A
Dissertation
On

VICE-CLUSTER HEAD SELECTION APPROACH FOR OPTIMAL NETWORK LIFETIME IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Numerous sensor nodes when networked together to share their sensed information forms a wireless sensor network. Because of its various applications and uses, it is becoming a new trend in the field of research. These sensor nodes are deployed randomly in the work field. They sense its environment in order to get useful information and impart this sensed information to Base Station also known as Sink Node via a previously elected node called Cluster Head. This information is major to base station for decision making.

In this dissertation, we have introduced a new approach for increasing the wireless sensor network lifetime. As we know, the nodes in wireless sensor networks have limited battery that cannot be recharged or cannot be changed when depleted completely. So, we need to use this battery very efficiently. Because once the battery of a node is completely depleted it can no longer transmit its sensed information to other nodes.

So, to perform better and to increase the lifespan of a wireless network such that more number of data packets or information can be send to Base Station we have proposed one new vice-cluster head selection approach.

This proposed approach overcomes one major limitation of previous approaches of non-uniform distribution of Cluster Heads in the field. Our proposed approach performs better than various previous approaches like LEACH, I-LEACH in terms of the number of data packets sent to Base Station, number of alive nodes, as well as the average energy of the network.

Keywords: Cluster, Base Station, Cluster Head, Network Lifetime.

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CERTIFICATE

This is to certify that the dissertation entitled "**VICE-CLUSTER HEAD SELECTION APPROACH FOR OPTIMAL NETWORK LIFETIME IN WIRELESS SENSOR NETWORKS**" is a bonafide record of work done by **Utkarsha Kumbhare, Roll No. - 2K14/CSE/20** at **Delhi Technological University** for the partial fulfillment of the requirement for the degree of **Master of Technology** in **Computer Science and Engineering**. This project was carried out under my supervision and has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma to the best of my knowledge and belief.

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List of Abbreviations

WSNs	Wireless Sensor Networks
CH	Cluster Head
BS	Base Station
SN	Sink Node
VCH	vice Cluster Head
AES	Advance Encryption Standard
DES	Data Encryption Standard
PGP	Pretty Good Privacy
LEACH	Low Energy Adaptive Clustering Hierarchy Protocol

WLAN	Wireless Local Area Network
OSI Model	Open Systems Interconnection Model
STCP	Sensor Transmission control Protocol
PORT	Price-Oriented Reliable Transport Protocol
PSFQ	Pump Slow Fetch Quick
MAC	Medium Access Control
PEGASIS	Power-Efficient Gathering in Sensor Information System
TEEN	Threshold sensitive Energy Efficient sensor Network protocol
APTEEN	Adaptive Threshold sensitive Energy Efficient sensor Network protocol
MECN	Minimum Energy Consumption Network
CSMA MAC	Carrier Sense Multiple Access Media Access Control
TDMA	Time Division Multiple Access

CHAPTER 1

INTRODUCTION

Our surroundings became smarter with the evolutionary progression done in the field of wireless communication. It is still in the development phase as everyday some new methods or new research is been carried out. The vision of this computing is based on the idea that in future computers will be incorporated to such an extent that they will one day become completely invisible to its users [1][2]. For such an environment distributed wireless micro sensors are essential. These micro sensors also called sensor nodes or nodes are available in different sizes. It may vary from a size of box to a size of dust. They have limited capabilities like storage, battery life, computation and processing. However, even with these limitations sensor devices can monitor the surrounding precisely when they work in collaboration with other sensor devices [3] [7]. Wireless sensor networks have many applications like earth monitoring, health care monitoring, area monitoring, industrial monitoring, landslide detection or natural disaster prevention etc. These sensor devices are randomly placed in the field to be monitored. They sense their surrounding and send this sensed information to a centralized body called Base Station (BS) or Sink Node. This BS has unlimited amount of power supply [4]. It collects all the information from sensor devices, computes it and make decision based on this computed information. Sensor devices have become much more efficient and cheaper due to many advancements in latest technology. It is now widely used in many applications [6].

WSN is becoming very popular field and attracting many researchers to do researches in this area because of its many applications and latest advancements. Sensor nodes can also be merged with internet to have a new, fast, innovative and efficient way to browse. As the battery is limited in the sensor nodes and it is not always possible to replace or change the battery researches are been carried out to effectively and efficiently use this battery life. In some applications, the sensors may be deployed in a wall, or near dangerous animals to observe them, or even buried in ground to test soil, in such situations it is not possible to change the battery of the device once it is depleted. So, many researches are based on the objective of utilizing this battery efficiently so that it need not to be changed for years. A device is capable of performing its task only when it has some battery in it. If its battery is discharged completely, then that node is considered as dead node as it will not be able to communicate or pass its information to other nodes in the field. So, that region which the node is covering will remain disconnected. When a node's battery is drained out completely, network lifetime decreases and so decreases the network throughput. So we need a method by which a node can able to pass or transmit as many information as it can to the BS or other sensor nodes without consuming much of the battery. To increase network lifetime many approaches have been proposed and implemented [8][9][11][28][29][30]. Optimal routing algorithm makes efficient use of battery life, increases network lifetime and also increases throughput.

If a small area is covered by many sensor nodes, then it may possible that all those sensor nodes sense similar information as the overlapped area will be more. In such cases, there will be more redundant information. Transmission tasks consumes more energy as compared to processing tasks [12]. Hence, there is a need of Data Aggregation. Various protocols use different types of Data Aggregation Technique to upturn the Network Lifetime and Throughput. Sensor node aggregate the redundant data before sending it to BS saving a significant amount of transmission energy [15]. It allows a node to transmit only the useful information rather than all the sensed redundant information. If data is aggregated by the sensor nodes before sending then BS will not take much time and energy to process the data. Like Data Aggregation, Data Compression is also a current issue of research. In Data Compression techniques, before sending any data to BS, the data is first compressed. So, by this method also it is consuming less transmission energy and making the network more efficient [16]. Whenever some information is passed through some medium or via some other party there is a need of security. Data security is also one of the area of investigation in the field of WSN. Security becomes essential in military monitoring or similar type of applications. Inter-cluster and intra-cluster communication security is one of the current challenges. Since in some applications these sensory nodes remain overlooked once deployed in the field [5][13]. The information sent between a sensor node and BS can be manipulated or tampered before reaching to the destination. Intruder can easily intrude a cluster. The information sent may be critical and hence data security is necessary. Security of data can be achieved through various encryption techniques like AES, DES or PGP.

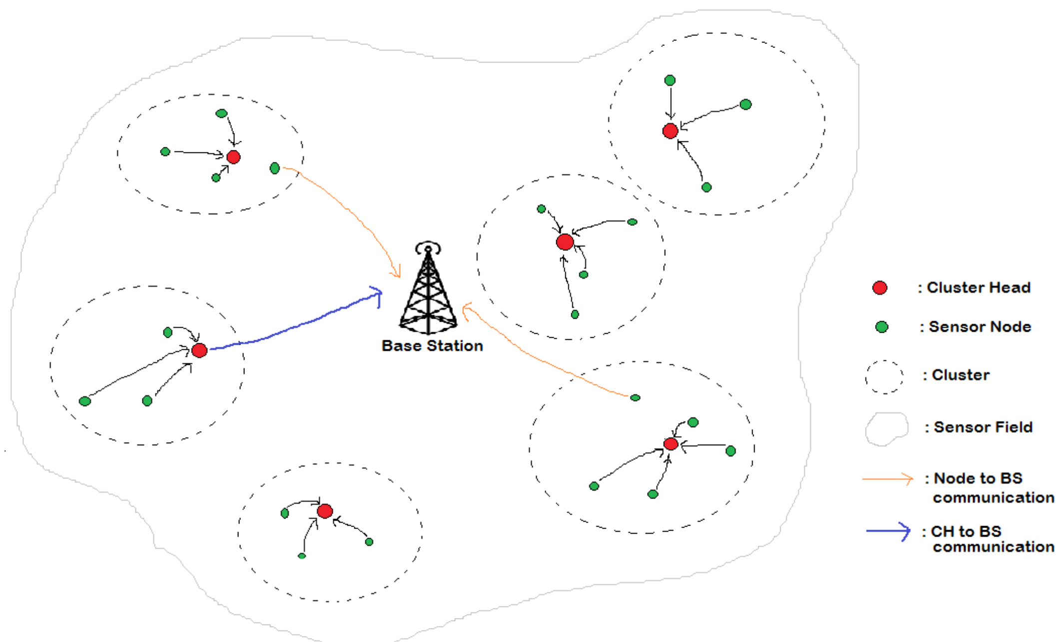

Figure 1.1 Wireless Sensor Network

Basic structure of WSN is shown in figure 1.1 above. The centralized body BS can be placed in between the sensor field or outside the sensor field as per the application requirement. In above figure it is placed in between the sensor field. Circles with dotted line are representing clusters. In each cluster there is a CH (represented by red dot) and some non-cluster head members (represented by green dots). CHs are responsible to gather all the sensed data from its cluster member nodes. Then to pass this collected data to the BS (represented by blue arrow). Sensor node which are closer to BS than to their CH can directly send their information to BS (represented by orange arrow). This type of system is called hierarchical system as every node is not transmitting its data directly to the destination rather they are communicating via some intermediary node, CH in this case. A system where every node sends its data directly to the BS is called as flat or direct system. This type of network is shown in figure 1.2. Every node can send its data to BS without any delay. Hence it is good for those applications where there is a need of information at high speed. The main disadvantage of this type of networks is that every node will send its information directly to the BS no matter how far the node is from the BS. In figure 1.2, node A will consume much more energy during transmission as compared to node B, as node A is at very large distance from the BS. So, it is not suitable for the nodes which are far away from the BS. Hence this type of networks are not been practically used for larger networks [10].

