Cluster Chain Based Relay Nodes Assignment

Gulnaz Ahmed[1], Asia Samreen[2]
[1](Department of Computer Science, Bahria university,Karachi Campus,Pakistan)
[2](Department of Computer Science, Bahria University,Karachi Campus,Pakistan)

ABSTRACT: *Wireless sensor Networks are very famous these days due to their coverage and enormous benefits. Clustering the sensor nodes efficiently and dynamically with least energy consumption is the current issue in front of researchers, so that lifetime of sensor nodes will be increased. Cooperation among Relay Nodes and Edge Nodes (ENs) along with restrained energy utilization depends upon some protocol such as LEACH for data transmission. In this paper, we propose a Cluster Chain Based Relay Nodes Assignment (CCBRNA) scheme to manage the energy constraints in WSN, which Assigns Relay Nodes (Cluster-Heads) on the basis of energy and distances parameters but priority is always given to the energy value. The primary model of CCBRNA based on LEACH and PEGASIS protocols is redeveloped to enlarge the lifetime span of network nodes. This scheme is sliced into two main steps. In the first step Cluster-Head is selected and then in second step data transmission starts using an internal chain of nodes according to the distances of nodes from Base Station. In data transmission step, data transportation between different clusters takes place and lastly data is sent to the end terminal moving via the nearest Cluster-Head. Simulation in MATLAB verifies the enhanced lifetime of the nodes. We have used the distance as the key parameter while data transmission takes place. The scheme is efficient as when there are large number of nodes, chaining will take very less time and as well as energy to transmit the data to Cluster-Head. We have further applied an external chaining among Cluster-Heads of different clusters. With the applied limitations and suggested resources such as additional processor, it works well in relaying process.*

Keywords: *Cluster-Head, Chaining within Clusters, Relay node Assignment, Lifetime, LEACH, PEGASIS*

1. INTRODUCTION

Wireless Sensor Networks (WSNs) are a novel class of wireless communication network, which combine communication technology, embedded computing and sensor technology [3]. Wireless sensor network consists of a large number of spatially distributed autonomous sensor nodes which are connected to each other through either wired or wireless medium to monitor different environmental and physical conditions and cooperatively pass this information to a main station normally called Base Station (BS). The modern wireless sensor networks are bidirectional and enable to control sensor activity. In the past, military applications such as battlefield surveillance, secure information communication etc. becomes the motivational step to introduce the concept of wireless sensor networks but now a day's these types of networks are used in different industrial and consumer applications. A sensor network node normally consists of several parts: a radio transceiver for communication with an external antenna, a microcontroller consisting an embedded electronic circuit for interfacing with the sensors and an energy source, and usually a battery source. Sensor nodes are usually powered by a battery source , so how efficiently and rationally can use energy to extend the network lifetime as much as possible has become one of the core issues of sensor networks [3]. Due to limited lifetime these devices face problems in long distance communication. Therefore, we need a better and an energy efficient hierarchy to increase the network lifetime. We use sensors and transducers called edge nodes to get information.

Fig 1.1 given below shows a Sensor node.

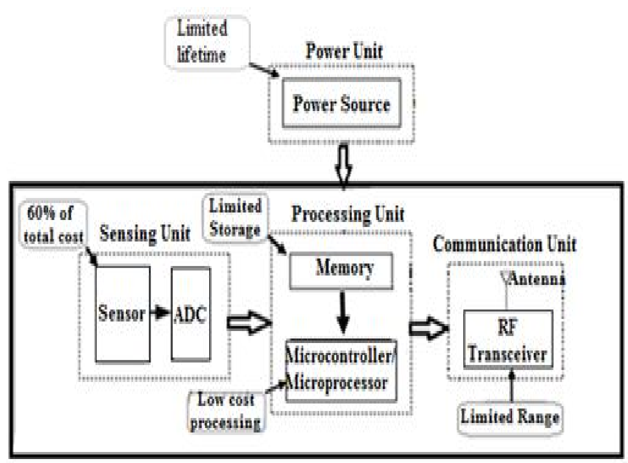

Fig 1.1 Sensor Node

1.1 Wireless Sensor Networks Topologies

Wireless Sensor Network topologies are broadly divided into two types of models as discussed below in Fig 1.2.

1.1.1 Single-hop models

One simple wireless sensor network topology is the single-hop models (Fig. 2(a) and Fig. 2(b)), in these architectures all sensor nodes transmit their data to the Base Station directly. In case of big areas these architectures are infeasible because in energy consumption case transmission cost becomes expensive and in the worst case, the Base Station may be unreachable.

1.1.2 Multi-hop models

Second topology is the multi-hop models, we can consider two architectures first are the Flat model (Fig. 2 (c)) and the second is a clustering model (Fig. 2 (d)). In the multi-hop flat model, overhead and energy consumption can be increased and becomes a limitation because all nodes should share the same information such as routing tables. On the other hand, in the multi-hop clustering model, sensor nodes try to maintain low overhead and energy consumption because chosen Cluster-Heads aggregate data and transmit them to the Base Station. Additionally, in the multi-hop flat model, wireless medium is shared and managed by individual nodes, which cause a problem in resource usage efficiency. In the multi-hop clustering model, resources can be assigned orthogonally to each Cluster to reduce collisions between Clusters and be reused Cluster by Cluster.

