IMPLEMENTATION OF ENHANCED DISTRIBUTED ENERGY EFFICIENT CLUSTERING PROTOCOL IN WIRELESS SENSOR NETWORKS

BACHELOR OF TECHNOLOGY

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ELECTRONICS AND COMMUNICATION ENGINEERING

Mini Project Report Submitted By

SAI JOSHITHA ANNAREDDY (17011A0423)

BAIRI NAVYA SRI (18015A0403)

KANNA SANTHI (17011A0428)

VISHAL PANDITA (17011A0444)

Under the esteemed guidance of

Dr. D. SRINIVASA RAO

Professor in ECE Department

Department Of Electronics and Communication Engineering

Jawaharlal Nehru Technological University Hyderabad

College of Engineering Hyderabad

Autonomous

(Kukatpally-Hyderabad-500085)

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Department Of Electronics and Communication Engineering
Jawaharlal Nehru Technological University Hyderabad
Kukatpally , Hyderabad – 500085

CERTIFICATE BY THE SUPERVISOR

This is to certify that the mini project entitled "**IMPLEMENTATION OF ENHANCED DISTRIBUTED ENERGY EFFICIENT CLUSTERING PROTOCOL IN WIRELESS SENSOR NETWORKS**" being submitted by

SAI JOSHITHA ANNAREDDY (17011A0423)
BAIRI NAVYA SRI (18015A0403)
KANNA SANTHI (17011A0428)
VISHAL PANDITA (17011A0444)

in partial fulfillment of the requirements for the award of degree in Bachelors of Technology in Electronics and Communication Engineering at the Jawaharlal Nehru Technological University during the academic year 2020-21 is a bonafide work carried out under my guidance and supervision. The results embodied in this mini project report have not been submitted to any other University or institute for the award of any degree or diploma.

Supervisor:
Dr. D. Srinivasa Rao
Professor of ECE
JNTUH College Of Engineering,
Kukatpally,
Hyderabad.

Department Of Electronics and Communication Engineering
Jawaharlal Nehru Technological University Hyderabad
Kukatpally , Hyderabad – 500085

CERTIFICATE BY THE HEAD OF THE DEPARTMENT

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In partial fulfillment of the requirements for the award of degree in Bachelor of Technology in Electronics and Communication Engineering at the Jawaharlal Nehru Technological University during the academic year 2020-21 is a Bonafide work carried out by them.

HEAD OF THE DEPARTMENT

Dr. K. ANITHA SHEEELA

Professor and Head,

Department Of ECE,

JNTUH CEH.

Department of Electronics and Communication Engineering

Jawaharlal Nehru Technological University Hyderabad

Kukatpally, Hyderabad – 500085

DECLARATION OF THE CANDIDATES

We hereby declare that the mini project report title "**IMPLEMENTATION OF ENHANCED DISTRIBUTED ENERGY EFFICIENT CLUSTERING PROTOCOL IN WIRELESS SENSOR NETWORKS**" is a bonafide record work done and submitted under the esteemed guidance of **Dr. D.Srinivasa Rao**, Professor, Department of ECE, JNTUH CEH, in partial fulfillment of the requirements for Mini project in Electronics and Communication Engineering at the Jawaharlal Nehru Technological University during the academic year 2020-21 is a bonafide work carried out by us and the results kept in the minor project have not been reproduced. The results have not been submitted to any other institute or university for the award of a degree or diploma.

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BAIRI NAVYA SRI (18015A0403)
KANNA SANTHI (17011A0428)
VISHAL PANDITA (17011A0444)

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ABSTRACT

Wireless Sensor Networks (WSNs) are envisaged to become the fabric of our environment and society. It has applications in the management of events, battlefield surveillance, recognition security, drug identification, and automatic security. Wireless sensor network contains hundreds of thousands of sensor nodes. These nodes are deployed randomly in the area of interest and have a low battery lifetime. Their lifetime expires when their energy is finished. So, energy is a scarce source for wireless sensor networks. We must manage the right use of energy for increasing sensor lifetime. In wireless sensor networks, all sensed data must be sent to a base station called a sink. One can retrieve required information from the network by injecting queries and gathering results from the sink. The clustering mechanism is the best and most efficient one to resolve the issue with the requirement of energy in WSN. In clustering, the network is divided into smaller clusters and each cluster includes a cluster head (CH) and its members. It is very much useful for reducing energy dissipation and enhancing the lifetime of the network.

The main aim of this project is to implement and evaluate the performance of Enhanced Distributed Energy Efficient Clustering (EDEEC) protocol in wireless sensor networks. The performance of the EDEEC is compared with other existing clustering protocols such as DEEC and DDEEC.

In Distributed Energy Efficient Clustering (DEEC) protocol, CH (cluster head) selection is based on probability which depends upon the residual energy of nodes and average energy of the network. Developed Distributed Energy Efficient Clustering (DDEEC) selects CHs based on nodes' residual energy. This protocol dynamically changes the CH selection criteria for nodes according to their residual energy.

The goal of EDEEC is to achieve energy efficiency by prolonging network lifetime. For this purpose, EDEEC used DEEC along with priority queue to save from packet drop. Distance between the nodes and cluster head is also considered to reduce the energy consumption during the transmission of packets. EDEEC protocol

is extended to three-level heterogeneity by adding an extra energy level as compared to DEEC, and DDEEC. The nodes are categorized as normal, advanced, and super nodes. The energy of Super nodes > Energy of advanced nodes > Energy of normal nodes.

Simulations are performed using MATLAB software to evaluate the performance of the DEEC, DDEEC, and EDEEC protocols. Performance of these protocols are evaluated based on the parameters like network stability, Network lifetime, Number of dead Nodes per round and also Alive nodes per round, Number of Cluster heads formed per round, Number of Data packets transferred from Cluster heads to Base Stations in a round, energy consumption, and throughput.

Table of contents

List of figures

Tables

CHAPTER-1

1.1 Introduction

Wireless Sensor Networks (WSNs) can be defined as a self-configured and infrastructure-less wireless network to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion, or pollutants, and to cooperatively pass their data through the network to the main location or sink where the data can be observed and analyzed. A sink or base station acts as an interface between users and the network. One can retrieve required information from the network by injecting queries and gathering results from the sink.

In contrast to conventional networks, sensor networks show a unique set of asymmetric traffic patterns. This is at large due to the functions of WSN, i.e., nodes persistently send sensed data to the BS, and BS occasionally sends control messages to nodes. Also, a wide range of applications causes asymmetry in traffic as well. In this context, the traffic of WSNs fall to one of the two categories: single-hop and multi-hop. Where the multi-hop category can be further divided based on the number of transmitting/receive nodes.

Routing protocols, especially cluster-based techniques, play an important role while achieving energy efficiency. According to this technique, members of the same cluster select a CH and nodes belonging to that cluster send sensed data to the CH which forwards the aggregated data to the BS. Energy-efficient, lifetime balancing data collection techniques can be utilized here. Clustering can be implemented either inhomogeneous or heterogeneous WSNs; Inhomogeneous networks, nodes are equipped with the same energy level, and in heterogeneous networks, these levels differ.

EDEEC protocol mainly used in

Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. A military example is the use of sensors to detect enemy intrusion

Health care monitoring: There are several types of sensor networks for medical applications: implanted, wearable, and environment-embedded. Implantable medical devices are those that are inserted inside the human body. Wearable devices are used on the body surface of a human or just near close to the user. Devices embedded in the environment track the physical state of a person for continuous health diagnosis, using as input the data from a network of depth cameras, a sensing floor, or other similar devices.

Air pollution monitoring: Wireless sensor networks have been deployed in several cities to monitor the concentration of dangerous gases for citizens. These can take advantage of the ad hoc wireless links rather than wired installations, which also make them more mobile for testing readings in different areas.

Landslide detection: A landslide detection system makes use of a wireless sensor network to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide. Through the data gathered it may be possible to know the impending occurrence of landslides long before it happens.

Data logging: Wireless sensor networks also are used for the collection of data for monitoring environmental information. This can be as simple as monitoring the temperature in a fridge or the level of water in overflow tanks in nuclear power plants. The statistical information can then be used to show how systems have been working. The advantage of WSNs over conventional loggers is the "live" data feed that is possible.

Water/wastewater monitoring: Monitoring the quality and level of water includes many activities such as checking the quality of underground or surface water and ensuring a country's water infrastructure for the benefit of both humans and animals. It may be used to protect the wastage of water.

Wine production: Wireless sensor networks are used to monitor wine production, both in the field and the cellar.

1.2 Aim:

The main aim of the project is to implement Enhanced Distributed Energy efficient Clustering Protocol in Wireless Sensor Networks and to compare various parameters between DEEC DDEEC and EDEEC clustering protocols like:

1.Network lifetime(No of alive nodes)

2.No of Data packets delivered from cluster head to Base station

3.Energy Consumption/Total remaining energy

4.No of Dead nodes per round

5.No of Cluster Heads formed per round

6.Throughput

1.3 Objectives:

- To Study about different wireless sensor protocols like DEEC,DDEEC,EDEEC.

- To implement Enhanced Distributed Energy Efiicient Clustering Protocol using MATLAB.

- To Study about Basics of Matlab required for these protocols and to Simulate the protocols using Matlab.

- To Compare the performance between DEEC,DDEEC and EDEEC using MATLAB simulation results.

