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ENERGY EFFICIENT PROTOCOLS FOR STABLE CLUSTERINGIN HETEROGENEOUS WIRELESS SENSOR NETWORKS

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Master Thesis

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Anmar Yahya Taher

DEDICATION

I would like to dedicate this work to my first teacher, my mother, my first supporter and role model, my father and my companion throughout the journey. Without you, this dream would never come true and to my brother and my sister who stood with me in order to achieve my dream.

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ABSTRACT

ENERGY EFFICENT PROTOCOLS FOR STABLE CLUSTERING IN HETEROGENEOUS WIRELESS SENSOR NETWORKS

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In a wireless sensor network (WSN), the limitation of the energy source is due to the battery capacity of the sensor nodes. The WSN clustering provides a help in reducing energy consumption for the reason of transmission energy which is associated with the distance resulted in the sender and receiver. The WSNs performance encountered a number of challenges summarized by energy consumption that is considered a field of hot research. The energy of WSN is utilized for transmitting the sensor node's data from either between each others or to a Base Station (BS). The researchers were focused on further prolong the WSN lifetime, they had proposed many routing protocols for clustering. Though, the energy consumption of the total network protocols are not well minimized and underestimated. Wireless Sensor Network (WSN) comprises a huge number of small sensors that have obtainable limited energy at their disposal. The sensor networks present a powerful collection of distributed sensing, computing and communication abilities. They provide themselves for supporting uncounted applications. however, simultaneously, offer various challenges because of their abnormal characteristics; mainly the stringent energy-availability restrictions imposed by sensing-nodes and typically the WSNs are subjected to them. The restrictions like Prolonged network lifetime, node mobility.

Keywords: Heterogeneous WSN, Energy Efficient Protocol, CCS & SEP, HPEEA protocol.

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LIST OF ABBREVIATIONS

APTEEN	Adaptive threshold-sensitive energy efficient protocols
BS	Base Station
CBERP	Cluster Based Energy Efficient Routing Protocol
CCBR	Context-aware and content-based routing
CH	Cluster Head
CCS	Concentric Clustering Scheme
DRAND	Distributed Randomized time slot assignment algorithm
HWSN	Heterogeneous wireless sensor networks
HEED	Hybrid energy efficient, and distributed
HPEEA	Heterogeneous Protocol Energy Efficiency
LEACH	Low Energy Adaptive Clustering Hierarchy
LCA	Linked Cluster Algorithm
MEMS	Micro-electro mechanical system
PEGASIS	Power-efficient gathering in sensor information systems
SEP	Stable Election Protocol
SPIN	Sensor protocols for information via negotiation
TEEN	Threshold Energy Efficient Network

TDMA	Time Division Multiple Access
VCP	Virtual cord protocol
WSN	Wireless Sensor Networks

1. INTRODUCTION

1.1 INTRODUCTION

Recently, self-organized wireless sensor networks (WSNs) have become widely accepted and used because of the improved efficiency of the microminiature sensor in terms of sensitivity and capability, as well as low cost[1]. They are basically made up of numerous sensors that monitor an area of interest, and they use unique routing protocols for the exchange of information. Usually, the use of the sensors is randomly employed in tough environment using aircraft, and organize by themselves. More so, the use of WSNs in detection of forest fire, medical systems and healthcare, and smart homes is as a result of the convenience of deployment, low price and self-organization[2].

In recent times, the attention of researchers has been drawn to Wireless Sensor Networks (WSNs) because of their applicability in numerous practical applications [3]. WSNs are distinguished from other traditional networks by some of the characteristics which they posses, and some of such characteristics include, their computational capabilities, sources of energy, and limited data storages [4]. Thus, when the WSNs are to be used, it is important that their characteristics be put into consideration. Several routing protocols have been introduced to facilitate the transfer of collecting data to a Base Station (BS), from where it is then forwarded to the end-user [5].

Wireless sensor networks are a type of ad-hoc networks that have nodes serving as sensors with communication and data sensing capability. These sensors often possess limited power, function independently, and require no supervision when they are used. The sensors consist of a radio transceiver, transducer, source of power (usually batteries) and micro-controller used for monitoring environments. Sensor nodes have the ability to sense different kinds of information from an environment, including direction of wind, humidity, light, temperature, pressure and lots more [6]. The data which is acquired is often transmitted by the sensor node via the radio frequency channel to the gateway or base station. Currently, the use of WSNs is employed in a wide range of applications like monitoring and control of industrial processing, environment monitoring, monitoring of habitat, home automation, health care applications, remote control, tracking of an object, traffic control and many more military and civilian applications.

Nevertheless, there are some limitations associated with the WSNs in terms of design and required resources for practical use [7]. Resource constraints are referred to the insufficient supply of valuable resources such as:

a) Lifetime

b) Energy

c) Processing power

d) Bandwidth

e) Communication range

f) Storage capacity

Therefore, network lifetime is one of the most crucial factors of design. One of the main techniques used in ensuring energy efficiency, is clustering, which facilitates the extension of the lifetime of a sensor through the decrease of energy consumed by the sensor nodes [8].

The aim of the current project in the area of WSNs is to address the discussed limitations through the new design concepts, creation of novel or improvement of extant protocols, as well as the development of novel algorithms. Currently, researchers are involved in the development of schemes that are capable of meeting these requirements of WSN. Energy consumption is one of the biggest problems associated with WSN. Therefore, it is important that such a problem, be carefully investigated so as to observe the patterns of consumption at each sensor node of the network. Gaining insight on this problem is crucial to the enhancement and development of an appropriate algorithm so that the ideal energy consumption can be achieved while the lifetime of the network is maximized [9]. Sensor nodes are basically powered by small batteries that can only store limited energy for short a period of time. In general, the use of sensor nodes is employed in remote unsupervised areas. In this regard, it is difficult to externally replace or replenish the energy of the battery. Thus, in this situation, the major goal will be to use a given energy to prolong the lifetime of the network. This issue should be addressed in a manner that reduces the consumption of energy in every aspect. One of the ways through which the consumption of energy can be reduced is by making the network power-aware of designing it in a manner that allows the strategic usage of the system. By means of the energy in the sensor nodes, a crucial task of real-time data recording from the sensors is fulfilled. Thus, this study is aimed at identifying ways through which protocols that are efficient and energy-aware can be designed to facilitate the prolongation of the lifetime of intact networks in WSN. One of the key parameters of WSNs is the lifetime of sensor nodes [10]. Another major issue related to WSNs is the identification of suitable cluster-heads and energy efficient routing protocol. This has recently been the focus of research and development, where many researchers are working on these lifetime extension.

In WSNs the sensors are regarded as homogeneous, but in the real sense, homogeneous sensor networks hardly exist. Even if they exist, they also have varying levels of initial energy, rate of depletion, etc.

On the other hand, heterogeneous wireless network is made up of sensor nodes that have different abilities like sensing range and computing power. In comparison with homogeneous WSN, the control of the topology and deployment of heterogeneous WSN involves a complex process.

The sensing in heterogeneous sensor networks, are typically performed by a large number of inexpensive nodes, while the energy of few nodes is relatively more than that of the remaining that perform the tasks of transport, filtering and fusion [11]. A variety of devices are used by these nodes, and these devices work collaboratively in order to achieve a goal. The use of small and inexpensive sensor nodes with high density is employed, and these small sensors can be attached to moving objects and humans within the environment that is being monitored. On the hand, stable data storage, intensive processing and actuation are provided by the powerful nodes.

The main objective of such a network is the distribution of workload based on the nodes' capabilities. To this end, it is important to study heterogeneous networks in which two or more kinds of nodes are considered [12]. The heterogeneity possessed by wireless networks can enhance the network reliability and lifetime. The usefulness of heterogeneous sensor networks is more prominent in practical applications due to their closeness to real life situations. The majority of the energy protocols that have been recently designed for heterogeneous networks are based on the clustering technique, and these protocols are effective in terms of scalability and energy conservation in WSNs.

This research is driven by the fact that the role of cluster head is rotated among the sensor nodes, thereby allowing the distribution of energy consumption optimally among nodes within the network. A network's energy efficiency is greatly enhanced by the selection of cluster head for such rotation. In this thesis, an investigation of several routing protocols and algorithms is carried out with the aim of identifying ways through which the consumption of energy can be minimized.

1.2 WIRELESS SENSOR NETWORK AND COMPONENTS OF SENSOR NODE

Wireless The constituents of a wireless sensor networks are a large number of sensors, that are placed in arranging manner or randomly deployed within a geographical location. The networking of these sensors is done through wireless links to enhance the formation of a WSN. With the use of these sensor nodes, the ambient condition of an environment can be processed, thereby revealing the characteristics of the phenomena occurring within the given environment in which the sensor nodes are deployed. For data to be integrated and disseminated, the sensor nodes within the WSN communicate with each other as well as with the base station.

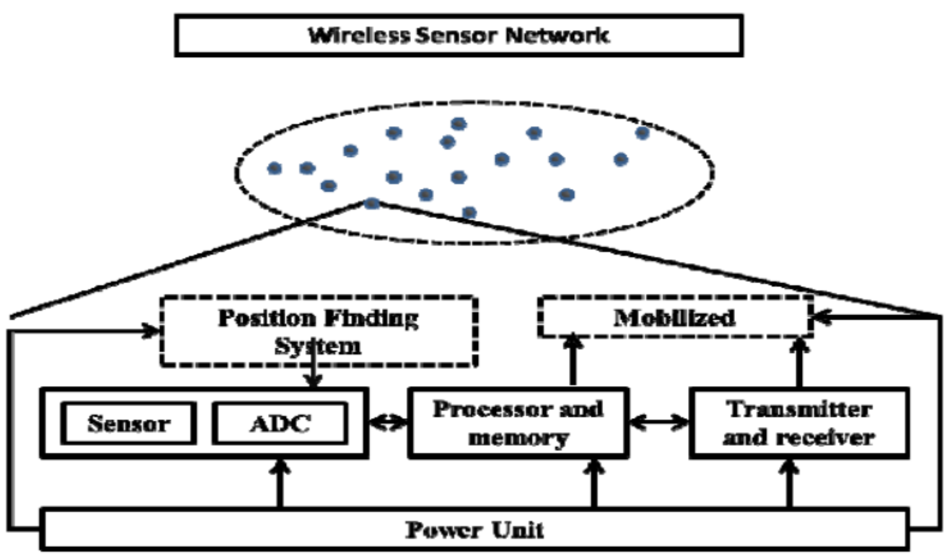


Figure 1.1: WSN And Components of Sensor Node

The use of WSNs is popularly employed in civilian, industrial and military applications. In military applications, WSNs are used for surveillance in the battlefield, detection of invasion, target field and imaging. Nevertheless, the use of WSNs is now employed in civilian applications in the areas of quantitative and qualitative analyses. They have also been used to monitor habitat and environment, in healthcare applications, traffic control and home automation. Typically, WSNs are made up of hundreds or thousands of sensor nodes that allow the accurate sensing of a larger geographical area.

As presented in Figure 1.1 there are three main components possessed by each node, and they are listed accordingly as sensing unit, processing unit, and transmission unit, they are discussed below:

1.2.1 Sensing Unit

The sensing unit is a unit that consists of two subunits, which are the sensors themselves, and analog-to-digital converters (AD-Cs). The signals which the sensors generate based on the phenomenon to be sensed are naturally analogous, and as such should be converted to digital so as to facilitate further processing [13]. Data within the environment is sensed and processed by the node, which also sends the processed data to the base station. Subsequently, the signals are fed into the processing unit which is described subsequently.

1.2.2 Processing Unit

After the data within the environment has been sensed by the node, it is then processed and sent to the base. The core sensor nodes are primarily made up of the processing unit, which is linked to a small storage unit. The two units work jointly for the purpose of managing the procedures that make the sensor node collaborate with the other nodes to perform the task of sensing. The following processors are employed in the sensor nodes; Intel Strong ARM, Atmel At Mega Microcontroller, MSP430, etc.

1.2.3 Transmission Unit

Through the radio frequency channel, a wireless connection is established by the transceiver unit, which is also connected to an omnidirectional antenna that facilitates unidirectional communications. The transceiver is primarily responsible for conversion of a bit stream arriving from the processing unit to electromagnetic radio waves. The node senses the data from the environment, processes it and sends it to the base station. The data can either be routed by these nodes to the base station or to other sensor nodes in a way that the data finally arrives the base station. The sensor nodes,in majority of applications are limited in terms of power supply and communication bandwidth. In order to power these nodes, irreplaceable batteries are used, and this means that the network lifetime becomes dependent on the consumption of energy in the battery. Therefore, for this limited energy and bandwidth to be efficiently used, innovative techniques have been developed.

For these techniques to work, all layers of the networking protocol are carefully designed and managed. For instance, at the network layer, it is important to find suitable methods that facilitate the discovery of an energy efficient route that will transmit data from the sensor nodes to base station. The aim of this is to prolong the lifetime of the network.

1.3 CLUSTERING IN WSN

The organizational unit of WSNs is referred to as clusters. Due to the fact that these networks are naturally dense, they need to be broken down into clusters so as to enable the simplification of tasks like communication. The scalability of a sensor network can be enhanced by grouping the sensor. The cluster head is the leader whose selection can be made either by the sensors within a cluster or it could be pre-designed by the network designer [14]. The membership of the cluster could be variable or fixed. In order to enhance the scalability and efficiency of communication in WSN, researchers have specially designed some algorithms. Energy efficient routing can be carried out in WSNs using the concept of cluster-based routing.

1.3.1 Cluster Formation

Since the power that is used by sensor nodes is irreplaceable, the computing capacity of the node, communication and storage are limited. It is important for the WSN protocols be energy efficient so that the lifetime of the network can be maximized. In response to this need, LEACH (Low Energy Adaptive Clustering Hierarchy), which is an energy-efficient communication protocol was introduced. With this protocol, a hierarchical clustering is done using the information that has been received by the base station as shown in Figure 1.2. Occasionally, the cluster head and cluster membership are changed so that energy can be conserved. The information is collected from the sensors and aggregated by the cluster head, and afterwards passed to the base station. Uniform distribution of energy consumption is achieved through the random rotation of cluster head. In the study carried out by Arati Manjeshwar, too many cluster heads were selected for the base station without putting into consideration the residual energy. Consequently, the energy of some cluster head got exhausted fast, and thereby reducing the WSN's lifespan.

Each round of the cluster formation, requires the implementation of two steps by the network for the selection of cluster head and transfer of aggregated data. The two steps are;

1. Set-up Phase, which has subdivisions including, Advertisement, Cluster Set Schedule Creation phases.

2. Steady-State Phase, which involves the use Time Division Multiple Access (TDMA) for the transmission of data.

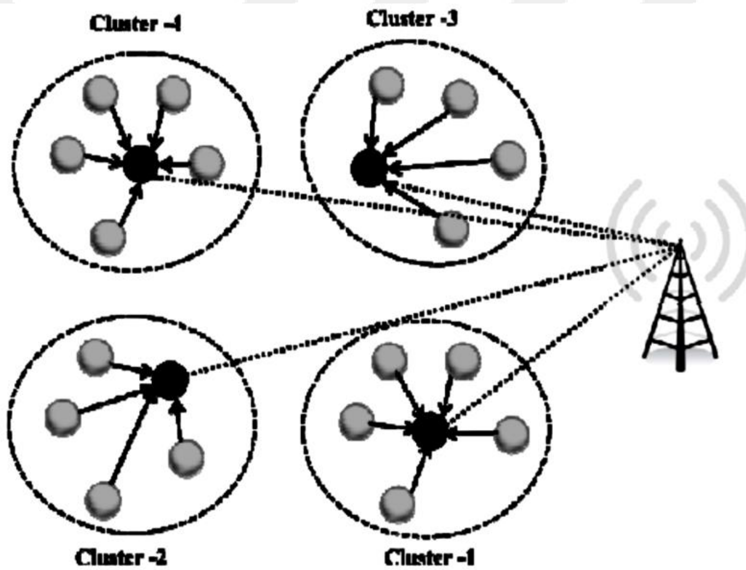


Figure 1.2: LEACH Clustering Communication Hierarchy for WSNs

There are some shortcomings associated with the selection of cluster head node in the LEACH protocol because of the existence of both very small and very large clusters within the network at the same time. Some of these shortcomings of clustering algorithms are listed below:

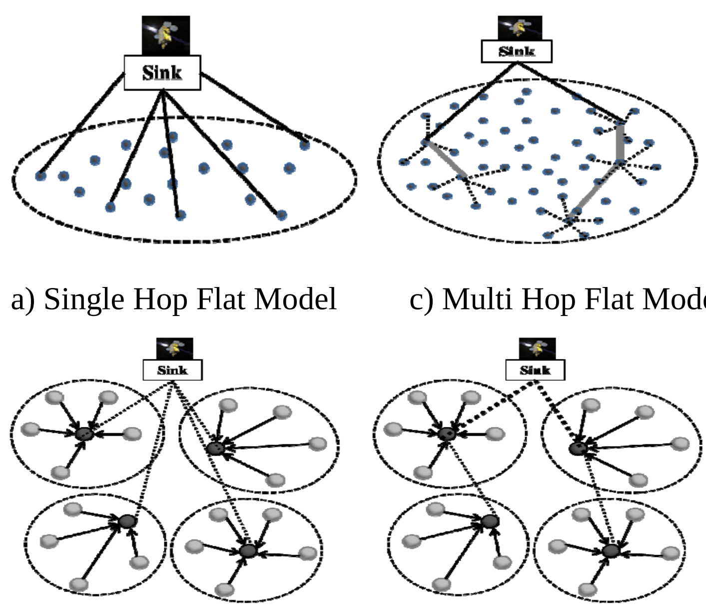
1. Unreasonable selection of cluster head can be made, while different energy is possessed by the nodes.
2. The death of cluster head leads to the depletion of cluster member nodes energy.
3. The nodes' location is not taken into consideration by the algorithm.
4. Residual energy, geographic location and other information are not taking into consideration, and this may lead to the rapid failure of the head node.