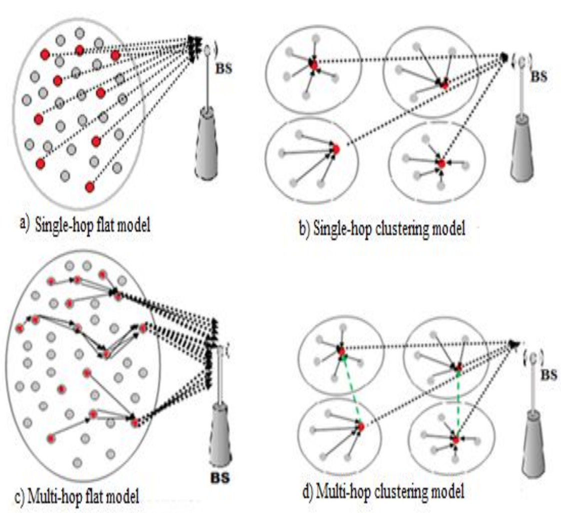

Fig 1.2 Wireless Sensor Network Topologies

1.2 Clustering

Clustering is a very effective method to build a hierarchical architecture in mobile ad-hoc networks. Different clustering schemes are discussed for mobile ad-hoc networks in [9], to meet certain needs of the system such as cost maintenance, to make system energy efficient, for load balancing to distribute overhead of a network. Cluster based organizations of wireless sensor networks have been identified as the best method of sensor organization for reducing the energy consumption of a WSN [7]. Clustering is the technique of making a set of nodes into groups (called clusters) so that the nodes in the one cluster are more similar (in some sense or another) to each other as compared to those in other clusters. Normally there are three types of nodes in cluster networks, Cluster-Head nodes, gateway or sometimes called Relay nodes and normal nodes or member nodes.

1.2.1 Clustering Strategies – Categorization

There are many Cluster-Head rotation/selection algorithms for wireless sensor networks in the literature out of which some are energy driven, some are time driven, some are size driven and some are distance driven etc.

In this ongoing field one initiating work is LEACH (Low-Energy Adaptive Clustering Hierarchy). LEACH is an application specific, and self organizing protocol that uses clustering to increase the network lifetime by evenly distributing the energy load throughout the whole network nodes. A Cluster-Head is selected with a high threshold value of energy as given below [4].

$$t\,(n) = \left\{ \frac{pout}{1 - pout \times \left(r \times mod \frac{1}{pout}\right)} \right\}$$

The main issue here is that depending on which parameters we decide the cluster-Head. However, the algorithm in the process of selecting the cluster-Head (CH) does not take the remaining energy of node into account, which problems that lower energy node may be selected to Cluster-Head, and all the Cluster-Heads directly communicate with the base station which will cause the nodes to premature death [3]. Many clustering proposals to enlarge the network lifetime span are reports suggesting different strategies of Cluster-Head selection and Cluster-Head role rotation among the sensor nodes, using different parameters. Depending on these parameters, one can categorize these strategies of Cluster-Head selection broadly as deterministic, adaptive and combined metric (hybrid) [10].

2 RELATED WORK

There are many researches focusing on the issues of Cluster-Head selection, and Cluster–Head duty rotation for wireless sensor networks. [1], integrates the dilemmas of Clustering and relay assignment into a unified problem and then interpret this more smoothly by utilizing the BIP (Binary Integer Programming) scheme. In sequential relaying, the beginner nodes sequentially select their relays. To solve the issue of relay node assignment in cooperative organizations a flexible vehicle Routing miniature is worthy. [1], works on the vehicle routing problem whose goal is to find the best shortest path for a fleet of vehicles to visit the starting and destination locations. In [2], to solve the above mentioned problem, development of an optimal polynomial Time algorithm, called ORA is discussed. An elementary thought behind this finding is a "linear marking" structure, that sustains linear complication of every repetition.

2.1 Distance, size and Direction based Cluster-Head Selection

With the passage of time the increase in traffic may increase the pollution.In [5], the Cluster- Head (CH) election is done based on distance and direction information. Since Clusters are formed all along the road, Cluster-Head's will take the responsibility of routing the packet to the destination**.** According to this algorithm each participating vehicle knows its own position using Global Positioning System (GPS). In [14], two variants of the Cluster-Head selection is examined, where first variant is the distance-constrained selection where every node in the network must be located within a certain distance to the nearest cluster-Head; and the second is the size-constrained selection where each Cluster is only allowed to have a limited number of members.

