DEBRE BERHAN UNIVERSITY

COLLEGE OF COMPUTING

DEPARTMENT OF INFORMATION TECHNOLOGY

An Energy Efficient Inter Cluster Multihop Communication Routing Protocol For Wireless Senor Network Based On Centralized Energy Efficient Clustering Routing Protocol (CEECR)

Makda Fekadie Tewolegne

Supervised by

Samuel Asferaw (PhD)

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Makda Fekadie

A Thesis

Submitted to The Department of Information Technology, College of Computing, Debre Berhan University, in Partial Fulfilment of the Requirements for The Degree of Masters of Science in Computer Networks and Security.

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EXAMINERS' APPROVAL SHEET

Approved by: We the examiners' board approve that this thesis has passed through the defense and review process.

Advisor:

Dr. Samuel Asferaw Signature________ Date __________

Internal Examiner:

Dr. Esubalew Yitayal Signature________ Date __________

External Examiner:

Dr.Eng. Yihenew Wondie Signature ________ Date ________

DECLARATION

I, the undersigned, hereby declare that this thesis is my original work performed under the supervision of **Dr. Samuel Asferaw,** has not been presented as a thesis for a degree program in any other university and all sources of materials used for the thesis are duly acknowledged.

Name: Makda Fekadie

Signature: ____________

Place: Debre Berhan

Date of submission: ___________________

This thesis has been submitted for examination with my approval as university advisor.

Samuel Asferaw (PhD) ________

Advisor **Signature**

DEDICATION

This Thesis Work

Is

Dedicated

To

ZEKARIAS TEFRI, ELIAS MELKA AND MY FAMILY'S

Makda Fekadie Tewolegne

ABSTRACT

WSNs is typically consist of a large number of senor nodes which collect and send various data to BS. WSN nodes are small battery powered devices having limited energy resources. Energy conservation is a major challenge because Wireless Sensor Networks are used in unattended locations. They have a restricted amounts of energy and are non-rechargeable batteries. Clustering enables in the efficient use and conservation of the limited energy resources accessible to distributed sensor nodes. Direct transmission in wireless sensor networks, where the cluster heads (CHs) and the base station (BS) are far from each other, is considered a critical factor because of its influence on network efficiency in terms of power consumption and lifetime. In multi-hop communication, the cluster head farthest away from the BS routes its data over several hops until they reach the BS. This thesis focuses on the discovery of an optimal path for an energy efficient intre cluster multi-hop communication between a source (CH) and a destination (BS) to reduce power consumption, which shall maximize network lifetimes, based on Centralized Energy Efficient Clustering Routing (CEECR).As the simulation results reveal that in terms of normalized average energy consumption ,network life time and packet delivery ratio the proposed algorithm achieves relatively better performance than both Energy Efficient Multi Hop Routing using Genetic Algorithm (E2HMR-GA) and Multi-Hop Technique for the Improvement of LEACH Protocol (MHT) .The evaluation of the proposed method is conducted in MATLAB simulator and compared with other related methods. For instance, the simulation results of when compared to MHT, E2HMR-GA showed an average improvement of 4.1 percent, and 2.5 in packet delivery ratio, 5.5 percent, and 2.5 percent in normalized average energy consumption respectively.

Keywords: WSNs, Intre Cluster multihop communication, CEECR, MHT, E2HMR-GA

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Makda Fekadie

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ABBREVIATIONS

ADC	Analog-to-Digital Communication
ARPANET	Advanced Research Projects Agency Network
BS	Base Station
CM	Cluster Member
CBM	Condition-Based Maintenance
CEECR	Centralized Energy Efficient Clustering Routing
DARPA	Defense Advanced Research Project Agency
DSN	Distributed Sensor Network
E2HMR-GA	Energy Efficient Multi Hop Routing using Genetic Algorithm
FNs	Fixed Nodes
IETF	Internet Engineering Task Force
IOT	Internet of Things
LEACH	Low Energy Adaptive Clustering Hierarchy
LEACH-C	Low Energy Adaptive Clustering Hierarchy Centralized
LEACH mobile	Low Energy Adaptive Clustering Hierarchy mobile
MBC	Mobility-Based Clustering
MWSN	Mobile Wireless Sensor Network
NASA	National Aeronautics and Space Administration
NCH	Neighbor Cluster Head
SN	Senor Node
SOSUS	Sound Surveillance System
US	United States
WSN	Wireless Senor Network

CHAPTER 1. INTRODUCTION

This chapter describes the basic introduction to the background of this thesis work and gives an overview of the fundamental concepts of Wireless Senor Networks, the significance of the study, objective of the study and contributions addressed in improving energy efficient in applications over Wireless Senor Networks routing protocols are discussed.

1.1 BACKGROUND OF THE STUDY

The Internet of Things (IOT) is a latest invention that aims to connect devices all over the world [1]. Wireless Sensor Networks (WSNs) play a crucial role in IOT paradigms. Because of their versatility and autonomy, WSNs are a good candidate for dominating the information gathering position in an IOT system [2].

WSNs are self-configuring, infrastructure-less wireless networks, composed of low-cost, self-directed, swarms of lightweight, intelligent, stationary or mobile sensor nodes scattered around specific regions of interest to monitor the physical environment. They are used in a wide range of applications including military defense, physical security, air traffic control, healthcare monitoring, environmental monitoring, market monitoring, therapeutic determination, condition checking, fire detection in forests and more. These self-contained sensor nodes or motes are capable of sensing, processing and wirelessly transmitting environmental data to a base station [3-5].

Though WSNs are vital and used in a variety of applications as stated above, WSNs are not free from limitations/challenges. The issues of energy efficiency, load balancing, scalability, fault tolerance, connectivity, robustness, coverage, security are among the challenges of WSNs as identified by IETF [6, 7]. To overcome these limitations, Scholars developed numerous routing protocols, which are broadly classified into three classes depending on network structure: hierarchical (cluster based), flat-based, and location-based routing protocol [8].

Hierarchical routing protocols have been used in WSNs to improve network existence, sensor node energy, network availability, scalability, and communication capacity while reducing overhead, latency, routing table size, and redundant message transmission. To enable all sensor nodes well organized to form a cluster in which, a Cluster Head (CH) is selected which acts as a leader to all other remaining sensor nodes. The main aim of this CH is to collect and aggregate all the information from its own cluster member sensor nodes and transmit data directly or through intermediate nodes to the Base Station (BS). Thus, one can obtain appropriate information from the network by inserting queries and collecting data from the BS or sink [9-11].

Though one can obtain appropriate information from the network by inserting queries and collecting data from the sink, hence the sensors are deployed in the harsh environment, it is tough or not possible to replace or recharge batteries. Therefore, to extend the network's lifetime nodes (whole network), an energy-efficient data transfer method, i.e. Inter Custer Communication, is required to transfer/ data from the CH to the BS [12-14].

In Cluster-based routing, most previous clustering algorithms used single hop routing to transfer data from CH to BS [15]. However, in single hop routing, hence the distance between cluster head and the base station is high, the energy consumption is also high. Thus, multi-hop communication would be more advantageous for transferring data with low energy consumption, reduce energy depletion, and improve network scalability, because multiple short hops require less energy than a long hop [16, 17].

Therefore, we integrate an energy efficient inter-cluster multi-hop communication method on CEECR (Centralized Energy Efficient Clustering Routing) clustering algorithm that results in gaining more prolonged lifetime of the whole network. We combine the parameters which are benefits for selecting optimum paths in an energy efficient inter-cluster multi-hop communication method. In this paper, we propose a method for extending the life and energy efficiency of sensor nodes by using an energy efficient inter-cluster multi-hop communication method between the cluster head and base station.

Figure 1, depicts the disparity between inter cluster single hop and inter cluster multi-hop (communication) i.e. In a multi-hop model, the CH may need to choose another node to connect to the base station as a nearest neighbor, but in a single-hop model, the CH of each cluster can communicate directly with the base station [18].

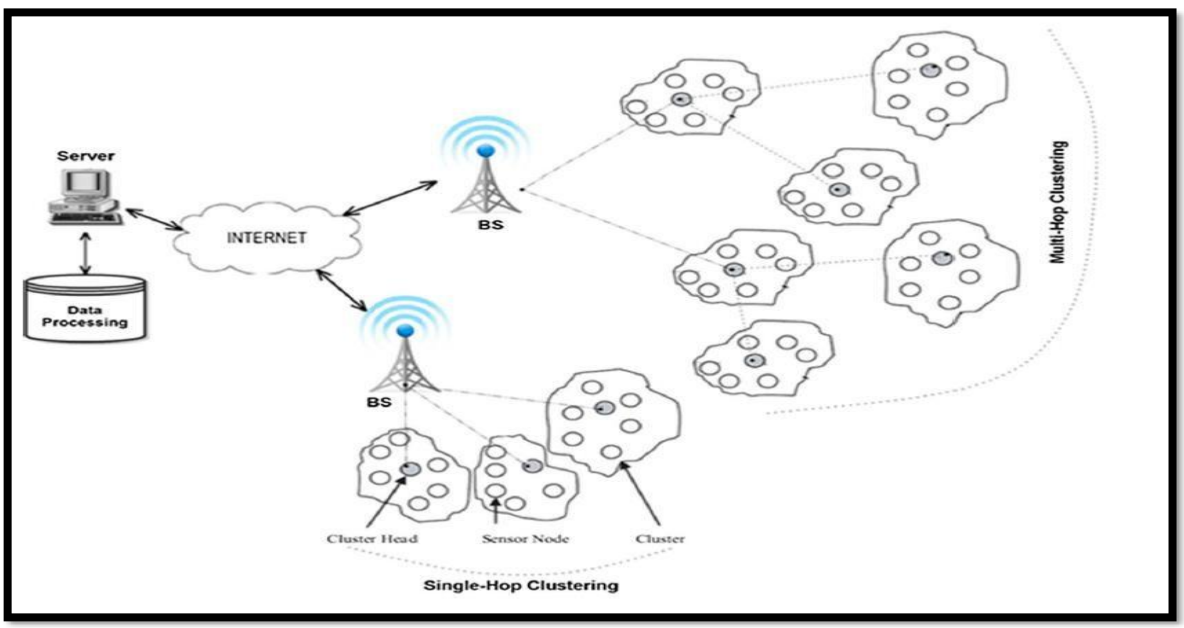

Figure 1.1 Clustering models in WSN [18]

1.2 MOTIVATIONS

The emerging field of Wireless Sensor Networks and their applications has the potential to improve a wide range of daily human activities, but strict energy constraints severely limit their functions and applications, which makes energy consumption one of the most critical concerns in WSNs.

As a result, in designing and implementing an energy-efficient sensor network, energy consumption is a critical factor to be considered. Since participants in Wireless Sensor Networks are resource constrained by nature, a network's sensor nodes must be sophisticated enough to allow it to self-organize and repair. Nodes must be able to adapt to changes in network size and shape while remaining connected over time. Sensor nodes are limited-resource machines that operate until the battery dies.

When a sensor node dies, the network is lost. Challenging sensor nodes distinctive properties, such as poor battery life, limited processing capacities and power transmission has motivated me to accomplish this research. After reviewing the current method, we decided to introduce a mechanism that minimizes the network's energy usage and thereby extends the network's lifetime.

1.3 STATEMENT OF THE PROBLEM

The Wireless Sensor Network (WSN) has attracted the attention of researchers and scientists due to its wide application in surveillance and monitoring [19]. The increased need for smartness in our everyday appliances, as well as novel applications for improved resources development, has resulted in a significant increase in sensor deployment. Sensors are becoming smaller and more effective as a result of technological advancements, and a huge number of sensor nodes are being deployed to cover a certain area [20, 21].

However, Sensor nodes are small with limited processing power, memory, and battery life. Due to limited battery capacity, wireless sensor networks must reduce energy consumption to maximize system lifetime. As a result, increasing the energy efficiency of sensor nodes, reducing packet loss, and extending network time are all key issues in WSNs [22, 23]. And Cluster-based routing has been found to be an effective approach of minimizing sensor node energy consumption while also providing a longer network lifespan than other techniques [13].

To improve the energy efficiency of WSNs, several clustered routing methods have recently been developed. For instance, Low Energy Adaptive Clustering Hierarchy (LEACH) [24] and Low Energy Adaptive Clustering Hierarchy Centralized (LEACH-C) [25]. The advancement of Wireless Sensor Networks led to the development of Mobile Wireless Sensor Networks (MWSNs). MWSN is a new field of study that is significantly more advanced than static WSN. The coverage of the sensing region is more efficient in MWSN since the sensor nodes are mobile [26].

It demands the development of novel energy-efficient solutions, one of which is hierarchical (clustering) routing protocols, which can support mobile WSNs in conserving energy while maintaining mobility [27]. Some clustering routing protocols have been developed to support mobility for instance Low Energy Adaptive Clustering Hierarchy mobile (LEACH mobile) [28] and Mobility-Based Clustering (MBC) [29].

Centralized Energy-Efficient Clustering Routing Protocol (CEECR) is proposed as better work to minimize average energy dissipation and improve packet delivery ratio. The centralized clustering algorithm is developed that periodically selects an optimal set of CHs depending on average node energy and the average node speed. Several variables are taken into account when choosing CHs for disconnected nodes [30].

Despite the fact that the CEECR routing protocol contributes significantly, it does not recognize the path how data is transmitted from cluster heads to the base station when they are near or far from the base station, so the energy is being consumed during the data transmission phase.

To fill this gap, the researchers developed the Energy Efficient Multi Hop Routing using Genetic Algorithm (E2HMR-GA) routing protocol by setting mechanisms how data is transferred between CH to BS when the CH and BS are far away. They set parameters to select the optimal neighbor CH's for multi-hop communication. They developed Fitness function which requires estimating inter-cluster distance, number of cluster members and remaining energy to achieve routing among Cluster Head (CH) and Base Station (BS) through multi-hops. The Fitness function is formulated by dividing the total energy of Neighbor Cluster Head (NCH) with the total value of its member node and intre-distance NCH [31].

Despite the fact E2HMR-GA that the routing protocol contributes significantly, there have been gaps. The first gap is the fitness function formulated incorrectly because the values of parameters are different measurements so cannot drive the one value from the different measurement. The second gap also the work could consider the mobile nodes

Therefore, this work attempts to fill the gap by proposing appropriate algorithm by implementing an energy efficient inter cluster multi-hop communication method on CEECR (Centralized Energy Efficient Clustering Routing) clustering algorithm.

Research Questions

To this end, the study investigates and answers the following research question

- How can develop an energy efficient intre cluster multihop algorithm based on CEECR?
- How can we implement an energy efficient inter-cluster multi-hop Communication algorithm based on Centralized Energy Efficient Clustering Routing (CEECR)?
- How to discover optimum path among neighbor paths for an energy efficient inter-cluster multi-hop communication algorithm?
- What are the parameters to select the optimum path among neighbor paths for an energy efficient inter-cluster multi-hop communication algorithm?

1.4 OBJECTIVE OF THE STUDY

General Objective

The general objective of the study is to develop an energy efficient inter-cluster multi-hop communication method for WSN based on Centralized Energy-Efficient Clustering Routing (CEECR) protocol.

Specific Objectives

To achieve the general objective the following specific objectives are identified:

- To develop an energy efficient intre cluster multihop algorithm based on CEECR.
- To implement an energy efficient intre cluster multihop algorithm based on CEECR
- To intend mechanism for discovering optimum path among neighbor paths for an energy efficient inter-cluster multi-hop communication algorithm
- To evaluate the performance of our proposed algorithm with MHT and E2HMR-GA

1.5 SCOPE OF THE STUDY

The Wireless Sensor Network faces numerous difficulties, but the aim of this research is to improve energy efficiency, network lifespan, throughput, and reliance for homogeneous mobile sensor nodes by implement an energy efficient inter cluster multi-hop communication method to find the optimal paths among neighbor paths on CEECR.

1.6 SIGNIFICANCE OF THE STUDY

Due to the extreme rapid expansion of mobile devices and improvements in wireless communication, as well as the rising range of commonly used applications, ad hoc networking has gained in popularity [32].

This study's contribution might support in the advancement of applications in a variety of important situations, including defending military targets, traffic congestion control, threat detection, security monitoring, forest fire detection, health monitoring, battlefield surveillance, landslide detection, sea exploration, wildlife protection, light sensing, and industrial application [33].

As a result of this research, the workload of the cluster head is decreased, packet delivery ratios are increased, communications bandwidth is maintained, and energy consumption is decreased. And also the device's robustness, performance and scalability have all been increased, which is especially important for battery-limited devices.

1.7 ORGANIZATION OF THE THESIS

The organization of the remaining parts of this thesis is as follows: Chapter Two deals with reviewing literature conceptually relevant and related to this study. In each section we discuss: overview of wireless senor network, structure of senor network, applications of Wireless Sensor Network, communication architecture of WSN, structure of a wireless sensor network, WSN characteristics, routing challenges and design issues, WSN routing protocols, Wireless Sensor Network standards and related work. Chapter three this thesis is devoted to describing the overall topological architecture and Modular architecture of the study. Chapter four focuses on stimulation tool, assumption of proposed work simulation, evaluation metrics and simulation parameters, simulation result analysis and discussion. Finally, in Chapter five, the conclusion and future work are addressed.

CHAPTER 2. LITERATURE REVIEW

This chapter covers the fundamental concepts of Wireless Sensor Networks: overview of WSN, structure of senor network, applications of WSN, communication architecture of WSN, structure of WSN, WSN characteristics, routing challenges and design issues, WSN routing protocols, WSN standards and related work.

2.1 Overview of Wireless Senor Network

The origins of WSNs started in the 1950s when US Military developed the Sound Surveillance System (SOSUS) used in submerged Acoustic Sensors [34] .For seismic activity surveillance, some SOSUS sensors are still operational. The Sound Surveillance System (SOSUS), which is utilized in Underwater Acoustic Sensors, was developed by the US military in the 1950s [35].