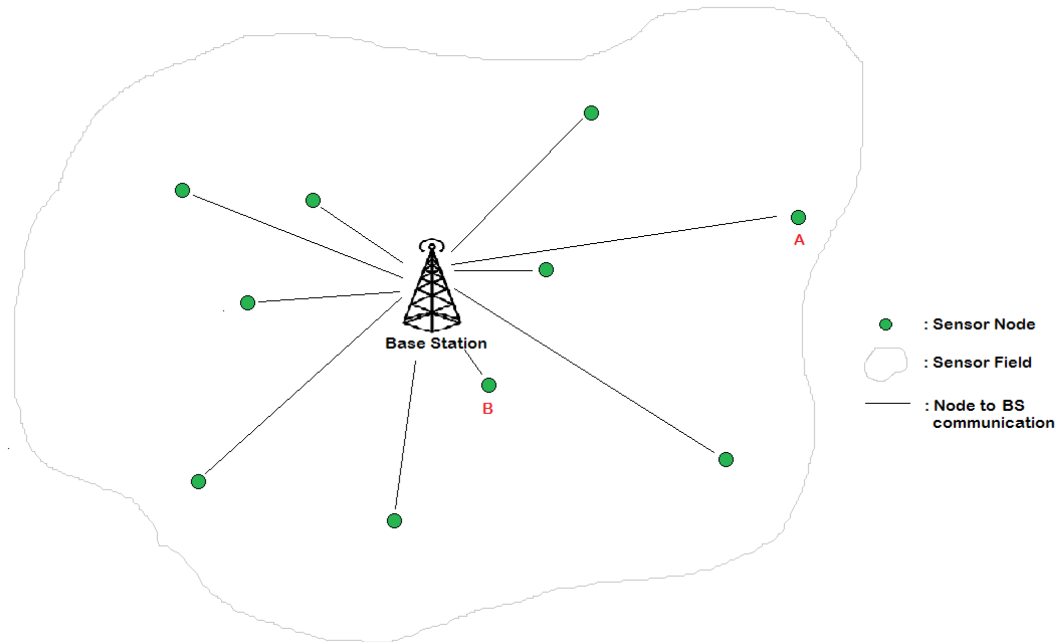

Figure 1.2 Flat Network

After this flat network technique, hierarchical or clustering techniques came into picture. In clustering, the sensor nodes are clubbed together based on some properties usually distance. Then one node is elected as a special representative node called CH which acts as a via-node to other sensor nodes in the cluster. This hierarchy was first introduced in LEACH [10]. Later many researches have done based on this idea of clustering [22]. Every non cluster head member send its information to the representative node CH. Then CH pass this information to the BS of the network. CH selection is based upon various parameters. Initially, almost in all protocols CH is selected based on the probability factor only. It too had many disadvantages which we will discuss in later sections.

1.1 Components of WSN

a) Sensor Node: It is the essential part of WSN. Its responsibility is to sense its environment. Next it converts this sensed data into digital signal to transmit it to the BS. Communication between sensor nodes is also required so it can also decode the communication protocol to send or receive data frames.

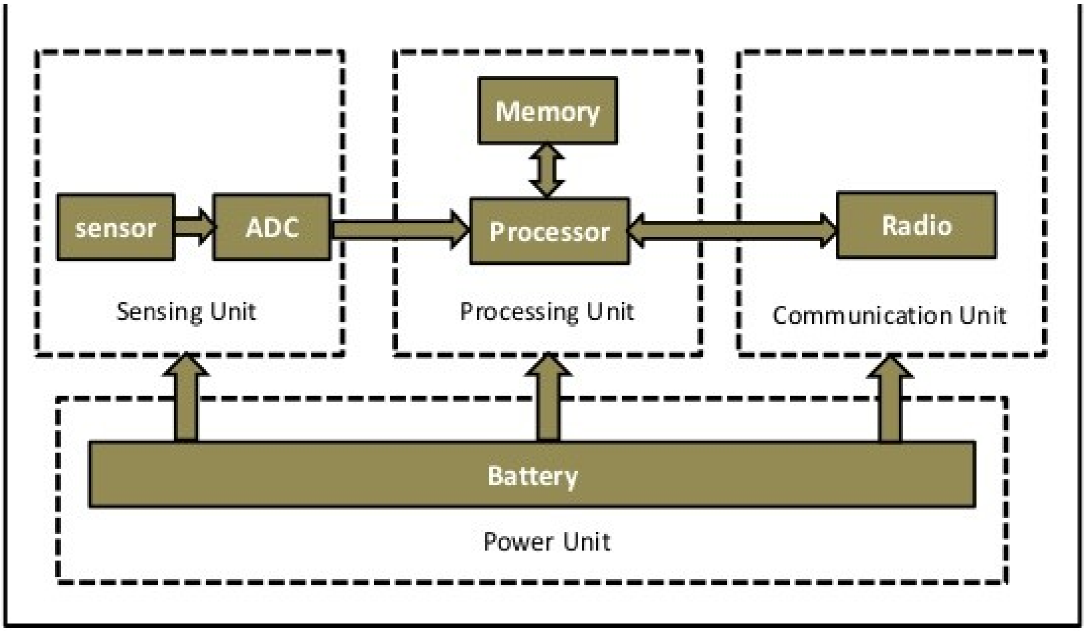

Figure 1.3 Architecture of Sensor Node

In order to fulfill all this requirements some hardware components are also equipped in a sensor node. These resources are:

- Sensor Subsystem: it helps in sensing environment and change it to digital form.
- Processor Subsystem: it helps in storing the data sensed by a sensor subsystem in local memory. It process data and take actions as per the requirement.
- Communication Subsystem: it helps a node in transmitting data packets to the other nodes which are in its vicinity.
- Power Subsystem: it provides DC power to the sensor nodes so that it can perform all the above mentioned tasks.
- Power Generator, Mobilizer, and Location Finding System are some other important components.

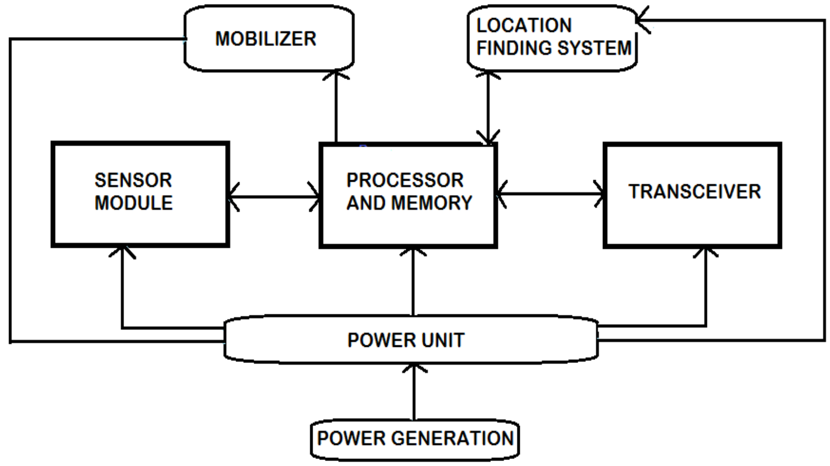

Figure 1.4 Components for a Sensor Node

b) Base Station (BS): It is also known as Sink Node. Unlike sensor node, a BS has huge computational power, huge storage space, and has an unlimited power supply. Its principal goal is to gather all the data coming from the sensor nodes, and analysis of this gathered data. In some applications, a BS also responsible for the routing or arrangement of sensor nodes. Next it pass this gathered and analyzed information to a remote server application and helps in decision making [14].

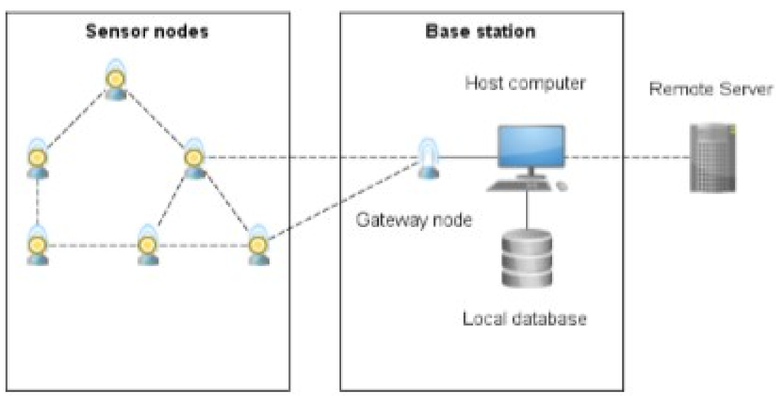

Figure 1.5 Example of WSN

c) Cluster: A cluster is formed when more than one sensor nodes are grouped together. This grouping of sensor nodes can be based on some parameters like energy level or distance. Cluster approach was first introduced in LEACH protocol. It increases network lifetime.

d) Cluster Head (CH): It is a sensor node with additional responsibilities. It act as a representative of a cluster. All the sensor nodes are its cluster members. CH receives data from its cluster members, aggregate this data, performs compression technique and then sends it to BS. If battery of CH is depleted completely then none of its cluster member would be able to communicate, if direct communication from cluster member to BS is not allowed.

1.2 WSN Architecture

It is essential to understand the architecture of WSN before its deployment. WSN architecture is similar to OSI Model. It consists of Application layer, Transport layer, Network layer, Data link layer and physical layer and three cross layer planes for Task management, Mobility management and Power management as shown in figure 1.6 [17].

