Performance Analysis of Cluster Based Energy Aware Routing Protocol for Wireless Sensor Network in Precision Agriculture

Tuba Adem Muhamed

A Thesis Submitted to

The Department of Electronics and Communication Engineering

School of Electrical Engineering and Computing

Presented in Partial Fulfillment of the Requirement for the Masters of Science Degree in Electronics and Communication Engineering

Office of Graduate Studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

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APPROVAL SHEET

We, the advisors of the thesis entitled **“**Performance Analysis of Cluster Based Energy Aware Routing Protocol for Wireless Sensor Network in Precision Agriculture” and developed by Tuba Adem Muhamed hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Tuba Adem Muhamed have read and evaluated the thesis entitled “Performance Analysis of Cluster Based Energy Aware Routing Protocol for Wireless Sensor Network in Precision Agriculture” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Electronics and Communication.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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DECLARATION

I hereby declare that this Master Thesis entitled "**Performance Analysis of Cluster Based Energy Aware Routing Protocol for Wireless Sensor Network in Precision Agriculture**'' is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Name of the student	Signature	Date
Tuba Adem Muhamed_____	_______________	_____________

RECOMMENDATION

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled “Performance Analysis of Cluster Based Energy Aware Routing Protocol For Wireless Sensor Network in Precision Agriculture” prepared under our guidance by Tuba Adem Muhamed submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in Degree in Electronics and Communication Engineering, Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

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Major Advisor	Signature	Date
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Co-advisor	Signature	Date

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LIST OF ABBREVIATIONS

ADCs	Analogue to Digital Converters
AODV	Ad-hoc On Demand Vector Routing
APTEEN	Adaptive Threshold sensitive Energy Efficient Sensor Network Protocol
BT	Bluetooth
BSMH	Balanced and constant **S**tretch protocol for bypassing Multiple Holes
CADR	Constrained Anisotropic Diffusion Routing
CH	Cluster Head
CHZ-LEACH	Cluster Head Zone based LEACH
CPUs	Central Processing Units
CSMA	Carrier Sense Multiple Access
DD	Direct Diffusion
DEEC	Distributed Energy-Efficient Clustering algorithm
DHAC	Distributed hierarchical agglomerative clustering
DSP	Digital Signal Processing
EACH	Low Energy Adaptive Clustering Hierarchy
ECG	Electro Cardio Graph
EECHE	Energy-Efficient Cluster Head Election Protocol
EEECP	Enhanced Energy efficient coverage preserving
EEHC	Energy Efficient Heterogeneous Clustered
ELCH	Extending Lifetime of Cluster Head
GBR	Gradient-Based Routing
GCEEC	Gateway Clustering Energy-Efficient Centroid-based routing

GPS	Global Positioning System
HEED	Hybrid, Energy-Efficient Distributed Clustering
IEEE	Institute of Electrical and Electronics Engineers
INSENS	Intrusion-tolerant Routing Protocol for Wireless Sensor Networks
LoRa	Long Range Radio
MANET	Mobile Ad-hoc Networks
MLDG	Maximum Lifetime Data Gathering
MLER	Maximum lifetime energy routing
MMSPEED	Multi path and Multi SPEED
MN	Mobile Nodes
MTE	Minimum-Transmission-Energy
PA	Precision Agriculture
PEABR	Traditional networks A path-based path equalization algorithm
PEGAS	Power-Efficient Gathering in Sensor Information Systems
PT	periodic Timer
QoS	Quality of Service
RF	Radio Frequency
RR	Rumor Routing
SAR	Sequential assignment routing
SEP	Stable Election Protocol
SPIN	Sensor Protocols for Information Via Negotiation
TC	Count Time
TDMA	Time Division Multiple Accesses

TEEN	Threshold sensitive Energy Efficient sensor Network protocol
TORA	Temporally-Ordered Routing Algorithm
TSEP	Threshold Stable Election Protocol
WSN	Wireless sensor network

ABSTRACT

Wireless sensor networks (WSNs) are currently widely used in sectors like engineering, research, agriculture, and a range of others including surveillance, military applications, and smart automobiles. Precision agriculture (PA) is one of the many applications of WSN. The purpose of putting WSNs in place in PA is to keep track of numerous environmental parameters like humidity, temperature, soil moisture, soil PH, weed monitoring, and so on. Precision agriculture (PA) is a management method that focuses on using information technology to boost quality and productivity. Sensor nodes have suffered from energy concerns and complex routing operations as a result of their restricted capabilities, resulting in data transmission failure and delay in sensor-based agriculture areas. Because sensor nodes are often battery-powered devices, a sensor network's lifetime may be substantially increased if the operating system, application layer, network protocols, and clustering strategy are all designed to be energy-aware. In order to avoid network failure in sensor-based agriculture fields, an energy-aware routing strategy for data transfer is required. In this thesis, we examine several energy-aware routing protocols and leverage heterogeneous sensor nodes to improve crop production quality through weed management and crop health detection. Their lifespan can be extended. We choose the best performing energy-conscious routing protocol, which is most suited for precision agriculture applications, and the heterogeneous aware routing protocol. From the available protocols, we choose SEP DEEC and TSEP and compare their performance. The results shows that TSEP is the best performing protocol in terms of network lifetime and energy efficiency in precision agriculture applications, as well as being more practical for small size areas and less sophisticated than others. TSEP shows better performance compared to the other two protocols. For this, we have evaluated the life time of the sensors from perspective of region size, number of rounds and nodes. We have considered the nodes in random deployment clustering approach to extend the network lifetime, minimize node energy consumption, and maintain coverage. MATLAB platform has been used in simulation scenarios and compare and analyze energy-aware routing protocols.

***Key Word**: Agriculture precision, Clustering, Energy aware, Routing protocol*

CHAPTER ONE

1 Introduction

1.1 Background of the Study

Sensor node networks are networks made up of sensor nodes. These sensor nodes aid in detecting, collecting, and measuring data from the environment in which they are installed, as well as transmitting that data to the user. Wireless Sensor Network (WSN) is a private network made up of a large number of sensor nodes that perform certain tasks and transfer data through wireless communication. The sensors can be deployed in remote, dangerous, and hazardous locations and use wireless communication for information transfer. Wireless sensor networks (WSNs) have gained a lot of attraction in recent years as a way to track environmental changes and have gotten a lot of attention from the research community and industry. Sensors bridge the gap between the physical and digital worlds by catching and disclosing real-world occurrences and converting them into data that can be analyzed, stored, and acted on [1].

Structured and unstructured WSNs are the two types of WSNs. Structured WSNs are those that are installed properly in a given area and can be readily reconfigured if a sensor node fails. Unstructured WSNs, on the other hand, are those in which a high number of sensor nodes are deployed without concern for architecture. These kinds of WSNs are often found in places where people find it difficult to go to and collect data from. Sensors are small in size with low computational power and energy resources.

If their energy is provided by batteries, the amount available is frequently limited. We could use energy-efficient sensor systems or create custom hardware to harvest energy from other devices or the environment. If their energy is provided by batteries, the amount available is frequently limited. Energy-efficient sensor systems or create custom hardware to harvest energy from other devices or the environment. Hundreds of sensor nodes are already being utilized to monitor broad geographic regions for pollution and floods modeling and forecasting, as well as gathering structural health information on bridges using vibration sensors, and managing water, fertilizer, and pesticide consumption to increase crop health and quantity [2].

A wireless sensor network is made up of nodes (motes) that work together to form a cooperative network. From figure 1-1 The initial part of each node is the sensing unit, which is where the sensor senses the ambient parameter. The second component is processing capabilities, which is made up of one or more microcontrollers, CPUs, or DSP chips, as well as numerous types of memory (program, data, and flash). The third component is the communication section, which includes an RF transceiver (typically with a single omni-directional antenna), and the power unit, which comprises a power source (e.g., batteries and solar cells) as well as various sensors and actuators, is the fourth component. Sensors and analogue to digital converters (ADCs) are typically found in sensing devices (Akyildiz et al., 2002).

A position detecting system, a power generator, and a mobilizer are among the application-specific accessories. After being deployed ad hoc, the nodes interact wirelessly and frequently self-organize. Many factors influence WSN design, including energy consumption, node deployment, scalability, fault tolerance, network longevity, and power consumption. WSNs are tiny, low-cost devices having limited sensing/processing, memory, and transmission capacity, among other things. The most significant constraints in the construction of a WSN, however, are energy efficiency and network lifetime [3].

Sensor node energy consumption in a WSN is highly sensitive. The ability of sensor nodes to communicate reliably is critical to the effectiveness of wireless sensor network applications. The physical resource constraint, which is energy resources, is one of the key problems in WSN settings [3]. Adjusting the network topology and managing the transmission power levels of nodes in the routing protocol can help manage energy consumption. In routing protocols, the clustering method is effective for reducing power consumption. Each sensor in a WSN has a limited quantity of energy when it is deployed.

Sensors are powered by the power subsystem, and each action made by a sensor incurs an energy cost that depletes the sensor's power over time. Some actions, such as communication, necessitate a big quantity of power, but others, such as data processing and sensing, necessitate a modest quantity of power. When a sensor loses power. It is no longer has the ability to perceive information, communicate with other nodes, or route data. The death of a single node has no significant influence on the WSN; nevertheless, as more nodes die out, the WSN's performance degrades as the network becomes partitioned and unreliable. The disadvantage of small and low-cost devices is that the network is resource constrained and has a finite lifespan.

WSN can be utilized in different types of application like pollution and flooding forecasting monitoring bridges hearth healthcare, military, transportation, security, and precision agriculture (PA). Sensor nodes have been put in healthcare to gather physiological and biometric data from patients, such as ECGs, heart rates, and blood pressure. Sensor nodes are used in the military to track soldiers on the battlefield, monitor them, find unit locations, and safeguard the forces. In terms of security, sensor nodes can keep a close eye on a risky scenario and remain alert against terrorist attacks. Sensor nodes are used in agriculture to monitor temperature, pressure, humidity, and wind speed. In addition, the sensor nodes detect environmental variables for weather forecasting, weed monitoring, and the likelihood of natural disasters occurring. To collect data from the agricultural field, which is further analyzed and used for precisely monitoring crop development. In this thesis we mainly focus on application of WSN in Precision Agriculture.

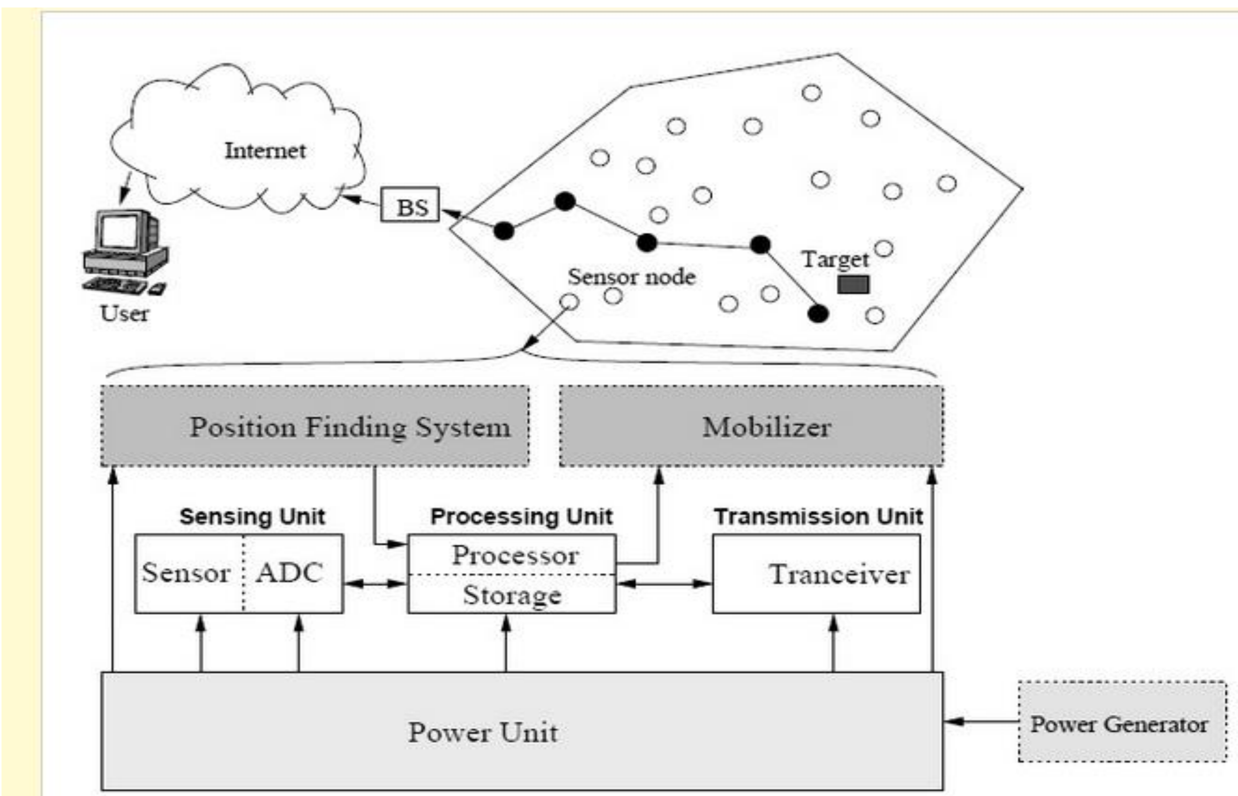

Figure 1-1 The components of a Sensor node [3]

1.2 Wireless sensor Network in Precision Agriculture

Precision agriculture (PA) is a management technique that focuses on using information technology to boost quality and productivity. Wireless sensor technology and management tools can help to create a highly efficient and environmentally friendly farm. Precision agriculture is the art and science of enhancing crop productivity and cost management through the use of advanced technology. Sensor nodes monitor physical or environmental conditions such as humidity, temperature, and illumination, as well as water level, and transmit the sensed data to the base station, which is where wireless sensor network (WSN) technologies play a major role in the development of precision agriculture (BS) via single-hop or multi-hop communication.