CHAPTER-2

2.1 Wireless Sensor networks

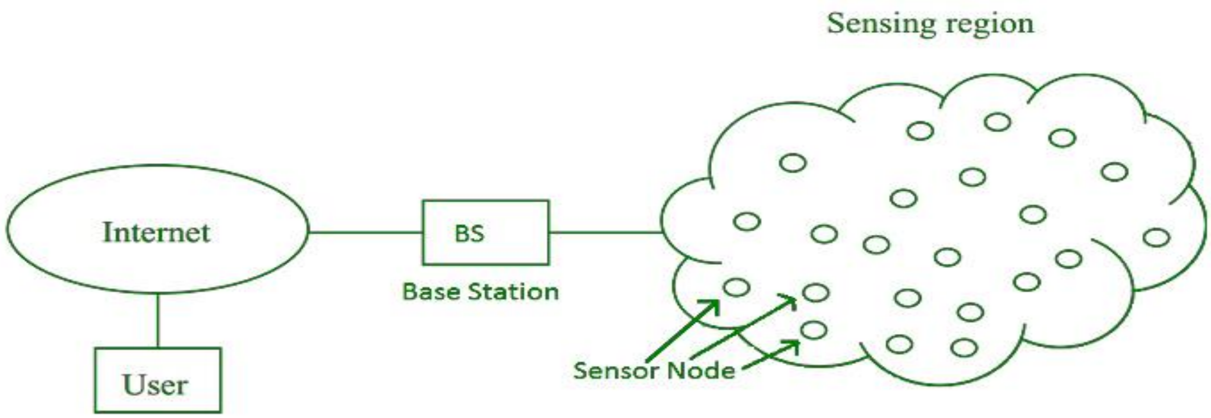


Figure 2.1 Basic block diagram for wireless sensor network

Sensing Region: Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring it's reflected and emitted radiation at a distance (typically from satellite or aircraft).

Sensor Node: A sensor node is a node in a sensor network that is capable of performing some processing, gathering sensory information, and communicating with other connected nodes in the network.

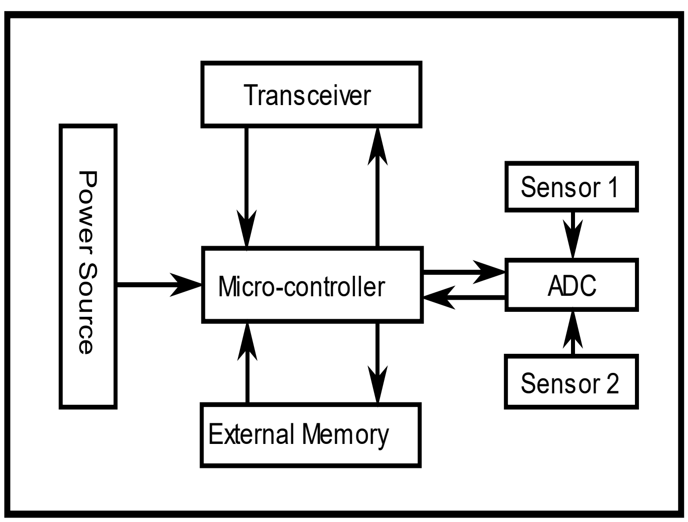


Fig2.2 Block Diagram of Sensor Node

Components

The main components of a sensor node are a microcontroller, transceiver, external memory, power source, and one or more sensors.

Controller

The controller performs tasks, processes data, and controls the functionality of other components in the sensor node. While the most common controller is a microcontroller, other alternatives that can be used as a controller are a general-purpose desktop microprocessor, digital signal processors, FPGAs and ASICs. A microcontroller is often used in many embedded systems such as sensor nodes because of its low cost, flexibility to connect to other devices, ease of programming, and low power consumption. A general-purpose microprocessor generally has a higher power consumption than a microcontroller, therefore it is often not considered a suitable choice for a sensor node. Digital Signal Processors may be chosen for broadband wireless communication applications, but in WSNs the wireless communication is often modest: i.e., simpler, easier to process modulation, and the signal processing tasks of actual sensing of data is less complicated. Therefore, the advantages of DSPs are not usually of much importance to wireless sensor nodes. FPGAs can be reprogrammed and reconfigured according to requirements, but this takes more time and energy than desired.

Transceiver

Sensor nodes often make use of the ISM band, which gives free radio, spectrum allocation, and global availability. The possible choices of wireless transmission media are radio frequency (RF), optical communication (laser), and infrared. Lasers require less energy, but need line of sight for communication and are sensitive to atmospheric conditions. Infrared, like lasers, needs no antenna but it is limited in its broadcasting capacity. Radio frequency-based communication is the most relevant that fits most of the WSN applications. WSNs tend to use license-free communication frequencies: 173, 433, 868, and 915 MHz; and 2.4 GHz. The functionality of both transmitter and receiver are combined into a single device known as a transceiver, Transceivers often lack unique identifiers. The operational states are transmitting, receive, idle, and sleep. Current generation transceivers have built-in state machines that perform some operations automatically.

Most transceivers operating in idle mode have a power consumption almost equal to the power consumed in receive mode. Thus, it is better to completely shut down the transceiver rather than leave it in the idle mode when it is not transmitting or receiving. A significant amount of power is consumed when switching from sleep mode to transmit a packet.

External memory

From an energy perspective, the most relevant kinds of memory are the on-chip memory of a microcontroller and Flash Memory—off-chip RAM is rarely if ever, used. Flash memories are used due to their cost and storage capacity. Memory requirements are very much application-dependent. Two categories of memory based on the purpose of storage are user memory used for storing application-related or personal data, and program memory used for programming the device. Program memory also contains identification data of the device if present.

Power source

A wireless sensor node is a popular solution when it is difficult or impossible to run a main supply to the sensor node. However, since the wireless sensor node is often placed in a hard-to-reach location, changing the battery regularly can be costly and inconvenient. An important aspect in the development of a wireless sensor node is ensuring that there is always adequate energy available to power the system. The sensor node consumes power for sensing, communicating, and data processing. More energy is required for data communication than any other process. The energy cost of transmitting 1 Kb a distance of 100 meters (330 ft) is approximately the same as that used for the execution of 3 million instructions by 100 million instructions per second/W processor. Power is stored either in batteries or capacitors. Batteries, both rechargeable and non-rechargeable, are the main source of power supply for sensor nodes.

Sensors

Sensors are used by wireless sensor nodes to capture data from their environment. They are hardware devices that produce a measurable response to a change in a physical condition like temperature or pressure. Sensors measure physical data of the parameter to be monitored and have specific characteristics such as accuracy, sensitivity, etc. The continual analog signal produced by the sensors is digitized by an analog to digital converter and sent to controllers for further processing. Some sensors contain the necessary electronics to convert the raw signals into readings which can be retrieved via a digital link (e.g., I2C, SPI), and many converts to units such as °C. Most sensor nodes are small in size, consume little energy, operate in high volumetric densities, be autonomous and operate unattended, and be adaptive to the environment. As wireless sensor nodes are typically very small electronic devices, they can only be equipped with a limited power source of less than 0.5-2 ampere-hour and 1.2-3.7 volts.

Sensors are classified into three categories: passive, omnidirectional sensors; passive, narrow-beam sensors; and active sensors. Passive sensors sense the data without actually manipulating the environment by active probing. They are selfpowered; that is, energy is needed only to amplify their analog signal. Active sensors actively probe the environment, for example, a sonar or radar sensor, and they require continuous energy from a power source. Narrow-beam sensors have a well-defined notion of direction of measurement, similar to a camera. Omnidirectional sensors have no notion of direction involved in their measurements.

Most theoretical work on WSNs assumes the use of passive, omnidirectional sensors. Each sensor node has a certain area of coverage for which it can reliably and accurately report the particular quantity that it is observing. Several sources of power consumption in sensors are: signal sampling and conversion of physical signals to electrical ones, signal conditioning, and analog-to-digital conversion. Spatial density of sensor nodes in the field may be as high as 20 nodes per cubic meter.

Base Station(Sink):

The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end-user as they typically forward data from the WSN onto a server.

The main **characteristics of a WSN** include

- Power consumption constraints for nodes using batteries or energy harvesting. Examples of suppliers are Revived Energy and Perpetuum.
- Ability to cope with node failures.
- Some mobility of nodes
- Heterogeneity of nodes and Homogeneity of nodes
- Scalability to a large scale of deployment
- Ability to withstand harsh environmental conditions
- Ease of use

Basic Principle of Wireless Sensor networks:

In WSN the main task of the sensor node is to sense the data and sends it to the base station in a multi-hop environment for which routing path is essential. For computing the routing path from the source node to the base station there are huge numbers of proposed routing protocols exist. The design of routing protocol for WSNs must consider the power and resource limitations of the network nodes, the time-varying quality of the wireless channel, and the possibility of packet loss and delay. To address these design requirements, several routing strategies for WSN have been proposed.

The first class of routing protocols adopts a flat network architecture in which all nodes are considered peers. Flat network architecture has several advantages, including minimal overhead to maintain the infrastructure and the potential for the discovery of multiple routes between communicating nodes for fault tolerance.

The second class of routing protocols imposes a structure on the network to achieve energy efficiency, stability, and scalability. In this class of protocols, network nodes are organized in clusters in which a node with higher residual energy, for example, assumes the role of a cluster head. The cluster head is responsible for coordinating activities within the cluster and forwarding information between clusters. Clustering has the potential to reduce energy consumption and extend the lifetime of the network.

The third class of routing protocols uses a data-centric approach to disseminate interest within the network. The approach uses attribute-based naming, whereby a source node queries an attribute for the phenomenon rather than an individual sensor node. The interest dissemination is achieved by assigning tasks to sensor nodes and expressing queries relative to specific attributes. Different strategies can be used to communicate interests to the sensor nodes, including broadcasting, attribute-based multicasting, geo-casting, and any casting.

The fourth class of routing protocols uses location to address a sensor node. Location-based routing is useful in applications where the position of the node within the geographical coverage of the network is relevant to the query issued by the source node. Such a query may specify a specific area where a phenomenon of interest may occur or the vicinity to a specific point in the network environment.

Clustering Mechanism:

Routing protocols, especially cluster-based techniques, play an important role while achieving energy efficiency. According to this technique, members of the same cluster select a CH and nodes belonging to that cluster send sensed data to the CH which forwards the aggregated data to the BS. Energy-efficient, lifetime balancing data collection techniques can be utilized here in clustering mechanism.

