

ANALYSIS OF LEACH PROTOCOL FOR LIFETIME OPTIMIZATION OF WIRELESS SENSOR NETWORK

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DECLARATION

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ABSTRACT

Analysis of LEACH Protocol for Lifetime Optimization of Wireless Sensor Network

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A Wireless Sensor Network (WSN) is an emerging field comprised of sensor nodes with limited resources like power, memory etc. It is used to monitor the remote areas where recharging or replacing the battery power of sensor nodes is not possible. So, energy is a most challenging issue in case of WSN. Low-Energy Adaptive Clustering Hierarchy (LEACH) is most significant protocol which consumes less amount of energy while routing the data to the base station (BS). All descendants protocols of LEACH have been discussed in Literature review chapter. Each descendants of LEACH has its merits and demerits which needs improvement. In this research work RCH-LEACH protocol (LEACH protocol using Relay Cluster Head Node) has been proposed using a relay cluster head node (RCH node) in each cluster. RCH-LEACH protocol has been simulated on MATLAB with fixed location of base station and with fixed percentage of cluster heads in the network. Results of RCH-LEACH has been analyzed using parameters like Energy Consumption per Round, Round when First Node Dies (FND), Round when half of Nodes Die (HND), Round when Last Node Dies (LND) and throughput. Analysis of results represent that FND, HND, LND and Throughput of RCH-LEACH are higher and Energy consumption per Round is lower than that of LEACH protocol. So, it can be concluded that RCH-LEACH outperforms LEACH protocol. This RCH model used in RCH-LEACH protocol can be further extended and implemented on other descendant protocols of LEACH to improve them as a part of future work.

Prashant Maurya

Er. Amanpreet Kaur

*I would like to dedicate this thesis to
my beloved parents, sisters and
almighty God.*

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“The successful completion of any task would be incomplete without accomplishing the people who made it all possible and whose constant guidance and encouragement secured us the success.”

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LIST OF ABBREVIATIONS

| Sr. No. | Full Form | Abbreviation |
|---------|--|--------------|
| 1. | Advanced- LEACH | Ad- LEACH |
| 2. | Base Station | BS |
| 3. | Carrier Sense Multiple Access with Collision Avoidance | CSMA/CA |
| 4. | Centralized LEACH | LEACH-C |
| 5. | Cluster Head | CH |
| 6. | Decentralized Energy-efficient Spare Selection Technique | DESST |
| 7. | Distributed Energy-Efficient Clustering | DEEC |
| 8. | Efficient-Routing Leach | ER-LEACH |
| 9. | Energy Efficient Routing | EER |
| 10. | Energy and Load-balanced LEACH | EL-LEACH |
| 11. | Energy Balanced Clustering | EBC |
| 12. | Energy Efficient Best Path Routing | EBRP |
| 13. | Energy Efficient Clustering Algorithm for Event Driven | EECED |
| 14. | Energy Efficient clustering scheme | EECS |
| 15. | Energy Efficient LEACH Protocol | EELP |
| 16. | Energy Efficient Protocol with Static Clustering | EEPSC |
| 17. | Energy Efficient Redundant Routing Tree | EE-RRT |
| 18. | Energy Efficient Weight Clustering | EWC |
| 19. | Energy LEACH | LEACH-E |
| 20. | Energy Potential LEACH | EP-LEACH |

| | | |
|-----|--|------------|
| 21. | Energy-Efficient Cluster Head Selection | NECHS |
| 22. | Far Zone LEACH | FZ-LEACH |
| 23. | First Node Dies | FND |
| 24. | Genetic Algorithm based LEACH | LEACH-GA |
| 25. | Global Positioning System | GPS |
| 26. | Half of Nodes Die | HND |
| 27. | Hierarchical Adaptive Balanced energy-efficient Routing Protocol | HABRP |
| 28. | Identity | ID |
| 29. | Improved-LEACH | I-LEACH |
| 30. | Last Node Dies | LND |
| 31. | LEACH using K-Medoids clustering algorithm | K-LEACH |
| 32. | LEACH using Relay Cluster Head node | RCH-LEACH |
| 33. | LEACH with Distributed Diffusion | DD-LEACH |
| 34. | Localized Power Efficient Data Aggregation Tree Protocol | LPEDAP |
| 35. | Low Energy Adaptive Clustering Hierarchy | LEACH |
| 36. | Matrix Laboratory | MATLAB |
| 37. | Measurement Redundancy Aware LEACH | MR-LEACH |
| 38. | Medium Access Control | MAC |
| 39. | Minimum Spanning Tree | MST |
| 40. | Minimum Transmission Energy | MTE |
| 41. | Mobile Enhanced LEACH | LEACH-ME |
| 42. | Mobile LEACH | LEACH-M |
| 43. | Modified LEACH | MODLEACH |
| 44. | Modified LEACH with Hard Threshold value | MODLEACHHT |

| | | |
|-----|--|------------|
| 45. | Modified LEACH with Soft Threshold value | MODLEACHST |
| 46. | Multi-hop Routing with LEACH | MRLEACH |
| 47. | Normal/Cluster/Gateway Node | NCG Node |
| 48. | Quadrant-LEACH | Q-LEACH |
| 49. | Received Signal Strength Indication | RSSI |
| 50. | Request Message | REQ |
| 51. | Simple Node | SN |
| 52. | Time Division Multiple Access | TDMA |
| 53. | Two-Level LEACH | TL-LEACH |
| 54. | Vice-LEACH | V-LEACH |
| 55. | Wireless Sensor Network | WSN |

CHAPTER 1

INTRODUCTION

1.1 Introduction

A sensor network is an infrastructure that consists of mobile or static nodes which are able to communicate with each other for transferring data more efficiently and autonomously. Nodes used in Wireless Sensor Networks (WSNs) are affordable and multifunctional with the capability of detecting characteristics of various environmental and physical phenomena like temperature, pressure, humidity etc. WSNs can be used in various fields of potential applications including environmental monitoring e.g. air, soil, water, habitat, security etc., industrial diagnostics e.g. appliances, production lines etc. and critical infrastructure protection e.g. power grids, oil & gas distribution, water supply (Heinzelman, Chandrakasan & Balakrishnan, 2000).

The network gives an administrator the ability to instrument, observe and react to events in a specified environment. The main objective of WSN is to reliably detect and estimate event features from the collective information provided by sensor nodes (Estrin, Govindan, Heidemann, & Kumar, 1999). An infrastructure of a wireless sensor network is shown in Figure 1.1.

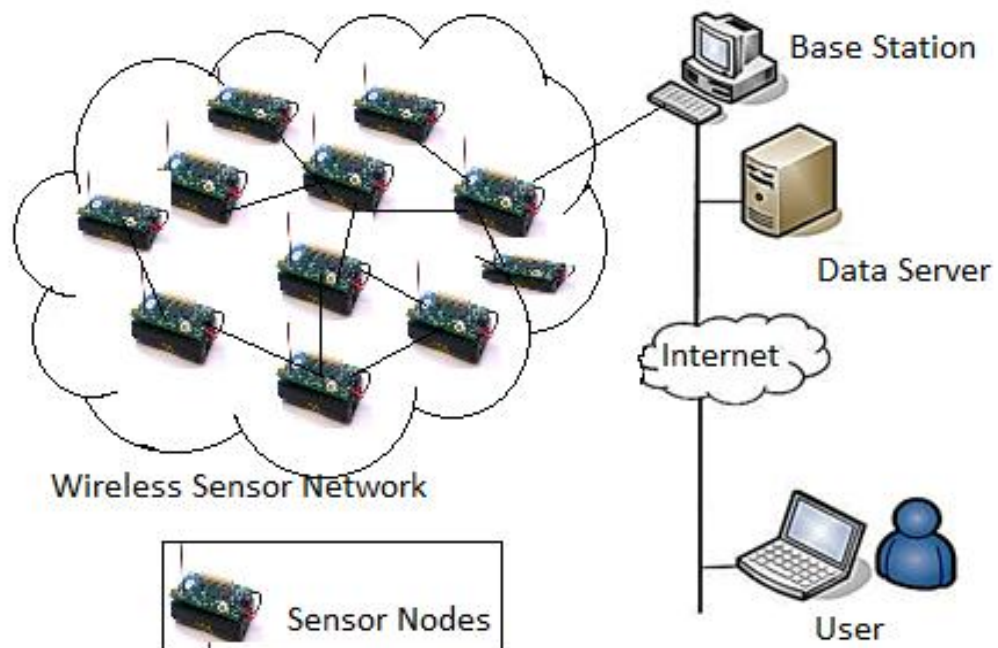


Figure 1.1: A wireless sensor network scenario

Various applications of Wireless Sensor Networks include Home Applications, Civil Applications, Environmental Applications, Industrial Applications, and Medical Applications.

1.1.1 Issue of Energy Efficiency in Wireless Sensor Network

Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery and have very low energy resources. This makes energy optimization more complicated in sensor networks because it involves not only reduction of energy consumption but also prolonging the life of the network as much as possible. This can be done by having energy awareness in every aspect of design and operation. This ensures that energy awareness is incorporated into groups of communicating sensor nodes of entire network and not only in the individual nodes (Heinzelman, Chandrakasan & Balakrishnan, 2000).

1.1.2 Introduction to Energy Efficient Routing

Energy saving is an important concern because limited energy source is the most challenging issue in sensor networks. Hence, it is desirable to develop energy-efficient processing techniques that minimize power requirements. The main goal of any Energy Efficient Routing (EER) protocol for WSN is to maximize network lifetime by minimizing energy consumption in end-to-end transmission. WSNs are largely application-specific which implies that routing protocols are also dependent on applications (Heinzelman, Chandrakasan & Balakrishnan, 2000).

1.1.3 Classification of Energy Efficient Routing Protocol

The protocols which minimize the amount of message passing for control and coordination are known as Energy-Efficient-Routing-Protocols (EER Protocol). Energy-Efficient Protocols in Wireless Sensor Network can be classified in many different categories according to different researchers. But here most popular classification of Energy Efficient Routing Protocols with their properties and examples are given in Table 1 (Akkaya & Younis, 2005).