Various strategies are available in Precision Agriculture (PA) to monitor and regulate the needed environmental conditions for the specific crop. Analyzing the strategies that may successfully maintain the correct environment is especially important. Real-time monitoring is used in precision agriculture to influence crop decisions and give rapid and appropriate responses, allowing us to make the best decisions for each zone on the farm. Unlike traditional networks, which assume that the user is a human actor, WSNs are focused on the physical environment, particularly the data. PA is made up of near and remote sensing techniques that use IoT sensors to monitor crop conditions at various stages of development [4].

In [4], for current precision agriculture monitoring, wireless sensor network technologies are rapidly being used. Wireless sensor networks have various advantages in agriculture, including high performance, increased production efficiency while lowering costs, reduced power consumption, and dispersed data collection. The sensor nodes interact with the environment in which they are situated, gathering data based on interesting physical occurrences, and communicating with one another.

The purpose of this evaluation of WSN adoption in PA is to measure various environmental parameters like as humidity, temperature, soil moisture, PH value of soil, and so on and surveying the land in order to improve farming, calculating the crop's resource requirements Determine the crop's need for fertilizers, irrigation, and pesticides over time. In order to improve crop quantity and quality. Furthermore, the WSNs aid in the reduction of natural resource usage in agriculture. As well as the different WSNs technologies that have been used for precision.

1.3 Routing Protocols for Wireless Sensor Network

The routing protocol is a method for selecting an appropriate path for data to flow from source to destination. When choosing a route, consider the network type, channel characteristics, and performance metrics, the process confronts numerous obstacles. In a wireless sensor network, the data gathered by the sensor nodes (WSN) is normally relayed to the base station, which connects the sensor network to other networks (such as the internet) where the data is collected, analyzed and some action is taken accordingly. Single-hop communication is used in extremely small sensor networks where the base station and motes (sensor nodes) are so close that they can communicate directly with each other. However, in most WSN applications, the coverage area is so broad that thousands of nodes must be installed. Because most sensor nodes are too far away from the sink node (gateway) to interact directly with the base station, this scenario necessitates multi-hop communication. Direct communication refers to single-hop communication, while indirect communication refers to multi-hop communication [5]. The main categories of the routing protocols are depicted in figure (1-2).

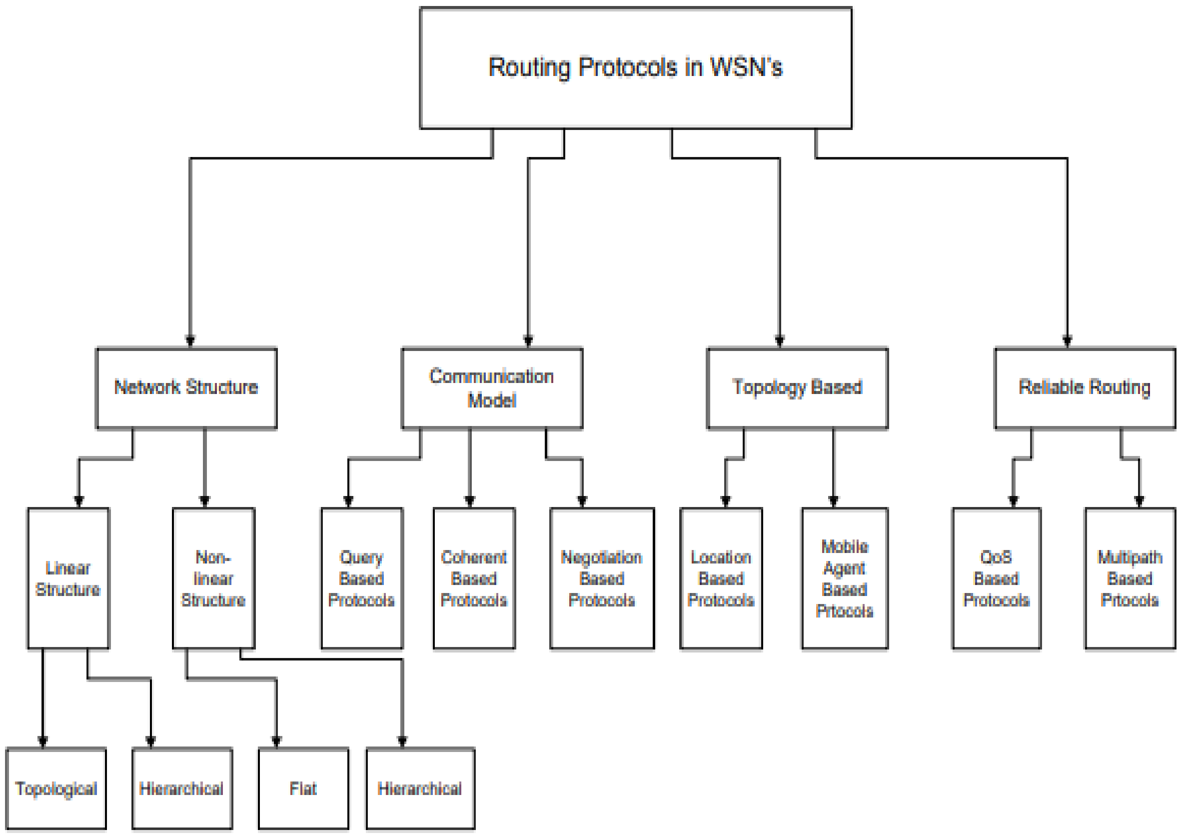

Figure 1-2 Classification of Routing protocol [6]

1.3.1 Network Structure Based Routing Protocol

In Flat topology, all nodes are treated equally depending on the network organization of wireless sensor network protocol. Flat topology is most commonly used in homogenous networks when all nodes have the same features and functions. Gradient-based routing (GBR), Cougar, constrained anisotropic diffusion routing (CADR), and Rumor routing are a few examples (RR). In the second type of this routing protocol, Hierarchical Structure, sensors can report their sensed data to the sink via clustering, an energy-efficient communication technique. The primary aim of hierarchical routing is to decrease the number of messages delivered to the sink by integrating sensor nodes in multi-hop communication within a cluster and performing data aggregation and fusion. LEACH PEGASIS, TEEN APTEEN, and HEED are examples of hierarchical clustering [6].

1.3.2 Communication Model and Reliable Routing

The communication model and reliable routing are commonly known as the operation-based routing protocol in this category there are different pillars the first one is Routing protocols that are of network traffic and QoS. This protocol is concerned with routing start-up and data latency from source nodes to destination, as well as bandwidth and energy. in order to increase energy efficiency, it is necessary to strike a balance between energy usage and data quality. Maximum lifetime data gathering (MLDG), Sequential assignment routing (SAR). Maximum lifetime energy routing (MLER) are examples of QoS-aware routing protocols.

Multi-path a routing protocol is the second part that provides multiple paths for data to reach the destination providing load balancing, low delay, and improved network performance as a result. Alternate path in case of failure of any path also provided by multiple routing protocols. Multiple path networks more interested in Dense networks. Multipath routing protocols examples are Multipath and Multi SPEED (MMSPEED), Sensor protocols for information via negotiation (SPIN). In Negotiation-based routing protocols to maintain the redundant information transmission level at a minimum [7], The sensor nodes negotiate with the other nodes and share their data with the adjacent nodes about the resources that are available, and after the negotiation process, information transmission decisions are made. SPAN, SAR, and DD are among examples.

The fourth part is coherent data processing routing protocol the minimum processing is performed by nodes (time-stamping, data compression, etc.) before sending data to additional sensor nodes or aggregators the fifth is that most query-based routing protocols are initiated by the recipient.

The sensor nodes will only communicate information in response to the destination node's requests. The target node senses the data and transmits it to the destination node, which sends a query of interest for obtaining some information across the network. For instance : SPIN, DD, COUGAR [8].

1.3.3 Topology Based Routing Protocol

In this protocol different types of routing protocols are given. The first one is location-based routing protocol depends on the location of Sensor nodes. The location of sensor nodes is addressed by their positions in location-based protocols. It uses location information for sensor nodes in sensor networks in order to compute the distance between two nodes so that energy consumption may be estimated. MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, and GeRaF are all location-based protocols [9]. Based on their applications, Routing protocols can be categorized into the two groups. Proactive Routing Protocols is the first. Nodes in a network give a continuous data report; nodes continue to sense, turn on their transmitters, and broadcast, making it ideal for applications that require information on a frequent basis. Reactive Routing Protocols are the second type: Reactive networks are suited for time-critical applications because nodes sense data constantly but only transmit when there is a significant change in sensed value [10].

1.4 Design challenges in WSN's

Routing in wireless sensor networks has always been a problematic source of concern, due to various factors ranging from unfavorable deployment conditions, constantly changing network topologies, network failures, resource limits at each sensor node, up to routing protocol design challenges. Routing protocol challenge that obstructs efficient routing in wireless sensor networks includes the following. First, Energy Consumption, which refers to the amount of energy that is consumed. The primary purpose of routing protocols is to ensure that information is delivered efficiently between sensor nodes and the sink. This can happen only if the nodes and sink have enough energy to deliver data. As a result, in the design of routing protocols in WSNs, energy consumption may be a crucial consideration.

The Second challenge is designing a Transmission Topology. The transmission topology design considers location changes. These approaches are capable of fulfilling the requirements of collaborative sensor networks in well-defined circumstances, but they are not capable of supporting collaborative sensor network requirements. The third challenge is the Complexity of the routing system. The complexity of a routing system can have an impact on the overall performance of a wireless network. The fourth issue in routing protocol design is scalability. Because hundreds, if not thousands, of sensors can be readily added to a wireless sensor network, and sensors are becoming more affordable every day, the protocol is becoming more popular. has to be able to handle additional sensor nodes. As a result, the routing protocol must accommodate network scalability.

Fifth challenge is delay monitoring. Temperature sensors and alarm monitoring, for example, require immediate reaction or response with no significant delay. As a result, the routing protocol should have least amount of latency or delay feasible. Coping up with environmental changes is sixth requirement that a typical routing protocol should acquire. In critical and loss situations, wireless sensor networks are commonly used. A sensor node may die or quit the wireless sensor network at any time. As a result, the routing protocol should be able to handle a wide range of situations.

The last challenge is routing protocol design is data transmission and models of data transmission. There are four forms of data transmission in wireless sensor networks, depending on the applications: query driven, event driven, continuous type, and hybrid type. The size of the network and the transmission medium determined the routing protocol's performance [11] . Hence routing protocol should consider models of data transmission. Researchers have designed a lot of routing protocols that can be used in WSN applications considering above challenges. The efficiency of routing protocols also determined in a manner they work to overcome these challenges. Working environment and application requirements determines the type of routing protocol to be employed in intended application. Hence selecting appropriate routing protocol for specific PA application or designing new protocol is very necessary. In this thesis we analyze performance of different routing protocols for PA applications and select the protocol with best performance.

1.5 Statement of the Problem

WSN is playing very crucial role for the success of Precision Agriculture implementation which enhances crop productivity and cost management through the use of advanced technology. WSN is advanced technology being implemented to meet the main objectives of Precision Agriculture. We can use PA technology in different type of agricultural applications like Smart Irrigation System, Smart Pest Control System and Early Crop Disease Detection and Control System.

Research work in [12], shows that these PA applications utilize different types of sensors. For instance, smart irrigation requires mainly weather sensors like humidity, temperature sensors and soil moisture sensors.

Whereas smart pest control and early crop disease detection and control systems utilize image sensors and location sensors in addition to weather sensors. Literature review shows researches have applied WSN technology in smart irrigation system of PA application [13]. However, there is no WSN protocol with best performance that identified to be applied in smart pest control and early crop disease detection and control systems. Since these systems utilize data intensive sensors (Image sensors) thus identifying and determining WSN routing protocol that maximize network life and optimize energy consumption in the system that utilize heterogeneous and data intensive sensor nodes found uncovered research issues.

In this thesis, the available WSN routing protocols that have been developed by different researchers have been reviewed. Since most of WSN routing protocols tested and implemented for smart irrigation system and other applications, their applicability for heterogeneous and data intensive sensor nodes should be analyzed. Hence, we have analyzed existing WSN routing protocols performance for heterogeneous and data intensive sensor nodes and selected the routing protocol that maximize network life and optimize energy consumption. From the existing routing protocols, this thesis focuses on cluster-based energy aware routing protocol for their performance and advantage.

1.6 Objective

1.6.1 General Objective

The general objective of this thesis is to analysis performance of cluster-based energy aware WSN routing protocols for Precision Agriculture applications.

1.6.2 Specific Objectives

- To determine precision agriculture applications where WSN technology currently not applied.
- To identifies the type and behavior of sensor nodes used in uncovered PA applications.
- To deploy determined sensor nodes using energy efficient deployment algorithm.

- To simulate and analyze the performance of existing WSN routing protocols for randomly deployed sensor nodes.
- To select and recommend WSN routing protocol with best performance in maximizing network life and optimizing energy consumption.

1.7 Significance of the Study

Wireless sensor technology and management tools can help to create greatly efficient and environmentally friendly agricultural. WSNs have been employed in a number of agricultural applications, including climate monitoring, and forecasting crop health, weed monitoring and agricultural product quality utilizing soil nutrient data. Increase the overall energy efficiency of the network by applying efficient routing protocol. WSNs enhance the accuracy of data obtained through collaboration among sensor nodes and online information processing at these nodes, allowing us to reduce the energy consumption of the sensor node and increase the life span of the network by select appropriate routing protocol for heterogeneous sensor node and we deploy the node in energy efficient clustering method.

1.8 Scope and Limitation

This thesis mainly focuses on reducing the energy consumption of sensor nodes and select energy-efficient cluster-based protocol for heterogeneous sensor nodes and analyzed their performance to the heterogeneous sensor nodes. Sensor nodes monitored many factors in agriculture to achieve precise control. In our case, we use three types of sensor node to monitor weed management and crop health. For this purpose, we deploy the sensor node in a random deployment mechanism by considering the energy level of each sensor type and for heterogeneous sensor node. The threshold stable election protocol (TSEP) is appropriate from the selected protocol. In this protocol, the data to be transmitted to the base station is based on hard and soft threshold and so that the information will not be transferred unnecessarily to Base Station (BS) since the nodes can never transmit directly to the BS. So, the node energy consumption is reduced and also it is convenient for small scale area and less complex than others.