After a nearly three-decade hiatus, the Defense Advanced Research Project Agency (DARPA) in the United States relaunched the Distributed Sensor Network (DSN) effort with the purpose of driving newly developed technologies and protocols in the framework of Sensor Networks [36]. Advanced Research is also being place at the same time. ARPANET (Advanced Research Projects Agency Network) started WSN research and development by collaborating with a variety of institutions and corporations [37]. Small Sensor nodes were first researched and developed by NASA's "Sensor web project" and "Smart dust project" in 1998 [38].

One of the project's objectives was to create a self-contained sensing and communication device that could fit in a cubic millimeter of space. Other early efforts in this subject, which began about 1999 at MIT, Berkeley, and the University of Southern California, were largely academic in nature [39]. This sensing technique is still in use today, although it's for more peaceful purposes like monitoring marine fauna and volcanic activity [40].

2.2 Structure of Senor Network

In general, there are two types of computer networks: Wired and Wireless Networks. Wireless networks, in particular, are always classified into two types: infrastructure-based and infrastructure-less [41].

WSNs are self-organizing Wireless ad hoc networks made up of a large number of resource-constrained sensor nodes. WSN allows humans and the physical world to interactive [42, 43].

The sensor nodes, which are capable of sensing and collecting significant information about the physical environment, to send all data to the base station, they use single-hop or multi-hop communications. The base station has a high storage capacity as well as processing capabilities for distribution. The data acquired by the sensor nodes is delivered to a server, from which the end-user can access it [44-47].

As shown in Figure 2.1 the sensing unit, processing unit, transceiver, and power unit are the four essential components of a sensor node. Among the application-specific accessories are positions detecting system, a power generator, and a mobilizer [48, 49].

- **Sensing Unit**

The sensor sensing unit is a device that detects environmental conditions. Each sensing unit is responsible for processing environmental data and producing a meaningful output in the form of an electrical or optical signal. Analog signals from the sensor are converted to digital signals before being sent to the processing unit via analog-to-digital communication (ADC).

- **Processor/Processing Unit**

The processor/processing unit has a microcontroller or chip with memory, which provides sufficient control to the sensor node. The data generated by a processing unit is saved in a local memory before being sent to a base station. The processor is performing tasks and processing data. The processing unit links with other motes in the same way that it communicates with data to maintain the most efficient network.

- **Transceiver**

A radio transmitter and a radio receiver combine to form the transceiver. In order to communicate completely with the others, each node must have both of these components. The transceiver receives data from the processor while transmitting and delivers it to other nodes via network connections. The transceiver receives data from another node's radio and sends it to the receiving node. In the receiving direction, the transceiver receives data from another node's radio and sends it to the CPU. These transceivers enable nodes to extend the system's lifetime by lowering energy consumption and switching idle nodes.

- **Power Supply**

The power supply is one of the most crucial components of a wireless sensor node. The first former technology uses a variety of tiny batteries made of vanadium oxide and molybdenum oxide sheets. The sensor system's battery is its beating heart because it determines how long the device will last. In order to lengthen the network's lifespan, the battery life must be increased. The battery should be as tiny as feasible and use as little energy as possible.

- **Memory**

The most significant sort of memory in a microcontroller is on-chip memory. The amount of memory required is usually determined by the application. They are used to storing and program application-related data on the device. There are only a few kilobytes of memory available (kB).

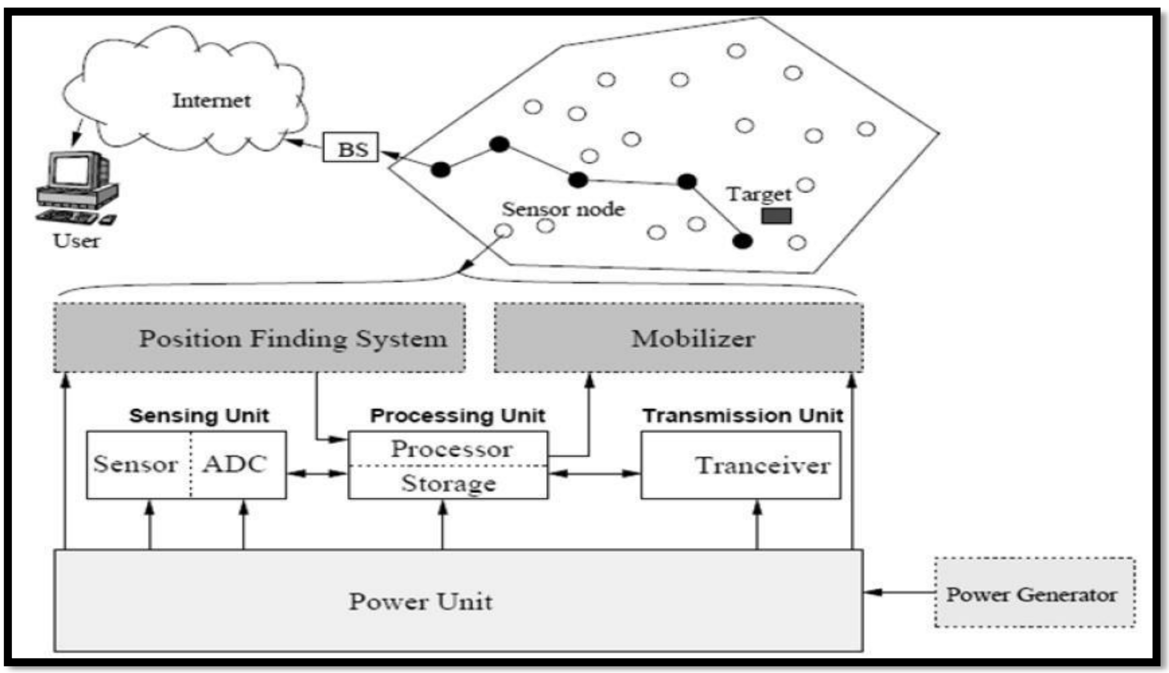

Figure 2. 1. The components of a sensor node [49]

2.3 Applications of Wireless Sensor Network

Wireless sensor networks have gained popularity as a result of their adaptability in solving problems in a wide range of applications and they have the potential to improve our lives in a variety of ways. WSNs have been shown to be useful in a variety of situations [50].

There are various types of ambient conditions that can be monitored including: temperature, humidity, vehicle movement, pressure, soil makeup, noise levels, lightning conditions, item speed and direction, stress level on attached objects, and the presence or absence of certain objects are all variables that can be monitored [51]. WSNs are used in a number of applications, as seen in Figure 2.2.

Various applications of sensor networks have been categorized and are discussed in the following subsections [52 -57].

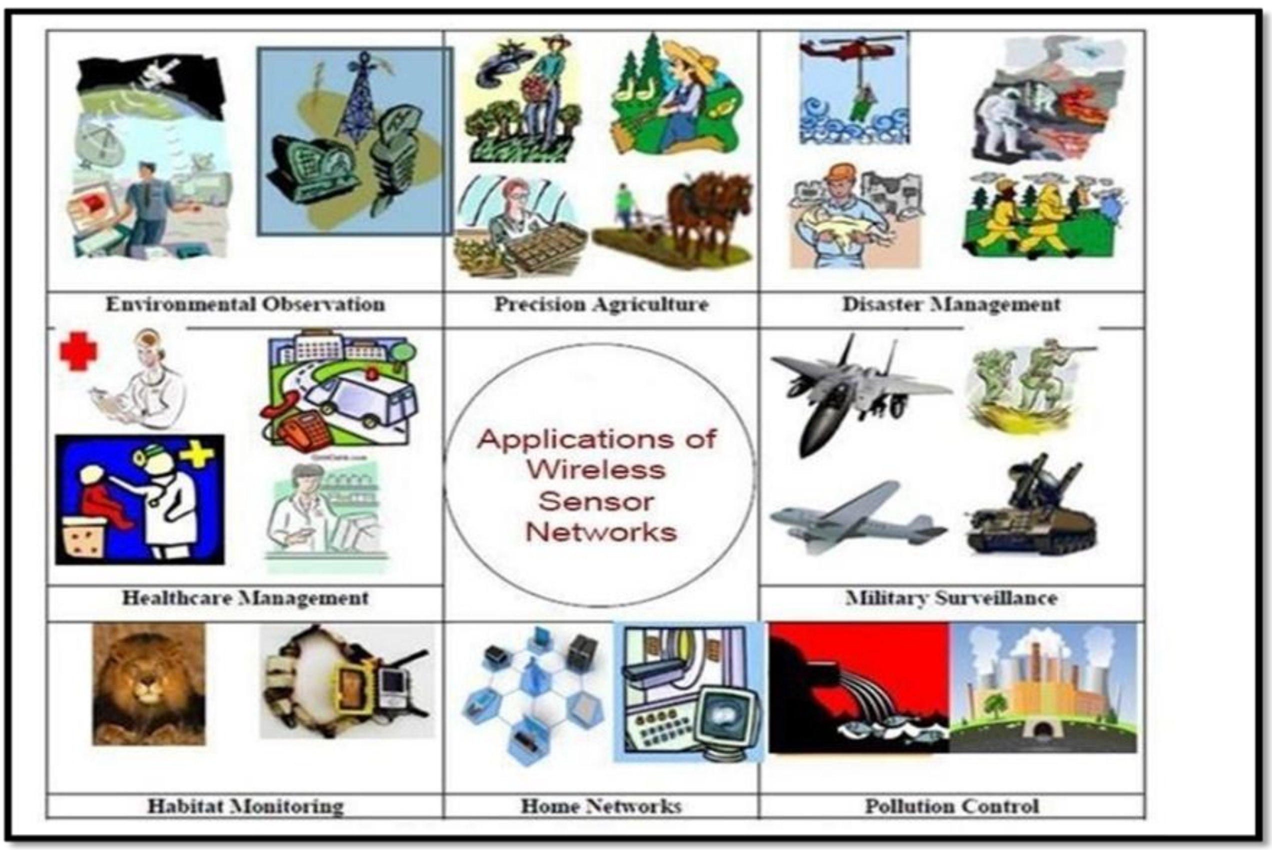

Figure 2. 2 Applications of Wireless Sensor Networks [50]

2.3.1 Military Applications

WSN is critical for armed command, control, communications, computing, intelligence battlefield surveillance, enemy monitoring, targeting systems, battle damage assessment and detection and reconnaissance of Nuclear Biological and Chemical (NBC) attack.

Due of its rapid exploitation, self-organization and selective error acceptance, sensor networks are an attractive sensing strategy for military systems. Sensor technology can be used by leaders and commanders to maintain track of armies as well as the quality and availability of weapons equipment and ammunition on the battlefield. During battle surveillance, critical terrains and corridors can be immediately covered using sensor networks and closely monitored for enemy troop activity.

2.3.2 Health Care Monitoring

In the healthcare environment, the use of WSN is now unavoidable. A number of physiological signals are detected, monitored, and tracked by sensors in the system. For further examination and diagnosis, the practitioner receives the perceived parameters.

In hospitals, sensor networks are valuable for patient tracking, diagnostics, and drug administration, as well as telemonitoring of human physiological data and clinician or patient monitoring. Patients can also stay at home instead of going to a treatment facility thanks to remote monitoring via a Wireless Sensor Network.

2.3.3 Security Monitoring

When networks are established would be through security monitoring from nodes that are positioned in an area at fixed places and continuously track one or more sensors to detect an anomaly. Every node must periodically verify the status of its sensors, but in the event of a security breach, it just needs to generate a data report.

The sending of warning signals in a timely and exact manner is the most basic mechanism required. Exceptions are reported through networks. If a node is disabled or fails, it signifies a security breach has occurred, which must be reported. The network should support security monitoring applications, with nodes checking each other's status.

2.3.4 Environmental Monitoring

Some of the most important uses of wireless sensor networks in the environmental application area are coal mining, earthquakes, flood warning, forest fire prediction, gas leakage, cyclones, rainfall range, water quality and volcanic eruptions.

It helps in the implementation of a safety measure to some level because the network allows for early detection and prediction of all of these environmental disasters. Data is collected by the sensors and transferred to the master station via the Internet station. This aids in both prevention and public knowledge of the impending disaster.

2.3.5 Home Automation

As sensor technology has progressed, a variety of uses for the house have been investigated. Smart sensor nodes and actuators will be employed in vacuum cleaners, microwave ovens, and refrigerators as technology progresses. These household sensors can communicate with one another and with the rest of the world through the internet or satellite. End-users can easily handle their home automation systems with their help.

2.3.6 Disaster Management

WSN is supposed to deliver real-time disaster area information, allowing rescue teams to plan and prepare more effectively. Location data of victims, rescuers, and disaster materials is critical for rescue operations.

It has been recognized that honesty, monitoring, and decision-making are essential for operationally efficient disaster management sensing. Timely and updated catastrophe information is crucial for effective response and successful actions; it will help disaster management make educated judgments and take action in a timely manner.

2.3.7 Vehicle Tracking

Smart transportation is another WSN application. Networked cameras and other sensors that are used to monitor traffic flow, follow urban cars for traffic violations and detect criminal activity around key infrastructure such as airports, train stations and other essential infrastructure. It offers the potential benefits of using a WSN-based traffic management system to improve vehicle transport quality and security.

2.3. 8 Node Tracking Scenarios

A Wireless Sensor Network is used to track a tagged object while a Sensor Network-monitored space region is employed. Controlling the location of important properties or resources can be advantageous at times.

2.3.9 Other Multi Usage

2.3.9.1 Structural Monitoring

Wireless sensors can be used to monitor movement inside bridges, flyovers, embankments, tunnels and other structures. Engineers can use engineering practices to remotely monitor assets instead of paying for expensive site visits.

2.3.9.2 Industrial Monitoring

WSNs were created to help with Condition-Based Maintenance (CBM) on equipment since they save time, money and allow new features. In wired systems, the cost of wiring limits the number of sensors that may be used.

2.3.9.3 Agricultural Sector

In a hostile environment, using a wireless network relieves the farmer of the obligation of maintaining the wires. Irrigation automation improves water consumption efficiency and to reduce pollution.

2.3.9.3 Forest Fire Detection

In a forest, sensor nodes are scattered around randomly and densely. Before the fire spreads uncontrollably, sensor nodes will broadcast the location of the fire's origin to users. Optical devices make use of sensor nodes. Solar cells and other power-harvesting techniques are also available. To spread of the nodes must be able to communicate with one another and overcome a variety of obstacles.

2.4 Communication Architecture of WSN

The sensor nodes are dispersed throughout the study region. To send an application request to the Wireless Sensor Network, users use a task management node. Through the internet or satellite, the application request is sent to the sink node. The WSN protocol stack consists of the application layer, transport layer, network layer, data connection layer, physical layer, power management plane, mobility management plane, and task management plane [58 -60]. Figure 4 shows the five layers of the WSN protocol stack, which include three power, mobility, and task management planes, with the application layer at the top and the physical layer at the bottom, comparable to the TCP/IP stack.

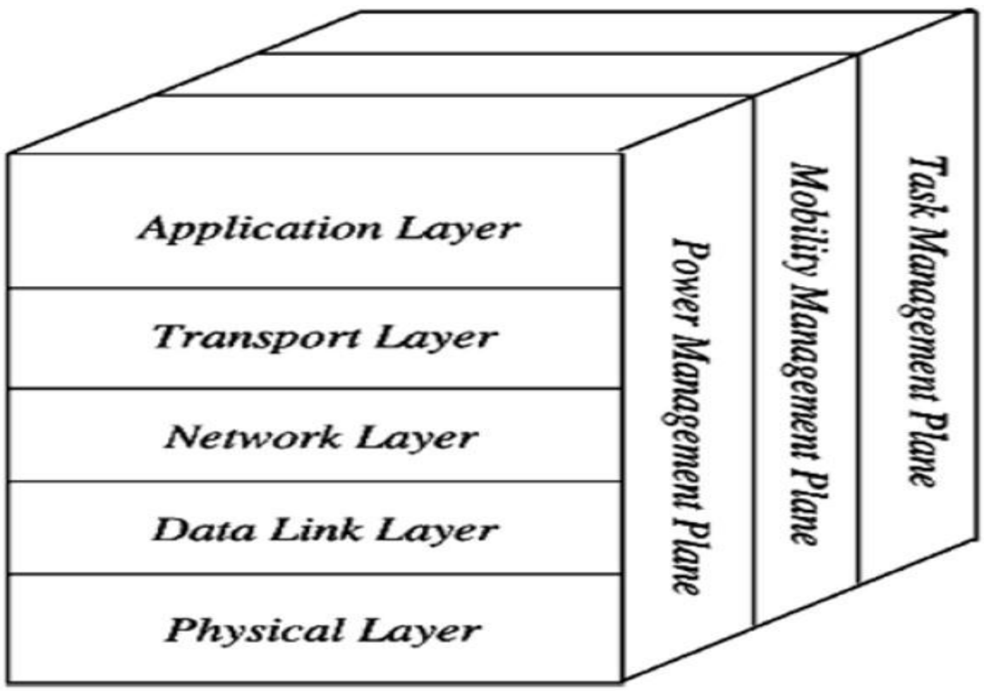

Figure 2.3 Wireless Sensor Network protocol stack [59]

- **Application layer:** Depending on the sensing task, the application layer can use and construct a range of application software. An application layer protocol makes lower-level hardware and software transparent to the application.
- **Transport layer:** The transport layer's goal is to reduce congestion and provide reliability, which it can accomplish through a variety of downstream and upstream protocols. Traditional transport layer protocols, such as TCP, which are used in wired networks, may not be practical in wireless sensor networks. Sensor Nodes are unable to implement acknowledgement-based protocols such as TCP due to their limited power and memory

resources. The data collected from sensor nodes is typically transported and used over wired networks in most wireless sensor network applications. Between the sink and the wired network, a split-level transport technique using the TCP or UDP protocol can be used, while communication, while communication between nodes in the wireless network is only UDP.

