Power LEACH - A Novel Power Aware Routing Protocol for Wireless Sensor Network

Thesis submitted in partial fulfillment of the requirements for the award of degree of

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in
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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "*Power LEACH - A Novel Power Aware Routing Protocol for Wireless Sensor Network*", in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Computer Science and Engineering* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Anil Kumar Verma* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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ABSTRACT

Wireless sensor network (WSN) is a group of sensor nodes for monitoring and recording the changes sensed by them and sends it to base station for further study. This procedure dissipates lots of network energy and nodes have limited power, hence they start dying and reduce the network lifetime. To deal with this problem many energy efficient algorithms were introduced and LEACH is one of them. LEACH follows a cluster head (CH) selection scheme, where network is divided into many cluster and each cluster has a cluster head for a round and for the next round new cluster head is chosen. But sometime it seems unnecessary because CH have sufficient energy to conduct the next round. This problem is the base of the thesis where an improvement in the cluster head selection scheme and the power usage of the network is done which further increase the network lifetime and make the algorithm energy efficient and the algorithm is named as power-LEACH. In this thesis, it is shown that CH selection is based on the threshold value; if the threshold value is greater than average energy then no selection of cluster head is being done. The power level to each node is also set, if nodes did an inter-cluster communication then high power level is assigned because at that time CH needs to communicate with base station which demands more power and for intra-cluster communication low power level is assigned. In this way network energy is being balanced and increase the network life time which is shown in our simulation results. The report shows vast improvement over basic-LEACH through simulation in MATLAB.

Keywords: *Wireless sensor network (WSN), cluster head (CH), LEACH (Low Energy Adaptive Clustering Hierarchy), power-LEACH, intra-cluster, inter-cluster.*

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LIST OF ABBREVIATIONS

ACK	Acknowledgement
ADV	Advertisement
ALEACH	Advance Low Energy Adaptive Clustering Hierarchy
API	Application Programming Interface
CDMA	Code Division Multiple Access
CH	Cluster Head
CLEACH	Comprehensive Low Energy Adaptive Clustering Hierarchy
CSMA	Carrier Sense Multiple Access
DD	Directed Diffusion
DELEACH	Differential Evolution based Low Energy Adaptive Clustering Hierarchy
DLEACH	Dynamic Low Energy Adaptive Clustering Hierarchy
Energy-LEACH	Energy based Low Energy Adaptive Clustering Hierarchy
ER-LEACH	Low Energy Adaptive Clustering Hierarchy Ensuring Reliable Data Delivery
FZLEACH	Far Zone Based Low Energy Adaptive Clustering Hierarchy
GEAR	Geographic and Energy Aware Routing protocol
GPS	Global Positioning System
LEACH	Low Energy Adaptive Clustering Hierarchy
LEACH-B	Balanced Low Energy Adaptive Clustering Hierarchy
LEACH-C	Centralized Low Energy Adaptive Clustering Hierarchy

LEACH-F	Fixed number of nodes in Low Energy Adaptive Clustering Hierarchy
LEACH-H	Hybrid Low Energy Adaptive Clustering Hierarchy
LEACH-ID	Identification based Low Energy Adaptive Clustering Hierarchy
LEACH-M	Mobile Low Energy Adaptive Clustering Hierarchy
MAC	Medium Access Control
MATLAB	Matrix Laboratory
MR-LEACH	Multiple Routing Low Energy Adaptive Clustering Hierarchy
NLEACH	Number of nodes supported in previous round in Low Energy Adaptive Clustering Hierarchy
PEGASIS	Power Efficient Gathering in Sensor Information System
QoS	Quality of Service
RR	Rumor Routing
SAR	Security Aware adhoc Routing
sLEACH	Solar panel based Low Energy Adaptive Clustering Hierarchy
SNGF	Stateless Non-deterministic Geographic Forwarding algorithm
SPEED	Stateless Protocol for End-to-End Delay
SPIN	Sensor Protocol for Information via Negotiation
SQL	Structured Query Language
TB-LEACH	Time Based Low Energy Adaptive Clustering Hierarchy
TDMA	Time Division Multiple Access
TEEN	Threshold sensitive Energy Efficient sensor Network protocol
TL-LEACH	Two-level Low Energy Adaptive Clustering Hierarchy

VLEACH	Vice cluster head Low Energy Adaptive Clustering Hierarchy
VRLEACH	Variable Round Low Energy Adaptive Clustering Hierarchy
WLEACH	Weighted Low Energy Adaptive Clustering Hierarchy
WSN	Wireless Sensor Network

CHAPTER 1: INTRODUCTION

In today's era network is most fascinating term in research area. Many researchers are engaged in with this term and try to get something useful out of it. There are many fields which fascinates researchers are sensing, communication, home application, military application like intrusion detection etc. however to work on these fields researchers need to setup a network, which consists of machine which sense what they are instructed to do.

1.1 Motivation

Due to keen interest in networking this topic has been chosen as the base theme of the project. Many researchers' selects networking as the base theme and over it generally two themes were applied. These themes are security in wireless networks and routing in wireless networks. Both themes are interesting and fascinating but after study routing has been chosen.

After study of wireless network protocols, it has been analyzed that most of the protocols has been standardized so decided to go for other side of wireless network which deals with sensors. Sensors deemed the market like touch phones or in body area networks (to be very specific about network). Finally choose wireless sensor network as the base of the project and on top of that routing is being chosen as the main theme of the project. While going through the wireless sensor network, a study on research issues of wireless sensor network has been done and a point is noted that energy efficiency and usage of network power efficiently is a major concern. After having a concerned study of routing protocols of WSN, LEACH (an energy efficient protocol) and its variants has been selected as the area of research. And then another version of LEACH i.e. power-LEACH has been introduced which shows vast improvement over basic LEACH and another variety of LEACH named as balanced LEACH.

1.2 Wired Networks

Devices connected with wires or cables and form a network are called as wired networks. In these networks[1] hubs, switches and routers are used as connecting devices to

establish the connection. These types of networks are usually cheap and easy to manage or setup.

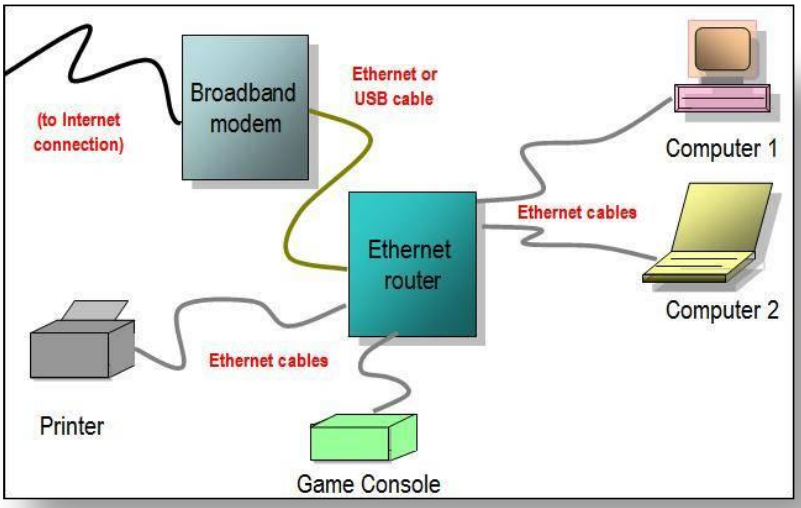

Figure 1.1 Wired network[2]

Advantages

- Once the connection is established there is a rare chance to get disconnected.
- It provides the speed of 100 to 1000 Mbps.
- Since they are wired sources, they are less prone to interference and network fluctuations.

Disadvantages

- People purchase laptops to use it anywhere they want but if wired network is available then they get restricted. Then people start thinking about the network where they connect any time anywhere and wired network starts depleting.

1.3 Wireless Network

Wireless networks are not restricted by wires and cables. This is the fundamental difference between wired and wireless network. For wireless communication[1], routers are needed for flow of information from one machine to another machine. People using

wireless networks are free to move in the network and are not restricted to one place for network.

Advantages

- These kinds of networks can be setup where wiring for the network is not possible.
- Setting up wireless network is easy because it reduces the need of pulling out cables through the ceilings.
- Network of this type are flexible and can adapt the changes easily after a simple configuration.
- People can access the network while they are roaming here and there inside or outside their office or home.

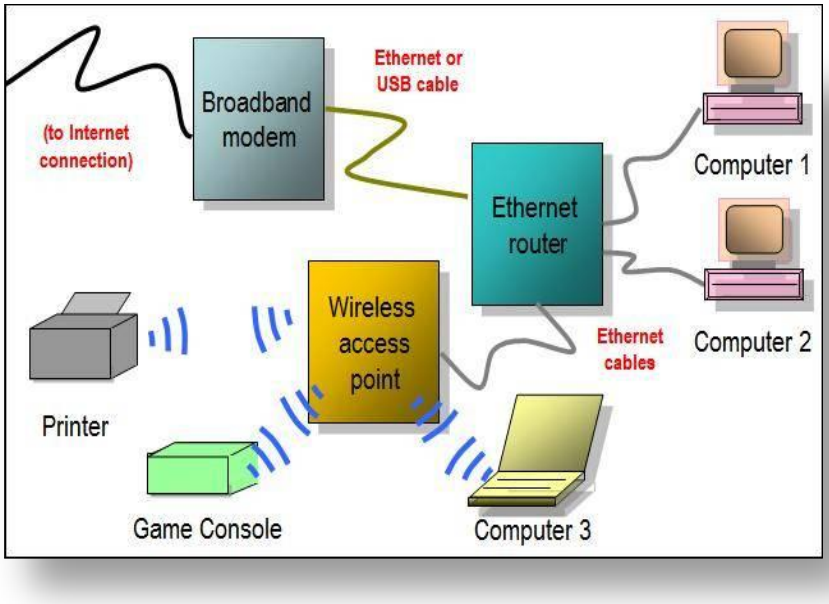

Figure 1.2 Wireless networks [2]

Disadvantages

- Signals of wireless networks are badly affected due to poor weather, inappropriate radio signals or due obstacles like wall.
- Signal of wireless network is also affected when there exist more than one connection for the same region.

Wireless network has a special subarea widely named as wireless sensor network. Following is the brief description of wireless sensor network and a small discussion about the applications of WSN and challenges faced by wireless sensor network.

1.4 Wireless Sensor Network

Wireless sensor network (WSN) [3] refers to a group of sensor nodes dispersed in an area to monitor the environmental conditions and record them and send it to a central location for further investigation and study. WSN is also called Sensornet [4] or embedded sensor network.

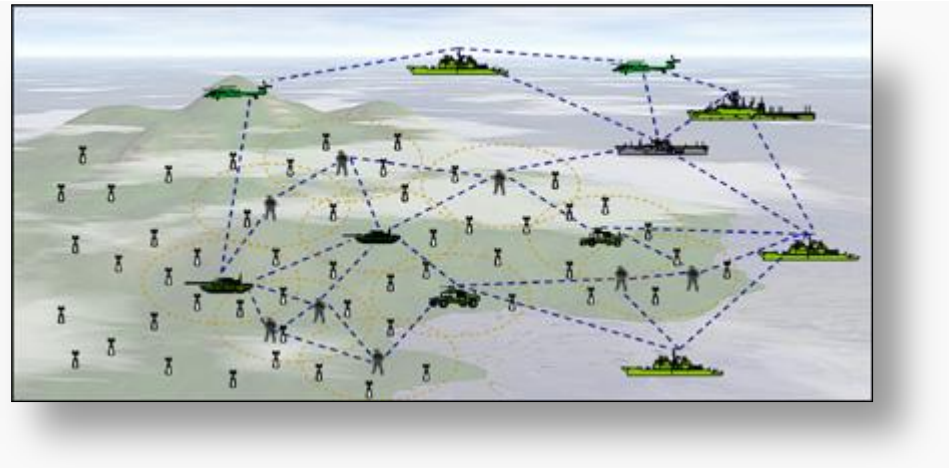

Figure 1.3 Wireless sensor network [5]

A Wireless sensor network [6] has any number of sensor nodes from a few hundreds to thousands. Sensor node is equipment that consist a radio transceiver along with an antenna, a micro-controller, an electronic circuit, and an energy source (i.e. battery). The size of the sensor nodes can also range from the size of piece of sugar to a size of telephone. Prices of sensor nodes may vary from few cents to hundreds and thousands of dollars which is based on the functionality parameters of sensor like energy consumption, computational speed rate, bandwidth, and memory. Every node in the network senses the environmental changes and passes this information to other nodes so that changes are in knowledge of every other node. Sensor nodes are great for deployment in hostile environment or very large geographical areas. As large number of sensor nodes are

usually deployed on remote and inaccessible places. Deployment and maintenance is easy and scalable.

1.5 Applications of Wireless Sensor Network

Wireless sensor network is popular area for researchers because it deals with so many applications. Major applications are discussed below with the help of figure 1.4.

- Military application [7] includes monitoring the intrusion detection at the borders and detection of nuclear attacks. Any change in environment is detected and informed by the equipments held in the network.
- Commercial and industrial application [7] includes machine health monitoring, process monitoring, waste monitoring and environmental control in industrial and office buildings, inventory control, vehicle tracking and detection, traffic flow surveillance.
- Environmental and habitat monitoring [7][8] includes air pollution monitoring, water quality monitoring, microclimates, landslide detection, forest fire detection, flood detection, precision agriculture, acoustic detection.

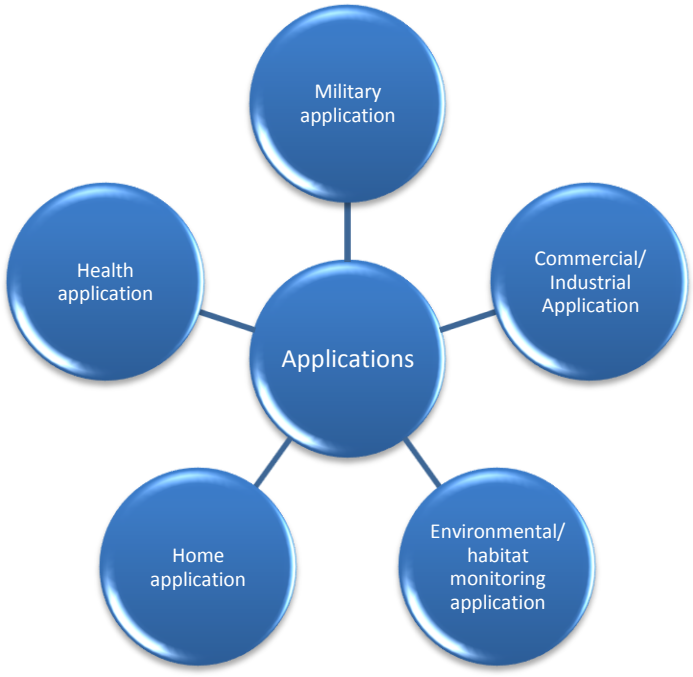

Figure 1.4 Applications of wireless sensor network

- Home application[8] includes smart home monitoring, home automation, instrumented environment, automated meter reading.