1.9 Main Contribution

- ✓ We have identified uncovered PA applications where WSN technology currently not applied.

- ✓ We have determined the type and behavior of sensor nodes used in such uncovered PA applications.
- ✓ We have simulated and analyzed existing WSN routing protocols for heterogeneous and data intensive sensor nodes.
- ✓ We have selected WSN routing protocol with best performance in maximizing network life and optimizing energy consumption.

1.10 Thesis Organization

The rest of this thesis is organized as follows.

Chapter 2 studies wireless sensor networks in precision agriculture systems deeply. Section 2.1 discuss flat and hierarchical based routing protocol in detail. Then in Section 2.2 survey on routing protocol, applicable for precision agriculture. Section 2.3 explains routing protocol more related to our work.

Chapter 3 is devoted to the discussion of the system model for routing protocol for precision agriculture. The system model, network architecture, and mathematical model for the system will be discussed. In Section 3.1 the system model discusses the selected protocol and the node deployment method in detail and also discusses the simulation method, system composition of our work.

Chapter 4 gives simulation results and discussions for the performance SEP AND LEACH protocol based on the given performance metric and also analyses the SEP protocol with DEEC and TSEP.

Chapter 5 presents the conclusions and recommendation of the paper. Section 5.2 gives indications for possible future works related to this work. This is what the organization of the paper looks like.

CHAPTER TWO

2 LITRATURE REVIEW

2.1 Survey on Routing Protocol

The development of an energy-efficient routing system is one of the key challenges in sensor networks [14]. The implementation of an energy-efficient routing system is one of the primary challenges in sensor networks. The data from sensing can be collected in a variety of ways. Direct transmission is the simplest method, in which one sensor delivers obtained data to the remote receiver independently of the others. It does not require any sensor communication. This method has a scalability issue from the beginning.

Clustering is another way, in which sensors create clusters with surrounding sensors based on their proximity, and one of the cluster's sensors is chosen as the cluster head, responsible for transmitting data from all of the cluster's sensors to the distant receiver/collector. This method has the potential to be more scalable and traffic can be localized [15]. The routing protocol is a method for selecting an appropriate path for data to flow from source to destination. There are different categories of routing protocols have been developed by different researchers at different time and for different types of applications. There are routing protocols developed for homogeneous and heterogeneous sensor nodes for instance. In this section we review different types of routing protocols have developed by different researchers according to their categories.

2.1.1 Flat Routing Protocol

In a flat topology, the sensor network's nodes all gather data in the same way. They all have the same information about the present state of the network. This category includes three forms of flat routing protocols: flooding, forwarding, and data-centric oriented routing. When a node gets a packet, it broadcasts it to all of its neighbors without first verifying the contents capabilities of node. This technique will be repeated until the packet's maximum number of hops is reached. Impulsion, overlap, and resource blindness are all factors that restrict flooding. Rather of broadcasting each packet to its whole neighborhood (components), gossiping sends each packet to a single neighbor picked at random from an adjacent table after all nodes have been tested. Gossiping will assist to decrease the number of copies of the same packet travelled in the network by picking a random node for packet relaying. Flat network architecture has various advantages, including minimal infrastructure maintenance costs and the possibility to discover several fault-tolerant paths between communication nodes.

SPIN (Sensor Protocols for Information through Negotiation) [15] is a group of Flat proto-cols . It is a data-centric routing system for propagating information in a sensor network based on a negotiation approach. It is intended to solve the shortcomings of flooding through resource adaptation and negotiation. It communicates via three different types of messages: ADV (Advertise), REQ (Request), and DATA. A sensor node will send ADV packets to other nodes within its transmission range, containing information on the sort of data it possesses. Nodes interested in this data can request it by sending a REQ packet to the advertising node. However, because nodes outside the transmission range cannot receive the advertising packet, it may not be suited for a wide geographical network. SPIN-BC, SPIN-PP, SPIN-EC, and SPIN-RL are some of the other SPIN protocols.

Directed Diffusion (DD) proposed in [16] is a data-centric routing system for data propagation, with an application-aware paradigm that leverages on-demand data inquiry and transmit data to enquiring destinations. There are various components to directed diffusion. Attribute-value pairs are used to name data. As an interest for named data, a sensing task is propagated throughout the sensor network. This propagation creates network gradients that are used to "draw" events. Events begin to flow in many directions towards the originators of interests. Maintaining localized interactions, such as message exchanges between neighbors or nodes within a specified network radius, is the primary objective in order to preserve network energy and extend its lifetime. Advantages of DD over in directed diffusion, there is no need to maintain global network topology since SPIN allows just interested nodes to query data on demand. DD has a several limitations. Because data cache memory inside the sensor node is limited, matching data to queries may need some additional overhead at the sensor nodes. Directed diffusion is not suited for applications that demand a continuous flow of data.

Rumor Routing (RR) is proposed by Braginsky and Estrin's [17] Directed Diffusion technique, which they presented in 2002. In the absence of geographical information, is a good energy-efficient technique in compared to flooding procedures. In RR whenever a node experiences an event, it stores it in its local events table and generates an agent, which is a long-lived packet that crosses the network to tell distant nodes about local events. The shortest pathways of events that occur in the WSN are kept. The nodes that are aware of the route can react to the query by looking at the route's event table. Otherwise, it can be sent in a random direction until it locates the event's route (path). The benefit of RR are as follows: Deliver requests to events over vast networks with fewer average cumulative hops and less energy usage than traditional flooding., as well as gracefully handle node failure. The path found by the agent is not always the shortest and may be unavailable if one of the path's links is broken. The agent may carry a huge amount of event routing information, and some events may disappear, it also fails when there are a high number of nodes because maintaining agents and event-tables in each node becomes prohibitively expensive.

GBR (Gradient-Based Routing) was introduced by Scourgers and Srivastava [18] as a better form of Directed Diffusion (DD) that incorporates the number of hops (hop-number) when the interest is dispersed throughout the network The packet is sent to the connection with the most gradient. GBR also uses traffic dispersion techniques to disperse traffic equally across the network. The data from several routes passing via a relay node may be combined. One of the advantages of GBR is that nodes convey messages in a point-to-point way rather than using the broadcast nature of wireless networks. The problem of data propagation via several hops' strategy is that bottleneck nodes appear to be unavoidable. The GBR nodes closest to the sink will be overworked and will perish before others. The failure of these nodes causes the entire network to fail.

2.1.2 Hierarchical or Cluster Based Routing Protocol

The hierarchical routing surveys concentrate on cluster-based routing strategies, which have the potential to be highly efficient for large networks and are scalable. They are energy efficient, can handle a high volume of traffic, have a vast sensing area, and can-do data fusion and aggregation. Depending on the network structure, hierarchical routing, and location-based routing is used. Sensor nodes are divided into clusters via the hierarchical routing protocol, which contains a

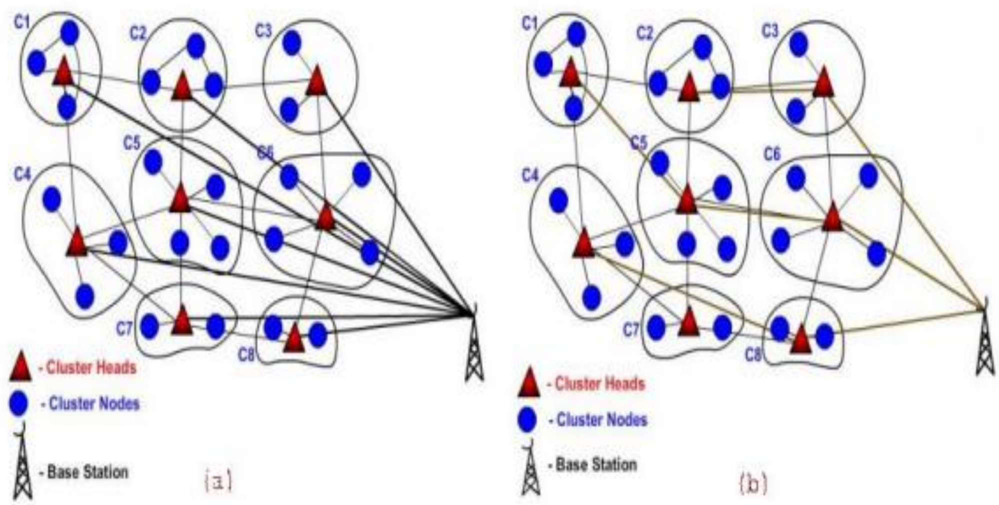

Figure 2-1 Single hop and Multi-hop Clustering in WSN [19]

hierarchy of cluster headers (CHs) and cluster member nodes. One of the energy-efficient ways for extending the lifetime of a sensor network is clustering. The cluster head is chosen from among the nodes in each cluster. The sensors' information is delivered to the cluster head first, and then to the sink. The data from the sensors can be fused by the cluster heads to reduce the amount of data sent to the sink. Direct transmission (single-hop) or multi-hop transmission are both options for data transport. In WSNs, the method through which sensed data is transmitted from the sensing point to the base station (BS) is critical. Using single-hop communication to send data straight to BS for each sensor node is a simple technique to accomplish this objective. Sensor nodes deliver data to BS via intermediate nodes in multi-hopping. As a result, the multi-hopping routing algorithm's primary aim is to find a group of intermediary nodes in order to build an efficient data forwarding path between the source and destination [20]. When the network grows larger, clusters can be structured hierarchically. In clustering protocol, we have to see in the homogeneous and heterogeneous sensor networks.

2.1.2.1 Routing Protocol for Homogeneous Sensor Network

All nodes in a homogeneous wireless sensor network have the same beginning energy. All sensor nodes have similar hardware capability. Once a cluster head is chosen in a homogeneous WSN, it will serve for the network's whole existence. In this section, many types of routing protocols are explored, including.

LEACH (Low Energy Adaptive Clustering Hierarchy) proposed by researchers in [21], for WSNs, and it is a well-known cluster-based routing protocol. LEACH was the first to introduce the concept of clustering in a WSN. Clustering saves a lot of energy in a WSN compared to other methods. LEACH divides the network's nodes into small clusters and assigns one of them as the cluster's leader. After sensing its target, the node delivers the relevant information to its cluster-head. The cluster head then collects and compresses the data from all of the nodes before sending it to the base station. One of the first significant advancements over traditional clustering methods such as minimum-transmission-energy (MTE) or direct-transmission, which do not result in consistent energy consumption, is a cluster-based protocol that decrease the amount of data that must be transferred to the base station by using local data fusion and classification.

Although LEACH clustering can be completed in a finite number of iterations, it does not guarantee appropriate CH distribution and assumes that CHs consume the same amount of energy. The sensor nodes send their data to a local cluster-head through LEACH, where beamforming is used to fuse the data. LEACH's advantages are that every node has an equal chance of becoming a cluster head, but no node can be picked as a cluster head in a subsequent round, so load is shared between nodes, and LEACH uses TDMA to prevent CH from collision. Limitations of LEACH include the usage of one hop transmission, which makes it unsuitable for large-scale networks; CH are chosen based on probability, so uniform distribution cannot be guaranteed, and load balancing is not possible.

The LEACH Algorithm is a periodic process with two phases in every cycle the set-up phase and s steady state phase.in set up phase LEACH perform cluster head selection based the probability the node generates a random number between zero and one and compare it to the threshold value. the random number of the nod is less than the threshold then the node elected as a cluster head. Set T (n) to 0 in each round of the loop if the node has been selected as the cluster head, so that the node is no longer re-elected as the cluster head. T (n) is the probability of selection for cluster head nodes that have not been selected; T (n) can be stated as.

$$T(n)=\begin{cases}\dfrac{p_{opt}}{1-p_{opt\left(r,\bmod\frac{1}{p_{opt}}\right)}}, ifs \in G \\ 0, Otherwise\end{cases} \tag{2.1}$$

P is the percentage share of all cluster head nodes, r denotes the election round, r P mod ($1/p_{opt}$) denotes the selected number of cluster head nodes in this round of the cycle, and G denotes the cycle in which no cluster head nodes were chosen. Based on a Carrier Sense Multiple Access (CSMA) protocol elected, cluster heads broadcast an advertisement message to all sensor nodes. CHs establish a TDMA schedule for each node to submit its data to the appropriate CH. In this phase cluster also performed; the network topology crated at the end of the set-up phase. The second phase starts when nodes are ready to operate. According to the defined TDMA slot schedule the data are sensed by the sensor node and send it the cluster head. For intra-cluster and inter-cluster communication phases, the steady state operation is divided into several frames. Each cluster's sensor nodes provide data to the cluster head once every frame during the designated time slot. As a result, the number of nodes in the cluster determines the frame time. The cluster heads are always awake, but the sensor nodes can sleep until the cluster heads are awake again. their assigned transmission slot is filled, and then until transmission is completed. [22].

PEGASIS (Power-Efficient Gathering in Sensor Information Systems) that proposed in [23] is a "chain-based protocol" and an update to "LEACH." To direct and acquire information, each node in "PEGASIS" only communicates with a close neighbor. It communicates with the BS in turns, decreasing the amount of energy needed every round. This chain can be computed by the BS and transmitted to all sensor nodes. This avoids the assumption of direct communication and decreases the relatively large overhead of the LEACH protocol. PEGASIS' network model uses a chain topology and assumes a homogeneous collection of nodes spread throughout a geographical location.

TEEN (Threshold Sensitive Energy Efficient Sensor Network protocol) that proposed in [25], is the first protocol designed specifically for reactive networks and is targeted towards them. At every cluster change time, the cluster-head communicates to its members in addition to the characteristics. All nodes must only communicate to their nearest cluster-head, conserving energy and time. Only the cluster head must do additional data computations. As a result, energy is again conserved. The nodes are constantly sensing their surroundings. The node turns switches on its transmitter and transmits detected data when a parameter from the attribute set is reached for the first time the hard threshold value. TEEN has the advantage of being able to manage data transmission by adjusting two thresholds and being ideally suited for time-critical applications.

