Optimal clustering Using Genetic Algorithm in Heterogeneous WSN

By

Adeel Mustafa

00000117841

Supervisor

Dr. Muazzam A. Khan

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Approval

It is certified that the contents and form of the thesis entitled **"Optimal Clustering Using Genetic Algorithm in Heterogeneous Wireless Sensor Networks"** submitted by **Adeel Mustafa** have been found satisfactory for the requirement of the degree

Advisor : Dr. Muazzam A.Khan
Signature :________________
Date :________________

Committee Member 1: : Dr. Asad Waqar Malik
Signature :________________
Date :________________

Committee Member 2: : Dr. Rizwan Ahmad
Signature :________________
Date :________________

Committee Member 3: : Dr. Anis-ur-Rehman
Signature :________________
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00000117841

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This thesis is dedicated to *my late Ammi who have stood by me and supported me in every odd of life and also my Abu whose support helped to reach me where I am today.*

Abstract

Recent advancements in wireless communication technology allowed rapid growth of wireless sensor networks (WSNs). WSN contains minute electronic devices that are called sensor nodes(SN). WSNs covers many areas like health care, environmental observation, industrial monitoring, battle fields and in security. SN exchange information with each other under transmission policies. SN are low dormant and energy reticent appliances; so the energy-saving routing protocols are the pre-eminent objective. To overcome these issues, we have suggested a new energy efficient and scalable routing scheme which uses Genetic Algorithm to get optimal solutions. The proposed scheme reduces the energy usage and elongate the lifetime of WSN.

Keywords: *Direct Transmission (DTS), (CTS), Energy Neutral Operation (ENO), Global Positioning System (GPS). Genetic Algorithm (GA).*

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Abbreviations

WSN	Wireless Sensor Networks
MAC	Medium Access Control
GPS	Global Positioning System
UP	User Priority
QoS	Quality of Service
TDMA	Time Division Multiple Access
CSMA/CA	Carrier Sense Multiple Access/ Collision Avoidance
ENO	Energy Neutral Operation
IE	Information Entropy
DT	Direct Transmission
CH	Cluster Head
CMs	Cluster Members
SNs	Sensor Nodes
GA	Genetic Algorithm
OSI	Open System Interconnection

CTS Co-operative Transmission Slot

BS Base Station

ED Euclidian Distance

Chapter 1

Introduction

1.1 Motivation

A network comprises of numerous disseminated tiny electronic devices using sensors to obtain results from healthcare, wildlife and in agriculture to raise the standard of mankind is known as wireless sensor networks (WSN). [1]. These small devices have different functions like sensing information, process that collected data and forward it to the further sensing nodes (SN), derive the concept of WSN .These SN are applicable in different areas like healthcare, monitoring,automation and in military applications. [2–8].

There are various edges of WSN, the major advantage is that Sensor Nodes (SN) can operate in un-attended and dangerous sites where human access is sometimes unfeasible and dangerous. So, SN are deployed in most un-common ways like dropped by helicopters, and then these SN form a network [9, 10]. To cover the large area, hundred and even thousands of SN are required to build a network. To build this huge size network, it requires architectural and management techniques. These SN are battery contrived and their batteries can not be replaced. So to cater this issue, WSN requires energy contrived routing techniques to preserve energy and enlarge life of the sensors [11].

The Routing techniques for WSN are normally categorised into two categories on the bases of flat , hierarchical and network structure rooted routing strategies. All the SNs have same abilities and performs same tasks in flat rooted routing technique.The flat routing uses flooding technique to send data from one hop to another hop [12]. To cater the scalability and energy issues, there is a strategy which is known as hierarchical/cluster based routing, in this whole network divides into various clusters, every cluster has its own Cluster Head (CH). Every SN communicates its collected information to its CH, then selected CH clumped that acquired information and forward it to BS. The BS has high abilities like more processing power,storage capabilities and longer life time than normal SNs [13, 14].

Since SNs are very small devices and low energy preserving abilities, there is a requirement of energy efficient routing strategies which can enlarge the stability period and network life time.

n this thesis, an optimal clustering using genetic algorithm in heterogeneous WSNs presented to enhance the adaptability and network lifetime using Genetic Algorithm (GA). The proposed technique and results are discussed in chapter 3.4.

1.2 Wireless Sensor Network (WSN)

1.2.1 Overview

The development and extension in the micro-electrical technology and wireless technology, WSNs become major player in various fields such as, military observations, sports, health care, transportation, underwater communication and so on. WSNs contains small devices which are called sensors/nodes spreads over the large region. There is one or more powerful sensor node which is called BS/sink. It acquired data from other SN. The BS/sink node is extra powerful,if we do comparison with the other nodes. The BS has high processing power, larger storing capacity and longer life time [15].A SN consists of (power cell, CPU, storage, sensing and transmission chip). These sensor nodes can build a network together and communicate information with each other [16]. There are many advantages of WSNs, but one major advantage is that WSNs mostly operates in unwanted and grating areas where human tracking is unfeasible, and some time is very risky. To overcome this issue, sensor nodes are deployed randomly some unmanaged resources like helicopter etc [17]. As nodes are deployed in unattended areas, their power (batteries) become more valuable because batteries cannot be replaced in those areas. Data gathering and data transformation to specific destination consumes more power[18, 19].So, there must be some energy aware routing algorithms which can expands the life span of SN. Energy aware communication is one of the major challenge in WSNs. There are some points that is why energy efficient routing is so important. Firstly, resources like battery life, processing power and transmission range are limited. Secondly, there cannot be globally addressing schemes like internet. WSNs cannot manage the topological changes as internet protocol (IP) does, because of large communication overhead. Third one, high chances of data duplication because of data gathering from numerous sensor nodes. Fourthly, many WSNs technologies needs only one communication strategy that is many to one, in which SN communicate their collected information to the destination. Lastly, many applications of WSNs is time oriented, so data transference should be completed in given time span. So, restriction for the data transference latency must be counted in this type of application [15]. Energy preservation is very much critical than level of quality. All the sensor nodes are directly dependent on battery for longer life span of the network [20] . The architecture of WSN and SN are described in the following diagram 1.1.

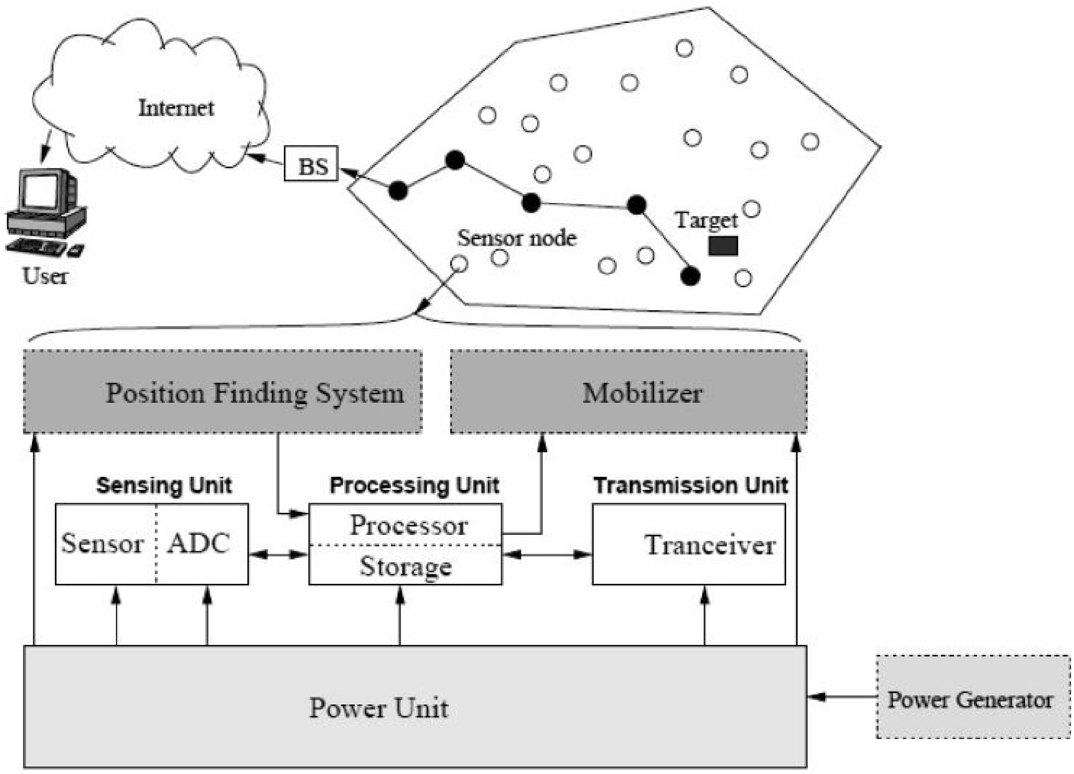

Figure 1.1: WSN Structure.

The routing schemes in WSNs are categorised on the basis network structure. And these are hierarchical/cluster, flat, and location rooted routing. As stated earlier that energy conservation in WSNs is very important because of short life span of sensor nodes. So, hierarchical/cluster rooted routing is very beneficial to save power and expanding network lifespan[21]. This thesis proposed a clustering technique which elongate the overall network life and stability period. The proposed methodology is explained in the chapter **??**

1.2.2 Architecture of WSN

Open system interconnection model is used in WSN. OSI model contains five different layers and these are physical,application,network,transport and dara link. And there are some further layers which are management, mobility and power management layers . These extra planes are there to improve overall efficiency of the network by forcing SN to work together [22, 23]. The architecture of the WSN is displayed in the figure 1.2

OSI layers for WSN

1. Application Layer:

The responsibility of this layer is to give stage for different applications to convert the communicated data into an understandable shape. It is also used to obtain different form of information for the user.The application of sensor nodes are in various fields like military, healthcare, supply chain management,agriculture and in automobiles [22, 24].

2. Transport Layer:

Transport layer is there to control packet loss, improve reliability of communication and to avoid the congestion.There are lot of transport layer protocols designed to avoid inconsistency in upstream(user to Bs) or in downstream (Bs to user). A transport layer is specifically required when a user wants to communicate with other networks. [25, 26].

3. Network Layer:

The basic functionality of layer 3 to direct the required data accurately to the required destination.There are also challenges on this layer which are limited energy resources, memory and buffering capacity [27].

4. Data Link Layer:

This layer facilitate system to control errors, well founded hop by hop data delivery and multiplexing of data [28, 29].

5. Physical Layer:

Physical layer is responsible to transmit bits over physical medium. It also responsible for data encryption and modulation,signal detection and carrier frequency selection.