Based on this, so many researchers have proposed different clustering as found in the literature. Such studies have suggested various strategies that can be used in the selection of cluster head as well as its rotation.

1.3.2 Wireless Sensor Network

There are four main categories of WSN topologies as presented in Figure1.3, while Table 1.1 illustrates WSN topology classification and Table 1.2 the illustrates the strengths and weaknesses of these models. It can be observed from Figures 1.3 (a) and (b) that all the sensor nodes in the single-hop models transmit their data to the sink node directly.

Due to the cost of transmission using these architectures, they are infeasible in large-scale areas; this cost becomes expensive in terms of energy consumption, and in the worst case the sink node may be unreachable. In the multi-hop models, consideration can be given to the flat model (Figure1.3 (c)) and the clustering model (Figure 1.3 (d)). The consumption of energy and overhead in the multi-hop flat model can be increased because all nodes are required to share the same information like routing tables.



a) Single Hop Flat Model c) Multi Hop Flat Model

b) Single Hop Clustering Model d) Multi Hop Clustering Model

Figure 1.3: Classification of WSN Topology

Table 1.1: WSN Topology Classification

Flat Model		Clustering Model	
Strength	Weakness	Strength	Weakness
• Good quality routes from source to sink • There is no topology management concept • All the nodes participate in routing • Simplicity • Scalability • Communication is by flooding.	• Flooding is an expensive operation which is normally avoided by sensor network routing protocols. • Non- uniform energy distribution • High Latency • A large number of redundant messages. • Sensors are not aware of new members or died members. • Lifetime of a sensor network decreases. • Highly unreliable. • High delay.	• Less Load • Less Energy: Consumption • More Robustness • Collision Avoidance • Load Balancing • Fault-Tolerance • Guarantee of Connectivity • Maximizing of the Network Lifetime	• Energy dissipation rate is higher. • Network connectedness may not be guaranteed.

Table 1.2: WSN models

Single Hop Flat Model		Multi Hop Flat Model		Single Hop Clustering Model		MultiHop Clustering Model	
Strength	Weakness	Strength	Weakness	Strength	Weakness	Strength	Weakness
• Data transmission is achieved hop by hop typically using the form of flooding	• Small network • No guarantee delivery of data	• Wireless medium is shared & accomplished by individual nodes • WSN Reachability by providing multihop routes to inaccessible or hidden nodes • Multi- hop aggregates data from neighbor routes by using peer nodes as relays	• Low efficiency in the resource usage. • Increased latency	• No delay because of buffering	• Increasing of power consumption	•Reduces collisions between clusters • Lower Latency	• Power consumption is high

In contrast, the multi-hop clustering allows the maintenance of low energy consumption and overhead due to the fact that the data is aggregated by certain cluster heads, and they are afterwards transmitted to the sink node. In addition, it is the individual nodes that share and manage wireless medium in the multi-hop flat model, and this in turn leads to low efficiency in the resource usage. The allocation of resources in the multi-hop clustering model can be done orthogonally to each cluster, so that collisions between the clusters can be minimized, and reused cluster by cluster. Consequently, the multi-hop clustering model is suitable for the sensor network deployed in remote large-scale areas.

1.3.3 Classification Of Clustering Strategies

While the limitations of LEACH are addressed, several proposals have been made for clustering that can increase the lifetime of the network. These proposed clustering suggest the use different strategies for the selection of cluster head, as well as the rotation of role among the sensor nodes, using various criteria [15]. Using the given parameters, these strategies can basically be classified as adaptive, deterministic and combined metric (hybrid). In deterministic schemes the sensor node possesses special attributes like identification number (Node ID), number of neighbors they have (Node degree), and in adaptive schemes the role of nodes is determined when the data is gathered, using the resource information like the initial energy of nodes, remnant energy, and energy dissipated during the last round. There are two categories under which the adaptive schemes fail, and they include self-organized or base station assisted. The categorization depends on the initiator of the cluster head selection. Again, depending on the parameters that are used in determining the role of a sensor node, the probabilistic schemes can further be categorized as resources adaptive or fixed parameter. Some of the benefits of clustering include [16]:

1. The reduction of the routing table size stored at individual nodes through the localization of the route configured within the cluster.
2. The communication bandwidth can be conserved through clustering, since the inter-cluster interactions are limited to the cluster heads, while the redundant exchange of messages among sensor nodes is avoided.
3. The battery life of the individual sensors as well as the lifetime of the network can be prolonged by the cluster head through the implementation of optimized management strategies.

4. Clustering cuts on topology maintenance overhead. Sensors would only focus on connecting with their CHs.
5. The aggregation of data can be performed by a CH within its cluster, while the amount of redundant packets is reduced.
6. Am CH has the ability to minimize the rate of energy consumption by scheduling activities within the cluster.

It is generally assumed by researchers that sensor networks are homogeneous, however, they hardly exist in reality. Various capabilities such as different levels of initial energy and rate of depletion are possessed by homogenous sensors. The sensing in heterogeneous sensor Networks, is often performed by a large number of inexpensive nodes, while the filtering, fusion and transportation of data is performed by a few nodes whose energy is relatively high. It is based on this that a study of heterogeneous networks is carried out, with two or more kinds of nodes considered. The reliability and lifetime of the network can be enhanced through the heterogeneity in wireless sensor networks. Heterogeneous sensor networks are popular, especially in practical deployments as described by[17]. The majority of the recently designed energy efficient protocols for heterogeneous networks, are based on the clustering techniques that enhance the scalability and energy efficiency of the WSNs.

1.4 ENERGY EFFICIENT ROUTE SELECTION POLICIES

One of the crucial issues associated with WSNs is energy efficiency. The extant energy-efficient routing protocols often choose the optimal path using parameters like a transmission power, residual energy, or link distance. This section focuses on the efficiency of energy in WSNs, as well as the policies governing the selection of route with new metrics so as to increase the sustainability of WSNs.

With the new metrics, stability can be achieved in the network connectivity, while the operations of route discovery are reduced. Some of the issues associated with the devices used in a WSN include, limited resources, low speed of processing, low storage capacity and limited communication bandwidth. More so, the network is required to operate for a long period of time despite being powered by batteries, and this in turn causes limits their overall operation. It is suggested that most of the components of the device such the radio be switched off, so that the consumption of energy can be reduced. It is also important to note that vital processing capabilities are possessed by sensor nodes, and this is considered an important characteristic. However, such capabilities are not demonstrated individually, but jointly by the sensor nodes. Nodes have to organize themselves, so as to administer and manage the network all together, and this is more difficult than controlling individual devices [18].

In addition, variations could occur in the connectivity of nodes due to environmental changes within the area where the network is deployed; this in turn influences the networking protocols. The key goal of the designs not just transmitting data from a source to destination, but to also prolong the network lifetime. To achieve this, energy efficient routing protocols can be used. The use of different kinds of designs and architectures has been employed in WSNs, depending on the kind of applications used. The design and architecture of the network determine the performance of the routing protocols, which is a vital feature of WSNs. However, the energy used for data transmission can be affected by the operation of the protocol. Most recent studies on WSNs focus on designing nodes and protocols that are energy efficient and capable of supporting different aspects of network operations. The initial efforts aimed at the development of energy-efficient sensors are mostly driven by academic institutions. Nevertheless, within the past 10 years, some commercial companies have also made some efforts based on the efforts made by academic institutions, and some such companies include Sensoria, Crossbow, Worsens, Dust Networks and Ember Corporation. These companies make provision of sensor devices that can be readily deployed in different applications alongside different management tools for maintenance, programming and visualization of sensor data. Similarly, current research is also driven towards the development of sensors' hardware, so as to provide solutions that are energy efficient. In addition to such efforts, some of the current research has focused on developing routing protocols that need less energy, thereby increasing the lifespan of the network. One of the easiest ways through which energy can be conserved is to lower energy consumption mode whenever possible. The problem is that the time and power consumption required to reach higher modes is not negligible. Therefore, it is important to have protocols and techniques that can transmit packets in a way that energy is conserved, thereby resulting in the increased lifetime of the network. Due to the fact that every node in WSN acts as a relay so as to forward the message, the untimely death of some nodes may occur as a result of lack of energy. This occurrence may be due to the inability of some nodes to communicate with each other. Consequently, there will be disconnected of network because of imbalance in energy consumption, and the lifetime of the network will be affected seriously. Thus, the most appropriate routing metrics that should be used in WSN is the integration of the shortest path and the prolongation of the network lifetime. In addition, the battery life determines the lifetime of the node to a large extent. Battery drainage is primarily caused by transmission and reception of data among nodes and processing elements.

1. Average Energy Dissipated: This metric is associated with the lifetime of the network, and it is through this metric that the average energy dissipation per node over time is known, because it is responsible for many functions such as transmission, reception, sensing and aggregation of data. Low Energy Consumption. The consumption of energy by a low energy protocol is less than that of the traditional protocols. This implies that any protocol which considers the remaining energy level of the nodes and chooses routes that prolong the lifetime of the network, is regarded as a low energy protocol.
2. Total Number of Nodes Alive: this another metric that is associated with the lifetime of the network. The metric provides an idea about the network coverage area over time.
3. Total Number of Data Signals Received at BS: This metric shows the energy which a protocol saves by not continuously transmitting data packets (hello messages) that are inconsequential.
4. Average Packet Delay: This metric is calculated as the average one-way latency observed between the transmission and reception of a data packet at the sink. By this metric, a packet’s temporal accuracy is measured.
5. Packet Delivery Ratio: It is calculated as the proportion of the number of distinct packets which the sinks receive to the number originally sent from source sensors. The reliability of data delivery is indicated through this metric.
6. Time until the First Node Dies: it is through this metric that the duration of all the sensor nodes alive is known. In some protocols, the energy of the first node on the network gets exhausted earlier than in other protocols, however, the operation of the network lasts for a longer period of time.
7. Energy Spent per Round: This is a metric which is associated with the total amount of energy that is used when messages are routed in a round. It is a short message which is primarily designed to provide an idea of the energy efficiency of any proposed method within a specific round.

8. Idle Listening: when a sensor node is in idle listening mode, it does not engage in the sending or reception of data, but is still able to consume a substantial amount of energy. In this regard, there is no need for this node to be in this mode, rather, it should put off.
9. Packet Size: it is through that packet size that the duration of transmission is determined. Thus, it is effective in energy consumption. It is important for the size of the packet to be reduced through a combination of many packets into a single large packet or by compressing the packets.
10. Distance: that power needed for the sending and receiving of packets can be affected by the distance between the transmitter and receiver. The consumption of energy can be reduced when the shortest path between nodes is selected by the routing protocols.

The main issues that should be given high priority in all networks is the choice of energy efficient protocols in WSNs. The selection of energy-efficient can be done based on many policies, however, the most popular one is regarded as "Call Packing". This policy involves the routing of new calls on links that are heavily loaded, instead of lightly-loaded. With this policy, high bandwidth calls are more favored, and this is one of the main advantages of this policy, while its major disadvantage is that some link get totally called-up, thereby reducing the network connectivity. In contrast to the call balancing, is the policy of load balancing, which involves the even distribution of load among the links. With the use of this policy, new calls are routed on lightly loaded paths, instead of on heavily loaded ones. The third policy is that which is referred to as "the min-hop policy", in which a call is routed on the minimum-hop path that meets the requirements of energy efficiency. This type of policy has traditionally been useful in energy-efficient WSNs. The policy also performs well in all topologies, while the worst policy in all topologies is the call packing policy.

Most of the time, it is only a very small difference that exists between load balancing and minimum-hop policies. In comparison to load balancing, the performance of call packing in sparsely connected networks is worse, as opposed to densely connect networks. More so, there are schemes for multi-hop routing. With the first scheme, the minimum lifetime of nodes is maximized, while the second scheme reduces the total energy consumption. In the simulation result, the energy used for transmission and reception are projected. Based on this comparison, the multi-hop routing is preferred by the first scheme when the ratio of transmitting energy to circuit energy is low and by the second scheme when this ratio is high. For the load to be balanced in the first scheme, the range of multi-hop routing is limited.

In this thesis, the metrics used include the number of dead nodes, the average energy of the network and nodes in different probabilities of cluster head selection.

1.5 PROBLEM STATEMENT

Some of the factors that are crucial to the prolongation of the network and enhancement of WSN performance area, distribution of energy consumption and energy of nodes.

1. Scalability and reliability problem of homogenous WSN, can be improved by heterogeneity in wireless sensor networks. Heterogeneous sensor networks are very much useful in real deployments because they are closer to real life situations.
2. The problem of energy balancing occurs as a result of the lack of energy efficiency in each node within the network.
3. The lifetime of the network is shortened due to imbalance in the distribution of energy consumption, which in turn affects that performance of the WSN.

1.6 STATEMENT OBJECTIVES

The main objectives of the project is to propose a clustering technique based on energy efficient protocol in heterogeneous wireless sensor networks. The specific objectives of the study are as follows:

1. To investigate the heterogeneous wireless sensor networks based on energy efficient protocol for the purpose of extending the lifetime of the network, while increasing the lifetime of the first node in the network. For this main objective to be achieved, the stability time in the network, as well as the reliability of the network in terms of offering prolonged service, must be increased.

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2. To implement three scenarios of heterogeneous WSN under three protocols; Hybrid Energy Efficient Protocol in heterogenous network, SEP, and CCS routing protocol.
3. To perform an evaluation of the performance of the three scenarios in terms of network lifetime (number of dead nodes), energy average of the network.

1.7 SCOPE OF THE PROJECT

In this project, a heterogeneous WSN is used with three scenarios under three protocols; Hybrid Energy Efficient Protocol in heterogenous network, SEP, and CCS routing protocol. The three scenarios are compared, while their performance under their algorithms is evaluated. More so, the study aims at increasing the network lifetime, while delaying the death of the first sensor node. Through the dissipation of energy at each round of operation and ensuring the balanced distribution of energy within the network, energy efficiency is achieved.

1.8 PROJECT ORGANIZATION

The remaining of the chapters of this thesis are briefly described as follows:

Chapter II provides an explanation of ideas and concepts related to wireless sensor networks based on the review of literature. Basically, the review of literature in this chapter describes the characteristics, architecture, challenges and application of wireless sensor networks.

Chapter III provides an elaborate discussion of the methodology of the study. More so, the chapter presents a discussion of heterogenous wireless sensor network based clustering technique will elaborate on the methodology used in this study in detail.

In Chapter IV, the protocols which are proposed for achieving an efficient network are presented. This includes various scenarios aspects and algorithms used. In addition, the chapter presents the details of software implementation and results of simulation of HEEP, SEP, and CCS protocols.

Chapter V is the last chapter in this thesis, in which the conclusion is given based on the study results, and the suggestion for future work in relation to the current study is given to be clouded from the results that have been obtained and any future works that are suggested to develop our work.

2. LITERATURE SURVEY

2.1 OVERVIEW

This chapter focuses on related studies. That is other studies in the area of developing different clustering algorithms for Homogenous and Heterogeneous Wireless Sensor Network. In routing algorithm for efficient energy WSN, many studies have been conducted. Studies that contribute toward energy efficient routing developed for sensor network are also discussed in this chapter.

An interesting area of research is the aspect of wireless sensor networks. To prolong WSN life and to route the correct data to the base station, a number of protocols were proposed. Each protocol has benefits and disadvantages. These are not proper for area monitoring applications. In WSN, battery power of individual sensor nodes is a valuable resource. For instance, to transmit 1-bit of data in berkely mote the power consumed is equal to the computation of 800m instructions [19]. The sensor node stops its operations in the network when the battery power of sensor nodes expires. Hence, one of the main concerns that pervades the design and operations of WSN is preserving battery power of the individual sensor nodes. By minimizing the number of communications, a larger battery lifespan may be achieved.

A Different communication pattern like one-to-one, one-to-all, one-to any, one-to-many, and many-to-one is supported by clustering. are the basic issues in cluster based wireless sensor network are the cluster information and leader election (called the cluster head, CH). The cluster leader, manages communication among the cluster members and organizes their data.

