 13) display that FDN in round 1000 is dies at 13 rounds in LEACH whereas for EAMMH is at 23 rounds. I-LEACH is at 40. PSO-K is at 41. Proposed PSO-K algorithm is the best.
9) Table (4.14) and Figure (4.14) present comparison used HDN metric. If round is 500, HDN in LEACH is done in round 95 and in EAMMH in round 100 whereas I-LEACH in round 250. So, HDN with proposed PSO-K is done in round 285. If round is 1000, HDN in LEACH is done in round 90 and in EAMMH in round 112 whereas I-LEACH in round 260. So, HDN with proposed PSO-K is done in round 278. The proposed PSO-K is accepting.
10) Table (4.15) and Figures (4.15) and (4.16); present comparison used LDN metric. If rounds are 500, LDN in LEACH is done in round 497 and in EAMMH in round 500 whereas I-LEACH that 21 alive nodes and 79 dead nodes at end of 500 round. So, LDN with proposed PSO-K is 38 alive nodes

and 62 dead nodes at the end of 500 rounds. When rounds are 1000, LDN is done in LEACH at round 500 when EAMMH at 345 round whereas 6 alive nodes and 94 dead nodes in I-LEACH at end of round 1000. But, LDN with proposed PSO-K alive nodes are 10 and 90 dead nodes in proposed PSO-K at end of round 1000. The proposed PSO-K is accepting.

11) Figures (4.18) and (4.19) present that the proposed PSO-K algorithm is best in distributed nodes in the interest of area. And the proposed PSO-K algorithm select optimal CH far from edge and far from BS.

12) Table (4.16) and Figure (4.20) presents that the average energy consumption for the proposed algorithm is less.

13) Figures (4.22) present that the proposed PSO-K algorithm improve the cluster information process via applied both optimal number of cluster (K) and Euclidian distance.

14) Figures (4.24), (4.25) and (4.26) present that the proposed PSO-K algorithm solve the sensor nodes at edge problem by prevent them become as CHs.

15) Figures (4.29) and (4.30); present that the proposed PSO-K algorithm solve the sensor nodes near BS by make them communicate BS directly.

5.3 Future Works

1. Build models Using mobile nodes to collect the data from the sensing field.
2. Develop a deterministic deployment model for a small area that is suitable for WSNs.
3. Suggest a scheduling algorithm that assigns a high priority for the necessary packets.
4. Apply metaheuristic algorithms to develop shortest path algorithm that suitable with WSNs.
5. In the future works can be additions to security features as well as for moving nodes.
6. Applied NS-2 as a simulator tool.

References

[1] Śliwa, Romana Ewa, Paweł Dymora, Mirosław Mazurek, Bartosz Kowal, Michał Jurek, Damian Kordos, Tomasz Rogalski, Pawel Flaszynski, Piotr Doerffer, Krzysztof Doerffer, Stephen Grigg, and Runar Unnthorsson. 2022. "The Latest Advances in Wireless Communication in Aviation, Wind Turbines and Bridges" Inventions 7, no. 1: 18.

[2] Carlos-Mancilla, M., López-Mellado, E., & Siller, M. (2016). Wireless sensor networks formation: approaches and techniques. Journal of Sensors, 2016.

[3] S. A. Alharthi, P. Johnson and M. A. Alharthi, "IoT architecture and routing for MV and LV smart grid," 2017 Saudi Arabia Smart Grid (SASG), 2017, pp. 1-6,
DOI: 10.1109/SASG.2017.8356507.

[4] Tripti Sharma," Challenges and Design Metrics of Wireless Sensor Network: A Survey", International Journal of Communication Systems and Network Technologies, Vol.4, No.3, 2015.

[5] Mohammed Saad Talib, "Minimizing the Energy Consumption in Wireless Sensor Networks ", Journal of Babylon University/Pure and Applied Sciences/ No. (1)/ Vol. (26): 2018.

[6] Asha G.R., Gowrishankar, " Energy efficient clustering and routing in a wireless sensor network", Procedia Computer Science, Volume 134, 2018, Pages 178-185, ISSN 1877-0509,
https://doi.org/10.1016/j.procs.2018.07.160.

[7] T. M. Behera, S. K. Mohapatra, U. C. Samal, M. S. Khan, M. Daneshmand and A. H. Gandomi, "Residual Energy-Based Cluster-Head Selection in WSNs for IoT Application," in *IEEE Internet of Things Journal*, vol. 6, no. 3, pp. 5132-5139, June 2019, DOI: 10.1109/JIOT.2019.2897119.

[8] Saad A. Alharthi and Princy A. Johnson, "Threshold Sensitive Heterogeneous LEACH Protocol for Wireless Sensor Networks", IEEE, 2016 24th Telecommunications Forum (TELFOR), DOI: 10.1109/TELFOR.2016.7818743.

[9] W. Abushiba, P. Johnson, S. Alharthi and C. Wright, "An energy-efficient and adaptive clustering for wireless sensor network (CH-leach) using leach protocol," 2017 13th International Computer Engineering Conference (ICENCO), 2017, pp. 50-54, DOI: 10.1109/ICENCO.2017.8289762.

[10] Mohammed Abu Zahhad, Sabah M. Ahmed, N. Sabor, and Shigenobu Sasaki, "Mobile Sink-Based Adaptive Immune Energy Efficient Clustering Protocol for Improving the Lifetime and Stability Period" IEEE Sensors Journal, Vol. 15, No. 8, pp 4576- 4586, Aug 2015.

[11] Amin Shahraki, Amir Taherkordi, Øystein Haugen, Frank Eliassen, "Clustering Objectives in Wireless Sensor Networks: A Survey and Research Direction Analysis ", Journal Pre-proof, 2020 Published by Elsevier B.V.

[12] Santosh Vishnu Purkar, R.S. Deshpande, "A Review on Energy Efficient Clustering Protocols of Heterogeneous Wireless Sensor Network ", Santosh Vishnu Purkar et al. / International Journal of Engineering and Technology (IJET), Vol 9 No 3 Jun-Jul 2017.