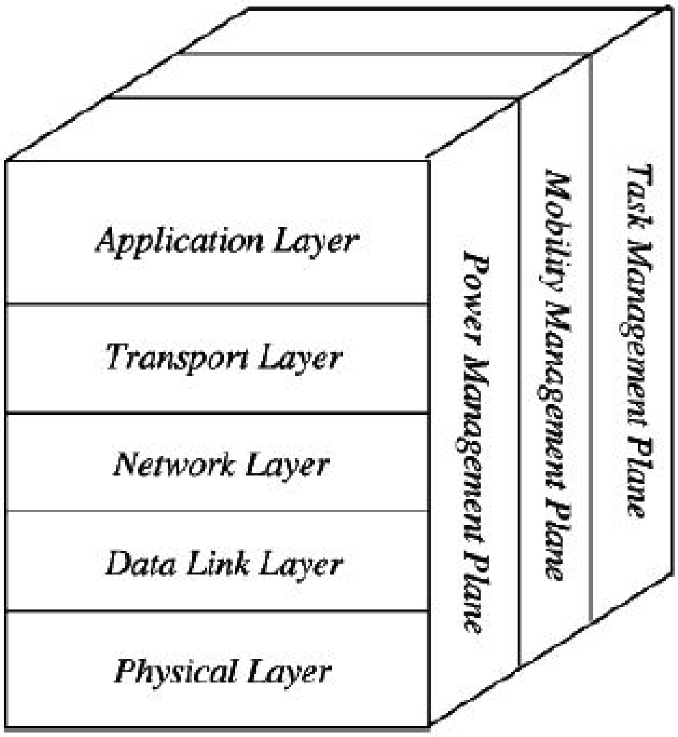

Figure 1.2: OSI Architecture.

1.2.3 Routing Protocols

Routing is a technique which finds out the best conceivable way between a sender and a receiver [30]. Wireless sensor nodes have non-rechargeable and non-replaceable batteries which means these types of networks are different from other networks, so they require more efficient and accurate routing [31]. The efficient communication can be accessed by through these following factors.

Routing Protocols Design Problems:

The immense furtherance in wireless sensor networks involved its application in different fields like military, healthcare, sports, physical world and in industries [32]. As the application of WSN increased, these networks face number of challenges like limited bandwidth, limited power supply, limited computing powers and limited memory while connecting these networks with each other. The major design aim of WSN is to sustain the communication while keeping SNs up for longer duration. Routing protocols faces many challenges in designing phase. There are some designing issues and challenges which influence the whole design process [32–35].

Node Deployment:

Wireless nodes formation in WSNs are application specific, which has a key role in routing protocols performance. The formation of the Nodes is either manually or randomly. Nodes which are deployed manually has different impact on routing, because they require pre-determined paths for communication. Whereas nodes which are deployed in self organizing manner needs reactive approach to route the data from one end to other.

Finite energy capacity:

As the wireless sensor nodes have batteries incorporated in which are non-rechargeable and non-replaceable, so they have limited energy resources. If the nodeâĂŹs energy depletes to the given threshold, they can not be able to communicate the desired information. Energy capacity has a leading role in to design energy efficient routing protocols.

Hardware limitation:

Sensor nodes have limited computational and storage resources, so they must use low power [36]. These hardware limitations raise many obstacles in designing of routing strategies.

Scalability:

In WSNs, there can be hundred and thousands of wireless nodes covering large area, so there must be a proper routing technique that can be able to allow communication between the nodes of large scale network.

Reliability:

Routing protocols designed for WSNs must provide accurate and error free data delivery over noisy and wireless channel.

Adaptability:

In WSNs, a wireless node may fail due to energy depletion, join and leave the network because of wireless range, this movement causes the topological changes in the network.

So, routing protocols should have ability to adapt the topological changes.

Channel Utilization:

As WSNs have limited resources of bandwidth, so the designed protocols for routing should make effective use of channel capacity to increase the channel utilization.

Fault Tolerance:

Since SN are deployed in abounded and tough environments. So wireless senor nodes should be fault tolerant in case of any kind of troublesome like node failure. Wireless protocol design should take care of that wireless nodes have the capability of self-testing and self-recovery in case of any failure.

Security:

A wireless network protocol design should present feasible security features which can prevent data from unauthorized access and malicious attacks in the network.

QoS Support:

Every wireless application requires different QoS support like reliability, accuracy, latency, bandwidth and security. For example, to track any specific node in the network, it requires low transmission delay while multimedia transmission requires high throughput.

Classifying routing protocols in WSN:

Routing protocols play a significant role while broadcasting data from a sender to receiver. Routing protocols are the effective way to find out the best way between a SN and BS. There exist routing tables which gives the best solution for the effective communication between nodes. Routing protocols are categorized into five ways according to the communication initiator, Route processing, network topology, protocol action, and next hop selection [31, 37–39]. The classification of routing protocols is shown in figure 1.3. Network structure represents the topological design of the network which can be flat, hierarchical (cluster based) and positional scheme.The flat scheme gives a idea in that each SN has identical role while in cluster-based,nodes have different roles according to their energy level etc.In location-based scheme, nodes places are used to direct the data. So, if there is a requirement of adaptable, accuracy, and power efficiency in the network, hierarchical routing scheme is a lot better choice.

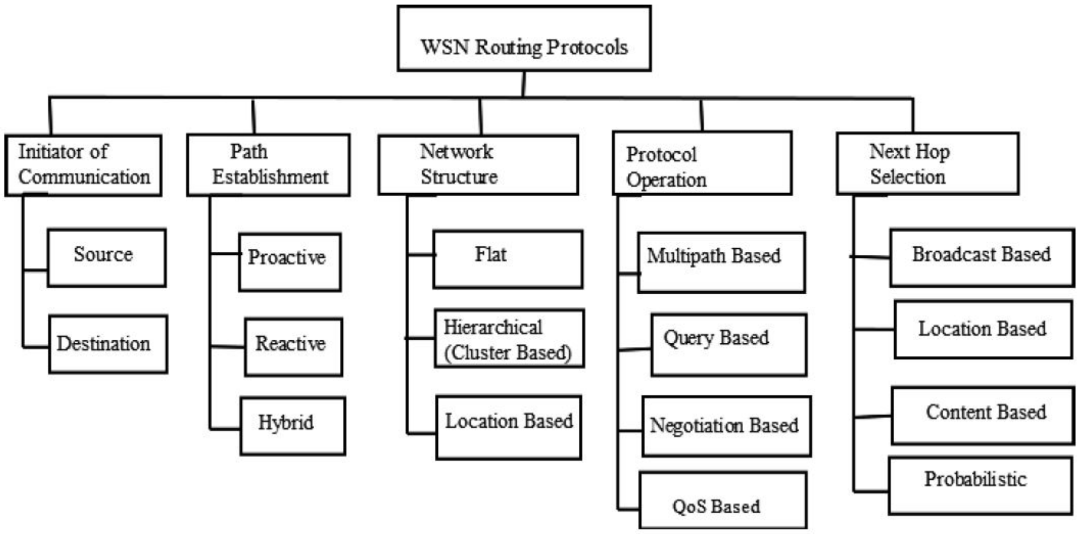

Figure 1.3: Types Of Routing Protocols.

1.2.4 Cluster-Based Routing:

This scheme is a good option in terms of energy efficiency. This methodology breaks down the complete area into different segments which are called clusters. Every cluster has more than one CHs and cluster members(CM). Nodes which have higher level of energy will be selected as CHs while further SN are named as cluster members(CMs). The architecture of hierarchical routing is presented in fig 1.4. In which CH is used to clump information and transmit clumped information to the BS. While CMs are used to sense the information in cluster and communicate information to BS. The hierarchical routing plays an essential part to achieve the application reliant on targets. [40, 41]. Generally there are two or three phases in Hierarchical/cluster based routing protocols. These stages are initial, cluster head (CH) selection and data communication stage.The Hierarchical/cluster based routing protocols consists of further three types which are Block , Grid and chain cluster based routing.

1. Block Based Routing

The block based clustering is the effective technique for the real-time observation. The famous block cluster based routing protocols are: LEACH,LEACH-ONCH,LEACH-AP, P-LEACH and W-LEACH [42–46].

2.Cluster Based Grid Routing

This routing technique basically specifies whole data space into countable grids, all the

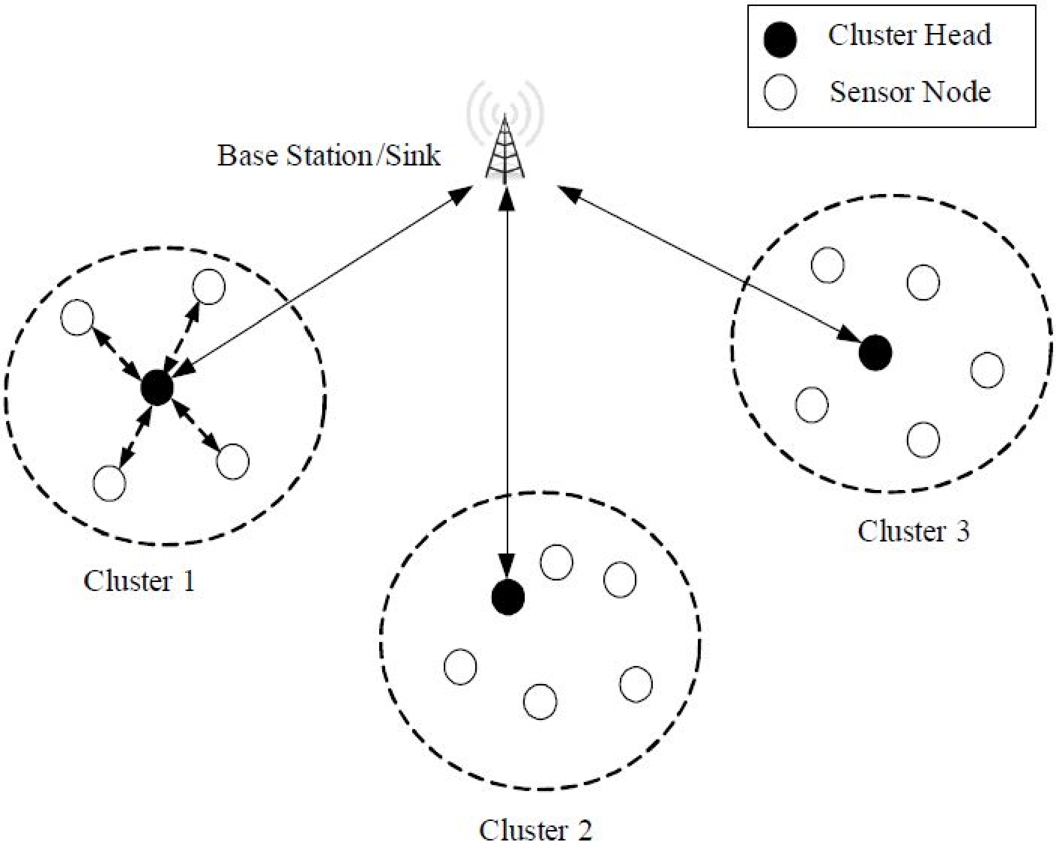

Figure 1.4: Hierarchical/Cluster-Based Routing.

operations of the network are performed on this grid. The protocols which used Grid Based clustering technique are: GAF, PANEL, TTDD and SLGC [47–50].