Table 1: Classification of Energy Efficient Routing Protocol (Akkaya & Younis, 2005)

| Sr. No. | Classification of Protocols | Properties | Example |
|---------|--|---|---|
| 1 | Data Relaying Protocols | <ul style="list-style-type: none"> • Simple in nature • Easy to implement • Routing table not required • Topology information not required | <ul style="list-style-type: none"> • Gossiping • Flossiping • LGossiping |
| 2 | Data Centric Protocols | <ul style="list-style-type: none"> • Query driven model based routing techniques • Data aggregation | <ul style="list-style-type: none"> • SPIN |
| 3 | Hierarchical or Clustering-Based Protocols | <ul style="list-style-type: none"> • WSN is broken into some clusters • Every cluster has a cluster head that performs data aggregation or data fusion before forwarding to the sink | <ul style="list-style-type: none"> • LEACH • E-LEACH • M-LEACH • LEACH-C • PEGASIS • TEEN • APTEEN |
| 4 | Location-Based or Geographical Protocols | <ul style="list-style-type: none"> • Rely on the location information of the sensor nodes • Selects most energy efficient path between a source node and the sink • Use of GPS devices to locate position of nodes | <ul style="list-style-type: none"> • GAF • GEAR • LEAR |
| 5 | Mobility-Based Protocols | <ul style="list-style-type: none"> • Wider coverage • Restricted movement within a few meters • Network topology changes frequently | <ul style="list-style-type: none"> • EAGRP • LBDD |

| | | | |
|---|-------------------------|---|--|
| 6 | Heterogeneous Protocols | <ul style="list-style-type: none"> • Sensor nodes that have different hardware characteristics • Perform different tasks • Nodes have different initial energy | <ul style="list-style-type: none"> • LEACH-HPR • SEP |
|---|-------------------------|---|--|

Although, a lot of protocols/algorithms have been proposed to solve energy issue in wireless sensor networks but in this research work protocols under hierarchical or cluster based approach have been discussed. Most popular protocol under this category is LEACH Protocol.

1.2 Low Energy Adaptive Clustering Hierarchy Protocol

Low-Energy Adaptive Clustering Hierarchy (LEACH) is most significant hierarchical and cluster based protocol in wireless sensor network. The main objective of LEACH is to minimize the energy consumption in sensor networks (Heinzelman, Chandrakasan & Balakrishnan, 2000).

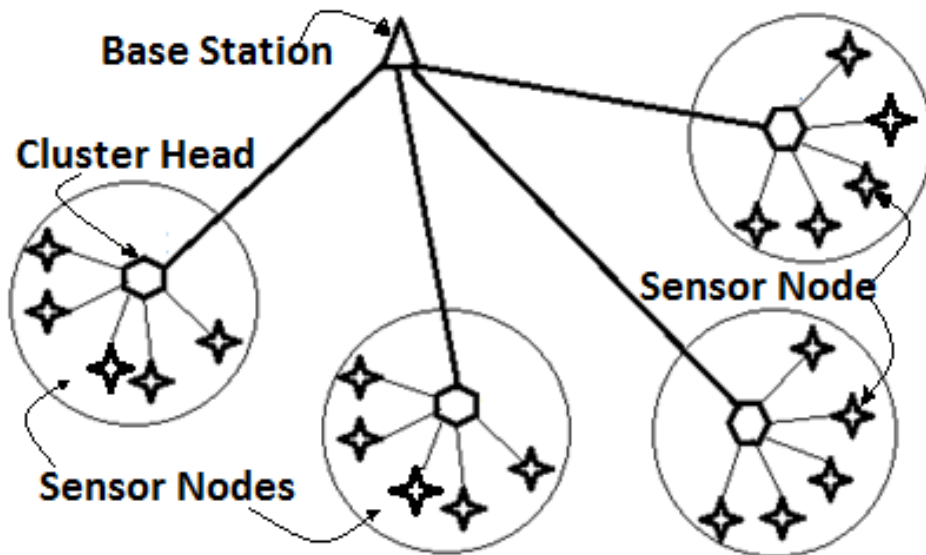


Figure 1.2: Architecture of LEACH Protocol

In LEACH Protocol nodes are randomly distributed in the field with capability of gathering and processing the data. LEACH protocol proceeds into several

rounds which are further divided into two phases as setup phase and steady state phase (Heinzelman, Chandrakasan & Balakrishnan, 2000).

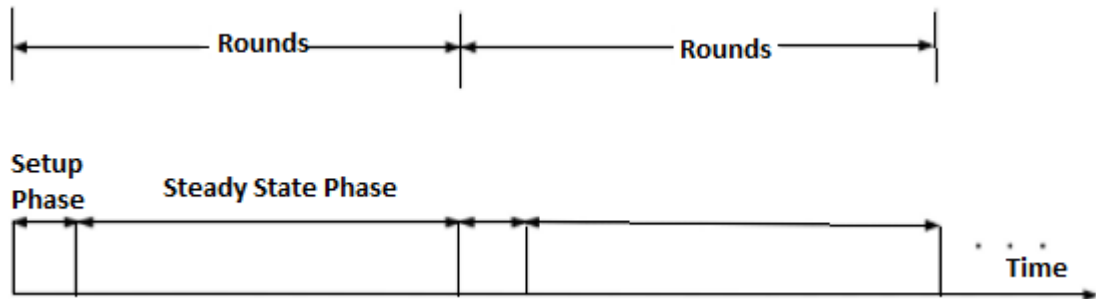


Figure 1.3: A round in LEACH Protocol (Heinzelman, Chandrakasan & Balakrishnan, 2000)

During the set-up phase, each sensor node chooses a random number between 0 and 1. If this random number is lower than the threshold for node n , then node becomes a cluster head node (CH). The threshold value $T(n)$ of node can be calculated using following formula (Heinzelman, Chandrakasan & Balakrishnan, 2000):

$$T(n) = \frac{p}{1 - p \left(r \bmod \left(\frac{1}{p} \right) \right)} \text{ if } n \in G \quad \dots (1)$$

Where $T(n)$ is the threshold value of node n and G is set of nodes which have not been CH in last $1/p$ rounds. When CH has selected successfully, it broadcasts an advertisement message to the other nodes. Based on the received signal strength of the advertisement, other nodes decide to which cluster it will join for this round and send a membership message to its CH. Now cluster formation completed (Heinzelman, Chandrakasan & Balakrishnan, 2000).

During the Steady State phase, normal nodes collect and send data to its corresponding CH. data transmission takes place based on the TDMA (Time Division Multiple Access) schedule and the cluster-heads perform data aggregation through local computation (Heinzelman, Chandrakasan & Balakrishnan, 2000).

1.2.1 Advantages of LEACH

Advantages of LEACH protocol are as follows:

- LEACH follows a completely distributed approach.
- It does not require any global information of network.
- It is a powerful and simple routing protocol.
- It uses random rotation of cluster head, which provides opportunity to each node to become a cluster head in a round.
- It uses TDMA so that each node can participate in rounds simultaneously.
- Each sensor node communicates only with its associated cluster head which provides localized co-ordination and control for cluster setup and operation.
- Only a cluster head node (CH) aggregates the data collected by the nodes to minimize the data redundancy.

1.2.2 Disadvantages of LEACH

Disadvantages of LEACH Protocol are as follows:

- In LEACH Protocol only cluster head (CH) is responsible for sending data to base station (BS) directly. So failure of CHs leads to lack of robustness.
- Single Hop Routing Technique is used in LEACH Protocol, which needs high energy for data transmission from CH to BS directly in case of large network.
- Selection of CH in any round is random and does not consider energy level of node, which can lead to drainage of a particular node.
- Dynamic clustering technique is used in LEACH which results in extra overhead like selection of CHs and advertisement.

1.3 Energy Model of Radio used in LEACH Protocol

Energy model provides information about energy consumption and energy dissipation with radio attached with transmitter, amplifier and receiver. In this research work each node have 0.5 joules initially and base station has unlimited energy. Energy dissipated by transmitter/receiver electronics are 50 nano-joules/bit. 100 pico-joules/bit/meter² energy is dissipated in amplification of signals

or by amplifier. In data aggregation i.e. $E_{DA}(k)$ is 5 nano-joules/bit energy is been dissipated and in free space in sensing the environment i.e. E_{Sense} is 0.01 pico-joules energy is dissipated by nodes (Heinzelman, Chandrakasan & Balakrishnan, 2000).

Energy dissipated by transmitter electronics in transmitting the k-bit data to distance d:

$$E_{TX}(k, d) = E_{TX-elec}(k) + E_{TX-amp}(k, d) \quad (2)$$

$$E_{TX-elec}(k) = E_{elec} * k \quad (3)$$

Where, k is the message size and d is the distance.

$E_{TX}(k, d)$ is energy consumed in transmission of amplified signals.

$E_{TX-elec}(k)$ is the energy consumed by transmitter.

E_{elec} is energy consumed in transmitting or receiving a single bit.

Energy dissipated in amplification of signals over distance d to transfer k-bit message

$$E_{TX-amp}(k, d) = \begin{cases} \varepsilon_{fs} * d^2 * k & \text{if } d < d_0 \\ \varepsilon_{fs} * d^4 * k & \text{if } d \geq d_0 \end{cases} \quad (4)$$

Where, $E_{TX-amp}(k, d)$ is energy consumed in amplifying the signals.

d_0 is cross-over distance.

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}} \quad (5)$$

Where, ε_{fs} is energy loss in free space.

ε_{amp} is energy loss in signal amplification.

Energy dissipated by receiver in receiving k-bit data

$$E_{RX}(k) = E_{RX-elec}(k) = E_{elec} * k \quad (6)$$

Where, $E_{RX-elec}$ is energy consumed by receiver.

$E_{RX}(k)$ is energy consumed in receiving the signals.