[13] Yuste-Delgado AJ, Cuevas-Martinez JC, Triviño-Cabrera A. A Distributed Clustering Algorithm Guided by the Base Station to Extend the Lifetime of Wireless Sensor Networks.

Sensors (Basel). 2020 Apr 18;20(8):2312. DOI: 10.3390/s20082312. PMID: 32325643; PMCID: PMC7219241.

[14] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-efficient communication protocol for wireless micro-sensor networks," Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, 2000, pp. 10 pp. vol.2-, DOI: 10.1109/HICSS.2000.926982.

[15] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," IEEE Transactions on Wireless Communications, vol. 1, pp. 660–670, Oct 2002.

[16] Umapathi G. R, Alakesh Berman, Dr. Ramesh babu H S, "ILEACH- An Integrated LEACH Routing Protocol for Elongating the Network Lifetime for WSN ", International Journal of Emerging Trends & Technology in Computer Science (IJETTCS). Volume 3, Issue 4, July-August 2014.

[17] Z. Beiranvand, A. Patooghy, M. Fazeli, "I-LEACH: An efficient routing algorithm to improve performance & to reduce energy consumption in Wireless Sensor Networks," The 5th Conference on Information and Knowledge Technology, 2013, pp. 13-18, DOI: 10.1109/IKT.2013.6620030.

[18] El Khediri, Salim; Khan, Rehan Ullah; Nasri, Nejah; Kachouri, Abdennaceur (2020). MW-LEACH: Low energy adaptive clustering hierarchy approach for WSN. IET Wireless Sensor Systems, Volume10, Issue3, Pages 126-129, June 2020.

[19] Pooja and S. Singh, "Improved O-LEACH protocol: A clustering-based approach in wireless microsensor network," 2016 10th International Conference on Intelligent Systems and Control (ISCO), 2016, pp. 1-4, DOI: 10.1109/ISCO.2016.7727015.

[20] H. M. Abdul Salam and L. K. Kamel, "W-LEACH: Weighted Low Energy Adaptive Clustering Hierarchy Aggregation Algorithm for Data Streams in Wireless Sensor Networks," 2010 IEEE International Conference on Data Mining Workshops, 2010, pp. 1-8, DOI: 10.1109/ICDMW.2010.28.

[21] Deok Hee Nam, "Comparison Studies of Hierarchical Cluster Based Routing Protocols in Wireless Sensor Networks ", EPiC Series in Computing Volume 69, 2020, Pages 334–344 Proceedings of 35th International Conference on Computers and Their Applications, 2020.

[22] S. Nasr and M. Quwaider, "LEACH Protocol Enhancement for Increasing WSN Lifetime," 2020 11th International Conference on Information and Communication Systems (ICICS), 2020, pp. 102-107, DOI: 10.1109/ICICS49469.2020.239542.

[23] Alkadhmawee, Ahmed Adil; Hasan Hasab, Mohanad Abdul Kareem; and Abood, Enas Wahab (2021) "Clustering and Neighboring Technique Based Energy-Efficient Routing for WSNs," Karbala International Journal of Modern Science: Vol. 7: Iss. 2, Article 6.

[24] Yu Song, Zhigui Liu, Xiaoli He, "Hybrid PSO and Evolutionary Game Theory Protocol for Clustering and Routing in Wireless Sensor Network ", Hindawi, Journal of Sensors. Volume 2020, Article ID 8817815, 20 pages.

[25] Azharuddin, M., Jana, P.K. PSO-based approach for energy-efficient and energy-balanced routing and clustering in wireless sensor networks. Soft Comput 21, 6825–6839 (2017). https://doi.org/10.1007/s00500-016-2234-7.

[26] R. S. Elhabyan and M. C. E. Yagoub, "Energy efficient clustering protocol for WSN using PSO," 2014 Global Information Infrastructure and Networking Symposium (GIIS), 2014, pp. 1-3, DOI: 10.1109/GIIS.2014.6934271.

[27] D. Garg, P. Kumar, Kompal, "Energy Efficient Clustering Protocols for Wireless Sensor Networks using Particle Swarm Optimization Approach", International Research Journal of Engineering and Technology, Volume: 04 Issue: 07, pp. 838-846, 2017.

[28] A. Balamurugan, S. Janakiraman, M. D. Priya and A. C. J. Malar, "Hybrid Marine predators' optimization and improved particle swarm optimization-based optimal cluster routing in wireless sensor networks (WSNs)," in China Communications, vol. 19, no. 6, pp. 219-247, June 2022, DOI: 10.23919/JCC.2022.06.017.

[29] K. Mishra and P. Sharma, "Improved Cluster Head Selection Using Particle Swarm Optimization and Neural Network in WSN," 2021 International Conference on Computing Sciences (ICCS), 2021, pp. 13-18, DOI: 10.1109/ICCS54944.2021.00012.

[30] S. L. Rex B R, S. T. Tumma, J. Chandra, L. Giffina and S. Renuga Devi, "Particle Swarm Optimization Method for Energy Efficient Secondary Grid Cluster Head Selection to Avoid Energy Holes in WSN," 2021 Asian Conference on Innovation in Technology (ASIANCON), 2021, pp. 1-7, DOI: 10.1109/ASIANCON51346.2021.9544990.

[31] Z. Hammodi, A. Al Hilli, Al-Ibadi, "Energy Optimization via Optimal Placement of Cluster Heads in Wireless Sensor Networks with Obstacles," 2021 7th International Conference on Signal Processing and Communication (ICSC), 2021, pp. 53-58, DOI: 10.1109/ICSC53193.2021.9673409.

[32] Aparna S. Shinde, Rajankumar S. Bichkar, "Optimal Cluster Head Selection and Clustering for WSN using PSO ", International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-9 Issue-3, January 2020.

[33] Solaiman, Basma. "Energy optimization in wireless sensor networks using a hybrid k-means PSO clustering algorithm." Turkish Journal of Electrical Engineering and Computer Sciences 24.4 (2016): 2679-2695.