- Health application[8] includes remote monitoring of physiological data, tracking and monitoring doctors and patients inside a hospital, drug administration and elderly assistance.

1.6 Research Issues in wireless sensor network[9]

- Real world protocol

Most of the WSN solutions in real world give vague results. So, the idea to improve this issue is to establish better model and invent some network protocols for wireless communication so they face the real world challenges. And afterward test them in real world settings.

- Real time

This also a major issue and most of the protocols ignore real-time and add assumptions to process the work faster in order to meet the deadlines.

- Programming abstraction

A programmer generally deals with queries written in an SQL-like format. However, real-world data issues such as probabilistic data, various levels of confidence in data and missing or late data sometimes make the SQL paradigm insufficient. It is likely that no programming abstraction for WSN will exist. Rather, a number of solutions will emerge, each better for certain domains.

- Power management

Slow progress in increasing the battery life or capacity creates a problem in developing the wireless network. As the nodes in the network communicate wirelessly and there is no wired power source with them so it is needed to increase battery capacity as the replacement of battery in hostile environment is not the feasible solution.

- Security and privacy

Sensor nodes are deployed on hostile environment where risk of physical attack is always there. And in case if a single node is traced then it is easier for hacker to trace the whole network and gather the information from them. So embedding secrecy, authentication and privacy in network is must.

1.7 Thesis Outline

The thesis has been organized into seven different chapters which includes introduction as well. Chapter 1 is an introduction chapter which includes why to choose this project, a brief summary about the base of the project i.e. wireless sensor network. It also includes the applications and research issues of WSN.

Chapter 2 is the literature review of routing protocol which is the main theme of the project. This chapter mainly devotes to the study of homogeneous cluster and non cluster protocols and LEACH is one of them. LEACH protocol is an energy efficient protocol which is the main idea of research.

Chapter 3 devotes to the problem statement which includes the gaps in the study and designs the objectives to fulfill those gaps throughout the project.

Chapter 4 includes the brief summary of platform to be used for the performance of the project and includes the implementation of power-LEACH and compares it with basic LEACH and balanced LEACH (LEACH-B).

Chapter 5 includes the simulation of the project which shows various graphs and based on these graphs comparison of all three protocols (power-LEACH, basic-LEACH, and balanced-LEACH) has been done and some findings were discussed.

Chapter 6 in this chapter conclusion of the project is drawn and a future scope has been discussed.

CHAPTER 2: LITERATURE REVIEW

2.1 Classification of routing protocols based on routing path

WSN Routing Protocols classified in four ways [10], according to the way of routing paths are established, according to the network structure, according to the protocol operation and according to the initiator of communications. Figure 2.1 shows the classification of WSN routing protocols.

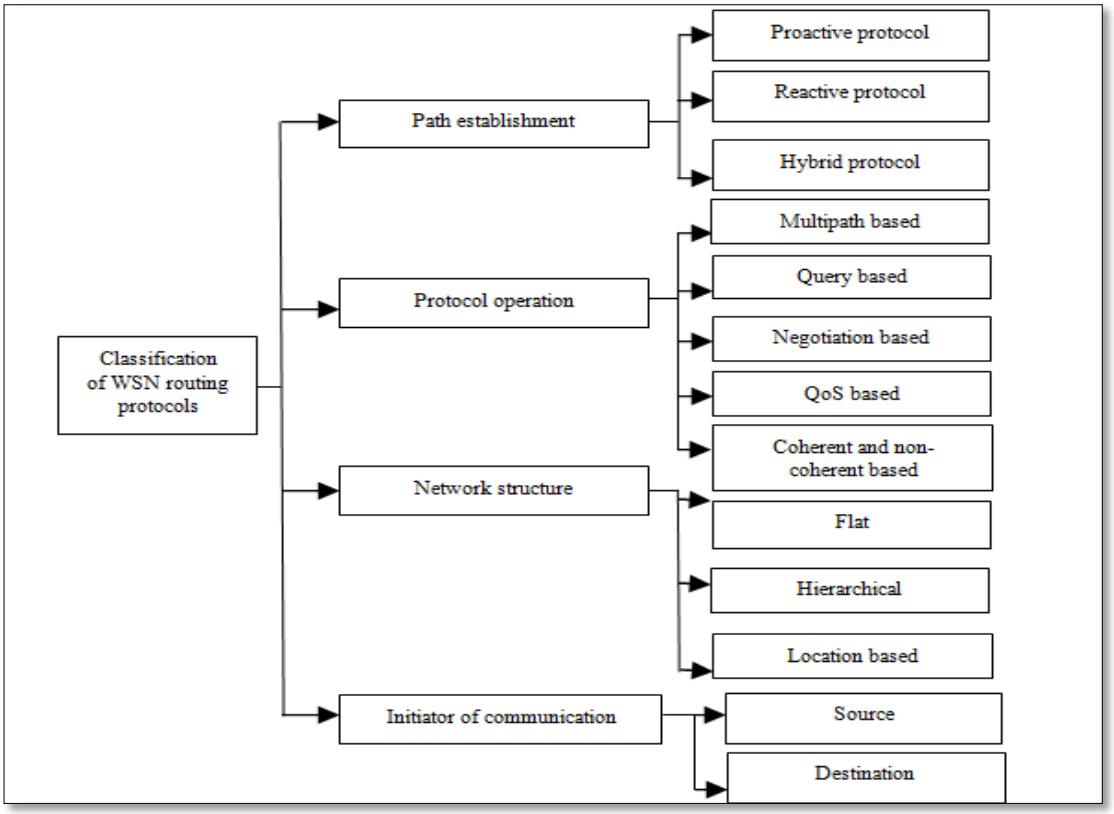

Figure 2.1 Classification of routing protocol based on routing path

Path establishment

Path establishment is done in three ways i.e. proactive, reactive and hybrid.

- Proactive protocols: Compute all the routes before they are actually needed and store these routes in routing table of every node. When a route changes then there is a need to update the table of each node but the problem is WSN have thousands of nodes and

updating thousands of node is not a good idea. This is the only reason that proactive protocols are generally not suited for wireless sensor network.

- Reactive protocols: Computation of route is only done while they are needed.
- Hybrid protocols: Hybrid protocols are the combination of above two ideas.

Network structure

According to network structure, routing protocol is divided into three broad categories, flat, hierarchical, location based.

- In flat-based routing, all nodes have same work.
- In hierarchical based routing, all nodes play different role in the network.
- In location-based routing, position of nodes is used for routing of data.

- Flat based routing (data centric routing)

  Assigning of global identifier is not feasible to every node because there is large number of nodes in the sensor network. Because of lack of global identifier and random deployment of nodes makes harder to query a specific sensor node in a network. Now the data is transmitted from every sensor node present in the deployment area with redundancy. This consideration led to data centric routing where sink sends query to a region and waits for data from sensor node located in that region.

- Hierarchical based routing

  Hierarchical based routing follows two steps, selecting the cluster head and then routing. Clusters were created to make the network more energy efficient and then special tasks were assigned to each cluster. Clustering increases the overall system scalability, lifetime and energy efficiency.

- Location based routing

  In order to estimate the energy consumption of the network distance between two nodes has to be calculated. To get the distance between them, location information is needed. Generally two techniques are used to get the location are (i) get the coordinates of neighboring node (ii) use GPS (global positioning system).

Protocol operation

Protocol operation is further divided into five routing protocols as multipath based, query based, negotiation based, QoS based, coherent and non-coherent based routing.

- Multipath based routing

  Multipath based routing protocols improves the network performance as they add on the power of fault tolerance to the network (it suggests the alternate path when the main path fails). Resilience is increased by maintaining multiple paths between two nodes instead of single path but it increase the expense of maintaining the alternate path. There is a tradeoff between the amount of traffic and the reliability of the network[11].

- Query based routing

  In query based routing, source node generate a query for data(sensing task)and one node pass to the other and every node get the query and whosoever node have that requested data sends the data back to the source node. Queries are generally defined in natural language or in high level language.

- Negotiation based routing

  Negotiation based routing comes into existence in order to remove the redundant data during transmission. As the flooding is used to disseminate the data and there is an overlap between the sent data; hence data is duplicated on the nodes. This consumes more energy by sending the same data to different nodes. This problem is solved by including negotiation messages before the transmission.

- QoS based routing protocol

  In order to satisfy certain QoS (Quality of Service) metrics, e.g., delay, energy, bandwidth, etc. when delivering data to the Base Station, the network has to balance between energy consumption and data quality[11].

2.2 Classification of routing protocols based on type of node

Broadly classified into two categories 1) homogenous 2) heterogeneous. Both are further classified into two sub categories i.e. clustered and non-clustered. Now each category has number of protocols which are shown in below figure:

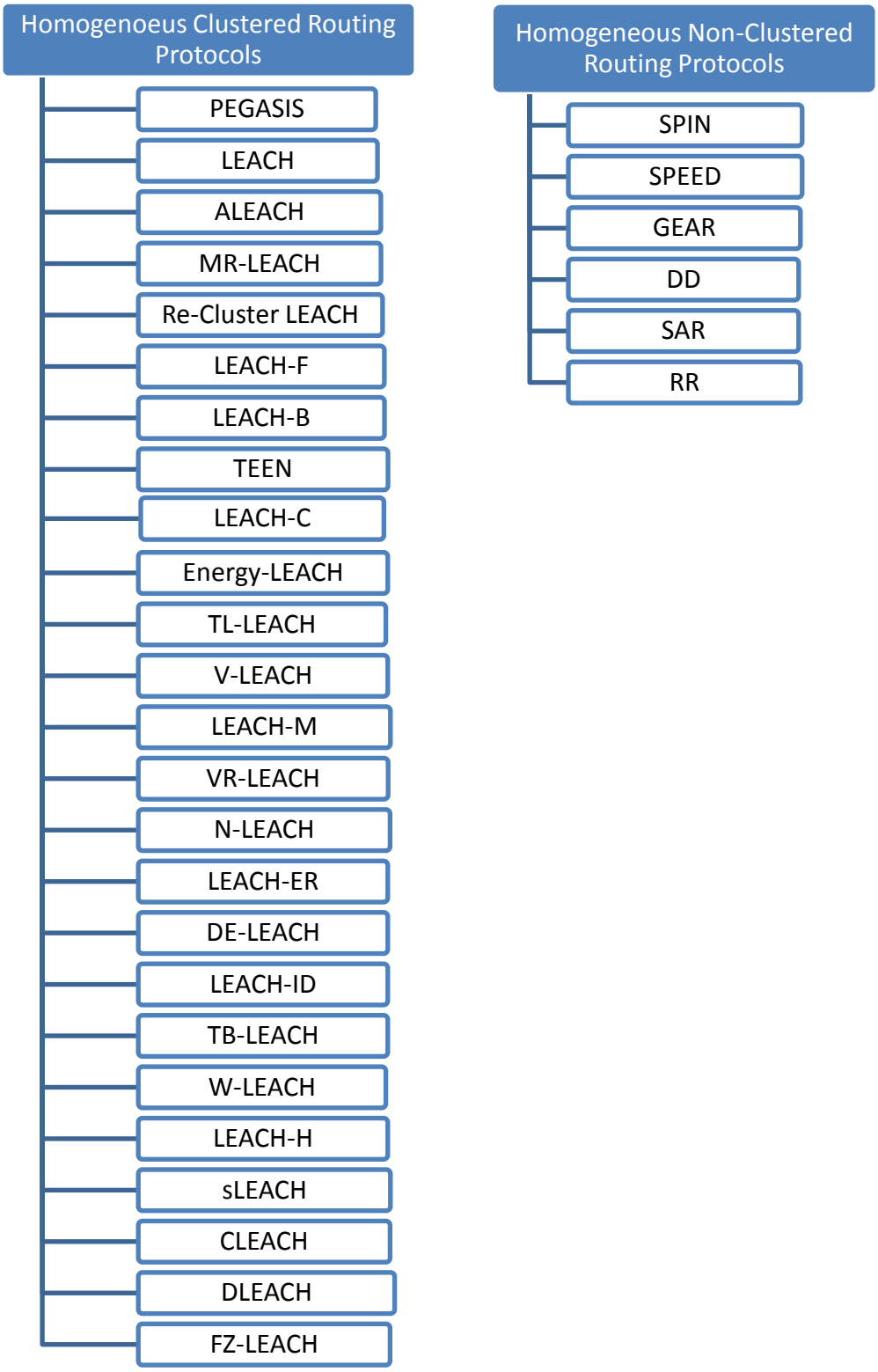

Figure 2.2 Routing protocols under the category of homogeneous clustered and non-clustered.

- Homogenous: Nodes in homogenous network are same in every sense whether it is their size, their configuration or the node they were using for their power source.
- Heterogeneous: Every node in the network is of different type whether its size, shape, power source.
- Clustered protocols: Nodes were grouped to form a clusters and data from node belongs to the same cluster are combined or aggregated. This makes network energy efficient and manageable.
- Non-cluster protocols: No need to form a cluster of nodes. Each and every node is free to send data to the Base station on its own.

2.3 Homogeneous clustering protocols

2.3.1 LEACH

LEACH [12][13] is defined as low energy adaptive clustering hierarchy. In this protocol a head is chosen among a set of node randomly and that node is then called to be cluster head (CH). If each node sends the data to base station then maximum of network energy gets wasted for transmission so to overcome this overhead a node is chosen as a head and all other node sends their data to head (CH) and this reduces the energy load of the network. Few main feature of LEACH are compression of data before sending it to sink node, random selection of cluster head and most important is to maintain a co-ordination between non CH nodes and CH node.

CH is chosen to the node which powerful than other node in every aspect because CH is the node which needs to communicate with all other normal nodes in the cluster which are placed distant in the cluster. LEACH is a protocol which changes the CH periodically because energy of cluster head becomes low while communicating with other nodes after one round so replacement of CH is done for the next round. Task of CH is to compress the data collected by normal nodes of the same cluster and send that aggregate data to the sink node or base station. Data collection is centralized and periodically. However the problem is data is not needed periodically and a lot of energy is wasted due to unnecessary data. LEACH [12] performs in two phases 1) Setup state and 2) steady phase.