Clustering can be implemented either in homogeneous or heterogeneous WSNs; inhomogeneous networks, nodes are equipped with the same energy level, and in heterogeneous networks, these levels differ. Low-energy adaptive clustering hierarchy (LEACH) is designed for homogenous WSNs; however, this algorithm performs poorly in heterogeneous networks because the low-energy nodes die more quickly than the high-energy ones since the clustering algorithm does not have inbuilt discrimination in terms of energy levels. Stable election protocol (SEP), distributed energy-efficient clustering (DEEC), developed DEEC (DDEEC), and enhanced DEEC (EDEEC) are examples of heterogenous WSN protocols.

2.2 Basic Protocol:

Low-energy adaptive clustering hierarchy ("LEACH") is a clustering and a basic routing protocol in wireless sensor networks (WSNs). The goal of LEACH is to lower the energy consumption required to create and maintain clusters to improve the lifetime of a wireless sensor network.

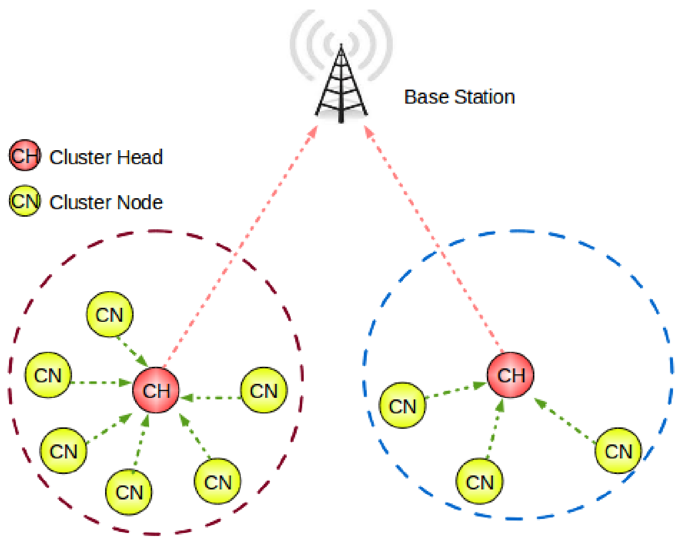


Figure 2.3 BASIC CLUSTERING PROTOCOL

Protocol:

LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compress the data and forward it to the base station (sink). Each node uses a stochastic algorithm at each round to determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the base station or the nearest cluster head, but that using this radio at full power all the time would waste energy.

Nodes that have been cluster heads cannot become cluster heads again for *P* rounds, where *P* is the desired percentage of cluster heads. Thereafter, each node has a 1/*P* probability of becoming a cluster head again. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster. The cluster head then creates a schedule for each node in its cluster to transmit its data.

All nodes that do not cluster heads only communicate with the cluster head in a TDMA fashion, according to the schedule created by the cluster head. They do so use the minimum energy needed to reach the cluster head, and only need to keep their radios on during their time slot.

Properties:

Properties of this algorithm include:

- Cluster-based
- Random cluster head selection each round with rotation. Or cluster head selection based on sensor having the highest energy
- Cluster membership adaptive
- Data aggregation at the cluster head
- Cluster head communicate directly with sink or user
- Communication is done with cluster head via TDMA
- Threshold value

Advantages and Disadvantages of LEACH

The various advantages of the LEACH protocol are:

1. The Cluster Heads aggregates the whole data which leads to reduce the traffic in the entire network.

2. As there is a single-hop routing from nodes to cluster head it results in saving energy.

3. It increases the lifetime of the sensor network.

4. In this, location information of the nodes to create the cluster is not required.

5. LEACH is completely distributed as it does not need any control information from the base station as well as no global knowledge of the network is required.

Besides the advantages of LEACH, it also has some demerits which are as follows:

1. LEACH does not give any idea about the number of cluster heads in the network.

2. One of the biggest disadvantages of LEACH is that when due to any reason Cluster head dies, the cluster will become useless because the data gathered by the cluster nodes would never reach its destination i.e., Base Station.

3. Clusters are divided randomly, which results in uneven distribution of Clusters. E.g., some clusters have more nodes and some have lesser nodes. Some cluster heads at the center of the cluster and some cluster heads may be at the edge of the cluster; this phenomenon can cause an increase in energy consumption and have a great impact on the performance of the entire network.

Low-energy adaptive clustering hierarchy (LEACH) is designed for homogenous WSNs; however, this algorithm performs poorly in heterogeneous networks because the low-energy nodes die more quickly than the high-energy ones since the clustering algorithm does not have inbuilt discrimination in terms of energy levels. distributed energy-efficient clustering (DEEC), developed DEEC (DDEEC), and enhanced DEEC (EDEEC) are examples of heterogenous WSN protocols.

2.3 DEEC(Distributed energy-efficient Clustering)Protocol:

Distributed multilevel clustering algorithm for heterogeneous wireless sensor networks is considered with the following characteristics the cluster head is elected by a probability based on the ratio between the amount residual energy present at each node and the average energy of the network. The lifetime of a cluster head is decided according to its initial energy and residual energy. So always the nodes with high initial and residual energy have a better chance to become a CH. DEEC is implemented based on the concepts of LEACH algorithm. The role of cluster head is rotated among all nodes of the network to uniformize the energy dissipation. Two levels of heterogeneous nodes (i.e., Normal nodes and Advanced Nodes) are considered in this algorithm to achieve a longer network lifetime and more effective messages than other classical clustering algorithms. It also works better for multilevel heterogeneous networks. In DEEC, all the nodes must have an idea about the total energy and lifetime of the network. The average energy of the network is used as the reference energy.

DEEC is designed to deal with nodes of heterogeneous WSNs. For CH selection, DEEC uses the initial and residual energy levels of nodes. Let n_i denote the number of rounds to be a CH for node s_i. $p_{opt}N$ is the optimum number of CHs in our network during each round. CH selection criteria in DEEC are based on the energy level of nodes. As in a homogenous network, when nodes have the same amount of energy during each epoch then choosing $p_i = p_{opt}$ assures that $p_{opt}N$ CHs during each round. In WSNs, nodes with high energy are more probable to become CH than nodes with low energy but the net value of CHs during each round is equal to $p_{opt}N$. pi is the probability for each node s_i to become CH, so, a node with high energy has a larger value of pi as compared to the p_{opt}. E(r) denotes the average energy of the network during round r which can be given as:

$$\overline{\mathrm{E}}(\mathrm{r}) = \frac{1}{N}\sum_{i=1}^{N} \mathrm{E_i}(\mathrm{r}) \qquad \ldots 1$$

Probability for CH selection in DEEC is given as

$$p_{\mathrm{i}} = p_{opt}\left[1 - \frac{\overline{\mathrm{E}}(\mathrm{r}) - \mathrm{E_i}(\mathrm{r})}{\overline{\mathrm{E}}(\mathrm{r})}\right] = p_{opt}\frac{\mathrm{E_i}(r)}{\overline{\mathrm{E}}(\mathrm{r})} \qquad \ldots 2$$

In DEEC the average total number of CH during each round is given as :

$$\sum_{i=1}^{N} p_i = \sum_{i=1}^{N} p_{opt}\frac{\mathrm{E_i}(r)}{\overline{\mathrm{E}}(\mathrm{r})} = p_{opt}\sum_{i=1}^{N}\frac{\mathrm{E_i}(r)}{\overline{\mathrm{E}}(\mathrm{r})} = Np_{opt} \qquad \ldots 3$$

pi is the probability of each node to become CH in a round where G is the set of nodes eligible to become CH at round r. If a node becomes CH in recent rounds then it belongs to G. During each round each node chooses a random number between 0 and 1. If the number is less than the threshold as defined below, it is eligible to become a CH else not.

$$T(s_i) = \begin{cases} \frac{p_i}{1 - p_i(r \bmod \frac{1}{p_i})} & if\ s_i \in G \\ 0 & otherwise \end{cases} \qquad \ldots 4$$

As p_{opt} is the reference value of average probability pi. In homogenous networks, all nodes have the same initial energy so they use p_{opt} to be the reference energy for probability pi. However, in heterogeneous networks, the value of p_{opt} is different according to the initial energy of the node. In two-level heterogeneous network the value of p_{opt} is given by:

$$p_{adv} = \frac{p_{opt}}{1+am}, \qquad p_{nrm} = \frac{p_{opt}(1+a)}{(1+am)}$$

…5

Then use the above p_{adv} and p_{nrm} instead of p_{opt} in equation (2) for two level heterogeneous network as:

$$p_i = \begin{cases} \dfrac{p_{opt} E_i(r)}{(1+am)\bar{E}(r)} & if\ \ s_i\ is\ the\ normal\ node \\ \dfrac{p_{opt}(1+a)E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ the\ advanced\ node \end{cases}$$

…6

The above model can also be extended to a multilevel heterogeneous network given below as

$$p_{multi} = \frac{p_{opt}\, N(1+a_i)}{(N + \sum_{i=1}^{N} a_i\ )}$$

…7

Above p_{multi} in equation (2) instead of p_{opt} to get pi for heterogeneous node pi for the multilevel heterogeneous network is given by :

$$p_i = \frac{p_{opt}\, N(1+a)E_i(r)}{(N + \sum_{i=1}^{N} a_i\ )\, \bar{E}(r)}$$

…8

In DEEC we estimate average energy E(r) of the network for any round are as

$$\bar{E}(r) = \frac{1}{N} E_{total}\ (1 - \frac{r}{R})$$

…9

R denotes total rounds of network lifetime and is estimated as follow

$$R = \frac{E_{total}}{E_{round}} \quad \ldots 10$$

E_{total} is the total energy of the network where E_{round} is energy expenditure during each round.

2.3.1 Advantages and limitation of DEEC

Advantages of DEEC

(1) DEEC extended to two-level heterogeneity with cluster based mechanism which helps in energy conservation in network

(2) It controls the energy expenditure of nodes.