- **Network layer:** Routing is the most important feature of the network layer. Memory constraints, buffering, and power savings are the most significant challenges this layer faces. The main assumption of a routing protocol is that it will use a metric scale to represent a reliable path and redundant paths, which varies from protocol to protocol.
- **Data link layer:** The data link layer's primary functions are data stream multiplexing, data frame detection, medium access control (MAC), and error correction
- **Physical layer:** The physical layer is responsible of signal frequency selection, carrier frequency generation, signal detection, modulation, and data encryption.
- **Management planes**: The management planes, which include power management, mobility management, and task management, are orthogonal to the protocol layers and can be implemented in any of them layers.
- **Power Management**: Power Management monitors sensor node power, detection, and communication. It also saves energy by disabling a number of energy-saving features. When a sensor node's power falls below a certain threshold, it may broadcast to its neighbors that it will stop routing and focus solely on detecting.
- **Task Management Plane:** It is unlikely that all sensors in a given area will be active at the same time. While a specific node performs the sensing function, other nodes in the same region may be in sleep mode. The power level of a node can be used to select it for a sensing task when compared to other nodes. To improve network reliability, task management distributes workloads among sensor nodes.

2.5 Structure of Wireless Sensor Network

A variety of topologies are required for the development of a wireless sensor network, such as they are for radio communications networks [61-66].

2.5.1 Star Network (Single Point-to-Multipoint)

A Star Network is a type of communication architecture in which a single base station can send and receive messages to multiple distant nodes. It is not permitted for remote nodes to connect with one another. Because of its simplicity or ability to keep the remote node's power consumption to a minimal, this form of network is suitable for wireless sensor networks.

The disadvantage of such a network is that it is less reliable than other networks because it is controlled by a single node and the base station must be within radio transmission range of all the other nodes.

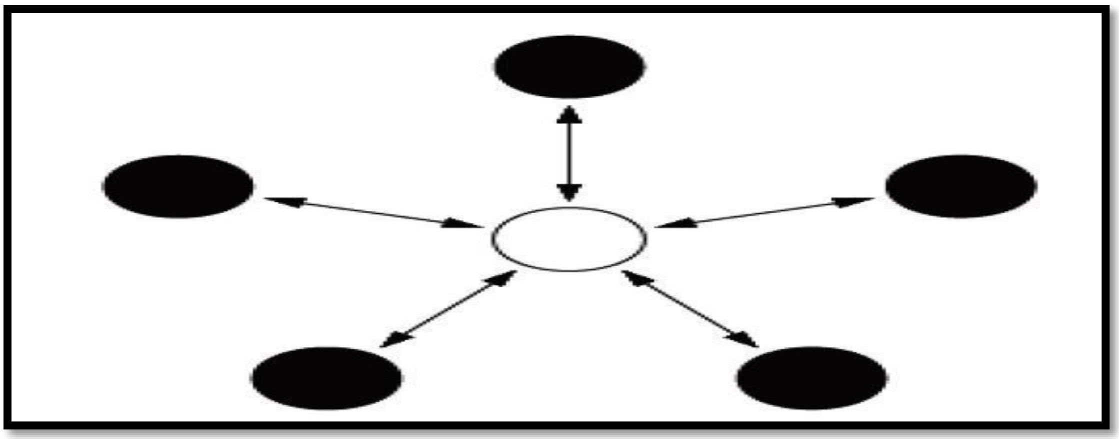

Figure 2. 3 Star Network Topology [64]

2.5.2 Mesh Network

A mesh network allows data to be transmitted from one node to another within the network's radio transmission range. This supports multi-hop communication, which means a node can send a message to another node that is out of radio range through an intermediary node

In this network topology redundancy and scalability, are crucial elements. If one of the nodes in its range fails, the other nodes can still connect to a distant node, which can then send the message to the intended recipient. The network's range isn't constrained by the range of individual nodes; it can easily be enlarged by simply adding more nodes to the system.

The downside of this network type is that nodes that use multi-hop communications consume more energy than nodes that do not, resulting in decreased battery life. Furthermore, the time it takes to transmit a message grows as the number of communication hops to destination increases, especially if the node is operating at low power.

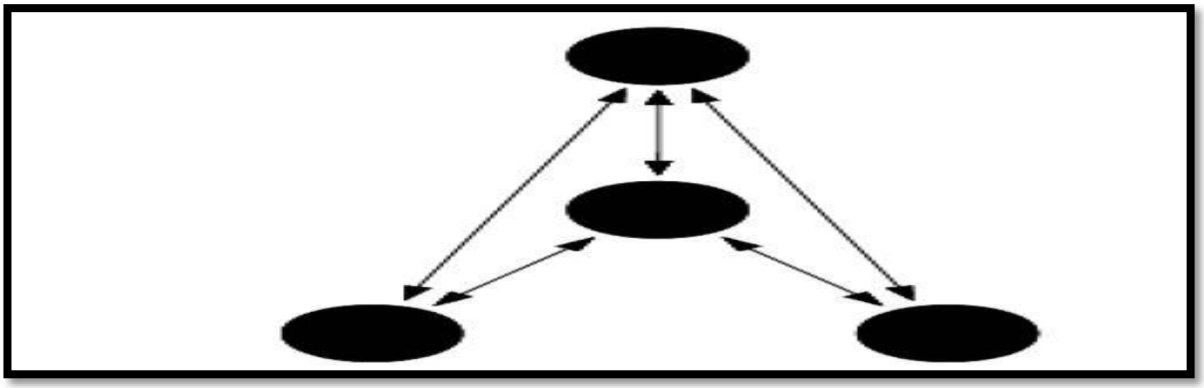

Figure 2. 4 Mesh Network Topology [61]

2.5.3 Hybrid Star — Mesh Network

A Star and Mesh network combined delivers a reliable and scalable communications network while allowing wireless sensor nodes to consume little energy as possible. In this network architecture, the sensor nodes with the lowest power are not authorized to forward messages**.** This allow, energy usage can be kept under control. This topology is imposed by ZigBee, the next mesh networking technology. The advantage of topology has flexibility to expand the range of the network and also fault tolerance. The downside of this network type is more complex and requires more effort to manage than any other Topology.

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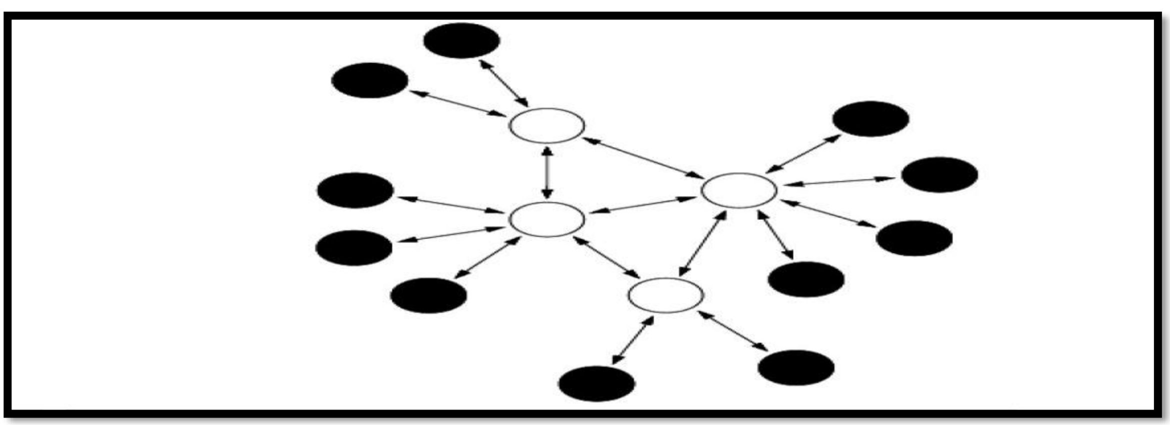


Figure 2. 5 Hybrid Star – Mesh Network Topology [63]

2.6 WSN Characteristics, Routing Challenges and Design Issues

The followings are some of the characteristics routing challenges and design issues, which are specific to WSN [67-69].

- Node Deployment: Sensor nodes are typically densely deployed in the field of interest, depending on the application influencing performance of routing protocol. Deployments that are deterministic or self-organizing are considered.
- Dynamic Network Topology: The topology of the network changes as nodes are added or removed, as well as due to node failure, energy exhaustion or channel fading.
- Energy Consumption: Computation and transmission are challenging to carry out while avoiding energy depletion because WSN sensor nodes have limited battery capacity. Because the battery influences the lifespan of sensor nodes, it is the most challenging issue to solve. The majority of the sensors are in inaccessible locations, with only a few in epileptically active areas.
- Restricted Hardware Resources: Because of their limited CPU and storage capacities, sensor nodes can only perform a limited number of computational activities.
- Limited Memory and Storage Space: Sensors have limited memory and storage space since they are small devices with limited code storage and memory.
- Self-configurable: Sensor nodes are often distributed at random in the absence of proper direction and design. Once deployed, sensor nodes must self-organize into a communication network on their own.
- Application Specific: Sensor networks are adapted to the specific of the application. A network is frequently developed and built with a specific goal purpose.
- No Global Identification: Because of the large number of sensor nodes, a global addressing system for a sensor network is frequently impossible to establish due to the high cost of identification maintenance.
- Distributed processing: When compared to a single sensor, a wireless sensor network can generate a lot more data. Even when using a sensor with a lengthy line of sight, obstacles may occur. As a result, environmental impediments benefit from scattered sensing.
- Wireless: The sensor node must be able to communicate wirelessly. Many of the applications being monitored lack built-in communication networks. As a result, the nodes should use

wireless channels to communicate. Because anodes are wireless, they may be utilized to set up a network by deploying nodes and in a variety of other investigations.

- Cost of deployment: The purchasing a sensor node is very substantial. As a result, deploying hundreds or thousands of nodes would result in a multiplier effect on both purchasing and maintenance costs.
- Fault tolerance: Sensor nodes are delicate devices that can fail due to a power outage or other external events. Because defective components in a network reduce throughput, lowering network efficiency and performance, fault-tolerant operation is crucial for the efficient operation of the WSN.
- Scalability: Wireless sensor networks can have thousands of nodes in any sensing region. A network routing strategy capable of handling the large number of sensor nodes. Additionally, sensor network routing algorithms must be scalable enough to respond to changing environmental conditions. It is also necessary, to deal with energy-related issues, sensor nodes in routing systems must also remain in the sleep state before any event occurs or begins.
- Quality of service (QoS): WSNs must provide a high quality of service because they are used in a variety of real-time and mission-critical applications. However, it is difficult because the network's topology changes over time, and the state information provided for routing is inherently inaccurate.
- Data Aggregation: The sensor node can generate duplicate data. To reduce communication traffic, WSN employs a data aggregation strategy. Some methods for aggregating data include suppression, as well as the min, max, and average characteristics. Because communication consumes more energy than processing, the data aggregation approach is used to conserve resources.
- Heterogeneity of nodes: Under certain conditions, nodes in a WSN can be homogeneous in terms of energy, bandwidth, and memory, but heterogeneous under others. These various nodes behave differently in the same network. As a result of the aggregation of diverse nodes, a slew of technological challenges emerge, including varying data speeds and a variety of data routing methods.
- Data Delivery Models: Depending on the implementation of sensor nodes and the time criticality of data reporting, data delivery models may be time driven, data driven, query

driven and hybrid (combination of delivery models). Such data delivery models have a strong impact on the design of routing protocols, especially in terms of reducing energy consumption.

- Robustness: In order for the system to withstand and respond to individual node failure and meet the required lifetime requirements, each node must be configured to be as robust as possible. System modularity is an important factor in the development of a dependable system. Because it frequently coexists with other wireless systems, a wireless sensor network must be resistant to external interference as well as node failure. The use of multi-channel and broadcast spectrum radios improves the system's robustness.

2.7 WSN Routing Protocols

Routing strategies are one of the most important research areas in WSNs. Many routing, power management, and data dissemination protocols were developed specifically for WSNs, where energy consumption is a critical design factor for long-term network viability and data transmission dependability. The majority of these activities are handled by routing methods.

Routing protocols should be designed to maximize network energy use by describing a collection of rules detailing how message packets connect effectively and with less energy usage from source to destination in the network. The three types of network structures: flat, hierarchical, and location based. Routing in a WSN is more difficult than routing in modern networking and wireless ad-hoc networks [70, 71]. The following is a summary of the issues.

- First and foremost, it is impossible to deploy a large number of sensor nodes using a global addressing method. As a result, typical IP-based protocols are incompatible with sensor networks.
- Second, unlike traditional communication networks, almost all sensor network implementations allow for the flow of sensed data from multiple areas (sources) to a single sink.
- Third, because multiple sensors in the vicinity of an event may generate identical data, generated data traffic has a high level of redundancy. Routing systems must use this redundancy to increase energy and bandwidth usage.
- Fourth, sensor nodes are limited in terms of transmission power, on-board energy, processing capacity, and storage space, necessitating the use of several sensors.

Due to such differences, many new routing protocols emerge continually to solve the challenging tasks of routing in sensor network.

2.7.1 Classification of Routing Protocols for WSNs

WSN routing protocols are classified according to how routing paths are defined, network structure, protocol activity, and communication initiator. Figure 8 depicts the classification of WSN routing protocols, which was compiled from various sources [72-78].

The way routing paths are defined, the network structure, protocol activity, and communication initiator are all used to classify WSN routing protocols.

2.7.2 Classification Based on Network Structure

WSN routing can be classified as flat-based routing (data-centric routing), hierarchical-based routing and location-based routing, depending on the network structure.

- Flat-based routing protocols

In this routing, each node plays the same role, and sensor nodes collaborate to perform the sensing task. The two forms of flat protocols are constructive and reactive flat protocols. In large networks, constructive protocols ensure that pathways to destinations are maintained. Only the paths to distinctions that are required are kept in reactive protocols. These routing protocols have drawbacks in terms of data redundancy and energy consumption.

- Hierarchical-based routing protocols:

In this type of routing, sensor nodes are arranged into clusters, and higher-energy nodes collect data from lower-energy cluster members (CM). In order to reduce the amount of messages delivered to the sink, cluster participants send sensed data to cluster heads, who undertake data aggregation and data fusion.

- Location-based routing protocols

Sensor nodes connect with other nodes based on their location in this category of routing protocols. Before the packet can be distributed, the position of the distinction must be determined. This location or distance can be computed in two ways: the distance between two neighboring nodes can be estimated by getting signal intensity and from the source using GPS (Global Positioning System).

2.7.3 Classification Based on Path Establishment

To reduce the redundancy in flat-based routing, proactive, reactive, and hybrid routing protocols were developed depending on how the source finds a route to the destination

- Proactive routing protocols

With proactive routing, all routes are computed before they are needed, and each node has one or more tables containing the most up-to-date information on routes to every other node in the network. The Proactive protocols are not ideal for larger networks because they require node entries for each and every node in the routing table of each node. This adds to the routing table's overhead in the routing table leading to increases energy consumption.

- Reactive Routing protocols

In reactive routing protocols the Routes are computed on demand. Reactive routing protocols find routes only when a source node wishes to interact with a destination node. The fundamental disadvantage of reactive routing is the significant routing overhead caused by Route Request (RREQ), Route Reply (RREP), and Route Error (RERR) messages used to maintain the network.

- Hybrid routing protocols: In Hybrid routing protocols use both reactive and proactive routing protocols strategies.

2.7.4 Classification Based on Protocol Operation

The protocols are classified into multipath-based, query-based, negotiation-based, QoS-based and Coherent and non-coherent processing routing techniques depending on protocol operation.

- Multipath routing protocols: Multiple paths are used to enhance network performance. It includes the algorithms that route the data through a path whose nodes have the largest residual energy. The path is changed whenever a better path is discovered.
- Query based routing protocols: The destination nodes propagate a query for data (sensing task) from a node through the network and a node having this data sends back the data to the node that matches the query to the query that initiates. Usually these queries are described in natural language, or in high-level query languages.
- Negotiation based routing protocols: In order to eliminate redundant data transmissions, these use high level data descriptors through negotiation. Based on the resources that are available to them, communication decisions are taken. The main idea of negotiation based routing in

WSNs is to suppress duplicate information and prevent redundant data from being sent to the next sensor node or the base-station by conducting a series of negotiation messages before the real data transmission begins.

- QoS-based routing protocols: the network has to balance between energy consumption and data quality. The network has to satisfy certain QoS metrics (delay, energy, bandwidth, etc. When delivering data to the Base Station, the network has to balance between energy consumption and data quality.
- Coherent and non-coherent processing: Data processing is a major component in the operation of wireless sensor networks. Hence, routing techniques employ different data processing techniques. In non-coherent data processing routing, nodes will locally process the raw data before being sent to other nodes for further processing. The nodes that perform further processing are called the aggregators. In coherent routing, the data is forwarded to aggregators after minimum processing.

2.7.5 Classification Based on Initiator of Communication

Depending on the initiator of communication, the protocols are classified into source and destination. Communication can be initiated either by the source of the data or by the destination. In source initiated protocols, the nodes send data to the base station soon after they take new measurements. Source initiated protocols use either time driven or event driven data reporting.

Destination initiated protocols use query driven reporting and the nodes respond to the queries that they receive. Destination initiated protocols incur a large amount of overhead because the requests are usually flooded through the network.

2.8 Wireless Sensor Network Standards

There is a need to create a broad, low-cost market for sensor products in the field in order to promote the global growth and implementation of WSNs. It is necessary to define relevant standards for this reason, so that sensor products from different manufacturers can integrate with each other. In order to unify the industry, a lot of attempts have been made and are under way in many standardization organizations, contributing to low-cost and interoperable products, and preventing the proliferation of incompatible proprietary network protocols [79].

The success of WSNs as a technology would, to a certain degree, depend largely on the success of these standardization efforts. The Standard for IEEE 802.15.4, is a specification developed by Task Group 4. IEEE 802.15, which defines the physical and MAC layers for WPANs at low rates. The first release of the IEEE 802.15.4 standard was delivered in 2003, as specified in its Project Authorization Request. [80, 81].