For token management, the leader election problem originally appeared in the token ring networks (distributed systems) [20]. To design the leader election algorithm for both wireless sensor network and ad hoc networks is difficult and complicated because many sensor nodes are distributed in a region in an unorganized and uncontrolled way. According to collection, cluster based WSNs are widely grouped into three;

(ii) Homogeneous sensor networks.

(iii) Heterogeneous sensor networks.

(iv) Hybrid sensor networks.

Sensor networks can be heterogeneous they are not always homogeneous. Homogeneous wireless sensor networks are simpler than the heterogeneous ones. To provide wireless sensor network's stability and to reduce consumption of energy, clustering is a good method. They are grouped according to network stability and efficiency of energy. In heterogeneous sensor networks, two or more different types of sensor nodes with different hardware abilities and battery power are used.

Compared to other nodes like cluster heads, the sensor nodes have higher hardware abilities and more battery power. A three-layer architecture for heterogeneous WSNs was proposed by [21]. The top layer comprises of only one sink in this architecture and this sink receives sensed data and analyzes them. The second layer made up of sensors that have no energy constraint. By connecting them to a wall outlet, these line-powered sensors, have little energy resource. The third layer is made up of battery-powered sensors that are one-hop away from a sensor that is line-powered. The reason for this architecture is that in a multi-hop sensor network with many-to-one delivery, use more energy than all other sensors in the network, and therefore should be line powered. In order to save energy, there is no communication among battery-powered sensors, therefore no sensor that is battery-powered can serve as a data forwarder on behalf of other sensors. Adequate number of line-powered sensors is needed in this architecture.

Some of the most popular algorithms heuristic- based node clustering a logarithms are

(i) Linked cluster algorithm.

(ii) Energy-efficient adaptive clustering.

(iii) Energy efficient distributed clustering.

In the Linked Cluster Algorithm (LCA) [22].all network nodes are classified into a set of node clusters with each node belonging to at least a cluster. Each cluster has its own cluster head, which serves as a local controller for the other nodes in the cluster. To link neighboring clusters and to provide global network connectivity, the cluster heads are linked through gateway nodes. If a node has the highest ID among its neighboring nodes, or if it has the highest ID in the neighborhood of one of its neighbors, it becomes the cluster head.

When nodes are arranged in order of their identities; that is, all but one node becomes a cluster head, poor clustering is obtained by the highest ID linked cluster algorithm. A greedy algorithm LCA2 [23], is another improved version of LCA where a node is elected as a cluster head using LID mechanism. The demerit of these two linked cluster mechanisms is that there is no uniformity in the distribution of cluster head among all the nodes. Another weakness of LCA is its relatively high control message overhead because the nodes- heads list has to be broadcasted. Furthermore, the node mobility, power efficiency issues and adaptive transmission range.

A common energy-efficient adaptive clustering algorithm is the low- energy adaptive clustering hierarchy which based on the received signal strength, it forms node clusters and uses these local cluster heads as routers to the base station. LEACH is an application-specific data dissemination protocol which uses clusters to extend the life of the wireless sensor network. A randomized rotation of local cluster heads is used by LEACH to evenly distribute energy load among the sensors in the network [17]. Three methods are used by LEACH, the randomized rotation of the cluster heads and corresponding clusters is the first, the second is localized coordination and control for cluster set-up and operation, while the third is local compression to lessen global communication. A finite number of iterations are stopped by LEACH clustering, but does not guarantee good cluster head distribution and assumes that for cluster heads, consumption of energy is uniform.

The hybrid energy efficient, and distributed (HEED) clustering approach for ad hoc sensor networks is another popular energy efficient node clustering algorithm[18]. The proposed main goals of HEED are:

(i) Extending network lifetime by energy consumption distribution,

(ii) Finishing the process of clustering within a constant number of iterations

(iii) Minimizing control overhead.

(iv) Creating a well-distributed cluster heads and compact cluster.

Cluster heads are selected periodically by HEED according to a hybrid of two clustering parameters, namely the residual energy of each sensor node as primary parameter and intra-cluster communication cost as a function of neighbor proximity or cluster density as secondary parameter. An initial set of cluster heads is probably selected using a primary parameter while the secondary parameter is used to break ties. HEED helps in good load balancing. Within a constant number of iterations, the process of clustering is terminated. Lifetime network is improved by HEED clustering over LEACH clustering because LEACH chooses cluster heads (and hence cluster size) randomly, which may lead to a faster death of some nodes. In HEED, the cluster heads finally selected in HEED are well distributed across the network and the cost of communication reduced.

In other energy-efficient clustering protocol, by dividing the network into clusters the authors propose that the life of the wireless sensor network can be extended. The cluster heads are chosen based on the primary parameter as hold back period and secondary parameter as the number of hops, to restrict cluster size [24].

2.2 CLUSTERING ALGORITHMS FOR HETEROGENEOUS WSN

According to researchers, there has been an increase in interest in the potential use of wireless sensor networks in the past few years. Wireless networks such as; border security surveillance, disaster management and battlefield surveillance. In such applications, a large number of sensor nodes are deployed and these sensor nodes work autonomously and are often unattended. To improve the lifetime of a sensor network by reducing consumption of energy, clustering is used. Network scalability can also be improved. Some researchers in the area of wireless sensor network are of the opinion that nodes are homogeneous, but prolong the lifetime of a WSN and reliability, some nodes may have different energy. With the advances in the technology, there have been developments in wireless communications and wireless sensor networks, micro-electro mechanical system (MEMS). In the past few years, wireless Sensor networks have become an interesting field of research. By assembling sensor nodes into groups, i.e. clusters, a sensor network can be scalable. All clusters have a leader, known as cluster head. Sensors in a cluster may elect an Am CH or pre-assign the network designer. The cluster membership may vary or be fixed. For scalability and efficient communication in WSNs, some clustering algorithms may be specially designed. To carry out energy efficient routing in WSNs, cluster based routing is also used. Higher energy nodes (cluster heads) can be used for information processing and sending while low energy nodes can be used to conduct the sensing in hierarchical architecture. Some routing protocols in this category are: LEACH, PEGASIS, TEEN, and APTEEN.

Generally, researchers assume that nodes in wireless sensor networks are homogeneous, but in real life, homogeneous sensor networks don’t really exist. Even homogeneous sensors have different abilities like different rate of depletion, different initial energy level, etc. Typically, many inexpensive nodes perform sensing in heterogeneous sensor networks while a few nodes having comparatively more energy to conduct data filtering, transport and fusion. This results in research on heterogeneous networks where two or more types of nodes put into consideration. To prolong the lifetime and reliability of the network, the heterogeneous nature of wireless sensor networks. According to [25] in real deployments, heterogeneous sensor networks are popular.

Recently, most protocols that are energy efficient designed for heterogeneous networks are based on the clustering method, which are beneficial in energy saving and scalability for WSNs. In this section, clustering algorithms proposed in the literature for heterogeneous wireless sensor networks (HWSNs) are classified. To lower energy consumption loopholes in PEGASIS, Concentric Clustering Scheme (CCS) has been proposed by [26]. The major idea of CCS is for the location of the BS to be considered to prolong lifetime and improve performance of the network. In CCS, the network is divided into a variety of concentric circular tracks which represent different clusters and each circular track is assigned to a level. Level-1 is usually the track closest to the BS and with an increase in the distance to BS, the level number also increases Therefore, each node in the network has its own level.

Furthermore, as in PEGASIS, chains are constructed within the track. One of the nodes in the chain at each level area is chosen as a CH. Some disadvantages exist:

(1) In each level, node distribution does not balance therefore levels with lesser number of nodes will first exhaust their energy, making the probability of electing a CH to be very high.

(2) On CH election, residual energy does not take into consideration which may lead to unbalanced energy consumption among all nodes.

(3) Chain-based protocols, such as PEGASIS and CCS, helps nodes interact with their closest neighbor, using low radio power, but the long chain leads to more delay].

(4) Rather than the residual energy of nodes, the CH selection for next hop is based on the location, therefore CH energy may dissipate quickly on the path among CHs, and even energy hole will appear in the network.

A WSN is made up of many sensor nodes randomly distributed. Clustering is one of the best ways to prolong sensor network lifetime by reducing the consumption of energy. It may also increase the lifetime of a network and scalability. To take the advantages of node heterogeneity,clustering algorithms for HWSNs should be energy efficient . Two major criterias are used to classify clustering algorithms: According to the stability and efficiency of energy. Generally, cluster head selection in energy efficient method depend on the average network energy, initial energy,rate of energy consumption, residual energy, or a combination of these. The time interval before the death of first node i.e. stability period is extended by the stable election protocols for clustered HWSN .

Kumar [22] implemented distributed energy efficient clustering scheme for heterogeneous WSN. Cluster heads election is based on the possibility of ratio of remaining energy of every node and the network's average energy in DEEC protocol. CH selection process is conducted on the behalf of starting and remaining energy of the node. The node which has more starting and remaining energy has the highest possibility of becoming a CH. Each node of the network does not have a similar initial energy. In the initial stage, all nodes should be familiar with the lifespan of the network and the absolute energy. In DEEC, all the nodes receive information that have to do with absolute energy and lifespan of the network from the BS.

2.3 ENERGY EFFICIENT CLUSTERING PROTOCOL FOR HWSNS

To conduct energy efficient routing in WSNs, cluster based routing is also used. In reducing energy consumption in WSNs, proper organization of sensor nodes into clusters is helpful. Based on the clustering structure of HWSNs, many energy efficient routing protocols are designed.Each clustering algorithm is made up of two stages: the cluster setup stage and steady state stage [6].

Heterogeneous WSNs require a very important task of clustering protocols to choose the cluster head so as to reduce energy consumption and extend the lifetime. A focus into different clusters head selection protocols that are energy efficient for HWSNs like C4SD, EEHC, SDEEC, DEEC, and DBEC. Energy Efficient Heterogeneous Clustered Scheme: An energy efficient clustered scheme for HWSNs was proposed by [27] it was based on weighted election probabilities of each node to become the cluster head. In hierarchal WSN, the cluster head is elected in a distributed fashion. The most popular clustering protocol in WSN is LEACH and the algorithm is based on it. An optimal percentage of nodes have become a cluster head in each round in LEACH algorithm. In the presence of heterogeneity nodes, this algorithm works on the election processes of the cluster head of Distributed Clustering Algorithm that is energy efficient for HWSN.

Cluster heads are selected by DEEC with the help of probability depending on the ratio between the average energy of the network and residual energy of each node. The initial and residual energy helps determine how long different nodes will serve as cluster heads. The authors assume that all wireless sensor network nodes have different amount of energy, which is a source of heterogeneity. DEEC is also based on LEACH; To expend uniformity in energy, the cluster head role is shared among all nodes. In this algorithm two levels of heterogeneous nodes are considered, and after that a general solution for multilevel heterogeneity is gotten. DEEC functions as follows: the total energy and lifetime of the network needs to be known by all nodes. The average energy of the network is used as the reference energy. [28] proposed an improvement of this algorithm known as stochastic DEEC

Choosing the cluster head overall network depends on nodes' residual energy in the Stochastic Energy Efficient Clustering (SDEEC). This protocol depends on DEEC that have new strategies. The intra-clusters transmission is reduced using stochastic strategy. Like DEEC, two levels of heterogeneity are considered in this method, but energy is saved by making non-CH nodes sleep, unlike DEEC. The network is divided into dynamic clusters in this protocol. According to the protocol, data is sent by all non- CH nodes to respective CHs at their supposed transmission time. The receiver of the CH node must be kept on, so as to get all the data from the nodes in the cluster. To compress the data into a single signal when it is received, some signal processing is conducted by CH. After this stage, the total data is sent to the prime by each CH. To save energy, each non-CH can turn off to the sleep mode. The disadvanrage of this protocol is that if non-CH nodes is on sleep mode when aggregation is been performed, the next round of CH selection will be likely unknown.

For efficient routing in WSNs, the virtual cord protocol (VCP) was proposed by [29]. It has to do with greedy routing on the cord and the exact location of node information is not needed. Since the nodes only need information about their direct neighbors, the protocol is scalable. However, the protocol does not tolerate fault. Additionally, two well known WSN routing algorithms are; adaptive threshold-sensitive energy efficient protocols (APTEEN) and power-efficient gathering in sensor information systems (PEGASIS). A Cluster Based Energy Efficient Routing Protocol

(CBERP)[30] proposed for Wireless Sensor Networks. Nodes are divided into clusters in CBERP and the headers that gather and transmit the data from their member nodes as in LEACH-C are selected. However, by using a number of candidate nodes to reduce overhead, CBERP advance header selection mechanism is used. After selecting the headers in this way, a chain of the headers is formed and data is sent to the base station through the chain as in PEGASIS. To improve lifetime of wireless sensor networks, an energy efficient clustering protocol (EECPL) [31]was proposed. A cluster head is elected by EECPL and a cluster sender in each cluster. To create and distribute the TDMA is the duty of the cluster head while cluster senders are responsible for sending the total data to the base station. Sensor nodesare are organized into clusters and a ring topology is used to send data packets so that each sensor node receives data from a former neighbor and sends it to the next neighbor. When the data aggregate is received from previous neighbors, cluster senders directly sends the data aggregate to the base station.

2.4 ENERGY EFFICIENT ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

The dynamic topology and distributed nature of Wireless Sensor Networks introduces important requirements in routing protocols that should be met. In order to be efficient for WSNs, the most important characteristic of a routing protocol is the energy consumption and prolonging the network's lifetime. Recently, a number of energy efficient routing protocols have been proposed for WSNs.

Sensor protocols for information via negotiation (SPIN) known as adaptive protocols that pass information at each node to every other node in the network was proposed by [32]. To address the weaknesses of the flooding method, the algorithm uses resource adaptation and negotiation. However, data delivery is not guaranteed by data advertisement mechanism in algorithm. The cluster head nodes put together data gotten from nodes that belong to the respective cluster and send the data aggregate to the base station so as to reduce data and transmission of the replicated data.[33] came up with a data gathering protocol for WSNs that takes care of periodic data collection requirements with ultra-low power consumption. The protocol suggest a coordinated technique to topology control, MAC-layer design, and efficient routing to reduce waste of energy in communication, in which using a tree-based network structure, packets are reliably routed towards the sink. Cugola et al., proposed a context-aware and content based routing (CCBR) protocol that is designed specially for multi-sink, mobile WSNs. A probabilistic receiver based technique is used to route and content-based addressing is used to support data-centric communication adequately.

Two basis for wireless routing were suggested by[34]which are: data path validation and adaptive beaconing. In the data path validation stage, data traffic discovers and fixes routing inconsistencies quickly. The adaptive beaconing stage reduces route repair latency and sending fewer beacons, which leads to extention of the trickle algorithm for routing control traffic.[30] proposed a Cluster Based Energy Efficient Routing Protocol (CBERP) for Wireless Sensor Networks. In CBERP nodes are divided into clusters and the headers that gather and transmit the data from their member nodes as in LEACH-C are chosen. However, header selection mechanisms is developed by CBERP by using a number of candidate nodes to lessen the overhead. As in PEGASIS, after selecting the headers in this way, a chain of the headers is formed and data sent to the base station through the chain.

CBRP is a distributed energy efficient protocol suggested by [35]for gathering data gathering in wireless sensor networks. By using new factors CBRP clusters the network and then a spanning tree is constructed for sending aggregated data to the base station. Only the root node of this tree communicates with the base station node by single-hop communication. The major challenge of CBRP is much communication overhead as a result of many control messages exchanged between sensor nodes.

To extend the lifetime of wireless sensor network (WSN) further, many clustering routing protocols have been proposed by different researchers all over the world. However, the total network energy consumption of most protocols is not well minimized and balanced. To reduce this problem.This protocol was simulated in homogeneous networks and heterogeneous networks. Simulation results reveal that this proposed protocol can reduce consumption of energy in the network, decay rate, extend the lifetime of the network, and improve the network throughput in the above two networks.

2.5 ENERGY EFFICIENT FOR HETEROGENEOUS WIRELESS SENSOR NETWORKS

To reduce energy loss in nodes, clustering is one of the best methods to use. The network is divided into the clusters. Every node has the part of a cluster and one node from the cluster is formed as a cluster head. The data is received by the by the cluster head node from ordinary nodes and is passed to the BS. Every node has the different starting energy in heterogeneous clustering.

Smaragdakis [36] came up with a heterogeneity based protocol SEP. There are two levels of heterogeneity in SEP. To elect the CH, weighted election probability of the node is used. The quotient of advanced nodes *m* and the supplemental energy factor between advanced and normal nodes are the two parameters of heterogeneous protocol. For the advance node and normal node, various equations are used.

Distributed energy efficient clustering scheme for heterogeneous WSN was implemented by [37]. In DEEC protocol, cluster heads election depends on the network's average energy and possibility of ratio of remaining energy of every node. The CH selection process is conducted on the behalf of starting and remaining energy of the node. The node with the most possibility of becoming a CH is the one with more remaining and starting energy. Each network node has different initial energy. Every node should be familiar with the absolute energy and network lifespan at the beginning. In DEEC, all the nodes get the information regarding absolute energy and lifespan of the network from the BS.