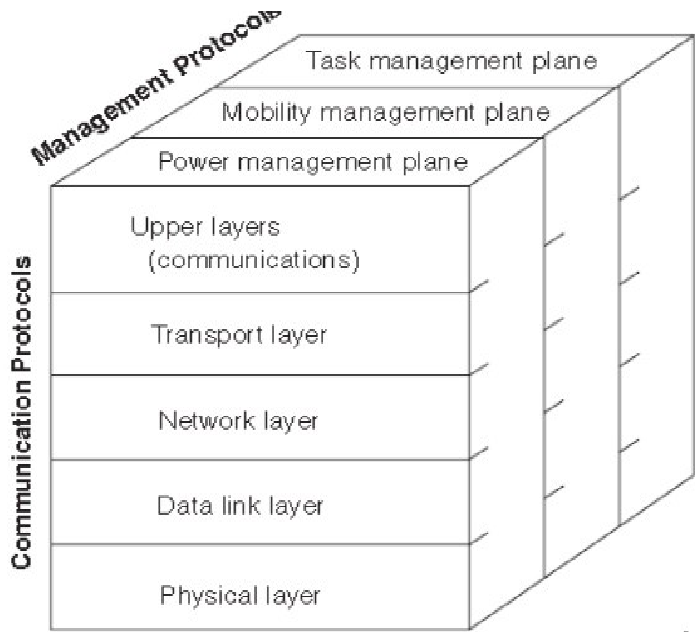

Figure 1.6 Architecture of WSN

These cross layers are there to efficiently manage the network and to make the sensor nodes work in synchronization as to achieve high performance. Table 1.1 shows difference between OSI, WLAN and WSN architecture [18].

Wireless Sensor Network	WLAN	OSI MODEL
WSN application	Application programs	Application layer
WSN middleware	Middleware Socket API	Presentation layer Session layer
WSN transport protocols	TCP/UDP	Transport layer

WSN routing protocols	IP	Network layer
Error control WSN MAC protocol	WLAN adapter & device driver WLAN MAC protocols	Data link layer
Transceiver	Transceiver	Physical Layer

Table 1.1 Difference between WSN, WLAN and OSI Model

a) Transport Layer: Its function is to offer reliability and congestion avoidance. A reliable multi hop transmission is more efficient than end to end, hence TCP is not suitable for WSNs. Transport protocols is divided into packet and event driven. STCP, PORT and PSFQ are some common protocols of this layer.
b) Network Layer: Routing is the main responsibility of this layer. Limited energy, limited memory, lack of global ID and self-organization of nodes are some of the problems this layer face. Data aggregation and Data fusion is also the responsibility of this layer.
c) Data Link Layer: its responsibility is multiplexing of data streams, MAC, error control and data frame detection. We require MAC Protocol to have energy efficiency, low access delays, reliability and higher throughput.
d) Physical Layer: it is responsible to transmit data stream bits over physical medium. Carrier frequency generation, signal detection, encryption, frequency selection and modulation is also provided by this layer.
e) Application Layer: it provides data management. It translate data into understandable form.
f) Mobility Management Plane: it detects the movement of sensor nodes.
g) Task Management Plane: Determines which sensor nodes are active and which are inactive.

1.3 Challenges of WSN

a) Hardware Constraint
b) Power Consumption
c) Network Deployment
d) Scalability
e) Flexibility
f) Reliability
g) Connectivity
h) Network Lifetime

1.4 Thesis Organization

Chapter 1 introduced WSN, its architecture, components and challenges. Next chapter 2, describes detailed review of conventional protocols which are correlated to our work and objective of this thesis. Chapter 3, explains the need and working of our proposed approach. In chapter 4, we compare our approach with the results of conventional protocols. In last chapter 5, we conclude our work and future work that can be done to further improve the network performance.

CHAPTER 2

LITERATURE SURVEY

In this section, we will discuss two hierarchical clustering protocols. Because of the scarcity of energy resources in WSN, efficient usage of energy is the main concern. In this section we have not chosen flat system protocols as they are not suitable for larger networks. Network lifetime is greatly affected by the restriction of battery-equipped sensor devices, the length of paths taken to transmit data to other nodes, reliability of path taken etc. Every node in flat network takes so much energy to transmit its data, and due to many other disadvantages over hierarchical networks as discussed in last chapter, we have considered only hierarchical clustering protocols. Clustering also reduces congestion as only few nodes would be sending data packets at a time.

In hierarchical based routing protocols different capabilities, different roles and different functionalities are given to different sensor nodes in the network. Whole network is grouped into many clusters. Every cluster have many sensor nodes called cluster members and only one node among the members is elected as the head node called CH. All the member nodes sense their environment and sends this sensed information to their CH. Now CH is responsible to gather the data from all its cluster members, manage and aggregate this data. It then pass this aggregated information to BS. Due to major responsibilities on CH, its selection procedure majorly affects the network performance and its lifetime. CH can be selected based on various parameters. It is still a current trend and many researches are been carried out to select optimal CHs in the network. CHs are elected periodically so that the overall consumed energy of the network is balanced. Periodic rotation of CHs are also important to avoid network hotspot and uniform consumption of energy in the network. Energy conservation also affects the network scalability [19].

The major benefit of using hierarchical clustering protocol is that redundant data will be less. In absence of CH all nodes directly send their data to BS without any aggregation. If BS is far away from nodes, all the nodes will consume more energy to transmit their data to BS, also the BS will then have to first aggregate the data, then only it can perform rest of its task. However, it has many disadvantages also. CH may have much more workload making it a hotspot of the network, requirement of large energy by the CH, Nodes deployment complications such that it can balance power consumption, and lack of scalability are some of the problems hierarchical-based routing face.

Many approaches uses hierarchical-based routing approach. Some of the examples are Low-'Energy Adaptive Clustering Hierarchical protocol (LEACH)', 'Power-Efficient Gathering in Sensor Information System (PEGASIS)', 'Threshold sensitive Energy Efficient sensor Network protocol (TEEN)', 'Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN)', 'Minimum Energy Consumption Network (MECN)', 'Improved-LEACH (ILEACH)'. In LEACH, based on the received signal strength clusters are formed. Selected CHs acts as a gateway to BS. In PEGASIS clusters are not formed rather it forms a chain and only one node is responsible for the transmission to BS. TEEN is a hierarchical-based protocol in which it is responsive to strong and rapid change in the sensed information. APTEEN considers both critical and periodically sensed information. MECN selects a sub network of WSN having less number of nodes and uses the energy to send information [3].

CLUSTERING PROCESS:

There are two steps required for clustering. One is selection of CH and another is to form a cluster. CH can be selected in three ways: Centralization by BS, by sensor nodes or hybrid of first two [4].

CHARACTERISTICS OF CLUSTERING:

- It allows data aggregation.
- Clustering reduces number of transmissions
- Reusability of resources
- CHs acts as virtual backbone for inter-cluster communications
- Gives an image of smaller and more stable network
- Improves network lifetime and throughput

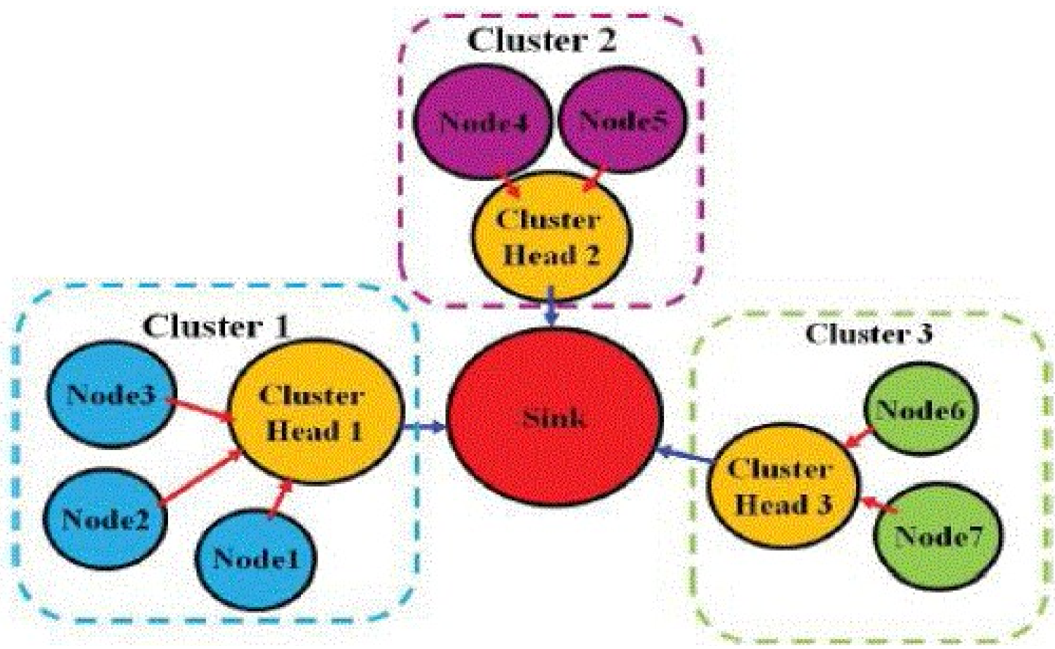

Figure 2.1 Clustering in WSN [26]

POINTS TO BE TAKEN CARE OF WHILE ELECTING A CH:

- It should not cover only few number of sensor nodes. Non-uniform distribution of CH will lead to early decay. So a proper balance must be there on the number of its member nodes.

- Distance between CH and BS should not be too large. Because this will consume more energy in transmission.
- CH itself should have significant amount of energy. If CH's energy is about to finish then there is no point of making it a leader.
- If sensor nodes are mobile in nature, then CH must have lowest speed of mobility.
- There should not be a huge delay in clustering process.
- Residual energy must be a parameter while re-electing a CH.

POINTS TO BE TAKEN CARE OF WHILE FORMING A CLUSTER:

- Sensor node must be attached to that CH which is more near to it. That is, the distance between the sensor node and CH should be less.
- One sensor node must be attached to single CH. Otherwise, redundancy will be more.
- Overlapping of two clusters should be minimum.

There are still lot of limitations and areas where improvement is required and many researches are going on so that the energy can be utilize efficiently and effectively by the sensor nodes. In our dissertation we have focused only on reactive homogenous network. Following are the two protocols that are related to our work.

2.1 LEACH

LEACH stands for Low-Energy Adaptive Clustering Hierarchy protocol. It was introduced by W.R.Heinzelman, A.Chandrakasan and H.Balakrishnan [10]. It is the very first hierarchical-based protocol. In this protocol, the micro sensor network considered is as follows:

- BS is fixed and is placed at a large distance from the sensor nodes in the network.
- All the nodes in the network have same energy level i.e. they are all homogeneous and have limited battery.