- **The ZigBee Standard:** The ZigBee standard is developed on top of the IEEE 802.15.4 standard and defines the network and application layers. The network layer provides networking functionalities for different network topologies, and the application layer provides a framework for distributed application development and communication. The two protocol stacks can be combined together to support short - range low data rate wireless communication with battery powered wireless devices. The potential applications of these standards include sensors, interactive toys, smart badges, remote controls, and home automation. The ZigBee protocol stack was proposed at the end of 2004 by the ZigBee Alliance, an association of companies working together to enable reliable, cost-effective, low - power, wirelessly networked, monitoring, and control products based on an open global standard. The first release of ZigBee was revised at the end of 2006, which introduces extensions on the standardization of application profit les and some minor improvements to the network and application layers.
- **The IEEE 1451 Standard:** The IEEE 1451 standards are a family of Smart Transducer Interface Standards that defines a set of open, common, network - independent communication interfaces for connecting transducers to microprocessors, instrumentation systems, and control/field networks. Transducers have a wide variety of applications in industry, the key feature of these standards is the definition of Transducer Electronic Data Sheets (TEDS), which is a memory device attached to a transducer for storing transducer identification, calibration, correction data, measurement range, manufacture-related information, and so on. The objective of 1451 is to make it easier for Transducer manufacturers to develop smart devices and to interface those devices to networks, systems, and instruments by incorporating existing and
- IEEE P1451.0: defines a set of common commands, common operations, and TEDS for the family of IEEE 1451 smart transducer standards. Through this command set, one can access any sensors or actuators in the 1451 – based wired and wireless networks.

- IEEE 1451.1: defined a common object model describing the behavior of smart transducers, a measurement model that streamlines measurement processes, and the communication models used for the standard, which includes the client - server and publish - subscribe models.
- IEEE 1451.2: defined a transducers - to - NCAP interface and TEDS for a point - to - point configuration.
- IEEE 1451.3: defined a transducer to NCAP interface and TEDS for multi-drop transducers using a distributed communication architecture. It allowed many transducers to be arrayed as nodes, on a multi drop transducer network, sharing a common pair of wires.
- IEEE 1451.4: defined a mixed mode interface for analog transducers with analog and digital operating modes.
- IEEE P1451.5: defines a transducer to NCAP interface and TEDS for wireless transducers. Protocol standards for wireless networks

CHAPTER 3. RELATED WORKS

The main aim of this chapter is to present the related research works regarding WSNs cluster-based routing protocol in inter cluster multihop communication. Recently, wireless communication between mobile users is becoming more popular than ever before.

3.1 Overview

The cluster-based protocols add more robustness, adaptability, scalability, flexibility, and energy efficiency in finding routes and are easy to manage as compared other [79]. That is why the research community has proposed a large number of cluster-based solutions for WSNs. Recently, various cluster based routing protocols and approaches have been developed by researchers to improve energy and enhancing network lifetime and are summarized below.

Heinzelman et al. proposed Low Energy Adaptive Clustering Hierarchy (LEACH) as the most widely recognized cluster-based routing scheme for increasing network lifetime in WSNs. Setup and steady-state are the two phases of LEACH. During the setup phase, clusters are created, and a CH is assigned to each one using the probability equation. A random number between 0 and 1 is generated by each sensor node. If the generated number is less than the threshold value, then it will be CH for the current round. Its disadvantage is that data may only be transmitted from CH to BS via a single hop link, preventing it from being utilized for a wide-area network [24].

Shuo Shi et al. proposed Low Energy Adaptive Clustering Hierarchy Centralized (LEACH-C) which would be a form of enhanced LEACH. At the start of each round of LEACH-C, the position information and residual energy value of all nodes were broadcast to the base station. The base station determines the average energy value of all nodes after receiving this information, and nodes with residual energy higher than the average are as the candidate, then the base station selects a group of cluster heads from the candidate. The cluster head group will then be announced to the remainder of the network. If its own ID appears in the cluster head group it received, the node will set itself up as a cluster head; if it does not, the node will make contact with the relevant cluster head and transmit data to the cluster head in the TDMA slot [25].

However, LEACH and LEACH-C are unable to handle node mobility. In other words, they're only useful in situations when nodes are fixed nodes (FNs). To deal with mobility, some distributed clustering routing approaches have been created.

Kim, Do-Seong et al., proposed Low-energy Adaptive Clustering Hierarchy-mobile (LEACH mobile) protocol supports the mobility of a sensor node by integrating their membership declaration into the LEACH protocol. The goal of this membership declaration is to ensure that all sensor nodes in a cluster are operating in steady-state mode. When a sensor node does not receive a request from its cluster head during two consecutive frames, it realizes it has moved out of the cluster and sends a cluster joint request message to join a new cluster in order to avoid losing any more packets. As a result, the LEACH-mobile protocol improves packet delivery rates while at the cost of increased control overhead [28].

Santhosh et al. proposed LEACH-mobile-enhanced protocol, cluster head election technique based on the "remoteness" mobility metric, implying that electing a cluster head who moves less than its neighbors is preferable. The cluster leader is more likely to be elected if a node has the least mobility or is in group motion with other members [82].

Samer et al. proposed cluster-based routing, adaptive TDMA scheduling, and a round-free cluster head protocol for mobile sensor nodes (CBR-mobile). According to the CBR protocol, a cluster head receives data not only from its members during the given TDMA timeslot, but also from other sensor nodes that just enter the cluster when it has a free time slot. In response to dynamic traffic and mobility situations in the network, the CBR protocol modifies TDMA scheduling [83].

Both the LEACH-mobile and CBR protocols strive to increase effective packet delivery rates while increasing control overhead, which could result in higher energy consumption and a shorter network lifetime.

Deng et al. proposed the mobility-based clustering (MBC) protocol for wireless sensor networks with mobile nodes. A setup phase and a steady-state phase are included in each round of MBC operation. During the setup phase, a sensor node determines itself whether or not to be a CH based on its remaining energy and mobility. In addition, the MBC protocol incorporates connection time during the cluster building process to develop a more reliable path based on the stability or availability of each link between the MN and CH nodes. The disadvantage of this approach is that, because the energy and mobility factors are both multiplied at the same time, the threshold function for selecting an SN as a CH may be smaller than LEACH, resulting in an unstable number of CHs and increased energy dissipation [29].

Jingxia et al proposed the Centralized Energy-Efficient Clustering Routing Protocol (CEECR) for Mobile Nodes in Wireless Sensor Networks to reduce energy dissipation and optimize packet delivery ratio.

This work makes a two-fold contribution: First, a centralized clustering algorithm is developed that periodically selects an optimal set of CHs based on a combination of average node energy and average node speed. And second, a detached node selects its optimal cluster head based on three parameters: node distance, node mobility, and node energy [30]. CEECR does not describe how data transmission is going.

As a result, we use inter-cluster communication techniques to improve this approach. We've compiled a list of the many literatures used in inter-cluster multihop communication.

In 2007, Fan Xiangning et al., proposed Multihop-LEACH protocol considers residual energy in the phase of cluster head selection. Multihop-LEACH protocol is almost the same as LEACH protocol, only makes communication mode from single hop to multi-hop between cluster heads and sink. First, multi-hop communication is adopted among cluster heads. Then, according to the selected optimal path, these cluster heads transmit data to the corresponding cluster head which is nearest to sink. Finally, this cluster head sends data to sink. The down side there is no parameters to select NCH [84].

Amira Ben Ammar et al. proposed the Multi-Hop LEACH based Cross-layer Design for Large Scale Wireless Sensor Networks algorithm, which improves the LEACH algorithm by adding a new algorithm for selecting cluster heads and a design algorithm for intra-cluster and inter-cluster communication. In inter- cluster multi hop communication they used two parameters i.e. residual energy and SNR.- The first source CH sends an RREQ packet to their neighbors CH in order to discover the routing path, and the neighbor CH compares its residual energy with the energy threshold and the SNR of compare with the SNR threshold. Then, if the energy exceeds the energy threshold and the SNR exceeds the SNR threshold. After that, the neighbor CH sent an RREQ request to its neighbors. If this is not the case, the RREQ packet is dropped. If it drops, proceed to the other neighbor, and finally, check neighbors based on thresholds. When the intermediate node gets to destination, the destination compares the various paths to select the optimal path to source CH. The source is then routed through the RREP reverse path [85].

The strongest point of this algorithm improves the LEACH protocol by introducing multihop communication and employing effective parameters for selecting next neighbors or intermediates CH. The weakness protocol does not set a mechanism when all nodes have less threshold in this condition how sources CH send data to BS.

Emad Alnawafa et al., proposed Multi-Hop Technique to Improve the LEACH Protocol. This study proposes a Multi-Hop Technique (MHT-LEACH) to improve the performance of LEACH. In order to deliver aggregated data, this protocol seeks to establish a multi-hop communication between CHs and BS.The CHs transmit data directly to the BS depending on the distance between the CHs and the BS. They use inter cluster to multi hop communication when the distance between the cluster head and the base station exceeds the distance threshold. As a result, the source CH transmits data to the neighbor CH if the distance between CH and the neighbor CHs is less than the distance threshold; if the distance between CH and the neighbor CH is greater than the distance threshold, the source CH compares the distance between CH to BS with distance between CH to the neighbor CH, then if the distance between CH and BS is less than the distance between the source CH and the neighbor CH, the CH will transmit data to the base station directly. The MHT algorithm, in general, is used for intra-cluster multi-hop communication with a distance parameter [86]. The strong point of this algorithm is that it achieves its goal, which means that there is no multihop communication in LEACH, so the researchers added new methods in LEACH for communication and reduce the energy consumption. The weakness of protocol is that it only uses single metric to select the optimal cluster head .Many critical parameters do not include for example the most critical parameter residual energy

Mohamed Elhoseny et al proposed Dynamic Multi-hop Clustering in a Wireless Sensor Network: Performance Improvement algorithm. They describe DCH-GA, a new CH selection technique based on GA (Genetic Algorithm) for both single-hop and multi-hop cluster models, in this study. The DCH-GA was created to meet the demands of dynamic dynamics by electing the CH based on six main features.

These features are the remaining energy, the consumed energy, the number of nearby neighbors, EAD, the node vulnerability, and the degree of mobility On the basis of features they select CH in the cluster. The CH can deliver the aggregate data to the base station either directly or via multihop transmission. The CHs can transmit data directly to the BS if the distance between them is less than a certain threshold.

When the distance between the CH and the BS exceeds a certain threshold, each must send data to an intermediate CH located between them and the BS. As a result, they provide an intre-cluster multihop algorithm for selecting the neighbor CH based on parameters such as distance from source CH to neighbor CH, distance neighbor CH to BS, remaining energy of neighbor CH, the counting of nodes in the cluster and the count of hindrance. Based on those parameters they derived the fitness value for selecting the optimum neighbor CH. The fitness value is adding all value of parameters if CH have higher value then select to as optimum neighbor CH [18]. The strongest of this algorithm uses the most critical parameters and they achieve the goals. The weakness of this algorithm the measurements of parameters is different but the algorithm without thinking the difference adding all so this fitness value is not logical.

Naeem Ayoub et al., proposed a Multi-Hop Advance Heterogeneity-aware Energy Efficient (MAHEE) Path Planning Algorithm for Wireless Sensor Networks. In this paper, they assessed the effects of multiple clustered routing on overall energy dissipation in sensor networks. MAHEE is proposed as a solution to the energy dissipation problem by selecting the best CHs for multi-hop inter-cluster communication, allowing all nodes to use the same amount of energy.

The proposed algorithm has choose the shortest path for multi-hop routing in inter-cluster communication. The MAHEE routing algorithm proposes two types of multi-hoping criteria: distance-based multi-hoping and Load Balancing-based Multi-hoping. Distance-based multihoping: In this algorithm, CHs that are further away from the BS choose an intermediate CHs node to transmit information to the BS. The selection criteria are based on the shortest distance between the CH and the BS. Load Balancing-based Multi-hoping in this method, the best path is determined by the traffic load on the intermediary nodes. All selected CHs re-announce the number of member nodes in their cluster in this cluster [87].

The weakness of this algorithm is it does not consider the energy of next cluster heads. Energy is the critical issue on wireless sensor networks.

Amanjot Singh Toor and A.K. Jain proposed Energy Aware Cluster Based Multi-hop (EACBM). EACBM is a three-level heterogeneous network routing protocol that combines clustering connectivity, multi-hop routing, and sub-clustering with a novel probabilistic equation that results in the efficient utilization of sensor nodes energy. The sensor nodes were CH, which had more energy or remaining energy than the others. EACBM uses intre-cluster multihop communication. The algorithm initiates intre-cluster multihop communication when the distance between cluster heads exceeds the distance threshold. They used the distance parameter to find best neighbors cluster head's. The distance between the source CH to neighbor cluster head is less than the distance threshold, Therefore the next optimum cluster head is selected for inter cluster communication. The source CH sends data to neighbor CH [88].

The weakness of this algorithm it used only single parameter for selecting the optimum neighbors for intre-cluster multihop communication.

Anchao Li et al., proposed a Discrete Energy - Efficient Clustering Algorithm based on Energy threshold and Location distribution (DEEC-EL). The method is well suited for multi-level energy heterogeneous sensor networks. The cluster head selection stage and the inter-cluster multi-hop transmission stage are the two stages of the algorithm. In the cluster head selection stage, the energy threshold and location distribution are defined so that nodes with high residual energy near the base station are chosen as cluster heads. During the multi-hop transmission phase, the neighbor CH node is determined by taking into account the node location, remaining energy, number of retransmissions, and cluster nodes.

By using cost factor formula, it is more reasonable and valid to select the node with the appropriate distance, higher residual energy, fewer number of forwarding nodes, and fewer number of nodes in a cluster selected as neighbor CH node. The enhanced routing algorithm performs even better in terms of network life cycle, data transmission, and energy efficiency [89].

The strongest point of the algorithm is achieving the objectives and using the critical parameters for selecting next optimal cluster heads .The weakness point of the algorithm is not setting the threshold value to higher and lower values; this yields not getting neighbor CH nodes that fully fill all parameters.

Mohammed Al-Shalabi et al., proposed Energy efficient multi-hop path in wireless sensor networks using an enhanced genetic algorithm. This study focuses on the discovery of an optimal multi-hop path between a source (CH) and a destination (BS) to reduce power consumption and maximize network lifetimes by presenting a new Optimal Multi-hop Path Finding Method (OMPFM).The OMPFM improves the LEACH protocol by sending data from the CH to the BS via other CHs chosen with care using the GA. The GA method is used to determine the most efficient route from a source CH to the BS via intermediate CHs. The suggested method's major purpose is to reduce the amount of energy consumed during data transfer from a CH to a BS.In order to attain this goal, numerous parameters in the fitness function are evaluated. The distance from each participant CH to the BS the total number of participating CHs in the transmission process and the number of each cluster member in a cluster. So neighbors CH is selected if it has small distance, small no of participating CH in transmission process and small no- of members in cluster [90].

The most powerful of this algorithm used the most appropriate parameters to achieve their goal. The weakness of this algorithm is that it does not take into account the energy of neighbors; energy is the most important factor in the wireless sensor world.

Karthik Soundarapandian et al., proposed the Ratings-Based Energy-Efficient Clustering Protocol (REEC) for Multi-hop Routing in Homogeneous Sensor Networks. The main goal of this technique is to reduce energy consumption and thus increase network lifetime and QoS metrics

In this approach, cluster heads (CHs) are selected based on the rating values of homogeneous sensor nodes computed using energy level, number of neighbors, and distance to the base station (BS). The communication path is also determined by the Energy Threshold and Minimum. ETMDRP is a table-driven, hierarchical routing system in which each sensor node maintains its own routing table. ETMDRP is used to communicate between clusters and within clusters. Communication between CHs and BSs is referred to as inter-cluster communication (IERCC). When CH is required to send data to BS.

First, this CH compared its available energy to the energy threshold in order to transmit, the available energy must be greater than or equal to the required threshold energy, and then it compared the cluster head's transmission range to the transmission range threshold. If the transmission range from CH to BS is less than threshold transmission range. Then the cluster head directly transmits data to the base station and the BS sends an ACK packet to CH when the data is delivered. If the transmission range falls within threshold transmission range or the transmission range from CH to BS greater than the threshold transmission range they used intre-cluster multihop communication .Then the nearest CH's compute the NFN algorithm. This NFN algorithm works by computing energy metrics to determine the nearest forward node for CH, then computing the energy of the next forward node using an energy threshold (Er). If the available energy of the next CH exceeds the needed energy, it is a candidate for being picked or eligible for NFN for neighboring. Otherwise, it is ineligible for NFN (next foreword). Then the NFN (next forward node) algorithm selects the nearest CH node from eligible neighbor CH's by using hop count metrics. After selection of neighbor CH, the source CH forward data to NFN, NFN acknowledges CHc1 [91].

The strong point is that this algorithm is checked initially before starting to transmit and receiving one sensor node should have enough energy by comparing the energy threshold it used for controlling the delay loss of data and battery. And for selecting optimal neighbor cluster heads the parameters used these are energy and hop count is good parameters for their objectives. But the weakness of this research is there is not considering many parameters for e.g. the distance from source CH to neighbor CH and neighbor CH to BS, the distance parameter is the most critical factor in energy consumption because distance and energy is directly proportional.

Amir Nader Shahbaz et al. proposed Multipath routing in wireless sensor networks protocol using the firefly algorithm and fuzzy logic. To improve network lifetime in WSNs, the suggested solution aims to reduce energy consumption and balance load in the network. They proposed a multipath routing approach for homogeneous WSNs in this paper. The proposed method includes 3 phases: clustering the network nodes, discovering the paths between CHs, and maintaining the paths. For transferring data from transmitter to receiver they establish a route so the algorithm suggests using multihop routing .The routing establishes the two paths from cluster head to base station. The cluster head uses the first primary path for transmitting, but the CH can use the second path if the first primary path is lost or broken.

Therefore to discover those paths they should fill some metrics for selecting CH's for paths. The first metrics the residual energy of CH, so if CH has higher residual energy or high level energy more preferable to transmit data. Thus, they achieve higher scores and participate in the process of establishing paths. The second metric is the distance from CH to Base station d (BS−CH): CH nodes are aware of the location of the base station and can derive their distance from the base station. The CH nodes which are close to the base station are more appropriate for transmitting data to the base station. Thus, they achieve higher scores and take part in establishing paths. The third metric is the traffic in CH nodes: CH nodes can estimate their traffic through assessing the number of data Packets in their buffer. In the process of establishing paths, the nodes with less traffic load are preferable since they prevent congestion in the network, packet delivery delay, and packet loss. Thus, they achieve higher scores and are given priority for participating in path establishment so higher energy, less distance and less traffic in the buffer are metrics for selecting neighbor cluster heads for establishing path [92].