TEEN's drawback is that if the threshold isn't met, the node won't interact, and data may be lost if CH can't communicate with each other.

APTEEN’ N (Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network Protocol) in [24], is proposed by combining that the greatest aspects of proactive (LEACH) and reactive networks (TEEN) to create a Hybrid network that delivers data on periodically and responds to rapid changes in attribute values. It enables for the retrieval of a large amount of data. The nodes in such a network not only react to time-critical events, but they also give a very energy-efficient overall view of the network at periodic intervals. In such a network, the user can utilize historical, one-time, and persistent queries to request data from the network in the past, present, and future. Once the CHs are determined in APTEEN, the cluster head broadcasts the following parameters: Attributes (A), Thresholds, Schedule, and Count Time (TC). APTEEN has a number of advantages. It gives the user a full view of the network by delivering periodic data; it provides by enabling the user to choose the (TC) time interval and threshold values for the attribute; and it conserves energy by delivering periodic data. The increased complexity required to implement the threshold functions and the count time is the primary drawback of this protocols.

HEED’ (Hybrid Energy-Efficient Distributed clustering) , proposed in [25], Cluster heads are selected on a regular basis using a combination of node residual energy and a secondary criterion such node closeness to its neighbors or node degree. HEED's main goal is to extend network lifespan by dispersing energy wastage, Ending the clustering process in a set number of iterations, reducing control overhead, and producing equally dispersed cluster heads are all goals. This protocol works well for scalability in data aggregation. This model covers a multi-hop network and it presupposes that all nodes are of equal importance, and that each node may function as both a source and a server (cluster head). that all nodes are of equal importance, and that each node may function as both a source and a server (cluster head). This system has several advantages, including a completely distributed routing mechanism that achieves load balancing and uniform CH distribution. and scalability through multi-hop communication the main disadvantages of HEED are uneven energy consumption as a result of increased CH generation, large overhead as a result of many rounds, and additional overhead as a result of many epochs.

ELCH (Extending Lifetime of Cluster Head) protocol proposed by [26], All accessible nodes in the networks voted for their neighbors to be the cluster leaders. A hybrid method is used in the procedure. as a consequence of which it consumes less energy and so extends the network's life. This technique combines cluster design with multi-hop routing. There are two phases in this ELCH. The first is that the cluster head is chosen and the cluster is built during the set-up phase. The Steady-State Phase is the second phase. Clusters are formed in this phase, after which information Flows from the head to the sink and from the sink to the head.

DHAC ’(Distributed hierarchical agglomerative clustering) proposed in [27], The steps below are used to create a cluster node: The first is that each node in the network acts as a cluster head and communicates with other nodes. In the second stage, the DHAC technique is employed, in which each cluster generates its own private similarity matrix and determines the minimum coefficient value. The hierarchical cluster tree is cut in the third step. In the fourth step, the cluster size may be specified, and clusters can be combined using the merge cluster technique. Finally, the cluster heads are determined. Between the two nodes that join the cluster in the initial stage, the DHAC chooses the lower id node. The CH chosen does not necessitate any additional processing. DEEC outperforms LEACH and SEP when dealing with many degrees of heterogeneity.

2.1.2.2 Routing Protocol for Heterogeneous Sensor Network

SEP (Stable Election Protocol) developed by researchers in [28] SEP extends LEACH in which cluster head is elected on the basis of initial energy of node. Is introduced heterogeneity which is based on two levels of heterogeneity. considers energy levels in the CH selection process and increases the stability of the hierarchical clustering process by adding energy between the advance node and the normal node, employing distinctive factors of heterogeneity. The likelihood of cluster head election is related to the sensor node's initial energy. SEP aims to keep energy usage low in order to extend the stabilization time. The fundamental drawback of the SEP protocol is that cluster head selection probability remains constant during the life of the sensor network and does not dynamically validate deviation from predicted energy consumption patterns.

DEEC(Distributed Energy-Efficient Clustering algorithm) proposed by researchers in [29], The ratio of current residual energy to average residual energy in the network determines the probability of cluster head selection in DEEC. The limitation of DEEC is that this knowledge necessitates extra energy consumption in order to disseminate the data across the sensor nodes Because DEEC uses average energy as a reference energy, it does not, request global data on the energy of the WSNs for each round. DEEC is more effective than LEACH and SEP.

E_SEP(Enhanced Stable Election Protocol) developed by researchers in [30], Nodes elect themselves as cluster heads depending on their energy levels in this protocol, resulting in more evenly distributed energy among sensor nodes. To ensure that concise information is provided to the sink, the aim is to reduce communication costs and increase network resources. Each node sends information to the cluster head closest to it, which aggregates the information. As a cluster leader, you should anticipate to waste more energy than a cluster member.

EEHC(Energy Efficient Heterogeneous Clustered) proposed in [31] is a heterogeneous aware protocol whose purpose is to extend the network's longevity and stability in the presence of heterogeneous nodes by using weighted selection probabilities of each node to become a cluster head based on each node's residual energy. In the presence of the same number of powerful nodes in the network, EEHC has extended the network's lifetime compared to LEACH.

EECHE (Energy-Efficient Cluster Head Election Protocol) proposed in [32] is intended to extend the longevity and stability of heterogeneous wireless sensor networks, which is important for a variety of applications. The initial energy of a node in comparison to other nodes in the network is weighted in the cluster head election criterion (CHs) EECHE can extend the duration between the death of the first node in the sensor field, which improves the system lifetime and stability.

TSEP(Threshold-sensitive Stable Election Protocol for WSNs) proposed in [33] is a reactive protocol that employs three degrees of heterogeneity, with nodes of varying energy levels. Normal Nodes, Intermediate Nodes, and Advance Nodes are the three types of nodes. as well as the threshold level. Each node produces a number between 0 and 1 at random. This node becomes CH if the produced value is less than the threshold. Despite the fact that the average number of CHs is the same as LEACH, SEP, and ESEP However, here a good aspect of TSEP is energy dissipation is reduced due to energy heterogeneity. Some benefits of TSEP, nodes keep on sensing continuously, as a result, energy usage is significantly lower than proactive networks. Because values of soft threshold, TR, and A hard threshold are transmitted anew when a cluster changes, depending on the criticality of the sensed attribute and application, the user may choose how often to sense and what parameters to sense, and the user can modify the attributes based on the requirement, since attributes are broadcasted at cluster change time.

2.2 Survey on Routing Protocol for PA

There are routing protocols that have been developed for Precision Agriculture applications. Hence, we review these routing protocols in this section, [29] proposed a review of the literature on precision agriculture utilizing wireless sensor networks It encompasses a wide range of approaches, sensors, algorithms, and sensor nodes for gathering data from agricultural fields. And also, to recognize the numerous WSNs in agriculture. In order to achieve precision agriculture, it also focuses on many environmental elements such as irrigation, monitoring, soil qualities, and temperature.

Furthermore, a thorough examination of several crops affected by WSN technology is carried out. Wireless sensor networks are divided into five categories for monitoring the parameters of the earth's surface, underground conditions, underwater conditions, multimedia, and area monitoring using sensor mobility. A literature review was used to determine the usefulness of sensor nodes in PA. Crop Monitoring, Crop Irrigation Management, and Crop Management Crop environmental parameters.

In [34] are proposed a periodic threshold sensitive hybrid routing protocol for precision agriculture the proposed protocol deploys sensor nodes using region-based static clustering techniques, ensuring efficient coverage of the entire agricultural area. The coverage-hole problem is best handled by deploying different types of nodes in different locations dependent on their mission and energy level. However, the sensed data regarding the agricultural area's environmental element is sent to the base station via the network's sensor nodes on a continuous basis (BS)when the user-defined periodic timer (PT) or the value of the detected characteristics exceeds the set threshold. The proposed method reduces the total amount of energy used by sensor nodes. A best method for coverage hole is the employment of fuzzy-based clustering algorithms for sends sensed data to the BS decreases sensor node energy consumption and improves network lifespan performance by deploying diverse types of nodes in different areas based on their performing task and energy level.

The work in [35] examines and compares several wireless communication protocols, as well as the taxonomy of energy-efficient and energy-harvesting techniques for wireless sensor networks (WSNs) that might be used in agricultural monitoring systems. The constraints and limitations of WSNs in the agricultural sector are discussed, as well as numerous techniques for power reduction and agricultural management for long-term monitoring are highlighted, Furthermore, several wireless protocols and standards that are utilized in agriculture are defined.

These wireless technologies are also compared to see which one is the most practical in terms of power consumption and range of communication. ZigBee Wireless Protocol, Bluetooth (BT) Wireless Protocol, Wi-Fi Wireless Protocol, GPRS/3G/4G Technology, Long Range Radio (LoRa) Protocol, and Sig Fox Protocol are some of the technologies available. However, power consumption and battery life, communication range, propagation losses, routing, localization and tracking, reliability, scalability, cost, real-time, data storage and recording, security, and delay tolerance are some of the challenges and limitations in existing agricultural applications based on WSNs.

In work [36] the potential of WSN in India's agricultural sector For system automation and monitoring, For the sugarcane crop, a multi-parameter monitoring system based on low-power ZigBee wireless communication technology is being developed. Wireless sensor nodes capture data in real time and send it to a base station through ZigBee. Data is collected to monitor soil temperature, soil moisture, and humidity. At the base station, the data is recorded and presented. This system overcomes the limitations of wired sensor networks by allowing for flexible equipment monitoring, simple equipment installation and removal, low-cost and reliable nodes, and high capacity. BSMH [37], Multiple Holes can be avoided by using the load-balanced and constant-stretch technique, is a novel geographic routing technique for WSNs. In terms of routing path length, control packet overhead, and load balance among nodes, it is more advanced than the previous protocol. Furthermore, BSMH strives to reduce routing path length and control overhead while increasing load balance. When compared to conventional protocols, BSMH extends the network lifetime by 30%.

The work in [38],Surveyed alternative for heterogeneous wireless sensor networks on several factors such as location awareness, clustering method, heterogeneity degree, and clustering attributes. Due to the energy constraints of wireless sensor networks, energy conservation and network lifetime extension have emerged as the most essential goals of various routing protocol. Clustering is a significant strategy for extending a sensor network's lifetime by lowering energy usage. Moreover, using a wireless sensor network with a few heterogeneous nodes is an excellent technique to extend the network's lifetime and stability. Several protocols have been proposed to operate in heterogeneous wireless sensor networks. The clustering technique is used in the majority of modern energy efficient protocols built for heterogeneous networks, and it is useful in reducing energy consumption for wireless sensor networks.

Research in [39] , compare the performance of two types of routing methods: hierarchical and flat network routing strategies in (WSN). They mostly used the protocols Intrusion-tolerant routing methods include the Temporally-Ordered Routing Algorithm (TORA), Low Energy Adaptive Clustering Hierarchy (LEACH), and Intrusion-tolerant Routing Protocol for Wireless Sensor Networks (INSENS). Due to the distant nature of WSN deployment, sensor nodes have problems with energy optimization and fast route discovery.

Various routing approaches have been developed to resolve these concerns. Low Energy Adaptive Clustering Hierarchy (LEACH) Hierarchical network routing (HNR) is a network routing method incorporating a clustering mechanism. The difference between Wireless Sensor Networks (WSN) and Mobile Ad-hoc Networks (MANET) is that WSN gather data with a higher number of nodes placed once throughout their lifetime, whilst the other is built for ad-hoc distributed computing. GCEEC is a Gateway Clustering Energy-Efficient Centroid-based routing scheme in which the cluster head and gateway nodes are picked from each cluster's centroid position. The gateway node, which delivers the data to the base station, reduces the data burden from cluster head nodes. In order to enhance load balancing across CHs and overall network energy usage, this protocol is recommended for agriculture precision WSN. The GCEEC protocol selects an efficient CH site near the energy centroid, as well as a gateway node for data transfer to the BS through multi hop communication, enhancing CH coverage while reducing CH transmission power.
Work in [40] Cluster Head Zone-based LEACH (CHZ-LEACH) is a new cluster head election method based on residual energy, average energy, and a cluster head zone, which is a designated location for cluster heads. Aims to enhance the performance of the LEACH protocol by ensuring that nodes use energy in a balanced manner. But, because of the long-distance communication, LEACH requires more energy for data transmission and results in the early death of sensor node It improves the LEACH protocol by distributing energy load among nodes uniformly. The selection of cluster heads in CHZ-LEACH is based on three factors: average energy, residual energy, and distance from BS. The cluster head zone in the network, a circular area is formed around the base station to keep the transmission distance between CH and BS to a minimum. If a

node falls into the cluster head zone and has higher residual energy than average energy it is selected as cluster head.

The work in [41] ,Surveyed a huge number of routing-related Wireless Sensor Networks (WSNs) that prioritize routing, either entirely or partially. These studies classify and describe significant routing protocols in the domains of classical, energy-efficient, secure, hierarchical, geographic, intelligent, and QoS-based routing protocols. This paper proposes an innovative classification based on survey publishing frequency and WSN survey publication is taxonomized into high, medium, and low focused regions based on the relevant routing-related variables.

Research in [42],developed a strategy for collaborative data collecting employing numerous mobile nodes (MN) as sink nodes, and one key challenge is how to plan the data collecting path of each mobile node under a set of limitations, including energy limitations. In addition, he researches routing strategy and path planning. Data is sent to base stations in classic WSNs via multiple-hop transmission. Multi-hop transmission, on the other hand, will result in problem including energy holes, unequal energy use, and unreliable data delivery. As a consequence, this study suggested a remedy for traditional networks typical network flaws. A path-based path equalization algorithm (PEABR) is proposed to adjust the MN's path, further reduce and equalize the MN's path length to satisfy the constraint conditions, and optimize the path planning scheme in order to allow the MN to complete data collection within the energy limit while also improving path balance.