Aderohunmu [38]proposed a new method SEP-E. It is an extension of SEP (Stable Election Protocol). In this study new nodes called intermediate nodes are proposed. The intermediate nodes contain the energy between the normal and advanced nodes. Each node has become CH on behalf of possibility of that node and each node become CH once in every round. Because of three level heterogeneity, energy consumption in this method is managed.

The DDEEC protocol for heterogeneous WSN, was proposed by [39]. It is an extension of DEEC protocol, where CH selection is conducted based on the starting energy and leftover energy of nodes. In this scheme all the nodes should be familiar with the network lifespan and total energy just like DEEC. On this possibility of advanced nodes is more to being CH than the normal nodes. To avoid DEEC protocol problems.

3. RESEARCH METHODOLOGY

3.1. INTRODUCTION

In this chapter, a detailed discussion of the proposed techniques for the enhancement of heterogenous WSN performance is provided. The proposed algorithms for Hybrid Energy Efficient Protocol for Stable Concentric Clustering in Heterogeneous Wireless Sensor Networks is also discussed in details. In the different scenarios, the simulation design was done using a collection node under three protocols. The use of MATLAB is employed in constructing these designs the MATLAB is considered as one of the currently used simulation designs.

3.1.1. Overall Methodology

An illustration of the process of initialization is given before the project initialization which involves two phases is explained. The phases are as follows:

i. Building Phase: involves the building of three protocols in different algorithms.
ii. Network Connection Phase: involves the establishment of connections between nodes.

An overview of the methodology of this project is represented in the Figure 3.1 below.

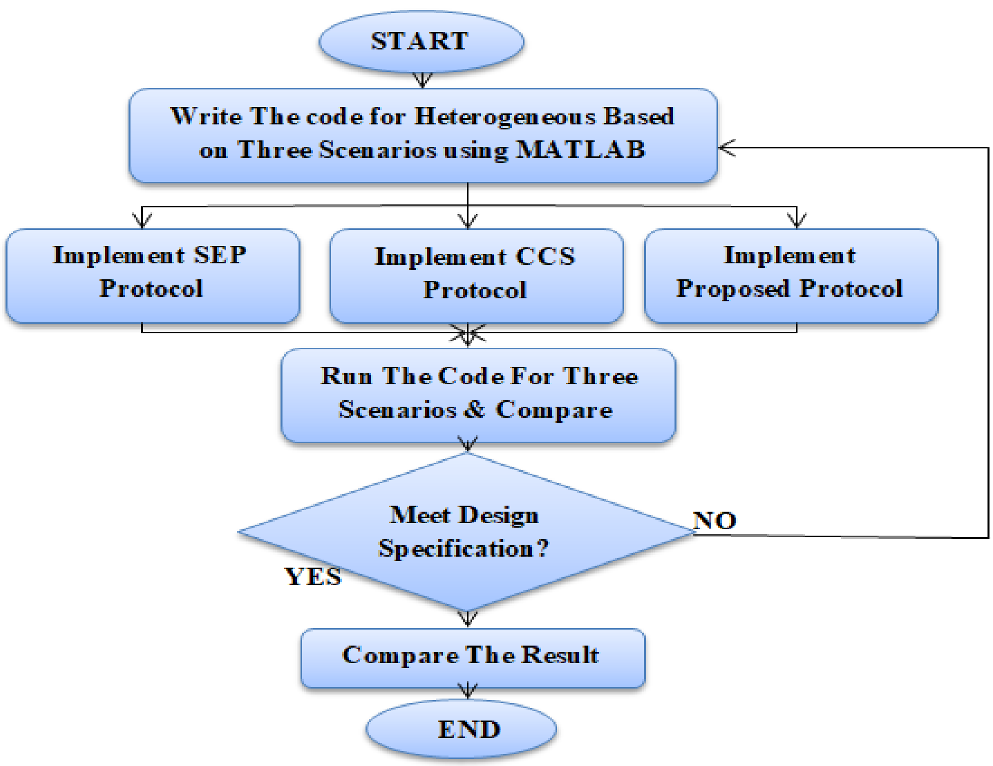

Figure 3.1: Overall methodology of the project

3.2 CLUSTER HEAD SELECTION USING K-THEOREM

The main idea behind the K-theorem is to select a candidate CHs based on a bunch of sensor nodes in a cluster. The K-Theorem, which was basically proposed for the selection of optimal server location, is relatively simple. The working details of the K-Theorem is presented in Table II. The value of 'ki' is set by the coordinator node for each cluster. The value of 'ki' is relative to the node density in a cluster and ratio (i.e. r) of the cluster heads in a WSN. The 'ki' value is derived from the number of nodes within a cluster and ratio. There can be a variation in the value of r from 0.01 to 0.99, but this value should not go beyond 0.50. When the 'ki' value is lesser, the possibility of obtaining a local optimum is higher. The 'ki' number of best sensor that can serve as the cluster head, is determined by the value of 'ki'. Though the value of 'ki', an alternative suboptimal option is provided, such that an optimal sensor node can be selected for cluster head.

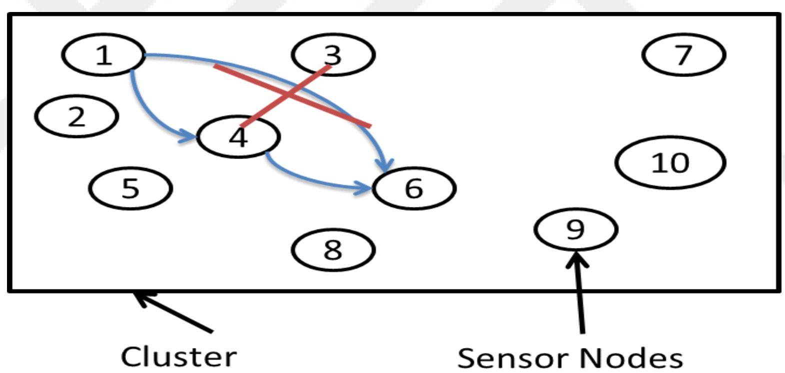

Figure 3.2: Working of ***K***-Theorem

The working of K-Theorem is illustrated in Figure 3.2 based on the selection of multi-hop route, whereby, each node selects its k nearest neighbors based on received signal strength indicator (RSSI). The 'ki' closest neighbors are selected for each sensor node that is deployed within the cluster based on the distance. The calculation of the distance between the sensor nodes can be done through received signal strength indicator (RSSI) or any other localization technique. The preferred communication route that is used when the nearest neighboring nodes are searched for, is multi-hop communication route, which is used in the case of a larger distance. The selection of neighbor a neighbor that has multi-hop connection in multi-hop communication requires less energy, because multi-hop communication is more energy efficient as compared to direct communication. Generally, multi-hop communication is favored because the main objective of clustering is to select a cluster head that is energy efficient. The multi-hop route selection phenomenon is shown in Figure 3.2. At that time the occurrence frequency of each sensor node can be calculated and then presented in table 3.1.

Table 3.1: List of nodes associated with ***K*-**nearest neighbors **&** frequency occurrences

Node ID	'ki' = 3 List of Terminals with its k nearest neighbor	Frequency of occurrence
1	2,3,4	3
2	1,4,5	4
3	1,4,6	5
4	2,3,6	6
5	2,4,6	4
6	3,4,5	7
7	3,9,10	2
8	5,6,9	2
9	6,8,10	4

3.3 EQUATION OF COMBINED RATING

The combined rating used to calculate the energy loss in sensor nodes during data transmission and communication between one hop neighbors is based on following criteria:

1) Residual Energy (RE).
2) Distance to co-coordinator node (D).

3.3.1 Residual Energy (RE)

The proportion of residual energy of a node, which is the amount of energy remaining in the nodes, is direct the combined rating. Due to the fact that the data aggregation is performed by cluster head, any node which will be selected as cluster head must dissipate more energy than other nodes. Thus, the node residual energy is directly proportional to the combined rate. Sensor nodes follow self-configuration scheme through which the set of nodes in the sensor network is distributed into subsets of coordinator nodes and non-coordinator nodes. The coordinator nodes stay is active mode so as to provide coverage and carry out the task of multi-hop routing, while the non-coordinator nodes remain in sleep mode.

3.3.2 Distance to Co-Coordinator Node (D)

The probability of nodes that are closer to the coordinator node to become the cluster head is higher. The following equation is used in calculating the combined rating, since the consumption of energy is directly proportionate to the square of distance.

$$\boldsymbol{C.R = RE/(D)^2} \tag{3.1}$$

Where RE=Residual energy & D=Distance between nodes.

3.4 THE PROPOSED PROTOCOL (HPEEA)

This study considers heterogeneous wireless sensor networks. The level of energy levels in sensor nodes may differ so that the lifetime of the WSN can be prolonged. The crucial factors to be considered in heterogeneous wireless sensor networks are reliability and stability of a node.

3.4.1 Stability

Stability refers to the time it takes that first sensor to die within the network. Energy efficiency was described at the time it takes the last node within the network to die. In the proposed protocol, these two factors are considered in the design of a hybrid protocol for heterogeneous wireless sensor networks. More so, in this study, the concept of concentric clustering scheme, which is based on the advanced node for the creation of clusters, while the use of k-theorem is employed in the selection of the cluster head; this is to ensure that they are selected appropriately. In the proposed protocol, a methodology that can facilitate the improvement of the instability and stability period of nodes within the network is proposed. However, there is room for improvement so that more accurate results can be obtained. In the current study, an equation is also provided to facilitate the selection of a cluster head from a candidate set of nodes. Based on the application used, there can be variation in the parameters that are used in the equation. More so, the alteration of the equation can be done in a manner that specifically focuses on network stability or the extension of a lifetime. The simulation of the protocol was performed for a limited number of nodes within the range of 100-250 nodes. However, it can further be improved so as to cover a larger number of nodes.

3.4.2 Reliability Of Node

The cluster head plays a very crucial role in the successful implementation of wireless sensor network. When the cluster head stops working, then the entire cluster will also not work. Lack of energy, environmental changes or physical damage in a candidate cluster sensor node can lead to its failure. Reliability deals with continuity of service. The main aim of the reliability of a node is to increase trustworthiness. In other words, through reliability, the trustworthiness of a node can be increased. In order to model the sensor node's reliability Ri(t), the use of the Poisson distribution is employed so that the possibility of not having failure within the time interval $(0, t)$ can be captured.

3.4.3 Protocol Objective

The proposed protocol basically aims at extending the lifetime of the network, while increasing the time which it takes the first node in the network to die. For this objective to be achieved, the stability time within the network and network reliability must be increased, so that the network will be able to render service for a longer period of time. This implies that the secondary objective of this protocol is to increase the stability and reliability of the network, so that the primary objective of the protocol can be achieved. Thus, for the stability of the network to be achieved, it is important to make use of the k-theorem technique and the concentric clustering concept for the selection of cluster head. When the cluster head is being selected, the use of a k-theorem approach is employed. The use of k-theorem involves selecting a cluster head based on the density of nodes. For the lifetime of the network to be increased to a certain extent, the use of two kinds of nodes can be employed. The nodes are referred to as advanced nodes and normal nodes, whereby, the advanced nodes have significantly more energy than the remaining nodes within the network, and can be used for long distance communication with the base station. A division approach that is based on zone can be implemented through the division of the network into concentric regions based on the advanced node's concentric regions. This way, the period of stability of sensor nodes can be increased.

The main aim of this protocol is to design a routing protocol that is energy efficient so that the network lifetime can increase with delayance in the death of the first sensor node. The efficiency of energy is achieved through the reduction of energy dissipation during each operation. The consumption of energy is reduced through the network operation which compensates for the excess overhead that occurs during the set-up phase. The aggregation and forwarding of data to the base station is performed by the cluster head. For the load to be evenly distributed among all the sensor nodes, it is important for the role of cluster head to be rotated throughout the cluster based on its residual energy and proximity to the advanced node.

Through the use of the decentralized routing protocols, information is routed by the sensor nodes autonomously to the cluster head, which in turn performs the aggregation of data and forwards to it to the respective advanced node of the cluster. Failure of node can be avoided by establishing alternate paths from each sensor node to the cluster head.

3.5 HYBRID ENERGY EFFICIENT PROTOCOL FOR STABLE CONCENTRIC CLUSTERING IN HETEROGENEOUS WIRELESS SENSOR NETWORKS

The emphasis of this protocol- (HPEEA) is on routing in concentric clustering network topology which involves the grouping of sensor nodes into concentric clusters. An advanced node and a cluster head are the leaders of each cluster. There is a significant difference between the HPEEA protocol and SEP protocol as well as EBK protocol. It is different because it is able to create concentric clusters based on where the advanced node is located, while the K-Theorem technique is used for the selection of cluster head. Through this routing protocol, concentric clusters are dynamically created based on where the advanced node is located in the network, thereby increasing the network lifetime. When the cluster head is selected based on residual energy and distance, the load will be evenly distributed among all the nodes within the network.

In heterogeneous wireless sensor networks (HWSN), routing protocols that are energy efficient primarily focusing on increasing the lifetime of the network. Because of the constraint of network energy, the efficient use of the limited energy leads to increased lifetime. The energy of nodes can be conserved using different methods, and one of such methods is clustering. The nodes in LEACH are grouped into clusters that are led by a cluster head. The majority of the extant energy-efficient routing protocols focus on the modification of the probabilistic equation for the selection of the cluster head so as to induce energy parameters in it instead of solely relying on heuristic probability. The aim of the SEP protocol is to increase the stability time of the network or to even cause delayance in the time taken by the first node in the network to die.

The SEP which was a ground-breaking protocol has proven to be a better option than others in terms of stability.

Nevertheless, it has been found that the period of instability, which is the interval between the death of the first sensor node within the network and the time of death of the last sensor is very low. The purpose of this protocol is to bridge the gap between the stability energy-efficient protocols in a HWSN. To achieve this, it is important to increase the period of instability and stability of the network.

At the initial stage, nodes are deployed in the field, and during this deployment, varying levels of energy are allocated to each node. Subsequent to the deployment, HELLO packets are broadcasted by the base station to the nodes. A node whose energy is higher than the threshold energy is referred to as advanced node which is responsible for reporting back to the sink, thereby forming a first concentric cluster. There are three phases involved in the entire working, and they are as follows:

1) Creation of a concentric cluster.
2) Election of cluster head.
3) Data transmission.

3.5.1 (Hpeea) Overview

The overview of the proposed protocol is represented in Figure 3.3 at the initial stage, the user provides the input which is in the form of number of nodes. The energies and positions of the generated nodes are randomly allocated and displayed. The moment the nodes are deployed, HELLO packets are sent by the base station, which also determines the position of advanced nodes and creates a concentric cluster around them. The selection of cluster head involves the use of the cluster head selection algorithm. The cluster heads are responsible for broadcasting the advertisement message to all its neighboring nodes, and hence the formation of clusters. The use of DRAND (Distributed Randomized time slot assignment algorithm) is employed because it allows the same frequency channel to be shared by many nodes through the vision of the signal into different time slots. The data from all nodes within the cluster is also aggregated by the cluster head, which then transmits the aggregated data to the advanced nodes, and then the information is then re-routed to the base station.

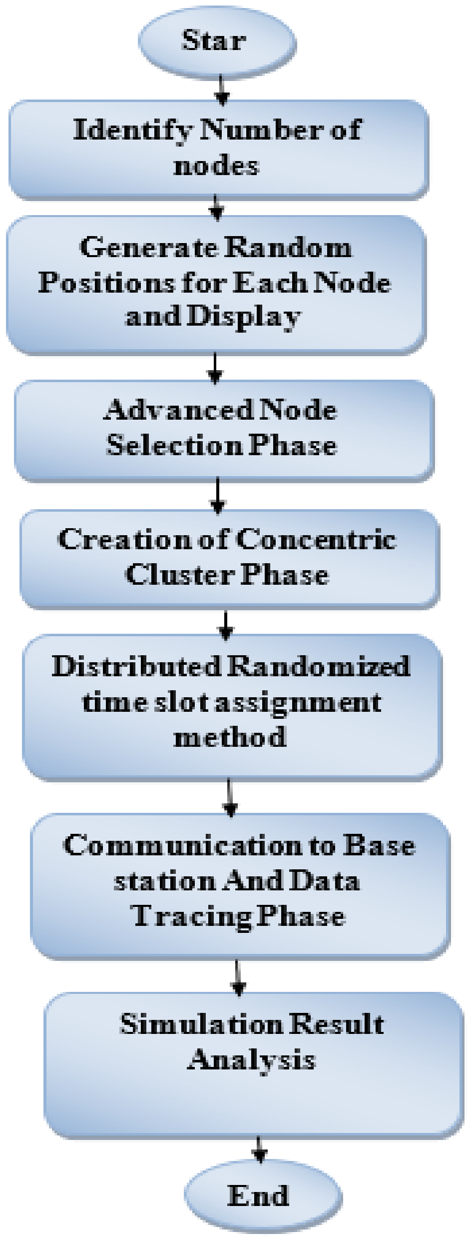

Figure 3.3: Flowchart of (HPEEA) Protocol

3.5.2 Creation Of Concentric Cluster

As observed in Figures 3.4 to 3.7, HELLO packets are broadcasted by the base station that is found at the corner of a network.