[34] Jaspreet Kaur, Dr.Vinay Chopra, (2015). Design of Improved iLEACH using ACO for WSN. International Journal of Engineering and Innovative Technology (IJEIT), Volume 4, Issue 11, May 2015

[35] S. Jiang, "LEACH Protocol Analysis and Optimization of Wireless Sensor Networks Based on PSO and AC," 2018 10th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC), 2018, pp. 246-250, DOI: 10.1109/IHMSC.2018.10163.

[36] T. Saravanan, S. Saravanakumar, "Modeling an Energy Efficient Clustering Protocol with Spider Cat Swarm Optimization for WSN," 2022 IEEE VLSI Device Circuit and System (VLSI DCS), 2022, pp. 188-193, DOI:1109/VLSIDCS53788.2022.9811491.

[37] Aranda, J., Mendez, D., & Carrillo, H. (2020). Multimodal wireless sensor networks for monitoring applications: A review. Journal of Circuits, Systems, and Computers, 29(02), 2030003.

[38] Laith Farhan, Rasha Subhi Hameed, Asraa Safaa Ahmed "Energy Efficiency for Green Internet of Things (IoT) Networks: A Survey ", Network 2021, 1, 279–314. https://doi.org/10.3390/network1030017 https://www.mdpi.com/journal/network.

[39] Behera, T. M., Mohapatra, S. K., Samal, U. C., Khan, M. S., Daneshmand, M., & Gandomi, A. H. (2019). Residual energy-based cluster-head selection in WSNs for IoT application. IEEE Internet of Things Journal, 6(3), 5132-5139.

[40] Aldeer, M., Howard, R., & Al-Hilli, A. (2016, October). Minimizing energy consumption in transmit-only sensor networks via optimal placement of the cluster heads. In Proceedings of the Eighth Wireless of the Students, by the Students, and for the Students Workshop (pp. 36-38).

[41] Li, Y., Ghosh, A., Zhang, Z., Yu, Z., & Wang, J. (2021). Sensors and Applications in Agricultural and Environmental Monitoring. Journal of Sensors, 2021.

[42] Brohi, A. M., Malkani, Y. A., & Chandio, M. S. (2018, March). Data provenance in wireless sensor networks (WSNs): A review. In 2018 International Conference on Computing, Mathematics and Engineering Technologies (iCoMET) (pp. 1-5). IEEE.

[43] El Khediri, S., Khan, R. U., Nasri, N., & Kachouri, A. (2021). Energy efficient adaptive clustering hierarchy approach for wireless sensor networks. International Journal of Electronics, 108(1), 67-86.

[44] Nagaraj, S., & Biradar, R. V. (2017, August). Applications of wireless sensor networks in the real-time ambient air pollution monitoring and air quality in metropolitan cities—a survey. In 2017 International Conference On Smart Technologies for Smart Nation (SmartTechCon) (pp. 1393-1398). IEEE.

[45] Ghanem, M., Mansoor, A. M., & Ahmad, R. (2021). A systematic literature review on mobility in terrestrial and underwater wireless sensor networks. International Journal of Communication Systems, 34(10), e4799.

[46] Haque, M., Ahmad, T., & Imran, M. (2018). Review of hierarchical routing protocols for wireless sensor networks. In Intelligent communication and computational technologies (pp. 237-246). Springer, Singapore.

[47] Amit Sarkar, T. Senthil Murugan, Routing protocols for wireless sensor networks: What the literature says? Alexandria Engineering Journal, Volume 55, Issue 4, 2016, pp. 3173-3183

[48] Huo, J., Deng, X., Al-Neshmi, H. M. M. (2020). Design and improvement of routing protocol for field observation instrument networking based on LEACH protocol. Journal of Electrical and Computer Engineering, 2020.

[49] U. Devee Prasan, "A Survey on Issues in Designing a Routing Protocol for Ad Hoc Wireless Networks ", INDIAN JOURNAL OF APPLIED RESEARCH, Volume: 3 | Issue: 5 | May 2013 | ISSN - 2249-555X.

[50] Vhatkar, S., Atique, M. (2013). Design issues, characteristics, and challenges in routing protocols for wireless sensor networks. International Journal of Computer Applications, 975(8887), 36-37.

[51] Raja Waseem Anwar, Majid Bakhtiari, "A Survey of Wireless Sensor Network Security and Routing Techniques", Research Journal of Applied Sciences, Engineering and Technology 9(11): 1016-1026, 2015.

[52] Patil, B., & Kadam, R. (2018, January). A novel approach to secure routing protocols in WSN. In 2018 2nd International Conference on Inventive Systems and Control (ICISC) (pp. 1094-1097). IEEE.

[53] Hesham Abusaimeh, Mohammad Shkoukani. Modified TCP Protocol for Wireless Sensor Networks. International Journal of Computer Science Issues (IJCSI), 10(2):279–285, Mar. 2013.

[54] H. P. Gupta and S. V. Rao. Demand-Based Coverage and Connectivity-Preserving Routing in Wireless Sensor Networks. IEEE Systems Journal, 10(4):1380–1389, Dec. 2016.

[55] Abedin, Z., Paul, S., Akhter, S., Siddiquee, K. N. E. A., Hossain, M. S., & Andersson, K. (2017, October). Selection of energy-efficient routing protocol for irrigation enabled by wireless sensor network. In 2017 IEEE 42nd Conference on Local Computer Networks Workshops (LCN Workshops) (pp. 75-81). IEEE.

[56] J. Ueyama, B. S. Faiçal, L. Y. Mano, G. Bayer, G. Pessin, and P. H. Gomes, "Enhancing reliability in Wireless Sensor Networks for adaptive river monitoring systems: Reflections on their long-term deployment in Brazil," Comput. Environ. Urban Syst., vol. 65, pp. 41–52, 2017.

[57] Noh, Y., Lee, U., Lee, S., Wang, P., Vieira, L. F., Cui, J. H., ... & Kim, K. (2015). Hydrocast: Pressure routing for underwater sensor networks. IEEE Transactions on Vehicular Technology, 65(1), 333-347.

[58] G. Han, J. Jiang, N. Bao, L. Wan, and M. Guizani, "Routing protocols for underwater wireless sensor networks," IEEE Commun. Mag., vol. 53, no. 11, pp. 72–78, 2015.