When the bulk of sensor nodes are located far away from the base station, data transmission uses more energy, resulting in a shorter period of stability and a longer network lifetime. To solve this challenge, employ hybrid routing, which increases network stability and lifespan. A RBHR approach that makes efficient use of the complete coverage area and it works for heterogeneity on two levels. The RBHR protocol uses region-based clustering to, install several types of sensor nodes in different locations based on their energy levels, and use hybrid data transport routing To reduce network energy usage, hybrid routing is used for data transfer [43].

2.3 Related Work

For distributed energy efficiency, a clustering (DEEC) approach has been developed. Heterogeneous wireless sensor networks are a type of wireless sensor network that uses a variety of technologies. The cluster heads in DEEC are chosen using a probability formula based on the ratio of each node's residual energy to the average energy of the network. Depending on their starting and residual energy, the epochs in which nodes become cluster head vary. DEEC calculates the reference energy that each node should consume throughout a cycle by estimating the optimum value of network life-time [38].

TSEP (Threshold Sensitive Stable Election Protocol) is a three-level heterogeneity reactive protocol. The protocol's reactive nature is due to the scheme's introduction of hard and soft thresholds, which ensure that data is not sent to the Base station unnecessarily. The scheme contains three levels of heterogeneity: normal nodes have the lowest energy, intermediate nodes have energy that is middle between normal and advanced nodes, and advanced nodes have much more energy. The Hard and Soft thresholds were established by TSEP to regulate how information is sent from one node to the next and finally to the base station. Data will not be transferred unnecessarily if these thresholds are attained [44].

In [45] In wireless sensor networks that are hierarchically clustered, the influence of node heterogeneity in terms of energy. Some nodes in these networks become cluster head, aggregating data from their cluster members and sending it to the BS. SEP is a heterogeneous-aware protocol that increases the time interval before the first node dies (what we term the stability period), which is important for many applications where sensor network output must be dependable. SEP is based on each node's weighted election probability of becoming cluster leader based on its remaining energy. The initial version of LEACH does not take into consideration for the differences in starting energy across nodes. and as a result, the sensor network's energy consumption is inefficient. The reason for this is because LEACH is solely dependent on the sensor network's spatial density.

To sum up, from the literature review we can conclude that Energy Aware Cluster-Based routing protocols demonstrated the best performance in maximizing network life and optimizing energy consumption for both homogeneous and heterogeneous sensor networks. However, when we see the application of WSN in Precision Agriculture we can notice that only homogeneous sensor network routing protocols like LEACH, CHZ-LEACH, and GCEEC are tested and implemented by researchers. Hence analyzing the efficiency of such protocols in Precision Agriculture applications that compose heterogeneous sensor networks can be considered as one research gap. In addition, developed and existing heterogeneous sensor network-oriented Energy Aware Cluster

Based routing protocols like TSEP and its versions, EEHC, and EECHE, performance analysis for Precision Agriculture applications also found as a mandatory contribution to the scientific community.

In this thesis selected heterogeneous sensor network routing protocols performance is analyzed for the applications of Precision Agriculture that compose heterogeneous sensor network. Due to this, we analysis SEP, DEEC and TSEP protocol. The TSEP protocol is more efficient than SEP and DEEC in terms of CH selection mechanism, stability period, increase network lifespan, and applicability in precision agriculture. And as mentioned in related work, the TSEP protocol is less complex than other heterogeneous aware protocol and also most of them are applicable in large geographical areas.

CHAPTER THREE

3 SYSTEM MODEL

3.1 Introduction

In this thesis Different reviews on wireless sensor networks, previous researcher's studies, different Institute of Electrical and Electronics Engineers (IEEE) articles, development in wireless sensor networks in precision agriculture, and the basics of routing protocol in wireless sensor networks in particular were reviewed in this thesis. Based on the input parameter and retrieved from the review of related literature and the statement of the problem in mind, the methodology of this study is designed as follows. The methodology of this the study is designed as follows, based on the input parameter and recovered through a review of related literature, as well as the statement of the problem in mind.

3.2 Materials

In this work, software such as MATLAB/R2017a, is used. MATLAB is the computing software which consists of technical toolboxes and Simulink.

3.3 Methods

In order to accomplish this thesis and attain the general and specific objectives of the study area, the following procedural methods will be followed.

3.3.1 System Design

- Outline of work flows of the selected routing protocol and node deployment.
- Prepare a mathematical model for calculating the radio Energy model.
- Prepare a mathematical model for energy consumption of a node.
  - ✓ Calculate the threshold value.
  - ✓ total energy of the network.
- Identify simulation parameters.
- The performance of heterogeneous protocol (SEP, DEEC, and TSEP) is analyzed.

3.3.2 Simulation Methods

- Outline of simulations work flow,
- Perform SEP, DEEC and TSEP comparison simulations;
- Perform energy consumption of sensor based on alive node and dead node on a given round
- Evaluation analysis whether the target requirement achieved or not.

3.4 TSEP Based Sensor Node Deployment

This section goes over the detailed description and working principle of the proposed protocol. When creating a communication protocol for a WSN, energy efficiency and node life span is the most significant consideration and in precision agriculture, we also consider the coverage area and coverage hole problem. As a result, an energy-efficient random based routing protocol is employed in this thesis for effective weed monitoring in the agricultural field. The selected protocol is the most suitable energy-efficient routing protocol for heterogeneous sensor node in precision agriculture and analyses their performance with the other selected heterogenous aware routing protocol.

3.4.1 Assumptions

Before delving into the specifics of the protocol, various network assumptions are made.

- Throughout the network's lifespan, network design employs clustering and selection of cluster heads.
- The base station is in the middle and has no energy constraints.
- The node has a function that is aware of its position. the node and base station are stationary after deployment.
- Each sensor node is within range of the base station.
- Three types of heterogeneous sensor nodes are explored for sensing and transmitting data to cluster heads and the cluster heads send to the BS.

3.4.2 System Composition

In this thesis, a well-suited network model for precision agriculture is considered. With simultaneous changing field circumstances (e.g., soil color, wind, plant color and shape, water or nutrient stress, or tissue damage), the proposed model employs a threshold stable election protocol to assess three environmental factors important for weed detection and identification. the first is the temperature and humidity sensor (SHT3x), the second one is the GPS (16x_hvs) sensor content of the field and third is the spectral sensor (Mjolnir VS-620) which are important for weed management. According to the value of the temperature and humidity sensor, GPS, and spectral sensor in the agricultural field, an automatic decision can be made as to when monitoring should begin, allowing farmers to increase product and crop quality by maintaining proper weed detection methods such as herbicide and pesticide spraying in the field during critical plant growth stages. The sensor network's basic setup is composed of two parts.

i. **Sensor Node:** There are three different types of heterogeneous sensor nodes the network considers class_A, class_ B, and class_C nodes. for detecting and transferring data to BS. Two or more different types of nodes with different sensing, storage, processing, communication, and energy capacity make up a heterogeneous sensor network. Every different sort of sensor node in the network is treated differently depending on the protocol chosen (i.e., class_ A, class_ B, and class_ C nodes). Temperature and humidity sensors, GPS sensors, and spectral sensors are included. Figure 3_1 shows the block diagram of three types of sensor nodes. The sensor nodes are deployed for sensing and transmitting the temperature and humidity of the environment, weed information and the GPS sensor used to know the exact location of the weed of the agricultural field to a BS.

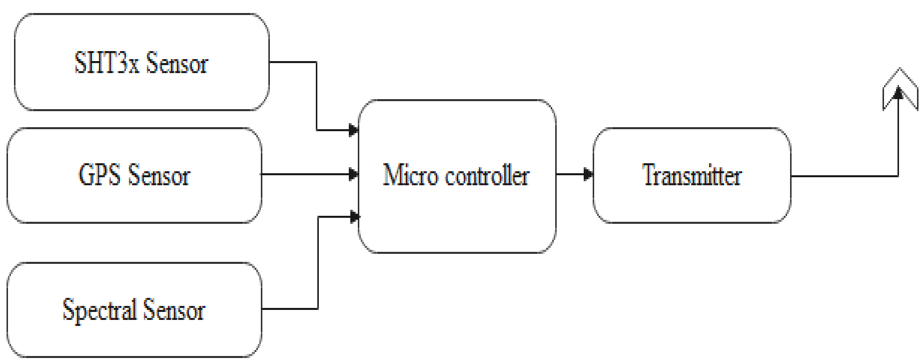

Figure 3-1 Types of sensor nodes

ii. **Base Station:** A transceiver, processor and LCD display make up the base station (BS). BS collects data on the field's temperature and humidity, the location of the weed, and the image of the weed levels so that an end-user can analyze the data and take the appropriate action. Because high-energy sensor nodes are more expensive, we have evaluated three types of sensor nodes in variety numbers in the network. Each class_ A, class_ B, and class _C sensor node has a different energy level, sensing range, and transmission range in the region-based protocol. We assumed that higher-energy sensor nodes would have greater sensing acuity. class_ A node’s energy < class _B node’s energy < class_ C node’s energy. Class_ A sensing range < class _B sensing range < class_ C sensing range. Class_ A nodes transmission range < class _B nodes transmission range < class_ C nodes transmission range.

3.5 Cluster Head (CH) Selection Method

The node is deployed in random manner and for selecting cluster head (HC) apply TSEP. The protocol considers energy levels in the sensor categories election process and increases the stability of the hierarchical clustering process by adding energy between the intermediate nodes (class_ B) and the advance node (class_ C), employing distinctive factors of heterogeneity. In order to extend the time, it takes for the system to stabilize, TSEP strives to maintain limited energy consumption. The advanced nodes will become CH more than normal nodes and will be powered more than normal nodes. TSEP is heterogeneous-aware, meaning that election probability is weighted by a node's initial energy compared to that of other nodes in the network. This increases the time until the first node dies (what we call the stability period), which is important for many applications where the sensor network's feedback must be reliable. Simulations show that TSEP has a longer stability period and higher average throughput than existing clustering heterogeneous-based methods. We show that TSEP is more resilient than DEEC and SEP at carefully using advanced and intermediate nodes' extra energy—TSEP delivers a longer stability region for higher quantities of excess energy. In DEEC and SEP assuming a uniform distribution of heterogenous nodes in space, the CH chose based on the ratio of the residual energy of node and the average energy of the network in DEEC. In SEP [46] the cluster head elected based the node generate a random number between 1 and 0 and compare to the calculated threshold if the random number less than the threshold the node become a cluster head in each round.

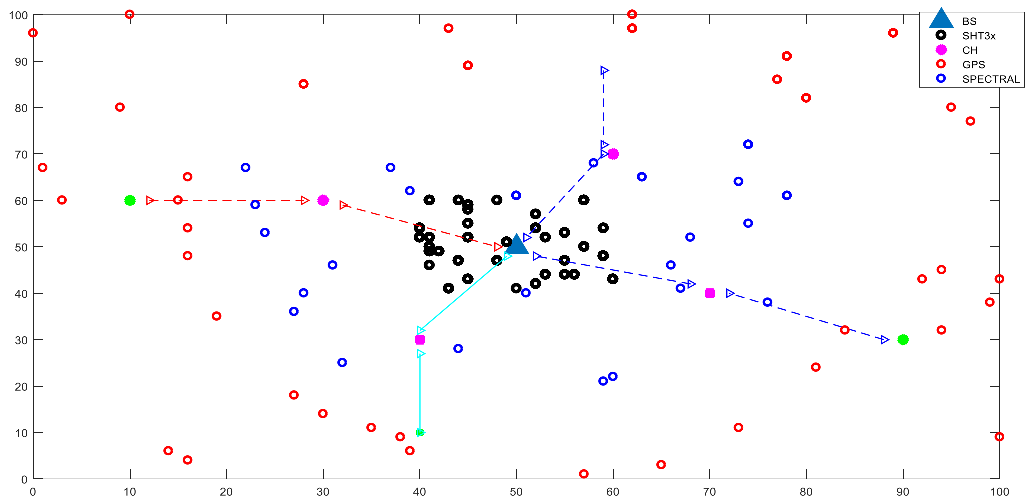

Figure 3-2 Node Deployment with Cluster Head

In TSEP the cluster head selection method is similar to SEP but in TSEP consider three types of sensor nod and the TSEP consider the hard and soft threshold for data transmission. become a cluster head exactly once every $\frac{1}{p_{opt}}$ round. As the epoch of the clustered sensor network, this number of rounds, $\frac{1}{p_{opt}}$ is used. With a probability of p_{opt} each node can become a cluster head at initially. On average, $n \times p_{opt}$ nodes must become cluster heads each round each epoch, with nodes elected to be CH in the current round not being able to become cluster heads in the same epoch. The non-elected nodes belong to the set G, and the probability of nodes G becoming cluster heads increases after each round in the same epoch in order to maintain a constant number of cluster heads per round. In [0,1], the selection is taken at the beginning of the random number. If the random number generated by each node $s \in G$ independently choosing a ran- T(s) is less than a threshold. In the current round, the node becomes a cluster head. the threshold is set as:

$$T(s) = \begin{cases} \dfrac{p_{opt}}{1 - p_{opt}\left(r, \bmod \frac{1}{p_{opt}}\right)}, & if s \in G \\ 0, & otherwise \end{cases} \tag{3.1}$$

Where r is the current round number

in TSEP [47], the initial energy of the normal node (class A) E_0 We have: energy for normal nodes , and for advanced nodes $E_{adv} = (1+\beta)E_o$ Assume for intermediate nodes, $E_{\text{int}} = (1+\alpha)E_o$

If we choose P_{nrm}, P_{int}, P_{adv} and for probabilities of becoming normal, intermediate and advanced nodes respectively. Hence, we have:

$$P_{nrm} = (P_{opt} / (1 + m \times \alpha + b \times \beta)) \tag{3.2}$$

$$P_{\text{int}} = (P_{opt} \times (1+\alpha) / (1 + m \times \alpha + b \times \beta)) \tag{3.3}$$

$$P_{adv} = (P_{opt} \times (1+\beta) / (1 + m \times \alpha + b \times \beta)) \tag{3.4}$$

We must set a new threshold for the election procedures to ensure that the sensor nodes must become cluster head as we assumed previously. The threshold between normal, intermediate, and advanced becomes ($T(n_{nrm})$) $T(n_{\text{int}}), T(n_{adv})$ respectively:

$$T(n_{nrm}) = \begin{cases} \dfrac{p_{nrm}}{1 - p_{\text{int}}(r \times \text{mod}(\dfrac{1}{p_{nrm}}))}, if n_{nrm} \in G \\ 0, Otherwise \end{cases} \tag{3.5}$$

$$T(n_{\text{int}}) = \begin{cases} \dfrac{p_{\text{int}}}{1 - p_{\text{int}}(r \times \text{mod}(\dfrac{1}{p_{\text{int}}}))}, if n_{\text{int}} \in G'' \\ 0, Otherwise \end{cases} \tag{3.6}$$

We have $n \times b$ intermediate nodes; with G″ as the set of intermediate nodes that has not become cluster head in the past $\dfrac{1}{p_{\text{int}}}$ round r

$$T\left(n_{adv}\right)=\begin{cases}\dfrac{p_{adv}}{1-p_{adv}(r\times \mathrm{mod}(\dfrac{1}{p_{adv}}))}, if n_{adv}\in G''' \\ 0, Otherwise\end{cases} \tag{3.7}$$

We have $n\times m$ advanced nodes; with G‴ as the set of advanced nodes that has not become cluster head in the past $\frac{1}{p_{adv}}$ round r.