A non-CH node dissipates energy in sensing the environment and transmitting the sensed data to respective CH node.

$$E_{non-CH} = E_{Sense} + E_{TX}(k, d) \quad (7)$$

Energy dissipated by a CH E_{CH} node is total energy dissipated in sensing the environment, receiving the data from other non-CH nodes, data aggregation and data transmission to BS.

$$E_{CH} = E_{Sense} + E_{RX}(k) + E_{DA}(k) + E_{TX}(k, d) \quad (8)$$

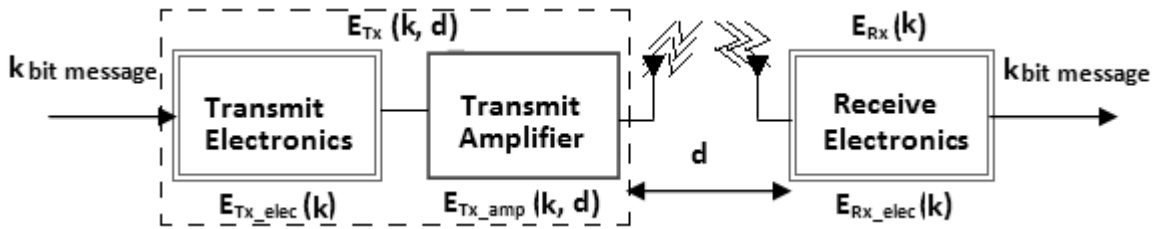


Figure 1.4: Energy Model (Heinzelman, Chandrakasan & Balakrishnan, 2000)

1.4 Problem Statement

Study of the literature indicates that all proposed protocols for improving LEACH focus on diminishing energy consumption by suggesting a better Cluster Head (CH) selection approach, cluster formation technique, better node deployment and better way to transfer collected data to Base Station (BS). Protocols which use centralized approach for enhancing cluster formation require node location by involvement of Global Positioning System (GPS) which makes it costly. Those protocols which select efficient CH, dissipate energy while choosing the energy efficient node. And those protocols which use multi-hop communication to transfer the data, drains energy of intermediate nodes. This research work is focused on modifying the communication between CH and BS by applying proposed model on LEACH Protocol.

1.5 Objectives

Objective of Energy Efficient Routing Protocols in Wireless Sensor Network is to reduce the energy-consumption. This research work is focused on achieving following objectives:

- To study and implement existing LEACH Protocol.

- To modify existing LEACH Protocol for optimizing Network Lifetime by changing communication technique between Cluster Heads and Base Station.
- To compare modified LEACH Protocol with existing LEACH Protocol.

CHAPTER 2

LITERATURE REVIEW

2.1 Review of Literature

The various protocols proposed under hierarchical classification to increase lifetime of sensor nodes are discussed below.

Heinzelman, Chandrakasan & Balakrishnan (2000) proposed LEACH which divides the whole Wireless Sensor Network (WSN) into some clusters each containing some sensor nodes and a cluster head (CH) which regulates channel access among the cluster members using Time Division Multiple Access (TDMA). The cluster members transmit data to the cluster head which then aggregates, fuses and finally transmits the data directly to the sink. At a fixed interval a new cluster head is dynamically elected from the not-yet-chosen cluster members. Each Cluster Head performs local computation on the gathered data to reduce its volume. But, due to broadcast required during the cluster head selection process, large amount of energy is wasted in setup phase which reduces the lifetime of network. A distant CH decreases scalability of protocol.

Heinzelman, Chandrakasan & Balakrishnan (2002) explored centralized LEACH (LEACH-C) in which selection of CH is controlled by base station. In this protocol the base station receives information from all sensor nodes about its state, location and remaining energy. Mean value of network nodes energy is calculated at the base station. After calculation of mean value of energy BS selects higher energy level node as a CH. Centralized control of nodes at BS requires GPS involvement and extra communication which drains energy of nodes and degrades performance of protocol. GPS involvement makes nodes costly.

Liu & Lee (2004) suggested Power Efficient Communication Protocols for Data Gathering on Mobile Sensor Networks. In this protocol each mobile sensor node is equipped with a GPS device to locate it in the network. Each mobile node calculates its distance from all its neighbours. In this protocol a round is categorized as invalid round, valid round and super round. A round that has not

any CH is called as an invalid round. On the other hand, a valid round elects some CH. A valid round followed by some consecutive invalid rounds in cluster head election phase is called as super round. An invalid round wastes energy leading to performance degradation of protocol and GPS involvement makes equipment costly.

Loscri, Morabito & Marano (2005) presented Two-Level LEACH (TL-LEACH) Protocol using two types of CHs in the network as first level cluster heads and second level cluster heads. Each node decides to be a primary (second level CH), secondary (first level CH) or simple node (SN). Data transfers from first level CH to the BS via second level CH. First level CH decides which second level CH it will join; similarly each simple node also decides which first level CH it will join. A lot of energy is wastage while choosing primary CH's and in data aggregation at each level of cluster heads.

Ye, Li, Chen & Wu (2005) used an energy efficient clustering scheme in wireless sensor networks (EECS) to optimize network lifetime. It selects cluster heads having more residual energy through local radio communication in an automated manner without any iteration. It also provides a good distribution of cluster heads and load among cluster head is balanced by using a distance based method. While calculating the distance between the nodes for good distribution of CH a lot of energy is wastage which degrades the lifetime.

Kim & Chung (2006) considered Mobile-LEACH (M-LEACH) protocol with same threshold formula which was used in LEACH protocol. To avoid the availability of node during data transmission phase it uses TDMA scheduling to confirm whether a mobile node is in communication range of CH or not. CHs sends REQ-DATA-TRANSMITION message at starting point of each TDMA slot. If two successive TDMA frames are missed by the node then node considers itself as out of range and is removed by the member list of CH. A lot of energy is wasted in establishing TDMA scheduling and recognizing nodes in the range of CHs.

Xiangning & Yulin (2007) discussed Energy-LEACH (E-LEACH) as an enhancement of LEACH by considering the residual energy of each node to select CHs. It uses a better way to select CHs after first round but dissipates a lot of

energy to calculate residual energy of each node which degrades the lifetime of network.

Chen & Shen, (2007) proposed MELEACH Protocol which uses shortened communication distance between sensor nodes to improve load balancing. The direct communication between CHs and BS reduces its capability for larger WSNs which requires a powerful radio on each sensor node making them costly and not suitable for large WSNs.

Zahmati, Abolhassani, Beheshti, Shirazi & Bakhtiari (2007) designed an energy efficient protocol with static clustering for wireless sensor network (EEPSC). It does partitioning of entire network into few static clusters to eliminate the overhead of dynamic clustering and tries to distribute the load among by choosing high energy sensor nodes as CHs. Static Clustering decreases overhead and efficiency of clusters and performance of protocol.

Chen & Shen, (2008) proposed a Large-scale WSNs (MELEACH-L) protocol as an extension to MELEACH in which size of each cluster is controlled and CHs are separated from backbone nodes by constructing backbone tree. Channel assignment problem among neighbour clusters and the cooperation among CHs during data collection is also been solved in this protocol. Constructing backbone nodes and spanning tree increase overhead and GPS involvement for location awareness of network make this protocol uneconomical.

Kumar, Paul & Jacob (2008) proposed Mobile-Enhanced-LEACH (LEACH-ME) protocol as an enhanced version of LEACH-M by selecting the less mobile nodes as CHs relatively to its neighbours. Each node broadcasts their IDs and estimates the distance to all other nodes. Nodes with least mobility factor and higher energy level are selected as CHs. To identify least mobile node extra energy is dissipated in transmitting successive request which adversely degrades the network lifetime.

Cheng, Qian & Wu (2008) explored Energy Efficient Weight Clustering (EWC) protocol as an extension to LEACH protocol in which residual energy, distance, and node degree are considered as metrics to select a CH. Nodes having more neighbours or with higher degree can serve more nodes which will

save more energy. EWC makes weighted clusters with selected CH which can serve more nodes effectively but drains high amount of energy of CH.

Buyanjargal & Kwon (2009) introduced Energy Efficient Clustering Algorithm for Event Driven (EECED). It enhances lifetime by balancing the energy usage of node. Base station is located in the center of area and is capable of processing messages with enough memory. Data is transferred from nodes to CHs only when an event occurs. Because of centralized BS and event driven algorithm election process of CH increases overhead.

Xiao-Tian, Shun-Yi, Pan & Ming (2009) suggested a Novel Energy Efficient Redundant Routing Tree for WSNs (EE-RRT) which uses virtual grid with a redundant routing tree to optimize WSN lifetime. Data transfer between CH selected in grid and BS takes place via a transmission agent which uses a redundant routing tree to reduce dynamic clustering time. Redundant routing tree and CH selection process increases overhead.

Yassein, Al-zou'bi, Khamayseh & Mardini (2009) presented Vice-LEACH (V-LEACH) protocol which has an alternative cluster heads (Vice-CH) along with active CH in each cluster. Vice-CH becomes CH to avoid isolation of cluster nodes from network in case CH dies. It insures the availability of cluster nodes and does not select a new CH each time when the CH dies. V-LEACH enhances the performance of LEACH when CH dies in any round but vice-CH is chosen on the basis of probability which can be a low energy node as vice-CH which adversely affects the V-LEACH protocol.

Hu, Shen & Kang (2009) discussed Energy-Efficient Cluster Head Selection (NECHS) protocol which uses fuzzy logic. At the time of input data fuzzy logic is applied and the original output can be received by applying de-fuzzy logic. Residual energy and degree of nodes are taken as input to the fuzzy mode to select CH. Fuzzification and Defuzzification increases extra overhead and advertisement collisions does not guarantee inclusion of normal nodes in a cluster.

Cai & Zhu, (2010) proposed LEACH-P (Performance) protocol with a different probability function i.e. probability function used in Energy Aware Multipath Routing (EAMR) to select CH. This new probability function optimizes

the choice of selecting CHs and cluster rebuilding. The best energy aware path is chosen by EAMR protocol between source node and destination node. EAMR uses two energy saving mechanisms as sleep control mechanism and data transmission control mechanism. The optimal energy saving can be achieved only through the cooperation between these two mechanisms. Each node calculates the selection probability for next hop node in the routing table. Calculating probability function and CH selection process used with EAMR protocol incurs extra overhead.

Kumar, Sitara, & Jacob (2010) proposed an adaptive cluster based routing scheme for mobile wireless sensor networks which considers the relative direction of the node mobility to improve the cluster formation. Each node broadcasts their IDs twice to estimate its distance to neighbours by using RSSI (Received Signal Strength Indication). Each node calculates relative distances from both received signals. A negative value shows that the two nodes are moving away from each other and a positive value shows that both nodes are moving towards each other and a zero value shows that they are stationary. A node declares itself as a CH only if there are more number of nodes which are stationary or moving towards a node. Each node decides its relative direction to its neighbours based on mobility factor. Calculation of mobility factor and node's direction increase extra overhead.

Farooq, Dogar & Shah (2010) designed Multi-hop Routing LEACH (MRLEACH) which uses multi-hop data transmission technique to send data from CH to BS. At the beginning of a round and before cluster formation each node builds a table which holds the information like node's ID, residual energy level, and node's status. The table of each CH holds the nodes ID's of its member nodes. Status of a node can be one of three values: unknown, cluster member or CH. CH is selected by using residual energy of node. CHs which are near to BS are layer-one CHs and which are away from BS are layer-two CHs. Although it decreases energy consumption of farther located CH but drains high amount of energy of intermediate nodes.