3.Cluster Based Chain Routing.

In this routing strategy, all SN communicate with their closest nodes to transmit their data. This chain type relation between sensor nodes decreases the amount of transmissions which ultimately decreases the energy usage and overhead as well.The protocol which have used this technique are: CSS, PEGASIS, TSC [51–53].

Limitations in Clustering Protocols

There is plenty of research work on clustering/Hierarchical based routing to find out the drawbacks and eradicate them but there are still problems to be focus on to improve the efficiency of Cluster/Hierarchical routing scheme.

- Method for Cluster Head Selection.
- Network Scalability.

- Network Topology
- culpability tolerance.

1.3 Applications of WSN

There are number of areas in which wireless sensor nodes are used which are Disaster relief operations, military operations, home applications, enviormental applications and medical applications. Some of the application are discussed below and also shown in the figure 1.5.

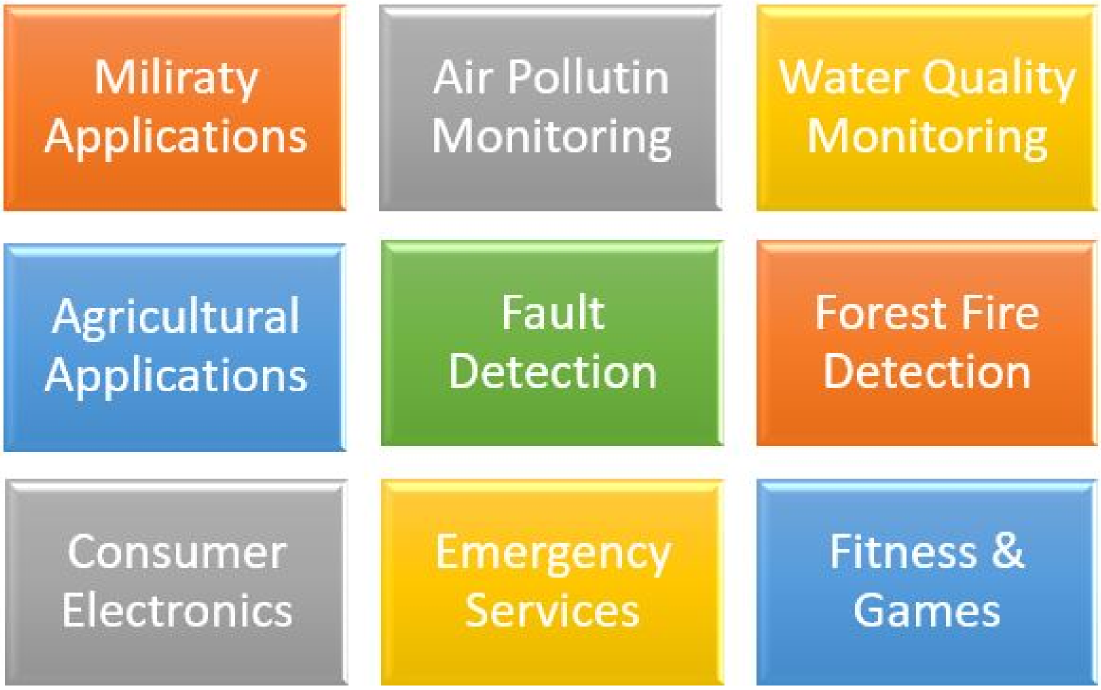

Figure 1.5: Applications of WSN.

- **Military Applications**

  The WSN are used for surveillance and also to detect emergency situations. These SN are also be useful to detect the exact location of bio or chemical attacks. These SNs can be helpful to detect wounded soldiers form the tough battlefield [54].

- **Home Applications**

  As the enhancement taking place in wireless technology, this technology can be found in household items like refrigerator, oven, vacuum cleaner, water system monitoring, and home security.

- **Environmental Applications**

  These wireless sensor nodes have number of applications in the above mentioned area. These SNs can be used to detect and monitor the affected area of jungle because of fire, wildlife, earth, soil and agriculture. These SNs are also used to detect the flood and earthquake as well. These SN can also be vital to detect the wind pressure and direction, temperature and humidity as well.

- **Medical Applications**

  WSN assist human beings and animals better health care and efficient monitoring. WSN also enables internal monitoring of a patient. A new concept in the field of healthcare is mobile-helath [55] ,4G-health [56] and internet of things (m-IoT) [57] enabled new and efficient of ways of patient of monitoring.

- **Water Quality Monitoring**

  Water is necessity for every alive thing in this world, but clean water is very important for humans health. A study says, over 20 percent of the world community does not have any safe and clean drinking water. By using sensor nodes in the water reservoirs, systems are collecting some important parameters like oxygen density, pH, temperature etc [58].

- **Fault Detection**

  The WSN are very beneficial in fault detection and monitoring of industrial machinery, buildings and Data Centers. These SNs are beneficial in those areas where access of humans are not that easy [59].

1.4 Wireless Sensor Networks Challenges and Research Issues

There are many issues and research problems in Clustering/Hierarchical routing which are addressed but still lot of them are remaining to be addressed to gain efficiency. Following figure 1.6 mentioned some issues that must be addressed to gain optimal results.

Figure 1.6: Wireless Sensor Networks Challenges.

- **Data Management**

  As WSN produces large amount of data, there must be a way to prioritize and manage the important and critical data. Less-important data should be discarded for a specific time. This method can be achieved by introducing a queue which only contain the important data and eradicate less-important data, this can vary from application to application.

- **Data Consistency**

  In WSN, Data may travel from some hundred meters to thousand meters containing critical information like a patient data, some environmental data or any emergency data. Any false information may create huge problems. So, there should be a way which can maintain data consistency.

- **Overhead**

  The transmission of control packets before the actual transmission causes overhead, this overhead can cause loss of data packets. To overcome this issue, there should be an access strategy which can reduce the overhead [60].

- **Data Flow**

  In WSN, Flow of data depends on two scenarios which are normal and emergency. There should be some mechanism which can prioritize the normal and emergency traffic. Data should be prioritize in such a way that there should be no impediment in the way of emergency traffic (ET).

- **Lifetime**

  As WSN are energy critical and sensor nodes (SN) are battery oriented, Batteries of SNs are irreplaceable, So there is a need of energy efficient algorithms [61] which can enlarge the lifetime of the WSNs.

- **Throughput**

  In WSN, the throughput of the network reduces due to packet collision, connectivity loss or overhead in the network. There are some applications which require some real time readings like border monitoring, m-Health and also in environmental monitoring. So there should be some efficient scheduling algorithms [61].

- **Mobility**

  There are some applications in WSN which requires mobility in the network like emergency scenarios. Every time a node changes its location, this can change the topology of the network, and the change in the topology should be disseminated to the whole network other information can be lost.

- **Scalability**

  WSN should be able to acquire any changes in the number of SN and in the architecture of the topology as well [**?**]

- **Reliability**

  The term reliability in WSN refers to the packet loss, delay in transmission, which is dependant on the medium situation and data needs. Implementing irrepressible data transmission mechanism can improve the reliability of the network.

1.5 Contribution

The research issues which are discussed and shown in the figure 1.6 are important to addressed, most of them are addressed but energy efficiency is a very critical problem in WSN. Following are the contribution that have made to improve the effectiveness of the WSN.

- An optimal clustering using genetic algorithm in heterogeneous WSN have proposed to improve over lifetime, stability and throughput of the network.
- Using Genetic Algorithm (GA), we choose two best nodes in each cluster as Cluster Heads, which reduces the computational processing as well as improve the efficiency of the network. More details about this topic are discussed in chapter 3.4
- There are some future trends and issues which are discussed in chapter 4.

Chapter 2

Literature Review

The motivation behind the related study is to evaluate previous work and there is much research work have taken place in cluster based routing protocols. A detailed study of the previous work is present in this chapter.

2.0.1 Cluster Based Routing Techniques

In [62], the DHRP policy is proposed to reduce the imposed overhead during clustering, escalate the life and adaptability of the network. To lengthen the SNs lifecycle, the proposed approach manages the clustering operations in such a way that clustering overspend is minimized while the burden is balanced on the nodes at a crucial time. Hyper round (HR) consists of dynamic rounds, which starts to form a beginning of around which includes a setup phase and it ends up with the new setup phase. Re-clustering of network triggers only when required.

In [63], authors has proposed an efficient clustering-based energy efficient routing protocol which improves the throughput and improves the overall life of the network. EE-MRP contains two stages, setup, and a steady. The network is separated into three logical stages in the first stage. Every stage has its own CH to gathers data from the member SN. The CHs are evenly distributed to increase the throughput and overall network lifetime.There are different time slots which are also allocated to SN by the cluster head so that every node can send its information in the allotted time slot. In steady stage,the CH clump the obtained information and communicate to the sink or forwarder node. A forwarder node is also deployed in this network, which has greater processing capacity and energy, the battery of the forwarder node also replaceable. The purpose of deploying a forwarder node is to minimize the distance between CHs and BS which helps in minimizing the use of energy consumption.

The Authors of [64], presented K-means clustering based routing protocol designed to transmit the optimal fixed sized packet to reduce the power usage of the individual node as well as improve the overall life of the network.. OPSKC has three phases, initial, cluster formation, and CH selection phase. In this phase, BS broad cost the initial request message in the network. All the nodes then send a response message with their initial energy levels and location. In the cluster formation phase, clusters are created using the Kmeans method. The cluster head selects because of two weight function. Weight function consists of residual energy, distance and the total quantity of energy to accept and aggregate information.

The idea behind [65] is to increase the network lifetime using power balanced clustering mechanism. This proposed protocol uses local density, remaining energy, and distance to select cluster heads. The CFSFDP-E has two phases, cluster formation and the steady-state. In the first stage, firstly the parameters are initialized, then the algorithm computes the remaining spark of every SN. If the energy of the SN depleted, it means node cant take part in an election of CHs. Lastly, CHs are elected by the support of remaining energy, distance, and local density. In second stage, CHs allocates the Time Division Multiple Access (TDMA) slots to SN. The Member SN transfer their collected information to the CHs at their allotted time slot. Cluster Heads first obtained the information from member SN then send collected information to the BS.