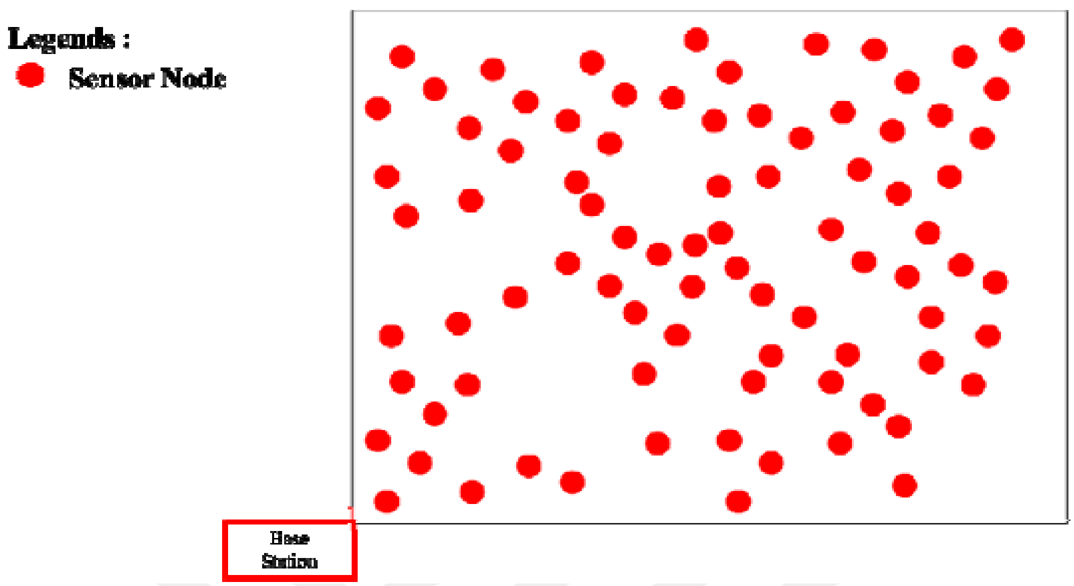

Figure 3.4: Sensor Nodes Deployed

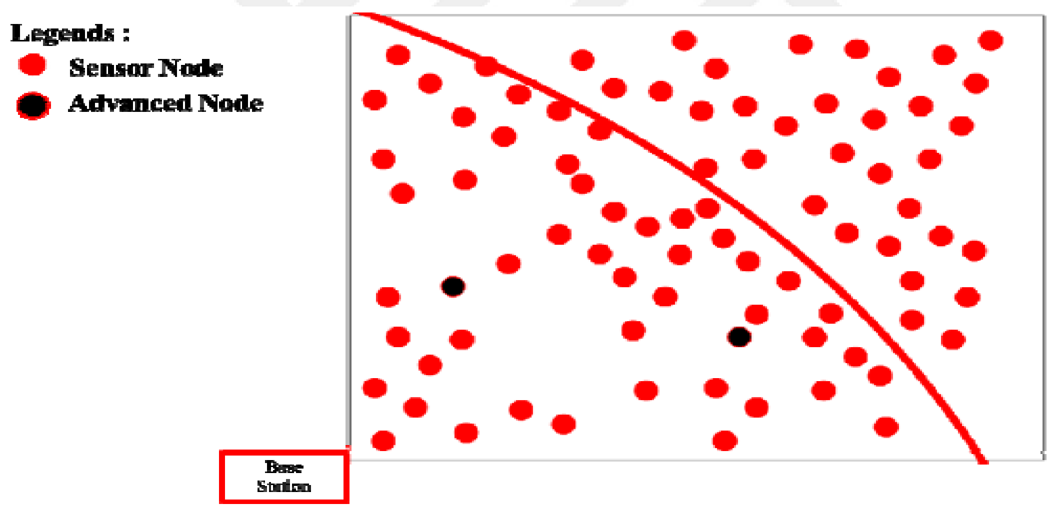

Figure 3.5: Advertisement message with Base Station

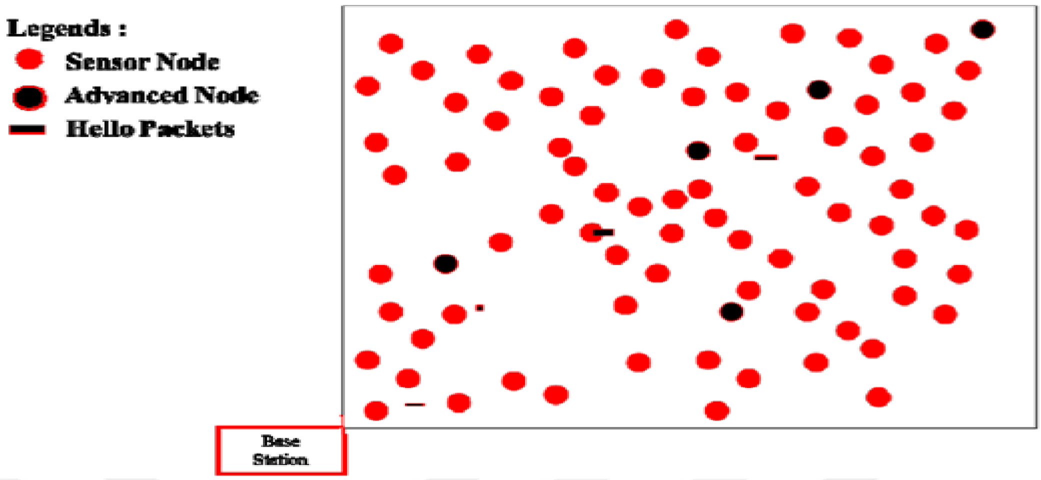

Figure 3.6: Sending back information to BS

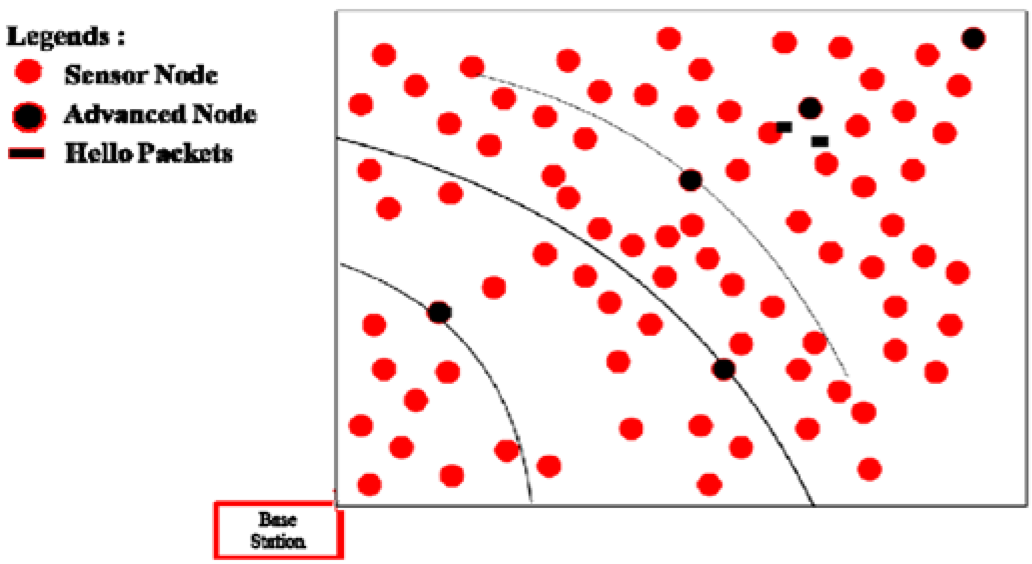

Figure 3.7: Creation of concentric cluster

Figure 3.5 indicates that the sensor node that possesses energy which is more than the threshold energy is labelled as advanced node, and indicated by the black dot.

The advanced node which has energy great acknowledgement packets to the Base Station as shown in the acknowledgment packets includes unique id, its energy and location information. When the first advanced node is encountered, an imaginary boundary is drawn, thereby leading to the formation of a first concentric cluster as shown in Figure 3.6. Likewise, while other advanced nodes are encountered, the formation of similar concentric circles occurs. Therefore, the whole region is partitioned into n clusters based on the number of advanced nodes as represented in Figure 3.7.

The use of advanced nodes is employed in the transmission of data either multi hop or single hop. The area between the base station and the subsequent base stations is categorized as individual clusters. The data which are sent to the cluster head by all the nodes within a cluster, are aggregated by the cluster head, which then forwards them to the base station as presented in Figure 3.8. Afterwards, the aggregated data information is forwarded by the advanced node to the base station for processing.

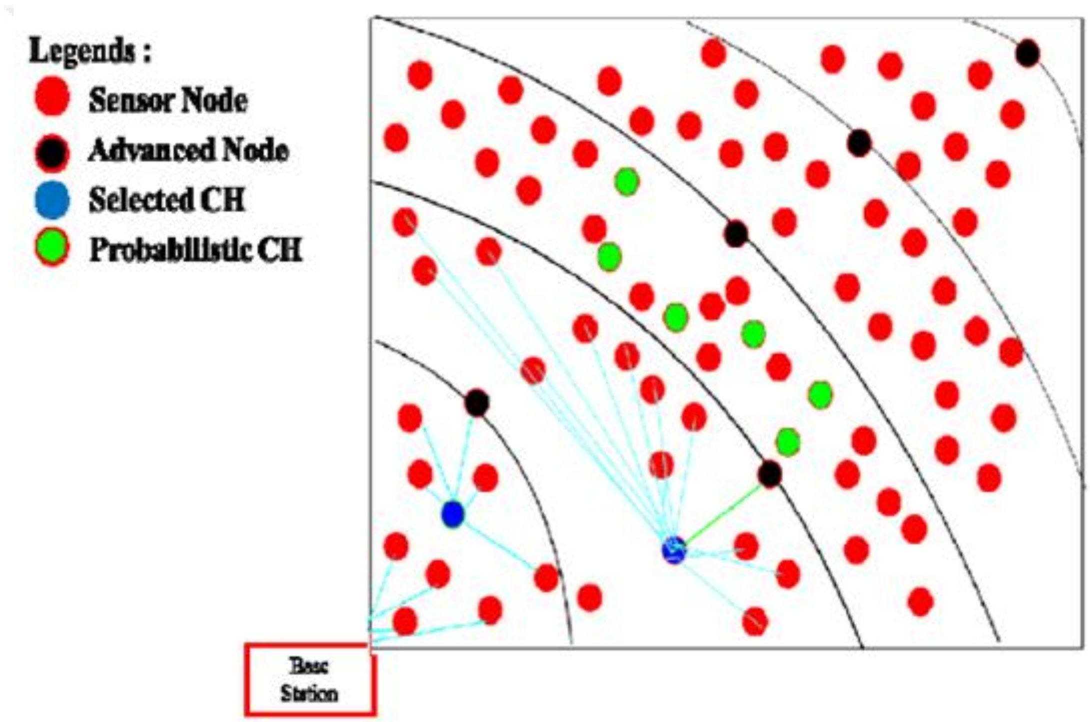

Figure 3.8: Cluster head candidate nodes and path formation

The following are the steps required for the Creation of Concentric Cluster as shown in Figure 3.9.

1. At the start, boundaries are set of x and y co-ordinates.
2. Initialize total number of nodes uniformly over the field.
3. If the energy of nodes > certain threshold (1.5 in Average energy of the network).
4. Plot and radius are calculated as advanced nodes.
5. If the energy of nodes >0, they should be plotted as normal nodes. HELLO packets are broadcasted to all nodes by the base station, and if the energy of the receiving node is greater

than the threshold energy, then the node selects it as the advanced node and sends back its location to base station. Afterwards, the selected advanced node is then advertised by the base station to the given region.

6. Advanced node's radius is calculated and the concentric cluster is drawn at that position.
7. Increase number of clusters.

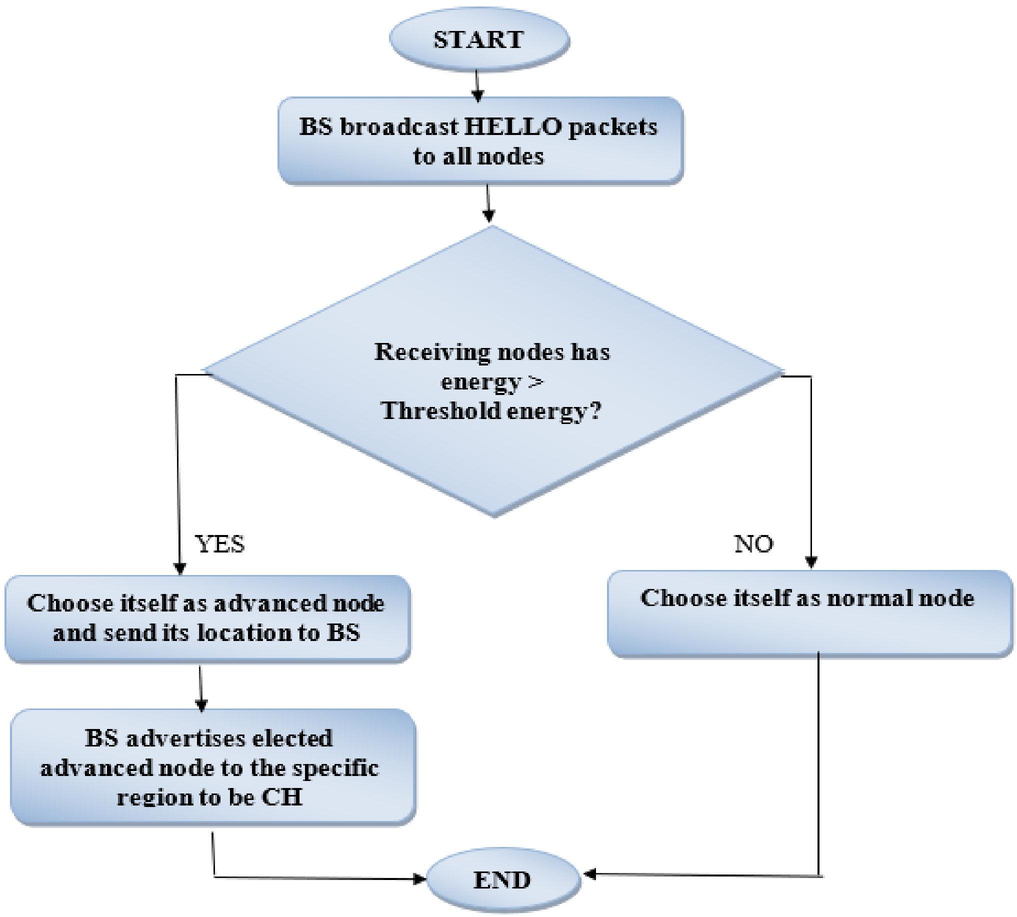

Figure 3.9: Flowchart for Creation of Concentric Cluster

3.5.3 Cluster Head Selection

In a concentric cluster, all the nodes are expected to send data to the advanced nodes. The best way through which data can be assembled is by electing cluster heads within the region. The selection of cluster head is done through the K-theorem. The procedure for cluster head selection is as follows:

8. Use the radius to determine if each node belongs to one cluster.
   if(((dis(number).di)>R)&&((R)>(dis(number-1).di)))

9. A number is allocated to the node.

10. Identify candidate cluster heads from all the clusters.

11. Select one node with highest residual energy and least distance to the advanced node as cluster head.

12. Use radio transmission, communication for the transmission of data.

The aim of the K-theorem algorithm enhances the even distribution of energy within a cluster through a technique that is reliable in terms of energy efficiency. The formation of the concentric clusters occurs, and it is presumed that the advanced node is aware of the formation of the cluster, as well as the information. The K theorem algorithm for the selection of cluster head is made up of the following steps:

i. The k for each round for each cluster is set by advanced node based on the density of nodes. Afterwards, the value of k is broadcasted by the advanced node to all the nodes within its cluster. In order to determine the k nearest number of nodes, the value of k is used.

ii. The k number of the closest neighbors to the advanced node is sent by all the sensor nodes within the cluster. The calculation of the distance to the node is done based on the time of return for the received signal.

iii. The selection of the candidate set of cluster is done with the advanced nodes, i.e. Ci for each cluster in the network. The value of Ki is always proportionate to the number of candidate cluster heads in a cluster i.e. C.

iv. A request is sent by the advanced node, requesting each node within the candidate set of cluster heads in the respective cluster to send their combined rating (CR).

v. Based on the distance to the coordinator node (D) and residual energy (RE), each candidate cluster head node calculates its own combined rating. Equation 1 provides the description of the precise relation of calculating the combined rating.

vi. A node is chosen by the coordinator node as a cluster head among a candidate of cluster heads based on combined rating. The node with the highest combined rating is elected as cluster head. Therefore, the higher the combined rating of node, the higher its chances of being the cluster head in a given cluster.