Nazir & Hasbullah (2010) used energy balanced clustering (EBC) in wireless sensor network for cluster formation, cluster head selection inter cluster communication and intra cluster communication. CHs are selected based on

residual energy of node, number of linked nodes or neighbour nodes and distance between node and base station. Although EBC enhances the lifetime of network but overhead gets increase in extra communication to choose efficient CH.

Ghosh, Bairagi, Kashem, Rezwan-ul-Islam & Uddin (2011) proposed an Energy Efficient Zone Division Multi hop Hierarchical Clustering Algorithm for Load Balancing which divides the network into four zones with their centre. These four zones can or cannot be divided again by the protocols based on the efficiency of CH. Managing and controlling these zones is very difficult which increases Overhead.

Maraiya, Kant & Gupta (2011) proposed an Efficient Cluster Head Selection Scheme for Data Aggregation in Wireless Sensor Networks (ECHSSDA) using re-clustering technique to reduces the overhead of clustering process, load over CH and energy consumption within cluster. It has an associated CH will become a CH in next round if the energy level of original CH becomes lower than the average energy which is computed by the BS. Re-clustering reduces overload on CH but increases network overhead.

Liu & Ravishankar (2011) presented LEACH-GA protocol using a genetic algorithm-based clustering technique to improve energy efficient protocols. Each node sends its node ID, location information and CH decision based on optimal percentage CH to the BS. BS applies genetic algorithm operations on received information to find out the optimal threshold probability and broadcast it for cluster formation. Complexity of genetic algorithm and calculation of threshold probability increases extra overhead.

Kumar & Kaur (2011) suggested an improved-LEACH (I-LEACH) protocol which uses residual energy of node to select CH node. It also considers the coordinate of node to select the nearest CH which requires GPS involvement to locate node. GPS involvement increases node's cost and extra communication used for locating nearest node degrades performance by increasing overhead.

Katiyar, Chand, Gautam & Kumar (2011) introduced far-zone LEACH (FZ-LEACH) as an enhancement of LEACH protocol to make it for large area network. This protocol creates a far zone of sensor nodes placed away from BS and have

lesser energy than the threshold energy level to transfer the data. This threshold value is decided by the average of the minimum reachability power of every node. It ensures the connectivity of nodes but threshold calculation increases overhead.

Wang, Yang, Zheng, Zhang & Kim (2012) introduced Multi-hop LEACH protocol to solve quick energy drainage problem of CH in single hop communication in case of large-area network. Intra-cluster communication takes place between CH and its cluster member nodes where CH receives data from all member nodes at a single-hop distance and aggregates and transmits the data directly to the BS or through intermediate CHs. Multi-hop inter-cluster communication takes place via when the distance between the CH and the BS is large and the CH uses intermediate CHs for sending data to the BS and drains energy of intermediate node. Data loss occurs in case intermediate CHs die because of energy drainage.

Al-Ma'aqbeh, Banimelhem, Taqieddin, Awad & Mowafi (2012) explored a Fuzzy Logic LEACH (FL-LEACH) as an extension to LEACH protocol which uses Fuzzy-Logic to find out the optimal number of CHs. Mamdani's fuzzy inference method is used in fuzzification to determine the fuzzy sets or membership values by taking the number of nodes and network density as crisp values of the input variables. The fuzzified inputs are applied to the antecedent and consequent parts of each fuzzy rule for rule evaluation. Then aggregation is done at the output fuzzy sets using the output variable. Finally, defuzzification of output is done at last step to get the crisp value of the output. Fuzzification and Defuzzification processes are very complex which increases extra processing to get accurate crisp output.

Yektaparast, Nabavi & Sarmast (2012) discussed cell-LEACH protocol. In cell-LEACH protocol a cluster is divided into seven sections which are called as cells. These seven clusters are divided using one central cell of hexagonal shape and other six cells at each face of central hexagonal shape with their own cell heads which can communicate to each other directly. Cluster head is chosen among all nodes of seven cells of a single cluster and cell heads forwards the aggregated cell data to CH. These clustering and celling is static and hence remain there for network lifetime. The only thing which changes is cell heads and

cluster heads. Static cell formation decreases efficiency of protocol if node distribution is irregular which lead to isolation of cells which have alive nodes.

Zhou, Zhang & Qian (2012) suggested an improvement of LEACH protocol based on uneven clustering algorithm which considers the distance between node and base station which helps in formation of clusters of different sizes. Those clusters which are nearby the base station will be small in size than the clusters which are far away from base station. By reducing the nearby cluster size energy depletion of cluster head node in case of multi-hop communication can be reduced which will prolong the network lifetime. A larger cluster situated away from BS will dissipate more energy in inter-cluster and intra-cluster communication affecting the performance of network adversely.

Iqbal, Akbar, Javaid, Bouk, Ilahi & Khan (2013) introduced Ad-LEACH (Advanced- LEACH) protocol for heterogeneous WSN routing which uses static clustering. CH in each cluster is selected by using Distributed Energy-Efficient Clustering (DEEC). Since cluster size is small and static, hence, CHs need to broadcast messages within a small area which reduces the power requirement of CH. Because of the small size of clusters number of CHs increases which requires more energy for inter-cluster and intra-cluster communication and finally degrades the network lifetime.

Bakaraniya & Mehta (2013) proposed K-LEACH protocol which optimizes the LEACH protocol by using K-Medoids clustering algorithm. K-Medoids algorithm provides highly uniform clustering of nodes. This protocol selects least distant node from the center of cluster as a CHs. A highly uniform clustering will reduce the energy consumption efficiently. Although, it reduces the energy consumption but increases the overhead while choosing least distant and centralized CHs.

Kodali & Sharma (2013) presented Distributed Diffusion LEACH (DD-LEACH) as an improvement over LEACH Protocol. It uses multi-hop routing of data from sensor nodes to base station. In DD-LEACH protocol data aggregation is done at multiple levels. First data aggregation is done at CH which collects the data from nodes. While forwarding data to BS all the intermediate CHs also

perform data aggregation. Although it saves energy of sensor nodes but drains high amount of energy at intermediate CHs leading network to die quickly.

Gnanambigai, Rengarajan & Anbukkarasi (2013) presented an energy efficient algorithm related to quadrant based directional routing protocol called as Q-LEACH which divides the whole network into quadrants. Those nodes which are nearby the sink node will broadcast the message. Since it uses a reactive routing mechanism and hence all nodes maintain the destination node information before finding the path to destination or sink node. It contains advantage of both location and hierarchical based routing protocols. This protocol uses route request packet to find the path to destination. Although, reactive routing mechanism delivers data to BS efficiently but increases overhead which leads network to die quickly.

Diane, Kacimi, Mammeri & Niang (2013) considered a measurement redundancy aware LEACH (MR-LEACH) which uses grouping of nodes based on the geographical location. At the time of data aggregation by CH node the information received by any node belonging to the same group is processed without receiving the data from other nodes of that group. This is done because all nodes of a group contain similar information which will waste the energy in data aggregation and hence neglected. This negligence of data received from same group nodes only save energy while data aggregation making them useless i.e. all other nodes are only wastage of resources if data received from them are discarded.

Xiao, Zhang & Dong (2013) explored an energy potential LEACH (EP-LEACH) which enhances the LEACH protocol by using energy potential function while selecting the cluster head. This energy potential function is used to measure the capability of a node for energy harvesting. There is no limitation on a node to become a CH i.e. a node may become CH repeatedly only if it's potential energy is higher than other nodes potential energy. Although it saves energy by avoiding CH selection mechanism in each round but drains energy of a single node by making it a CH multiple times and leading network to isolation of node quickly.

Tumer & Gunduz (2014) suggested Energy Efficient LEACH Protocol (EELP) which uses two threshold values as lower and upper values. Lower

threshold value is the minimum amount of sensed data and upper threshold value shows the danger level of data. If sensed data is below lower threshold value then the data will not be sent to base station. If value of data is more than upper threshold value then the data should be sent to base station directly. XOR operation is applied on received data from different CHs at base station to avoid data redundancy. Threshold values can be applied only on sensed data which makes sensors to continuous sensing. If sensed data is below the lower threshold then discarding those data makes useless but huge amount of sensed data at many places is more than upper threshold values then congestion may occur at BS which degrades the network performance.

Kodali & Aravapalli (2014) discussed Multi-Level LEACH as extension to TL-LEACH. It includes 3L-LEACH (Three Level LEACH) and 4L-LEACH (Four Level LEACH) protocols. Working of 3L-LEACH and 4L-LEACH is same as TL-LEACH, but only difference is number of levels increase between two different level CHs. The lower level CH forwards aggregated data to the upper level CHs. Aggregation is performed at each level CHs and energy consumption of farther CHs are reduced because of multi-hop communication but drainage of intermediate CHs may lead to node isolation from network which will affect the performance and lifetime of network adversely.

Ramya & Santhi (2014) explored Localized Power Efficient Data Aggregation Tree Protocol (LPEDAP) which uses Minimum Spanning Tree (MST) technique with the distributed nature of shortest weighted path based routing scheme to make routing algorithm energy efficient. Although, MST makes LPEDAP robust, scalable and self-organizing in nature but drains a lot of energy in making MST affecting network lifetime.

Study of Literature indicates that first significant protocol introduced for lifetime optimization of wireless sensor network was LEACH Protocol. LEACH uses probabilistic approach to select cluster head. Probabilistic approach can lead to cluster isolation by selecting a low energy cluster head. Moreover, LEACH-C Protocol was introduced with centralized control over network which requires GPS involvement and makes it uneconomical. Many protocols were proposed for optimization of LEACH Protocol which uses energy CH selection technique, static

clustering technique, multi-hop communication between CH and BS, node's mobility, complex optimization techniques and direction based communication techniques. Protocols like LEACH-CH, EWC, LEACH-P, EE-RRT, EBC, ECHSSDA, EP-LEACH and EELP which use energy cluster head selection technique increases overhead in selection of cluster heads and decreases efficiency of protocols. Other protocols like EEPSC, FZ-LEACH, Cell-LEACH and Q-LEACH may decrease the efficiency of network in case of irregular and inefficient static clustering. Multi-hop communication techniques used in TL-LEACH, MR-LEACH, DD-LEACH, Multi-Level LEACH, Q-LEACH, FZ-LEACH may lead to energy drainage of intermediate nodes which can cause node isolation. LEACH-M, LEACH-ME, MELEACH and MELEACH-L protocols use mobile nodes which may lead to coverage problem and communication failure during data transmission. EEPS, LEACH-GA, K-LEACH, EP-LEACH and LPEDAP protocols uses some complex optimization technique for efficient and faster clustering but make protocol more complex with increased overhead. FZ-LEACH, DD-LEACH, Q-LEACH and LPEDAP uses directional communication for data transfer which increases network overhead while finding the direction to BS. Literature review also indicates that there are some shortcomings in each protocol as discussed in table 2 which has been resolved or to be resolved.