In [66] protocol, a new duty cycle based CH selection using energy harvesting scheme is proposed to prolong the latency, throughput, and overall lifespan. The CH selected based on the nodes current status of harvested energy. Harvested energy status shows that after how many rounds this node can again become a cluster head. In ECO-LEACH nodes uses solar light to harvest the energy. ECO-LEACH proposes a unique TDMA scheme, in which time slots are evenly distributed into two sub-slots, a direct transmissio (DTS) and a cooperative transmission slot (CTS). Every node in the network uses this unique TDMA based scheme, in which every node is available to act as a relay. All relay nodes listen to the transmission of the nodes in the DTS slot time and best relay node transmit the received packet in the CTS slot time. In the proposed duty cycle, member nodes can skip the allotted TDMA slot to maintain the Energy Neutral Operation

(ENO). ENO means SN do not transmit their information to save the energy in the allotted time slot to expand the overall life span of the network.

The basic idea behind [67] is to lessen the power usage and enhancing lifespan of the network. The K-medoids calculates the best medoids point between the sensor nodes. After that, the best cluster head can be selected using this pivotal point. KCA operates in two steps, a setup and communication stage. In the setup stage, K-medoids scheme is used to group the nodes into clusters and then used to select the best node as CHs. In the communication phase, all SN communicste their collected data to their own CHs. CH alloy acquired information and sends it to the BS. Network efficiency and lifetime are achieved by balancing the network load between clusters.

In [68], the idea focuses on the problem of imbalanced distribution of CHs in WSN. This imbalanced distribution causes unequal distribution of energy which leads to an early death of the sensor nodes. Ultimately network lifetime reduced. To overcome this problem, a segmented LEACH approach is proposed in which the whole network is evenly segmented into five segments. These segment numbers are user-defined. A mathematical approach to game theory is also implemented to enhance life and reduces the energy usage of the network. In improved-LEACH, classic leach is implemented in every segment separately.The LEACH has two stages. One is the setup stage in which clusters and clusters heads are created. Clusters heads are selected based on probability. Every node participates in a cluster head election. All SN send their acquired information to their own CHs. In the data transmission phase, clusters heads sum up the received information and send it to the BS. Game theory model is also implemented in this scheme. This model has three stages. These are initialization, setup and steady phase.

ML-Leach [69] covers the problem area of multi-hopping. If a network uses multi-hopping, nearest nodes to the BS depletes their power rapidly. So, to resolve this issue, the suggested scheme contains three stages. The initial stage is a selection of CH and a forwarder node, second is a rotation of CH and third is routing. In the first stage, the network is separated into two layers, layer one and two. The layer one nodes broadcast their current statuses. Nodes which receive this broadcast message set their routing table as their forwarding node. The role of the CH rotates to the suitable SN which has high remaining capacity and high node density among the member nodes. To enlarge the overall lifetime and maximize the utilization of network, better routing strategies are needed. In the proposed scheme,a multi layer cluster design is proposed which consists of a forwarder, non-forwarder, and backup forwarder to enhance the routing techniques in the network.

The proposed scheme in [70] is developed for continuous monitoring of the fluctuated events. Its a 2-logical overlapping topology based scheme which ensures that the collected information from two adjacent nodes of the event location will send to the same CH for aggregation. A hybrid time and eventdriven scheme are also introduced for prolonging the network lifetime. The EEOAC works in multiple stages, every stage consists of cluster formation and steady stage. Every stage is consisting of additionally five substages which are data gathering, CH selection, Cluster generation, data dissemination, cluster head re-adaptation and cluster re-location. In the data collection phase, all the local and global information will be gathered. Firstly, the main node disseminates the HELLO message in the network. All the nodes respond it with their information. The main node computes the area from itself to the ordinary SN through the Euclidean distance(ED). Cluster head will be selected using left-over energy and distance of the nodes. Cluster generation stage completes using 2- logical overlapping scheme. This scheme consists of threetime intervals which help in the generation of clusters. Data disseminates using a hybrid approach which consists of event and time driven. This hybrid approach provides continuous monitoring of the network. In the cluster head re-adaptation stage, when the node depletes its left-over energy to the given threshold, the closest member node which has more left-over energy than the CH will be specified as CH in the next round. The existing CH also disseminates the shifting cluster head message in the network. A demand driven cluster re-location technique is used to relocate the cluster on demand.

The purpose behind [71] is to regulate the cluster size considering load balancing among cluster nodes to elevate the power efficiency for the network. The required target is achieved through load balancing among clusters and the base station. The proposed scheme consists of two stages, one is nodes establishment and the other is rounds stage. Round stage is further divided into two parts. One is creating regions and its heads while the other one is data dissemination. In the nodes establishment part, SN are deployed in the specific zone that is called the sensing area. While in the Round stage, firstly regions are created uniformly, and their heads are selected based on more left-over energy and access of closest nodes. The node which has maximum left-over and a most number of neighboring nodes will be the head of that round for that specific region.

The focus of [72] is to reduce the energy usage by disseminating the nodes having unequal energy. DK-LEACH is designed to form the optimal clusters in a heterogeneous environment. Just like LEACH, DK-LEACH also comprises of two steps, one is set up and other is data transmission step. In the beginning, BS sends a hello message to all the other SN. Then all SN send their sensed information to sink, then sink accumulates the mean power of nodes and selects CH having maximum left-over energy and minimum distance from the BS. CHs allot slots based on TDMA to all the member nodes. While in second phase, member SN communicate sensed information on the allotted time frames. CHs then fuses the retrieved information and transfer it to sink node.

In [73], a duty cycle based clustering approach is pro-posed which also uses energy harvesting (EH). The Proposed routing protocol has two duty cycles to sustain an energy neutral operation. One duty cycle is for selecting the CH, a CH is selected on the bases of nodes power capacity and energy harvesting capacity. Second duty cycle is for data transmission which is also considered the energy harvesting and data transfer rate in non-cluster head (NCH) mode. DC-LEACH performs well to enlarge the latency, throughput and overall network lifetime.

The idea behind [74] is to elongate overall life of network and save power by proposing the double CH routing protocol based on a clustering algorithm. Data fusion strategy of information entropy(IE) is handed-down in DFD-LEACH to avoid the redundancy of the data and enhance the efficiency of data transmission. The proposed idea is divided into two steps. One is to create clusters and another one is data transmission. In the first step, the network is separated into clusters using the K-medoids clustering technique. Then two CHs are selected based on probability. There is a thresh hold for cluster head selection, which is 0 to 1. Every node will participate in the election. A node which is matching the given threshold value will be selected as a CH. There will be two CHs, one is for communication with the sink node, and the one accumulates the information from the nodes and transmit it to the main CH. This strategy reduces nodes participating in the communication which will ultimately reduce the energy consumption. While in last step which is the data transmission phase, the main cluster head uses data fusion of information entropy which helps in efficient data communication, data accuracy and remove the redundancy of the data.

The improved multi-hop technique(IMHT) [75] which is built on LEACH is suggested to prolong life and enhance the flow rate of the WSNs. The focus of the proposed scheme is to lower the energy usage during communication with the BS and CH, or BS and CHs are positioned far from other nodes. IMHT also reduces power usage in the scalable environment. This routing algorithm proposed two levels of communication which are an upper level and lower level. These Levels are defined from the distance b/w CH to the BS. These levels allow CHs to transmit with other SN or straight to the BS. IMHT has four phases. For the initial step, it is assumed that all the SN are positioned in the network. CH are selected just like LEACH. All CHs knows their positions via a global positioning system (GPS), and they calculate their distances from the BS. The second phase is about the announcement, all the cluster heads disseminate a message which contains the position and distance of the CH. While in the routing phase, all the CHs create their routing tables. In the last stage which is about aggregation of data, the focus of aggregation is eleminating the redundancy and channelized the accumulated information to sink. Accumulation is done at the CHs.

The proposed scheme in [76] designed to accomplish energy efficient clustering using energy harvesting. Every SN in the cluster based routing scheme in CREW has rechargeable batteries which has limited storage capacity and they use the photo-voltaic solar panels to harvest the energy. CREW contains two step, cluster generating and data transmission. In cluster generating step, algorithm generates different layer using distance from SN to BS. These layers are called network gradients. The size of the clusters is different because of varying distance from the BS. Nodes which has minimum distance to the BS generates one layer while the nodes which are far from BS builds another layer. The CH is selected based on average energy. The data transferring step consists of multi hopping and direct data delivery. When the average power capacity of CH is above from the power of other CMs and the gain energy is above from the consumed energy than cluster head uses direct communication instead of multi hopping. Multi hoping is used only when power of the CH is at average level.

In HCCA [77] is to enhance the network lifetime using hybrid routing algorithm. Its three layered routing architecture which consists of sensor nodes at layer 0, cluster head (CH) at layer 1, grid head at layer 2 and BS at layer 3. The HCCA has top to bottom approach in which heads are selected first at grids level (layer 2) through centralized approach. Grid heads are selected directly by the BS by considering the remaining power capacity and nodes location. While CHs are selected at layer 1 by distributed approach among the SN. Likewise, LEACH proposed scheme also consists of rounds. The grids and clusters are generated in every round separately. Data flow in HCCA from bottom to top. All the SN in a cluster transmit their information to the respective CHs. CHs fuse the received information and transmit it to respective grid heads (GHs) using CSMA/CA approach. After receiving the data from cluster heads (CHs), grid heads (GHs) send data directly to the BS using CSMA/ CA approach.

In [78], The CTEF forecasts the energy for the next round using the difference of current and classic energy levels. There are four stages in CTEF, one is estimation of average energy which is accomplished through classic average energy. Another is CH election.The choice of CHs is based on a cost function and area between SN. Cost function consists of quality of link, packet loss ratio and residual energy. A node which has high link quality, less packet loss ratio and higher left-over energy. Cluster formation totally dependant on the area of separated SN. The distance is calculated through received signal strengths (RSSI) from all the cluster heads. A node will transmit join request message to the nearer cluster heads. Last one is tree generation within in cluster to minimize the responsibility of CH. The nodes which have more cost function value will be selected as non-cluster head nodes. These non CH nodes act as relay between CH and other SN.

In [79], work is presented to improve network life time using energy efficient neighboring clustering approach. Neighbor discovery has done by using log-normal shadow (a propagation model), received signal strength indication (RSSI) and to find transmission range. It works in two steps. One is initial step; SN are deployed in the network randomly. All SN compute their distances after receiving broad cast message form base station. Now, cluster heads are selected on three parameters which are remaining power, one hop distance and distance by the gateway SN. In the first step, sensor nodes transmit their collected information from the respective area and send it to the CH. then CH accumulates that received stats and transmit it to the gateway node.

Chapter 3

Proposed Methodology

In WSN, SN has a very limited capacity to process the data due to its restricted battery power. Therefore,an energy saving routing protocols are very crucial to enhance the overall network lifetime. From chapter 2, it is observed that most of the techniques either deplete the sensor nodes energy rapidly or have very low accuracy, there is need for robust energy efficient routing techniques which improves network efficiently and accurately. Therefore, a unique routing algorithm has designed and described in this chapter to improve the efficiency and network lifetime. We have proposed an optimal solution for efficient clustering using **Genetic Algorithm** to make the network energy efficient.