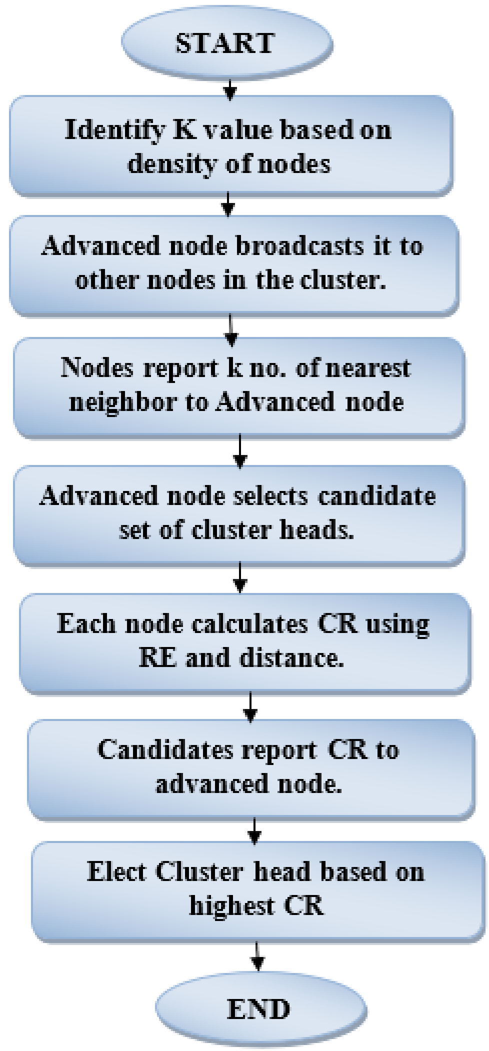

Figure 3.9: Flowchart of Selection of Cluster Head using K-theorem

CR: Combined Rating.R. E: Residual Energy.k: Number of candidate cluster heads in the cluster (4-6) depending upon the node density.

3.6 IMPLEMENTATION AND PERFORMANCE ANALYSIS

The proposed protocol was simulated using the MATLAB simulation tool. A comparison of the proposed protocol with other traditional protocols (CCS and SEP) is carried out. The area of simulation of the field measured is 200X100m. The network is a static densely deployed network. A large number of sensor nodes are deployed in a two-dimensional geographic space, leading to the formation of a network which is a static deployed network. The sensor nodes' initial energy is within the range of 1 to 1.5 joules, while that of the advanced nodes is >= 5 joules. There is variation in the number of sensor nodes from 100 to 300 within different environments of simulation, while an evaluation of the performance of the sensor network in these environments, is performed. The calculation of the network parameter of dead nodes in each round is done and compared with popular protocols. The varying environments in terms of sensor nodes are executed for 5000 rounds.

Table 3.2: List of Simulation Parameters

Simulation Parameters	Value
Simulation Area	200X100m
Initial Energy Of The Nodes	(1-1.5) joules
Advanced nodes Energy	>= 5 joules
Number Of Sensor Nodes	(100-300)Nodes
Number Of Rounds	800,5000 Rounds

3.6.1 Assumptions And Dependencies For Implementation

For the simulation, the following were assumed:

1) Sensor nodes are not aware of the environment, i.e. position algorithms and GPS cannot assist a sensor node to obtain information about its location.

2) The use of (x, y) co-ordinates provided by the user is employed is the statistical deployment of sensor nodes.

3) The energy of sensor nodes are not rechargeable.

4) There exists only one base station, which is deployed at a fixed place outside and has infinite power, computability and memory.

5) Compression of data arriving from the nodes belonging to the respective cluster is performed by the cluster head, which also sends an aggregated packet to the Advanced node, so that the amount of information to that is to be transmitted to the advanced node is reduced [40]

6) The information is then re-routed by the advanced node to the base station because the location of base stations is very far, and as such, more energy is dissipated in order to communicate with the BS.

7) The Base station is located at the geometric edge of the network.

8) A distinct ID is possessed by each node, and it is through this ID that the node is differentiated from other nodes.

3.7 SUMMARY

The newly proposed protocol for heterogeneous wireless sensor network, which is a Hybrid Energy Efficient Protocol using Stable Concentric Clustering, is based on the sensor nodes' residual energy and location information of the sensor nodes. The proposed protocol is a hybrid model that bridges the existing gap between energy efficiency and stability within heterogeneous networks. The use of the concept of concentric cluster creation is employed in the proposed protocol based on the position of the advanced nodes and a K theorem for the selection of cluster head. The proposed protocol is capable of delaying the death of the first node in the network by using the k-theorem and selecting a cluster head based on its distance and residual energy. This delayance of the death of the first node, will in turn increase the lifetime and stability period of the network. More so, the prolongation of the network life is achieved by dividing the cluster based on where the advanced nodes are located, and the selection of cluster head based on the combined rating.

4. IMPLEMENTATION AND PERFORMANCE ANALYSIS

For the simulation, the use of the MATLAB a simulation tool was employed. A comparison of the proposed protocol (HPEEA) with conventional protocols which include the CCS and SEP, was done. The simulation area of the field measured is 200X100m. The network is a static densely deployed network. A large number of sensor nodes are deployed in a two-dimensional geographic space, thereby leading to the formation of a network which is a static deployed network. The initial energy of the sensor nodes was within the range of 1 to 2 joules, while that of the advanced nodes is = 5 joules. There is a variation in the number of sensor nodes within the range of 100 to 300 in different environments of simulation environments. More so, an evaluation of the performance of the sensor network within these environments is performed. The calculation of the network parameter of dead nodes is done in each round and compared with popular protocols. The varying environments in terms of sensor nodes are executed for 5000 rounds.

4.1 ASSUMPTIONS AND DEPENDENCIES FOR IMPLEMENTATION

For the simulation, the following were assumed:

1. Sensor nodes are not aware of the environment, i.e. position algorithms and GPS cannot assist a sensor node obatain information about its location.
2. The use of (x, y) co-ordinates provided by the user is employed is the statistical deployment of sensor nodes.
3. The energy of sensor nodes are not rechargeable.
4. There exists only one base station, which is deployed at a fixed place outside and has infinite power, computability and memory.
5. Compression of data arriving from the nodes belonging to the respective cluster is performed by the cluster head, which also sends an aggregated packet to the Advanced node, so that the amount of information to that is to be transmitted to the advanced node is reduced.

6. The information is then re-routed by the advanced node to the base station because the location of base stations is very far, and as such, more energy is dissipated in order to communicate with the BS.
7. The Base station is located at the geometric edge of the network.
8. A distinct ID is possessed by each node, and it is through this ID that the node is differentiated from other nodes.

4.2 SIMULATION ANALYSIS OF PROTOCOLS FOR THE NUMBER OF DEAD NODES

The results of simulation are presented in Figure 4.1 with the round number being compared against each time of the CH selection. The simulation is performed for 5000 numbers of rounds. The first simulation involves the deployment of 100 sensor nodes in sensor networks. A comparison of the proposed protocol (HPEEA) with two other protocols, namely SEP and CCS are done.

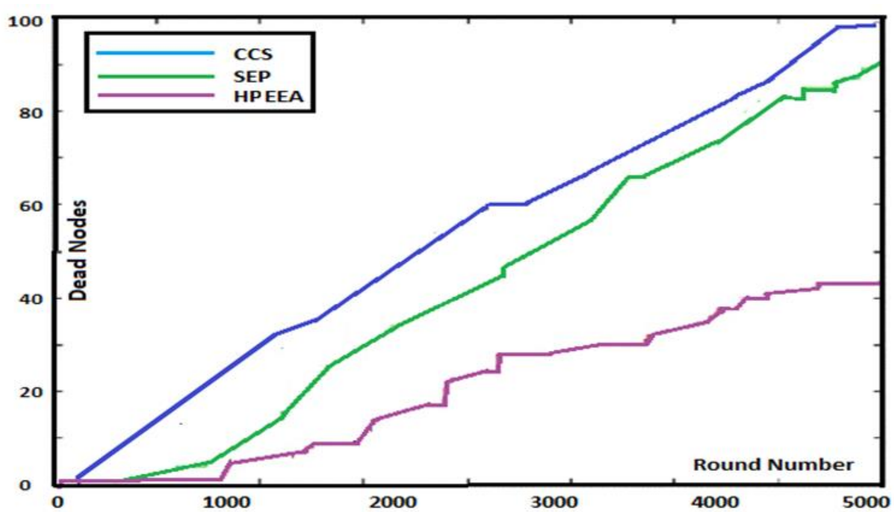

Figure 4.1: Protocol Comparisons for number of Dead Nodes for 100 nodes

It was observed that in the proposed protocol the dissipation of energy in the nodes is comparatively lower than that of the two other protocols (SEP and CCS). The number of the dead nodes in SEP and CSS increased linearly, while the change in the number of dead nodes is almost insignificant after 4700 rounds in the proposed protocol. It was found that there was a significant improvement in the results as an increase occurred in the number of rounds. In the proposed protocol, it was observed that as an increase occurred in the number of dead nodes, the number of rounds increased. On the other hand, a rapid increase occurred in the other two protocols.

Figure 4.1 indicates the number of dead nodes as the round number increases. It was observed that after the 5000 rounds the number of dead nodes in the SEP, CCS and the proposed protocol (HPEEA) were 99, 90 and 45 respectively. These results provide the basis for the conclusion that the efficiency of (HPEEA) is 55% more than that of SEP, and 58% more than that of CCS.

The results of simulations for the comparison of round number against each time of the selection of CH from the available candidate CH, is presented in Figure 4.2. The simulation is performed for 5000 round numbers. The second simulation involved 200 sensor nodes in sensor networks. A comparison of the proposed protocol with SEP and CCS is done. Based on the results of the simulation, it was observed for SEP and CCS that an increase occurs in the number of dead nodes as the number of nodes within the network increased, while the increase in the number of dead nodes is almost insignificant in the proposed protocol.

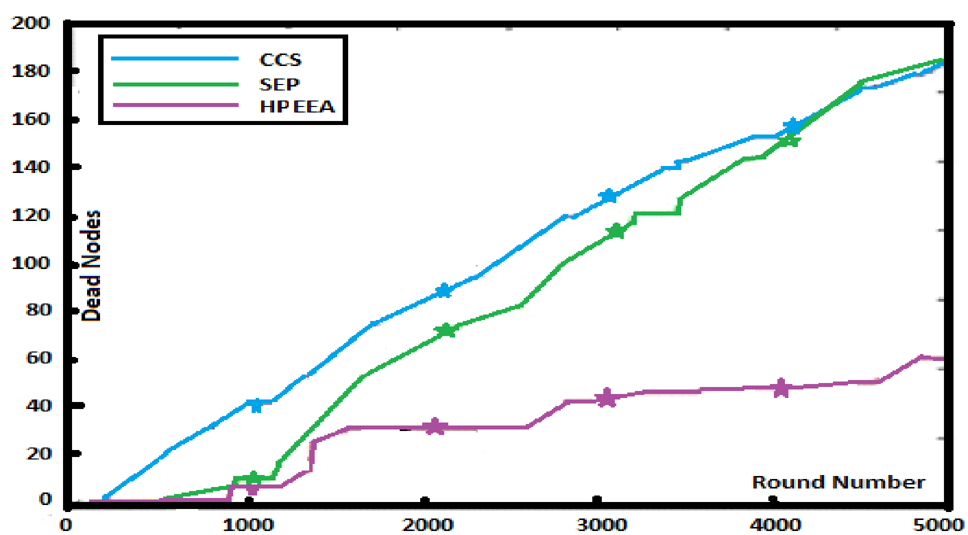

Figure 4.2: Protocol Comparisons for number of Dead Nodes for 200 nodes

The graph given above shows the number of dead nodes as an increase occurs in the round number. After the 5000 rounds, the number of dead nodes recorded for SEP, CCS and HPEEA are 182, 1180 and 44 respectively. Based on the result, a conclusion can be drawn that the efficiency of the proposed protocol is 70% more than that of SEP and 66% than that of CCS.

The results of the simulation for 300 sensor nodes are presented in Figure 4.3. Here, the round number is compared against each time the selection of the CH is made from the available candidate CH. The simulation is performed for 5000 round numbers. The simulation involved sensor network possessing 300 sensor nodes. The deployment of these nodes is done randomly. A comparison is done for the proposed protocol, and SEP as well as CCS. The results of the simulation revealed that a significant increase occurs in the number of dead nodes as an increase is occurring in the number of nodes within the network, however, in the proposed protocol the increase in the number of nodes is almost insignificant.

Figure 4.3 is a graph showing the number of dead nodes as an increase occurs in the round numbers. After the 5000 rounds, it was observed that the SEP, CCS and the proposed protocol had the following number of dead nodes, 215, 210 and 82 respectively. The results given above prove that the efficiency of the proposed protocol is 62% more than that of SEP, and 61% more efficient than that of CCS.

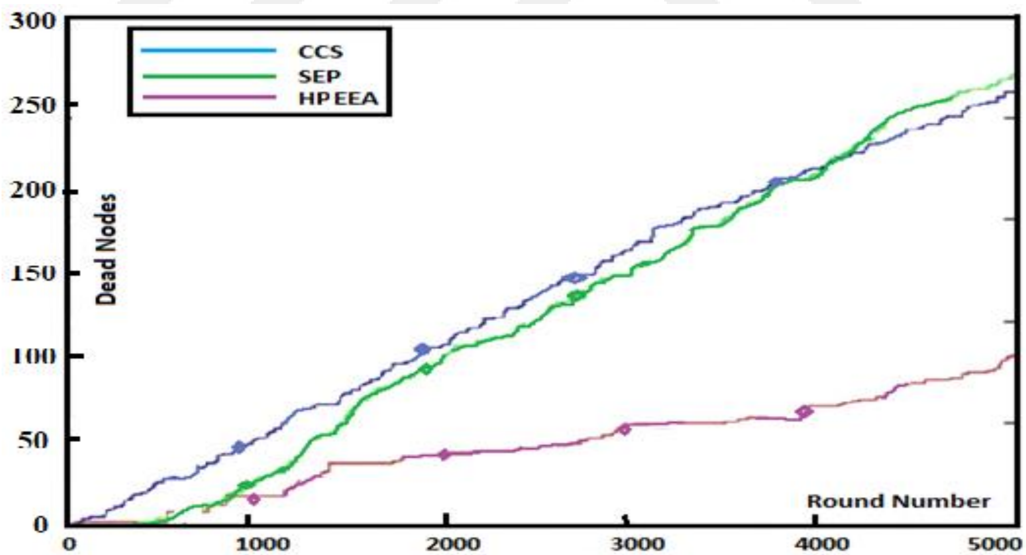

Figure 4.3: Protocol Comparisons for number of Dead Nodes for 300 nodes

Based on the graphs above, it can be seen that at the end of 5000 rounds, the number of nodes in the network increases, the number of dead nodes reduces significantly as compared to other protocols in heterogeneous WSN. The graphs also show that despite the fact that the proposed protocol and the SEP have two hop routing in protocols to the base station, the level of stability of the proposed protocol is lower than that of SEP, because the amount of distance covered to reach the next immediate node in SEP collectively is much shorter compared to a more static CH and advanced node scenario in (HPEEA). More so, in SEP rapid changes occur in the cluster head, thereby allowing the dissipation of less energy by the nodes within regular intervals. However, the stability of our proposed protocol is far better than that of the CCS protocol. Nevertheless, it was found that the number of dead nodes was significantly lesser in the network. In other words, the lifetime of the network in the proposed protocol was more prolonged than in a SEP or CCS

4.3 SIMULATION ANALYSIS OF PROTOCOLS FOR THE AVERAGE ENERGY OF THE NETWORK

Based on the simulation of the three protocols (HPEEA), CCS and SEP use MATLAB, the results in this subsection are presented. In order to obtain trustworthy results for a given number of rounds, the size of the network increased in steps of 50. Upon the deployment of the nodes within an environment, the nodes are regarded as stationary. In to enhance a more accurate observation of the difference in the values as the energy reduces to zero and are closely following each other for a large number of rounds, the number of rounds was fixed for 800. The conclusion is drawn using various network sizes.