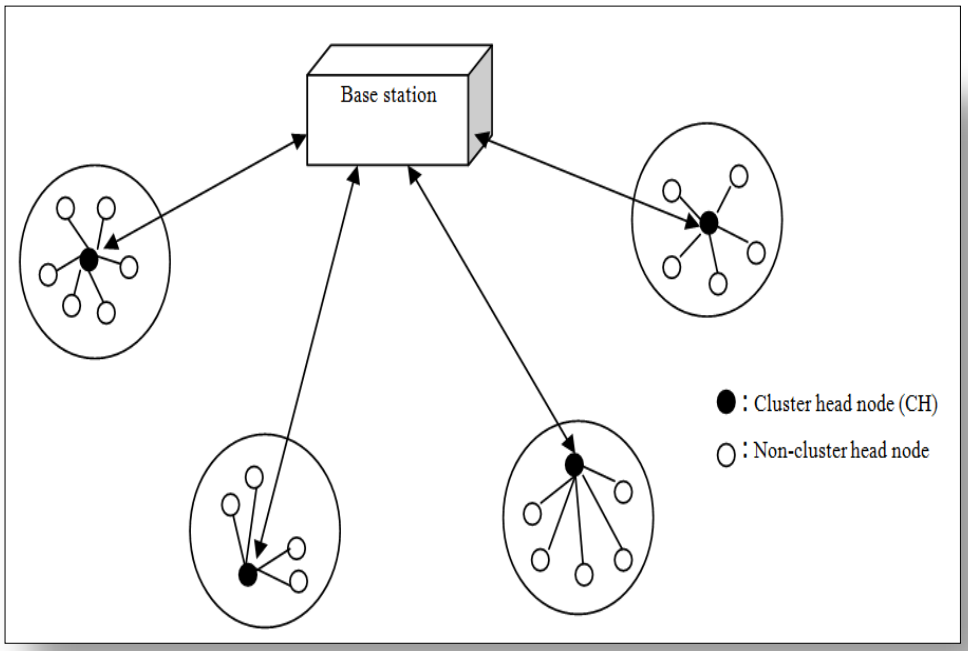

Figure 2.3 Architecture of LEACH

Setup phase: Selection of cluster head which is random in case of LEACH is under the setup phase. A predetermined fraction of nodes i.e. p is needed to elect CH among themselves only. Each node in cluster selects a random number between 0 and 1 and a threshold a selected i.e. T(n). If random number is less than a T(n) then the node become the cluster head for that round. Except threshold a node must satisfy one more condition to become cluster head. The condition is that node was not selected as CH in last (1/p) rounds. If a node satisfies both the conditions then the probability of becoming CH for that node become high. The threshold value is given by equation (1) [13]:

$$T(n) = \begin{cases} \dfrac{f}{1 - f * (r \bmod 1/\mathrm{f})} & if\ n \in G \\ 0 & otherwise \end{cases} \qquad (1)$$

Where,

G: Group of nodes participated for CH election

T(n): Calculated threshold value

f: Fraction of nodes

r: Current round

After selection of CHs for each cluster, CHs broadcast advertisement to all non cluster head nodes CH uses CSMA protocol to broadcast the advertisement message to all nodes in the same cluster and based on the signal strength normal node joins the cluster and send an acknowledgement message to CH. When all nodes do the same then CH creates a TDMA schedule and allots a time quant to every node. Nodes must transmit the data in the allotted time quant. This schedule must broadcast to every node.

Steady phase: In this phase all nodes transmits the data and CH aggregates the collected data and then send it to base station after that round gets finished and then again for the next round setup and steady state starts. Each Cluster uses different CDMA codes in order to reduce the interference between them.

After study of homogeneous protocols it is being analyzed that LEACH is most popular among researchers and from a decade researchers tries to improve it by adding different aspects of other area like adding differential evolution from mathematics, ant colony optimization from swarm intelligence and many more. And it is evident that there are more than 20 varieties are already proposed and they were discussed briefly in next sections.

2.3.2 ALEACH

ALEACH is defined as Advance LEACH. In this LEACH cluster formation is slightly different from the basic LEACH; Clusters were formed based on autonomous decision of nodes in the network without any interference of central control. Clusters were formed without knowing the exact location of other nodes of the cluster and no global communications is needed to form a cluster. In this protocol what matters is the current state of the node. Selection of cluster head is quite different in ALEACH. In basic LEACH CH is chosen based on the threshold value, T(n) which depends on the round without knowing the state of other nodes of the cluster but in ALEACH this is not the case. In ALEACH selection of cluster head is not only depends on round but also on the current energy. If two nodes have different current energy then the node having higher current

energy is chosen as CH, so that all nodes die at the same time, this is the major idea behind that rule.

So after considering the current state energy the threshold equation [14] becomes

$$T(n) = general\ probability + current\ state\ probability$$

$$T(n) = \frac{f}{N - f\left(r \bmod \left(\frac{N}{f}\right)\right.} + \frac{E_{current}}{E_{n-\max}} \times \frac{f}{N} \qquad (2)$$

Equation 2 is improvement on equation (1) where

N=total number of nodes

$E_{current}$=current energy of node

$E_{n\text{-}max}$= initial energy

After having cluster head for the round, CH creates a TDMA schedule and transmits to the cluster so that it is known to all its members. Now the nodes send the data to CH following the TDMA schedule to avoid the collision during the transmission during the steady state phase.

2.3.3 MR-LEACH

Multi-hop routing LEACH divides the network into layers of clusters and for each cluster, CH is chosen. CH of upper most level (Chosen by Base station) [15] acts as supervisor for them and directs them to route the data towards the base station. CHs in MR-LEACH not only act as collection node but also act as relaying nodes to route the data to the base station. Before discovery of MR-LEACH, some protocols were discovered which follows the multi-hop routing with unequal partitioning of clusters. This kind of partitioning creates a problem in scheduling because of unequal clusters. To solve this problem CSMA (carrier sense multiple access) [15] is used which is quite expensive in comparison with TDMA. So the idea of equal clusters rises which reduces the average distance between each cluster which shows improvement in remaining energy hence increase the network lifetime. Since number of clusters was equal so they are able to use TDMA schedule.

2.3.4 Balanced LEACH

Selection of CH is based on the residual energy of the nodes. If the number of CH in the network is less than n*p [16] then a timer is created and at this time interval a advertisement for CH is send among the nodes of the cluster but if the timer expires then change to CH and again broadcast for CH advertisement. If the number of CH is not less than n*p then sorting of CH is done based on the residual energy [17] and the CHs which have residual energy less than average energy must eliminate from the CHs list.

2.3.5 Re-cluster LEACH[18]

Basic–LEACH protocol is a single hop protocol and it doesn't consider the remaining energy of the node. It just selects the CH from whole network in every round, while in re-cluster LEACH CH is selected inside the same cluster for each round. But the main difference between LEACH and re-cluster LEACH is the procedure to make the clusters. Re-cluster LEACH forms the clusters based on the node density in an area. After formation of cluster and selection of CH, data transmission is done based on CSMA/CD instead of TDMA.

2.3.6 LEACH-C

In centralized LEACH [19] after clustering, each node sends its residual energy as well as their ID to the base station and based on the higher residual energy base station selects the CH. This the major difference between basic-LEACH and LEACH-C[20], CH selection is not inside the cluster but outside the cluster by the base station. Hence base station has knowledge of every node in the network and after choosing the CH, base station broadcast the ID of CH, so those members of cluster know about their CH. It uses GPS technique to get the location of nodes but it is not robust.

2.3.7 Energy LEACH

It follows the improved selection of cluster head[21]. Residual energy is the decision factor in this algorithm. In this algorithm, CH is selected randomly for the first round

because at that time residual energy is same for each node and after first round each node have different residual energy. On the basis of residual energy, selection of cluster head has been done for every round after first round[22]. After selection of CH, a TDMA schedule forms for data transmission in steady state phase.

2.3.8 Fixed number of cluster- LEACH

LEACH- F [23] is very much similar to LEACH-C. Base station generates the cluster head order and based on this CH role is rotated between the nodes. After the clustering algorithm, the CH role sequence starts. Advantage of LEACH-F over other LEACH, there is no overhead of designing an algorithm for cluster head selection and it comparatively less costly as no CH selection for every round. But it doesn't solve the problem of becoming energy efficient protocol.

2.3.9 TL-LEACH(Two Level-LEACH)[24][25]

Two-level LEACH protocol nodes divides themselves into cluster autonomously without intervention of central control and clustering is based on node density. To save the energy consumption the nodes are divided into hierarchy of clusters, so that message from the maximum of nodes doesn't need to travel the larger distance. The network has top cluster head then secondary cluster head and then simple nodes at the lowest level. It follows the CSMA scheme for scheduling.

2.3.10 V-LEACH

VLEACH stands for vice cluster head[26] LEACH. Instead of having only CH for data transmission, there is vice CH also. When the load on CH increases then the residual energy of that node reduces and soon it becomes dying. In that case the data collected during a round will waste because of death of CH. To solve this problem a node under the CH is assigned who will work after the CH death so that collected data will not lost and reach to the base station. It also improves the network lifetime.

2.3.11 LEACH-M [27]

This protocol had a slight improvement over basic LEACH is that steady state phase supports the mobility of nodes. TDMA schedule is revised every time when a new node arrives at the cluster. When a node sends a data and the data doesn't reach to the CH then it assumes that node must enter into some other cluster and time slot for that node must be removed from the CH memory, and CH of nearby cluster adds that node to its own cluster and update its TDMA schedule. To get the location information of the node GPS technique is used.

2.3.12 VR-LEACH

Variable round LEACH[28], as the name suggest, round for the data transmission must be variable in length. In the setup phase, those nodes were eliminated which have energy less than the average energy of the network. Because if the node with energy less than average energy selects as CH then it will die soon and the data gathered by them will lost. Rest of the node participated in the CH election. After that most appropriate node is selected as CH and cluster formation starts then CH creates and broadcast the TDMA schedule to every node of the cluster and data transmission begins. Depending on the length of round time, a next round begins. Round time changes if some of the node will die from the cluster and will not able to participate for data transmission then slot occupied by them must remove and change the round length, so that LEACH works properly and efficiently.

2.3.13 N-LEACH (Number of nodes supported in previous round)

If number of nodes inside the same cluster head increases then the load on that node also increases. As the LEACH follows the scheme to join the cluster based on the distance from the CH. Nodes joins the CH which was nearest to them and in this way nodes in the each cluster become uneven and load on CH become also uneven. In NLEACH a new method of CH selection is introduced which balances the energy consumption of every node and also balances the load. In this scheme initially data transmission for all nodes become (-1) and check if nodes energy is greater than zero then if the data transmission[29][30] is greater than 0 and also satisfies threshold, T_n then the node

become cluster head and data transmission increases by (n/k)*N[29]. otherwise no selection of cluster head and next round starts.

2.3.14 DE-LEACH (Differential evolution algorithm-LEACH)[31]

Premature of death is the main problem basic-LEACH was facing and researchers try to solve the problem by improving the LEACH algorithm. A new algorithm was proposed which uses Differential evolution algorithm for cluster head selection. DE is used to optimize the multi-objective CH selection algorithm and on the basis of swarm the ID's of node is sorted after finishing the first generation and then crossover is held between them and then selection takes place based on adaptation. Then cluster head is selected after reaching the termination condition. Now DE-LEACH follows the same track as the LEACH follows. But this improvement in selection of CH is a marked history.

2.3.15 LEACH-ID (Identification based LEACH)[32]

In this protocol, a unique ID is assigned with binary number to each sensor node. Based on this ID data is send using a single path i.e. unicast instead of broadcast which improves the network lifetime and shows high energy efficiency. These unique ID's are temporary and change after every round.

2.3.16 LEACH-ER (LEACH ensuring reliable data delivery)

This type of leach ensures the reliable delivery of data to the sink node. Sink node creates a list of node and the list is structures as follows [34]:

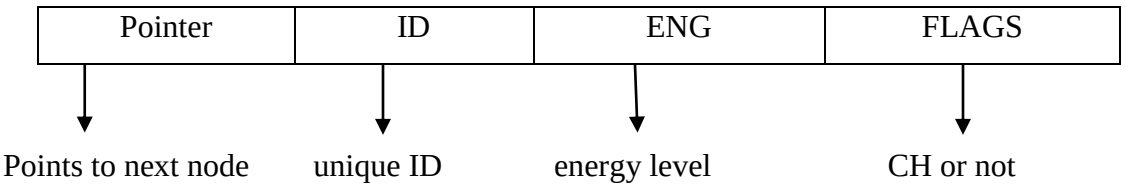

Figure 2.4 Structure of sink list

The selection of CH is based on change of energy level (ENG) and any change in cluster nodes is judged. Selection of CH is done by following ways:

- If Energy field of CH is not changed and greater than zero then CH sends the data packets directly.
- If energy field is changed and the greater than zero then firstly subtract 1 from the ENG field and store it as the new value of ENG . After that send the data packets but it will not send the ID to the sink.
- If energy field is equal to zero, then CH send ID to sink and leave the position of CH and change its FLAG to zero. Now the base station chose the CH based on the highest ENG level of node. And the node that leaves the position of CH is now reset and place again to the sink list.

2.3.17 TB-LEACH [35][36]

It is known as time-based LEACH, it also follow the distributed algorithm where nodes select their CH without any central control. Instead of depending on a random number for cluster head selection, it is based on the time interval. The node having shorter time interval will win among the other for becoming the CH. In this algorithm a counter has been set for selecting only constant number of CHs. When the counter expires then election of cluster head finishes, this is the terminating condition of CH selection. After that rest of the process is similar to basic LEACH.

2.3.18 W-LEACH (Weighted LEACH)

W LEACH is weighted LEACH which handles a network which have similar types of nodes (homogeneous) as well as the networks which have different nodes (heterogeneous). As the name says WLEACH is based on the weight of the nodes. Weight decides whether the node become CH or the sender of the message to CH. WLEACH is little different from basic LEACH, after selection of CH every node inside the cluster sends their messages to the CH node but in case of WLEACH only few nodes send their message to CH and those nodes are selected based on the weight.

The weight of the node is decided based on following criteria[37]:

- If the remaining energy of the node is high then the weight for that node must be high.
- Density of nodes must be directly proportional to the weight.
- If there is no node in the range of other node then the density is set to 1 and if all in range then density is n.

2.3.19 LEACH-H (hybrid cluster head selection-LEACH)

Hybrid LEACH uses simulated annealing for selection of CH. For the very first round, base station selects the CH based on simulated annealing technique for the optimized selection. And after the first round current cluster head selects the cluster head for the next round. To be a cluster head, a node must satisfy the following conditions[38]:

- It must not be CH for the current round.
- The residue energy must be higher than the average energy.
- The node must be close to the center of the cluster.

If above all conditions are not satisfied at the same time then the node which is closer to the center to the cluster is selected as CH for the next round. CH of the next round must have higher residual energy to conduct the next round otherwise data transmission become halted. Distance between CH and the next cluster head is minimum so the in the next round non-cluster head nodes doesn't need to travel the larger distance to transmit its information. That's why it is the base rule of the algorithm is that the CH must be from the center of the cluster so that every node has to follow the minimum distance.