Table 2: Shortcomings in Literature Review

| Sr. No. | Author's Name | Protocol Name | Shortcomings |
|----------------|--------------------------|--|--|
| 1. | Heinzelman et.al. (2000) | LEACH | Limited scalability and random selection of CH. |
| 2. | Heinzelman et.al. (2002) | LEACH-C | Extra overhead on the BS. Not suitable for large area networks and GPS involvement makes it uneconomical. |
| 3. | Liu & Lee (2004) | Power Efficient Communication Protocol for Data Gathering on Mobile Sensor Network | Extra overhead on electing CHs. |

| | | | |
|-----|--------------------------|-----------|--|
| 4. | Loscri et.al. (2005) | TL-LEACH | Extra overhead for electing secondary CHs and cluster formation. |
| 5. | Ye et.al (2005) | EECS | While calculating the distance between the nodes for good distribution of CH a lot of energy is wastage which degrades the lifetime. |
| 6. | Kim & Chung (2006) | LEACH-M | LEACH-M is not considered efficient in terms of energy consumptions and data delivery rate because a large number of packets are lost if the CH keeps moving before the selecting a new CH For the next round. |
| 7. | Xiangning & Yulin (2007) | E-LEACH | The CHs must keep its receiver turned on to receive all the data |
| 8. | Chen & Shen (2007) | MELEACH | Inappropriate for Large scale WSNs because providing a powerful enough radio on each sensor node for MELEACH is costly. |
| 9. | Zahmati et.al. (2007) | EEPSC | Static Clustering decreases overhead but decreases efficiency of clusters and performance of protocol. |
| 10. | Chen & Shen (2008) | MELEACH-L | Utilization of multiple channels increases overhead and economic cost taking much frequency spectrum, backbone tree and the spanning tree . |
| 11. | Kumar et.al. (2008) | LEACH-ME | Extra overhead on electing CHs. |

| | | | |
|------------|--------------------------------|--|---|
| 12. | Cheng et.al (2008) | EWC | Extra overhead processing so more energy is consumed to select CHs. |
| 13. | Buyanjargal & Kwon (2009) | EECED | Extra overhead on the BS and elector nodes to select CHs. |
| 14. | Xiao-Tian et.al (2009) | EE-RRT | Extra overhead processing to select CHs. |
| 15. | Yassein et.al. (2009) | V-LEACH | Extra processing for selecting vice-CH. |
| 16. | Hu et.al. (2009) | NECHS | Collisions of join or advertisement packet do not guarantee inclusion of non CH node in cluster. |
| 17. | Cai & Zhu (2010) | LEACH-P | Extra overhead to calculate probability selection formula for selecting CHs. |
| 18. | Kumar et.al (2010) | An Adaptive Cluster Based Routing Scheme for Mobile Wireless Sensor Networks | Extra overhead on calculating node's movement direction. |
| 19. | Farooq et.al. (2010) | MR-LEACH | Although it decreases energy consumption of farther located CH but drains high amount of energy of intermediate nodes. |
| 20. | Nazir & Hasbullah (2010) | EBC | Although EBC enhances the lifetime of network but overhead gets increase in extra communication to choose efficient CH. |
| 21. | Ghosh et.al. (2011) | Zone Division Multi Hop Hierarchical Clustering for Load Balancing | Overhead on controlling and management of the zones. |

| | | | |
|------------|--------------------------------|---|--|
| 22. | Maraiya et.al. (2011) | ECHSSDA | Extra processing for selecting CHs. |
| 23. | Liu & Ravishankar (2011) | LEACH-GA | Complexity and extra overhead on the BS to evaluate the CHs percentage. |
| 24. | Kumar & Kaur (2011) | i-LEACH | GPS involvement increases node's cost and extra communication used for locating nearest node degrades performance by increasing overhead. |
| 25. | Katiyar et.al. (2011) | FZ-LEACH | It ensures the connectivity of nodes but threshold calculation increases overhead. |
| 26. | Wang et.al. (2012) | Multi-hop-LEACH | Problems arise in case one of CHs hops die as result the gathered data will be lost. |
| 27. | Al-Ma'aqbeh et.al. (2012) | FL-LEACH | Complexity and the accuracy in the fuzzification and defuzzification process. |
| 28. | Yektaparast et.al. (2012) | Cell-LEACH | Static cell formation decreases efficiency of protocol if node distribution is irregular which lead to isolation of cells which have alive nodes. |
| 29. | Zhou et.al. (2012) | Improvement of LEACH Protocol based on uneven clustering algorithm | A larger cluster situated away from BS will dissipate more energy in inter-cluster and intra-cluster communication affecting the performance of network adversely. |
| 30. | Iqbal et.al. (2013) | Ad-LEACH | Because of the small size of clusters number of CHs increases which requires more energy for inter-cluster and intra-cluster |

| | | | |
|------------|---------------------------|----------|--|
| | | | communication and finally degrades the network lifetime. |
| 31. | Bakaraniya & Mehta (2013) | K-LEACH | Although, it reduces the energy consumption but increases the overhead while choosing least distant and centralized CHs. |
| 32. | Kodali & Sharma (2013) | DD-LEACH | Although it saves energy of sensor nodes but drains high amount of energy at intermediate CHs leading network to die quickly. |
| 33. | Gnanambigai et.al. (2013) | Q-LEACH | Although, reactive routing mechanism delivers data to BS efficiently but increases overhead which leads network to die quickly. |
| 34. | Diane et.al (2013) | MR-LEACH | Extra overhead on the BS, probability of message failure and routing the sensed data of Multi hop could fail. |
| 35. | Xiao et.al. (2013) | EP-LEACH | Although it saves energy by avoiding CH selection mechanism in each round but drains energy of a single node by making it a CH multiple times and leading network to isolation of node quickly. |
| 36. | Tumer & Gunduz (2014) | EELP | If sensed data is below the lower threshold then discarding those data makes useless but huge amount of sensed data at many places is more than upper threshold values then congestion may occur at BS which degrades the network performance. |

| | | | |
|------------|----------------------------------|-------------------|--|
| 37. | Kodali & Aravapalli (2014) | Multi-Level LEACH | Drainage of intermediate CHs may lead to node isolation from network which will affect the performance and lifetime of network adversely. |
| 38. | Ramya & Santhi (2014) | LPEDAP | Although, MST makes LPEDAP robust, scalable and self-organizing in nature but drains a lot of energy in making MST affecting network lifetime. |

CHAPTER 3

SIMULATION SETUP AND METHODOLOGY

3.1 Software Used

The protocols can be simulated and analyzed on that software which supports networking architecture for programming, called as simulators. Simulators create virtual environment for networking where a protocol can be implemented and analyzed using simulation parameters. Following software are used in this research work:

3.1.1 MATLAB

Matrix Laboratory (MATLAB) is a high-level language and interactive environment for numerical computation, visualization and programming. MATLAB can be used for analyzing data, developing algorithms, and creating models and applications. The language, tools, and built-in math functions enable users to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java. MATLAB can be used for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. More than a million engineers and scientists in industry and academia use MATLAB, the language of technical computing (MATLAB and Simulink for technical computing, 2014).

In this research work MATLAB R2013a is used which is already installed in Computer Lab of Central University of Punjab.

The key features of MATLAB 2013 are given below (MATLAB and Simulink for technical computing, 2014):

- It uses High-level language for numerical computation, visualization, and application development.
- It provides Interactive environment for iterative exploration, design, and problem solving.

- It supports Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, numerical integration and solving ordinary differential equations.
- Built-in graphics for visualizing data and tools for creating custom plots.
- Development tools for improving code quality and maintainability and maximizing performance.
- Tools for building applications with custom graphical interfaces.
- Functions for integrating MATLAB based algorithms with external applications and languages such as C, Java, .NET, and Microsoft Excel.

3.1.2 Operating System

Any application software needs an operating system as a platform to run at any machine. MATLAB requires Microsoft Windows Operating System.

In this research work Microsoft's Windows 7 Operating System is used as a platform to install MATLAB 2013 in University Computer Centre.

3.2 Methodology

The work flow of this research work is divided into various phases as follows.

Phase 1: To Study the LEACH Protocol

In this phase, Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol and its descendents protocol have been studied.

Phase 2: To Implement LEACH Protocol on MATLAB

This phase is divided into two stages:

Stage 1: In this stage working of LEACH Protocol on MATLAB is studied.

Stage 2: In this stage LEACH Protocol is implemented on MATLAB R2013a.

Phase 3: To Analyze Performance of LEACH Protocol

In this phase the LEACH Protocol has been analyzed using the simulation parameters according to Table 2 and performance metrics like Time when First Node Dies, Last Node Dies, Half of Nodes Dies, Energy Consumption per round and Throughput.

Phase 4: To Implement Proposed Model of Modified LEACH Protocol

This phase further consists of two stages:

Stage 1: In this stage LEACH protocol is modified with proposed solution to increase Network Lifetime.

Stage 2: In this stage modified LEACH Protocol has been implemented on MATLAB.

Phase 5: To analyze performance of Modified LEACH Protocol

In this phase modified LEACH Protocol using the proposed Solution has been analyzed under the same scenario which was used for analyzing LEACH Protocol.

Phase 6: Comparative Analysis of LEACH and RCH-LEACH Protocol

In this phase the output results of LEACH Protocol and RCH-LEACH Protocol has been compared to make a conclusion about network lifetime.