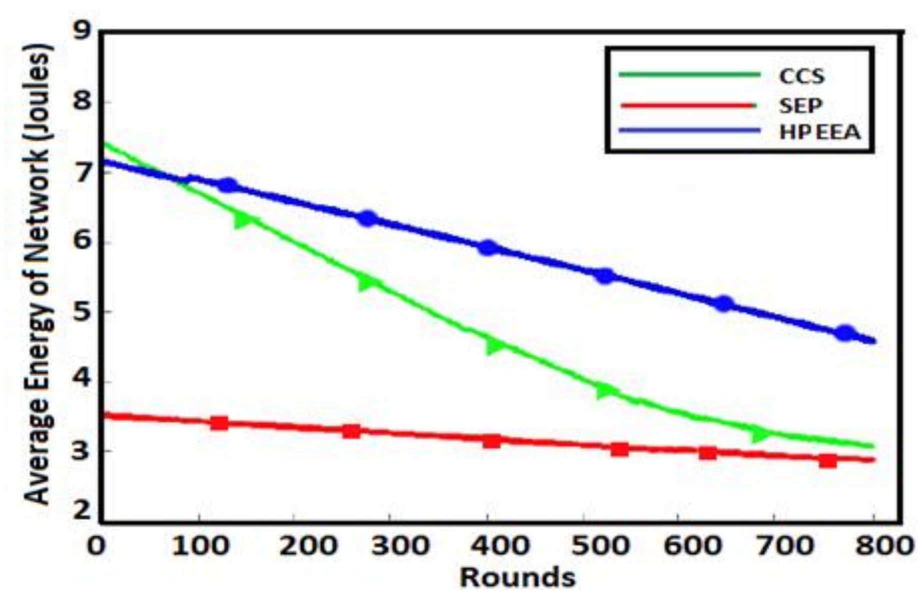

Figure 4.4: Protocol Comparisons for Average Energy for 100 nodes

Figure 4.4 reveals that at the end of 800 rounds, the average energy of the network is higher in the three protocols (HPEEA than in SEP and CCS). More precisely, the values obtained were 4.8, 3.4 and 3.2 in HPEEA, CCS and SEP, respectively. It can be concluded that the efficiency of HPEEA is 41% and 50% more than that of CCS and SEP, respectively. This is expected because a lesser amount of nodes dies in the case of HPEEA.

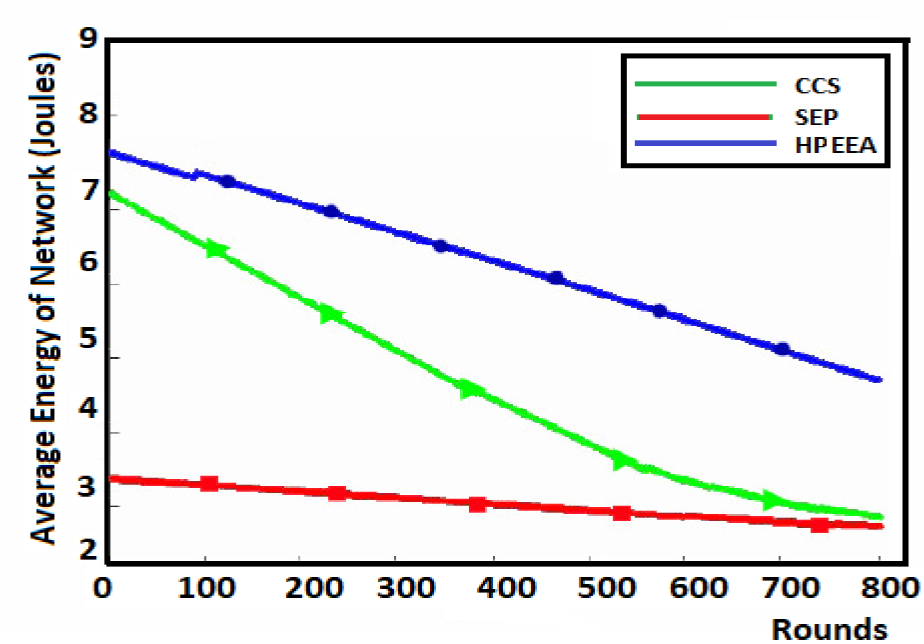

Figure 4.5: Protocol Comparisons for Average Energy for 150 nodes

In this case when the network is deployed with HPEEA, an average that is higher than that of SEP and EECS is obtained. Given the values 4.86, 3.06 and 2.95 for HPEEA, CCS and SEP found at the end of 800 rounds, it was found that the efficiency of HEEPSCC was 59% and 64% more than that of CCS and SEP respectively. Figure 4.6 shows that similar results were obtained form the values of the average energy of the network as 4.54, 2.95 and 2.80 in HPEEA, CCS and SEP respectively. Therefore, the efficiency of HPEEA in a network of 200 nodes is 53% and 62% more than that of CCS and SEP respectively. It is obvious that the average of SEP is almost equivalent to CSS because the amount of dead nodes are almost equal.

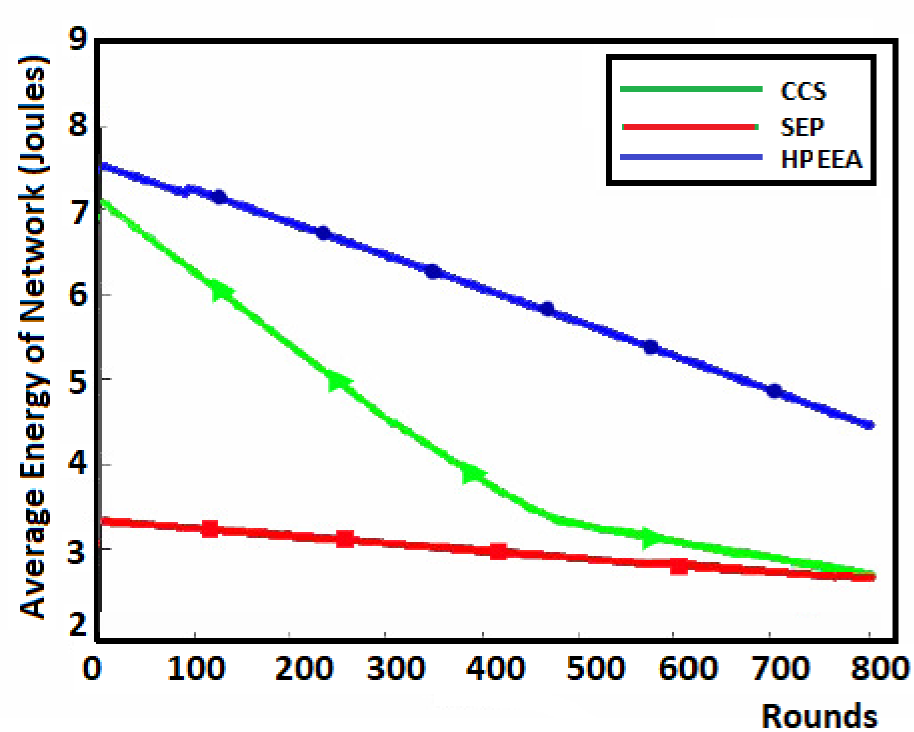

Figure 4.6: Protocol Comparisons for Average Energy for 200 nodes

In this case, an increase in the size of the network or the number of nodes enables the stability of the throughput of SEP, and more than CCS. However, in terms of the average energy of the active nodes, the HPEEA beats both of them. As seen in Figure 4.7, the exact value of energy was 4.31, 2.68 and 2.75 in HPEEA, CCS and SEP respectively. Thus, the efficiency of the HPEEA was found to be 60% and 50% more than that of CCS and SEP, respectively.

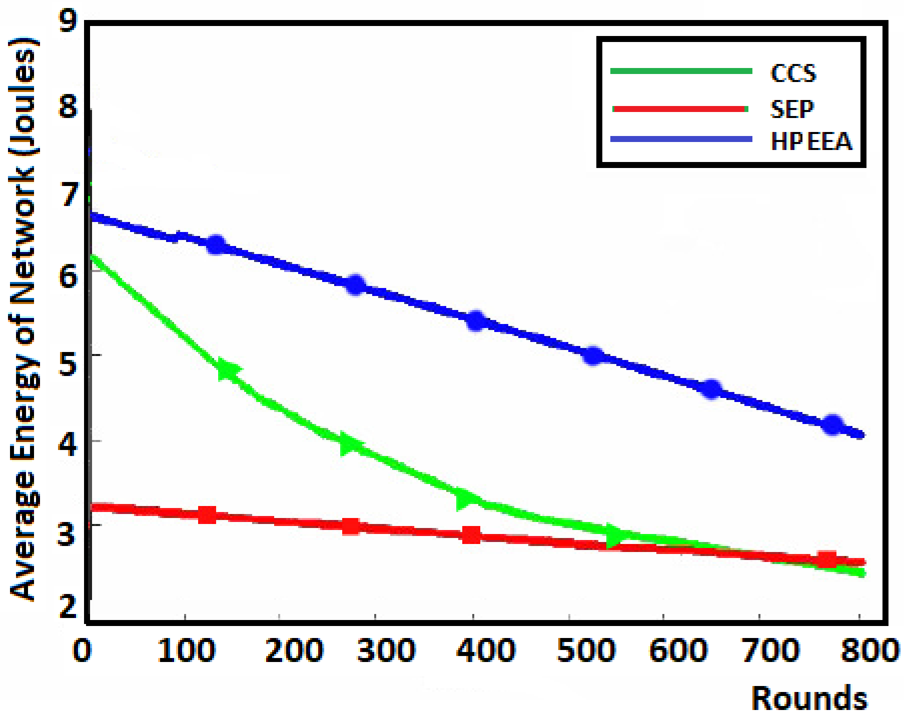

Figure 4.7: Protocol Comparisons for Average Energy for 250 nodes

As presented in Figure 4.8, network using CCS demonstrates an average energy that is less than SEP, and reduces rapidly as the size of the network increases. The value in HPEEA, the value was found to be 4.31, 2.68 in CCS and 2.75 in SEP. Since the number of dead nodes in HPEA is significantly less, the majority of the nodes are alive and constitute towards the average energy. The performance of HPEEA is better in this case as it demonstrates efficiency that is 68% and 49% more than that of CCS and SEP, respectively.

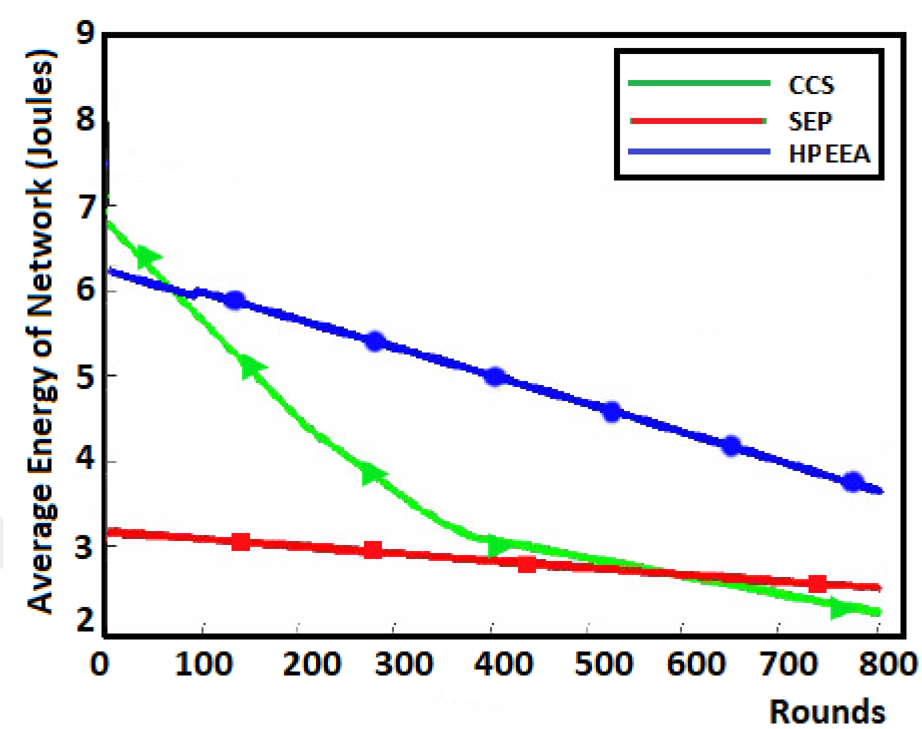

Figure 4.8: Protocol Comparisons for Average Energy for 300 nodes

The results obtained above are coherent with that achieved protocol comparison of the number of dead nodes. Since the average energy for CCS in larger network is less, it has a higher amount of dead nodes. A total number of 800 rounds were fixed because an increase occurs in the number of nodes that die as the operations or rounds increase. Due to the reduction of energy to zero in any protocol, the protocols cannot be effectively compared.

The calculation of the energy dissipation begins from the first round, and since the initial energy of each node was assigned to be less, the average energy differs at the beginning depending on the number of dead nodes. In comparison to CCS and SEP, the K-theorem proposed in HPEEA facilitates a more efficient selection of a cluster head, so that its distance from the sink can be reduced, while less energy is dissipated when data is being transmitted. In terms of the number of dead nodes, the proposed HPEEA outperformed the other two protocols. The above results complement the results obtained from the average energy because less number of dead nodes implies more residual energy, and therefore the higher average of network energy. It was also observed that among the three protocols, the SEP demonstrated the best stability in throughput. This is because under SEP, the death of the normal nodes is followed by the advanced node as the weighted probability for cluster head selection leads to the consumption of energy in each node according to the initial energy of the node. However, HPEEA that still has high energy levels even at the end of all operations is more appropriate for use in environments where data sensing takes place within a limited period of time. More so, such protocol is needed in military applications, where rapid changes occur, but lasting for a short period of time. This is because of the need to have accurate and fast data sensing with less energy.

4.4 ENHANCING WSN LIFETIME WITH COMBINED PROTOCOL FOR ENERGY EFFICIENT CLUSTERING

The primary aim of the proposed protocol is to design a routing protocol that is energy efficient within a network, so that the lifetime of the network can be prolonged through the use of duty-cycle. In order to achieve energy efficiency, the dissipation of energy in each round of operation is reduced when duty-cycle is used. A random number ranging from 0 to 1 is generated by the sensor nodes that are deployed within the network, and these sensor networks configure themselves by comparing with the threshold value. The aggregation of data, as well as its dissemination to the base station is primarily carried out by the cluster head. For the load to be evenly distributed among all the sensor nodes within the cluster, the role of the cluster head is rotated throughout the cluster depending on its residual energy and distance to the advanced node. The information is routed by the sensor nodes to the cluster head through the use of distance vector routing protocol. Afterwards, the data is aggregated by the cluster head and sent back to the sensor node. The node is fortified against failure through the establishment of multi paths from each sensor node to the cluster head.

4.4.1 Working Model Of The Proposed Protocol

At the initial stage, nodes are deployed in the field, and then during this deployment, different levels of energy within the range of 0-10 J is allocated to each node. Subsequent to the deployment of the node, the node is divided into many clusters. The entire operation is performed in three phases.

1. Clusters and cluster head creation.

2. Cluster Head selection.

3. Transmission of data.

4.4.2 Implementation And Analyses

The simulation of the proposed protocol, which was performed within an area of 500m x 500m, involved the use of MATLAB tool. The results obtained, were for different number of sensor nodes within the network for two parameters, which are rated of the fall energy and lifetime. The performance of the proposed protocol is reflected through the simulation results. The proposed protocol was simulated with a duty cycle applied to the nodes. A comparison of the protocol with and without duty cycle was done. This way, the network lifetime and efficiency of energy can be measured as represented in the figures below. Results for the network lifetime simulated for 100, 200 and 300 nodes are presented in Figure 4.9. It was observed that when duty cycle was applied, the lifetime of the ended at 82 with 100 nodes, and without duty cycle it ended at 31. Likewise for 200 and 300 nodes, it was observed that the lifetime ended at 61, 18 and 70, 28 respectively. The results of the simulation presented above shows that the efficiency of the network lifetime were 35.8% more with the application of duty-cycle.

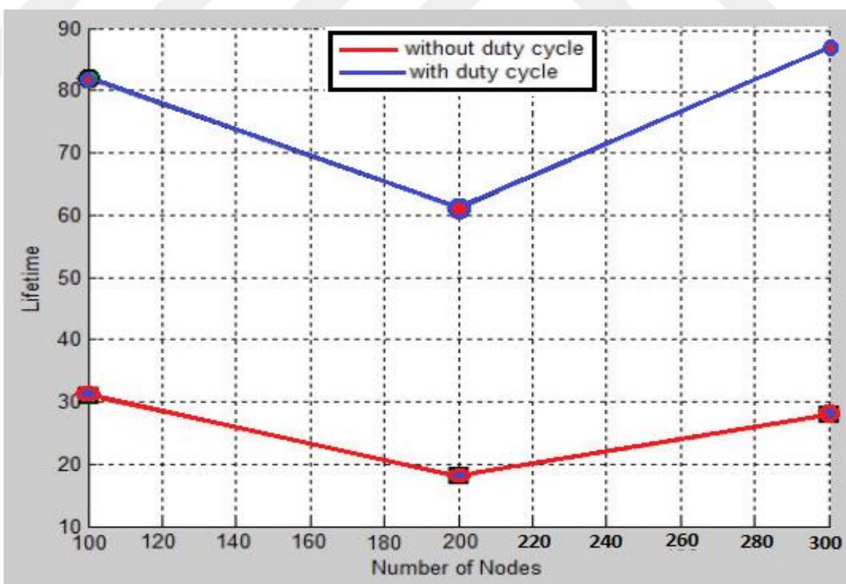

Figure 4.9: Lifetime comparisons for 100, 200, 300 nodes

The results of the nodes energy fall rate simulated for 100, 150 and 200 nodes are presented in Figure 4.10. Based on Figure 4.10, a decrease occurs in the energy fall rate with the application of the duty cycle. For 100 nodes without duty cycle, the rate of fall of energy of nodes with duty cycle is 2.871mJ and 9.355 mJ. In the same vein, for 150 and 200 nodes, the rate of fall of energy is 2.283 mJ, 6.286J and 1.600 mJ, 4.643 respectively. Based on the results obtained, it can be concluded that when duty-cycle is applied, the rate of fall of energy is 34% more efficient.