Amandeep Kaur, Ruchi Garg et al proposed Energy Efficient Multi Hop Routing Using Genetic Algorithms for Wireless Sensor Networks (E2MHR-GA) protocol. The Proposed protocol E2MHR-GA performs LEACH based clustering and multi-hop routing with use of GA fitness function. This algorithm improves the LEACH algorithm by adding intre-cluster multihop communication because and this assumption is not affordable for larger networks because more distance between BS and CH consumes more energy.

To overcome this limitation, they propose E2MHRGA based routing protocols that establishes communication between CH and BS through multi-hop network links and results with an augmented lifespan of WSN. Fitness function requires estimating inter-cluster distance, number of cluster members and remaining energy to achieve routing among Cluster Head (CH) and Base Station (BS) through multi-hops. In setup phase to be the CHs among the randomly deployed SNs in sensing area by probabilistic equation like LEACH. To route the packet CH selects its neighbor CH with the highest fitness function. CH with higher battery power, shorter distance and less number of registered nodes has higher fitness function. This multi-hop routing process continues till aggregated data reaches to CH. The strongest point of the algorithm is enhancing the LEACH protocol by adding a multi hop concept and achieving the objectives by using most critical parameters like energy, distance and degree of member. The weakness point is the fitness function is not correct which means when see the parameters are different measurement therefore they cannot value of fineness and also the work could consider the mobile nodes [31].

CHAPTER 4. PROPOSED MODEL

4.1 Overview

The proposed algorithm develop to improve the energy efficiency and network lifetime of sensor nodes in the whole network. It mainly deals with implementing an energy efficient Inter-cluster Multi-hop Communication method in the CEECR algorithm. In the early stage, CEECR algorithm worked on improving selection parameter of cluster head and detect detached node in WSN.

As a result, CEECR did not set a mechanism on how data transfer between CHs and BS in the network made when inter-cluster communication for transferring information from Cluster Head (CH) to Base Station (BS) either in multi-hope or uni-hope scenario. By not using the inter-cluster multi-hop communication among CHs, the node would be affected by energy exhaustion, minimum network lifetime and packet losses in the network.

We use then distance parameters, residual energy, number of member nodes in a cluster and speed to select the optimum path for multi-hop CHs communication. Like other hierarchical routing .routing protocols, the operations are divided into round, , each round takes account of two main phases which are set-up phase and steady state phase, proposed work starts in steady phase or when the actual data transmission starts.

Set-up Phase

Our proposed work performs this setup phase for the purpose of: cluster head selection, cluster head advertisement, cluster formation and schedule creation .Those activities are inputs for our proposed algorithm.

Steady Phase

In the steady phase which is the actual data communication phase. In this stage CH receives and aggregates data. After completing this stage, our proposed work starts when CHs send data packets to the BS either directly or by multi-hop data transmission.

When CH sends data to BS, if the distance much longer than transmission rang then we use intre-cluster head multi-hop transmission. For using Intre-cluster multi hop communication, we should select the optimal path for transmission process. So our critical work is selecting intermediates cluster heads as optimal path by optimal parameters.

4.2 Topological Architecture of Proposed Work

The topology of our proposed work contains member nodes, cluster head nodes and sink or base station. Each of the abovementioned units have their own role for the proposed work. Member nodes sense, gather and transmit information from the particular environment and send to its cluster-head on its schedule through directly or via intimidate nodes.

The main responsibility of the CH nodes are receiving the data from member nodes, aggregate the data and finally send it to the base station by single hop or using multi-hop communication. Base stations, which are one or more WSN components, have significantly higher processing, energy, and communication resources than other components. They act as a bridge between sensor nodes and end users, allowing WSN data to be sent to a central server. General topology of proposed work shown is figure 4.1.

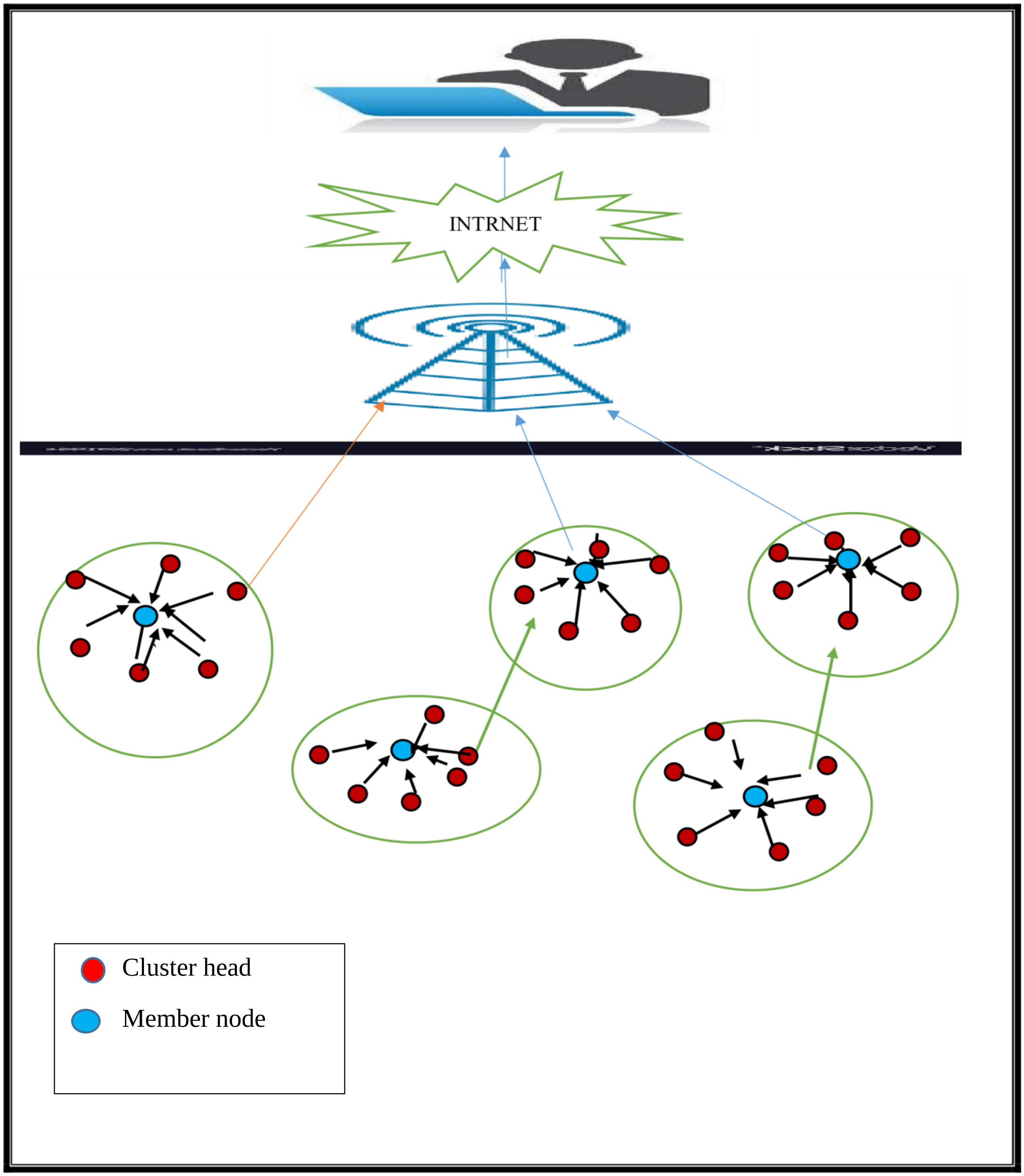


Figure 4.1 Topological architecture of proposed work

4.3 Modular Architecture of the Proposed Work

The proposed architecture has different types of modules: clustering module, scheduling module, data transmission module, data aggregation module and inter-cluster communication module.

In Wireless Sensor Networks, the clustering module is one of the most essential strategies to extend the network lifetime (WSNs). The approach includes clustering sensor nodes and electing cluster heads (CHs) for each cluster based on a set of parameters or algorithms.

Under the scheduling module cluster-head schedules cluster members when to send the data using TDMA based on systematic way. After the cluster is fully formed and the schedules are well set up, actual data transmission is started on the steady state module. Data aggregation module is a process of collecting and combining the useful information in a particular region of interest. The last module is inter cluster communication module in which cluster-head send aggregated data to base station or sink either inter cluster single hop (directly) or inter cluster multi-hop communication . Modular Architecture of proposed work shown is figure 4.2.

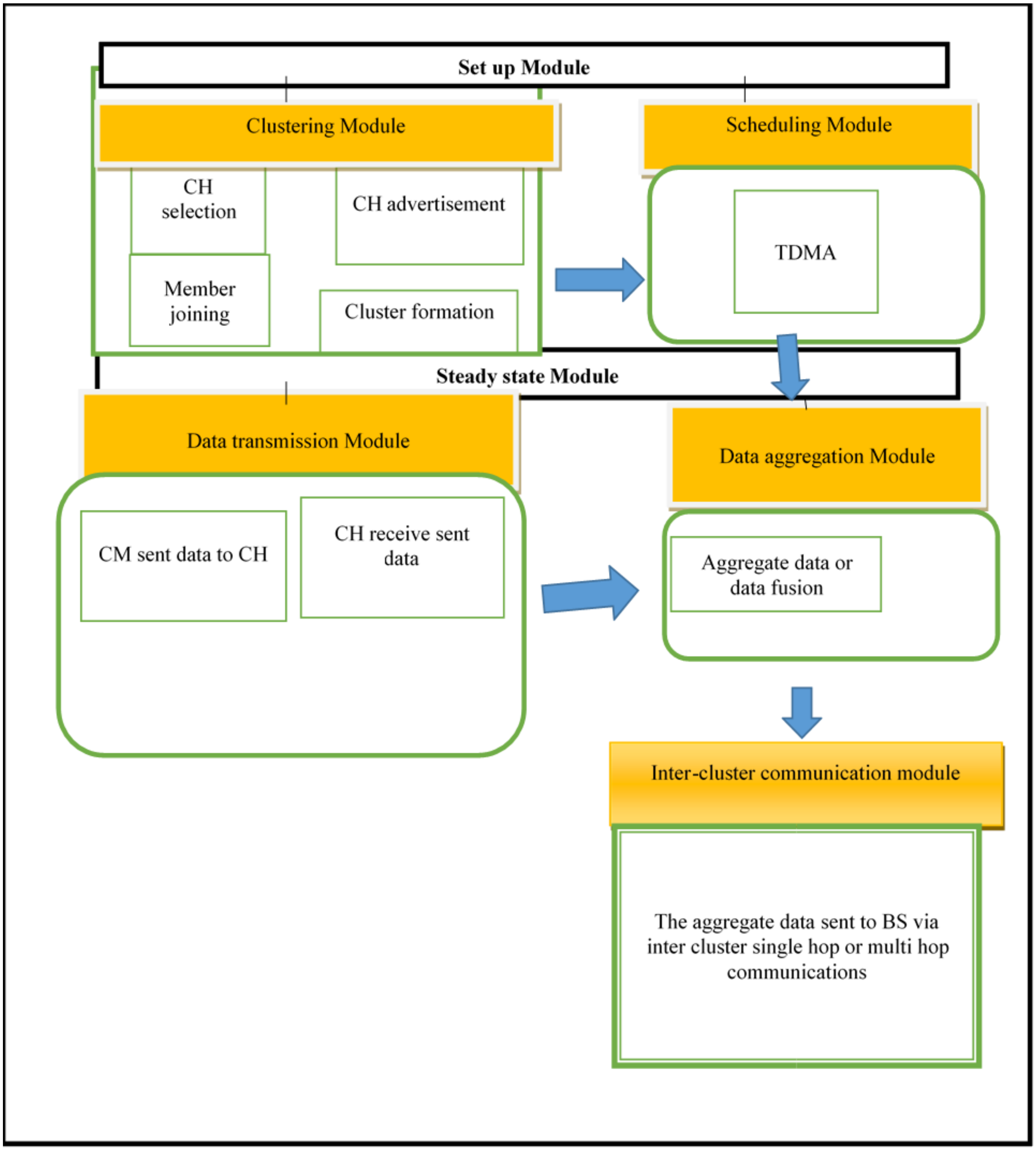


Figure 4. 2 Modular architecture of proposed work

3.3.1 Clustering Module

The clustering module has four sub-modules: cluster head selection, CH advertisement, member joining, and cluster formation. The CH is selected based on different criteria when the sensor is depressed in a region of interest, and the CH is then broadcasted or advertised to the CMs. CM asks to enter CH once he receives the advertising. A cluster is formed when CH accepts a join request. The process is shown in figure 4.3 Pseudo code

Notation: BS = Base Station CH = Cluster Head CM= Cluster Member **Input** senor node Process 1) Senor node deployment 2) The senor node send information of its energy, speed and potion to base station 3) The base station compute the algorithm to select CH 4) **If** senor node have high speed and high energy 5) **Then** CH selected 6) **Else** other senor node to be cluster member 7) The CH broadcast the advertisement message to senor node 8) The CM receive the advertisement message 9) The CM send the join request message to CH 10) The CH receive the join END IF **Output : Cluster formed**
Cluster formation

Figure 4.3 The Cluster formation procedure

4.3.2 Schedule Module

Scheduling module include the TDMA schedule sub module. This type of scheduling is used to assign schedules for nodes to transmit their data without collision; after a cluster is formed the CH creates the schedule to its CM. When the CM wants to send data based on the assigned time slot. The process is shown in figure 4.4 Pseudo code.

Notation:
 	
BS = Base Station CH = Cluster Head
 	
CM= Cluster Member
 	
Input Registered CH
 	
Input: Selected Cluster Head **Process:**
 	
1) CH check the CM registered in cluster
 	
2) CH crate TDMA schedule for each CM in cluster
 	
3) The CM wait the schedule from CH
 	
4) The CH send the schedule to CM
 	
5) The cm receive schedule
 	
END IF
 	
End FOR
 	
Output : Assign time slot (TDMA schedule) to send data

Time Division Multiple Access(TDMA) Scheduling

Figure 4. 4 Time Division Multiple Access (TDMA) Scheduling

4.3.3 Data Aggregation Module

For our proposed work we can use different data aggregation methods depending on the application requirements as well as the relative energy savings. The process is shown in figure 4.5 Pseudo code.-

Notification : BS = Base Station CH = Cluster Head CM= Cluster Member Input : Cluster with in scheduling process 1)The CM send sensed data in allocated time slot via intra single or multihop 2)The CH receive the data from CM 3)The CH send ACK to CM 4)The CM go to sleep state 5)The CH aggregate or compute data fusion in received sensed data 6)The CH aggregated data END Output : the sensed data is aggregated
Data aggregation or data fusion

Figure 4.5 Data aggregation or data fusion

4.3.4 Steady Module

The steady state operation in this proposed work is the CM sends data to CH then the CH receives and aggregate data. Then the CH is ready to transfer data to BS.

4.3.5 Inter-cluster Head Communication Module

In the Inter-cluster communication module the CH uses the CSMA approach to transmit the data to the base station using either uni-hop or multi hop communication. The CH is discovering the optimal path for transferring data to BS in multihop communication. The pseudo code of steady and inter cluster communication is shown in figure 4.6 below which is pseudo code of proposed algorithm.

BS = Base Station CH = Cluster Head

CM= Cluster Member NCH= Neighbor Cluster Head

Input: Aggregated data in CH

Process

1) The source CH want transfer the aggregated data to BS
2) The source CH use the intre-cluster head communication either single hop or multi-hop for transfer in data to BS.
3) The source CH computes sits distance from its to BS
4) **If** distance from source CH to BS is less than or equal to source CH transmission range
5) **Then** source CH uses intre-cluster single hop(or direct) communication to send data to BS
6) **Else** source CH uses intre-cluster head multi-hop communication/use intermediate neighbor's cluster heads for sending data to BS.
7) **Then** the source CH sends hello packets with some information to its

neighbor's CHs.

7.1) The neighbor CH receives hello packet.

7.2) Then each neighbor's sent ACK concatenating with the information of its remaining energy, no –of members in its cluster, distance from it to BS and its speed (mobility) to source cluster head.

7.3) The source CH receives ACK.

7.4) The source CH compute the distance of NCHs for selecting optimal path between source (CH) and distinction (BS)

8) **If** the distance from source CH to BS >= distance from NCH's to BS.

9) **Then** source CH selects NCH as candidate optimal path.

10) **Else if** the residual energy of candidate NCH's >= Eth (energy threshold).

11) **Then** source CH select NCH as candidate optimal path

12) **Else if** the number of member node in a cluster of candidate NCH's <= Mth (member node threshold)

13) **Then** source CH select NCH as candidate optimal path.

14) **Else if** candidate NCH's has small speed (mobility) among relatively.

15) **Then** source CH select NCH as candidate optimal path

16) **Then** the source CH select NCH as the optimal path that have less number of distance, higher residual energy, less member of node in cluster and low speed.

17) The optimal path is selected.