2.3.20 sLEACH (solar-aware LEACH)

Sometime sensor nodes are deployed in remote and in non-accessible area such as forests. Major issue with these nodes is that we are unable to maintain the power source for them. But in sLEACH we improve the life span of sensor nodes using solar panels[39]. Solar panels charge the sensor nodes in hostile environment and the nodes with higher solar power become the stronger candidates for Cluster head selection.

2.3.21 CLEACH (Comprehensive LEACH)

Comprehensive LEACH follows a different approach to divide the nodes into set of clusters. Approach is named as particle swarm optimization. In this method cluster are divided based on the splitter line (U=(x,y,θ)) and the cluster division algorithm [40] follows the following steps:

- Every node of the network send a message to the sink node and the sink node will divide the network into cluster after receiving the messages and define P particles.
- Select random numbers for parameter x,y,θ and made a splitter line which further divide the network into cluster i.e. PX2.
- Compare the fitness function and based on that select the general extrum and individual extrum.

This method continues till said number of clusters was not made. And after division of clusters, CH is elected based on the residual energy and weighted distance. And after that data transmission used ant colony optimization technique which uses pheromone value for routing.

2.3.22 DLEACH (Dynamic LEACH)

DLEACH is based on the similarity of data[41] to be transmitted to the CH. In each round, many frames are transmitted based on number of members in the cluster. CH checks and calculates the amount of duplicacy and based on that duplicacy CH assigns a probability to each node. The assigned probability decides whether they can send the data to base station or not[42]. The similarity of data is checked by the method of boot-strapping simulation.

2.3.23 FZ-LEACH

FZ is defined as Far zone LEACH[43]. There is always some location which is far from the central location of the network. These zones are created when minimum reachability power is less than average minimum reachability power. Average minimum reachability

power is calculated through the minimum power of each node in a cluster. Sometime to transmit message from this zone to CH takes to while so that the energy of that node finishes and it becomes dead. To solve this problem, an algorithm is designed which take care of that far zone. In this algorithm, zone is treated as a cluster and based on that cluster a zone head (ZH) is selected having highest energy. The ZH collects the data from the far zone and aggregate them. After that ZH gives the aggregated data to the CH where the far-zone is actually present and then CH aggregates the data from other nodes and from the ZH and send it to base station.

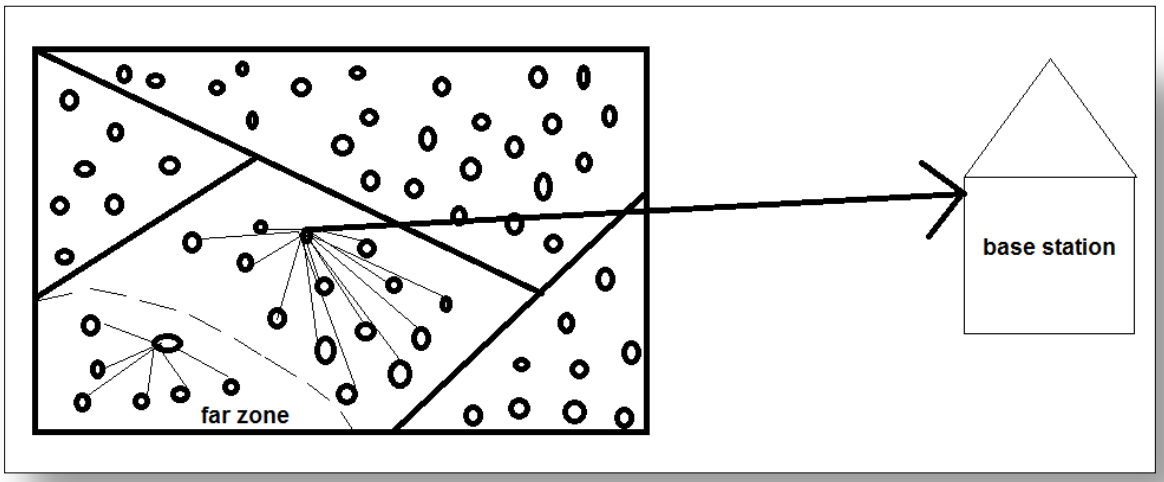

Figure 2.5 Showing far-zone in the network

2.3.24 TEEN

TEEN is the first reactive protocol and it is defined as Threshold sensitive Energy Efficient sensor Network protocol[44]. This protocol is based on two values i.e. hard threshold and soft threshold. It is the threshold value for sensed data. In hard threshold, if sensed value is gone beyond this value then the node which goes beyond it turns on its transmitter and inform to its CH for that change. But in soft threshold if the sensed value is goes beyond this value then the node turns its transmitter on and starts transmitting. Since the hard threshold only allow those transmission which are under their range of interest and soft threshold will avoid those transmission which are occurs due to small change in the sensed value after hard threshold is set. For scheduling since TDMA creates delaying

in reporting problem, so CDMA solves the purpose. Some of the important features [45] of TEEN protocol as follows:

- Since it transmits the data instantly so it is suited for time critical applications.
- In this protocol transmission takes more energy than sensing of data in the network. So it is used where limited amount of energy is provided because transmission is not done too frequently.
- When cluster changes all attribute must broadcast so that user didn't face any problem in fetching the previous information.

2.3.25 PEGASIS

PEGASIS [46] is presented as the improvement over the basic LEACH. It is defined as Power Efficient Gathering in Sensor Information System. It is a chain based protocol. Close neighbor of the central node transmit the data to the node and the node aggregates the data and send it to base station. Construction of chain follows the greedy approach and it is very much similar to travelling salesman problem. After creation of chain, cluster follows the token passing scheme to gather the data to n location. The central node sends the token to the farthest node using its neighbor node. Once the token reaches to the end then the end node transmit the data to the node which is placed next to it in the direction of central node and after traversing each node the data starts aggregating at each level. And when data reaches to the central location then it sends the data to the base station and the rounds continues.

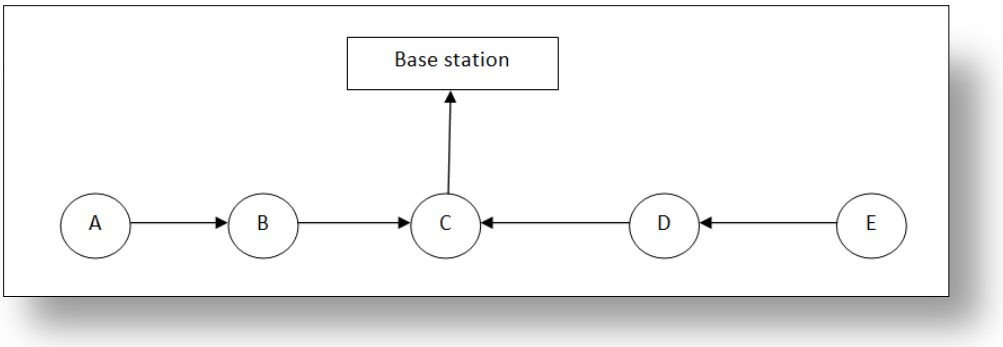

Figure 2.6 C is a leader, passes the fused data to Base station

Table 2.1 Comparison of varieties of LEACH

Parameter → / Protocols ↓	To create schedule	Number of levels in cluster	Knowledge about CH	Energy dissipation	Aggregation of data allowed	Number of hops	Is no of clusters are fixed?	Knowledge about route	Mobility	GPS technique for location information
LEACH	TDMA	Single	Yes	Highest	Yes	Single	No	No	No	No
A-LEACH	TDMA	Single	Yes	Medium	Yes	Single	No	No	No	No
MR-LEACH	TDMA	Multiple	Yes	Medium	No	Multiple	No	Yes	No	No
Re-Cluster LEACH	CSMA/CD	Single	Yes	Medium	No	Multiple	No	No	No	No
LEACH-F	TDMA	Single	Yes	Medium	Yes	Single	Yes	No	No	No
E-LEACH	TDMA	Single	Yes	Low	No	Single	No	No	No	No
LEACH-C	Not used	Single	No	Medium	No	Single	No	No	No	Yes
TL-LEACH	TDMA	Two level	Yes	Low	No	Multiple	No	Yes	No	No
VLEACH	TDMA	Multiple	Yes	Low	No	Multiple	No	No	No	No
LEACH-M	TDMA	Single	Yes	High	No	Single	No	No	Yes	Yes
VR-LEACH	TDMA	Single	Yes	Very low	Yes	Single	No	No	No	No
NLEACH	TDMA	Single	Yes	Low	Yes	Multiple	No	No	No	No
DE-LEACH	-	Single	Yes	Low	Yes	-	No	No	-	-
LEACH-ID	TDMA	Single	Yes	Low	Yes	-	No	Yes	-	-
LEACH-ER	TDMA	Single	Yes	Low	No	Multiple	No	Yes	No	No
TB-LEACH	TDMA	Single	Yes	Low	No	Multiple	No	No	No	-
W-LEACH	-	Single	-	Low	Yes	-	No	No	-	-
LEACH-H	-	Single	Yes	-	-	-	-	-	-	-
sLEACH	TDMA	Single	Yes	Low	Yes	Single	No	Yes	-	No
CLEACH	-	Single	Yes	Low	Yes	Multiple	Yes	No	-	-
DLEACH	TDMA	Single	Yes	Medium	Yes	Single	No	No	No	No

FZLEACH	TDMA	Multiple	Yes	Medium	Yes	Multiple	No	Yes	No	Yes

2.4 Homogenous non-cluster protocols

2.4.1 SPIN

SPIN is Sensor Protocol for Information via Negotiation [47] which follows the data centric approach. SPIN protocol divided into three phases i.e. initialization phase, data collection phase and negotiation phase. This is the protocol is suited for the place where the application is event driven.

Initialization phase: All nodes in the networks are synchronized to a global time and after that data packets are generated which are further used during transmission.

Data collection phase [48]: A node in the network collects the data from its neighboring nodes. The data packet contains information like address of origin, sequence number, sensor reading and payload. Payload is stored in the node itself.

Negotiation phase: an advertisement has been sent before sending of data. After receiving the advertisement final data packet has been sent.

2.4.2 SPEED(Stateless Protocol for End-to-End Delay)

SPEED is a stateless protocol for real time communication like unicast, multicast and anycast. It increased the speed for efficient delivery. it is a MAC layer protocol[49] and consist of following components like API (unicast, multicast and anycast) and SNGF (stateless nondeterministic geographic forwarding algorithm) is a module which selects the next node for efficient delivery of data, backpressure rerouting(it is the module responsible for diverting or reduce the traffic when any kind of congestion occur), last mile processing(supports all three kinds of communication) , control of feedback loop is also responsible for diverting the traffic and beacon exchange to get the geographic location of the neighbor nodes.

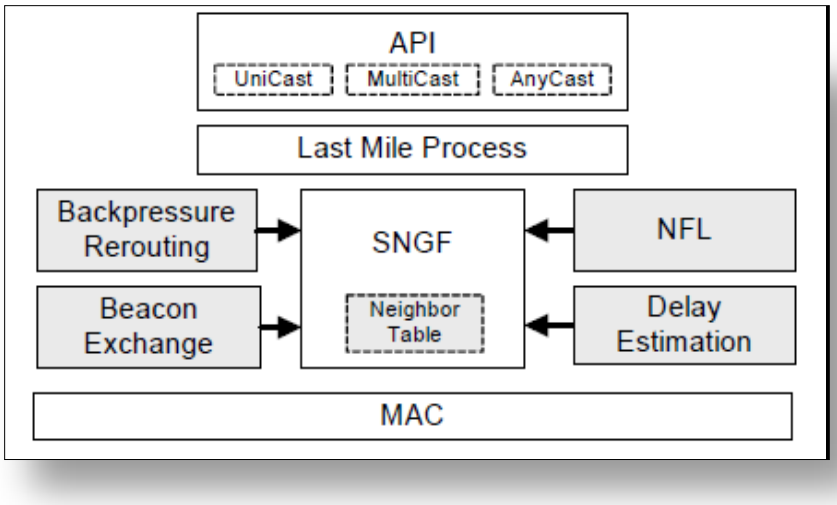

Figure 2.7 SPEED architecture[49]

2.4.3 GEAR

GEAR is defined as Geographic and Energy Aware Routing protocol. It comes to solve the problem of flooding. In flooding a request is sent to all nodes at a time which cause network traffic. And in GEAR based on the location the request has been sent. It follows the scheme of restricted flooding. During forwarding of data packets, it must follow two phases [50]:

- Forward the packet towards the target location (a) if neighbor are closer to target or sink node then select the node which is closer to the sink node (b) if neighbors are quite far then it is considered as hole and next node for data transmission is selected based on the minimum cost.
- When forwarding of packet is within the target location then recursive geographic algorithm and restricted flooding is used.

2.4.4 Directed Diffusion

Directed diffusion only follows the communication based on the data. The nodes follow the directed diffusion are always directed to reach the goal node efficiently. Directed diffusion is based on certain terms named as interest, data, gradient and reinforcement.

When a user on a node wants a data from some other node then it sends the interest message or it can be said as the query message. Every interest message is coated with the description of the task to be done by the received data. Data is the information needed for the completion of routing purpose. For dissemination purpose a network designed some events using gradients. Gradient give direction to the data [51] towards the node from where interest is received. Sometime it may happen that multiple gradients is received and based on that most optimal path is chosen among them.

2.4.5 SAR

Security Aware adhoc Routing [52] have security feature along with basic routing. It follows the negotiation metric to discover the optimal route for transmission. The main agenda of this kind of routing is to create a trust relation and trust value. Based on the trust value decision of routing was taken in future. Traditionally the goal of routing protocol is to find the best optimal path of transmission but the idea of security is still not embedded in them. Then SAR comes into existence which applies security policy in the basic protocols and these policies are part of QoS.

2.4.6 Rumor routing[53]

Rumor routing follows some characteristics of flooding. It fills the gap between event flooding and query flooding. Unlike flooding, instead of sending query to every node, it sends the query based on the random walk until event path is not found. Flooding of events needs a special packet named agent. In rumor routing every node maintains the event table, whenever an event generates an entry is made in the table and agent is created. The agent travels to the network and inform other nodes about the event especially to the distant nodes. In this way information of all nodes stored in the table and whenever sink node generates a query then with the help of event table the path is generated. Hence need of flooding the query to the whole network become obsolete and it also reduces the communication cost of the network.