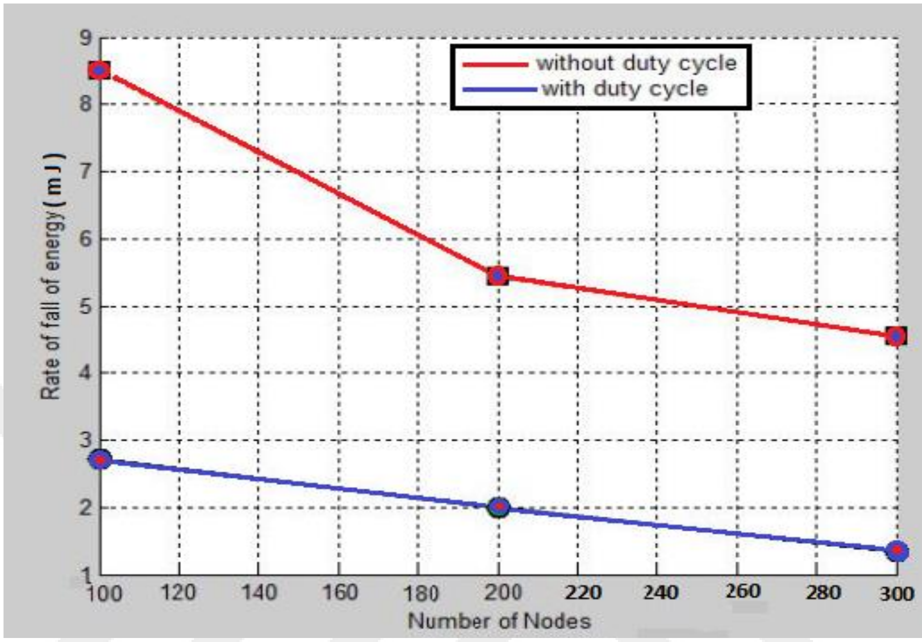

Figure 4.10: Rate of fall Energy comparisons for 100,150,200 nodes

The results for the network lifetime, simulated for 250, 300 and 350 nodes are represented in Figure 4.11 below. The graph below shows that the lifetime of the network with a duty cycle ended at 89 with 250 nodes, and without duty cycle, ended at 19. In the same fashion, the lifetime simulated for 300 and 350 nodes, ended at 82, 41 and 94, 38 respectively. The above results provide the basis for the conclusion that the efficiency of network's lifetime is 30.8% more when duty-cycle is applied with the nodes.

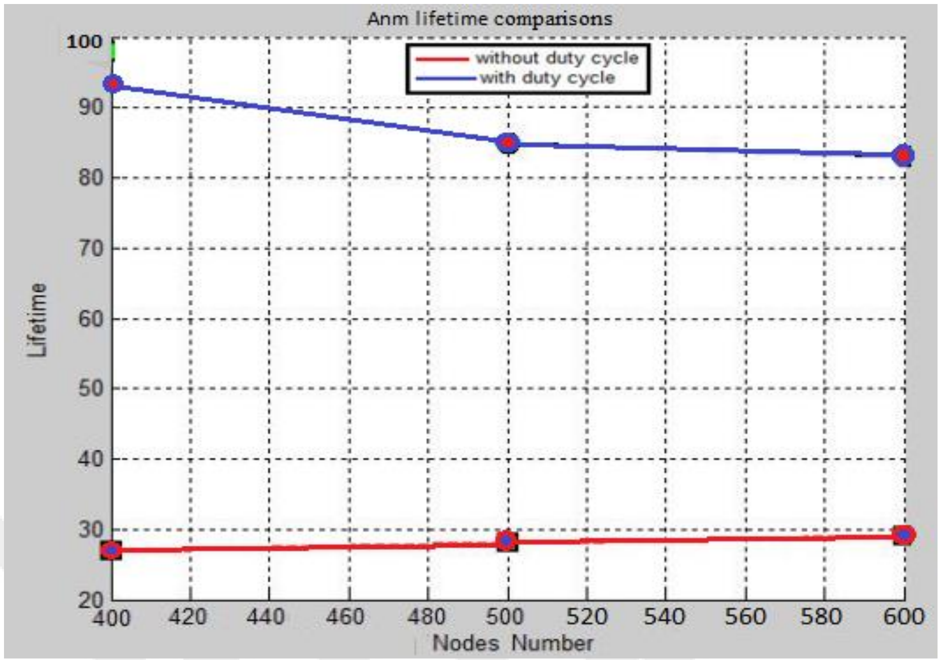

Figure 4.11: Lifetime comparisons for 400, 500, 600 nodes

Figure 4.12 represents the results of the rate of fall of energy of nodes, simulated for 250,300 and 350 nodes. The graph above shows that with the application of duty cycle, a decrease occurs at the rate of energy fall. When a duty cycle is applied for 250 nodes, the rate of fall of energy is 0.001600, and 0.003941 without duty cycle. Likewise, for 300 and 350 nodes, the rate of fall of energy is 0.001179, 0.003171and 0.000884, 0.002727, respectively. The results presented here show that with the application of duty-cycle, the rate of fall energy is 30% more efficient.

In Figure 4.12, the results of the network lifetime, simulated for 400, 450 and 500 nodes, are presented. The graph shows that, with the application of duty cycle, the lifetime of the network ended at 92 with 400 nodes, and without duty cycle it ended at 27. Similarly for 450 and 500 nodes, the lifetime ended at 85, 28 and 86, 29 respectively. The above results show that the efficiency of the network lifetime is 30.8% more when nodes are applied with duty-cycle.

The results in the nodes energy rate of fall, simulated for 400, 450 and 500 nodes are presented in Figure 6.10. It can be observed from the graph below that a decrease occurs at the rate of fall of energy when the duty-cycle is applied. For 400 nodes without the application of duty-cycle, the rate of fall of energy is 0.000884, and 0.002407 without duty cycle. Similarly for 450 and 500 nodes, the rate of fall of energy is 0.000647, 0.002151 and 0.000541, 0.001776, respectively.

The results given above show that when duty cycle is applied, the rate of fall of energy is 30% more efficient.

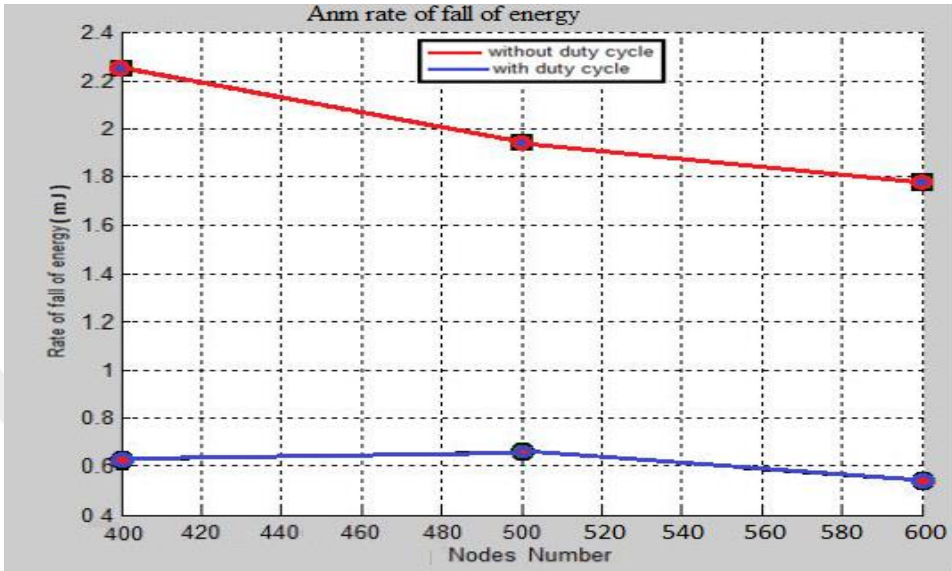

Figure 4.12: Rate of fall Energy comparisons for 400, 500. And 600

The final results of the network's lifetime when nodes ranging from 100 to 600 are deployed in the network, are presented in Figure 4.13. The conclusion is that the efficiency of the network's lifetime is 30% more when the duty cycle is applied.

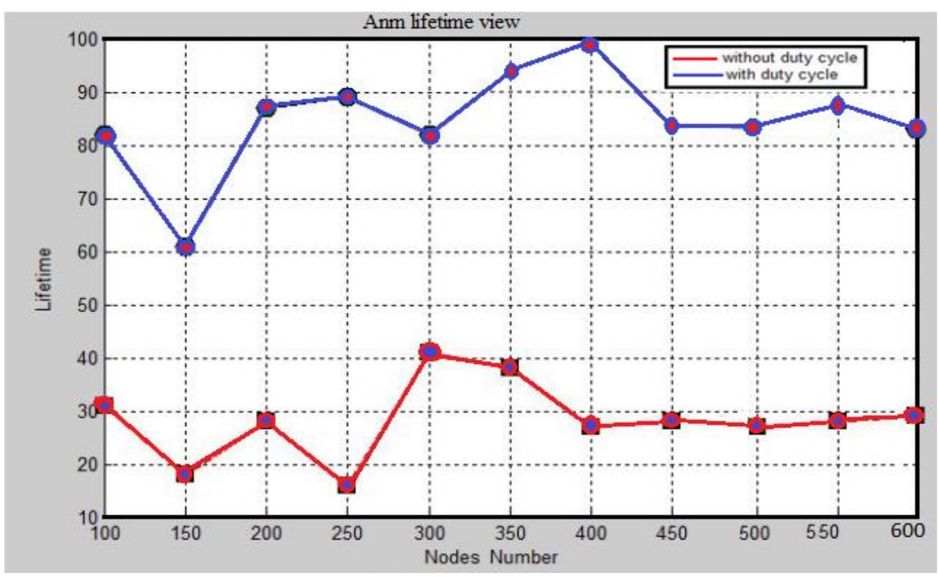

Figure 4.13: Network's lifetime graphical view

The results of the performance evaluation of the rate of energy fall when nodes within the range of 100 to 600 are deployed in the network shown in figure 4.14. The conclusion is that the rate of energy fall is 34% when nodes are applied to the duty cycle.

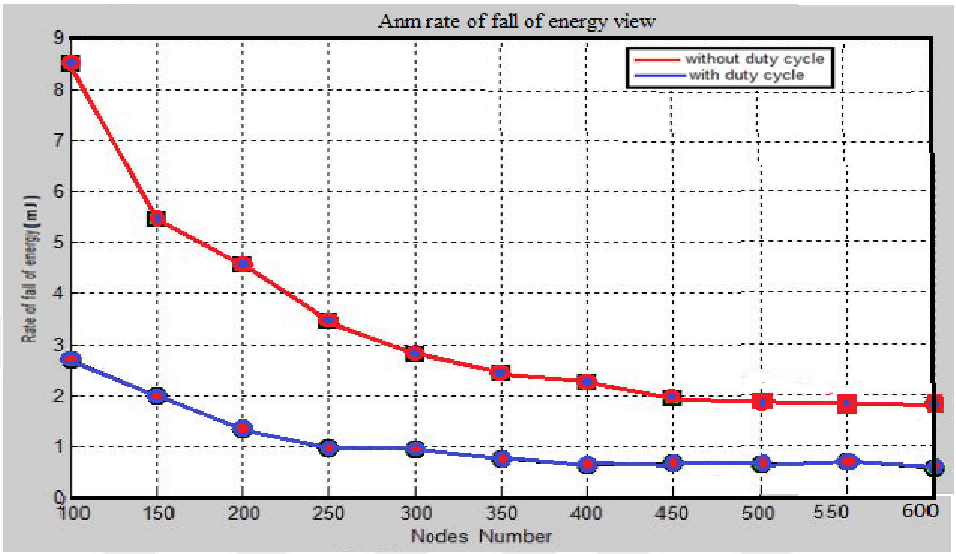

Figure 4.14: Rate of fall energy graphical view

4.5 SUMMARY

The new proposed protocol for heterogeneous WSN, focuses on Hybrid Energy Efficient Protocol by using a Stable Concentric Clustering is established with the residual energy of the sensor nodes and their location information. It is considered as a hybrid model that made a gap bridge between energy efficiency and stability in heterogeneous networks. The creative concept of concentric cluster had been used in this protocol which based on the advanced nodes position and K theorem to choose a cluster head. By choosing a cluster head and using of k theorem based on its residual energy and distance, the proposed protocol can delay the first node's death in the network, therefore the stability period will be increasing in the lifetime of the network. The clusters made be sectioned, based on the advanced nodes position besides a cluster head selection created with the rating combination will make definitely a network will be existent for a longer time.

Hence, a conclusion that nodes supported by proposing protocol applying to HWSN can survive for a longer period while associated with protocols like CCS or SEP. As the network is considered an energy constraint, then a usage of an efficient partial energy can result in a longer lifetime of the network. In HWSN, every node is with different amount of energy allocation. A concentration on both energy efficiency and stability in this proposed protocol. It proposes a methodology for improving the nodes instability period and the stability for extending the network lifetime. The protocol was simulated for a limited number of nodes ranging from 100-300 nodes; the protocol can further be enhanced to cover more number of nodes and sufficient changes to accommodate a larger number of nodes. While this protocol was designed keeping in mind a heterogeneous network with the same kind of sensors and different amounts of energy, an another type of heterogeneous network with different kinds of sensors can also be incorporated in the scope of this protocol with suitable changes.

5. CONCLUSIONS AND FUTURE WORK

5.1 CONCLUSION

Many WSN applications are valid for obtaining data from a variety of sources for multiple ranges and places. However, up to now it is not noticeable in the WSN literature, if there is any clustering protocols used to Cluster Head are greatest prepared towards diversity improvement. The most combined approaches used to select the CH in WSNs focusing on how to minimize the energy expenditure, to balance the energy consumption or routing through a less number of nodes for maximizing the function time that's needed to the network. Clustering protocols, and routing claim for improving the sensor network lifetime. Providing the energy methods can be considered an essential feature needed in wireless networks for efficient operation.

The routing protocol in this thesis depends on the protocols of clustering to select the Cluster Head are established for Heterogeneous WSNs. These protocols are verified that Heterogeneous protocols can be considered a novel energy efficient data gathering protocol in which clustering is created on the allocation of the growth budget with neighbors.

A proposed Protocol for heterogeneous WSN (HPEEA) is built on the residual energy in addition to the location information of the sensor nodes. HPEEA is a scheme which gets better energy efficiency in such networks. The implementation of this protocol proves that, the number of dead nodes in the network may be delayed by the K-theorem support and alternative rotation result in the candidate cluster head. In addition, the existence of the network will be for a longer time, which caused by the division of clusters, founded on the advanced nodes position and selected by the cluster head through its collection rating.

A simulation results and analysis achieved for this proposed protocol over this study can be as follows:

The gap between stability and energy efficiency in heterogeneous WSN is narrowed by the proposed HPEEA Protocol and it delays the death of the first node in the network, therefore increasing the stability period in the lifetime of the network using stable concentric clustering by selecting the cluster head based on combined rating and the position of the advanced nodes, leveraging K-therom. Also with this Protocol, as the number of nodes in the network increases, the number of dead nodes at the end of 5000 rounds is far less compared to other protocols in Heterogeneous WSN.

Also, from the result graphs it can be shown that as the number of nodes in the network increases, the dead node numbers at the end of 5000 rounds will be far a lesser amount when compared to the different protocols in Heterogeneous WSN. Thus, the conclusion is that, nodes following the proposed protocol in HWSN can survive for a longer time when compared to protocols such as SEP or CCS.

For duty-cycle application of the combined algorithm for Energy Efficient for WSN, it can survive for a longer time in comparism to the nodes where duty-cycle in this algorithm is not applied, which gives 32% of the average increase in lifetime and 35% of the average increase in the efficiency of energy.

5.2 FUTURE WORK

For the determination of the network overall lifetime, the different proposed routing protocols, as well as other third party routing protocols with a changing number of nodes besides rounds periods of time, some simulation experiments can be proposed that the sources commonly generate data and make a route towards a sink. The new guidance functions with total data transferring can measured for determining any routing protocols can achieve best lifetime.

In spite of the requirements for efficient protocol design and energy aware can be accomplished, there still a lot of issues must be addressed. A need for proposed solutions for homogeneous integrated with heterogeneous WSN and can be integrated with cloud computing as future work for these networks

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