At the network field data transmission stage from CH to BS consists of three main activities, the first is data gathering, by the help of member node the CH collects data from the sensing environment. The next one is data aggregation, after CHs accept data from member nodes, instead of transmitting all the data, they check the contents of received data and then combine them by removing redundant data. Finally, the cluster head send the aggregated data to BS based on hard and soft threshold this process called Data Sending.

3.6 Radio Energy Dissipation Model

The energy spent by the radio to achieve an acceptable Signal-to-Noise Ratio (SNR) when delivering a kbit message across a distance d, according to the radio energy dissipation model depicted in Figure 3-3 is provided by;

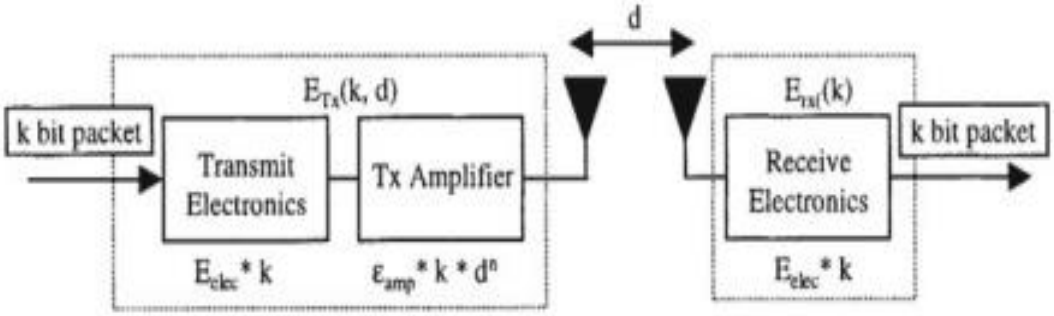

Figure 3-3 Radio Energy Dissipation Model [48]

$$E_{TX}(K,d) = \begin{cases} K \times E_{elec} + K \times E_{fs} \times d^2 & if \ d < d_0 \\ K \times E_{elec} + K \times E_{mp} \times d^4 & if \ d > d_0 \end{cases} \tag{3.8}$$

E_{mp} and E_{fs} are dependent on the energy dissipated per bit to run the transmitter or receiver circuit for a short and long-distance transmutation respectively. while E_{elec} is the electronic components of energy dissipated per bit to run the transmitter or receiver circuit. We used the transmitter amplifier model, where the distance between the transmitter and recipient is denoted by d. In order to receive a kbit the radio sends out the following message:

$$E_{Rx} = E_{elec} \times K \tag{3.9}$$

The energy dissipation of each CH and CM node is calculated using the first-order radio energy model developed for a 3-level heterogeneous wireless sensor network. The amount of energy dissipated in a CH node throughout the particular round is computed.

$$En_{CH} = \begin{cases} k \times (E_{elec} \times E_{DA}) + E_{FS} \times k \times d_{BS}^2 & if \ d < d_0 \\ k \times (E_{elec} \times E_{DA}) + E_{mp} \times k \times d_{BS}^4 & if \ d > d \end{cases} \tag{3.10}$$

Where $d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}}$ The energy of data aggregation is E_{DA}, while the average distance between CH node and a base station is d. The amount of energy wasted by the CM node in a given round is the same as;

$$En_{CM} = \begin{cases} k\times(E_{elec}\times E_{DA}) + E_{FS}\times k\times d_{CH}^{2} & if\ \ d<d_0 \\ k\times(E_{elec}\times E_{DA}) + E_{mp}\times k\times d_{CH}^{4} & if\ \ d>d \end{cases} \tag{3.11}$$

The average distance between a CM node and its CH is d_{CH} a node E is the total starting energy of the entire heterogeneous network. Express by Eq. (3.12)

$$\frac{1}{p_{opt}}(1+mx\beta+bx\alpha) \tag{3.12}$$

The total energy of the network expresses as E_{total};

$$E_{total} = n\times E_0(1+m_{0\times\alpha}+m_1\times\beta) \tag{3.13}$$

where E_0 is the starting energy of class_ A nodes. The energy factors in the network are α and β, which means that class_ C nodes have β times greater energy than class_ A nodes and class_ B nodes have α times more energy than class_ A nodes. for all the other variables defined in Eq. (3.12) are given in Table 3_1.

$P_{opt,}$ or the optimal probability of a sensor node becoming a cluster head, can be calculated as follows for a given kopt is the optimum number of clusters:

$$P_{opt} = \frac{k_{opt}}{n} \tag{3.14}$$

in TSEP, the initial energy for normal nodes (class_ A) is Eo, and for advanced nodes (class_ C) $E_{adv} = (1+\beta)E_0$. Assume for intermediate nodes (class_ B), $E_{\text{int}} = (1+\alpha)E_0$. And the new epoch of the system must be equal to $\frac{1}{p_{opt}}(1+mx\beta+bx\alpha)$ [30].so the CH elected as the threshold value defined in Eq. (3.5), (3.6), (3.7) and compare it to the random number generated by the sensor node.

3.7 Simulation Settings

3.7.1 Performance of SEP, DEEC and TSEP

The SEP protocol creates sensor network heterogeneity based on two levels of heterogeneity. The cluster head election SEP methodology is carried out at random based on the probability of each node type. As a result, two-level heterogeneity boosts throughput, network life, and stability. The fundamental disadvantage of SEP is that it is not well suited for use in multilevel heterogeneous sensor networks with more than two types of sensor nodes. As a result, DEEC outperforms SEP. In DEEC, the cluster head is chosen based on the ratio of each node's residual energy to the network's average energy, and each node expends energy equitably by rotating the cluster head role among all nodes.

Under comparison to TSEP, the lifespan of the network in the DEEC protocol is increased due to the consideration of residual energy for CH selection. By using a heterogeneous-aware clustering algorithm, DEEC can extend the network lifetime, particularly the stability phase. In the DEEC, advanced nodes always punish, especially when their residual energy is lowered and they enter the range of normal nodes. The advanced nodes die faster than the others in this location [48]. Because the cluster head selection process and data transfer from cluster head to based station in TSEP is better than in SEP and DEEC, the network life span is extended, the sensor node's energy consumption is optimized, and the stability period is increased [49].

Using MATLAB, we created a heterogeneous clustered WSN model with area dimensions of (100× 100) m^2. A total of 100 (n) sensor nodes (of various sorts) are deployed in a network area of 100 ×100 m^2. Sensor node installation and deployment in agricultural applications such as irrigation and pest control are dependent on the detecting range of the sensors, which means that certain sensor nodes must cover (or detect) every area of the agriculture field. The maximum number of sensor nodes required to ensure network coverage and connectivity. The radio parameters used for the simulations are given in Table 3_1.

Table 3-1 Simulation Parameter

parameter	value
Total number of sensor nodes in network (n)	100
Data Packet size (k)	4000 bits
Initial Energy of a Class_A node (E0)	0.5J
Initial Energy of a Class_B node (E0 * (1 +α)	1J
Initial Energy of a Class_C node (E0 *(1+β))	1.5J
Energy factor (α) and (β)	α=1, β=2
Energy consumed by amplifier to transmit over a longer distance (E_{amp})	0.0013pJ/bit/m^4
Energy consumed by amplifier to transmit over a shorter distance (E_{fs})	10pJ/bit/m^2
Energy consumed in the electronics circuit to transmit or receive the signal (E_{elece})	50nJ/bit
Data aggregation energy (EDA)	5nJ/bit/report
d_0	87m
Network field	(100,100)

Finally, figure 3-4 show that the generals over view of the above detail description of system model.

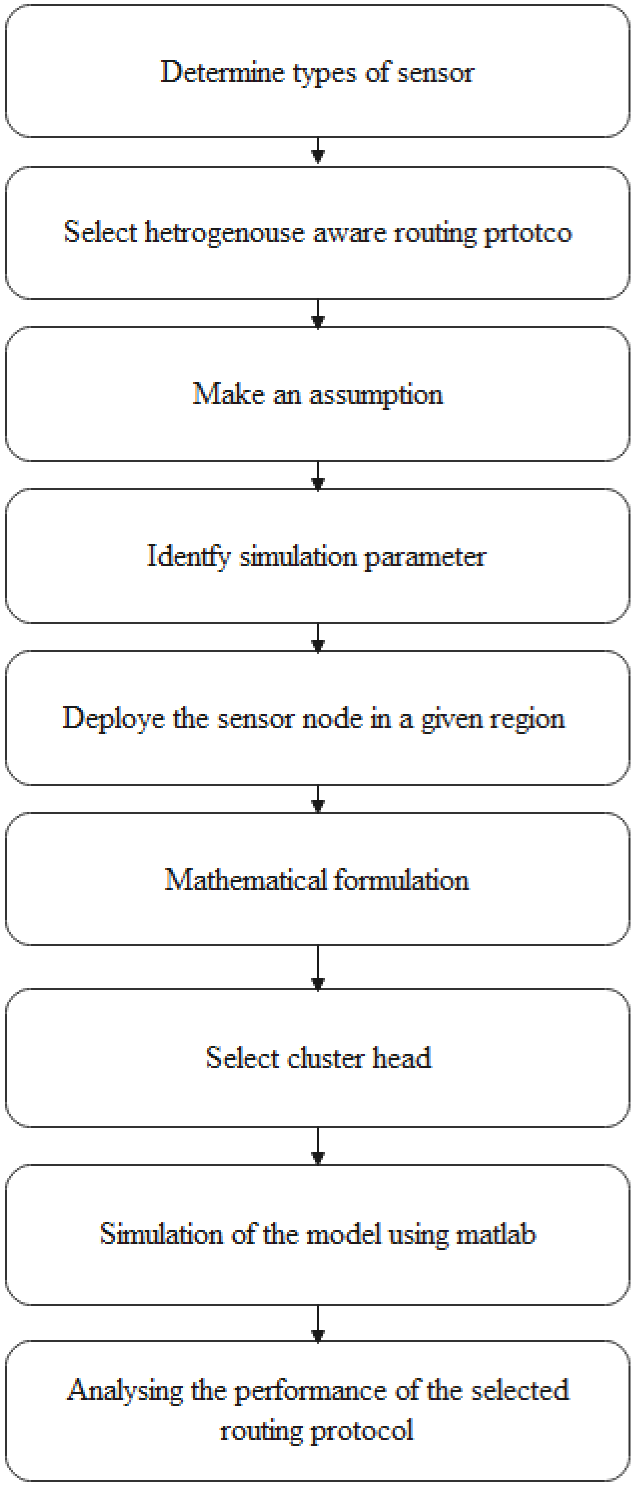

Figure 3-4 The Block Diagram of Research Methodology

Finally, figure 3-4 show that the generals over view of the above detail description of system model.

CHAPTER FOUR

4 RESULTS AND DISCUSSIONS

4.1 Simulation Results

Using MATLAB simulator, we analyze the performance of SEP, DEEC and TSEP and also, we further evaluate the one which performs better with different parameters. The performance evaluation is based on the following metrics: a number of packet size which is the quantity of data messages statistics which indicates how many data messages the network sends to the base station, number of Alive nodes and stability and instability period of a protocol in a given round. The network operates well and also will have a long-life time if the node lifespan is high. The duration between the start of network operation and the death of the first node is known as the stability period whereas the instability period is the time between the first dead node and the last dead node.