[59] Deok Hee Nam, "Comparison Studies of Hierarchical Cluster-Based Routing Protocols in Wireless Sensor Networks ", EPiC Series in Computing Volume 69, 2020, Pages 334{344 Proceedings of 35th International Conference on Computers and Their Applications.

[60] T. AlSkaif, B. Bellalta, M. G. Zapata, J. M. B. Ordinas, “Energy efficiency of MAC protocols in low data rate wireless multimedia sensor networks: A comparative study,” Ad Hoc Networks, vol. 56, pp. 141–157, 2017.

[61] G. Han, J. Jiang, M. Guizani, and J. J. P. C. Rodrigues, “Green routing protocols for wireless multimedia sensor networks,” IEEE Wirel. Commun., vol. 23, no. 6, pp. 140–146, 2016.

[62] Yousif, Y. K., Badlishah, R., Yaakob, N., & Amir, A. (2018, June). An energy efficient and load balancing clustering scheme for wireless sensor network (WSN) based on distributed approach. In Journal of Physics: Conference Series (Vol. 1019, No. 1, p. 012007). IOP Publishing.

[63] Fang, W., Zhang, W., Shan, L., Assefa, B., & Chen, W. (2020). Hierarchical routing protocol in wireless sensor network: a state-of-the-art review. International Journal of Computational Science and Engineering, 22(1), 107-113.

[64] Hiu Fai CHAN, “Energy Efficient Clustering and Routing Algorithm in Wireless Sensor Networks “, Ph.D. thesis, School of Engineering College of Science, Engineering and Health RMIT University, July 2020.

[65] Manisha R. Dhage, Srikanth Vemuru, “Routing Design Issues in Heterogeneous Wireless Sensor Network “, International Journal of Electrical and Computer Engineering (IJECE) Vol. 8, No. 2, April 2018, pp. 1028~1039 ISSN: 2088-8708, DOI: 10.11591/ijece. v8i2.pp1028-1039

[66] Arjunan, S., Pothula, S. (2019). A survey on unequal clustering protocols in wireless sensor networks. Journal of King Saud University-Computer and Information Sciences, 31(3), 304-317.

[67] Mehta, D., Saxena, S. (2018, August). A comparative analysis of energy-efficient hierarchical routing protocols for wireless sensor networks. In 2018 4th International Conference on Computing Sciences (ICCS) (pp. 53-58). IEEE.

[68] Jain, A. (2022). Unequal Clustering Protocols for Wireless Sensor Networks—Taxonomy, Comparison and Simulation. Wireless Personal Communications, 124(1), 517-571.

[69] M. M. Zanjireh and H. Larijani, "A Survey on Centralised and Distributed Clustering Routing Algorithms for WSNs," 2015 IEEE 81st Vehicular Technology Conference (VTC Spring), 2015, pp. 1-6, DOI: 10.1109/VTCSpring.2015.7145650.

[70] Corn, J., & Bruce, J. W. (2017, January). Clustering algorithm for improved network lifetime of mobile wireless sensor networks. In 2017 International conference on computing, networking, and communications (ICNC) (pp. 1063-1067). IEEE.

[71] A. Karmaker, M. M. Hasan, S. S. Moni, M. S. Alam, "An efficient cluster head selection strategy for provisioning fairness in wireless sensor networks," 2016 IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE), 2016, pp. 217-220, DOI: 10.1109/WIECON-ECE.2016.8009121.

[72] T. M. Behera, S. Nanda, S. K. Mohapatra, U. C. Samal, M. S. Khan, and A. H. Gandomi, "CH Selection via Adaptive Threshold Design Aligned on Network Energy," in IEEE Sensors Journal, vol. 21, no. 6, pp. 8491-8500, 15 March 2021, DOI: 10.1109/JSEN.2021.3051451.

[73] S. Sharma and N. Mittal, "An Improved LEACH-MF Protocol to Prolong Lifetime of Wireless Sensor Networks," 2018 IEEE 8th International Advance Computing Conference (IACC), 2018, pp. 174-179, DOI: 10.1109/IADCC.2018.8692096.

[74] M. Haneef, Z. Wenxun, Z. Deng, "MG-LEACH: Multi group based leach, an energy-efficient routing algorithm for wireless sensor network", 14th IEEE International Conference on Advanced Communication Technology (ICACT), pp. 179-183, 19-22 Feb. 2012.

[75] Solangi, S. A., Hakro, D. N., Lashari, I. A., Khoumbati, K. U. R., Bhutto, Z. A., & Hameed, M. (2017). Genetic Algorithm Applications in Wireless Sensor Networks (WSN): A Review. International Journal of Management Sciences and Business Research, 1(4), 152-166.

[76] Vinay Kumar, Hardeep Singh Saini, Varun Marwaha, Rajesh Kumar, "Q-LEACH Protocol using Intermediate Gateway Nodes for WSN ", Proceedings of the International Conference on Inventive Computing and Informatics (ICICI 2017), IEEE Xplore Compliant - Part Number: CFP17L34-ART, ISBN: 978-1-5386-4031-9

[77] B. M. Sahoo, R. K. Rout, S. Umer, H. M. Pandey, "ANT Colony Optimization based Optimal Path Selection and Data Gathering in WSN," 2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM), 2020, pp. 113-119, DOI: 10.1109/ICCAKM46823.2020.9051538.

[78] S. Ramisetty, Kavita, S. Verma, W. Mansoor, "Intra Cluster-based Energy Efficient PSO-GA Routing Protocol in WSN," 2021 4th International Conference on Signal Processing and Information Security (ICSPIS), 2021, pp. 92-95, DOI: 10.1109/ICSPIS53734.2021.9652441.

[79] K. Mishra and P. Sharma, "Improved Cluster Head Selection Using Particle Swarm Optimization and Neural Network in WSN," 2021 International Conference on Computing Sciences (ICCS), 2021, pp. 13-18, DOI: 10.1109/ICCS54944.2021.00012.