Table 2.2 Summary of related work

S No.	Protocol	Proposed by	Platform used	Year	Description
1.	**LEACH**	Heinzelman et al.[12][13]	NS2	2000	Random selection of CH.
2.	**LEACH-C**	Heinzelman et al.[19][20]	NS2	2000	Every node send their information to BS and BS selects the CH.
3	**DD**	Intanagonwiwat et al.[51]	NS2	2000	Gradient directs the transmission of data.
4.	**PEGASIS**	Lindsey et al.[46]	NS	2000	Data is send based on creation of chain.
5.	**GEAR**	Yu et al.[50]	NS2	2001	Geographic and energy aware.
6.	**TEEN**	Manjeshwar et al.[44][45]	NS	2001	Based on hard and soft threshold.
7.	**SPIN**	Kulik at al.[47]	NesC	2002	Data centric approach.
8.	**RUMOR**	Braginsky et al.[53]	-	2002	Query is sent not to all nodes but it is based on random walk.
9.	**SAR**	Al-Karaki et	-	2002	Apply security

		al.[52]			constraints in it.
10.	**SPEED**	He at al.[49]	GloMoSim	2003	For real time communication
11.	**TL-LEACH**	Loscri et al.[24][25]	NS2	2005	Two level approach so that distance of transmission decreases.
12.	**Energy-LEACH**	Xiangning and Song[21][22]	MATLAB	2007	CH selection is based on residual energy.
13.	**sLEACH**	Islam J. et al.[39]	OmNeT++	2007	Solar panels are attached to node to increase the node lifetime.
14.	**TB-LEACH**	Junping et al.[35][36]	NS2	2008	Selection of CH is based on time interval.
15.	**ALEACH**	Ali M. et al.[14]	NS2	2008	Selection of cluster head is based on the current state of the energy.
16.	**ID-LEACH**	Torkzaban et al.[32]	MATLAB	2009	Based on ID base station select the CH.
17.	**LEACH-H**	Wang et al.[38]	NS2	2009	Simulated annealing is the criteria for

					selection of CH.
18.	**Recluster-LEACH**	Yi et al.[18]	OmNeT++	2009	Clustering is based on node density.
19.	**VLEACH**	Yassein M. et al.[26]	OmNeT++	2009	Vice cluster head in addition of CH.
20.	**DLEACH**	Hou G. et al.[41][42]	MATLAB	2009	Similarity of data is the main theme of this LEACH.
21.	**LEACH-B**	Tong and Tang[16][17]	MATLAB	2010	Selection of CH is based on residual energy and number of CH must be n*p.
22.	**VR-LEACH**	Peng and LI[28]	NS2	2010	Nodes which have energy greater than threshold should participate in CH election not all nodes.
23.	**N-LEACH**	Zhao and Jiang[29][30]	MATLAB	2010	Balances the energy consumption of every node.
24.	**LEACH-ER**	Guo et el.[33][34]	MATLAB	2010	Ensure reliable delivery of data.
25.	**DE-LEACH**	Li et al.[31]	NS2	2010	DE algorithm is used to optimize the CH selection.

26.	**MR-LEACH**	Farooq et al.[15]	MATLAB	2010	Upper most CH is chosen by the BS.
27.	**WLEACH**	Abdulsalam and Kamel[37]	MATLAB	2010	CH is chosen based on the weight assigned to the node.
28.	**LEACH-M**	Regadevi G. et al.[27]	NS2	2013	Nodes are mobile and after every round number of nodes changes in the cluster.
29.	**FZ-LEACH**	Muthulakshmi [43]	MATLAB	2013	Problem of far zone is considered.
30.	**LEACH-F**	Wang W. et al. [13]	NS2	2013	Order of CH role is fixed.
31.	**Comprehensive LEACH**	Tang C.[40]	MATLAB	2014	PSO is used for cluster formation and ant colony optimization is used for data transmission.

CHAPTER3: PROBLEM STATEMENT

3.1 Gaps in study

Routing in wireless sensor network is divided into two types, based on the type of nodes inside the network i.e. homogenous and heterogeneous network. Researchers design many algorithms for supporting the same. But everyone has to deal with the same problem such as limited battery life and poor network life. These two problems are connected with each other if nodes have limited power source and after routing if they lose their energy and become dead then the network lifetime also decreases. The assumption made is $Battery\ life\ of\ node \propto Network\ lifetime$. Another major problem is to make the algorithm energy efficient. In homogenous clustered routing algorithms, network is divided into clusters and each cluster has a cluster head who communicate with the base station on behalf of all nodes in the cluster. Many algorithms improve the network life time by improving the selection of cluster head of the cluster. Improvements like applying ant colony optimization, differential evolution, selection based on residual energy of nodes. During study an energy efficient algorithm, LEACH comes into frame. Many versions of LEACH try to solve all three problems (energy efficiency, network lifetime, battery life of node) a network was facing but not in significant way. To make a network energy efficient researchers apply complex algorithm at each phase of LEACH and increase the complexity of the system instead of solving the basic problem i.e. how to choose cluster head? Many solutions were proposed like ordering the cluster head role in fixed pattern and increase the network lifetime by using other algorithms. But another problem rises "is it mandatory to choose cluster head for every time?

3.2Problem statement

The ultimate goal of wireless sensor network is successful transmission of data to the base station. The existing algorithms face the problem of sudden death of nodes in the cluster and after death of nodes network is of no use. The problems like limited battery power and low network lifetime is somehow managed by most of the algorithm but not in the efficient way. Algorithms of researchers make the system complex which takes extra

energy while choosing the cluster head after every round. Hence the problem of limited network lifetime is still exists for those algorithms. The main idea of the algorithm is to study the energy efficient algorithm of wireless sensor network i.e. LEACH and its variants and findings the gaps among them. The main gap of -*"is there any need of selecting Cluster Head for every round"*, has been shortlisted to be addressed in the presented work. .

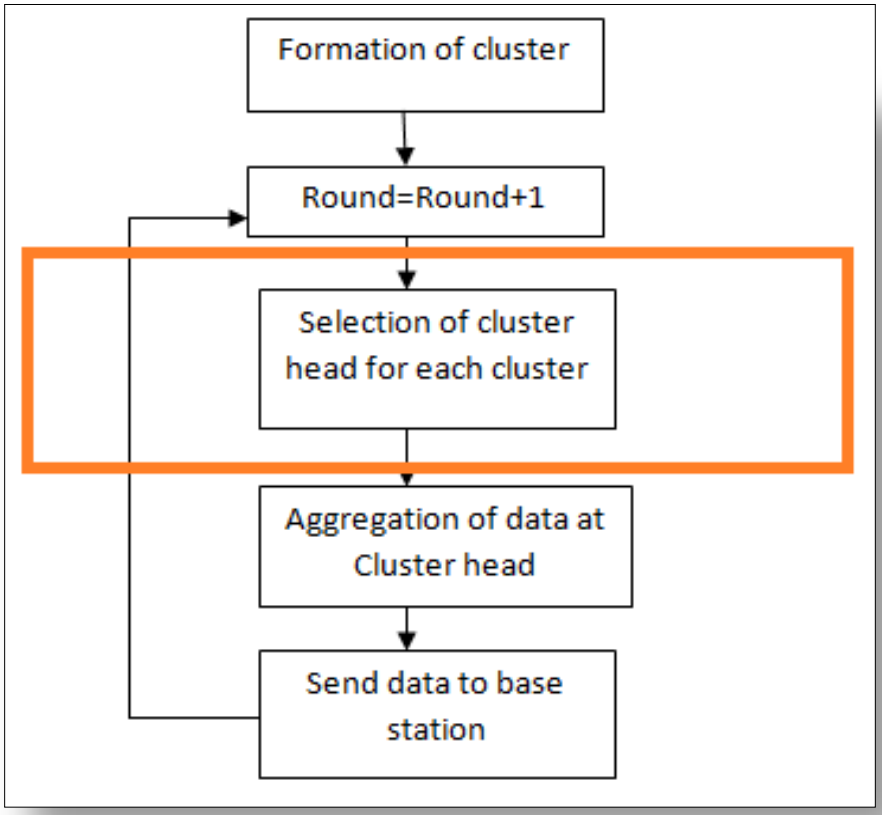

Figure 3.1 Is it mandatory to follow the highlighted step?

And keeping that in mind, a new algorithm has been proposed named as power-LEACH which not only increases the network lifetime but also makes the data transmission efficiently using minimum network power.

3.3 Sub-tasks and objectives

- Study the research issues in wireless sensor network.
- Comprehensive study of routing protocols in wireless sensor networks.

- Choose the research issue among all and filter the routing protocols and choose a variety among them. Like in this case energy efficiency and power management are the research issues to be chosen and to solve them study on LEACH starts.
- After studying all varieties of LEACH, find the gaps in the study and design an algorithm which fills the gaps.
- Simulate the algorithm and compare the results with the existing algorithm and find the improvement percentage.

CHAPTER 4: IMPLEMENTATION

4.1 MATLAB[54]

Power LEACH is implemented using MATLAB(R2012a). MATLAB is abbreviated as MATrix LABrotory. MATLAB is under MathWorks.com organization. It is computation and visualization tool. Its environment is user friendly and interactive system. The problems solved in MATLAB are easily expressed in terms of mathematical notations.

MATLAB is generally bifurcated into five subparts as follows:

- Developing environment: It is the place where coding is done with the help of inbuilt function. It provides a set of tool which helps in using the functions efficiently. Developing environment includes editor window, command window, debugger, workspace, browser for online help.

- Function library: MATLAB contains a huge collection of algorithms which helps in performing simple tasks (sum, cosine of a function, sine of a function and many more) to typical tasks like inverse of a matrix, FFT etc.

- Language: it is high level language supports control flow statements, input output, data structure programming, object oriented programming. It helps to program large and complex programs.

- Graphics: it creates graphs using simple plot statement which further helps in comparison with other graphs to find the improvement.

Table 4.1 Graphics options

Color options	Line option	Markers
y: yellow	- solid	+
m: magenta	- - dash	o

c: cyan	: dotted	*
r: red	-. dash-dot	x
g: green		.
b: blue		^
w:white		s
k: black		d

Command: plot(x1, '-r', x2, '-go');

- API: API allows the programmer to write programs in C and FORTRAN to interact with MATLAB.

Code file is saved with extension of ".m" and workspace which contains the results of the algorithm is saved with the extension of ".mat". Workspace has the facility to draw the graph manually by firstly selecting the type of the graph then select the x coordinate and y coordinate and launch the graph.

4.2 Why to choose MATLAB

During the study of LEACH protocol, it has been noticed that after 2009 most of the researchers found MATLAB a suitable platform for simulation of algorithm, because of its simplicity and power of computation and the power of visualization. It is found so simple to compare two algorithms without interfering with each other. It helps to simulate the algorithm without interference of the simulating environment.

4.3 Existing algorithms used in thesis

4.3.1 Basic LEACH

Basic LEACH follows two main steps during whole transmission process. These steps are as follows:

- **Setup phase:** In this phase network is divided into cluster and election of cluster head is held. After election is over there is cluster head in each cluster of the network. CH is selected to reduce the overhead of direct communication with base station. CH does this job on behalf of other nodes of the cluster. And then CH creates a TDMA schedule and based on that schedule nodes transmit the information in the next phase. TDMA schedule is broadcast among nodes of cluster.
- **Steady phase:** In this phase nods follows the TDMA schedule and transmit the data to CH. After transmission is over CH aggregates the data and send it to base station at the end of the round.

After transmission the next round starts and again most suited node is elected as CH and the process continues till all nodes become dead.

4.3.2 Balanced LEACH

In balanced LEACH, during setup phase selection of CH is based on the residual energy of the nodes. If the number of CH in the network is less than n*p then a timer is created and at this time interval a advertisement for CH is send among the nodes of the cluster but if the timer expires then change to CH and again broadcast for CH advertisement. If the number of CH is not less than n*p then sorting of CH is done based on the residual energy and the CHs which have residual energy less than average energy must eliminate from the CHs list. And steady state phase is same as the basic LEACH have. After finishing of a round again the same procedure continues.

4.4 Proposed algorithm

In our proposed algorithm, proposer tries to overcome one of the major limitations of all varieties of LEACH. In traditional LEACH and balanced LEACH, cluster head is being changed after every round and if a node becomes cluster head for a round then it can never

be CH for (1/f) rounds. After selection of CH for each round whole process of cluster head creation being enacted. So it has been tried to improve the selection of cluster head and add a scheme that improves the power consumption of a network.

Setup phase

- A cluster head is selected for the very first round and sends the advertisement (ADV) to the all the non CH nodes.
- Nodes which are closer to CH join the cluster and send the acknowledgement (ACK). But the nodes which show weak signal strength from CH waits for another ADV of different cluster.
- When first round is completes and second round starts then we check the energy level of CH of the last round. If the energy level is less than threshold then new CH is selected for that round otherwise same CH is taken for next round.
- After that CH creates a TDMA schedule for each non CH node for data transmission. But if cluster head is same as that of previous round then same TDMA schedule is used as for the last round. After that setup phase finishes.

Steady state phase:

- Follow the TDMA schedule, and check if the communication between the nodes is inter-cluster or intra-cluster.
- If the communication between the nodes in intra-cluster then low power is provided to them because less energy needed to transmit a message inside same cluster. However, a large amount of energy is needed to transmit a message outside the cluster or to the base station.
- After that check the sensor value, if the sensor value is less than threshold then wait for other value otherwise transmission of message starts.

Different kind of energy is supplied to node as, if node is a cluster head then high power is supplied to it but if it becomes the normal node then low level power is supplied. This is the energy comparison between proposed LEACH, balanced LEACH and Traditional LEACH. LEACH and balanced LEACH requires same kind of energy for all type of communication. Comparison of all three algorithms is done in the next chapter.