Table 4-1 Compression for Performance of Protocol on given Alive Nodes per Round

	Number of alive nodes		
Number of rounds	SEP	DEEC	TSEP
0	100	100	100
1000	100	100	100
2000	4	51	100
3000	1	1	100
4000	0	0	37
5000	0	0	3
6000	0	0	0
7000	0	0	0
8000	0	0	0
9000	0	0	0

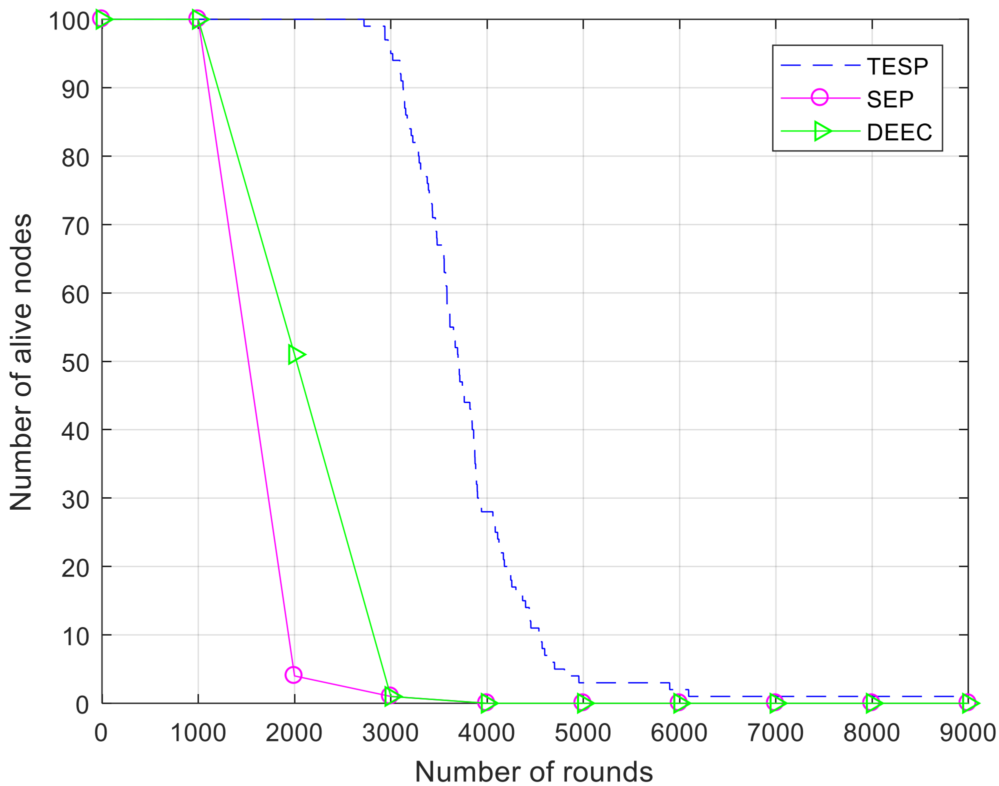

Figure 4-1 Number of alive nodes per number of rounds

Figure 4.1 shows the comparison of SEP, DEEC, and TSEP in terms of the number of alive nodes per a given number of each transmission round. In SEP, the first node dies at 1064 round. After this round, the number of alive nodes decrease from round 3204 to 4194 and the number of alive nodes becomes 1 and finally it becomes zero until 9000 rounds. However, in DEEC the all-number node alive until 1295 round. After this point, the number nodes start to die and it becomes 0 between 3408 and 9000 rounds. The network lifetime is enhanced significantly in DEEC compared to SEP. In TSEP, there is no dead nodes up to 2780 round and after this round, the number of nodes starts dead and it becomes 0 from 6560 to 9000. Then, all the alive nodes disappeared up to the end of the simulation period. This comparison clearly shows that the greater number of nodes are alive in TSEP than DEEC and SEP therefore the life time of TSEP becomes better than the rest two due to less energy consumption. Moreover, the stability and instability period of TSEP increases and decreases respectively.

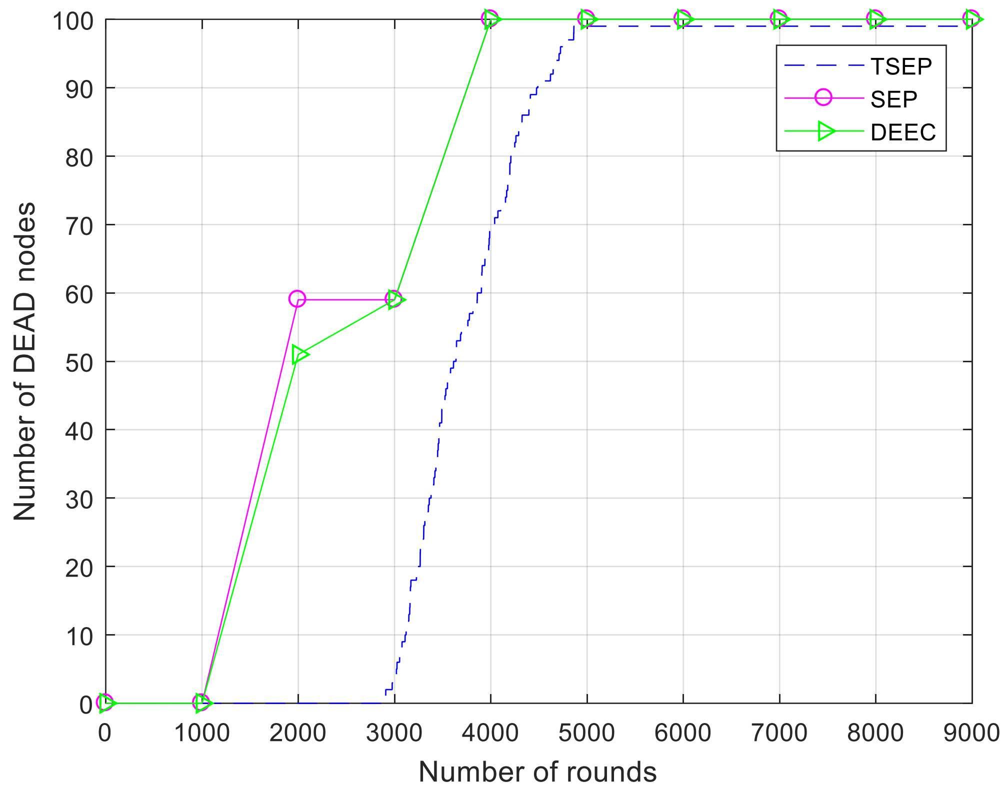

Figure 4-2 Number of dead nodes per number of rounds

Figure 4.2 depicts the number of dead nodes per transmission round of the three routing protocols. From the figure, a number nodes start to die at 1240 rounds and after this point the number of nodes begins to reduce at faster rate up to 2900. After this point, the number of dead nodes becomes 100 and this means there is no alive node. In DEEC, at round 1280 the number of nodes start to die and continue up to 3005 and all nodes die after this point. Here, TSEP has better stability status as the first node starts dying at 2620 round. This shows that nodes live longer time in TSEP. So, the TSEP protocol has better network performance than SEP and DEEC in terms of energy consumption, battery life, and stability period.

Table 4-2 Compression for Performance of Protocol on given Packet to bs per Round

Packet to bs			
Number of rounds	SEP	DEEC	TSEP
0	0	0	0
1000	10901	10901	12245
2000	16693	18955	24641
3000	18421	24710	36905
4000	19679	40138	45564
5000	20757	46130	47603
6000	21757	46975	47903
7000	22757	47030	48085
8000	23757	48335	48228
9000	24757	48335	48382

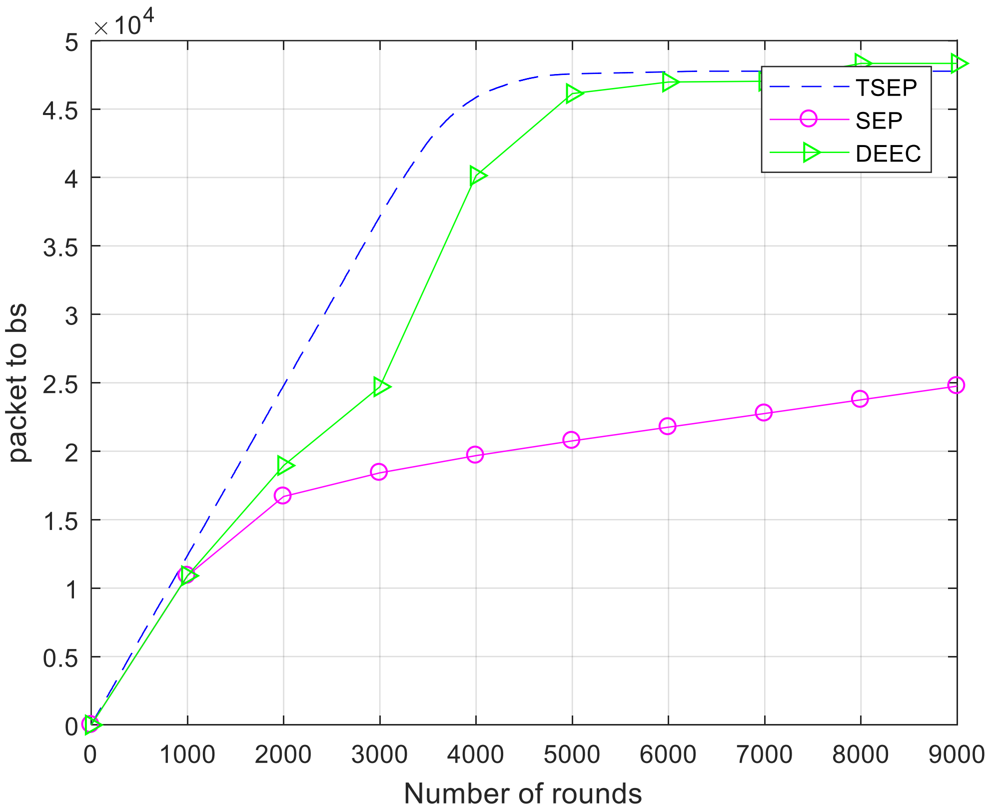

Figure 4-3 Packet to BS per number of rounds

Figure 4.3 presents the effect of number of rounds on the packet size to be transferred to the BS through the cluster head of SEP, DEEC and TSEP. For all protocols, increase in each round leads to increase in number of packets to be transmitted. However, when the three protocols are compared, SEP performs less than the other two and TSEP performs better. For instance, at 6000 rounds, the number packets are $2x10^4$, $4.6\ x10^4$ and $4.7x10^4$ for SEP DEEC and TSEP respectively. The rate of increase between SEP and DEEC is greater than the rate of increase between DEEC and TSEP. The reason behind better performance of TSEP is that TSEP consider the hard and soft threshold for data to be sent from sensor node to base station. This also enhances the network life span and reduce the energy consumption.

In the next part we analyze the performance of TSEP, SEP and DEEC by reducing the number of rounds and analyze the TSEP by varying the number of nodes, the number of round and the area of the network and also initial energy of the network.

Table 4-3 The performance SEP, DEEC and TSEP in different round

Performance metrics	Round =9000			Round =6000		
	SEP	DEEC	TSEP	SEP	DEEC	TSEP
Number of rounds when the first node dies (stability period)	1120	1295	2482	1163	1342	2946
Number of rounds at which 50% of the node die	1400	2049	3780	1365	2082	3831
Number of rounds wherein all sensor nodes die	4821	3407	Greater than 9000 rounds	3800	2908	Greater than 6000 rounds

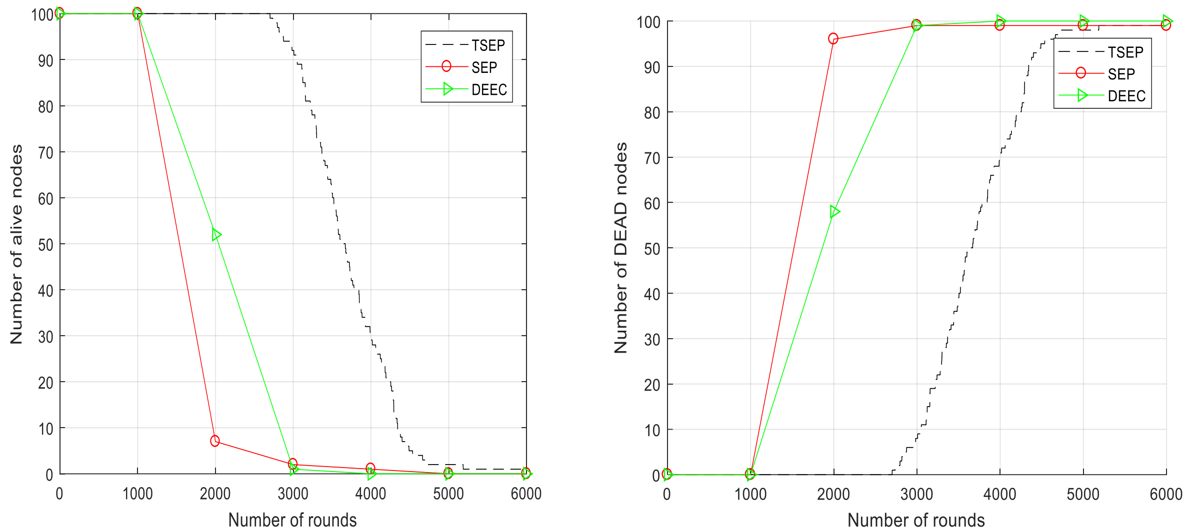

Figure 4-4 The number alive nodes and dead nodes per round

Figure 4.4 shows the comparison of three types of routing protocol in 6000 and 9000 rounds from figure 4-4 and 4-1 respectively. As the number round grows up, the number of alive nodes decreases and the stability period is reduced eventually. As shown in Table 4.3 TSEP at 9000 maximum number of rounds the first node starts to die at 2482 rounds but in 6000 maximum rounds, first node dies at 2946 and the half of the sensor nodes die at 3780 and 3831 rounds in 9000 and 6000 round respectively. Similarly, in DEEC and SEP at the given 9000 round the first node die at 1295 and 1120 respectively. In DEEC at total of 6000 rounds, the first node dies at 1342 and also the half the node alive until 2082 round and the number of node alive up to 3800. So, the stability period increases in TSEP than SEP and DEEC in a given number of rounds and the life span of the sensor network prolonged as the number round decrease and also reduce the instability period.

In the rest of the portion below, we analyze the performance of TSEP protocol by varying the maximum number of nodes to be deployed, the number of rounds, initial energy and area of deployment.