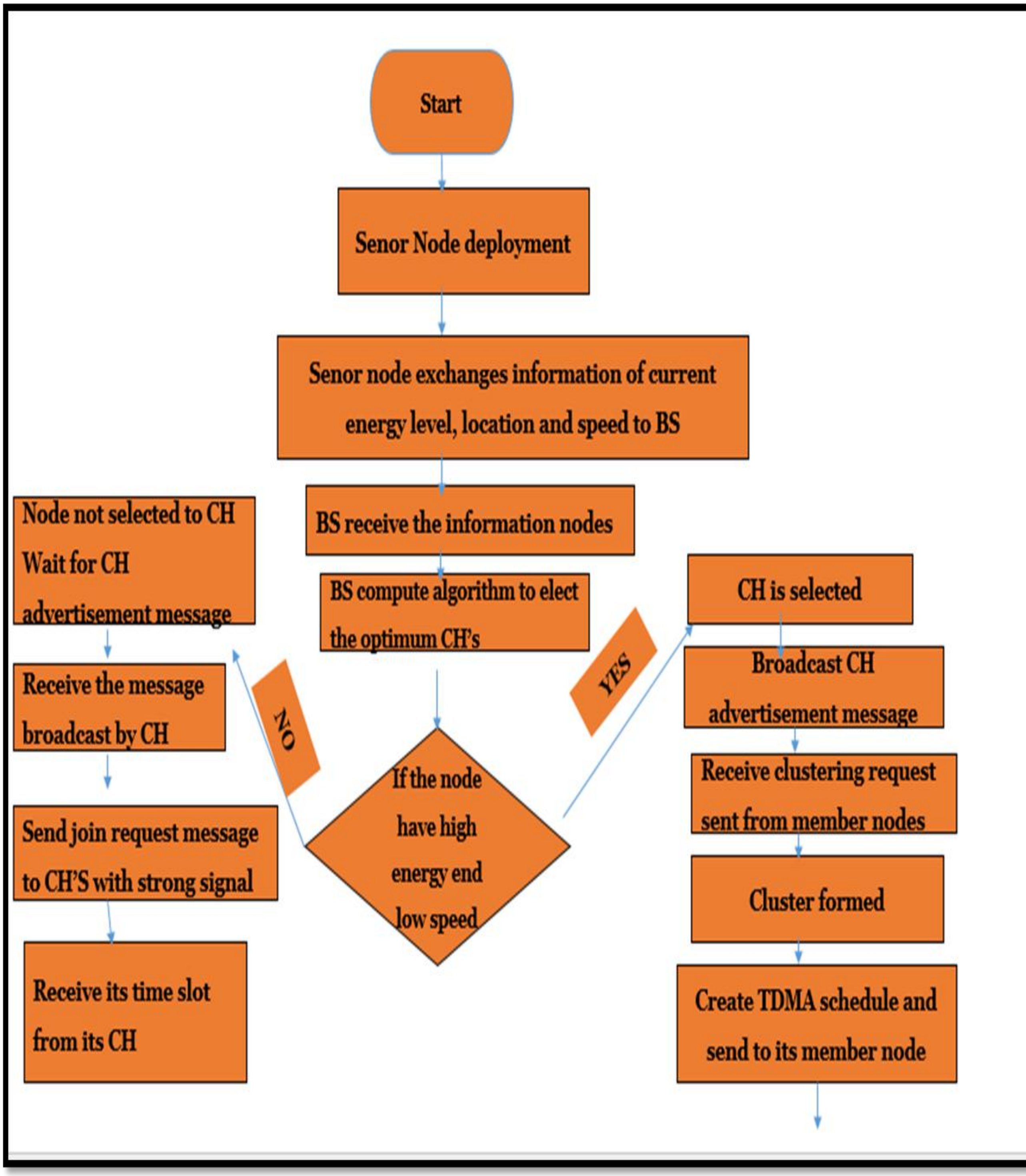
17.1) The source CH sends data to neighbor CH by using optimal path.

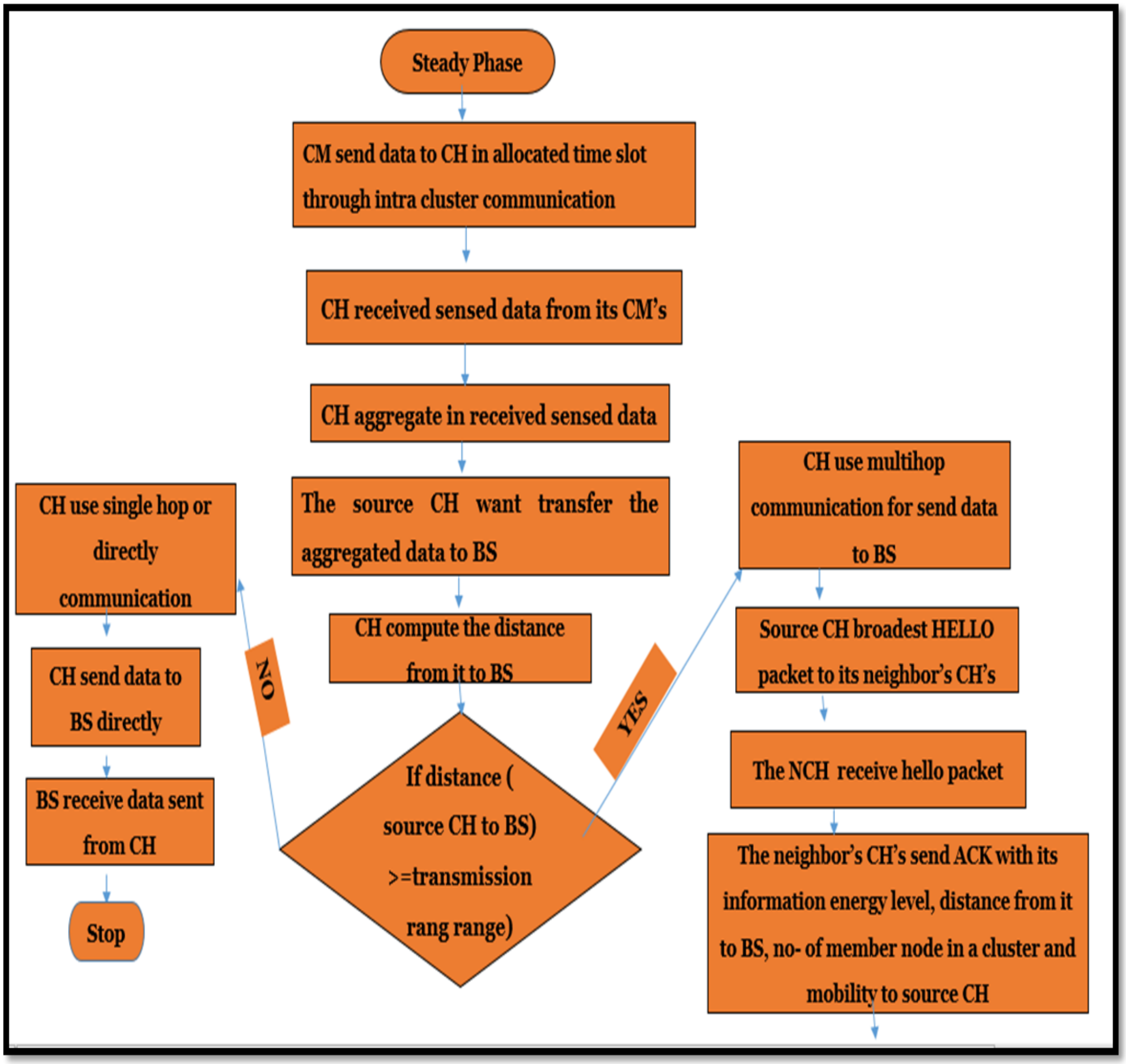
17.2) The neighbor CH receives data sent from source CH.

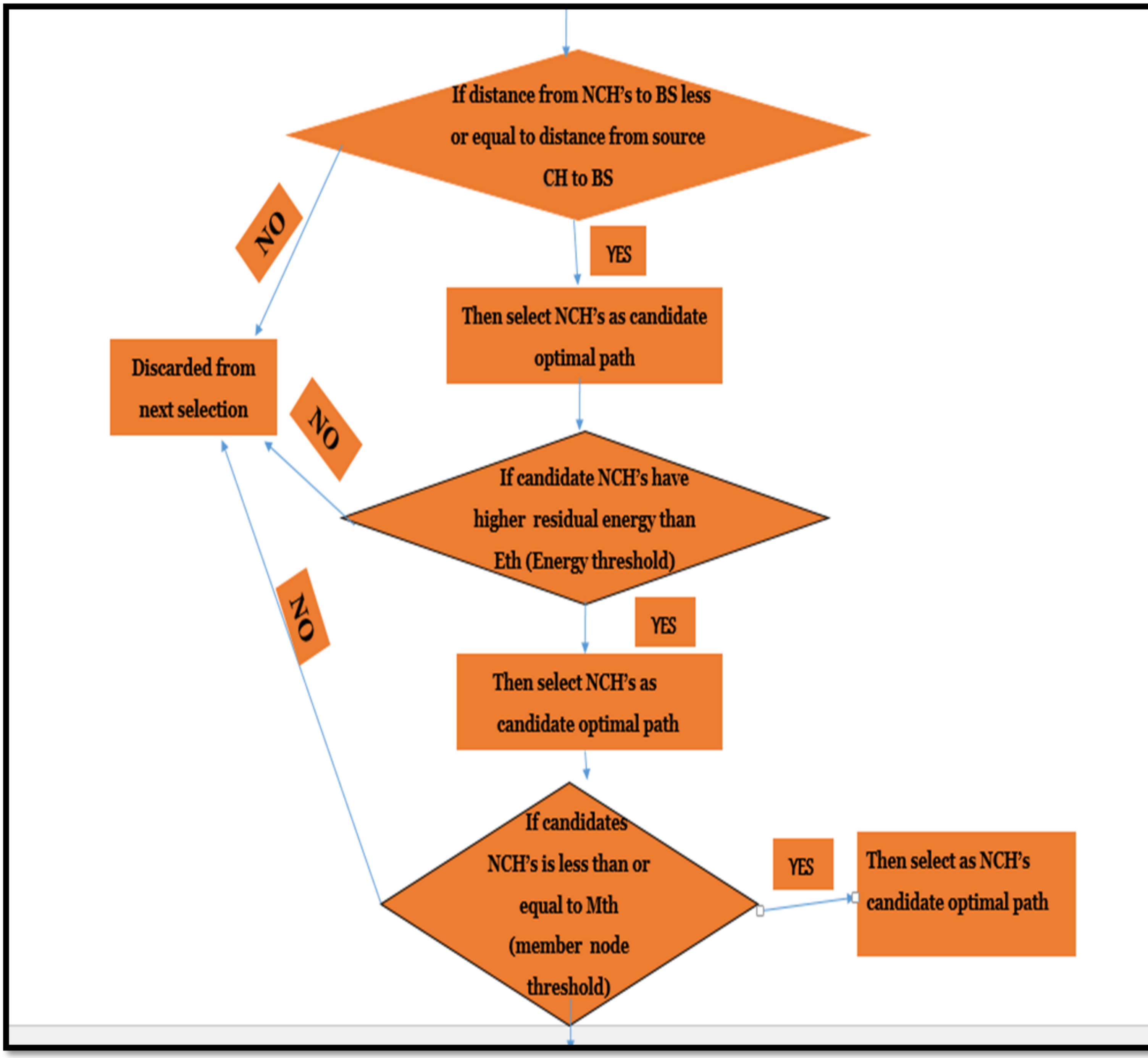
17.3) The neighbor CH use single hop or multi hop to send data to BS.

17.4) Then up to deliver data to BS .The process is repeated. 18) The BS deliver data. 19) **Else** the distance from source CH to BS < distance from NCH's to BS when source CH try three times. 20) **Then** source CH use hop count metrics to select optimal path. END End If End If End If End If
Actual data transmission

Figure 4.6 The pseudo code of steady and inter cluster communication (proposed algorithm)


Start
Senor Node deployment
Senor node exchanges information of current energy level, location and speed to BS
BS receive the information nodes
BS compute algorithm to elect the optimum CH's
If the node have high energy end low speed
NO
YES
Node not selected to CH Wait for CH advertisement message
Receive the message broadcast by CH
Send join request message to CH'S with strong signal
Receive its time slot from its CH
CH is selected
Broadcast CH advertisement message
Receive clustering request sent from member nodes
Cluster formed
Create TDMA schedule and send to its member node


Steady Phase
CM send data to CH in allocated time slot through intra cluster communication
CH received sensed data from its CM's
CH aggregate in received sensed data
The source CH want transfer the aggregated data to BS
CH compute the distance from it to BS
If distance (source CH to BS) >=transmission rang range)
NO
YES
CH use single hop or directly communication
CH send data to BS directly
BS receive data sent from CH
Stop
CH use multihop communication for send data to BS
Source CH broadest HELLO packet to its neighbor's CH's
The NCH receive hello packet
The neighbor's CH's send ACK with its information energy level, distance from it to BS, no- of member node in a cluster and mobility to source CH


If distance from NCH's to BS less or equal to distance from source CH to BS
NO
YES
Then select NCH's as candidate optimal path
Discarded from next selection
NO
If candidate NCH's have higher residual energy than Eth (Energy threshold)
NO
YES
Then select NCH's as candidate optimal path
If candidates NCH's is less than or equal to Mth (member node threshold)
YES
Then select as NCH's candidate optimal path

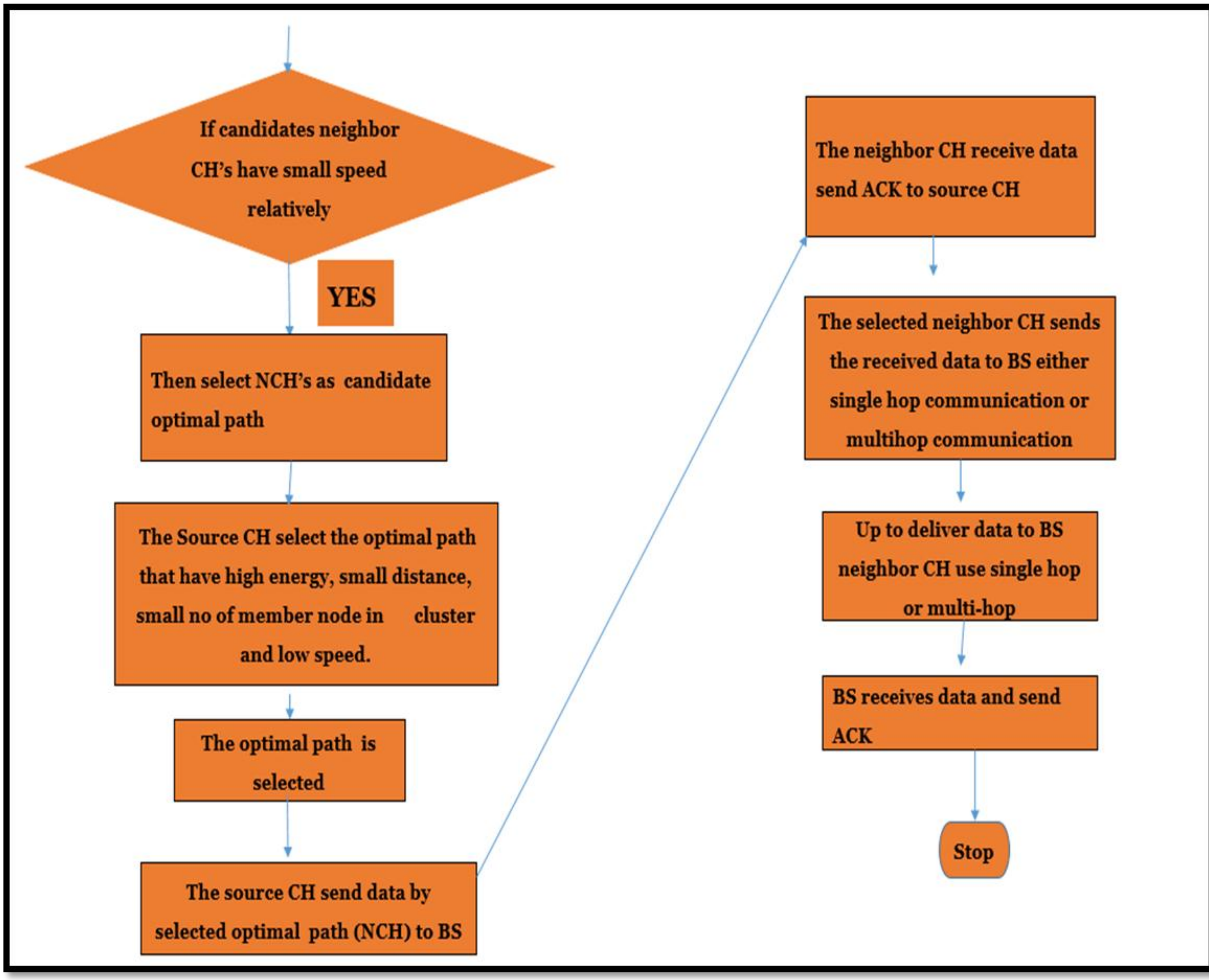


Figure 4. 7 The flow chart of proposed Algorithm

CHAPTER 5.IMPLEMENTATION AND PERFORMANCE EVALUATION

5.1 Simulation Tool

We used MATLAB simulation tool to perform a simulation experiment to evaluate the performance of the proposed work. For planning, implementing, and testing routing protocols for WSNs, simulation is the most popular, effective, and practical method. Simulator try to replicate and anticipate real-world behavior in a variety of scenarios. Cost, scalability, speed, and ease of deployment are all advantages of simulation-based systems .Besides that, MATLAB is an advanced WSN simulator. We recommend using MATLAB 9.6 to implement our proposed sensor node deployment strategy (R2019a). The name MATLAB stands for matrix laboratory. It's a powerful and technical computing language. It combines calculation, visualization, and programming in an easy-to-use interface that expresses problems and solutions in standard mathematical notation. It contains a variety of toolboxes such as mapping, database, and image processing, and so on. It is commonly used for data acquisition, algorithm development, modeling, simulation, prototyping, maths and computation, data analysis, exploration, visualization, and application development, including the creation of graphical user interfaces [93, 94].

5.2 Assumption of Proposed Work Simulation

In this section, we present the system model for analysis of the proposed algorithm .The model of a WSN with mobile nodes is investigated in this study. It is considered that this network model contains sensor nodes uniformly scattered in an area of M×M meters.

The model assumptions are made below:

1. All nodes are homogeneous and they have the same capabilities.
2. All nodes have the same initial energy.
3. The BS is placed at (0, 0); the origin of the area of deployment.
4. Nodes are mobile.
5. Node transmits its data directly to its respective cluster head within a particular cluster.
6. The base station (BS) is fixed or stationary and located in the center of the sensing field.
7. The BS are not energy-constrained.