[80] T. Sharma, G. Tomar, B. Kumar and I. Berry, "Particle Swarm Optimization based Cluster Head Election Approach for Wireless Sensor Networks", International Journal of Smart Device and Appliance, pp. 11-24, 2014.

[81] Sinde, R., Begum, F., Njau, K., & Kaijage, S. (2020). Lifetime improved WSN using enhanced-LEACH and angle sector-based energy-aware TDMA scheduling. Cogent Engineering, 7(1), 1795049.

[82] A. Hamzah, M. Shurman, O. Al-Jarrah and E. Taqieddin, "Energy-Efficient Fuzzy-Logic-Based Clustering Technique for Hierarchical Routing Protocols in Wireless Sensor Networks," Sensors (Basel), Vol. 19, Issue 3, Feb. 2019.

[83] Energy Aware Multi-Hop Multi-Path Hierarchical (EAMMH) Routing Protocol for Wireless Sensor Networks" European Journal of Scientific Research ISSN 1450-216X Vol. 88 No 4 October 2012.
[84] M. Farsi, M. A. Elhosseini, M. Badawy, H. Arafat Ali and H. Zain Eldin, "Deployment Techniques in Wireless Sensor Networks, Coverage and Connectivity: A Survey," in IEEE Access, vol. 7, pp. 28940-28954, 2019, DOI: 10.1109/ACCESS.2019.2902072.
[84] P. Jiang, Y. Xu, and F. Wu, "Node self-deployment algorithm based on an uneven cluster with radius adjusting for underwater sensor networks," Sensors, vol. 16, no. 1, p. 98, 2016.
[85] Y. El Khamlichi, A. Tahiri, A. Abtoy, I. Medina-Bulo, and F. Palomo-Lozano, "A hybrid algorithm for optimal wireless sensor network deployment with the minimum number of sensor nodes," Algorithms, vol. 10, no. 3, p. 80, 2017.
[86] I. Khoufi, P. Minet, A. Laouiti, and S. Mahfoudh, "Survey of deployment algorithms in wireless sensor networks: coverage and connectivity issues and challenges," Int. J. Auton. University of Ghana. Adapt. Commun. Syst., vol. 10, no. 4, pp. 341–390, 2017.
[87] R. Elhabyan, W. Shi and M. St-Hilaire, "Coverage protocols for wireless sensor networks: Review and future directions," in Journal of Communications and Networks, vol. 21, no. 1, pp. 45-60, Feb. 2019, DOI: 10.1109/JCN.2019.000005.
[88] Tisha Lafaye Brown, "Deployment, Coverage and Network Optimization In Wireless Video Sensor Networks for 3D Indoor Monitoring ", Ph.D. Thesis in the Department of Computer and Information Science, University of Mississippi, 2017.
[89] X. Xu, Z. Dai, A. Shan, T. Gu, "Connected Target ϵ-probability Coverage in WSNs with Directional Probabilistic Sensors," in IEEE Systems Journal, vol. 14, no. 3, pp. 3399-3409, Sept. 2020, DOI: 10.1109/JSYST.2019.2939178.
[90] V. Sharma, R. Patel, H. Bhadauria, and D. Prasad, "Deployment schemes in a wireless sensor network to achieve blanket coverage in large-scale open area: A review," Egyptian Informatics Journal, vol. 17, no. 1, pp. 45{56, 2016.
[91] T. Brown, Z. Wang, T. Shan, F. Wang, J. Xue, "On wireless video sensor network deployment for 3D indoor space coverage," SoutheastCon 2016, 2016, pp. 1-8, DOI: 10.1109/SECON.2016.7506744.
[92] Belal Al-Fuhaidi, Abdulqader M. Mohsen, Abdulkhabeer Ghazi, Walid M. Yousef, "An Efficient Deployment Model for Maximizing Coverage of Heterogeneous Wireless Sensor Network Based on Harmony Search Algorithm ", Hindawi Journal of Sensors, Volume 2020, Article ID 8818826, 18 pages.
[93] Nidhi Suthar, Prof. Indr jeet Rajput, Prof. Vinit Kumar Gupta, "A Technical Survey on DBSCAN Clustering Algorithm ", International Journal of Scientific & Engineering Research, Volume 4, Issue 5, 2013.
[94] A. Venkateshwar and V. C. Patil, "A Decentralized Multi Competitive Clustering in Wireless Sensor Networks for the Precision Agriculture," 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), 2017, pp. 284-288, DOI: 10.1109/CTCEEC.2017.8455019.