3.3 Simulation Parameters

The Wireless Sensor Network will be analyzed under following scenario:

Table 2: Simulation Parameters

| Parameters | Value |
|---|--|
| Simulator | MATLAB R2013a |
| Number of Sensor Nodes | 100 |
| Topography/Field Dimension (m*m) | 100*100 |
| Sink Position (x, y) | (50,175) |
| Desired percentage of Cluster Heads (%) | 5.0 |
| Initial Energy per Node | 0.5 Joule |
| Energy Dissipation of Transmitter Electronics | 50×10^{-9} Joule/bit |
| Energy Dissipation of Receiver Electronics | 50×10^{-9} Joule/bit |
| Energy Dissipation of Transmit Amplifier | 100×10^{-12} Joule/bit/m ² |
| Energy Dissipation of Data Aggregation | 5×10^{-9} Joule/bit |
| Energy Consumption in free space/air | 0.01×10^{-12} Joule |

3.3.1 Performance Metrics

The simulation was done to analyze the performance of the network for various parameters which are related to the networks lifetime as follows.

3.3.1.1 Energy Consumption per Round

Energy Consumption per round is total amount of energy which has been consumed in a single round.

$$\text{Energy Consumption in } i^{\text{th}} \text{ Round} = \sum_i^n \text{Energy} - \sum_i^{n-1} \text{Energy} \quad (9)$$

Where $\sum_i^n \text{Energy}$ is Energy consumed in i rounds and $\sum_i^{n-1} \text{Energy}$ is Energy consumed in $(i-1)$ rounds.

3.3.1.2 FND (First Node Dies)

First Node Dies (FND) represents the round in which first node of network dies. It also represents the stable time of the networks i.e. the time till network works efficiently and after this the performance of network starts decreasing. FND of any network i.e. stable period should be maximum.

3.3.1.3 HND (Half of Nodes Die)

Half of Nodes Dies (HND) is that round when half of the total nodes present in the network have been died. After this time only half of the network is working. HND occurs in unstable period of network.

3.3.1.4 LND (Last Node Dies)

Last Node Dies (LND) is that time when last node of the network dies i.e. the time till network exists. It is also known as Network Lifetime. LND of any network i.e. Network lifetime should be maximum.

3.3.1.5 Throughput

It is the amount of data which is received at base station in unit time.

$$\text{Throughput} = \frac{\sum \text{Data Received at Base Station}}{\sum \text{Total Time}} \quad (10)$$

OR

$$\text{Throughput in } i^{\text{th}} \text{ round} = \sum_i^{n+1} \text{Data} - \sum_i^n \text{Data} \quad (11)$$

Where \sum_i^{n+1} Data is total data received in $(i+1)^{\text{th}}$ Round and \sum_i^n Data is total data received in r^{th} round.

3.4 Basic Assumptions

Following are the basic assumption of Sensor Network:

- The Network is homogeneous i.e. all sensor nodes have equal energy.
- Sensor nodes are randomly and uniformly distributed in the area.
- Base Station and Sensor nodes are immobile i.e. they are static.
- All sensor nodes are eligible to calculate it's current energy level.
- Nodes do not have location information.
- Each sensor node knows the location of sink or Base station.
- Dimension of the sensor field is fixed.
- Sink or Base Station is not energy limited.
- All sensor nodes participate in network sensing.
- Data aggregation is done at the cluster head only.

3.5 Proposed Model of RCH-LEACH (LEACH using Relay Cluster Head node) Protocol

In LEACH Protocol all sensor nodes send their data to Cluster Head nodes associated with them and then Cluster Head node aggregates the received data and sends the aggregated data to Base Station. Proposed model is similar to LEACH Protocol. All steps upto aggregation of data received from base station is similar to LEACH Protocol. In proposed model a higher energy node has been selected by CH in its cluster for relaying the data of CH to BS which is termed as Relay Cluster Head (RCH) Node. After aggregating the received data CH forwards the aggregated data to a selected RCH sensor node in its cluster. After receiving the data from CH, RCH node forwards it to base station. Since, LEACH protocol has been enhanced by using a RCH node hence modified LEACH protocol is called as RCH-LEACH protocol (LEACH using Relay Cluster Head node). By applying this model the energy consumption of cluster head can be reduced which will increase the network lifetime.

3.5.1 Flowchart of RCH-LEACH Protocol

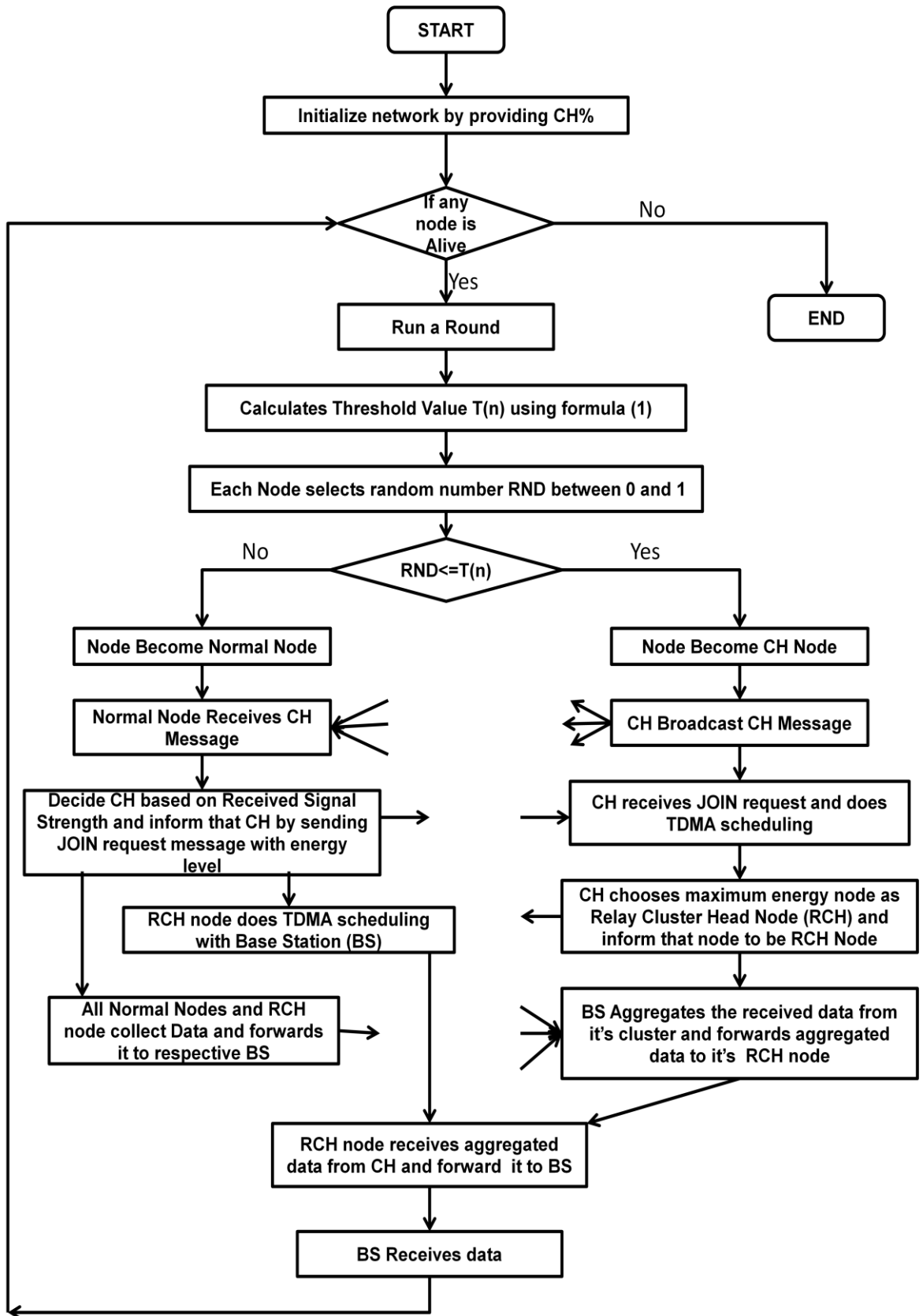


Figure 3.1: Flowchart of RCH-LEACH Protocol

3.5.2 Steps Involved in Proposed Model of RCH-LEACH

Following steps are involved in proposed model of RCH-LEACH Protocol.

Step 1: Define percentage (p) of Cluster Heads in the network.

Step 2: Now, protocol proceeds into several rounds till network dies. Each round consists of Setup phase and Steady state phase as follows:

Step 2.1: Setup Phase

- a) Each Sensor node chooses a random number between 0 and 1.
- b) Calculate Threshold Value using formula:

$$T(n) = \frac{p}{1 - p \left(r \bmod \left(\frac{1}{p} \right) \right)} \text{ if } n \in G$$

- c) If random number of eligible cluster head sensor node is less than threshold value then cluster node becomes CH.
- d) Cluster Head Node announces that it is a cluster head in this round.
- e) All other sensor nodes receive announcement message and selects their cluster head located on minimum distance.
- f) Sensor Nodes join their respective cluster head nodes to form clusters.
- g) CH selects highest energy normal node in it's cluster and makes it cluster relay node of it's cluster.

Step 2.2: Steady State Phase

- a) All sensor nodes sense the environment.
- b) Normal nodes of a cluster send their data to its respective CHs.
- c) Cluster Head Node aggregates all collected data including its own data.
- d) After aggregation, cluster head forwards aggregated data to its relay node.

- e) After receiving the data from cluster head node, cluster relay node forwards the same data to base station.
- f) Base station receives the data for further processing.

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter outputs of experiments performed are given in graphical form along with discussion of results.

4.1 Analysis of LEACH Protocol

LEACH is an energy efficient routing protocol in wireless sensor network. Sensor nodes collect data and forward data to CH which aggregates and forwards that data to BS. Since significant amount of energy is consumed of CH in aggregation of data. Hence, number of CHs should be balanced in the network. Figure 4.1 represents the energy consumption in LEACH protocol at different percentage of cluster heads. It is clear from the figure 4.1 that if energy consumption increases as percentage of CHs increases. But lesser percentage of CH has fluctuating graph than higher percentage. Energy consumption should be minimum but without any larger fluctuation or deviation which is achieved at 5% of CH.