8. Each node is aware current position, energy level, and velocity.

5.2.1 Radio Model of Proposed Work

In order to measure the energy consumption of SNs, we utilize the similar radio model as CEECR used. If the distance d between the transmitter and receiver is less than a predefined threshold d0, the free space channel model (d2 energy loss) is used; otherwise, the multipath channel model (d4 energy loss) is used. As a result, the transmission and receiving costs for sending and receiving a l-bit message across a distance d are defined as follows [95]:

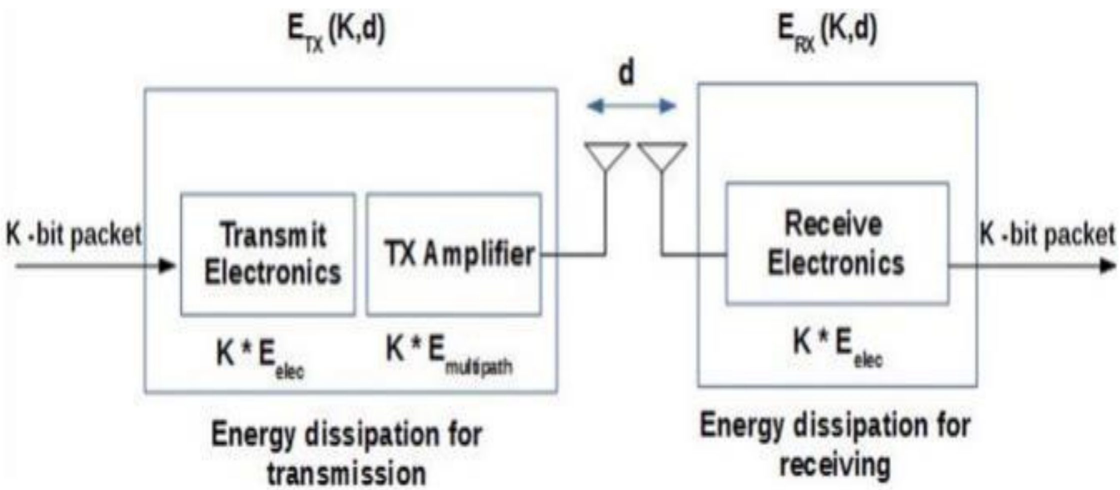


Figure 5. 1 The Radio energy dissipation model [98]

The energy required to transmit and receive a k-bit packet over a distance d is expressed in Equations where both the free space and the multi-path fading channel models are used in the model [96]:

Equations 1 ETx (k, d) = ETx-elec (k) + ETx-amp (k, d) ----------------------------------(96)

Equations 2 Efs = KEelect + Kef^d2 d<=do -------------------------------------(96)

Equations 3 Emp= KE-elect + Kef^d4 d>do --(96)

Equations 4 do = Squirt(Ef s/Emp) --(96)

Likewise, the energy consumed to receive this message is shown in

Equation 5 ERX (K) =kEelect ---(96)

Where

ETx-elec = Energy consumed for transmit electronics

ERx-elec = Energy consumed for receive electronics

ETx-amp = Energy consumed for transmission amplifier electronics

Eelec = Energy consumed for transmit and receive electronics

Єamp = Amplification coefficient of free-space signal

d = Distance between transmitter and receive

k = Number of message bits

Efs =Energy consumed by the transmitter amplifier for the free space model

Emp =Energy consumed by the transmitter amplifier for multipath model.

d0 =threshold transmission distance

5.2.2 Multi-hop Data Transmission

All cluster nodes send the data they collect from the sensing field to the CH. The CH gathers data from cluster members, aggregates it, and delivers it to another CH or directly to the BS. The inter-cluster link uses multi-hop data transmission to eliminate long-distance data transport, which consumes a lot of energy and causes CH to die prematurely.

Our method is a multi-hop protocol that is commonly used in wireless sensor networks. It consists of data transfer as well as environmental sensors transmitted through other nodes that serve as routers. Other sensor data destined for Cluster heads is routed through intermediate nodes between clusters. The router nodes are selected in such a way that the transmit amplifier consumes the least amount of energy possible. After determining the distance between each cluster, CH compares the distance to the transmission range. When the transmission range is shorter than the distance between the source and the destination, multihop communication is used for selecting the optimal path.

Throughout the route-finding procedure, each CH calculates a score based on the parameters. The CHs with the highest scores contribute to the construction of a path between the CHs and the base station.

- **The distance** from CH nodes to the base station (DBS−CH): CH nodes are aware of the location of the base station and can derive their distance from the base station through

  Equaction 6 DBS−CH = squroot ((xBS− xCH) sqr+ (yBS− yCH)^2) ---------------------(97)

Where

(xCH, yCH), (xBS, yBS) indicate the coordinates of the CH node, the coordinates of the base station,

DBS−CH indicate the distance from the CH to the base station, respectively.

This input of the normalized using Eq. (7): DNorm−BS−CH = DBS−CH /DMax−BS−CH-----------(98)

Where

DBS−CH indicates the distance from the CH to the base station

DMax−BS−CH is the maximum distance from a CH node to the base station that is determined based on the network size. The CH nodes which are close to the base station are more appropriate for transmitting data to the base station. Thus, they achieve higher scores and take part in establishing paths

- **The residual energy of CH nodes (ECH)**

CHs are aware of their own energy level. The CH nodes with a higher level of energy are more appropriate for transmitting data the BS. It ensures that the remaining energy of a node stays above a minimum value Eth. This amount will be reserved only for sensing or transmitting their own data. This constraint allows the balancing of energy consumption throughout the network. The threshold is used to determine the appropriate CH to serve as a neighbor hop during the routing of data to the BS. The election energy threshold presented is determined by taking the average value of the RE of neighbor CHs to a transmitting CH. This is represented as: Equation 8.

Equation 8=. $$T_{nhCH} = \frac{\sum_{n=1}^{m} RE\ (neighbour\ CHs)}{m}$$ --(98)

Notation:

TnhCH is the election energy threshold,

RE (neighbor CHs) is the residual energy of neighbor CHs

m is the number of neighbor CH.

- **The number of members in each cluster**

CH aware its number of members when the cluster formed and also check availability through hello packets because the nodes are mobile. This factor also is important in order to prevent the CHs that have many member nodes in their clusters to participate in the path. The increasing number of members will increase the energy consumption in the CH due to the receiving and aggregating processes can be calculated as equation 9

Can be calculated as: members = Σ^ni= member

Equation 9= ------------------- (100)

Where $$members = \sum_{i=1}^{N} member_i$$

Member is the number of member nodes in cluster I

N is the number of clusters for each CH in the path

M threshold is used to determine the appropriate CH to serve as a neighbor hop during the routing of data to the BS. The Member threshold is determined by taking the average value of the members of node in cluster divided by s the number of neighbor CH. For select the neighbor CH is should less than or equal to Mth.

$$MthCH = \Sigma\, n^m = 1\ mn\ (\text{neighbor CHs})/m$$

Notation:

MthCH the election member threshold,

mn the member node of neighbor CHs

m is the number of neighbor CH.

- **Speed nodes**

It can estimate their mobility nodes through assessing the speed of CH. In the process of establishing paths, the nodes with less speed are preferable since they prevent instability and overhead of network Thus, they achieve low speed are given priority for participating in paths establishment.

5. 3 Evaluation metrics and simulation parameters

5.3.1 Evaluation metrics

To evaluate performance of our proposed work we used Network life time, packet delivery ratio, average energy dissipation and the total Number of packets sent to the BS metrics [100-104].

- Packet delivery ratio (PDR): The ratio of data packets reaching the destination node to the total data packets generated at the source node.The proportion of packets successfully received (Nrecv) by the sink to the total number of data packets sent (Nsend). PDR (%) is shown in Equation 9.

Equation 9 PDR = (Nrecv / Nsend) * 100 ------------------- (105)

- Normalized Average Energy consumption respect to data packet: Represented as the average energy consumed (Consumed) at each node divided by data packet for simulation time.NAER (%) is evaluated as shown in Equation 10.

Equation 10 Normalized Average energy consumption = (Econsumed/datapacket)*100 ----------------- (106)

- Network life time: Generally defined as the time during which the network is operational. In other words the lifetime of network is defined as the operational time of the network during which it is able to perform the dedicated task.

5.3.2 Simulation Parameters

The input data or simulation parameter list for our work is presented in Table below

Table 5. 1 Parameters list

No	Parameter list	Specified
1	Simulation area	300 * 300
2	Number of nodes	200
3	Cluster head probability	0.1
4	Base station coordinates	(100,100)
5	Round length	500s
6	Default energy for Transmit, (ETX)	30*0.000000001;
7	Default energy for receive (ERX)	30*0.000000001;
8	Energy for process(for Sense and Computation)	4* 0.000000001
9	Energy consumed by the transmitter amplifier for the free space model(Efs)	10*0.000000001
10	Energy consumed by the transmitter amplifier for multipath model(Emp)	30*0.000000001
11	Eo	100 J

5.4 Simulation Result Analysis and Discussion

This section presents a detailed analysis of the simulation result based on the generated the simulation along with the justification.

5.4.1 Normalized Average Energy Consumption

The amount of energy consumed by sensor nodes in various routing algorithms to transmit data to the base station is illustrated in Figure 5.2. When there are between 0 and 140 data packet the energy consumption of different routing algorithms as seen in Fig 5.2.

When the number of packet size increases, it affects their performance. When compared to MHT and E2MHR-GA, our proposed algorithm reduces energy consumption by 5.5 percent, and 2.5 percent, respectively, in a network with 120 packets. In general, our proposed algorithm consumes less energy than MHT and E2MHR-GA, resulting in a longer network lifetime. A lot of things have supported this success.

Several reasons have contributed to this enhancement:

1) When selecting intermediate CHs as optimal path for multihop communication, nodes with low residual energy levels are not selected, and a threshold is set to protect low-energy nodes, resulting in improved energy consumption.

2) When establishing a path between a CH node and a base station, the CH nodes closest to the BS are given priority for participating in the process, as well as the position of intermediate CH adjacent to the source, so that process of exchanging data requires less energy;'

3) When establishing a path between a CH node and the base station, the CH node with the fewest members is selected since transmitting and receiving packets consumes the least amount of energy when the cluster members are small. As the number of members increases, the CH's energy consumption increases as a result of the receiving and aggregating processes, as well as when the source broadcasts packets to CHs for route finding. When the number of members expands, so does the energy consumed because those members receive data and ignore requests to perform these activities

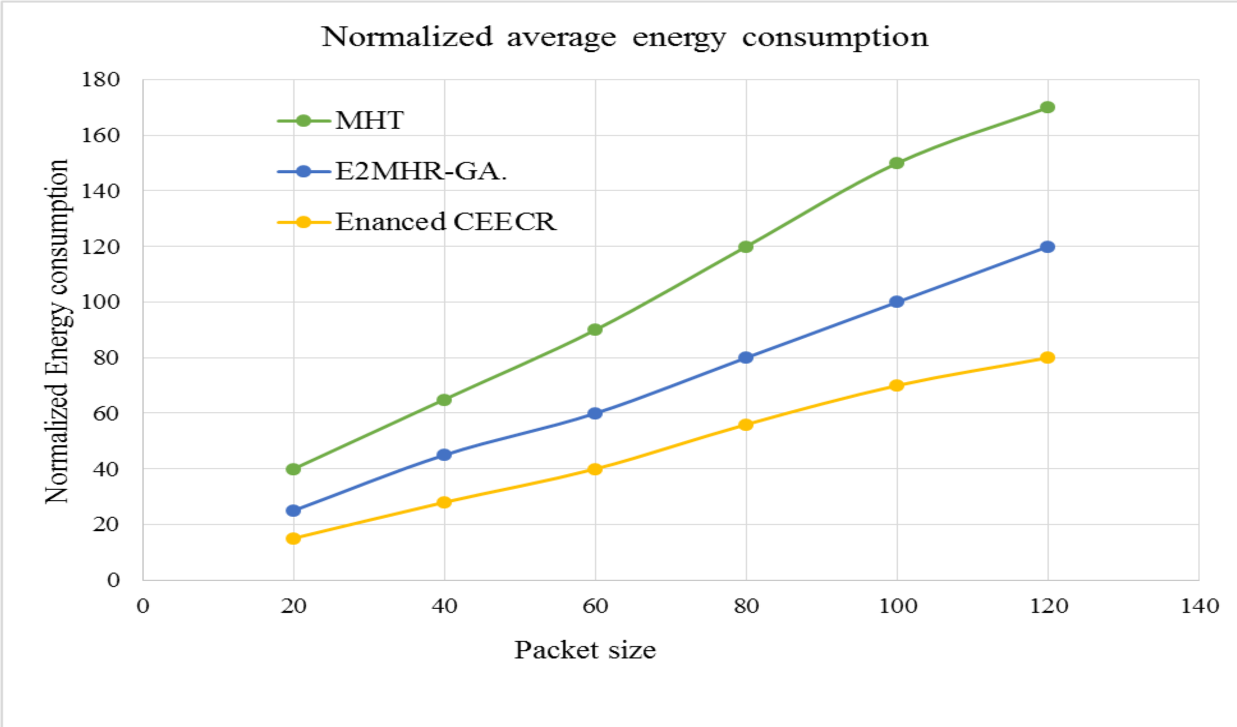


Figure 5. 2 Normalized average energy consumption respect to data packet

5.4.2 Network Lifetime

To demonstrate network life time, we employed a network of 200 sensor nodes. The energy of some sensor nodes is depleted, and they eventually die. Figure 5.3 shows the drop rate of life time of sensor nodes in different routing strategies. As illustrated in Fig 5.3, the proposed method effectively extends a network's lifetime. As it can be seen in the diagram, the proposed method can properly increase network lifetime. Here, first node death-time interval is far superior to other methods. In fact, FND is 173 sec while in MHT, E2MHR-GA is 200and 220sec, respectively. It could be seen that the proposed method properly balances the energy consumed in the network by 3.5 percent, and 4.2 since routing processes rely on the energy of nodes.

As shown Figure 5.3, compared with MHT, and E2MHR-GA, enhanced CEECR has the highest network life time when the stimulation go to many round or death time of node the energy is high because,

1) During the selecting of intermediate CHs as optimal path, the intermediate neighbor CH has been used as a route for sources that have residual energy that is higher or equal to Eth. The energy threshold, on the other hand, is set to protect low-energy nodes, extending the network's life cycle. As a result, the network's life time is extended due to the selection of a sufficient ewer threshold to protect low-energy nodes, hence extending the network's life cycle. As a result, the network life time of each node or the entire network increases.

2) When establishing a path between a CH node and a base station, the CH nodes closest to the BS are given priority for participation in the process, as well as the position of the intermediate CH relative to the source, so that sending and receiving data requires less energy. The energy and the network life time is directly proportion which means if the node is have higher energy it can sustain for long time and also the distance and the energy is directly proportional which means if the distance is higher from source to intermediate CH/BS and intermediate CH BS then used higher energy for transfer data. Therefore when the distance is short our energy used is small so indirectly our network life time go to high because they used small energy for transfer with in small distance.

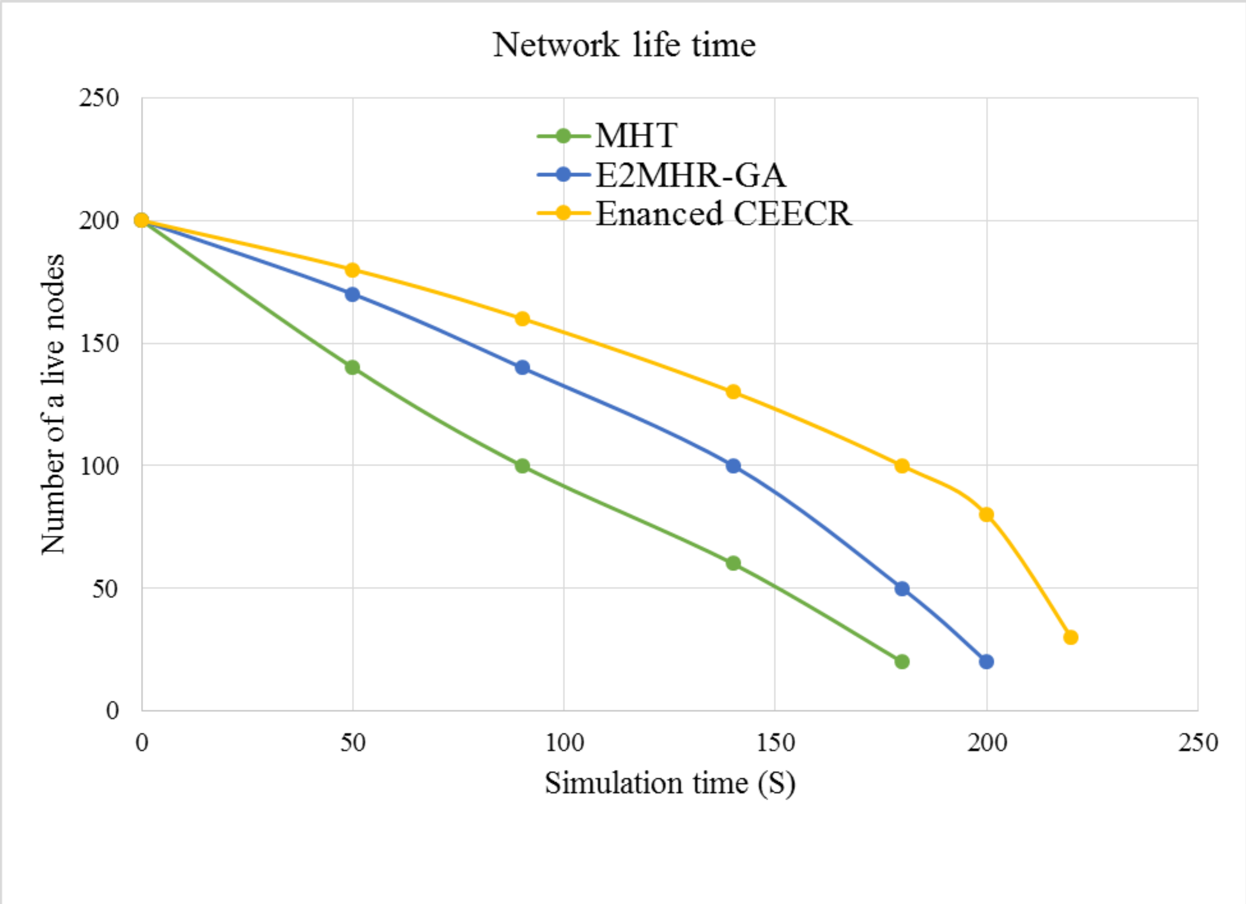


Figure 5. 3 Network life time in different round

5.4.3 Packet Delivery Ratio

The packet delivery ratio is low because this proposed routing algorithm selects less-mobile routes. Lower route mobility drastically reduces network congestion. When compared to MHT and E2MHR-GA, Figure 5.4 shows that the proposed routing method's packet loss ratio has decreased by 4.1 percent and 2.5 percent, respectively. Increasing the number of sensor nodes also results in a small increase in the packet loss ratio of our suggested approach. Our routing method is scalable and adaptive to a variety of network sizes.