3.0.1 Optimization

Optimization is a method for discovering the best feasible solution. Optimization is concerned with finding the values of input through which the "best" output can be achieved. The definition of the term "best" can vary in different problem domains, however in mathematical terminology, it is said that by varying the input parameters one can maximize or minimize the objective functions. Search space is made up of all the possible solutions or values which the input can take. In this pool of search space there recline a tip or set of tips which gives best solution. So optimization strategies are specifically implement to find the pin spot which gives the ultimate solution.

3.0.2 Genetic Algorithm

A GA is a meta-exploratory scout based on biological inspired procedure used to solve optimization problems. This algorithm works according to the Charles Darwin theory evolutionary genetics and natural selection. GA was proposed by John Holland in 1960âĂŹs and his students assisted him for development of newly invented approach. In GA, a population of candidate solutions (called individuals) is evolved towards better solutions. The process starts from an initial population of individuals also known as generation which is randomly generated and evolves in multiple iterations for better solution. These individuals are composed of set of bit strings known as genes. The set of strings are called chromosome which is actually a candidate solution [80]. Once the population of chromosomes is generated, the fitness of each separate index is processed. The suitableness can be defined as a value of the suitableness function of optimization case. This fitness function required to be minimized or maximized according to the problems requirement (i.e. minimizing evacuation time). The better fit solutions are selected from the population of each previous generation as parents of next generation and these parents are passed through the process of cross over and random mutation to produce offspring for new generation. The string from a candidate solutions is then used in the next iteration to evaluate the fitness and the same process continues until supreme number of strings be generated, or a termination point has been arrived. The work Flow of GA is shown in the following figure 3.1

3.1 Proposed Solution

To develop a routing protocol, there is a need for a network model. In our proposed solution, there is N SN, a CH and a BS. The total zone in which SN are deployed is 1000*1000 meters, all the SN are randomly distributed in the network zone, CH is stationed in network area while BS is deployed outside the network area. The main points of the network model is as under,

- Nodes are randomly deployed, network is heterogeneous on the basis of packet size, all other capabilities like sensing,communication and processing are the same.
- Sensor Nodes are energy strained.

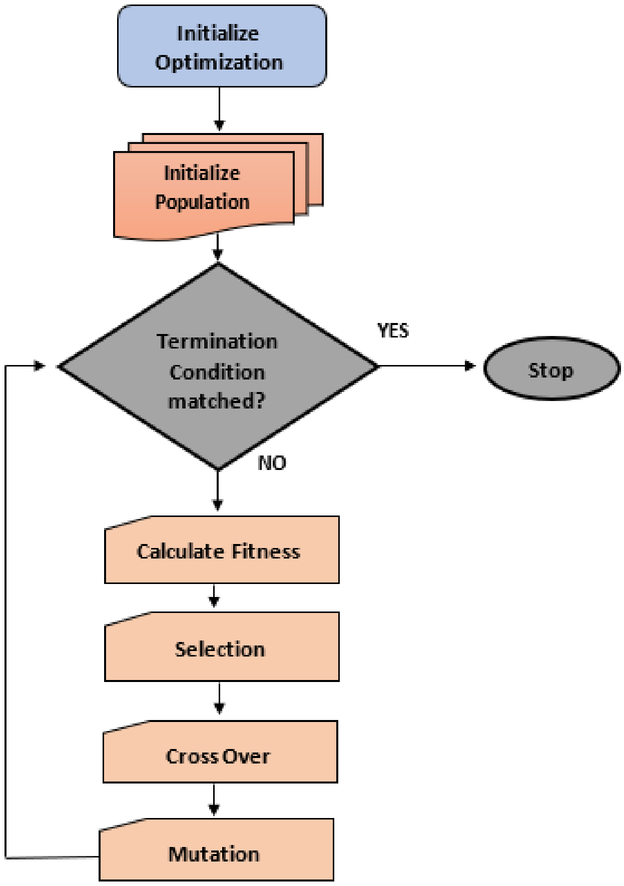

Figure 3.1: Genetic Algorithm Work Flow.

- BS is far from SN and static.
- All SN have equal chance to become CH in each round.
- CH has more processing, storage and power capacity.
- Initially all the SN have same energy.

3.1.1 Energy Model

It is very true that the energy available for the nodes is not only finite but also it may decline very easily. So, the management of the energy is very crucial. There are different suppositions regarding energy depletion, but we have assumed that the power usage of the SN because of communication and processing. We used the same energy model as used in [81, 82] and also shown in the following figure 3.2. The energy usage in transmission of a packet having size of $\boldsymbol{k}$ bits over a communication distance $\boldsymbol{d}$, is shown as under

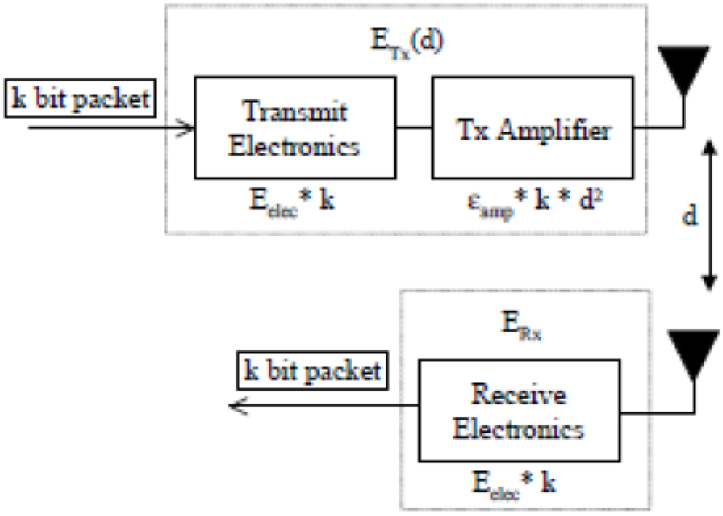

Figure 3.2: Radio Energy Template.

$$\boldsymbol{E}_{Tx}(k,d) = k(E_{elec} + \varepsilon_{Amp} d^{\lambda}) = E_{elec}K + \varepsilon_{Amp} k d^{\lambda} \tag{3.1.1}$$

Where k = size of the packet

d= distance between sender and receiver

E$_{elec} = ElectronicEnergy$

$\varepsilon_{Amp} = transmitteramplifier$

$\lambda = pathlosses(2 \leq \lambda \leq 4)$

Energy consumption in packet reception is as under

$$E_{rx} = E_{elec} k \tag{3.1.2}$$

So, Total power while in sending and receiving of information over a distance (d) is as under,

$$E_{total}(d) = k(2E_{elec} + \varepsilon d \lambda) \tag{3.1.3}$$

3.2 Algorithm

This work contains two algorithms, First algorithm 1 explains the selection of CH using genetic algorithm. The advantage of using GA is that it gives best optimal solution. while the other one 2 shows, how energy is computed for the said work.

3.3 Design of Energy Efficient Routing Protocol

The though backing our proposed scheme is to delineation power aware and scalable routing protocol which provides efficient information routing and good data conveyance. The SN are randomly distributed in the field, and end user requirement is to obtain high level function data which is collected from different environment events. There is a need of efficient CH selection algorithm, and optimized routing technique to design power aware and scalable routing protocol. In our proposed scheme, SN are randomly distributed in the wireless zone, the selection of CH occurred randomly through GA, while BS is stationed outside the wireless zone.

3.3.1 Setup Phase

The setup phase contains establishment in the area of 1000*1000 meter field, all the SN are randomly distributed in the area. The SN are responsible to transmit the collected data to CH, CH accumulates that data and communicate that to BS. The placement of the CH in the network field reduces the distance between SN and BS, so in a result overall power usage of network will be reduced.

3.3.2 Cluster Head Selection phase

After the network establishment and SN deployment in the zone, next phase is to select the CH. In the suggested scheme, CH picking occurred through GA, which selects the most suitable node as a CH. The GA selects CH on the basis of optimal energy which is calculated through CH selection formula. The selected CH broadcast its status via Carrier Sense Multiple Access (CSMA), All member nodes calculates their received signal strength indication(RSSI) from the CH. The CH allocates time slots to the SN nodes to transmit collected information to the CH using TDMA. All the SN send information in their allotted time slots while in sleep mode during un-allotted time slots.

3.3.3 Steady state phase

After CH picking, the next step is steady state. All SN transmit acquired information to CH in their granted time frames and during their un-alloted time slots they remain in sleep mode. This routing algorithm (TDMA) is best choice to preserve power of the network. The work movement of suggested scheme is represented in the following diagram 3.3.

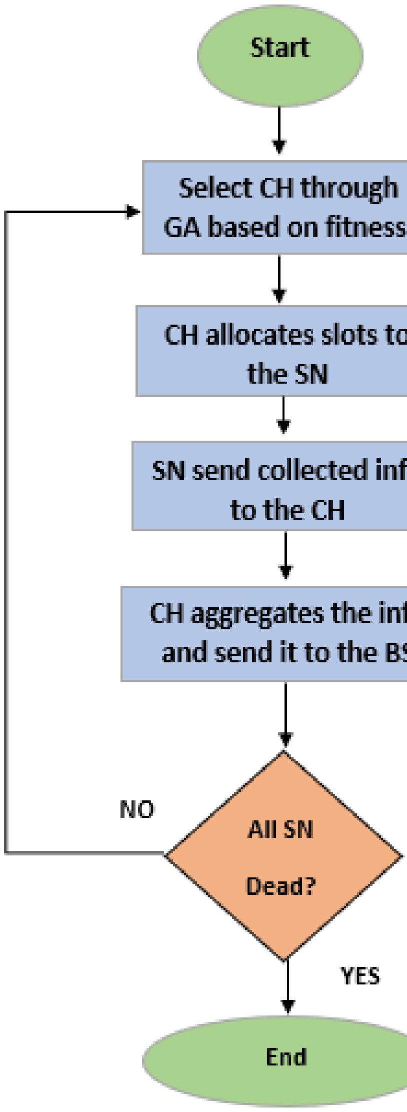

Figure 3.3: Proposed Algorithm Work Flow.

3.4 Results

This section contains the detail discussion about the results which we have got during our experimentation. We have used MATLAB R2016a to run the simulation and following table 3.1 contains the values which we have used during our simulation. The results we have obtained is compared with [81] and [82]. The achievement of the suggested scheme is compared with the base protocols on following terms.

- **Network Life time:**

  A time which has taken by the node from starting to its death is called life of the SNs nexus.

- **Reliability Period**

  The reliability of the network is calculated through time which a SN has taken from its initialization to its death.