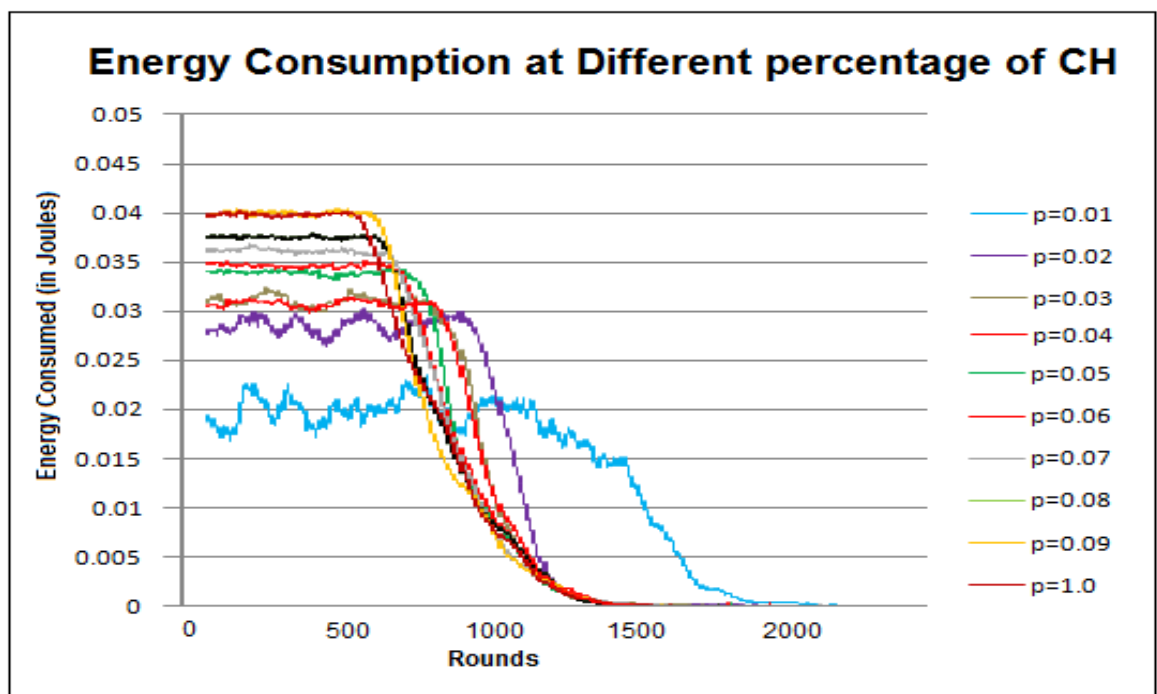


Figure 4.1: Energy Consumption at different percentage of BS in LEACH

After deciding a balanced percentage of 5% CHs, performance of LEACH has been analyzed with different locations of BS. Figure 4.2 represents that if BS is located far away from target area then performance decreases. But establishing a base station in remote area is not easy so that BS is located outside the WSN region at a reasonable distance. In this research work location of Base station is taken at (50,175) coordinates.

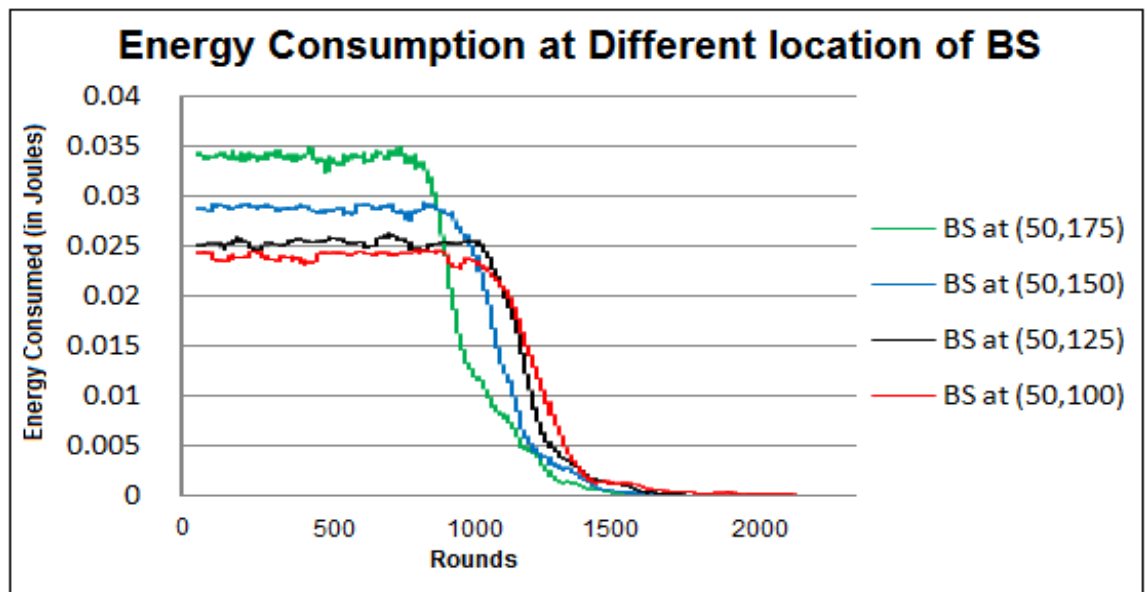


Figure 4.2: Energy consumed at Different Location of BS in LEACH

4.2 Analysis of RCH-LEACH Protocol

Now, the RCH-LEACH protocol has been analyzed at different locations of base stations having 5% of CH nodes. Figure 4.3 represents that RCH-LEACH behaves similar to LEACH protocol on changing the location of BS.

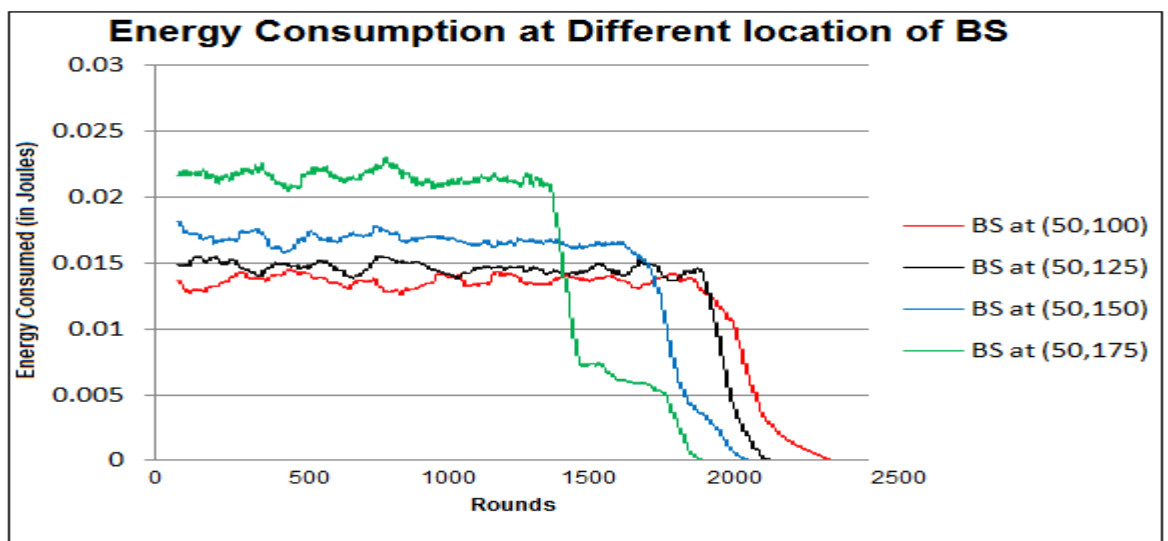


Figure 4.3: Energy Consumption at Different Locations of CH in RCH-LEACH

4.3 Analysis of LEACH and RCH-LEACH Protocol

4.3.1 Energy Consumption per Round

The output result graph in Figure 4.4 shows that energy consumption of RCH-LEACH is lower than the energy consumption in LEACH protocol. Reduced energy consumption of modified LEACH or RCH-LEACH protocol optimizes the network lifetime. Because of reduced energy consumption FND of RCH-LEACH is higher than that of LEACH protocol.

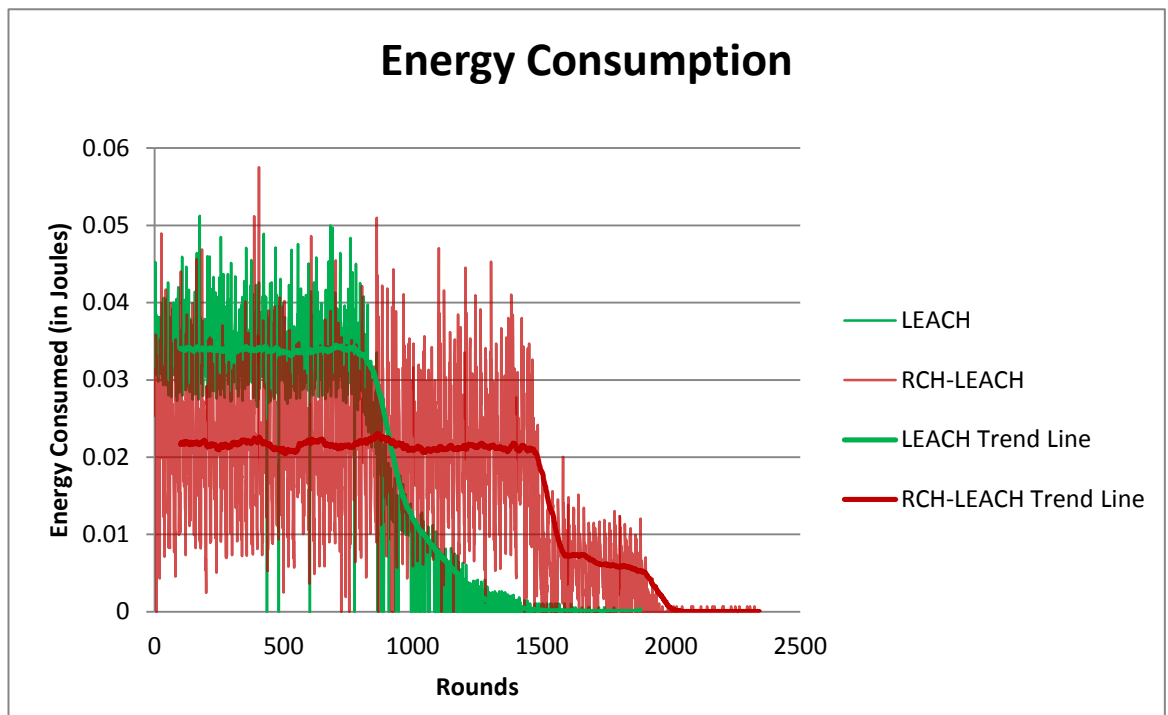


Figure 4.4: Energy Consumption per Round

4.3.2 Throughput

It represents total data sent over the network in a unit time (round). The output result graph in Figure 4.5 shows that throughput achieved in a single round by RCH-LEACH is more than the throughput achieved in LEACH protocol. RCH-LEACH protocol gives better throughput till its FND which is larger than the FND value of LEACH. So overall throughput received at base station by RCH-LEACH is also greater than the data received by LEACH.