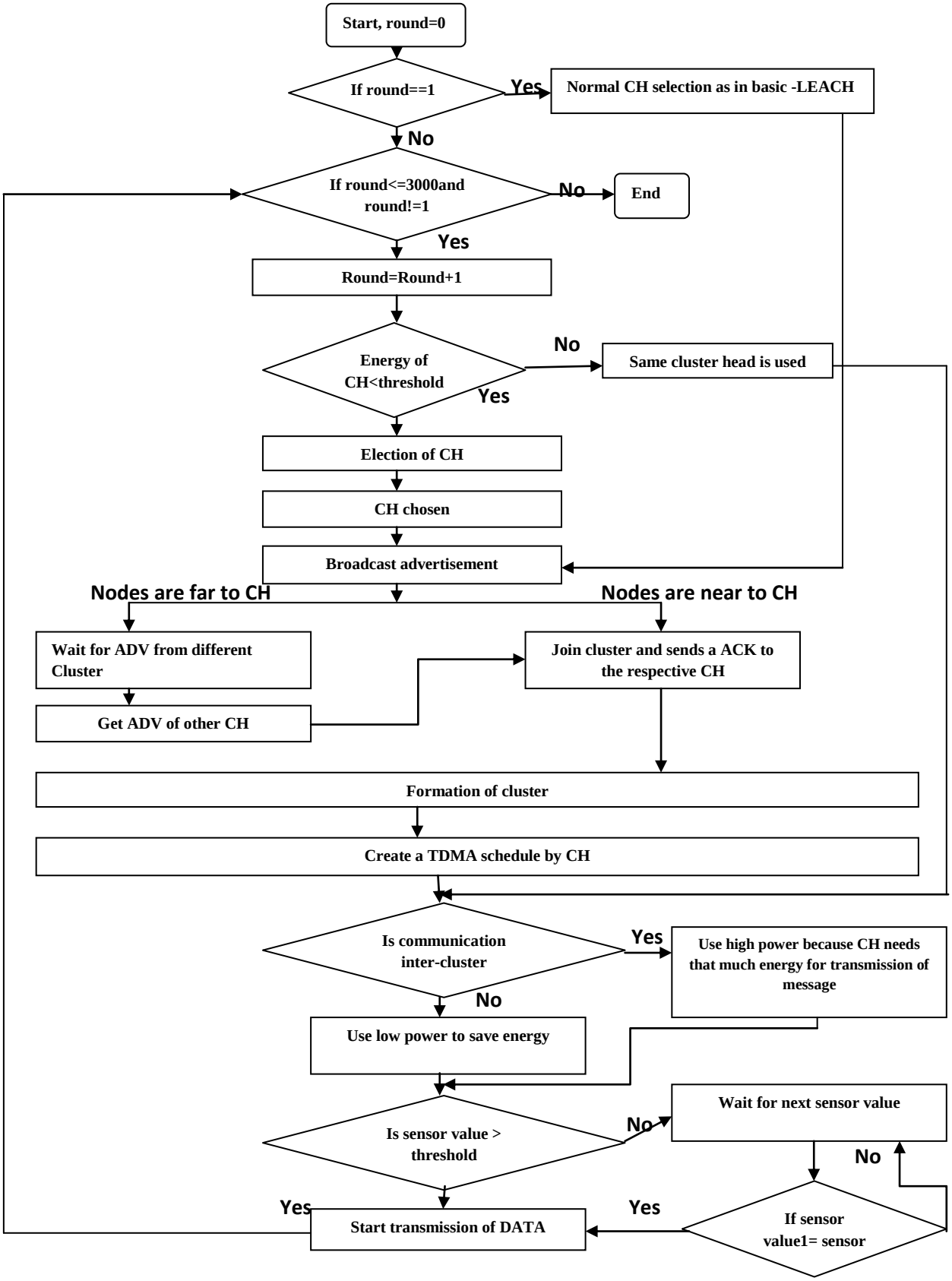

Figure 4.1 Flowchart of proposed algorithm

4.5 Inter-cluster communication in different probability using proposed algorithm

From the following table it is proved that communication between CH and base station increases as the factor of probability increases. Number of CH in the network increases then the communication with base station must increases. Since probability of choosing CH is directly proportional to sending packets to base station.

Table 4.2 Results of inter-cluster communications on different probability from 0.1 to 0.5

Probability ,p	**Number of packets to reach the base station for communication**
p=0.1	21146
p=0.2	72055
p=0.3	112009
p=0.4	140060
p=0.5	224869

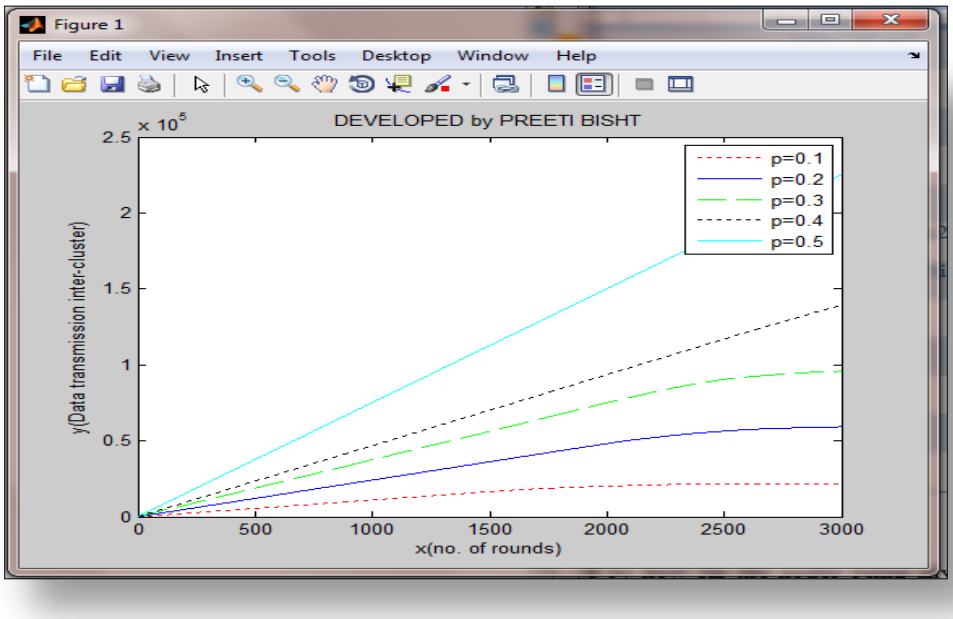

Figure 4.2 Graph showing inter-cluster communication variation on different probabilities.

4.6 Intra-cluster communication in different probability using proposed algorithm

From the following table it is noticed that on increasing the probability number of packets to reach the cluster head decreases. If the number of cluster head increases in the network then the nodes under the clusters get reduced and number of nodes doing communication with base station increases. Hence, the nodes having communication with cluster head decreases.

Table 4.3 Results of intra-cluster communications on different probability from 0.1 to 0.5

Probability, p	**Number of packets to reach the cluster head for communication**
p=0.1	108591
p=0.2	72873
p=0.3	60976
p=0.4	49168
p=0.5	23689

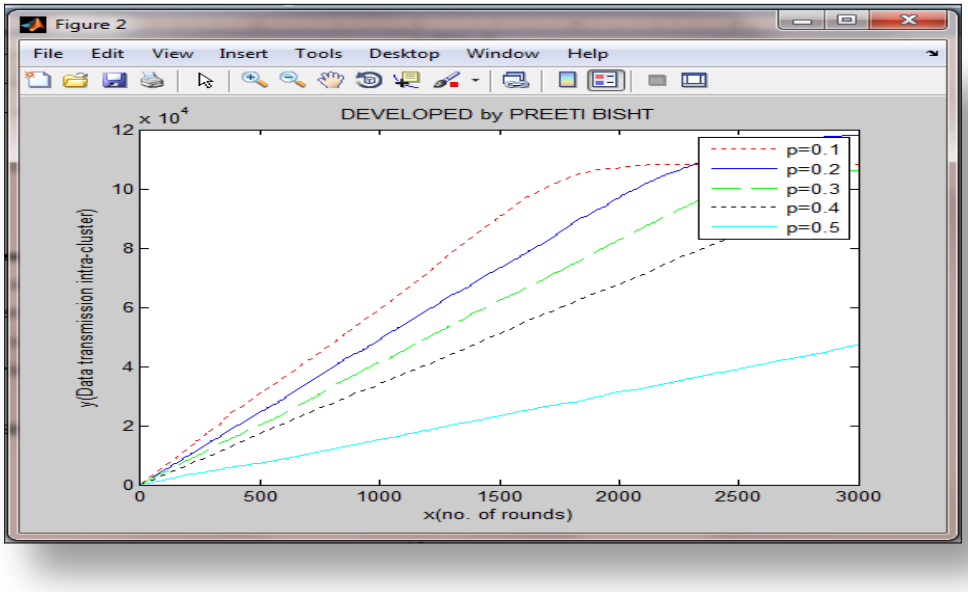

Figure 4.3 Graph showing inter-cluster communication variation on different probabilities.

CHAPTER 5: RESULTS AND DISCUSSION

After simulation of algorithm over MATLAB, results were taken based on some metrics like network lifetime, balance energy, count of CH and energy consumption and compare them with basic LEACH protocol and balanced LEACH. Results are discussed in following sections.

5.1 Parameters for simulation

Table 5.1 Simulation parameters

Parameters	**Value**
Network Size	100x100 m^2
Initial energy for each sensor node	0.5J
Packet size	1000 bits
Energy in idle state	50 nJ/bit
Aggregation energy	5 nJ/bit
Inter cluster Energy when $d>=d_o$	E_1=10pJ/bit/m^2
Inter cluster energy when $d<=d_o$	E_2=0.0013pJ/bit/m^2
Intra cluster energy when $d>=d_1$	$E_{11}=E_1/10$
Intra Cluster energy when $d<=d_1$	$E_{22}=E_2/10$
Location of BS	X=50; Y=50
Total number of nodes	100
Total number of rounds	3000

5.2 Network lifetime

A good lifetime of a protocol is judged by how far the nodes being alive. Figure 5.2 shows nodes for power-LEACH were alive till 2429 rounds and in LEACH node were alive till 1160 rounds and in case of balanced LEACH nodes were alive till 1418 rounds after that all nodes become dead. But the other side of the flip coin is that it can also be judged by number of dead nodes. If number of nodes start dyeing in early round then it

doesn't support good lifetime otherwise they do. Power-LEACH shows good performance because of improvement in CH selection. Figure 5.1 shows improvement in network lifetime based on dead node and power LEACH shows improvement over LEACH.

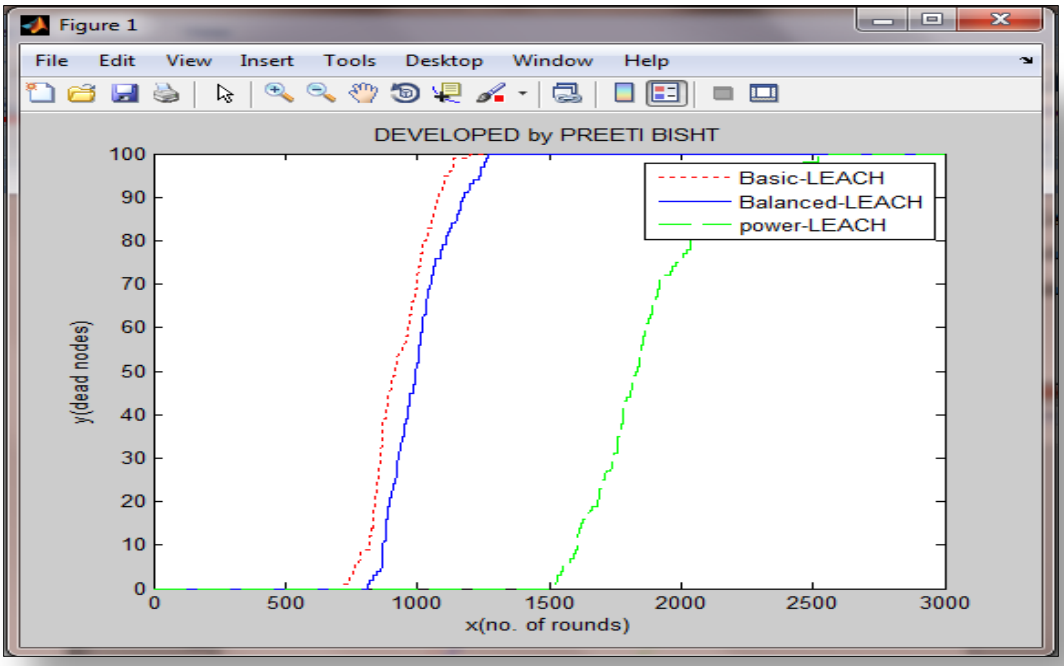

Figure 5.1 Number of Dead nodes vrs. Number of rounds

Table 5.2 First and last dead node in the network

Parameter	Basic LEACH	Balanced LEACH	Power LEACH
First node dead at round	731	799	1513
Last node dead at	1160	1418	2429

Improvement of power LEACH over basic LEACH for the first dead node is calculated as:

$$\text{Improvement \%} = \frac{1513-731}{1513}\times 100 = 51.95\%$$

Improvement of Power LEACH over balanced LEACH for first dead node is calculated as:

Improvement %= $\frac{1513-799}{1513} \times 100 = 47.19\%$

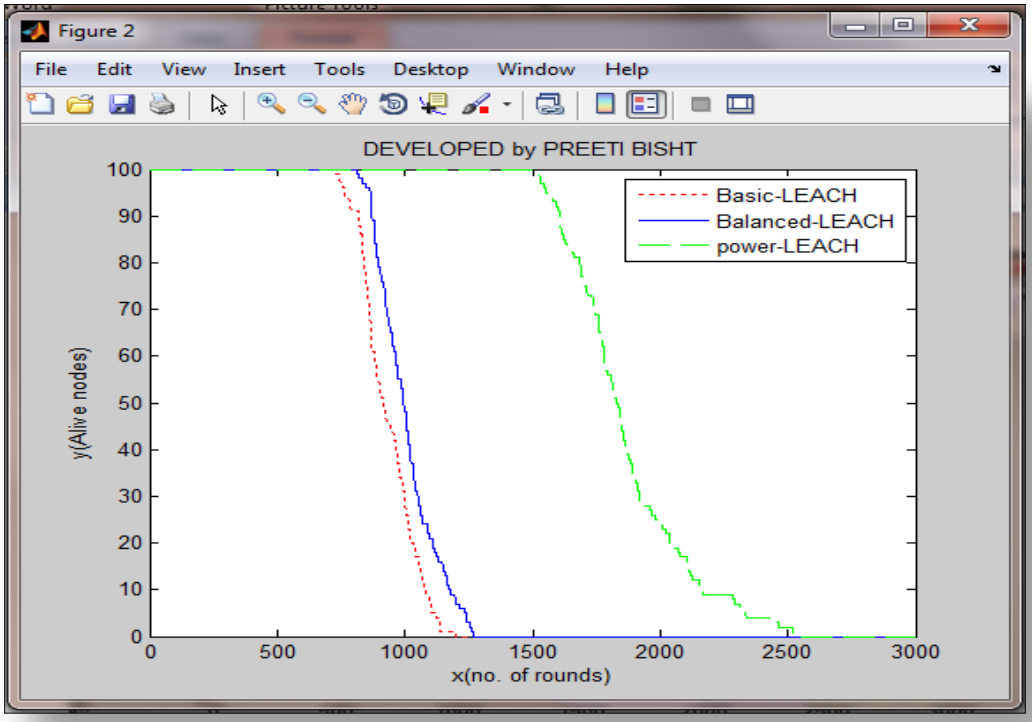

Figure 5.2 Number of Alive nodes vrs. Number of rounds

Table 5.3 First and last alive node in the network

Parameter	Basic LEACH	Balanced LEACH	Power LEACH
First node alive at round	0	0	0
Last node alive at	1160	1418	2429

This shows improvement of power LEACH over basic LEACH as 51.95% and over balanced LEACH is calculated as 47.19% when calculation is based on the last alive node.