Table 3.1: Simulation Parameters

Parameteres	**Values**
Network Area(meter)	100*100
Sensor Nodes	100
BS Location	150*150
Number of Rounds	6000
Initial Energy(E_0)	0.5J
Channel	Wireless
E_{Tx}	50nJ
E_{Rx}	50nJ
E_{amp}	100pJ/bit/m^2
MAC Protocol	IEEE 802.15.4

- **Alive Sensor Nodes**

  A total number of SN which have not yet consumed their power and left more energy to pursue communication process.

- **Dead Sensor Nodes**

  The Total amount of SN which have completely depleted their energies and left with zero energy to communicate with each other.

- **Throughput**

  The piece of information which is travelled from SN to CHs, CHs to BS in a given amount of time is called Throughput.

- **Scalability**

  After the establishment of the network, given network have to cater more topological changes (increase in amount of SN) these change will not effect the performance of the network.

3.4.1 Nodes Placement

In this portion, we have deployed nodes randomly in the network. The following figure 3.4 is showing the nodes placement.

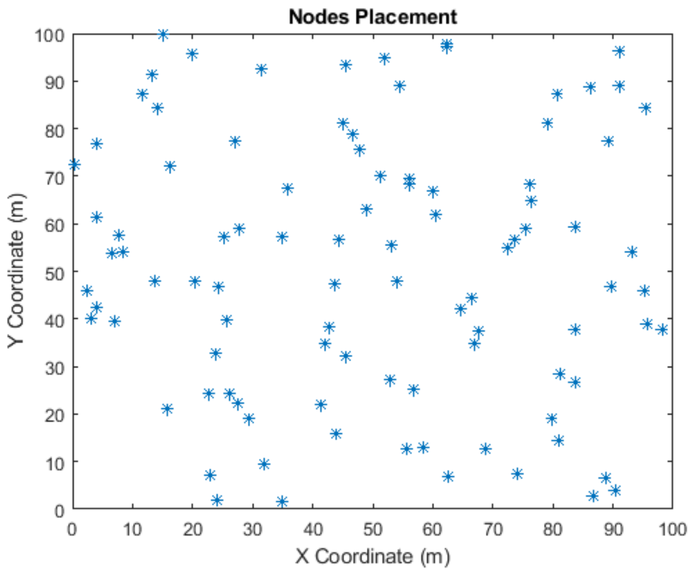

Figure 3.4: Nodes Placement.

3.4.2 Alive Sensor Nodes

The following figure 3.5 shows the amount of alive SN after their whole network lifetime.

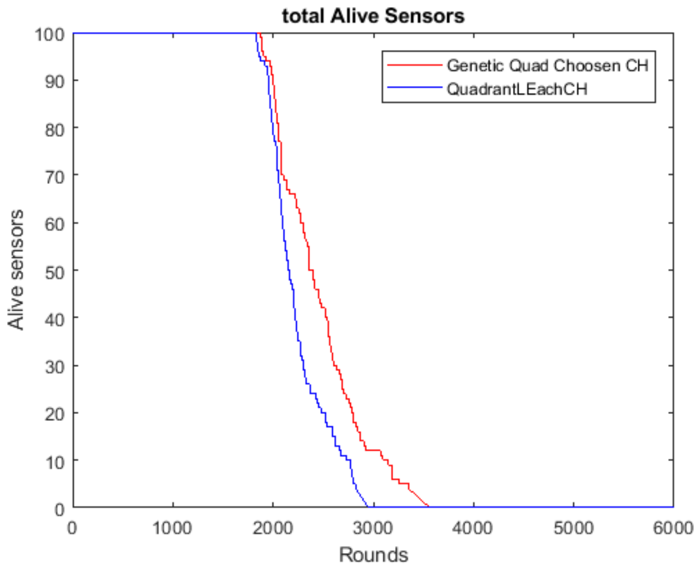

Figure 3.5: Alive Sensor Nodes

One side contains the amount of total rounds, while the other side has the total amount of sensors. The alive SN means, they haven't depleted their energy fully and still have enough energy for communication. Our proposed scheme achieved better results than the base schemes.

3.4.3 Number of Dead Sensor Nodes

The SN which completely depleted their energies and left with zero capacity to communicate are dead SN. The figure 3.6 shows the total dead SN. The x-axis shows the total rounds while the y-axis represents total dead SN. Our proposed scheme performs outstanding than the other two schemes.

3.4.4 Throughput of All SNs

The following diagram 3.7 presented the degree of efficiency in terms of data dissemination, it shows the total bits sent in the whole life of SNs, the suggested scheme performs better than opponent schemes.

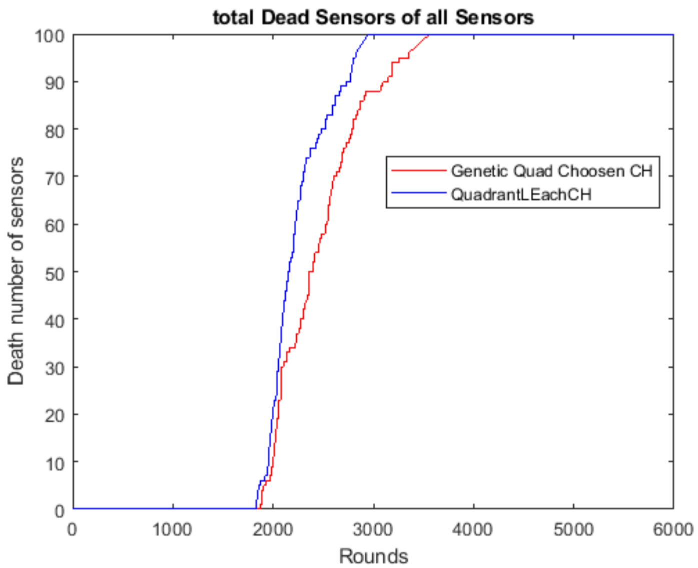

Figure 3.6: Dead Sensor Nodes

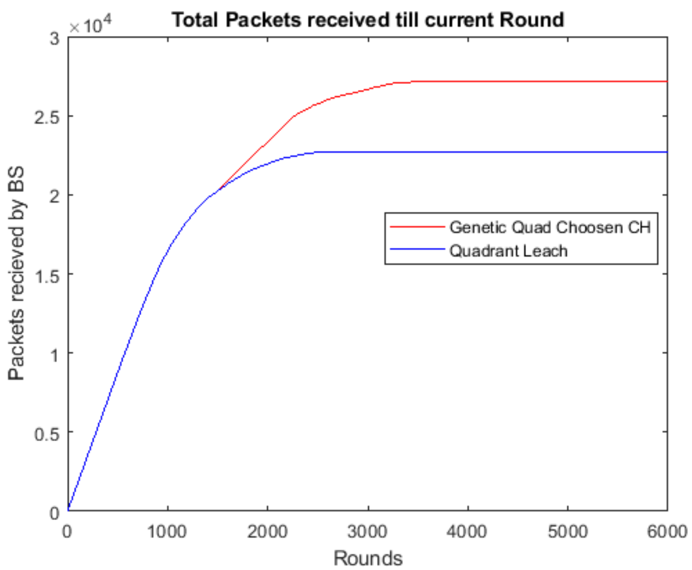

Figure 3.7: Throughput of All SNs

Algorithm 1 CH Selection Using GA

Input: Total SN, Rounds, Population Size, Generation Number, Mutation Percentage

Output: Best CH selected after optimization

```
Initialize : Randomly deployed SNs, Positioned BS
SN_status = [0,1] ∵ (0 for CH, 1 for CMs)
Generation 0, Random Deployment of Sensors As CHs.
for k=1 to population size do
  for m=1 → rounds do
    ClusterHead(i,j)= ⌊ Totalsensors*rand()⌋;
  end for
  Fitness(i) = AllRound Energy (ClusterHead(i,j));
end for
Sorting:
Sort CH row wise with respect to Fitness
for generation = 1 → Generation Number do
  Copying:
  for k= population size/2 → population size do
    ClusterHead (k,m)= ClusterHead(i-population size/2+1);
  end for
  Mutation:
  Change the copied CH chromosomes as Mutation ratio
  Cross Over:
  for k= population size/2:2:population size do
    Swap (ClusterHead (k,1:round/2);
    ClusterHead(k+1,1:rounds/2);
  end for
  for i=1 → population size do
    for j=1 → rounds do
      fitness= AllRounds Energy (ClusterHead(k,m);
    end for
  end for
  Sort With respect to Fitness end
return Best choromose= ClusterHead (1,:);
```

Algorithm 2 Allround Energy Calculation

Input: Number of SNs and BS

Output: Energy Calculation For CHs and CMs

Initialize : Position of SNs

Position of BS

$$SN\_status = [0,1] \qquad \because \begin{Bmatrix} 0 \text{ for CH} \\ 1 \text{ for CMs} \end{Bmatrix}$$

p= All SNs packet size for All rounds

Energy = Allround Energy (ClusterHead per Chromosome (i,:));

for round no=1 : total rounds **do**

  energy per round = 0;

  k= sum(p(:,round no));

  d= distance (CH,BS coord);

  $\boldsymbol{E}_{Tx}(k,d) = k(E_{elec} + \varepsilon_{Amp}d^{\lambda}) = E_{elec}K + \varepsilon_{Amp}kd^{\lambda}$;

  $\mathrm{E}_{rx} = E_{elec}totalbits$;

  energy per round = energy per round + ETx+Erx;

  for i= 1 → total sensors **do**

    if i== CH **then**

      continue;

    else

      totalbits= p(i,round no);

      d= distance (sensors, ClusterHead);

      $E\mathrm{Tx} = k(E_{elec} + \varepsilon \mathrm{Amp} d^{\lambda}) = E\mathrm{elec}K + \varepsilon_{Amp}kd^{\lambda}$;

      $\mathrm{E}_{rx} = E_{elec}k$;

      energy per round = energy per round + $\mathrm{E}_{Tx} + E_{rx}$;

    end if

  end for

  Energy Rounds = (roundno= energy per round);

end for

return energy= Sum(Energy Rounds); =0

Chapter 4

Conclusion and Open Research Issues

4.1 Open Research Issues

Potential future problems for WSN are identified in this Chapter. In Section 4.1, open research issues are presented that can help the research community to make WSN more efficient.The current trends and techniques for WSN are presented in the table 4.1. From analysis, following open research issue in WSN are identified.

- Energy Harvesting:

  SN are most of the time deployed in difficult area, where recovery or change of SN is difficult. In the case of emergency situation, SN have to respond regularly, it demand extra energy. There are various options that might be helpful to expand the life of the SN, like solar,vibration, RF and sound. So, there must be a energy harvester (EH) who produces extra power to elongate the sensors life. The development of EH is healthy challenge to improve the productivity of the network.

- Security:

  Sometime these SN are deployed in critical areas like border, battlefield area. In mission critical or emergency scenarios, SN can easily be jeopardize. Target can use the jeopardized SN for transmission of fake SN or bogus data. This could affect the overall performance..