[95] M. Hatamian, S. S. Ahmadpoor, S. Berenjian, B. Razeghi, H. Barati, "A centralized evolutionary clustering protocol for wireless sensor networks," 2015 6th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2015, pp. 1-6, DOI: 10.1109/ICCCNT.2015.7395190.
[96] Nalluri Prophess Raj Kumar, Josemin Bala Gnanadhas, "Cluster Centroid-Based Energy Efficient Routing Protocol for WSN-Assisted IoT ", Advances in Science, Technology and Engineering Systems Journal Vol. 5, No. 4, 296-313 (2020).
[97] P. Prabhu, "Method for Determining Optimum Number of Clusters for Clustering Gene Expression Cancer Dataset ", International Journal of Advanced Research in Computer Science, Volume 2, No. 4, July-August 2011.
[98] H. Echoukairi, A. Kada, K. Bouragba and M. Ouzzif, "A novel centralized clustering approach based on K-means algorithm for wireless sensor network," 2017 Computing Conference, 2017, pp. 1259-1262, DOI: 10.1109/SAI.2017.8252252.
[99] Darong, H., & Peng, W. (2012). Grid-based DBSCAN algorithm with referential parameters. Physics Procedia, 24, 1166-1170.
[100] Sauravjyoti Sarmah, Dhruba K. Bhattacharyya," An Effective Technique for Clustering Incremental Gene Expression Data", IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 3, No 3, May 2010.
[101] Daniel Morariu, Radu Cretulescu, Macarie Breazu - The WEKA Multilayer Perceptron Classifier, Int. Journal of Advanced Statistics and IT&C for Economics and Life Sciences, Vol 7, No 1, ISSN 2067-354X, 2017.
[102] Cretulescu, R. G., Morariu, D., Breazu, M., & Volovici, D. (2019). DBSCAN algorithm for document clustering. International Journal of Advanced Statistics and IT&C for Economics and Life Sciences, 9(1).
[103] Radu G. CREŢULESCU, Daniel I. Morariu, "DBSCAN Algorithm for Document Clustering ", International Journal of Advanced Statistics and IT&C for Economics and Life Sciences June, Vol. IX, no. 1, 2019.
[102] Saadaldeen Rashid Ahmed, Israa Al_Barazanchi, Zahraa A. Jaaz, "Clustering algorithms subjected to K-mean and Gaussian mixture model on multidimensional data set "Periodicals of Engineering and Natural Sciences, Vol. 7, No. 2, June 2019, pp.448-457
[103] M. Mishra, C. R. Panigrahi, J. L. Sarkar and B. Pati, "GECSA: A game theory based energy efficient cluster-head selection approach in Wireless Sensor Networks," 2015 International Conference on Man and Machine Interfacing (MAMI), 2015, pp. 1-5, doi: 10.1109/MAMI.2015.7456580.
[104] Pu, X. and E. Arias-Castro, "An EM algorithm for fitting a mixture model with symmetric log-concave densities", Communications in Statistics-Theory and Methods 49(1), 78–87,2020.
[105] Yu, K. (2019). Data Science Foundations: Geometry and Topology of Complex Hierarchic Systems and Big Data Analytics. Boca Raton, FL: Chapman & Hall/CRC Press, 2017, xviii+ 205 pp., $93.95 (H), ISBN: 978-1-49-876393-6.
[106] Contreras P, "Search and Retrieval in Massive Data Collections", Ph.D. Thesis. Egham, UK: Royal Holloway, University of London; 2010.

[107] K. Thangaramya, R. Logambigai, L. SaiRamesh, K. Kulothungan, A. Kannan and S. Ganapathy, "An Energy Efficient Clustering Approach Using Spectral Graph Theory in Wireless Sensor Networks," 2017 Second International Conference on Recent Trends and Challenges in Computational Models (ICRTCCM), 2017, pp. 126-129, DOI: 10.1109/ICRTCCM.2017.41.

[108] Ding L, Gonzalez-Longatt FM, Wall P, Terzija V, “Two-step spectral clustering controlled islanding algorithm”, IEEE Trans Power Syst 28(1):75–84, 2013.

[109] A. Jantan, “An approach for malware behavior identification and classification,” 3rd International Conference on Computer Research and Development, 2011, vol. 1, pp. 191–194.

[110] Saja Alqurashi, Omar Batarfi, “Automated Malware Detection Based on HMM and Genetic K-means “, International Journal of Intelligent Computing Research (IJICR), Volume 8, Issue 3, September 2017 Copyright © 2017, Infonomics Society 849.

[111] Celebi, M. E., Kingravi, H. A., & Vela, P. A. (2013). A comparative study of efficient initialization methods for the k-means clustering algorithm. Expert systems with applications, 40(1), 200-210.

[112] M. Bahrepour, N. Meratnia and P. J. M. Havinga, "Online unsupervised event detection in wireless sensor networks," 2011 Seventh International Conference on Intelligent Sensors, Sensor Networks and Information Processing, 2011, pp. 306-311, DOI: 10.1109/ISSNIP.2011.6146583.

[113] P. Gupta and K. Sharma, "Review paper on various clustering schemes," 2017 IEEE International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM), 2017, pp. 44-48, DOI: 10.1109/ICSTM.2017.8089125.

[114] He Jiang, “Clustering and Mixture Modeling: Some Methodology and Theory “, Ph.D. Thesis in UNIVERSITY OF CALIFORNIA SAN DIEGO, 2022.

[115] Garima, H. Gulati, P. K. Singh, "Clustering techniques in data mining: A comparison," 2015 2nd International Conference on Computing for Sustainable Global Development (INDIACom), 2015, pp. 410-415.

[116] Rocci, R., S. A. Gattone, and R. Di Mari, “A data-driven equivariant approach to constrained Gaussian mixture modeling”, Advances in Data Analysis and Classification 12(2), 235–260, 2018.

[117] Monyeki, P. (2021). Data mining to analyze recurrent crime in South Africa (Doctoral dissertation).

[118] S. L. Rex B R, S. T. Tumma, J. Chandra, L. Giffina and S. Renuga Devi, "Particle Swarm Optimization Method for Energy Efficient Secondary Grid Cluster Head Selection to Avoid Energy Holes in WSN," 2021 Asian Conference on Innovation in Technology (ASIANCON), 2021, pp. 1-7, DOI: 10.1109/ASIANCON51346.2021.9544990.

[119] K. Mishra and P. Sharma, "Improved Cluster Head Selection Using Particle Swarm Optimization and Neural Network in WSN," 2021 International Conference on Computing Sciences (ICCS), 2021, pp. 13-18, DOI: 10.1109/ICCS54944.2021.00012.

[120] Amirhossein Barzin, Ahmad Sadegheih, Hassan Khademi Zare, “A Hybrid Swarm Intelligence Algorithm for Clustering-Based Routing in Wireless Sensor Networks “, Journal of Circuits, Systems, and Computers Vol. 29, No. 10 (2020).

[121] T. T. Huynh, H. -N. Phan-Thi, A. -V. Dinh-Duc and C. H. Tran, "Prolong the network lifetime by optimal clustering based on intelligent search algorithms in wireless sensor networks," 2014 International Conference on Advanced Technologies for Communications (ATC 2014), 2014, pp. 251-255, DOI: 10.1109/ATC.2014.7043393.

[122] I. S. Akila, R. Venkatesan and R. Abinaya, "A PSO based energy efficient clustering approach for Wireless Sensor Networks," 2016 International Conference on Computation of Power, Energy Information and Communication (ICCPEIC), 2016, pp. 259-264, DOI: 10.1109/ICCPEIC.2016.7557207.