Limitations of DEEC

(1) Advanced nodes always punish in the DEEC, particularly when their residual energy is reduced and when they come in the range of the normal nodes. During this position, the advanced nodes die rapidly than the others

2.4 DDEEC(Developed Distributed Energy Efficient Clustering) Protocol:

DDEEC implements the same strategy as DEEC in terms of estimating the average energy of networks and the cluster head selection algorithm which is based on residual energy where:

- The average energy of r_{th} round is set at eq(9).
  where R denote the total rounds of the network lifetime and is defined at equation (10).
- E_{Round} is the total energy dissipated in the network during a round, is equal to:

$$E_{round} = L(2 * N * E_{elec} + N * E_{DA} + K * \varepsilon mp * d^4{}_{\mathrm{toBs}} + N * \varepsilon f * d^2{}_{\mathrm{toCH}}) \quad \ldots 11$$

Where k is the number of clusters, E_{DA} is the data aggregation cost expended in the cluster heads, d_{toBS} is the average distance between the cluster head and the base station, and d_{toCH} is the average distance between the cluster members and the cluster head.

- Because we assuming that the nodes are uniformly distributed, we can get:

$d_{toCH} = M/\sqrt{2\pi k}$, $d_{toBS} = 0.765*M/2$ …(12)

- The optimal number of clusters is defined as:

$$K_{opt} = \frac{M}{d^2{}_{toBS}} \frac{\sqrt{N}}{\sqrt{2\pi}} \frac{\sqrt{Ef_s}}{\sqrt{Emp}} \quad \ldots 13$$

In this way, we continue to punish more just these nodes, so they spent more energy and they will die quickly 1. To avoid this unbalanced case, our protocol DDEEC introduces some changes to equation 6. These changes are based on using a threshold residual energy value Th_{REV} , which is equal to:

$$Th_{REV} = E_0(1 + \frac{\mathrm{aE_{disNN}}}{\mathrm{E_{disNN}} - \mathrm{E_{disAN}}}) \quad \ldots 14$$

Therefore, the cluster head election will be balanced and more equitable. So, the equation (6) which represents the nodes average probability pi to be a cluster head will change as follow:

$$p_i = \begin{cases} \dfrac{p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & for\ Nml\ nodes\ , E_i(r) > Th_{REV} \\ \dfrac{(1+a)p_{opt}\,E_i(r)}{(1+am)\bar{E}(r)} & for\ Adv\ nodes\ , E_i(r) > Th_{REV} \\ c\,\dfrac{(1+a)p_{opt}\,E_i(r)}{(1+am)\bar{E}(r)} & for\ Adv, Nml\ nodes\ , E_i(r) \geq Th_{REV} \end{cases} \quad \ldots 15$$

The value of Th_{REV} is written as $Th_{REV} = b_{Eo}$ where

$$b = (1 + \frac{\mathrm{aE_{disNN}}}{\mathrm{E_{disNN}} - \mathrm{E_{disAN}}}) \quad \ldots .(16)$$

2.5 EDEEC (Enhanced Distributed Energy Efficient Clustering) Protocol:

E-DEEC implements the same strategy for estimating the energy in the network as proposed in DEEC.

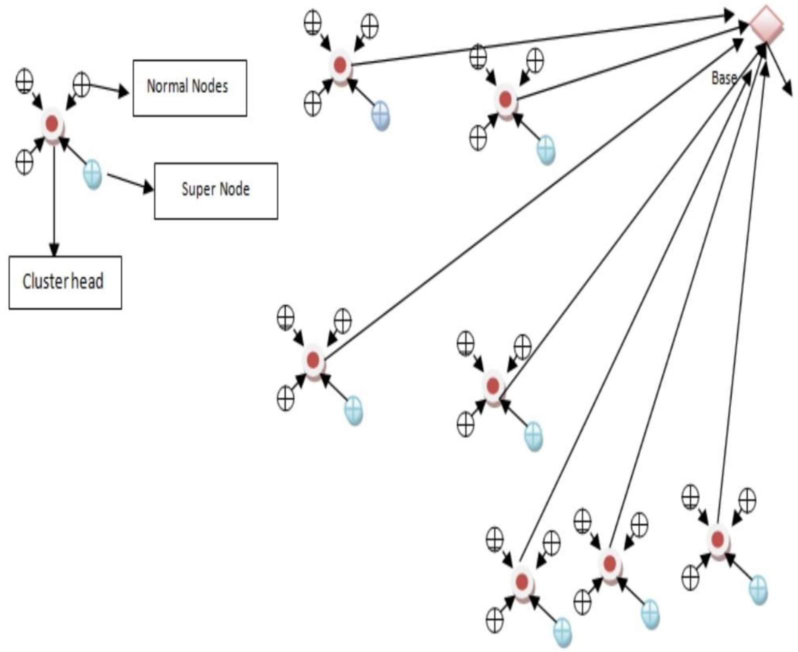


Figure 2.4 EDEEC model with cluster head and normal nodes.

Since the probabilities calculated depend on the average energy of the network at round r, hence this is to be calculated. This average energy is estimated in equation (9).

Where R denotes the total rounds of the network lifetime. R can be calculated in equation (10).

d_{toBS} & d_{toCH} is calculated in equation (12) .

During each round, the node decides whether to become a CH or not based on the threshold calculated by the suggested percentage of CH and the number of times the node has been a CH so far. This decision is taken by nodes by choosing a random number between 0 & 1. If the number is less than threshold T(s), the node becomes a CH for the current round. A threshold is calculated as:

$$T(s) = \begin{cases} \frac{p}{1-p(r mod \frac{1}{p})} & if\ s \in G \\ 0 & otherwise \end{cases}$$

…17

where p, r, and G represent, respectively, the desired percentage of cluster-heads, the current round number, and the set of nodes that have not been cluster-heads in the last 1/p rounds. Using this threshold, each node will be a cluster head, just once at some point within 1/p rounds. In the three-level heterogeneous networks, there are three types of nodes normal nodes, advanced nodes, and supernodes, based on their initial energy. Hence the reference value of p is different for these types of nodes. The probabilities of normal, advanced, and supernodes are:

$$p_i = \begin{cases} \frac{p_{\text{opt}} E_i(r)}{(1+m(a+m_o b))\bar{E}(r)} & if\ s_i \text{ is the normal node} \\ \frac{p_{\text{opt}}(1+a) E_i(r)}{(1+m(a+m_o b))\bar{E}(r)} & if\ s_i \text{ is the advanced node} \\ \frac{p_{\text{opt}}(1+b) E_i(r)}{(1+m(a+m_o b))\bar{E}(r)} & if\ s_i \text{ is the super node} \end{cases}$$

…18

The threshold for cluster head selection is calculated for normal, advanced, supernodes by putting the above values in Equation (17)

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_i(r\ mod \frac{1}{p_i})} & if\ p_i \in G' \\ \frac{p_i}{1-p_i(r\ mod \frac{1}{p_i})} & if\ p_i \in G'' \\ \frac{p_i}{1-p_i\left(r\ mod \frac{1}{p_i}\right)} & if\ p_i \in G''' \\ 0 & otherwise \end{cases}$$

… (19)

where $G'$is the set of normal nodes that have not become cluster heads within the last 1/pi rounds of the epoch where s_i is a normal node, $G''$is the set of advanced nodes that have not become cluster heads within the last 1/pi rounds of the epoch where s_i is an advanced node, G''' is the set of super nodes that have not become cluster heads within the last 1/pi rounds of the epoch where s_i is super node.

2.6 Comparison of Protocols:

Type	**Energy Levels**	**Network Lifetime**	**CH Mobility**	**CH selection**	**Threshold Energy**
DEEC	Two	Good	Variable	Residual Energy and Average energy	Not Present
DDEEC	Two	Better	Variable	Average energy and Initial energy	Present
EDEEC	Three	Best	Variable	Residual Energy and Average energy	Present

Table 2.1

Compare the performance of DEEC, DDEEC, EDEEC:

For m=0.8, m o=0.6, a=2.0 and b=3.5

Protocols	First node die	All nodes die	Packet send to BS
DEEC	969 rounds	5536 rounds	153936 packets
DDEEC	1355 rounds	5673 rounds	141696 packets
EDEEC	1432 rounds	8638 rounds	407642 packets

Table 2.1.1

For m=0.5, m o=0.4, a=1.5 and b=3

Protocols	First node die	All nodes die	Packet send to BS
DEEC	526 rounds	5380 rounds	136468 packets
DDEEC	1252 rounds	4523 rounds	108024 packets
EDEEC	1291 rounds	6920 rounds	288186 packets

Table 2.1.2

Flowchart of DEEC DDEEC and EDEEC:

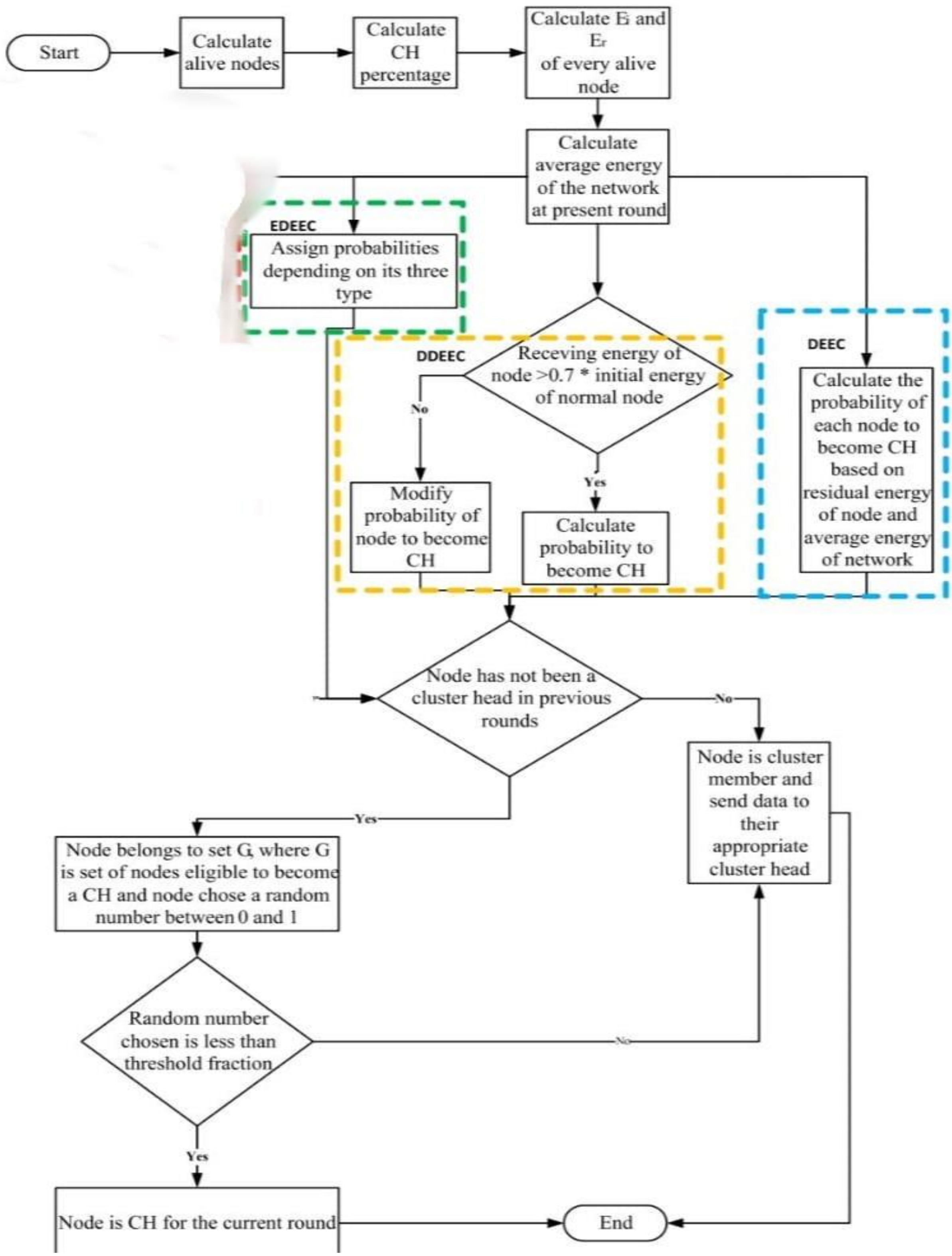


figure 2.5 flow chart for DEEC DDEEC and EDEEC

CHAPTER-3

MATLAB Simulator

3.1 Introduction to Matlab

MATLAB (an abbreviation of "matrix laboratory") is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.

The MATLAB application is built around the MATLAB programming language. Common usage of the MATLAB application involves using the "Command Window" as an interactive mathematical shell or executing text files containing MATLAB code.

3.2 Basic Commands in Matlab

Variables

Variables are defined using the assignment operator, =. MATLAB is a weakly typed programming language because types are implicitly converted.[33] It is an inferred typed language because variables can be assigned without declaring their type, except if they are to be treated as symbolic objects,[34] and that their type can change. Values can come from constants, from computation involving values of other variables, or from the output of a function. For example:

```
>> x = 17
x =
 17
```

Vectors and matrices

A simple array is defined using the colon syntax: initial:increment:terminator. For instance:

```
>> array = 1:2:9
array =
 1 3 5 7 9
```

Functions: When creating a MATLAB function, the name of the file should match the name of the first function in the file. Valid function names begin with an alphabetic character and can contain letters, numbers, or underscores. Variables and functions are case-sensitive.

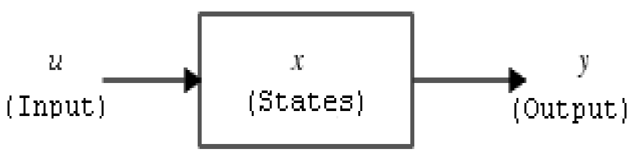
S Function: S-functions (system-functions) provide a powerful mechanism for extending the capabilities of the Simulink® environment. An *S-function* is a computer language description of a Simulink block written in MATLAB.

S-functions use a special calling syntax called the S-function API that enables you to interact with the Simulink engine. This interaction is very similar to the interaction that takes place between the engine and built-in Simulink blocks.

S-functions follow a general form and can accommodate continuous, discrete, and hybrid systems S-functions define how a block works during different parts of the simulation, such as initialization, update, derivatives, outputs, and termination. In every step of a simulation, a method is invoked by the simulation engine to fulfill a specific task. S-function basics require fundamental knowledge of mathematical relationships between the block inputs, states, and outputs.

Mathematics of Simulink Blocks:

A Simulink block consists of a set of inputs, a set of states, a set of parameters, and a set of outputs, where the outputs are a function of the simulation time, the inputs, parameters, and the states.



Rand Function: The rand function generates arrays of random numbers whose elements are uniformly distributed in the interval (0,1).

Y = rand(n) returns an n-by-n matrix of random entries. An error message appears if n is not a scalar.

Y = rand(m,n) or Y = rand([m n]) returns an m-by-n matrix of random entries.

Y = rand(m,n,p,...) or Y = rand([m n p...]) generates random arrays.

Y = rand(size(A)) returns an array of random entries that is the same size as A.

rand, by itself, returns a scalar whose value changes each time it's referenced.

s = rand('state') returns a 35-element vector containing the current state of the uniform generator. To change the state of the generator:

rand('state',s)	Resets the state to s.
rand('state',0)	Resets the generator to its initial state.
rand('state',j)	For integer j, resets the generator to its j-th state.
rand('state',sum(100*clock))	Resets it to a different state each time.

Commands for Managing a Session

MATLAB provides various commands for managing a session. The following are such commands −

Command	Purpose
clc	Clears command window.
clear	Removes variables from memory.
disp	Displays contents of an array or string.
Input	Displays prompts and waits for input.
Length	Computes number of elements.
Linspace	Creates regularly spaced vector.
max	Returns largest element.
min	Returns smallest element.
Ones	Creates an array of ones.
zeros	Create an array of zeros.
axis	Sets axis limits.
grid	Displays gridlines.
plot	Generates XY plot.
print	Prints plot or saves plot to a file.

title	Puts text at top of the plot.
Xlabel	Adds text label to the x-axis.
Ylabel	Adds text label to the y-axis.
axes	Create axes objects.
close	Closes the current plot.
close all	Closes all plots.
figure	Opens a new figure window.
Hold	Freeze's current plot.
Legend	Legend placement by mouse.
Refresh	Redraws current figure window.
set	Specifies properties of objects such as axes.
Subplot	Creates plots in subwindows.
bar	Creates bar chart.

MATLAB has tightly integrated graph-plotting features.

For example, the function plot can be used to produce a graph from two vectors x and y. The code:

```
x = 0: pi/100:2*pi;
y = sin(x);
plot(x,y)
```

produces the following figure of the sine function

CHAPTER-4

Simulation Scenario and Simulation Results

4.a Simulation scenario and Simulation results:

Parameter	**Value**
Network size	500m*500m
Number of Nodes	500,1000
Probability of cluster heads p0	0.1
Initial Energy E0	0.5
Fraction of Energy Advancement of Advance nodes(a)	1
Packet size	4000 bits
Rounds(r max)	5000,10000
Transmitting Energy cost	50nJ/round
Receiving energy cost	50nJ/round
Other parameters	• m=0.5 • m0=0.4 • b=3

Table 4.1

4.2

Let the number of nodes be 500

Let Rounds=5000(for figure 4.4.1 and figure 4.4.2)