Several reasons have contributed to this enhancement:

1) When selecting intermediate CHs as optimal path for multihop communication, nodes with low mobility levels are selected. When not considering the mobility factor This yields the

selected path instability because when establishing the route for source they selected NCH which may have higher speed mobility as high speed mobile CH changes location frequently which makes the path unstable and increases overhead.

2) When selecting intermediate CHs as optimal path for multihop communication, nodes with low residual energy levels are not selected, and this helps to transmit higher data or packet successfully from source to destination by optimal path.

3) When selecting intermediate CHs as optimal path for multihop communication, nodes with low distance, and this helps to transmit higher data or packet successfully from source to destination by reducing latency because energy consumption low when the distance is low therefore packet successfulness is increase from source to destination .

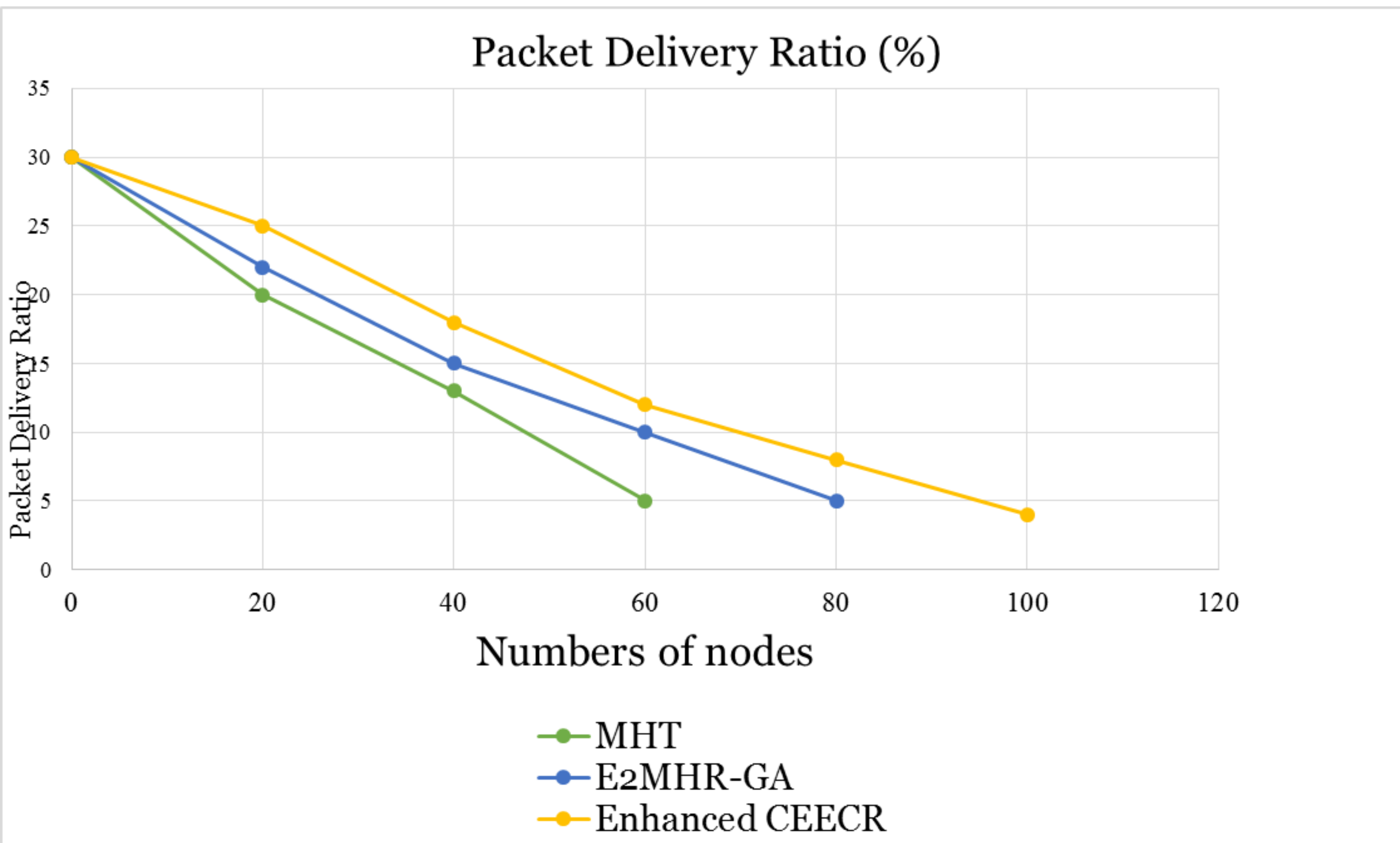


Figure 5. 4 Packet delivery ratio VS no- of node

CHAPTER 6. CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

WSN based upon cluster formations for routing is remarkable to enhance lifespan of the network. Out of the many protocols, CEECR is one of protocol used for clustering in WSN. But gap of CEECR is that it not set how data is transfer from CH and BS either single hop or multihop. To overcome this gap, implementing an energy efficient the intre cluster multihop communication that establishes communication between CH and BS through intermediates neighbor's and results with an augmented lifespan of WSN and energy efficiency is preferable mechanism.

In WSNs, data transmission has a considerable impact on the performance of a network in terms of its lifetime. Direct transmission is a problem in WSNs due to its effect on increasing energy consumption, especially if a source CH is far from the BS. Moreover, selecting proper neighbor CHs is also a problem that significantly affects the lifetime of the network.

The main contribution of this thesis was the development of energy efficient inter cluster multihop communication based on CEECR. Enhanced CEECR routing protocol that can minimize energy consumption and maximize network lifetime by selecting the optimal path for routing from source to destination. Our algorithm used critical parameters like distance, residual -energy, no-of member in cluster and speed or mobility to select the optimal path from other neighbor paths.

In this thesis, we made a performance comparative analysis on WSNs routing protocols namely MHT, Enhanced CEECR and E2HMR-GA. Several literatures have been reviewed and comparative analysis has been done using Matlab simulator. Accordingly, both the reviewed literature and the results of the experimental analysis have proved that enhanced CEECT to be a promising candidate to best perform in energy efficient. Therefore, as the performance of Enhanced CEECR has been found better in our simulation than MHT and E2HMR-GA.

In conclusion, the proposed enhanced CEECR routing protocol which selection of optimal path by different parameters performs better in terms of normalized average energy consumptions ,packet delivery ratio and network lifetime.

6.2 Future Work

In the Future work we will includes selection of cluster heads by using location parameters ,set mechanism when source CH have neighbor CH but the neighbor set on back position of source CH ,add other parameters intre cluster multihop communication and set strategy to intra cluster communication.

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APPENDIX

```
close all;

n=200 ;            % Number of Nodes in Network

xmax=300;     % Boundaries of Network   Sensor Field is 0-xmax by 0-ymax (square/ rectangle)

 ymax=300;

sink.x =100;            % Distance of base station from the network

sink.y=100;

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

E0=100J;                   %% Initalize the energy in each node

ETX=30*0.000000001;       %% Energy values for Transmit, Receive, Sense and Computation

ERX=30*0.000000001;       %% Energy values for Receive

Eprocess= 4* 0.000000001; %%  Energy values for Sense and Computation

Efs=10*0.000000001;             %%  Energy consumed by the transmitter amplifier for free path model(Emp)

Emp=10*0.000000001;             %% Energy consumed by the transmitter amplifier for multipath model(Emp)

EDA=5*0.000000001;        %%  Energy values for data aggrgation

rmax=500;    %% Maximun round value

do=sqrt(Efs/Emp);

Residual_Energy=E0;

 m = 32;

 mn=45;

Eth=Residual_Energy/m;

Mth=mn/m;

TR=20;       %% transmission range of nodes%% Eav=E0/n;   %%
```

```
average energy vi=3;                    %%% speed of nodes%%

Rn=vi/n;      %%% average speed of nodes%%

Count CH=0; cluster =1; not cluster=1; max distance=40;

For a = 1:n

 N(a).xd= rand(1,1)*xmax;

 N(a).yd= rand(1,1)*ymax; end

for i=1:1:n

    S(i).xd=rand(1,1)*xm;     XR(i)=S(i).xd;

    S(i).yd=rand(1,1)*ym;     YR(i)=S(i).yd;

    distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 + (S(i).yd-(S(n+1).yd) )^2 );

    S(i).distance=distance;

    S(i).G=0;

    %initially there are no cluster heads only nodes

    S(i).type='N';     S(i).E=Eo;

    Et=Et+S(i).E;

    figure(a*1)

      plot(S(i).xd,S(i).yd,'bo');       text(S(i).xd+1,S(i).yd-0.5,num2str(i));       hold on; end

plot(S(n+1).xd,S(n+1).yd,'o',           'MarkerSize',           19,           'MarkerFaceColor',           'r');
text(S(n+1).xd+1,S(n+1).yd-0.5,num2str(n+1)); hold off ;

% election of cluster head for a=1:n   if N(a).ch >= Eav   elseif N(a).ch < RN        CountCH =
CountCH                        +1;                                   packets_TO_BS=packets_TO_BS+1;
packets_TO_BS_per_round=packets_TO_BS_per_round+1;
PACKETS_TO_BS(r+1)=packets_TO_BS;

                        S(i).type='C';

                S(i).G=round(1/p)-1;
```

```
C(cluster).xd=S(i).xd;

C(cluster).yd=S(i).yd;

%plot(S(i).xd,S(i).yd,'k*');

  distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 + (S(i).yd-(S(n+1).yd) )^2 );

C(cluster).distance=distance;

C(cluster).id=i;

X(cluster)=S(i).xd;

Y(cluster)=S(i).yd;

cluster=cluster+1;

 %Calculation of Energy dissipated

distance;          if (distance>do)

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

if (distance<=do)

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

end

end

STATISTICS.COUNTCHS(h,r+1)=countCHs;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Election of Associated Cluster Head for Normal Nodes    for i=1:1:n     if ( S(i).type=='N' && S(i).E>0 )     if(cluster-1>=1)
```

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

%Calculating the culsterheads% if(min_dis_cluster~=0) min_dis; if
(min_dis>do)

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

if (min_dis<=do)

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

S(C(min_dis_cluster).id).E = S(C(min_dis_cluster).id).E- ( (ERX + EDA)*4000
);

packets_TO_CH=packets_TO_CH+1;

else min_dis; if (min_dis>do)

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

if (min_dis<=do)

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

packets_TO_BS=packets_TO_BS+1;

packets_TO_BS_per_round=packets_TO_BS_per_round+1;

PACKETS_TO_BS(r+1)=packets_TO_BS; end

S(i).min_dis=min_dis;

S(i).min_dis_cluster=min_dis_cluster;

else min_dis=sqrt( (S(i).xd-S(n+1).xd)^2 + (S(i).yd-S(n+1).yd)^2 );

if (min_dis>do)
```

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

        if (min_dis<=do)

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

        packets_TO_BS=packets_TO_BS+1;

        packets_TO_BS_per_round=packets_TO_BS_per_round+1;

   end  end     end

%Route from SN to Sink Node CH/ decrement energy  indexCH(i)= find(CH_IndexMatrix== Source_Node(i),1);

 Rte= ClusterHead(indexCH(i)).Rte;

 for k= 1:length(Rte)  %Not a Broadcast CH

 if ismember(Rte(k), BroadCastCH)== 0

 ClusterHead(Rte(k)).E=   ClusterHead(Rte(k)).E-   ERxEprocess-   ETx;      e_tally(Rte(k))= e_tally(Rte(k)) + ERx+ Eprocess+

ETx;  % Broadcast CH  else

 ClusterHead(Rte(k)).E=  ClusterHead(Rte(k)).E-  ERxEprocess-  ETx*CHmember_Ct(Rte(k)); e_tally(Rte(k))= e_tally(Rte(k)) + ERx+ Eprocess+

ETx*CHmember_Ct(Rte(k));  end  end

 disp('**********')  rds_ctr=1;  % Rotate CH  SaveEnergyValues;  clear ClusterHead

 ElectCH;

 CHadj;

 CH_isotest;

 CH_Route;

 CHmem= [ClusterMemberRd2.index];

 CHind= [ClusterHead.index]
```

SNCH= ClusterMemberRd2(1).ch Choose_BroadcastCH e_tally= zeros(1, CountCH); CH_IndexMatrix= [ClusterHead.index];

CM_IndexMatrix= [ClusterMemberRd2.index];

% Route From Source Node CH to Sink Node CH/ decrement energy

Rte= ClusterHead(CH).Rte; for j=1:length(Rte) % Not a Broadcast CH

if ismember(Rte(j), BroadCastCH)== 0

ClusterHead(Rte(j)).E= ClusterHead(Rte(j)).E- ERxEprocess-ETx; e_tally(Rte(j))= e_tally(Rte(j)) + ERx+ Eprocess + ETx;

for i= 1:CountCH

N(ClusterHead(i).index).E= ClusterHead(i).E; end

for i=1:n-CountCH

N(ClusterMemberRd2(i).index).E= ClusterMemberRd2(i).E; end

if distance(source_CH_to_Bs) >= TR

disp(use_single_hop_intre_cluster_communcaction) ;

else disp(use_multihop_communcation_intre_cluster_communcaction);

end function [select_optimal_NCH] =(source, dest, inte)

distance(soutrce CH:dest)= inf; distance(soutrce inte:dest)= inf; distance(source) =CH; distance(inte) =NCH;

distance(source_BS_to_CH)= squr((squr(xBS-xCH)+ squr(yBS-yCH))) distance(source_BS_to_CH)= squr((squr(xBS-xNCH)+ squr(yBS-yNCH))) if distance(source_CH_to_Bs)>= distance(neghibour_CHs_to_BS) disp(select_as_candiate_CHs)

% Determine the Energy Value for each neghibour CH

NCHenergy= [NClusterHead.E];

[sortedValuesE, sortedIndexE] = sort(NCHenergy(:), 'asece'); NCHenergy= [NClusterHead.E];

threshold_for_energy= average_of total_energy_of_nighbour_CH/total noumbr_of_CH; elseif NCHenergy >= threshold_for_energy disp(select_as_candiate_CHs)

CHmember_Ct= zeros(1,CountCH);

% Determine how many clustermembers each NCH has for i= 1:length(ClusterMemberRd2)

NCHmember_Ct(ClusterMemberRd2(i).Nch)= NCHmember_Ct(ClusterMemberRd2(i).Nch) +1;

[sortedValues, sortedIndexclsutermememer] = sort(NCHmember_Ct(:), 'desece');

NCHmemeber= [NCHmemeber.membernode]; end

elseif totalMembers<= threshold_for_memeber_node disp(select_as_candiate_CHs) speed =Rn;

NCHspeed= [NClusterHead.Rn];

[sortedValuesE, sortedIndexE] = sort(NCHenergy(:), 'desece'); elseif speed(candiate_CHs)~= small_speed_relativly disp (select_as_candiate_CH); else disp(use_hop_count); end

%%%

% Plot Results %

% Plot network Topology Network_Topology= figure; hold on for a=1:n

plot(N(a).xd, N(a).yd, 'go'); %Allows you to see Sink Node plot(N(1).xd, N(1).yd, 'b*'); end hold off axis([0 xmax 0 ymax])

xlabel('Sensor Coordinate X (meters)') ylabel('Sensor Coordinate Y (meters)') % title('enhanced CEECR using intercluster communcaction')

Iteration1= figure; hold on for a=1:n plot(N(a).xd, N(a).yd, 'go'); plot(N(1).xd, N(1).yd, 'b*');

for i=1:CountCH-NewClusterHead1-NewClusterHead2 plot(ClusterHead(i).xd, ClusterHead(i).yd, 'r+') end end

%Allows you to see Sink Node

% for i=1:CountCH-NewClusterHead1-NewClusterHead2

% plot(ClusterHead(i).xd, ClusterHead(i).yd, 'r+')

% end

axis([0 xmax 0 ymax])

xlabel('Sensor Coordinate X (meters)') ylabel('Sensor Coordinate Y (meters)') %title('normalized energy consumpction') hold off

% Plot new ClusterHeads

% New ClusterHeads Black Diamond

Iteration2=figure; hold on for a=1:n plot(N(a).xd, N(a).yd, 'go'); %Allows you to see Sink Node plot(N(1).xd, N(1).yd, 'b*');

for i=1:CountCH-NewClusterHead1-NewClusterHead2 plot(ClusterHead(i).xd, ClusterHead(i).yd, 'r+')

for i=CountCH-NewClusterHead1-NewClusterHead2+1:CountCHNewClusterHead2 plot(ClusterHead(i).xd, ClusterHead(i).yd, 'kd') end end end hold off axis([0 xmax 0 ymax])

xlabel('Sensor Coordinate X (meters)') ylabel('Sensor Coordinate Y (meters)')

%title('network life time')

% Plot new ClusterHeads

% New ClusterHeads Red Star Iteration3=figure; axis([0 xmax 0 ymax]) hold on for a=1:n

plot(N(a).xd, N(a).yd, 'go'); %Allows you to see Sink Node plot(N(1).xd, N(1).yd, 'b*');

for i=1:CountCH-NewClusterHead1-NewClusterHead2 plot(network life time 'r+') for i=CountCH-NewClusterHead1-NewClusterHead2+1:CountCHNewClusterHead2 plot(average energy consumpction yd, 'kd') for i=CountCH-NewClusterHead2+1:CountCH plot(packet delivery ratio).yd, 'rp')

end end end end hold off end end