Table 4.1: Comparison of Cluster Based Routing Protocols.

Name	Year	Energy Harvesting	Security	Mobility	Energy Consumption	Network Lifetime	CH Backup	Delays	Throughput	Intra Cluster Comm.	Inter Cluster Comm.
DCS-DHRP	2018	No	No	No	Less	Improved	No	Average	Average	One Hop	Yes
EE-MRP	2018	No	No	No	Less	Improved	No	Less	Improved	One Hop	Yes
EEKCBR-OPS	2018	No	No	NA	Less	Improved	No	NA	Improved	One Hop	No
CFSFDP-E	2018	No	No	No	Less	Improved	No	Less	NA	One Hop	No
ECO-LEACH	2018	Yes	No	No	Less	Improved	No	Less	Improved	One Hop	No
KCA	2018	No	No	No	Less	Improved	No	NA	NA	One Hop	No
I-LEACH	2017	No	No	No	Less	Improved	No	NA	NA	NA	One Hop
ML-LEACH	2018	No	No	No	Less	Improved	Yes	NA	Improved	One Hop	Yes
EEAOC	2017	No	No	No	Average	Improved	No	NA	Improved	One Hop	No
ILCSA	2017	No	No	No	Average	Improved	No	NA	NA	One Hop	No
DK-LEACH	2017	No	No	No	Less	Improved	No	Average	NA	One Hop	No
DC-LEACH	2017	Yes	No	No	Less	Improved	No	NA	Improved	One Hop	No

- Cluster Head Failure:

  CH failure is the main concern for hierarchical/cluster based routing protocols, CH is the main source which transmit the collected information from the sensors to the BS. In emergency scenarios like hospitals, battle fields,water levels and etc, if CH fails during the transmission,user will not be able to get right information at the high times. This failure of CH may cause serious damage to the user. So to over come this problem, there should be backup of the CHs to reduce the damages.

4.2 Conclusion

In this research, we have presented an energy efficient scheme using GA. We have studied various related schemes, and collected prominent features and construct a detailed table 4.1, which contains pros and cons of observed schemes. We reached at a point where every scheme is lacking in life of a SN. Because SNs are tiny electronic devices and have non-replaceable power resources. So, we have improved the results using GA, an optimization technique which select a SN having good energy values as CH,as long as CH alive in the network, data communication will not stop.

References

[1] Technical report.

[2] Santar Pal Singh and SC Sharma. A survey on cluster based routing protocols in wireless sensor networks. *Procedia computer science*, 45:687–695, 2015.

[3] Yashwant Singh, Suman Saha, Urvashi Chugh, and Chhavi Gupta. Distributed event detection in wireless sensor networks for forest fires. In *Computer Modelling and Simulation (UKSim), 2013 UKSim 15th International Conference on*, pages 634–639. IEEE, 2013.

[4] Zhicheng Dai, Shengming Wang, and Zhonghua Yan. Bshm-wsn: A wireless sensor network for bridge structure health monitoring. In *Modelling, Identification & Control (ICMIC), 2012 Proceedings of International Conference on*, pages 708–712. IEEE, 2012.

[5] Abdul Saboor, Rizwan Ahmad, Waqas Ahmed, Adnan K Kiani, Yannick Le Moullec, and Muhammad Mahtab Alam. On research challenges in hybrid medium access control protocols for ieee 802.15. 6 wbans. *IEEE Sensors Journal*, 2018.

[6] Luca Ghelardoni, Alessandro Ghio, and Davide Anguita. Smart underwater wireless sensor networks. In *Electrical & Electronics Engineers in Israel (IEEEI), 2012 IEEE 27th Convention of*, pages 1–5. IEEE, 2012.

[7] Zhong Rongbai and Chen Guohua. Research on major hazard installations monitoring system based on wsn. In *Future Computer and Communication (ICFCC), 2010 2nd International Conference on*, volume 1, pages V1–741. IEEE, 2010.

[8] Tian He, Sudha Krishnamurthy, John A Stankovic, Tarek Abdelzaher, Liqian Luo, Radu Stoleru, Ting Yan, Lin Gu, Jonathan Hui, and Bruce Krogh. Energy-efficient

surveillance system using wireless sensor networks. In *Proceedings of the 2nd international conference on Mobile systems, applications, and services*, pages 270–283. ACM, 2004.

[9] Katayoun Sohrabi, Jay Gao, Vishal Ailawadhi, and Gregory J Pottie. Protocols for self-organization of a wireless sensor network. *IEEE personal communications*, 7(5):16–27, 2000.

[10] Rex Min, Manish Bhardwaj, Seong-Hwan Cho, Eugene Shih, Amit Sinha, Alice Wang, and Anantha Chandrakasan. Low-power wireless sensor networks. In *VLSI Design, 2001. Fourteenth International Conference on*, pages 205–210. IEEE, 2001.

[11] Richard A Burne, Ivan Kadar, John C Whitson, and Eitan R Eadan. Self-organizing cooperative ugs network for target tracking. In *Unattended Ground Sensor Technologies and Applications II*, volume 4040, pages 181–191. International Society for Optics and Photonics, 2000.

[12] Xuxun Liu. A survey on clustering routing protocols in wireless sensor networks. *sensors*, 12(8):11113–11153, 2012.

[13] Vikas Kawadia and PR Kumar. Power control and clustering in ad hoc networks. In *INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies*, volume 1, pages 459–469. IEEE, 2003.

[14] Stefano Basagni. Distributed clustering for ad hoc networks. In *Parallel Architectures, Algorithms, and Networks, 1999.(I-SPAN'99) Proceedings. Fourth InternationalSymposium on*, pages 310–315. IEEE, 1999.

[15] Xuxun Liu. A survey on clustering routing protocols in wireless sensor networks. *sensors*, 12(8):11113–11153, 2012.

[16] M Mehdi Afsar and Mohammad-H Tayarani-N. Clustering in sensor networks: A literature survey. *Journal of Network and Computer Applications*, 46:198–226, 2014.

[17] Ameer Ahmed Abbasi and Mohamed Younis. A survey on clustering algorithms for wireless sensor networks. *Computer communications*, 30(14-15):2826–2841, 2007.

[18] Swati Mishra, Rukhsar Bano, Suresh Kumar, and Vimal Dixit. A literature survey on routing protocol in wireless sensor network. In *Innovations in Information,*

Embedded and Communication Systems (ICIIECS), 2017 International Conference on, pages 1–4. IEEE, 2017.

[19] K Pavai, A Sivagami, and D Sridharan. Study of routing protocols in wireless sensor networks. In *Advances in Computing, Control, & Telecommunication Technologies, 2009. ACT'09. International Conference on*, pages 522–525. IEEE, 2009.

[20] Xuxun Liu. Atypical hierarchical routing protocols for wireless sensor networks: A review. *IEEE Sensors Journal*, 15(10):5372–5383, 2015.

[21] Jamal N Al-Karaki and Ahmed E Kamal. Routing techniques in wireless sensor networks: a survey. *IEEE wireless communications*, 11(6):6–28, 2004.

[22] Ian F Akyildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci. Wireless sensor networks: a survey. *Computer networks*, 38(4):393–422, 2002.

[23] Kazi Chandrima Rahman. A survey on sensor network. *Journal of Computer and Information Technology*, 1(1):76–87, 2010.

[24] Jennifer Yick, Biswanath Mukherjee, and Dipak Ghosal. Wireless sensor network survey. *Computer networks*, 52(12):2292–2330, 2008.

[25] Paulo Rogério Pereira, António Grilo, Francisco Rocha, Mário Serafim Nunes, Augusto Casaca, Claude Chaudet, Peter Almström, and Mikael Johansson. End-to-end reliability in wireless sensor networks: Survey and research challenges. In *EuroFGI Workshop on IP QoS and Traffic Control*, volume 54, pages 67–74. Citeseer, 2007.

[26] Anis Koubâa, Mário Alves, and Eduardo Tovar. Lower protocol layers for wireless sensor networks: a survey. 2005.

[27] Ian F Akyildiz, Tommaso Melodia, and Kaushik R Chowdhury. A survey on wireless multimedia sensor networks. *Computer networks*, 51(4):921–960, 2007.

[28] Abdelmalik Bachir, Mischa Dohler, Thomas Watteyne, and Kin K Leung. Mac essentials for wireless sensor networks. *IEEE Communications Surveys & Tutorials*, 12(2):222–248, 2010.

[29] GUNN Meghan and GM Simon. A comparative study of medium access control protocols for wireless sensor networks. *International Journal of Communications, Network and System Sciences*, 2(08):695, 2009.

[30] Ahmad Abed Alhameed Alkhatib and Gurvinder Singh Baicher. Wireless sensor network architecture. In *International Conference on Computer networks and Communication Systems (ICNCS 2012)*, volume 35, pages 11–15, 2012.

[31] Musharaf Chaudhary. Wireless sensor networks: A comprehensive comparison of routing protocols and energy efficient techniques. *Communications on Applied Electronics (CAE), Foundation of Computer Science FCS*, 2(1):1–9, 2015.

[32] Ponukumati Sivaram and Suresh Angadi. Wireless sensor networks: Routing protocols, challenges, solutions. *Interantional Journal of P2P Network Trends and Technology (IJPTT)*, 3(4):214–217, 2013.

[33] Ponukumati Sivaram and Suresh Angadi. Wireless sensor networks: Routing protocols, challenges, solutions. *Interantional Journal of P2P Network Trends and Technology (IJPTT)*, 3(4):214–217, 2013.

[34] Sangeeta Vhatkar and Mohammad Atique. Design issues and challenges in hierarchical routing protocols for wireless sensor networks. In *Computational Science and Computational Intelligence (CSCI), 2014 International Conference on*, volume 1, pages 90–95. IEEE, 2014.

[35] Sangeeta Vhatkar and Mohammad Atique. Design issues, characteristics and challenges in routing protocols for wireless sensor networks. *Int. J. Comput. Appl.(IJCA)*, 1(2):42–47, 2013.

[36] Chalermek Intanagonwiwat, Ramesh Govindan, Deborah Estrin, John Heidemann, and Fabio Silva. Directed diffusion for wireless sensor networking. *IEEE/ACM Transactions on Networking (ToN)*, 11(1):2–16, 2003.

[37] Shazana Md Zin, Nor Badrul Anuar, Miss Laiha Mat Kiah, and Al-Sakib Khan Pathan. Routing protocol design for secure wsn: Review and open research issues. *Journal of Network and Computer Applications*, 41:517–530, 2014.

[38] R Devika, B Santhi, and T Sivasubramanian. Survey on routing protocol in wireless sensor network. *International Journal of Engineering and Technology*, 5(1):350–356, 2013.

[39] Jamal N Al-Karaki and Ahmed E Kamal. Routing techniques in wireless sensor networks: a survey. *IEEE wireless communications*, 11(6):6–28, 2004.