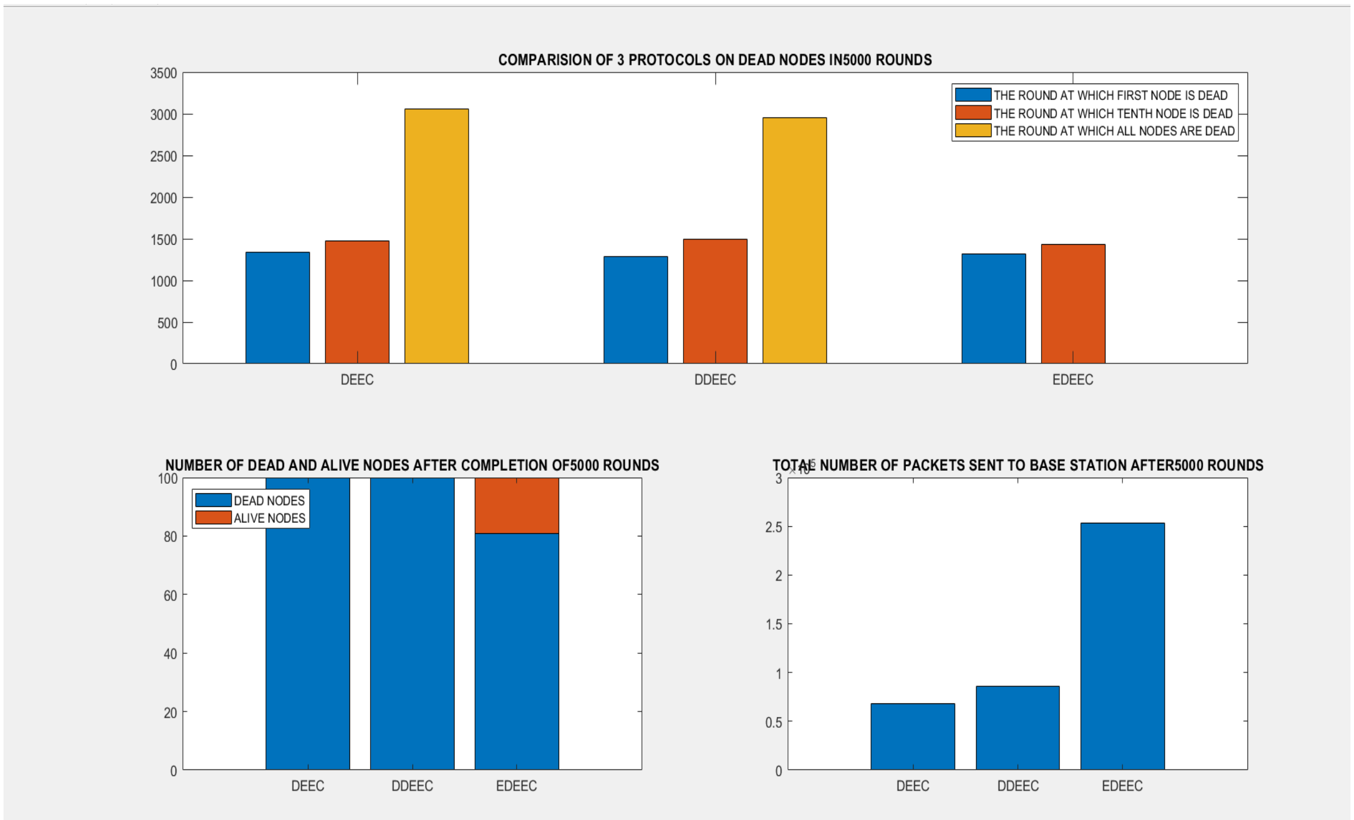


Figure 4.2.1 (i)represents the comparison of DEEC DDEEC and EDEEC protocols on dead nodes in 5000 rounds for 500 nodes

(ii). represent the no. of dead and alive nodes after 5000 rounds for 500 nodes.

(iii). represent the total no. of packets sent to the base station after 5000 rounds

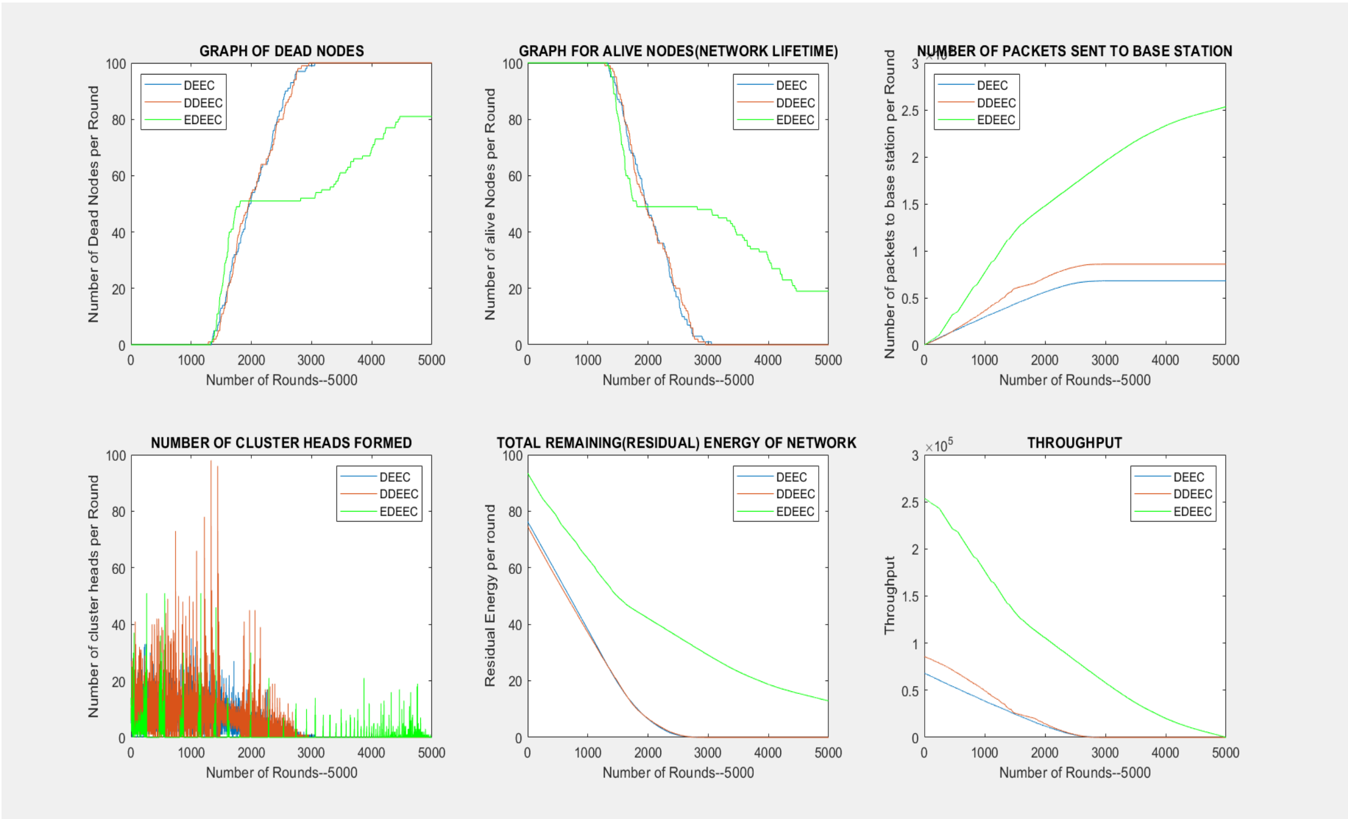


Figure 4.2.2

(i) represents the graph of dead nodes for no. of dead nodes per round. Rounds upto 5000.

(ii) represents the graph for alive nodes i.e., no. of alive nodes per round.Rounds upto 5000.

(iii) represents the graph for no. of packets sent to the base station per round. Rounds upto 5000.

(iv) represents the graph for the number of cluster heads formed per round. Rounds upto 5000.

(v) represents the graph for total residual energy per round. Rounds upto 5000.

(vi) represents the graph for throughput per no. of rounds

4.3

Let the number of nodes be 500

Let Rounds=10000(for figure 4.3.1 and figure 4.3.2)

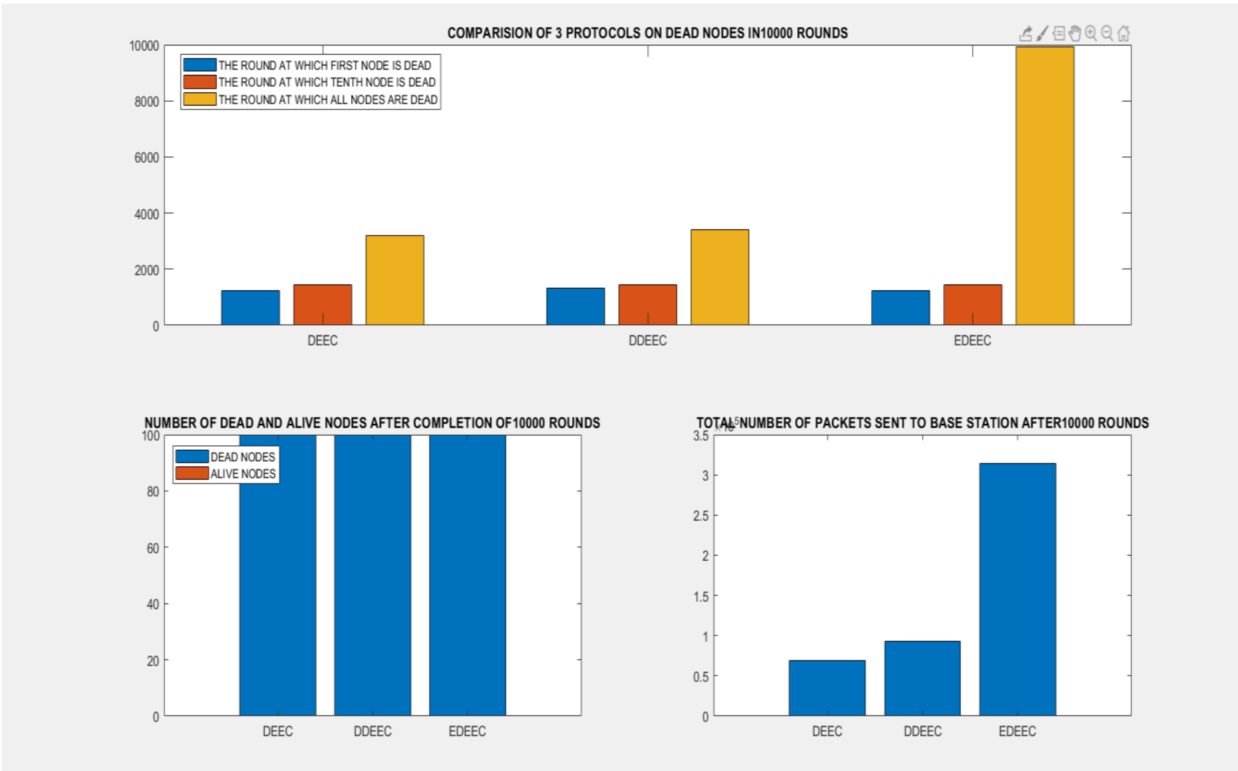


Figure 4.3.1 (i)represents the comparison of DEEC DDEEC and EDEEC protocols on dead nodes in 10000 rounds for 500 nodes

(ii) represent the no. of dead and alive nodes after 10000 rounds for 500 nodes.