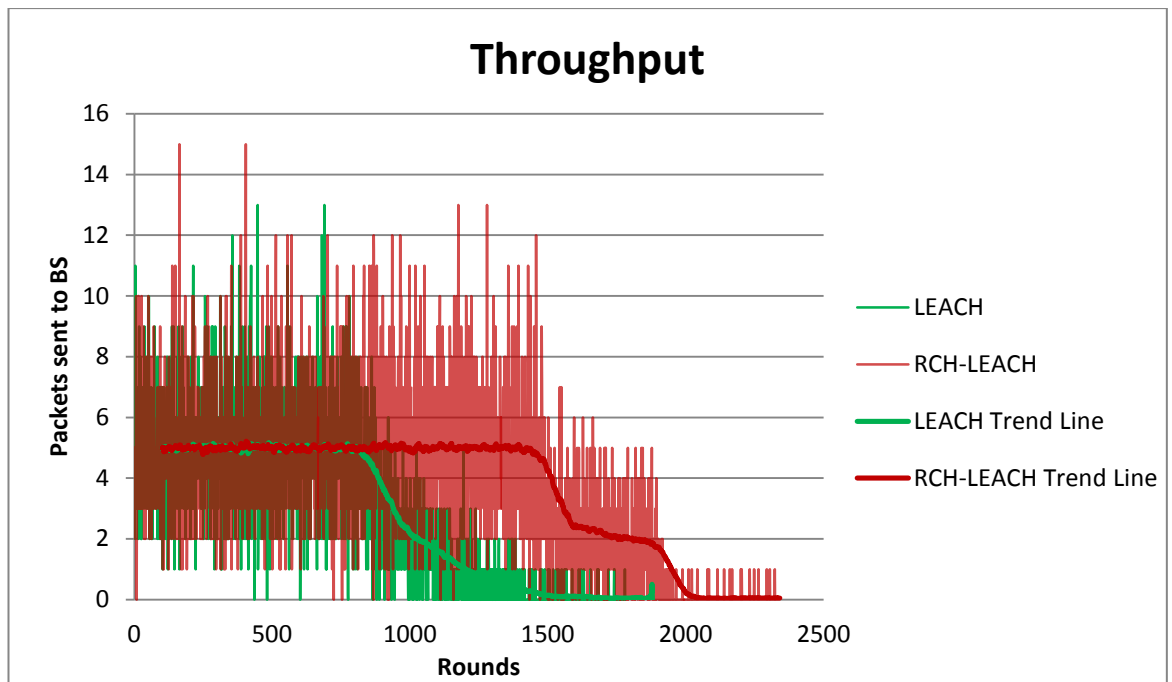


Figure 4.5: Throughput

4.3.3 Number of Dead Nodes

It represents the total number of dead nodes present in the network with time. The output graph in Figure 4.6 represents that first node dies earlier in LEACH protocol than in RCH-LEACH Protocol. In LEACH number of nodes increases gradually after FND but in RCH-LEACH half of nodes die quickly after first node die. RCH-LEACH gives larger lifetime than the LEACH protocol.

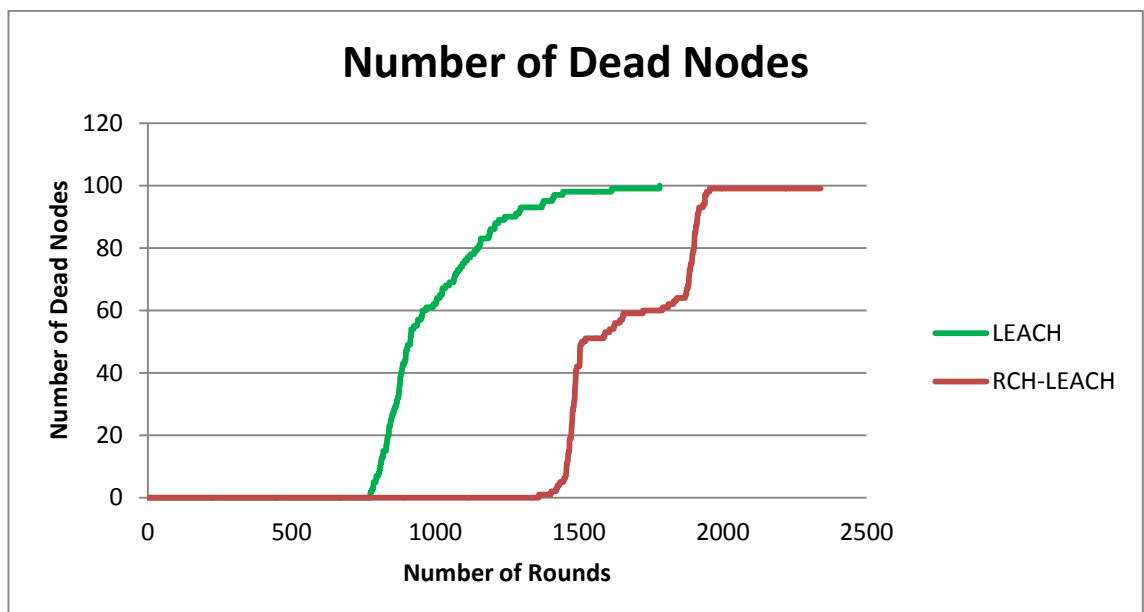


Figure 4.6: Number of Dead Nodes

4.3.4 Effect of Location of Base Station on Network Lifetime

In Figure 4.7 network lifetime using FND, HND and LND has been analyzed which shows that network lifetime in RCH-LEACH protocol is higher than network lifetime of LEACH protocol at same location of base station i.e. FND, HND and LND of RCH-LEACH is higher than the than in LEACH if location of base station is kept fixed.

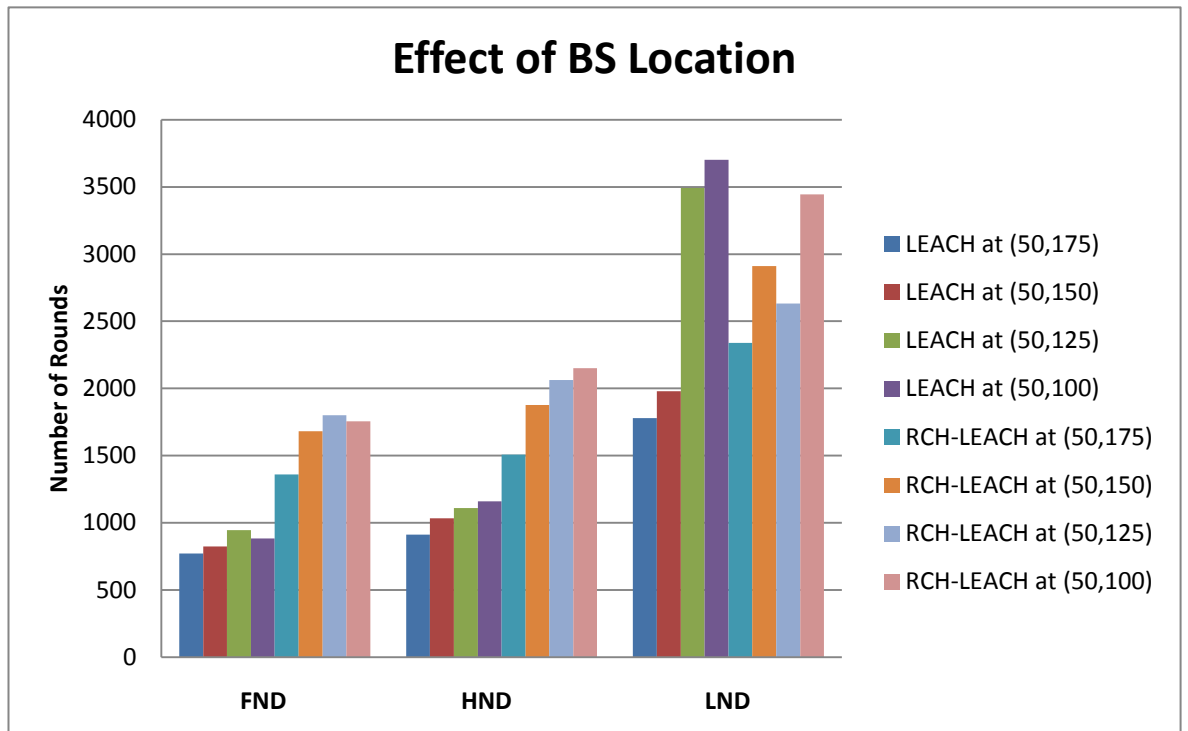


Figure 4.7: Effect of Location of Base Station

Hence, it has been observed that RCH-LEACH outperforms LEACH in every aspect whether it is FND, HND, LND, energy consumption per round and throughput per round which shows that RCH-LEACH has optimizes network lifetime.

CHAPTER 5

CONCLUSION AND FUTURE WORK

All sensor nodes are dependent on limited battery power and can not be recharged because they are deployed in remote locations. This limitation of energy makes it as a key issue for research to increase lifetime of WSNs.

In this research work LEACH Protocol which is a significant energy efficient routing protocol has been implemented and analyzed with the modified LEACH protocol which is called as RCH-LEACH protocol. RCH-LEACH protocol uses a highest energy node in the cluster which is selected by cluster head to relay the cluster head's aggregated data to base station. The output results of RCH-LEACH Protocol show that throughput achieved and energy consumption is better than the LEACH protocol i.e. the values of FND, HND, LND and throughput is higher and value of energy consumption per round is lower in RCH-LEACH protocol than in LEACH protocol. Hence, RCH-LEACH protocol optimizes the network lifetime of Wireless Sensor Network.

In this research work RCH model which uses highest energy node in cluster to relay the aggregated data to base station has been applied on LEACH protocol to optimize it. This model can be used in other descendent protocols of LEACH to optimize them. RCH-LEACH is using undirected two-hop communication with probabilistic selection of CH for static nodes. It can be extended in future by using multi-hop communication instead of two-hop communication, mobility of nodes, energy efficient cluster head selection and direction to BS.

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