5.3 Energy Consumption

If energy consumption of a protocol is high then this shows usage of high energy which cause early death of whole network. In figure 5.3, LEACH shows high energy consumption than power-LEACH, and from balanced LEACH. Consumption is high because of selection of CH for every round whether it is needed or not. The idea is if energy of CH >threshold energy then there is no need of choosing the cluster head. Hence it reduces the energy consuption of the proposed algorithm.

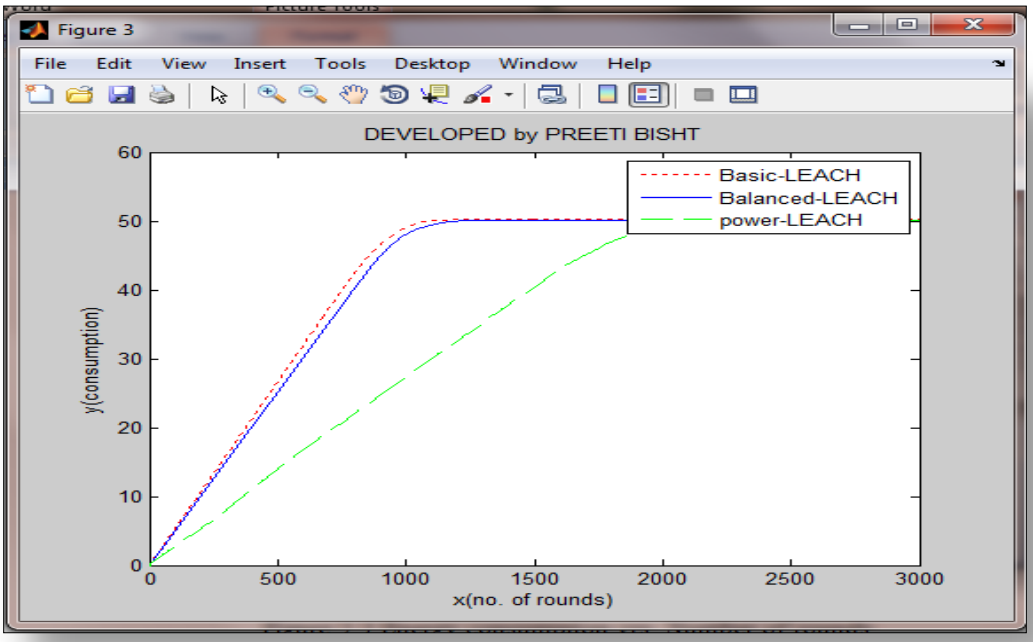

Figure 5.3 Energy consumption vrs. Number of rounds

Table 5.4 Maximum Energy Consumption

Parameter	Basic LEACH	Balanced LEACH	Power LEACH
Maximum consumption of energy is	50	45	40

Improvement of power LEACH over basic LEACH is

$$\text{Improvement \%} = \frac{50-40}{50} \times 100 = 20\%$$

Improvement of power LEACH over balanced LEACH is:

$$\text{Improvement \%} = \frac{50-45}{50} \times 100 = 10\%$$

5.4 Number of Cluster head

Since selection cluster head for every round is not necessary. If the residual energy is much more than the threshold then same CH is selected for the next round but if energy is less than threshold then new cluster head is selected based on the election between the nodes. In the figure below the selection of CH is stable for some round in case of power LEACH.

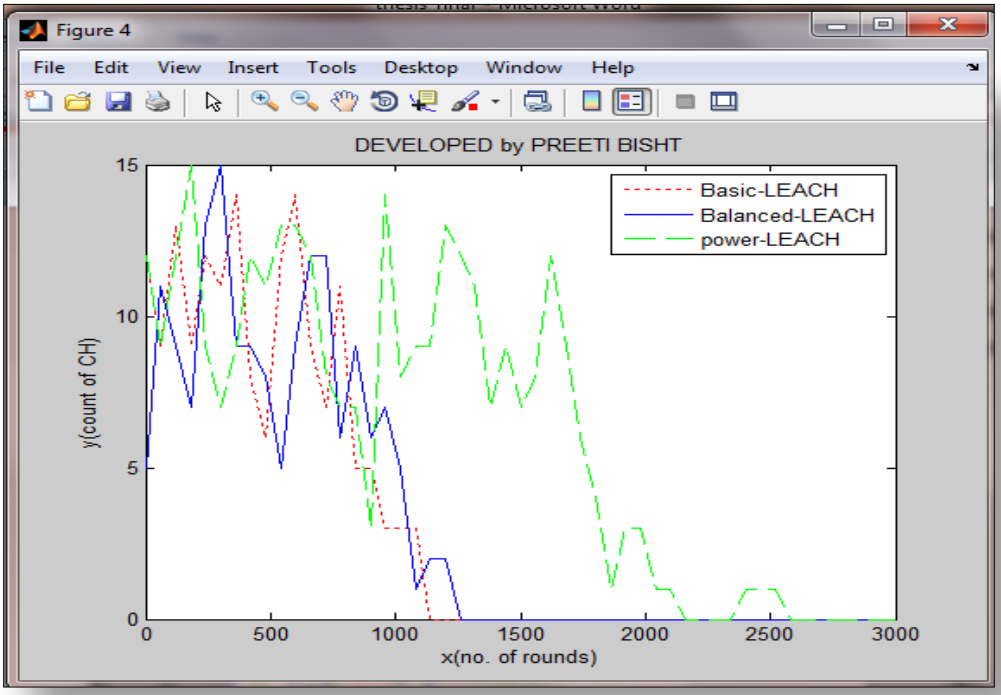

Figure 5.4 Number of CH selection vrs Rounds

5.5 Residual energy

Figure 5.5 shows energy exists for high number of rounds in power-LEACH and low for LEACH. As maximum number of nodes dies because most of the energy is dissipated for CH selection in basic LEACH and most of the nodes dies before1200 rounds. However in

power LEACH, CH is not selected for every round hence, energy is not wasted during CH selection and the energy remains exists for more than 2000 rounds which shows a vast improvement of 47.82% over basic LEACH and 39.83% over power LEACH.

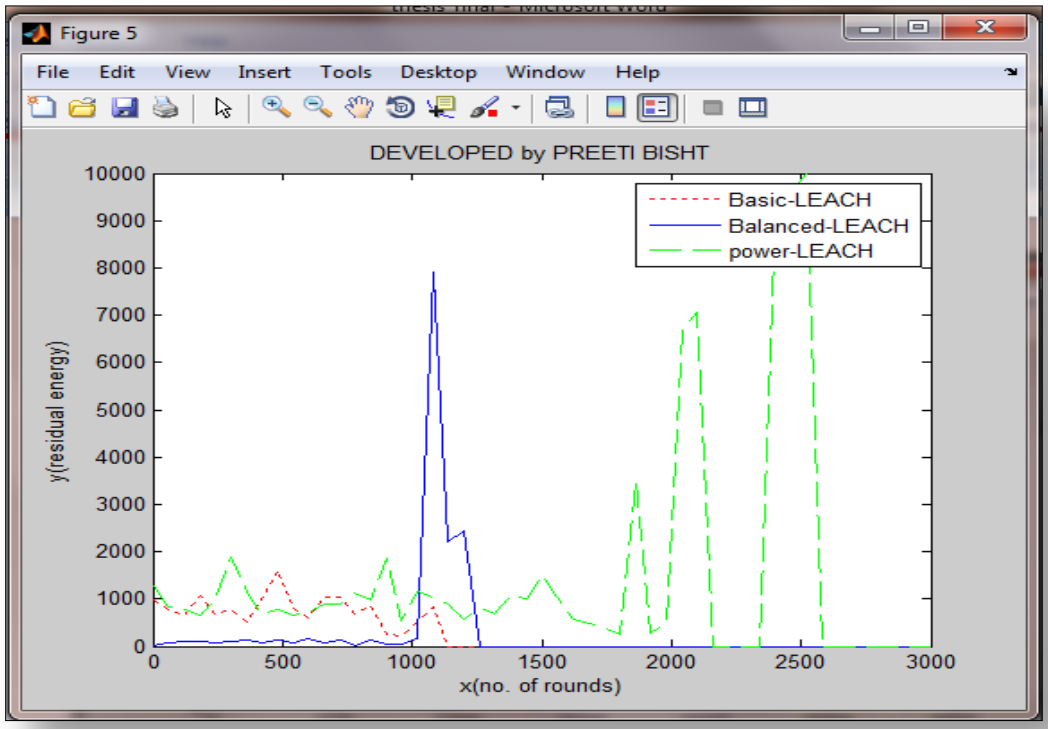

Figure 5.5 Balance energy vrs. Number of rounds

Table 5.5 Energy remains in the network

Parameters	Power LEACH	Basic LEACH	Balanced LEACH
Energy is high till round	2300	1200	1400

Improvement in residual energy of power LEACH over basic LEACH

$$\text{Improvement \%} = \frac{2300-1200}{2300} \times 100 = 47.82\%$$

Improvement in residual energy of power LEACH over balanced LEACH

$$\text{Improvement \%} = \frac{2300-1400}{2300} \times 100 = 39.13\%$$

5.6 Data transmission inter-cluster and intra-cluster

When the transmission of data is inside the same cluster then this type of communication is said to be intra cluster but when transmission is between two clusters and with the base station then this type of communication is known as inter cluster. Data transmission show how much packet transfer from cluster head to base station or between cluster head and non cluster head node. If transmission rate is high that means data easily reached to base station. Modification in basic LEACH forms power LEACH, however this modification almost doubles the transmission rate of basic LEACH and shows improvement of 50% but in case of balance LEACH the improvement is not done because transmission become less when CH selection is not done for some rounds Figure 5.6 and 5.7 shows the same.

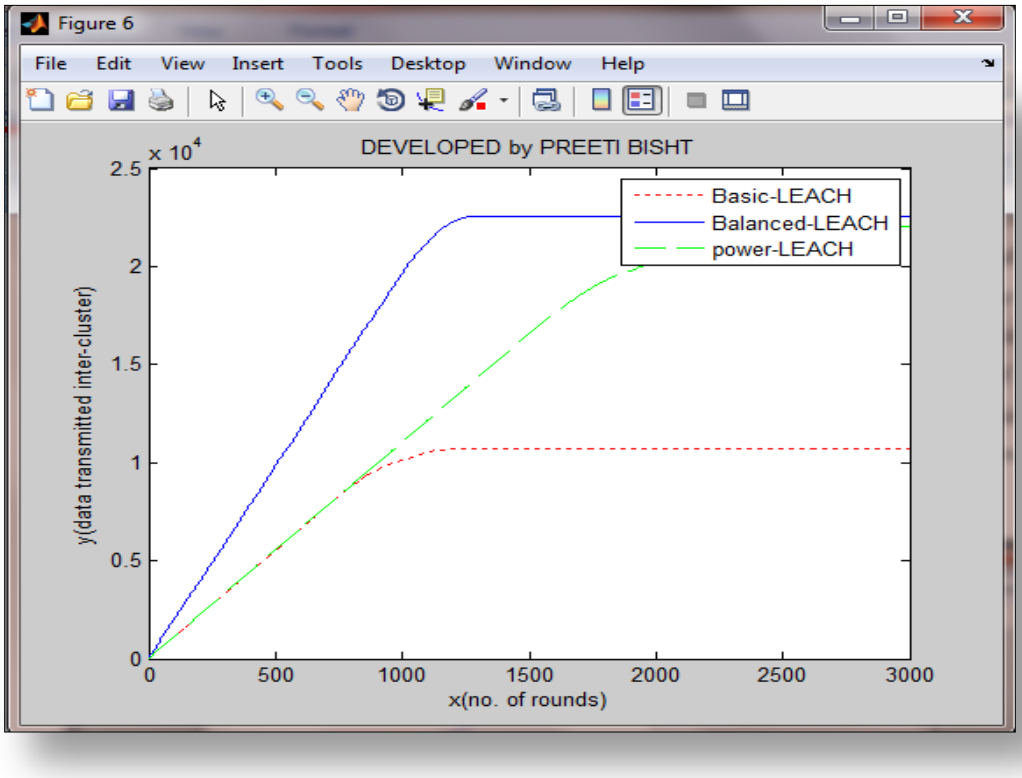

Figure 5.6 Inter-cluster data transmission vrs. Number of rounds

Table 5.6 Inter-cluster data transmission

Data transmission inter cluster	Basic LEACH	Balance LEACH	Power LEACH
Maximum transmission is	10637	26091	21860

Improvement on data transmission of power LEACH over basic LEACH

$$\text{Improvement \%} = \frac{21860 - 10637}{21860} \times 100 = 51.34\%$$

And power-LEACH shows no improvement over Balance LEACH.