[40] Seema Bandyopadhyay and Edward J Coyle. An energy efficient hierarchical clustering algorithm for wireless sensor networks. In *INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies*, volume 3, pages 1713–1723. IEEE, 2003.

[41] Gaurav Gupta and Mohamed F Younis. Load-balanced clustering of wireless sensor networks. In *ICC*, volume 3, pages 1848–1852, 2003.

[42] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan. Energy-efficient communication protocol for wireless microsensor networks. In *System sciences, 2000. Proceedings of the 33rd annual Hawaii international conference on*, pages 10–pp. IEEE, 2000.

[43] Gino Alvarado, Carlos Bosquez, Fernando Palacios, and Luis Córdoba. Low-energy adaptive clustering hierarchy protocol and optimal number of cluster head algorithm in a randomized wireless sensor network deployment. In *Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT), 2017 International Conference on*, pages 1–4. IEEE, 2017.

[44] Illsoo Sohn, Jong-Ho Lee, and Sang Hyun Lee. Low-energy adaptive clustering hierarchy using affinity propagation for wireless sensor networks. *IEEE Communications Letters*, 20(3):558–561, 2016.

[45] Abdul Razaque, Musbah Abdulgader, Chaitrali Joshi, Fathi Amsaad, and Mrunal Chauhan. P-leach: energy efficient routing protocol for wireless sensor networks. In *Systems, Applications and Technology Conference (LISAT), 2016 IEEE Long Island*, pages 1–5. IEEE, 2016.

[46] Hanady M Abdulsalam and Layla K Kamel. W-leach: Weighted low energy adaptive clustering hierarchy aggregation algorithm for data streams in wireless sensor

networks. In *2010 IEEE International Conference on Data Mining Workshops*, pages 1–8. IEEE, 2010.

[47] Ya Xu, John Heidemann, and Deborah Estrin. Geography-informed energy conservation for ad hoc routing. In *Proceedings of the 7th annual international conference on Mobile computing and networking*, pages 70–84. ACM, 2001.

[48] Levente Buttyán and Péter Schaffer. Position-based aggregator node election in wireless sensor networks. *International Journal of Distributed Sensor Networks*, 6 (1):679205, 2010.

[49] Haiyun Luo, Fan Ye, Jerry Cheng, Songwu Lu, and Lixia Zhang. Ttdd: Two-tier data dissemination in large-scale wireless sensor networks. *Wireless networks*, 11 (1-2):161–175, 2005.

[50] Haiyun Luo, Fan Ye, Jerry Cheng, Songwu Lu, and Lixia Zhang. Ttdd: Two-tier data dissemination in large-scale wireless sensor networks. *Wireless networks*, 11 (1-2):161–175, 2005.

[51] Lakshmanarao Battula and P Vamsikrishna Raja. Power efficient gathering in sensor information systems protocol using k-means clustering algorithm. *International Journal of Science, Engineering and Computer Technology*, 6(4):133, 2016.

[52] Sung-Min Jung, Young-Ju Han, and Tai-Myoung Chung. The concentric clustering scheme for efficient energy consumption in the pegasis. In *Advanced Communication Technology, The 9th International Conference on*, volume 1, pages 260–265. IEEE, 2007.

[53] Navin Gautam, Won-Il Lee, and Jae-Young Pyun. Track-sector clustering for energy efficient routing in wireless sensor networks. In *Computer and Information Technology, 2009. CIT'09. Ninth IEEE International Conference on*, volume 2, pages 116–121. IEEE, 2009.

[54] Nazeeruddin Mohammad, Shahabuddin Muhammad, Abul Bashar, and Majid Ali Khan. Design and modeling of energy efficient wsn architecture for tactical applications. In *Military Communications and Information Systems Conference (MilCIS), 2017*, pages 1–6. IEEE, 2017.

[55] Emil Jovanov. Wireless technology and system integration in body area networks for m-health applications. In *Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005. 27th Annual International Conference of the*, pages 7158–7160. IEEE, 2006.

[56] Robert SH Istepanian, Emil Jovanov, and YT Zhang. Guest editorial introduction to the special section on m-health: Beyond seamless mobility and global wireless health-care connectivity. *IEEE Transactions on information technology in biomedicine*, 8(4):405–414, 2004.

[57] Kaleem Ullah, Munam Ali Shah, and Sijing Zhang. Effective ways to use internet of things in the field of medical and smart health care. In *Intelligent Systems Engineering (ICISE), 2016 International Conference on*, pages 372–379. IEEE, 2016.

[58] Ruan Yue and Tang Ying. A water quality monitoring system based on wireless sensor network & solar power supply. In *Cyber Technology in Automation, Control, and Intelligent Systems (CYBER), 2011 IEEE International Conference on*, pages 126–129. IEEE, 2011.

[59] Sunny Katyara, Jan Izykowski, Bhawani Shankar Chowdhry, Hyder Abbas Musavi, and Rashid Hussain. Wsn-based monitoring and fault detection over a medium-voltage power line using two-end synchronized method. *Electrical Engineering*, 100 (1):83–90, 2018.

[60] Vignesh Raja Karuppiah Ramachandran, Eyuel D Ayele, Nirvana Meratnia, and Paul JM Havinga. Potential of wake-up radio-based mac protocols for implantable body sensor networks (ibsn)âĂŤa survey. *Sensors*, 16(12):2012, 2016.

[61] Jamil Y Khan and Mehmet R Yuce. Wireless body area network (wban) for medical applications. In *New developments in biomedical engineering*. InTech, 2010.

[62] Peyman Neamatollahi, Mahmoud Naghibzadeh, Saeid Abrishami, and Mohammad-Hossein Yaghmaee. Distributed clustering-task scheduling for wireless sensor networks using dynamic hyper round policy. *IEEE Transactions on Mobile Computing*, 17(2):334–347, 2018.

[63] Muhammad Kamran Khan, Muhammad Shiraz, Kayhan Zrar Ghafoor, Suleman Khan, Ali Safaa Sadiq, and Ghufran Ahmed. Ee-mrp: Energy-efficient multistage

routing protocol for wireless sensor networks. *Wireless Communications and Mobile Computing*, 2018, 2018.

[64] Madiha Razzaq, Devarani Devi Ningombam, and Seokjoo Shin. Energy efficient k-means clustering-based routing protocol for wsn using optimal packet size. In *Information Networking (ICOIN), 2018 International Conference on*, pages 632–635. IEEE, 2018.

[65] Yiming Zhang, Mandan Liu, and Qingwei Liu. An energy-balanced clustering protocol based on an improved cfsfdp algorithm for wireless sensor networks. *Sensors*, 18(3):881, 2018.

[66] Mohammed S Bahbahani and Emad Alsusa. A cooperative clustering protocol with duty cycling for energy harvesting enabled wireless sensor networks. *IEEE Transactions on Wireless Communications*, 17(1):101–111, 2018.

[67] Jin Wang, Kai Wang, Junming Niu, and Wei Liu. A k-medoids based clustering algorithm for wireless sensor networks. In *Advanced Image Technology (IWAIT), 2018 International Workshop on*, pages 1–4. IEEE, 2018.

[68] Wenliang Wu, Naixue Xiong, and Chunxue Wu. Improved clustering algorithm based on energy consumption in wireless sensor networks. *IET Networks*, 6(3): 47–53, 2017.

[69] Sadia Din, Anand Paul, Syed Hassan Ahmed, Awais Ahmad, and Gwanggil Jeon. A multi-layer low-energy adaptive clustering hierarchy for wireless sensor network. In *e-Health Networking, Applications and Services (Healthcom), 2017 IEEE 19th International Conference on*, pages 1–6. IEEE, 2017.

[70] Yuan Hu, Yugang Niu, James Lam, and Zhan Shu. An energy-efficient adaptive overlapping clustering method for dynamic continuous monitoring in wsns. *IEEE Sens. J*, 17(3):824–847, 2017.

[71] Chih-Hsien Chien and Ming-Shi Wang. An improving of load balancing in clustering algorithm for wireless sensor network based on distance. In *Mechanical, Control and Computer Engineering (ICMCCE), 2017 Second International Conference on*, pages 165–168. IEEE, 2017.

[72] Xu-Xing Ding, Min Ling, Zai-Jian Wang, and Feng-Lou Song. Dk-leach: An optimized cluster structure routing method based on leach in wireless sensor networks. *Wireless Personal Communications*, 96(4):6369–6379, 2017.

[73] Mohammed S Bahbahani and Emad Alsusa. Dc-leach: A duty-cycle based clustering protocol for energy harvesting wsns. In *Wireless Communications and Mobile Computing Conference (IWCMC), 2017 13th International*, pages 974–979. IEEE, 2017.

[74] Hongjun Wang, Huiqing Chang, Hui Zhao, and Youjun Yue. Research on leach algorithm based on double cluster head cluster clustering and data fusion. In *Mechatronics and Automation (ICMA), 2017 IEEE International Conference on*, pages 342–346. IEEE, 2017.

[75] Emad Alnawafa and Ion Marghescu. Imht: Improved mht-leach protocol for wireless sensor networks. In *Information and Communication Systems (ICICS), 2017 8th International Conference on*, pages 246–251. IEEE, 2017.

[76] Xiangfei Zhang, Yongsheng Ding, Guangshun Yao, and Kuangrong Hao. An adaptive clustering routing algorithm for energy harvesting-wireless sensor networks. In *Evolutionary Computation (CEC), 2016 IEEE Congress on*, pages 4699–4704. IEEE, 2016.

[77] Jin-Shyan Lee and Tsung-Yi Kao. An improved three-layer low-energy adaptive clustering hierarchy for wireless sensor networks. *IEEE Internet of Things Journal*, 3(6):951–958, 2016.

[78] Zhen Hong, Rui Wang, and Xile Li. A clustering-tree topology control based on the energy forecast for heterogeneous wireless sensor networks. *IEEE/CAA Journal of Automatica Sinica*, 3(1):68–77, 2016.

[79] Cheikh Sidy Mouhamed Cisse, Khandakar Ahmed, Cheikh Sarr, and Mark A Gregory. Energy efficient hybrid clustering algorithm for wireless sensor network. In *Telecommunication Networks and Applications Conference (ITNAC), 2016 26th International*, pages 38–43. IEEE, 2016.

[80] Melanie Mitchell. *An introduction to genetic algorithms.* MIT press, 1998.

[81] Basit Manzoor, Nadeem Javaid, O Rehman, M Akbar, Q Nadeem, Adeel Iqbal, and M Ishfaq. Q-leach: A new routing protocol for wsns. *arXiv preprint arXiv:1303.5240*, 2013.

[82] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan. Energy-efficient communication protocol for wireless microsensor networks. In *System sciences, 2000. Proceedings of the 33rd annual Hawaii international conference on*, pages 10–pp. IEEE, 2000.