As every node have same energy level, there is no node with very high energy via which the communication can be proceeded. The key features of LEACH are:

- For cluster set-up and operations, local control and coordination is there.
- Periodic rotation of CHs.

- Data is compressed locally to avoid global communications.
- Adaptive clusters.
- Self-Organizing.

To uniformly distribute the energy load among the sensor nodes LEACH uses randomization. In each cluster one node act as a local BS or CH. All member nodes transmit their data to their CH, while CH node receives data from all of its member nodes, aggregates that data and then transmit it to the remote BS.

Once the CH is out of energy, it is no longer functioning. Hence, all of its cluster members is not able to pass their information making the cluster dead. Periodic rotation to select CH is used so that no sensor node will be dead due to energy depletion.

The operation of LEACH is divided into two major steps:

- Set-Up Phase
- Steady-State Phase

LEACH works into rounds. In each round, Set-up phase is used to form clusters and Steady-State Phase to do the actual transmission of data to the BS. Set-up phase is long and takes more time as compared to Steady-state phase to diminish overhead on the BS.

SET-UP PHASE: when sensor nodes are created and deployed in the network field. The next step is to decide whether or not they want to become a CH of a cluster. This decision is made based on the probability factor and how many times a node has become CH previously. To decide this they have used an equation of threshold value given in equation 2.1:

$$Threshold(N) = \begin{cases} \dfrac{Per}{\left(1 - Per * \left(R_{curr} \, mod \left(\dfrac{1}{Per}\right)\right)\right)}, \wedge if\ N \in G \\ 0, \wedge Otherwise \end{cases}$$

(2.1)

Where,

Per : Desire percentage to be CH

R_{curr} : Current Round

G : Set of those sensor nodes that are not CH for 1/Per rounds.

Every node generates a random number between 0 and 1. It is compared with the value given by equation 2.1. If the value is less than the threshold value then that node will become the CH for that round. LEACH ensures that every node will become CH once in 1/Per rounds. After 1/Per rounds, every node is eligible once again to become CH of a cluster.

After becoming a CH, the node will send a message to all nodes declaring it is now the new CH for this round. For this purpose it uses CSMA MAC protocol. Hence to receive such advertisement from CHs, a node should always keep its receiver on during this phase.

When CHs are selected, every non-CH node will now decide to which CH it should be attached. This decision is dependent upon the received signal strength. Stronger the receiving signal means it is nearer. Again using same protocol CSMA MAC, all the non-CH nodes will send their own details to the CH they want to be attached with. So to receive this details every CH now must keep their receiver on.

STEADY-STATE-PHASE: CH creates TDMA sessions for the member nodes to send their data. Once all this is fixed, transmission can be started. Non-CH node will turn off its radio once its TDMA session is over, minimizing the energy dissipation. While CH has to keep its radio on all the time until every member node has send its data. After gathering all the data from its member node, CH performs aggregation on that gathered data. Also, after some time all this process is repeated for next round [10][20].

LEACH has many advantages like in this load is balanced as every node gets a chance to become CH. Also no node can become CH in consecutive rounds. Data Collision is prevented as it uses TDMA protocol for transmissions. Also a node saves a lot of its energy by keeping its radio on only in its assigned TDMA session, and in rest of time it keeps its radio off. It has many limitations also, some of them are as follows:

- CH distribution is non-uniform.
- CH always sends its data to BS in single hop.
- CH selection is completely based upon random factor.
- Selection of CH does not consider residual energy.

- Expandability is limited.
- No security related issues are covered.

2.2 ILEACH

LEACH does not consider properties of a node and various parameters like residual energy, distance between non-CH nodes and CH and between CH and BS, number of neighbors, location in any of the Set-up or Steady-state phase. Because of which a node can become a CH even if it is having very less energy or even if it is deployed very far away from BS or CH. Transmissions on larger paths consumes great amount of energy. Also, if a CH itself is having very less energy as compare to other nodes, there is no point of making it CH and giving it lot more responsibilities than a normal node resulting in early depletion of battery [8][21].

ILEACH is an improvement of LEACH protocol. It does consider all these parameters which further reduces the energy consumption of a node. By this protocol, consumed energy reduces significantly. Following are the specifications of ILEACH:

- Every node have equal energy initially and battery of sensor nodes are not rechargeable. A sensor node is considered as dead if it has zero energy.
- Sensor nodes are deployed randomly over the network field and are fixed. They are not mobile in nature.
- Every sensor node is aware of its energy level, its ID and its location.
- Every node have sufficient power to directly communicate with the BS.
- Nodes can sense different data.
- Each node consists of computational and memory unit.

Analogous to other hierarchical-based protocols, it also works in different rounds. Every rounds consists of three phases. These are:

- CH Node Selection Phase
- Cluster Formation Phase
- Data Transmission Phase

Unlike LEACH, it calculates more parameters during Set-up phase, in this protocol, the CH node selection phase.

CH NODE SELECTION PHASE: Similar to previously proposed hierarchical-based protocols like LEACH, it also selects the CH on the basis of probability. The selection of CH directly affects the overall performance of the network. It considers number of neighbors of a node, location, energy level of a node, and distance between node to CH and CH to BS. In this phase, a sensor node having maximum number of neighbor node have high probability to become CH. Many of the previous protocols does not consider residual energy which is a very crucial factor of a sensor node. In this protocol, the node having higher energy than the average energy of all the nodes present in the network have high probability to be selected as CH. Also, the ratio between the average distance of all the nodes from BS and the distance between the nodes to BS is also taken. It is indirectly proportional. The more the distance from the BS, the less chances are there to become CH.

Similar to LEACH, every node generates a random number between 0 and 1. Then it is compared with modified threshold value given in equation 2.2. If the value generated by the node is less than the modified threshold then it becomes CH otherwise not.

$$Threshold_{modified}(n)=\begin{cases}\dfrac{\dfrac{\dfrac{\dfrac{Per}{\left(1-per*\left(r_{curr}\,mod\left(\dfrac{1}{Per}\right)\right)\right)}*Energy_{curr}}{Energy_{avg}}*nbrs_{n}}{nbrs_{avg}}*BSdist_{avg}}{BSdist_{n}}, & n\in G\\ 0, & Otherwise\end{cases}$$

(2.2)

Where,

Per : Desire percentage to be CH

r_{curr} : Current Round

G : Set of those sensor nodes that are not CH for 1/Per rounds.

$Energy_{curr}$: Current energy of sensor node

$Energy_{avg}$: Average energy of network

$Nbrs_n$: Number of neighbors of node n

$Nbrs_{avg}$: Average number of neighbors in network

$BSdist_{avg}$: Average distance of all nodes from BS

$BSdist_n$: Distance of a node from BS

CLUSTER FORMATION PHASE: In this phase the priority is given to the distance between CH and BS. CH assign a TDMS slot to all of its cluster member nodes.

DATA TRANSMISSION PHASE: In this phase, CH gathers the data from all of its cluster member nodes and perform integration to combine that gathered data. To avoid interference, it uses CDMA protocol to transmit data from CH to BS.

A node which is closer to the BS than any other CH can directly send its data to the BS. Making the transmission much more economical. Some of the advantages of this protocol is it considers other important factors also while selecting a CH. Residual energy is considered. A node closer to BS is allowed to send its data directly to the BS. It has many limitations also like:

- It did not overcome the problem of non-uniform distribution of CH which was also there in LEACH.
- Size of cluster in unequal.

2.3 Research Objective

As described in previous sections, LEACH and ILEACH do not ensure uniform distribution of CH in the network. Some of the CHs may have many number of its cluster members making it overloaded while some of the CHs may have very few number of cluster members.

The objective of this research is to:

- Develop an energy efficient protocol in order to improve network lifetime
- Efficiently transmit information to BS, increasing threshold of the system
- Reduce the extra workload on CH

CHAPTER 3

RESEARCH METHODOLOGY

In this chapter, we have specified the system model and assumptions made to help understanding the system in depth.

3.1 System Model

System model of our proposed approach consists of two models: Network model and Energy model. Network model specifies the network field environment and also describes the different capabilities of a sensor nodes. While Energy model describes the energy usage of sensor nodes during any transmission in the network.

3.1.1 Network Model

There are total 'n' nodes installed randomly in the network field. Once deployed they are not able to move to some other location. The network field if of (x_m*y_m) dimension. BS is placed at the center point of the network field having unlimited power supply. E_int_0 is the initial energy given to a sensor node. As we have considered a homogeneous network every node have same initial energy given to them. This energy is not chargeable or cannot be changed with new battery. Every sensor node in the field have their unique identity and they are aware of their attributes like position in the field, their energy level, their ID, and the BS they are attached to. Every node is capable of sensing and transmitting their sensed data to other nodes. Depending upon the current energy level of a node its transmission range is defined. Sensor nodes senses their environment but sends this information only in their allotted TDMA slot. BS is responsible for processing the data as to satisfy the end user.

3.1.2 Energy Model

We have considered a simple first order radio model as used in many previously proposed approaches [8][10][21][22][23][25]. As shown in figure 4.1, in this radio model transmitting electronics, receiving electronics and transceiver amplifier is the main components of this model. A lot more researches are going on in the area of low-energy radios.

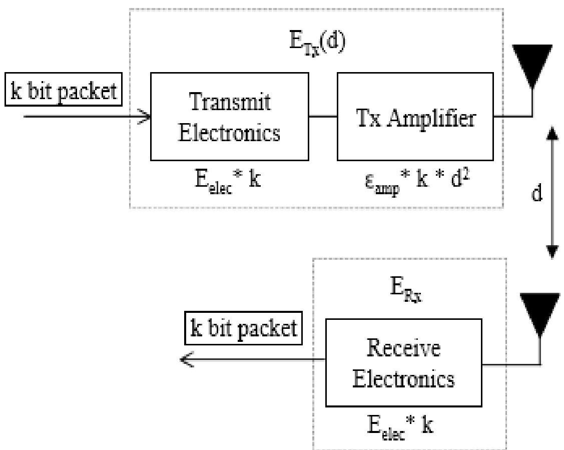

Figure 3.1 First Order Radio Model

In our approach, to use transceiver and receiver electronics, radio wastes $Energy_{elec}$ of 50 nJ/bit. $Energy_{amp}$ of 100 pJ/bit/m^2 for transmit amplifier as specified in Table 3.1.