[123] Anitha G., Vijayakumari V., and Shankar Thangavelu. A Comprehensive Study and Analysis of LEACH and HEED Routing Protocols for Wireless Sensor Networks - With Suggestions for Improvements. Indonesian Journal of Electrical Engineering and Computer Science, 9(3):778–783, Mar. 2018.

[124] Hicham Ouldzira, Hajar Lagraini, Ahmed Mouhsen, Mostafa Chhiba, Abdelmoumen Tabyaoui, “MG-leach: an enhanced leach protocol for wireless sensor network”, International Journal of Electrical and Computer Engineering (ICE), Vol. 9, No. 4, August 2019.

[125] Awj R. Tarawneh, Banan Malahmeh, Abdullah Al-Odienat, “Improved LEACH Protocol for Increasing Network Lifetime Based on Circular Patches Clustering”, Universal Journal of Applied Science 7(1): 8-17, 2020.

[126] Cai, X., Geng, S., Wu, D., Wang, L., & Wu, Q. (2020). A unified heuristic bat algorithm to optimize the LEACH protocol. Concurrency and Computation: Practice and Experience, 32(9), e5619.

[127] A. Pathak, Zaheeruddin and M. K. Tiwari, "Clustering in Wireless Sensor Networks based on Soft Computing: A Literature Survey," 2018 International Conference on Automation and Computational Engineering (ICACE), 2018, pp. 29-33, DOI: 10.1109/ICACE.2018.8687053.

[128] Muhammad Farooq-i-Azam and Muhammad Ayyaz Naeem. Location and Position Estimation in Wireless Sensor Networks. arXiv e-prints, abs/1611.03420,Oct. 2016.

[129] P. Kumar and A. Chaturvedi, "Evaluation of Energy Efficient Clustering Algorithms (E2CA) for Query Based WSNs," 2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE), 2019, pp. 16-19, DOI: 10.1109/ICCIKE47802.2019.9004332.

[130] Jau-Yang Chang and Ting-Huan Shen. An Efficient Tree-Based Power Saving Scheme for Wireless Sensor Networks With Mobile Sink. IEEE Sensors, 16(20):7545–7557, Oct. 2016.

[131] L. I. Voronova, V. I. Voronov and N. Mohammad, "Modeling the Clustering of Wireless Sensor Networks Using the K-means Method," 2021 International Conference on Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS), 2021, pp. 740-745, doi: 10.1109/ITQMIS53292.2021.9642747.

[132] Patel, E., & Kushwaha, D. S. (2020). Clustering cloud workloads: K-means vs gaussian mixture model. Procedia computer science, 171, 158-167.

[133] T. M. Behera, U. C. Samal, and S. K. Mohapatra, “Energy Efficient Modified LEACH Protocol for IoT Application,” IET Wirel. Sens. Syst., vol. 8, no. 5, pp. 223 – 228, 2018.

Appendix A

Papers Published and Accepted

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Selecting an Optimal Cluster Head using PSO Algorithm in WSNs

Publisher: IEEE Cite This PDF

Dheyab Salman Ibrahim ; Saad Talib Hasson ; Princy A. Johnson **All Authors**

Abstract

Document Sections

I. Introduction

II. Related Work

III. Particle Swarm Optimization

IV. K-Means

V. Proposed PSO-Kalgorithm

Show Full Outline

Authors

Figures

References

Keywords

Abstract:
A Wireless Sensor Network (WSN) represents a set of deployed sensors in an area to track or monitor specific activities. Sensors are utilized to gather certain data and forward it to the sink or a Base Station (BS). Sensors are operated by limited-energy batteries. Optimizing the consumed energy will prolong the WSN's lifetime. One approach to reducing the consumed energy is by applying a cluster-based routing protocol. Optimizing the Cluster Head (CH) selection represents another approach to prolonging the WSN lifetime. This paper proposes an optimization algorithm to select the CH. The residual energy, the distance between sensors, and the centrality of the sensor node are used as significant features in selecting the CHs in this paper. The proposed algorithm is based on Particle Swarm Optimization (PSO) algorithm and K-Means algorithm. This study proposed approach is called the PSO-K algorithm. It helps in reducing energy consumption and increasing the network lifetime. MATLAB is used to model and simulate this developed algorithm. the number of sensors, number of rounds, number of CHs, the first dead nodes, the half-dead nodes, and the last dead nodes are used to evaluate the WSN performance. A comparison with other closely related works such as LEACH, EAMMH, and iLEACH shows that the PSO-K algorithm is the best in energy consumption and network lifetime.

Published in: 2022 International Conference on Software, Telecommunications and Computer Networks (SoftCOM)

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I. Introduction

Wireless sensor networks (WSNs) represent an important type of wireless network. These networks have been interested due to their practical important applications. WSNs are being applied in various fields such as the industrial, military, agricultural, medical, environmental, and other fields either civil or mil[...] networks are coming from their particularity in their establis[...]tures. Sensors are usually small in size, can easily deploy, are cheap, and easy to in observation and control. Although the sensor nodes have many advantages, they also suffer from different limitations such as

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A New Modeling Approach to Process the Sensors Communication based on Their Locations

Publisher: IEEE Cite This PDF

Dheyab Salman Ibrahim ; Saad Talib Hasson ; Princy A. Johnson All Authors

Abstract:
Wireless Sensor Network (WSN) is a specific type of wireless network which is deployed sensor nodes within a range for specific environments. Energy is the main challenge in WSNs. Sensors are powered by a limited battery. A hierarchical routing protocol is considered an energy-efficient technique for saving energy and prolonging the network lifetime. Clustering

Date of Conference: 26-28 September 2022 **DOI:** 10.1109/ICSIMA55652.2022.9929107

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I. Introduction

Wireless sensor networks (WSNs) play a main role in several applications including health care, environmental monitoring, industrial and agriculture, etc. [1]. The WSN goal is to gather data from the area of interest and send information to the base station (BS) via Wireless links. Sensors have limited battery and limited processing capabilities. Limited power represents a significant effect on the lifetime of the WSNs [2]. Consuming energy in WSNs is an essential factor, replacing or recharging the sensors or their batteries is a very challenging process. To improve the lifetime of WSNs, designing energy-aware routing protocols are urgent to increase their applications [3]. The traditional routing protocols may not guarantee the balanced consumption of the energy in a r Sign in to Continue Reading n clustering represents one of the solution approaches [2]. A olong the lifetime of the WSN. In clustering techniques, Sensors are collected into sets (called clusters) and each