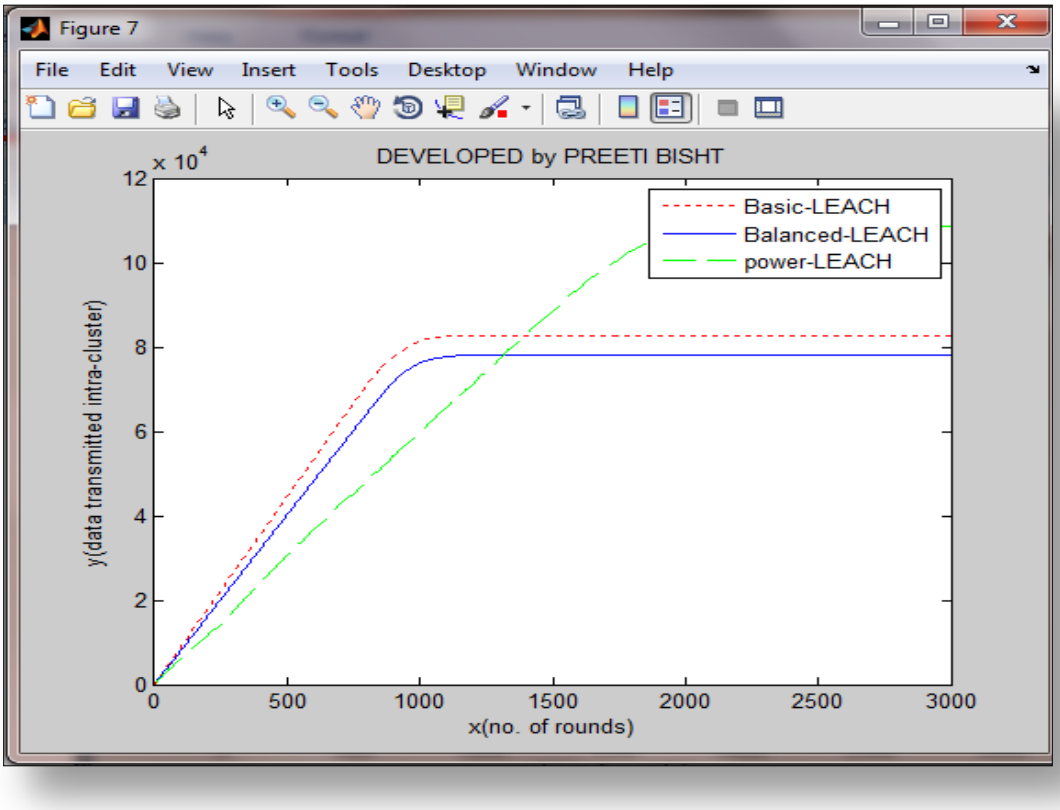

Figure 5.7 Intra-cluster communication vrs. Number of rounds

Table 5.7 Intra-cluster data transmission

Data transmission intra cluster	Basic LEACH	Balance LEACH	Power LEACH
Maximum transmission is	82407	76517	108601

Improvement on data transmission intra cluster in power LEACH over basic LEACH:

$$\text{Improvement\%} = \frac{1086517 - 82407}{1086517} \times 100 = 92.4\%$$

Improvement on data transmission intra cluster in power LEACH over balance LEACH:

$$\text{Improvement \%} = \frac{1086517 - 76517}{1086517} \times 100 = 92.5\%$$

CHAPTER 6: CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

Demand of energy efficient protocols are always in for wireless sensor networks. A set of energy efficient protocols (LEACH and its variety) has been studied and find gaps among them. After finding gaps an algorithm has been proposed which is named as power-LEACH. The improvement is due to finding a common gap i.e. selection of CH in every round. During simulation of power LEACH with the existing two versions i.e. balanced LEACH and basic LEACH, power LEACH shows vast improvement over them. The network life is calculated by the number of rounds the nodes in the networks are alive. After simulation of power LEACH its shows an improvement of 51.95% and 47.19% over basic LEACH and balanced LEACH respectively. It is known that higher the energy consumption, worst the algorithm is. Power LEACH shows significant improvement of 20% and 10% over basic and balanced LEACH. For measuring an algorithm is good or not, researchers calculate the residual energy. If the amount of residual energy is high then lifetime of network is also high. About 47.82% and 39.13% of improvement is recorded over basic and balanced LEACH. 92.4% and 92.5% improvement is recorded for intra cluster communication in power LEACH over other two versions.

6.2 Future scope

The proposed algorithm shows quite good results over basic LEACH and balanced LEACH. But it still doesn't show any improvement during inter cluster data transmission when compared with balanced LEACH. It may be due to too many cluster division in network while running power LEACH over it. This can be improved by further modification in cluster head division algorithm. This can be done by setting a counter which decides the number of clusters in the network. If this small improvement is embedded in the proposed algorithm then it shows good results.

REFERENCES

[1] T.S. Andrew, W.J. David, *Introduction in Computer Networks*, 5th ed. Netherlands, WA:Pearson, 2011,ch. 1,sec.1, pp. 2.

[2] https://www.google.co.in/search?hl=en&site=imghp&tbm=isch&source=hp&biw=1517&bih=741&q=wireless+network&oq=wireless+network&gs_l=img.12..0l10.2961.9682.0.11443.16.8.0.8.8.0.316.1227.2j3j2j1.8.0...0.0.0..1ac.1.15.img.cQ6Pjghnm9k *accessed on 25/4/2014.*

[3] www.ent.mrt.ac.lk/dialog/documents/ERU-2-wsn accessed on 5/3/2014.

[4] http://www.springerreference.com/docs/html/chapterdbid/63462.html accessed on 20/4/2014**.**

[5] https://www.google.co.in/search?q=wireless+sensor+network&espv=210&es_sm=93&source=lnms&tbm=isch&sa=X&ei=772RUvmJIoWErAej34GIDg&ved=0CAkQ_AUoAQ&biw=1366&bih=666#facrc=_&imgdii=_&imgrc=LpC4gF8lsu962M%3A%3BvPDMkSEsGfZJuM%3Bhttp%253A%252F%252Fwww.ece.vt.edu%252Fnews%252Ffall05%252Fimages%252Fwirelessnetwork.jpg%3Bhttp%253A%252F%252Fwww.ece.vt.edu%252Fnews%252Ffall05%252Fsensornetwork.html%3B430%3B198 *accessed on 17/4/2014.*

[6] http://www.techopedia.com/definition/25651/wireless-sensor-network-wsn accessed on 30/4/2014.

[7] T. Arampatzis, J. Lygeros, S. Manesis, "A Survey of Applications of Wireless Sensors and Wireless Sensor Networks," *Proceedings of the 13th Mediterranean Conference on Control and Automation, IEEE*, pp. 719-724, 2005.

[8] N. Xu, *A Survey of Sensor Network Applications*, http://courses.cs.tamu.edu/rabi/cpsc617/resources/sensor%20nw-survey.pdf accessed on 30/4/2014.

[9] J. Stankovic, "Research Challenges for Wireless Sensor Networks," *University of Virginia*, 2005.

[10] P. Kumar, M.P. Singh, "A Review of Protocols In Wireless Sensor Network," *International Journal of Engineering Research & Technology*, vol. 1, no. 4, pp. 1-13, 2012.

[11] J.A. Al-Karaki, A.E. Kamal, “Routing Techniques in Wireless Sensor Networks: A Survey*,” *ICUBE initiative of Iowa State University, Ames, IA 50011*, 2002.

[12] W. Heinzelman, A. Chandrakasan, H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," *Proc. of 33rd Hawaii International Conference on System Sciences*, 2000.

[13] J. Zheng, A. Jamalipour, “Wireless sensor Network: a networking perspective,” *WILEY publication*, ch.4, sec 4.3.1, pp.73-77**.**

[14] M.S. Ali, et al., “ALEACH:Advanced LEACH Routing Protocol for Wireless Microsensor Networks,” *5th International Conference on Electrical and Computer Engineering*, 2008.

[15] M.O. Farooq, et al., “MR-LEACH: Multi-hop Routing with Low Energy Adaptive Clustering Hierarchy,” *4th International Conference on Sensor Technologies and Application*, 2010.

[16] M. Tong, M. Tang, “LEACH-B: An Improved LEACH Protocol for Wireless Sensor Network,” *6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM),IEEE*, 2010.

[17] J. Wan, D. Yuan, “A Review of Routing Protocols in Wireless Sensor Networks,” *IEEE*, 2008.

[18] G. Yi, S. Guiling, et al., “Recluster-LEACH: A Recluster Control Algorithm based on Density for Wireless Sensor Network,” *2nd International Conference on Power Electronics and Intelligent Transportation system, IEEE,* 2009.

[19] G. Sikander, M.H. Zafar, et al., “Comparison of clustering routing protocols for Wireless Sensor Network,” *Proc. of the IEEE International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA)*, 2013.

[20] A. Norouzi, A.H. Zaim, “An Intergrative Comparison of Energy Efficient Routing Protocols in Wireless Sensor Network,” *Scientific sciences*, vol. 4, pp. 65-75, 2012.

[21] F. Xiangning, S. Yulin, “Improvement on LEACH protocol of Wireless Sensor Network,” *International conference on sensor technologies and application, IEEE,* 2009.

[22] N. Rathi, J. Saraswat, P.P. Bhattacharya, "A REVIEW ON ROUTING PROTOCOLS FOR APPLICATION IN WIRELESS SENSOR NETWORKS," *International Journal of Distributed and Parallel Systems (IJDPS)*, vol. 3, no. 5, pp. 39-58, 2012.

[23] W. Wang, Y. Peng, "LEACH algorithm based on Load balancing," *TELKOMNIKA*, vol. 11, no. 9, Sept., 2013.

[24] V. Loscri, G. Morabito, S. Marano, "Two-Levels A. Hierarchy for low-energy adaptive clustering hierarchy(TL-LEACH)," *IEEE*, pp. 1809–13, 2005.

[25] S. Tyagi, N. Kumar, "A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks," *Journal of Network and Computer Applications, Elsevier*, pp. 623-645, 2013.

[26] M.B. Yassein, A. Al-Zou'bi, W. Mardini, "Improvement of LEACH protocol of Wireless Sensor Network (VLEACH)," *International Journal Of Digital Content Technology and its Application*, vol. 3, no. 2, 2009.

[27] S. Kumar, V. Paul, et al., "Mobility Metric based LEACH-Mobile Protocol," *IEEE*, pp. 248-253, 2008.

[28] Z. PENG, X. LI, "The Improvement and Simulation of LEACH Protocol for WSNs," *IEEE*, pp. 500-3, 2010.

[29] Y. Zhao, C. Jiang, "Research about improvement of LEACH protocol," *ICISE*, 2010.

[30] M. Aslam, N. Javaid, A. Rahim, et al., "Survey of Extended LEACH-Based Clustering Routing Protocols for Wireless Sensor Networks," *Networking and Internet Architecture :5th AHPCN in conjunction with 14th HPCC-2012*, 2012.

[31] X. Li, L. Xu, et al., "A Differential Evolution-Based Routing Algorithm for Environmental Monitoring Wireless Sensor Networks," *Sensors*, 2010.

[32] V. Torkzaban, S. Rahmani, M. Dehghan, "An ID-based routing protocol for WSN," *IEEE*, 2009.

[33] Y. Guo, Y. Liu, et al., "Study on the energy efficiency based on improved leach in wireless sensor networks," *Second international Asia conference on informatics in control. Automation and Robotics(CAR-2010), IEEE*,2010.

[34] H. Al-Refai, A. Al-Awneh, K. Batiha, A. Abu, Y. Rahman, "Efficient routing LEACH(ER-LEACH) enhanced on LEACH protocol in wireless sensor networks", International Journal of Academic Research 3(3):42–8, 2011.

[35] H. Junping, J. Yuhui, et al., "A Time-based Cluster-Head Selection Algorithm for LEACH," *IEEE,* pp. 1172-6, 2008.

[36] K. G. Vijayvargiya, V. Shrivastava, "An Amend Implementation on LEACH protocol based on Energy Hierarchy," *International Journal of Current Engineering and Technology,* vol. 2, no. 4, pp. 427-431, 2012.

[37] H. Abdul, L. Kamel, "W-LEACH: Weighted Low Energy Adaptive Clustering Hierarchy Aggregation Algorithm for Data Streams in Wireless Sensor Networks," *IEEE International conference on Data Mining Workshops*, pp.1-8, 2010.

[38] W. Wang, Q. Wang, et al., "LEACH-H:An Improved Routing Protocol for Collaborative Sensing Network," *IEEE,* 2009.

[39] J. Islam, M. Islam, N. Islam, "A-sLEACH: An Advanced Solar Aware Leach Protocol for Energy Efficient Routing in Wireless Routing in Wireless Sensor Networks," *Proc. Of Sixth International Conference on Networking, IEEE,* 2007.

[40] C. Tang, "Comprehensive energy efficient algorithm for WSN," *International journal of Computer science and Communication*, pp. 209-216, 2014.

[41] R. Hou, W. Ren, Y. Zhang, "A wireless sensor network clustering algorithm based on energy and distance," *Second international workshop on computer science and engineering,(WCSE2009),IEEE*, pp. 439-42,2009.

[42] L. Villalba, A. Orozco, et al., "Routing Protocols in Wireless Sensor Networks," *sensors*, pp. 8399-8420, 2009.

[43] V. Muthulakshmi, "Advanced LEACH Protocol in Large Scale Wireless Sensor Networks," *International Journal of Engineering Sciences and Research Technology,* vol. 2 no. 5, pp. 1324-1329, 2013.

[44] A. Manjeshwar, D. P. Agarwal, "TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks*," *15th International Parallel and Distributed Processing Symposium. IPDPS*, pp. 2009-2015, 2001.

[45] A. Joshi, L. Priyam, "A Survey of Hierarchical Routing Protocols in Wireless Sensor Network," *MES Journal of Technology and Management*, pp. 67-71, 2005.

[46] S. Lindsey, C.S. Raghavendra, "PEGASIS: Power-Efficient Gathering in Sensor Information Systems," *Aerospace Conference Proceedings, IEEE,* 2002.

[47] Z. Rehena, K. Kumar, S. Roy, et al., "SPIN Implementation in TinyOS Environment using nesC," *Second International conference on Computing, Communication and Networking Technologies, IEEE,* 2010.

[48] J. Kulik, W. Heinzelman, H.Balakrishanan, "Negotiation-Based Protocols for Disseminating Information in Wireless Sensor Networks," *Wireless Networks,* vol. 8, pp. 169–185, 2002.

[49] T. He, J. Stankovic, C. Lu, et al., "SPEED: A Stateless Protocol for Real-Time Communication in Sensor Networks," *23rd International Conference on Distributed Computing Systems,* pp. 46-55, 2003.

[50] Y. Yu, R. Govindan, D. Estrin, "Geographical and Energy Aware Routing: a recursive data dissemination protocol for wireless sensor networks," *Technical Report: UCLA Computer Science Department,* 2001.

[51] C. Intanagonwiwat, R. Govindan, et al., "Directed Diffusion for Wireless Sensor Networking," *In Proceedings of the Sixth Annual International Conference on Mobile Computing and Networking (MobiCOM '00),* 2000.

[52] S. Yi, P. Naldurg, R. Kravets, "A Security-Aware Routing Protocol for Wireless Ad Hoc Networks," *MobiHoc '01 Proceedings of the 2nd ACM international symposium on Mobile ad hoc networking & computing*, pp. 299-302, 2001.

[53] D. Braginsky, D. Estrin, "Rumor Routing Algorithm For Sensor Networks," *WSNA '02 Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications*, pp. 22-31, 2002.

[54] R. V. Dukkipati, *MATLAB: An Introduction with Applications*, 4th edition, New age international publisher, 2010.

LIST OF PUBLICATIONS

[1] P. Bisht, A.K. Verma, "Power-LEACH- A Cluster-Based Routing Protocol for Wireless Sensor Network", accepted in *2nd International Conference on Emerging Research in Computing, Information, Communication and Application-ERCICA2014*, Bangalore, 2014 (Sponsored by Elsevier).

[2] P. Bisht, A.K. Verma, "Analysis and Simulation of TinyOS Application using AVRORA and TOSSIM", accepted in *International Multitrack Conference on Sciences, Engineering and Technical Innovation, IMTC-2014*, Jalandhar, 2014 (In association with DST, New Delhi).

[3] P. Bisht, A.K. Verma, "Descriptive Study of LEACH and its Variants" communicated in *First International Conference on Networks and Software Computing 2014*, IEEE, Hyderabad, 2014.

[4] P. Bisht, A.K. Verma, "A Comprehensive Study of Homogeneous Routing Protocols of Wireless Sensor Network" communicated in *Information Resource Management Journal (IGI Global)*, USA, 2014.