OPERATION	**ENERGY DISSIPATED**
Transmitter Electronics ($E_{Tx\text{-}elec}$)	50 nJ/bit

Receiver Electronics($E_{Rx\text{-}elec}$)	
Transmitter Amplifier ($\in_{amp}$)	100 pJ/bit/m^2

Table 3.1 Radio Characteristics

There are two propagation model in this energy model. These are:

- Free Space Propagation: when there is a direct path available between sender and receiver.
- Two Ray Ground Propagation: when there is no direct path and data has to be send via some other path.

Hence, to transmit a message of 'm-bits' to a path of distance 'dist' using this radio model, the energy consumed is given by:

$$Energy_{Tx}(m, dist) = \begin{cases} m * Energy_{elec} + m * \in_{fs} * dist^2, dist < do \\ m * Energy_{elec} + m * \in_{mp} * dist^4, \wedge dist \geq do \end{cases}$$

(3.1)

Where,

$Energy_{Tx}$: is the energy dissipated by sender node.

$Energy_{elec}$: is the energy required to run the transceiver and receiver electronics.

$\in_{fs}$: is the amplifier parameter for free space.

$\in_{mp}$: is the amplifier parameter for two ray ground.

d_o : Optimal distance and is given by:

$$d_o = \sqrt{\in_{fs} / \in_{mp}}$$

(3.2)

If the ‘dist’ is less than d_o then free space model is used otherwise two ray ground propagation model is used.

Energy dissipated by a node in receiving an ‘m-bit’ message is given by:

$$Energy_{Rx}(m) = m * Energy_{elec} \tag{3.3}$$

3.2 Working

After setting all the network and energy parameters following steps are repeated for every round till maximum number of rounds, initially every node have equal energy:

- Sensor nodes are created and installed randomly over a network field
- For every node, if its energy is greater than zero. Then, based on node’s parameter value like energy, distance from BS and neighbors a value is calculated as given by equation 3.4. If this value is greater than or equal to a random number which is generated by that node between and is between 0 to 1.if the value is greater or equal then that node is selected as CH for that round.

$$¿ \frac{\frac{\frac{\frac{Per}{\left(1-per*\left(r_{curr}\, mod\left(\frac{1}{Per}\right)\right)\right)}*Energy_{curr}}{Energy_{avg}}*nbrs_n}{nbrs_{avg}}*BSdist_{avg}}{BSdist_n} \tag{3.4}$$

$$¿\ Random\, number\,(between\, 0-1) \leq ¿$$

Where,

Per : Desire percentage to be CH

r_{curr} : Current Round

G : Set of those sensor nodes that are not CH for 1/Per rounds.

$Energy_{curr}$: Current energy of sensor node

$Energy_{avg}$: Average energy of network

$Nbrs_n$: Number of neighbors of node n

$Nbrs_{avg}$: Average number of neighbors in network

$BSdist_{avg}$: Average distance of all nodes from BS

$BSdist_n$: Distance of a node from BS

For the calculation of neighbors of a node, if the distance between two sensor nodes is less than or equal to radius 'R', calculated in equation 3.5.

$$R=\sqrt{\frac{x_m * y_m}{pi * CH_{opt}}}$$

(3.5)

Where,

x_m,y_m : is the field dimensions

CH_{opt} : is the optimal number of CHs that should be in a network [12] and is given as

$$CH_{opt}=\sqrt{\frac{n}{2*pi}}*\sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}*\left(\frac{x_m * y_m}{BSdist_{avg}^2}\right)$$

(3.6)

Where,

n : is the number of sensor nodes in a field

$\in_{fs}$, $\in_{ms}$: is free space and multi path fading

$BSdist_{avg}$: is the average distance between node and BS

- After finding all this information, a CH is selected.
- Now neighbors of all CH is calculated. If number of the neighbors of a CH is greater or equal to threshold value '$threshold_{max}$' then, one more leader is selected in that cluster. The value of '$threshold_{max}$' is calculated as given in equation 3.7.

$$threshold_{max} = \frac{Number\ of\ sensor\ nodes}{CH_{opt}} \tag{3.7}$$

- If there is a need of one more leader then it is selected as the previous CH is selected.

CHAPTER 4

PROPOSED APPROACH

In this chapter, we have described a new approach for hierarchical-based homogeneous network to overcome the problem of non-uniform distribution of CHs in the network field. This chapter is divided as, in first section we have described the need of such approach and the limitations of related protocols that our approach is trying to overcome. Next, working of our proposed approach is described and its flow chart of the whole procedure is shown. Simulation results comparison with other protocols are analyzed in next chapter.

4.1 What is the Need of Such Approach?

In I-LEACH and other previous clustering algorithms [8][10][21], CH selection was not based on the number of its cluster members. Hence, CH distribution is not uniform. It means some of the CH have more number of cluster members while some CH have very less number of its cluster members. As a result, those CHs having more number of its cluster members will be doing much more work as compared to the one having few number of cluster members. This will lead to early decay of that CH because more number of cluster members means CH will continuously be receiving data packets and sending these data packets to BS. Also, huge number of sensor nodes in single cluster is of no use because then those sensor nodes will only be collecting or sensing redundant information. Then redundancy removal technique such as data aggregation should be there. So, the overall workload on that CH will be much more. As the CH dies, none of its cluster members is able to communicate with the BS. Leading in decrement of network throughput. In this proposed approach, this workload on CH is distributed among two nodes. When the CH of a cluster is dead then its responsibility is taken over by the helping node. We called this helping node as Vice Cluster Head node (VCH), it is to be noted that VCH is there in cluster only and only when the number of the cluster members is greater than a predefined value. This predefined value is calculated only in starting and is represented by an equation described in later sections. Electing a node as some special node also takes energy that is why in our approach we are not electing VCH in every cluster.

4.2 Working

As discussed earlier, we have proposed this approach to adjust the extra workload which is there on a cluster head when there are huge number of its cluster members. We have seen earlier, one of the limitation of previously proposed algorithms is that the distribution of CH is not uniform. No parameter in those algorithms is controlling the maximum number of nodes that should be attached to a particular CH. Lack of consideration of this issue leads to .early decay of CH.

When there are many cluster members in a cluster, there will be more transmissions as every cluster member will send its data packet to its CH. Hence, energy level of CH will drop down drastically because it will always keep its radio on for receiving data packets from its members, will perform aggregation on that data to neglect any redundancies present in the data. When a CH of a cluster is dead, the communication of whole cluster gets affected. This is because every sensor node in a cluster sends its data to BS via its CH, except those sensor nodes that are much closer to BS than its CH because then they can directly send their data to BS without the help of CH.

So, to distribute this workload we divide this work to two leaders in a CH. It will not let the cluster die early because even if one of the leader is dead there will be another leader present that can take the responsibility of previous leader in the cluster.

4.3 Flow Chart

Above working is shown in flow chart in figure 4.1 below.

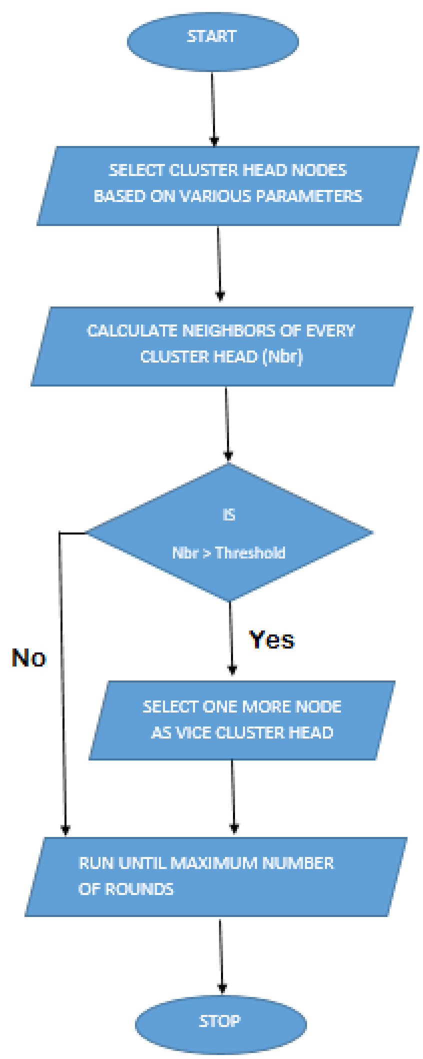

Figure 4.1 Flow Chart of Proposed Approach

CHAPTER 5

SIMULATION RESULTS AND COMPARISION

Simulation is an effort to represent a hypothetically assumed or real life situation in computer system in order to get the knowledge of how the system will work. Predictions can be made for the system behavior by changing the simulation values. A tool is required to analyze the system.

5.1 Simulation Setup

For simulation we have used MATLAB 7.7.0. We have compared our proposed approach with LEACH [1] and ILEACH [8] protocols to analyze its results in terms of alive nodes, average energy and throughput of the system.

We have deployed 200 homogeneous nodes in our network field as shown in figure 5.1. The deployment is random. Network field length is 200m in length and 200m in breadth. BS is placed at center position at (100,100). We have assumed the length of the data packets send in every protocol is 4000bits.