Table 4-4 Performance analysis of different number of nodes at a given area

Performance metric	Area=100*100m^2			Area=50*50m^2		
	n=10	n=25	n=30	n=10	n=25	n=30
Number of rounds at which first node dies (stability period)	3660	2590	2580	4599	3007	2505
Number of rounds at which 50% of nodes die	4449	3325	3194	5574	3620	3444
Number of rounds at which all sensor nodes die	Greater than 7000 rounds	6320	4420	Greater than 7000 rounds	6144	6040

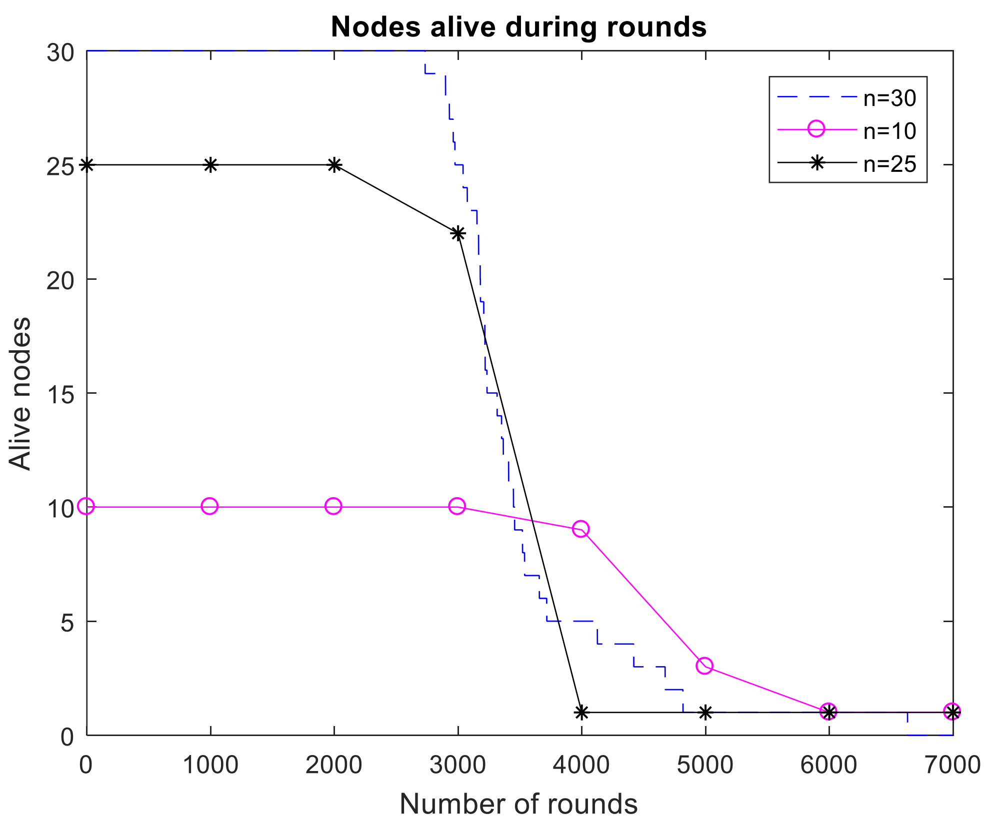

Figure 4-5 The number of alive per round for n=30, n=25 and n=10 at 100^{2}m

Figure 4.5 shows different number of alive nodes per number of rounds. We have evaluated the alive nodes using different total number of nodes to be deployed within a given area. We have also evaluated the number of rounds at which first node dies (stability period), number of rounds at which 50% nodes die and number of rounds at which all the nodes become dead. Accordingly, the first node starts to die for n=10, 25 and 30 at rounds 3660, 2590 and 2580 respectively. Again, for n=10, 25 and 30 the round at which half of the number of nodes becomes dead is at rounds 4449, 3325 and 3194 respectively. Finally, we have also checked the rounds at which all number of nodes become dead for each maximum number of deployed nodes. From this we observe that decrease in number of deployed nodes decreases the number of dead nodes and increases duration at which the first node starts dying. As a result, we can conclude that the greater the number of node alive the less number node survive at a given area.

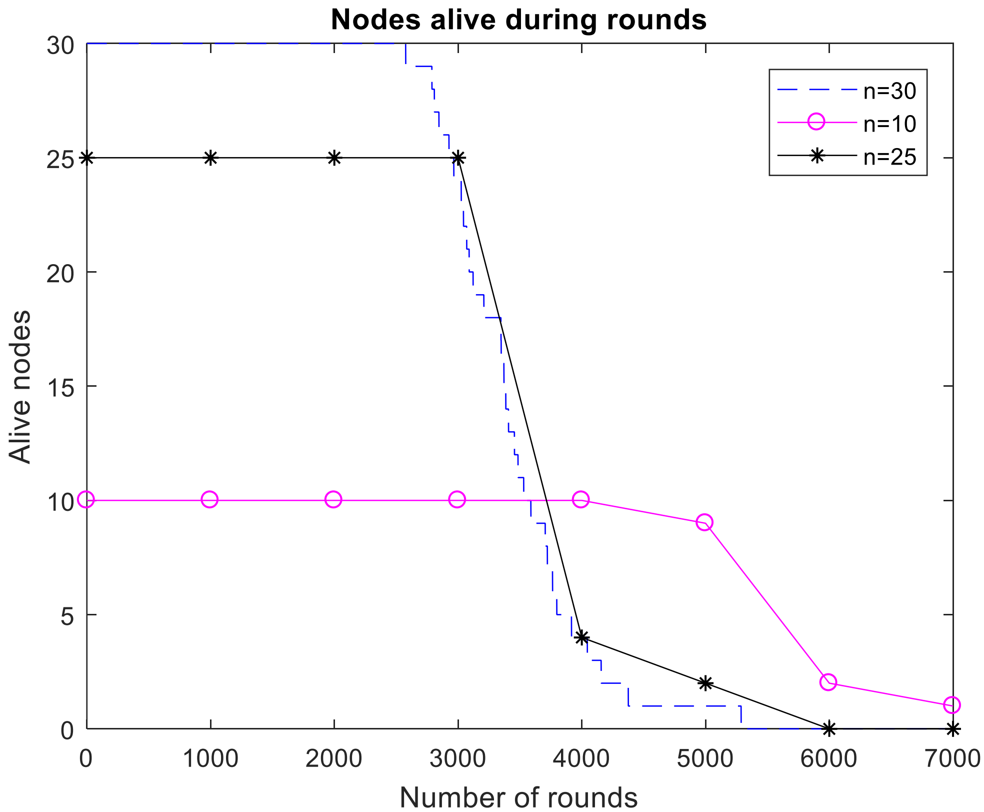

Figure 4-6 The Number of alive per round for n=30, n=25 and n=10 at 50^2m

Figure 4.6 presets the effect of deployment area on the status of the nodes. As the size of deployment area increases and decreases, the number of alive nodes increases and decreases at each round as well. As shown in figures 4.5 and 4.6, the smaller the size of the deployment area, the greater the number of alive nodes occur. For instance, the number of alive nodes in figure 4.6 is greater than that of 4.5.

Table 4-5 Performance of alive nodes by varying initial energy and number of rounds

Performance metric	E_0=0.6, round=6000			E_0 = 0.4, round=8000		
	n=10	n=25	n=30	n=10	n=25	n=30
Number of rounds the first node dead (stability period)	5540	3551	3344	3843	2400	2105
Number of round 50% node dead	5980	4238	4080	4202	2909	2700
Number of rounds the all number of node dead	4 nodes alive	2 nodes alive	1 node alive	1node alive	1 node alive	6059

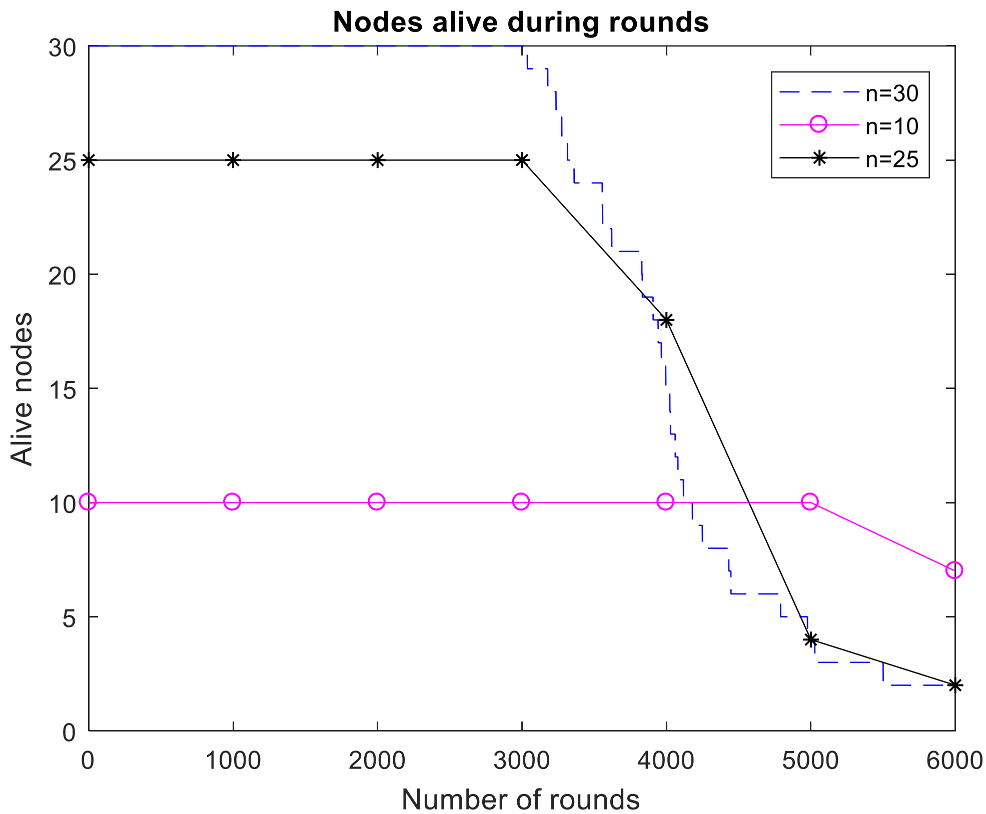

Figure 4-7 The number of alive Vs round for Initial Energy(E0) = 0.6, r=6000

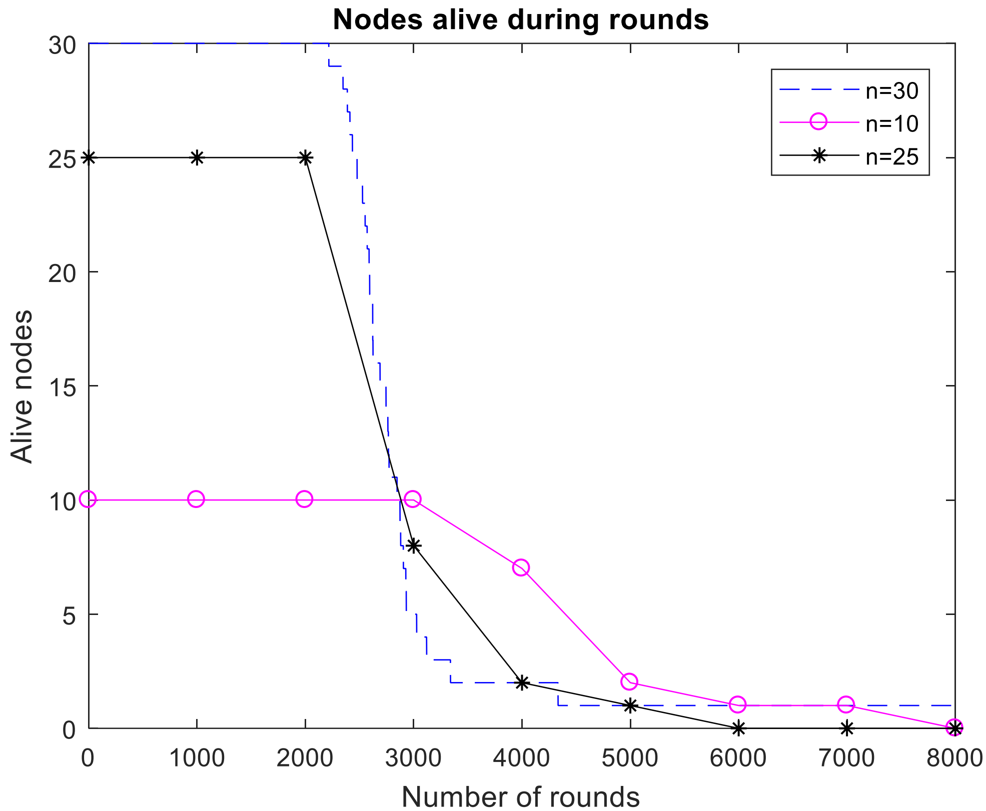

Figure 4-8 The number of alive vs round at initial energy (E0) =0.4, r=8000

Figure 4.7 shows that the performance each sensor node at initial energy change from 0.5 to 0.6 and the number round at 6000. Even though decreasing the number of rounds also increases the number of alive nodes, the effect of increase in initial energy surpasses the effect of decreasing the number of rounds. Therefore, In Figure 4.7, a greater number of alive nodes are recorded than that of figure 4.8. For example, In, Figure 4.8 shows the performance of the sensor node by lowering the initial energy and by increasing the number of rounds from 6000 to 8000. In this case the first node dies at n=10 and the round reduce from 5540 to 3843 and also the half of the sensor node dies at less round compared to figure 4.7, So, get better stability period and increase the network lifetime by considering the sensor node have high initial energy.

5 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

In this thesis random deployment-based clustering network deployment of heterogeneous sensor nodes is evaluated by classifying the nodes in to different categories as class_A, class_B and class_C. After deployment of the specified nodes in a given area, clustering is done depending on the algorithm of each protocol and so that the cluster heads are selected using energy level and some random numbers compared to a threshold. Furthermore, we have evaluated SEP, DEEC and TSEP protocols using packet sizes, stability period and instability period. After finding the best performing protocol we have also further evaluated its performance. For this it has been observed that TSEP shows better compared to the other two. TSEP is the threshold-based cluster head selection and the data transmission thresholds (hard and soft threshold) can be set to reduce the unwanted data transmission and to accept data according to users' demand. Therefore, the information regarding the agricultural field received at the base station helps the farmer to make a decision about weed detection. Due to this reason, TSEP is found to have best stability period and network life time compared to the DEEC and SEP protocols. Therefore, TSEP is more preferrable for agricultural precision due to its high network life time and intensive packet size to be transferred to a base station.

5.2 Recommendation

This work might also be expanded to provide an energy-efficient routing protocol for a wireless sensor network with a multi-hop communication paradigm for monitoring a broad area. And improve TSEP protocol on the bases of multi-hop communication.

RESEARCH FUND ACKNOWLEDGEMENT

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