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Date: October 4, 2021
Paper ID: MAICT_54

LETTER OF ACCEPTANCE

Dear Authors,

On behalf of the MAICT -21 Committee, and based on the reviewers' evaluation after double blind peer review Process and Guest Editors' approval we are pleased to inform you that your paper entitled:

" Optimizing LEACH Routing Protocols for WSN: An Analysis Study"

Written By

Dheyab S. Ibrahim , Saad T. Hasson and Princy A. Johnson

Has been accepted and will be processed for possible publication in the **AIP Conference Proceedings** (ISSN: 0094-243X, 1551-7616, MAICT-2021). It is our pleasure to invite you to attend Al-Kadhum 2nd International Conference on Modern Applications of Information and Communication Technology (MAICT_2021), IKC College, Baghdad, Iraq at 8-9 December 2021 to present your paper. We congratulate you for your achievement, the technical details about the publication will be informed later. The publication of the accepted paper will be provided by the end of February 2022.

We Will encourage more quality submissions from you and your colleagues in future

REGARDS,

Jyoti S. Banerjee

PROF. DR. JYOTI S. BANERJEE

SPECIAL ISSUE GUEST EDITOR OF MAICT_21

AIP Publishing

Caution: This Acceptance Letter Made by MAICT Conference Main Guest Editors, All Approval Inquiries Should Made to Editorial Board Members of MAICT Conference, as all Accepted Papers will Process for publication in **AIP Conference Proceedings.**

الخلاصة

تمثل شبكات الاستشعار اللاسلكية نوعًا مهمًا من الشبكات اللاسلكية. يتم تطبيق WSNs في مختلف المجالات مثل المجالات الصناعية والعسكرية والزراعية والطبية وغيرها من المجالات المدنية أو العسكرية. تتميز هذه الشبكات بخصائص وميزات مثل صغر حجمها وسهولة نشرها ورخص ثمنها. لكنها تعاني أيضًا من قيود مختلفة مثل قيود في الطاقة والذاكرة والحوسبة. تعاني شبكات WSN أيضًا من العديد من التحديات اهمها استهلاك الطاقة. حيث يعد استهلاك الطاقة أحد أهم العوامل التي تؤثر على كفاءة وموثوقية شبكات ال WSN.
حد أهم الطرق لتحسين أداء الشبكات اللاسلكية هي طريقة التجميع او العنقدة. يمكن تصنيف بروتوكولات التوجيه في شبكات WSN بناءً على بنية الشبكة إلى بروتوكولات توجيه ثابتة وبروتوكولات قائمة على الموقع وبروتوكولات توجيه هرمية.
ركزت هذه الأطروحة على تطوير بروتوكولات التوجيه الهرمي بناءً على خوارزميات العنقدة من خلال المساهمات التالية.
اقتراح واشتقاق نموذج رياضي لتحديد العدد الأمثل للعناقيد التي يتم انشاءها. هذا العدد الأمثل من المجموعات يكون هو أفضل رقم ممكن يمكن الوصول إليه بشكل تكراري بواسطة طرق العنقدة الأخرى مثل .k-mean
اقتراح واشتقاق نموذج رياضي آخر لتقسيم المنطقة المراد مراقبتها إلى ثلاثة قطاعات. القطاع الأول هو المستشعرات المحيطة او القريبة من بالمحطة الأساسية BS بقطر يساوي نطاق اتصالات المستشعرات R، والقطاع الثاني هوالمستشعرات التي تقع في حافة أو حدود المنطقة التي تم نشر المستشعرات فيها ، في حين أن القطاع الثالث هو باقي منطقة المنتشرة (بين القطاعين).
اقتراح خوارزمية هجينة تجمع بين خوارزمية تحسين السرب PSO وخوارزمية التجميع K-mean لأختيار CH الأمثل للمجموعات التي تم إنشاؤها. تسمى هذه الخوارزمية الهجينة في هذه الأطروحة خوارزمية PSO-Kوتختارال CH بناءً على الطاقة المتبقية والمسافة.
اقتراح تقنية مثالية لتشكيل العناقيد تعتمد هذه التقنية على كل من مقياس Euclidian والعدد الأمثل للعناقيد.
اقتراح وتنفيذ نموذج رياضي لأيجاد حل أمثل لمشكلة أجهزة الاستشعار الموجودة على حافة الشبكة. يمنع هذا الموديل هذه العقد من أن تكون CHs لا يمنح النموذج الرياضي المقترح SNs الموجودة على حافة الشبكة أي فرصة للعب دور CH .
اقتراح موديل رياضيً لأيجاد حل أمثل لمشكلة SNs الموجودة على مسافة قريبة من BS. أجهزة الاستشعار القريبة من BS غير قادرة على لعب دور CH وفقًا للنموذج المقترح. يُسمح لهذه المستشعرات بالاتصال مع BS مباشرة.
تم تقييم أداء النظام المقترح باستخدام MATLAB . أهم المقاييس المستخدمة هي معدل استهلاك الطاقة ، وعدد العقد الحية والميتة في كل دورة وتمت مقارنة نتائج هذه الأطروحة مع البروتوكولات مثل بروتوكولات LEACH و EAMMH و ILEACH . أظهرت خوارزمية PSO-K المقترحة تحسنًا بحوالي 52٪ على بروتوكول LEACH وحوالي 54٪ على بروتوكول EAMMH وحوالي 10٪ على بروتوكـول I- LEACH.

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طريقة موفرة للطاقة بالاعتماد على تقنية الأمثلية المطورة لأطالة عمر شبكات الأستشعار اللاسلكية

اطروحة

مقدمة الى كلية تكنوولوجيا المعلومات جامعة بابل كجزء
من متطلبات نيل درجة الدكتوراه فلسفة في تكنولوجيا المعلومات/ شبكات
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