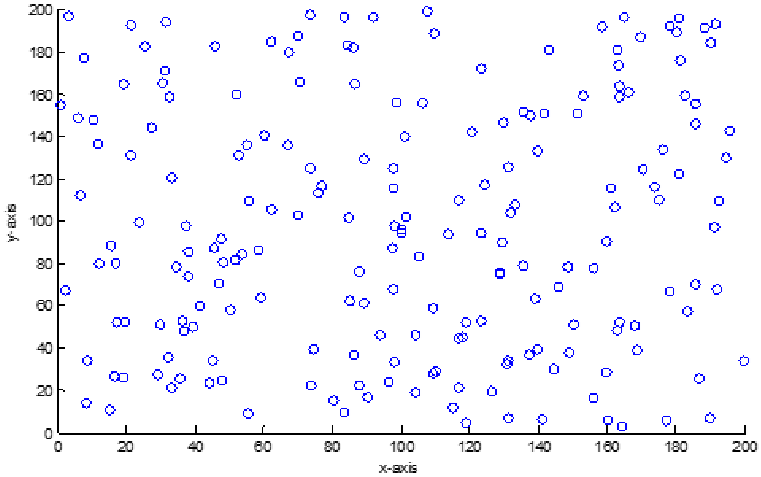

Figure 5.1 Initial Network Field

PARAMETERS	VALUE
Network Field Dimensions M= (x_m*y_m)	(200*200) meter
Coordinates of BS	$(0.5\ x_m)*(0.5y_m)$
Total number of sensor nodes, n	200
Election Probability to become CH, p	0.1
Initial Energy of Sensor Nodes, E_o	0.5 Joules
ETX, ERX (E_{elec})	50 nJ/bit
E_{fs} (Free Space)	10 pJ/bit/m^2
E_{mp} (Multipath Fading)	0.0013 pJ/bit/m^4
E_{DA} (Data Aggregation Energy)	5nJ/bit/signal
Data Packet Size	4000 bits
dtoBSavg (Average Distance to BS)	0.765*(M/2)

Table 5.1 Network Parameters used in Simulation

Network parameters are shown in table 5.1. Parameters for all the protocols used in comparison are taken as same.

5.2 Performance Evaluation

In this section, we have used MATLAB 7.7.0 as a simulation tool to present the result of our proposed approach and compared it with LEACH [1] and ILEACH [8] protocols. The total number of rounds till which we have run our algorithm is 5000. Below performance matrices are used to compare the performance between different protocols.

5.2.1 Performance Matrices

- Alive Nodes: it represents the total number of alive nodes in a particular round.
- Average Energy: it represents the average energy of the network.

- Throughput: it represents the number of data packets send to BS by either CH or VCH in every round.

5.2.2 Simulation Result

Simulation results of every protocol is presented in this section. The result is based on the performance matrices described in above section. First, results of all three protocols are shown separately in figure 5.2 to figure 5.10. Next the compared figure of all three result is shown in figure 5.11 to figure 5.13.