(iii) represent the total no. of packets sent to the base station after 10000 rounds

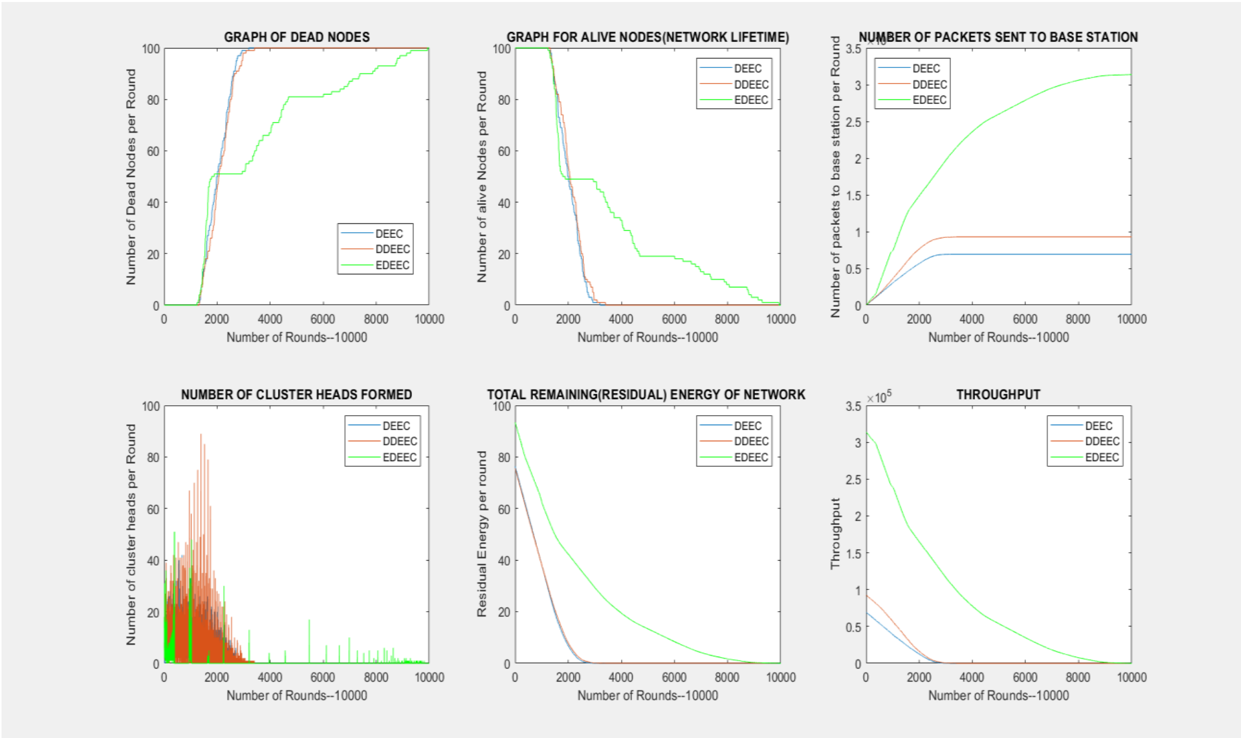


Figure 4.3.2

Fig (i) represents the graph of dead nodes for no. of dead nodes per round and rounds up to 10000.

Fig(ii) represents the graph for alive nodes i.e., no. of alive nodes per round and rounds up to 10000.

Fig(iii) represents the graph for no. of packets sent to the base station per round and rounds up to 10000.

Fig(iv) represents the graph for the number of cluster heads formed per round and rounds up to 10000.

Fig(v) represents the graph for total residual energy per round and rounds up to 10000.(

Fig(vi) represents the graph for throughput per no. of rounds(packets/sec)

4.4

Let the number of nodes be 1000

Let Rounds=5000(for figure 4.4.1 and figure 4.4.2)

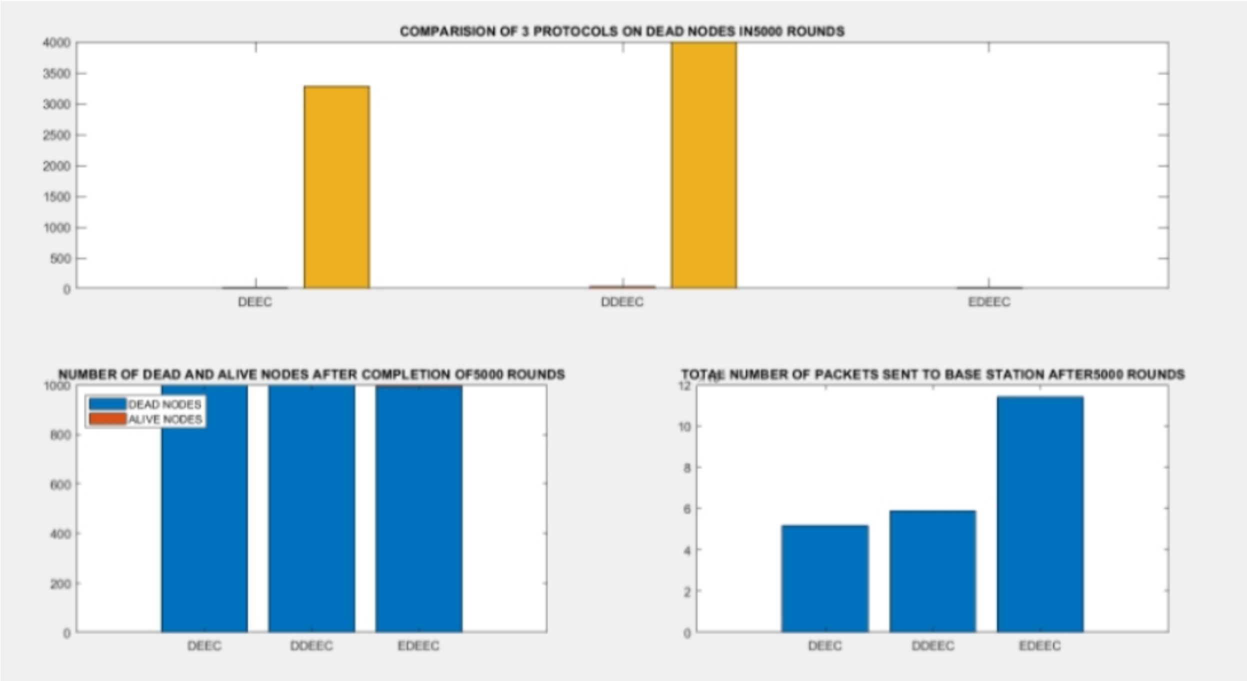


Fig 4.4.1

Fig (i) Comparision of different protocol on dead nodes in 5000 rounds for 1000 nodes.

Fig (ii) No. of Dead nodes and Alive nodes after completion of 5000 rounds for 1000 nodes

Fig (iii) Total No. of packets sent to the base station after 5000 rounds for 1000 nodes

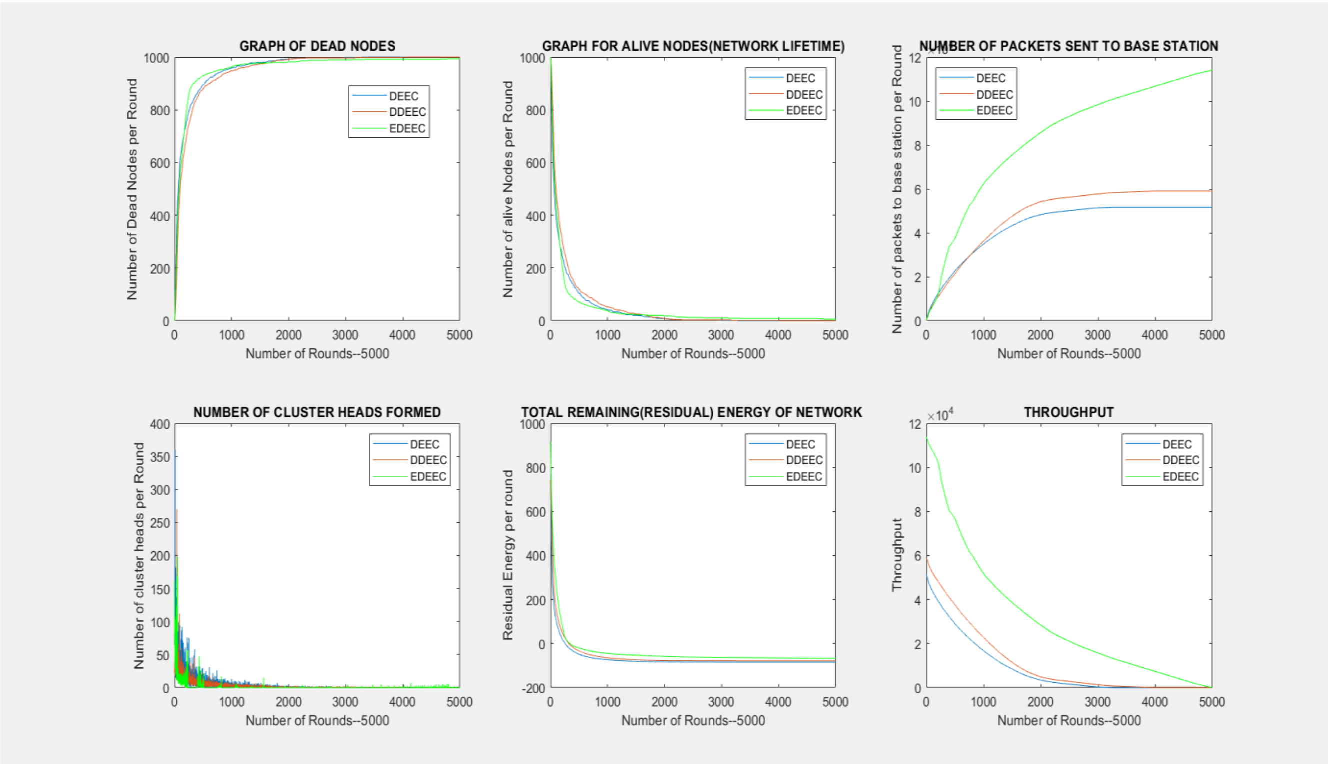


Fig 4.4.2

Fig (i) represents the graph of dead nodes for no. of dead nodes per round and rounds up to 5000.

Fig(ii) represents the graph for alive nodes i.e., no. of alive nodes per round and rounds up to 5000.