- ***<u>SIMULATION RESULTS OF LEACH</u>***

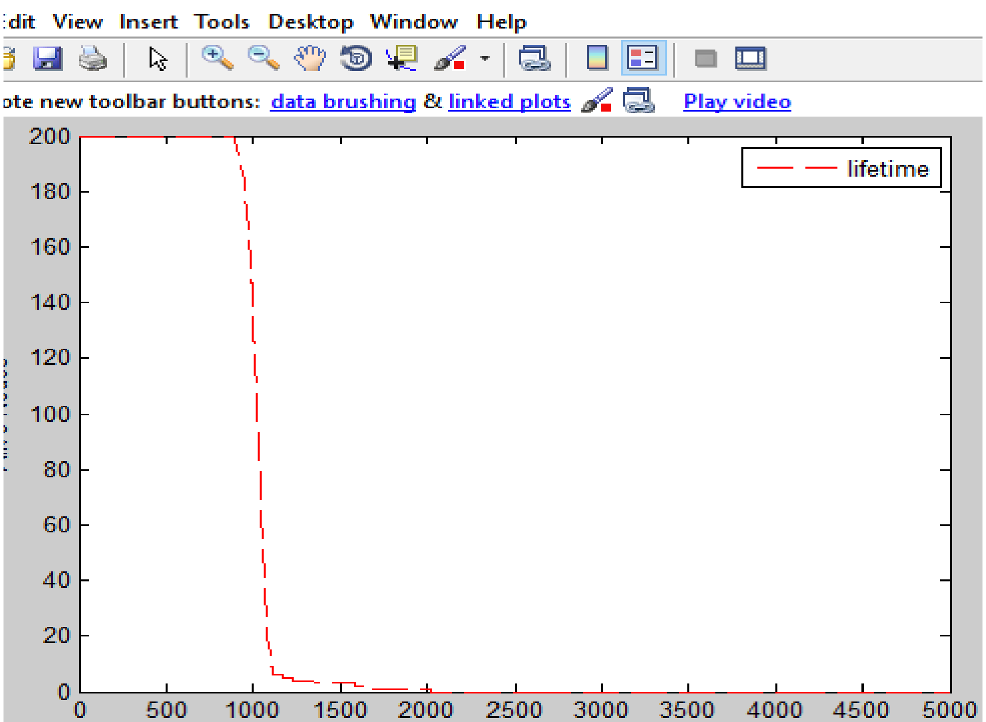

Figure 5.2 Alive nodes per round

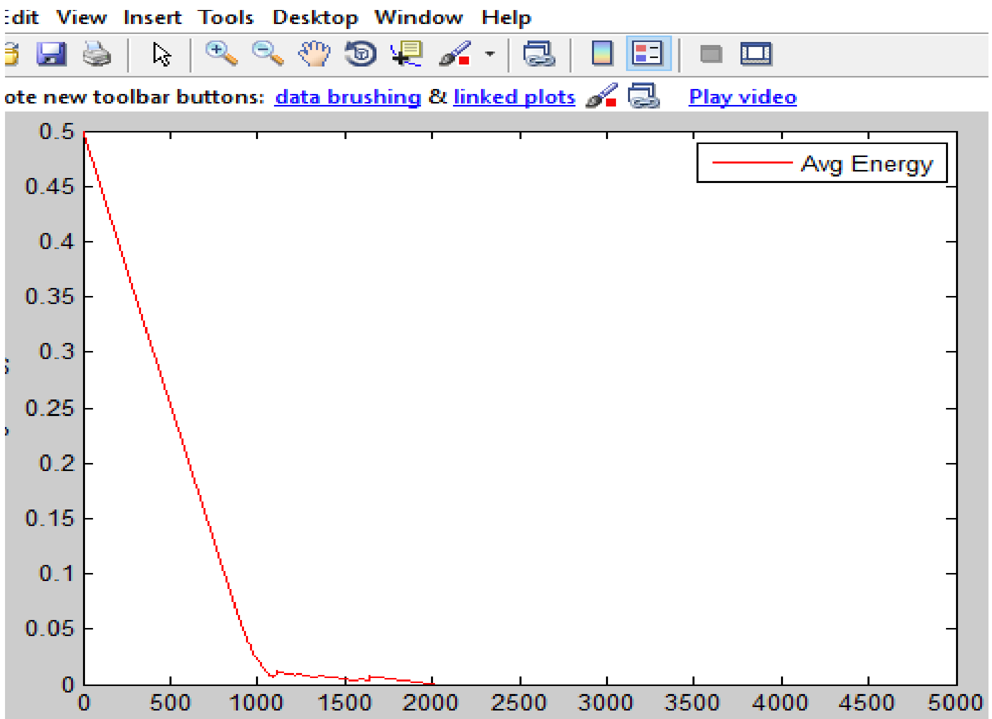

Figure 5.3 Average energy per round

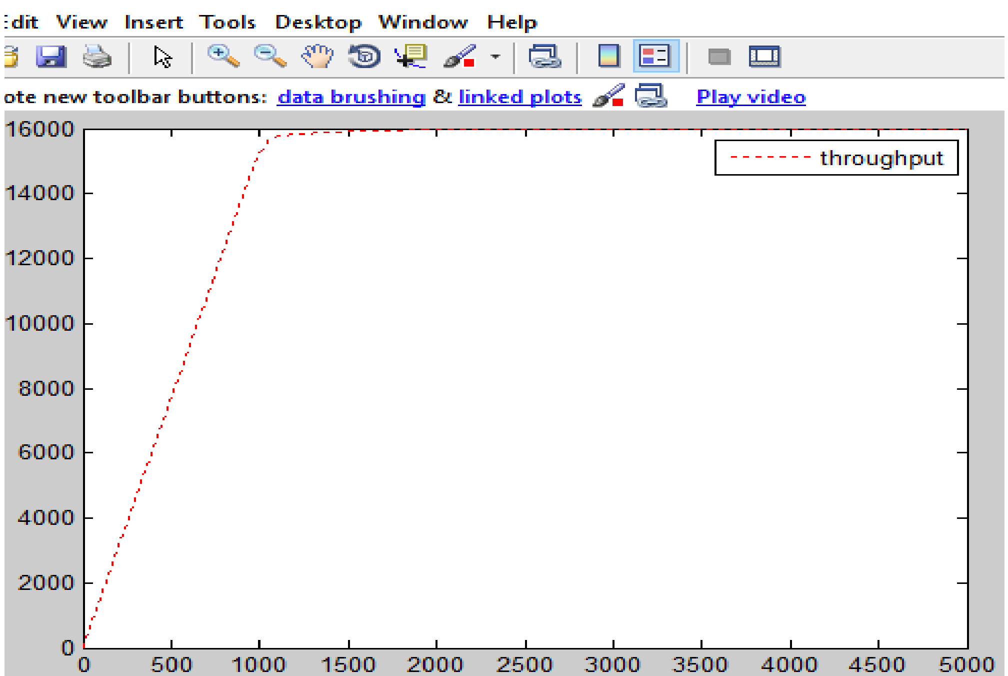

Figure 5.4 Throughput of network

- ***SIMULATION RESULTS OF ILEACH***

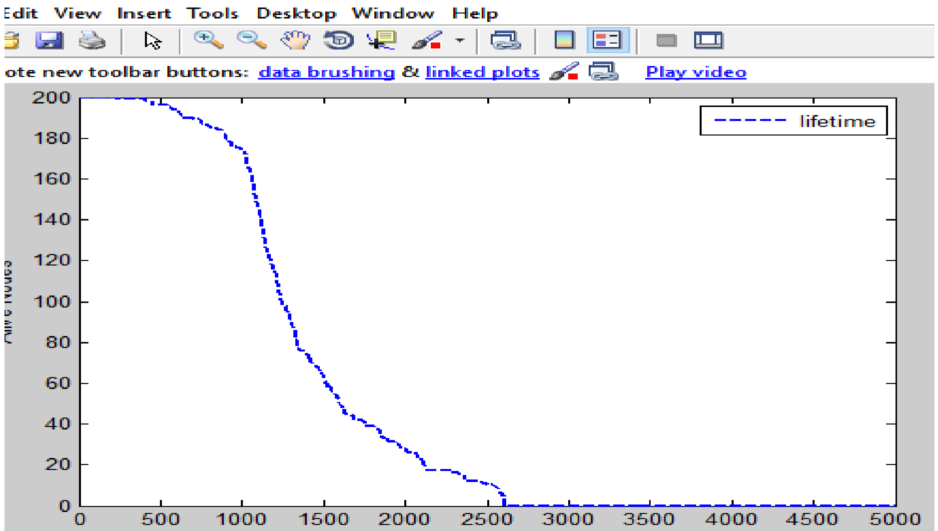

Figure 5.5 Alive nodes per round

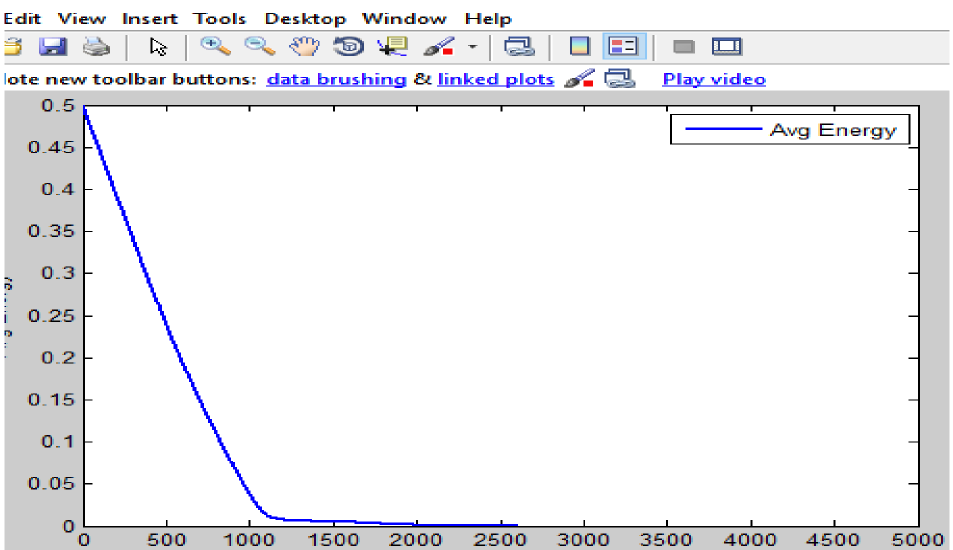

Figure 5.6 Average energy per round

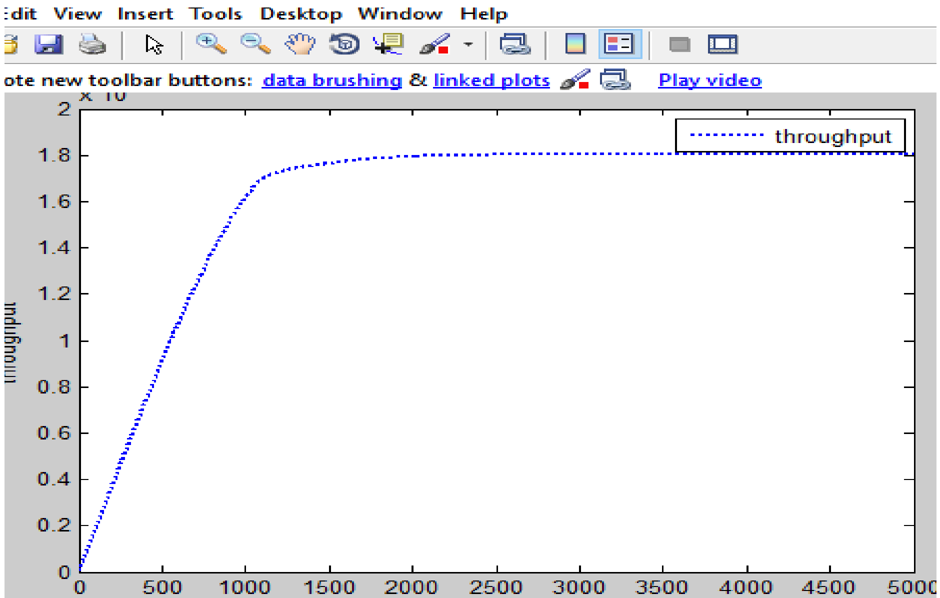

Figure 5.7 Throughput of network

- ***SIMULATION RESULTS OF PROPOSED ALGORITHM***

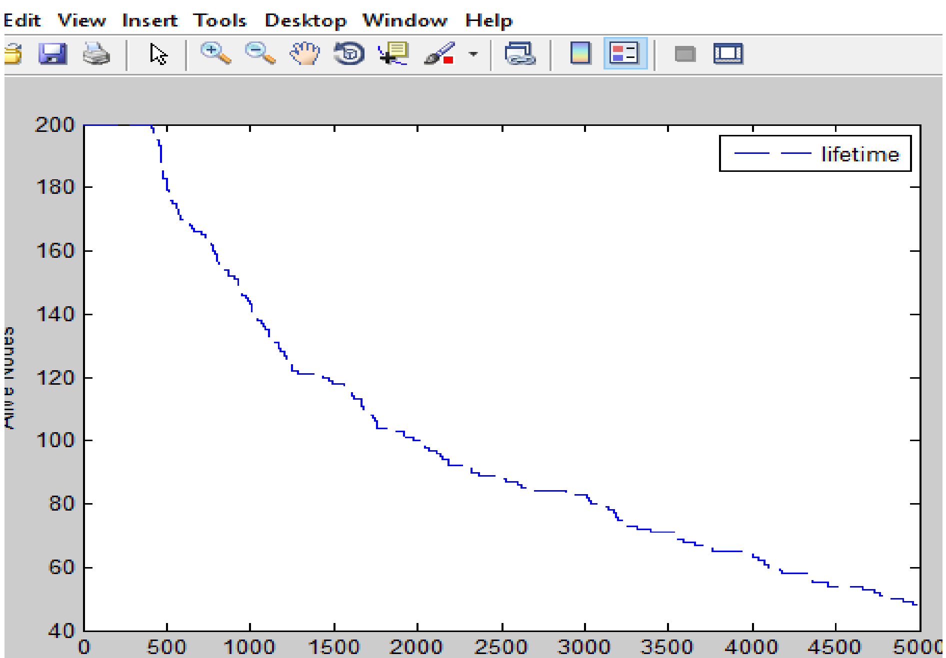

Figure 5.8 Alive nodes per round

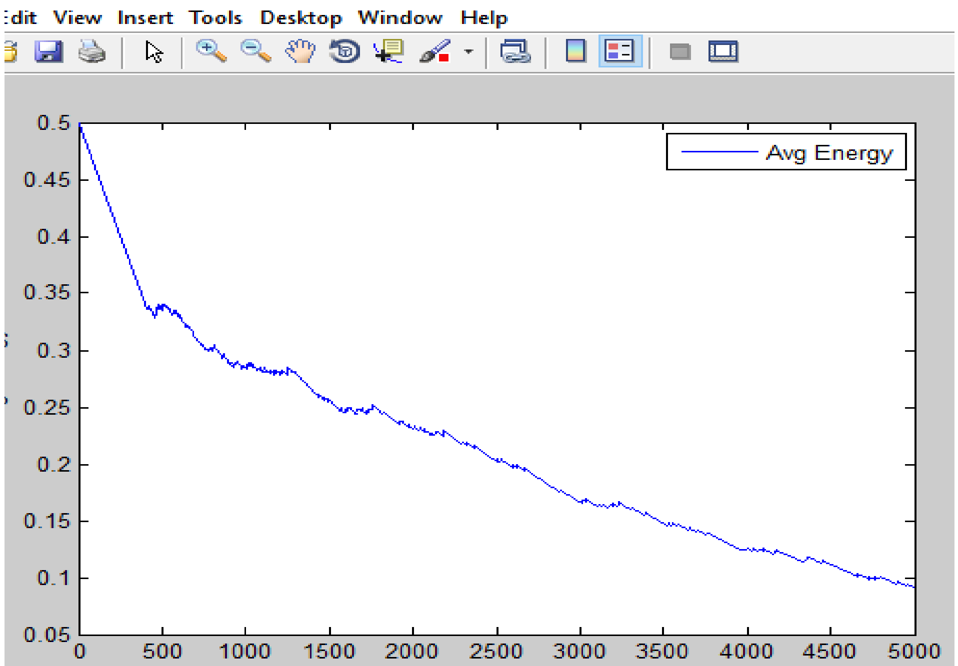

Figure 5.9 Average energy per round

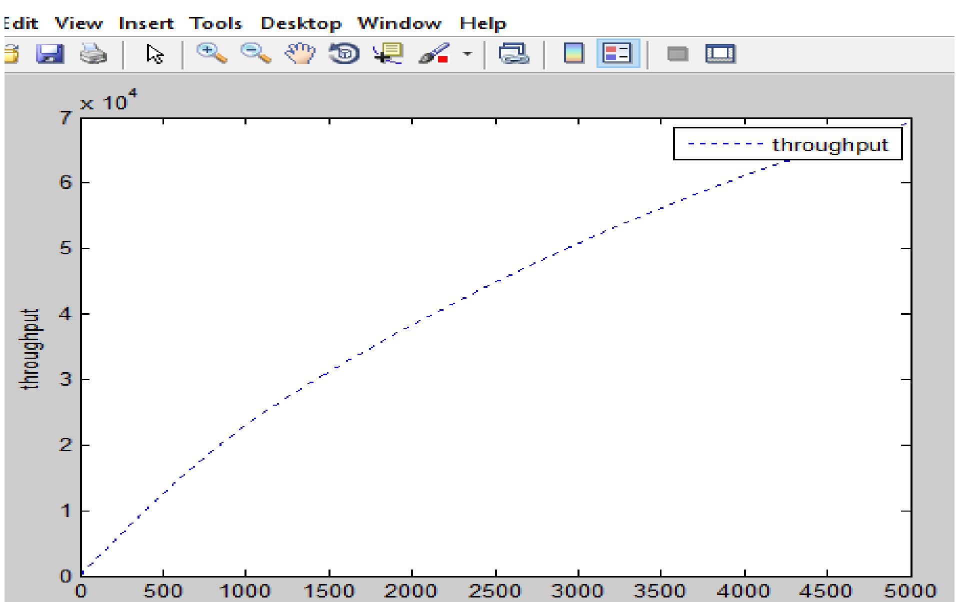

Figure 5.10 Throughput of network

- ***COMPARISON RESULTS***

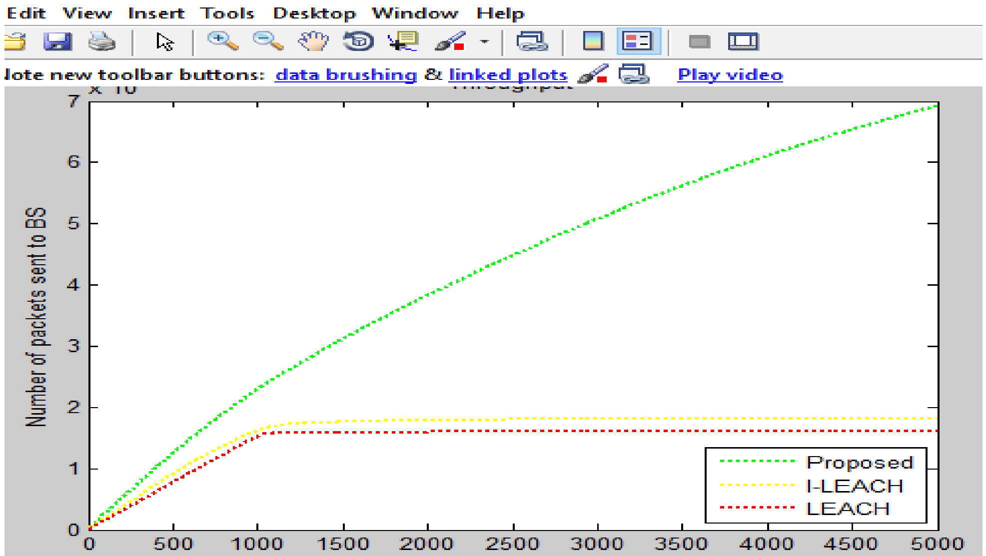

Figure 5.11 Number of packets sent to BS

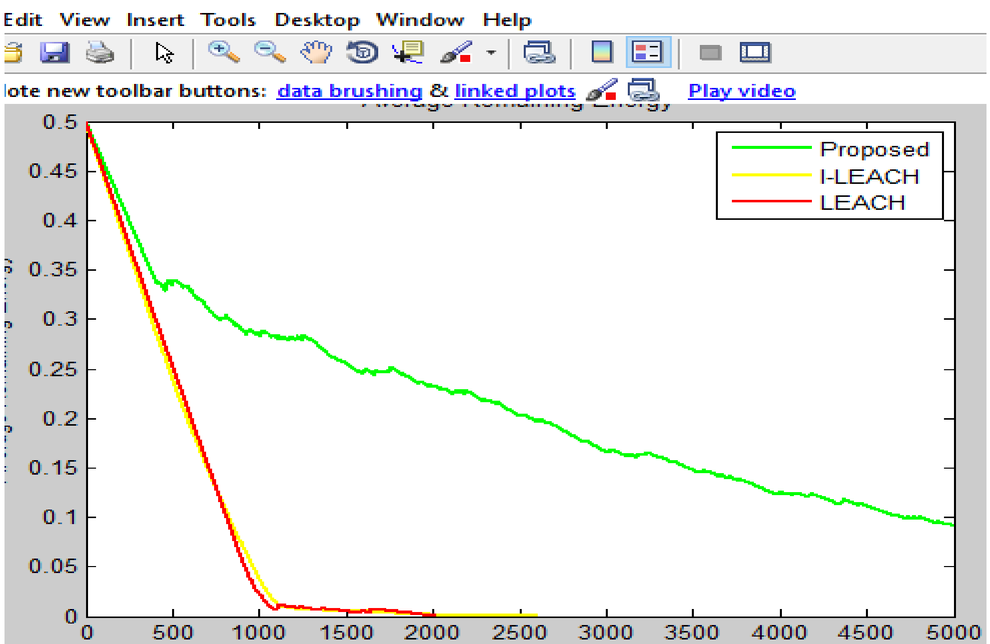

Figure 5.12 Average remaining energy per round

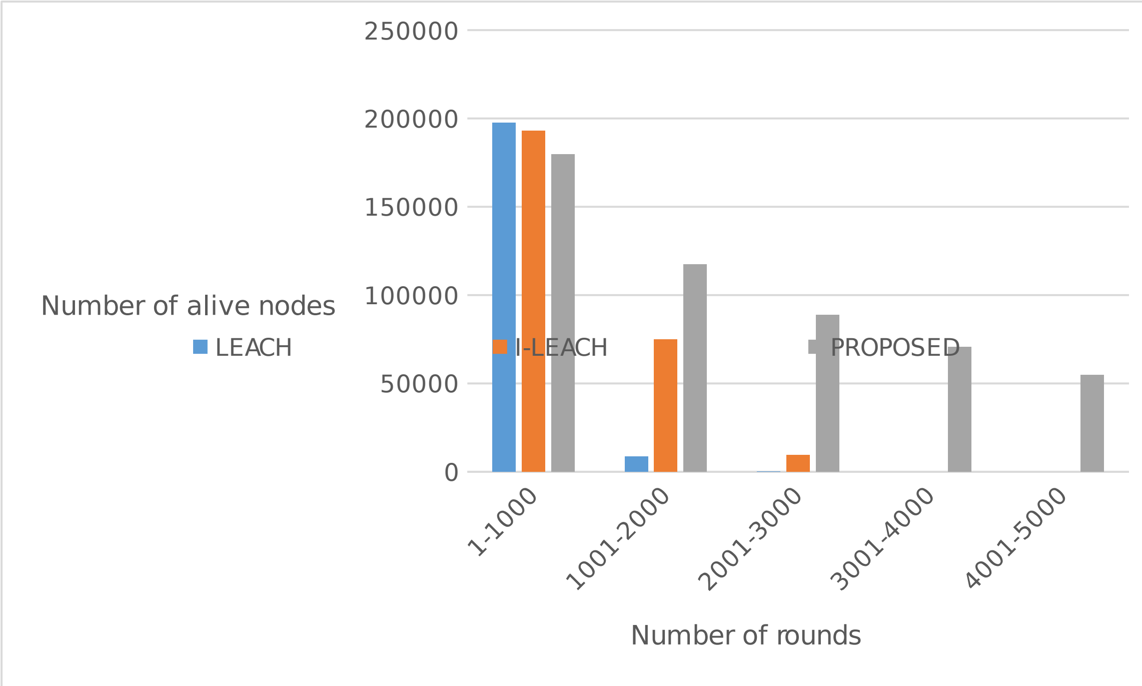

Figure 5.13 Alive nodes comparison with other protocols

Results shows that our proposed algorithms works better than the two approaches in every performance metrics. Next section gives in-depth analysis of above protocols.

5.2.3 Analysis

In table 5.2, we have shown the conclusion values from above simulation results.

Protocols	Average Alive Nodes (in rounds)	Lifetime (in rounds)	Throughput (in packets)
LEACH	41.2538	1973	$1.47*10^4$
ILEACH	55.5298	2610	$1.89*10^4$
PROPOSED	102.3358	>5000	$7*10^4$

Table 5.2 Analysis

Average alive nodes in above table is calculated as summation of alive nodes of each round divided by maximum number of rounds for which the algorithm is executed. It can be seen from above table that our proposed approach performs better than LEACH and ILEACH in terms of number of alive nodes, lifetime of the network and throughput.

CHAPTER 6

CONCLUSION AND FUTURE WORK