Fig(iii) represents the graph for no. of packets sent to the base station per round and rounds up to 5000.

Fig(iv) represents the graph for the number of cluster heads formed per round and rounds up to 5000.

Fig(v) represents the graph for total residual energy per round and rounds up to 5000.

Fig(vi) represents the graph for throughput per no. of rounds.

4.5

Let the number of nodes be 1000

Let Rounds=10000(for figure 4.5.1 and figure 4.5.2)

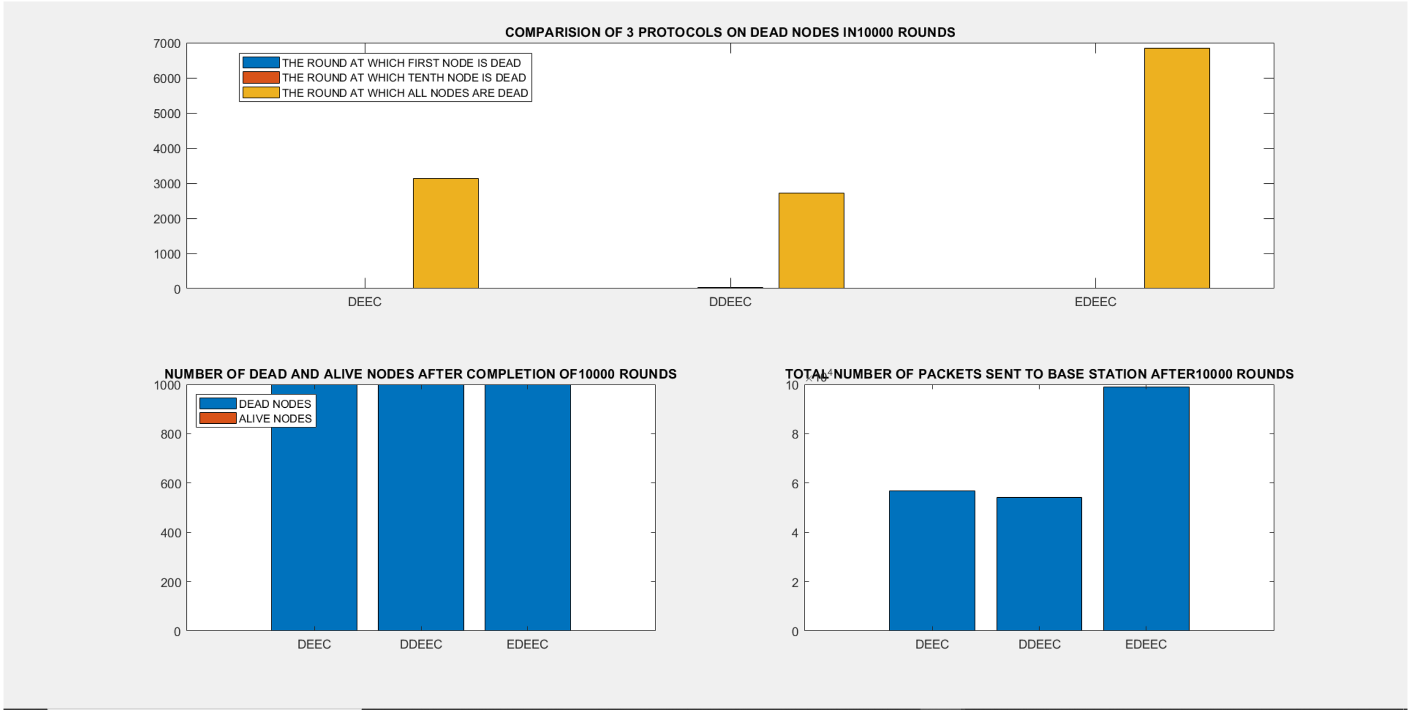


Figure 4.5.1

Figure 4.4.1 (a)represents the comparison of DEEC DDEEC and EDEEC protocols on dead nodes in 10000 rounds for 1000 nodes

(b). represent the no. of dead and alive nodes after 10000 rounds for 1000 nodes.

(c). represent the total no. of packets sent to the base station after 10000 rounds for 1000 nodes.

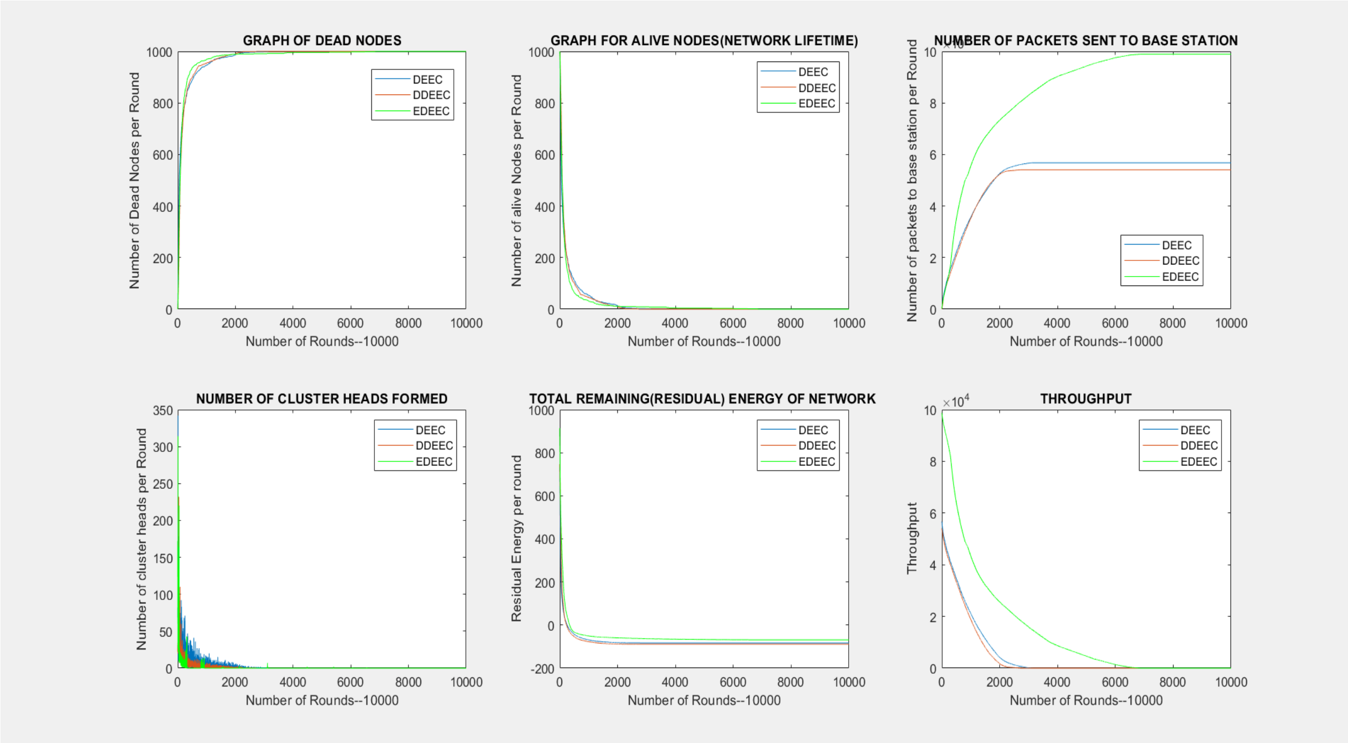


Figure 4.5.2

Fig(i) represents the graph of dead nodes for no. of dead nodes per round and rounds up to 10000.

Fig(ii) represents the graph for alive nodes i.e., no. of alive nodes per round and rounds up to 10000.

Fig(iii) represents the graph for no. of packets sent to the base station per round and rounds up to 10000.

Fig(iv) represents the graph for the number of cluster heads formed per round and rounds up to 10000.

Fig(v) represents the graph for total residual energy per round and rounds up to 10000.

Fig(vi) represents the graph for throughput per no. of rounds (packet/sec)

Conclusion:

In this project, EDEEC (Enhanced Distributed Energy Efficient Clustering) protocol improves the stability and energy-efficient property of the heterogeneous wireless sensor network. In terms of the number of packets transmitted to the BS, Enhanced DEEC gives a substantial improvement of 70.85 % when compared to DDEEC and 69.6% when compared to DEEC. whereas in terms of first node dead Enhanced DEEC shows an improvement of 97.2% when compared to DEEC and 91.5% when compared to DDEEC. When the last dead node is considered, there is an improvement of 99.2% when compared with DEEC and 98.1% when compared to DDEEC. Simulation results show that EDEEC performs better as compared to DEEC and DDEEC in a heterogeneous environment for wireless sensor networks.

Protocol/ Parameters		**DEEC protocol**	**DDEEC protocol**	**EDEEC protocol**
Dead Nodes	**1st**	211th round	219th round	380th round
	All	3131th round	3147th round	9914th round
Network lifetime (Nodes are alive up to…)		3130 rounds	3146 rounds	9913 rounds
Packets sent to base station after 10000 rounds		45920 packets	51840 packets	67890 packets
Energy Consumption per round (Joules)		79.63J	75.87J	49.54J
Throughput		21packets/sec	73packets/sec	78packets/sec

Table 4.2

Limitations:

- In EDEEC, Sensor nodes are uniformly deployed and fixed.
- EDEEC protocol contains 3 types of nodes, Probability for CHs selection for super and advanced nodes is higher than that of the normal nodes. EDEEC continues to punish super and advanced nodes even when these have the same energy level as the normal nodes.
- Nodes which are not in use are still active and energy is wasted unnecessarily.

Future Scope:

- Nodes are fixed and protocol can be extended to mobility of nodes.
- Only Data transfer is considered, Protocol can be extended to Audio, Video transfer.
- Heterogeneity can be extended to multilevel.
- It is a single way communication i.e.; data is sent from nodes to base station. Can be extended to two-way communication.

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