The main advantage of this approach is that even when the CH is dead there is one more node that can perform the working of CH, making the communication unaffected. Also, this other leader called VCH is not selected in every cluster. Because a cluster may have only one, two or very few sensor node members. In that case there is no need to select VCH. This saves the energy required in advertising the message after becoming CH. When one node is selected as

CH, it broadcast this message to every sensor node in its cluster as described in previous chapters. This broadcast of message also need energy. Also every cluster member sends its attribute value like its ID, location, and energy level etc. to its CH. During this period CH have to keep its receiving radio on as to get these messages from its cluster member nodes. So this energy is saved as not all cluster is having VCH. Even with many members the cluster will remain alive and operational because of the VCH. This improves the overall network lifetime as compared to previous algorithms where a cluster is dead when its CH is dead. Increase in lifetime will lead to increase in the number of packets send to the BS or in other words, we can say the throughput of the network will get increased.

In our approach we tried to provide a solution for the limitation present in previously proposed algorithms of non-uniform distribution of CHs in the hierarchical-based homogeneous proactive network. Due to the unequal size of the clusters in the field, workload is more on some cluster heads. This problem is solved by dividing this workload between two nodes. So, we balanced the workload of CHs among other node by making it VCH where needed. For future enhancements, we can include security based requirement. Security issue are not yet included in proactive networks. This will ensure a safe data transmissions over the network.

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