2.2 Energy based Cluster-Head Selection

In [4], a Relay Based Clustering algorithm (RBC) is proposed to solve the problem of remaining energy in a Cluster for heterogeneous energy Wireless sensor networks. The "Relay" system considers the nodes remaining energy to relay the position of Cluster-Head to its successor in the network. In HEED [13],[12] sensor nodes use residual (remaining) energy as a criterion to decide on their role as a Cluster-Head and make up their mind setting the probability to a value expressed in terms of remaining energy, maximum energy and the optimum percentage of Cluster-Heads required for a particular data gathering round which is not allowed to fall below a minimum pre-decided threshold. In [6], the Cluster-Head (CH) selection is done based on considering consumed energy as a factor for Cluster-Head selection of each node to enlarge the network lifetime span of Wireless Sensor Network rather than its remaining energy . In [8], the Cluster-Head selection is done on the basis of genetic algorithm for optimal Cluster-Head selection that not only reduces the overhead but also it is stable. In [11], Cluster-Head(s) selection is based on an efficient trust model. As in wireless sensor networks the Cluster-Head can change from time to time depending on distinctive aspects such as flexibility, energy density, and distance among nodes. To solve this problem [15], focused on three algorithms which are A Density and Distance based Cluster-Head, An Energy Efficient Algorithm for Cluster-Head Selection in Wireless Sensor Networks, Consumed Energy as a Factor for Cluster-Head.

2.3 Energy and Distance based Cluster-Head Selection

In [16], Power-Efficient Gathering in Sensor Information Systems (PEGASIS) protocol is discussed, which is a near optimal chain-based protocol, is used for Cluster-Head selection. The primary thought behind the concept of PEGASIS protocol is that, the nodes that are close to each other (called neighbors) in the sequence can communicate to enlarge the network lifetime span. Data accumulation of each node in a sequence reduces the amount of exchanging data among nodes and their Cluster-Head, to preserve node energy [17]. This offers exceptional energy redeeming and enlarges the Cluster-Heads lifetime span. In [18], an application of PEGASIS, EECB (Energy-Efficient Chain-based routing protocol) is discussed. EECB scheme avails two legends. One is stated as, "distances among the nodes", the distance among nodes and the end terminal (BS)". Another legend states as, "remaining energy levels of sensor nodes". In [19], the Fuzzy Logic System (FLS) is used for Cluster-Head election in a network.

3 RADIO ENERGY MODEL FOR CLUSTER CHAIN BASED RELAY NODES ASSIGNMENT

In this study, we introduce a miniature of radio, introduced in [19], that is the primary order miniature of the radio. For first order radio model, the amount of energy required to keep the transmitting circuit or the receiving circuit of the node in action, called the electron energy *Eelec* = 50nJ/bit. The transmitter amplifier energy for free space is given as, *ϵamp* = 100pJ/bit/m2.The radios have power to control and can spend the minimum required energy to reach the specified recipients. The radios can be turned off to avoid receiving transmissions from unspecified recipients. Equations (1) and (2) are used to calculate the energy, denoted by *ETx (k, d)*, used in transmitting k bits message over a distance d.

Transmitting

ETx (k, d) = ETx-elec (k) + ETx-amp (k, d) (1)

ETx (k, d) = Eelec* k + ϵamp* k* d2 (2)

Where *k* is the size of the data packet and *d* is the distance between transmitter and receiver.

Receiving

Equation (3) is used to calculate the energy, denoted by *ERx (k)*, used in receiving k bits message.

ERx (k) = ERx-elec (k) = k*Eelec (3)

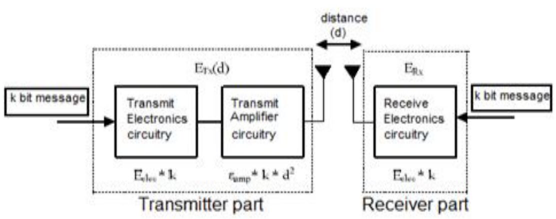

Fig 3.1 Radio energy model

Where *ETx-elec* is the energy dissipation of transmitter electronics and *ERx-elec* is the energy dissipation of receiver electronics circuitry. *ETx-amp* is the energy of transmitter amplifier. Assume that *ETx-elec* = *ERx-elec* = *Eelec*. Receiving data is also a high cost procedure. Thus, the transmission and receiving operation numbers should be less. An assumption is made that the radio channel is symmetric so that the energy required to transmit a message from node *i* to node *j* is the same as the energy required to transmit a message from node *j* to node *i* for a given signal to noise ratio.

4 Details of Cluter Chain Based Relay Nodes Assignment

4.1 Cluster-Head selection method

There are five main cases as given below, depending on which the Cluster-Head selection is done. In this scheme both energy values and distances of nodes from base stations are seen but priority is always given to energy of the node if distances of any two nodes become equal.

Case 1:

If [(E_i>E_{i+1}) and (d_i<$_{di+1}$)] OR [(E_{i+1}>E_i) and (d_{i+1}<d_i)]

Then node with greater energy value and having less distance from BS is selected as Cluster-Head.

Case 2:

If [(E_i>E_{i+1}) and (d_i<$_{di+1}$)] or [(E_{i+1}>E_i) and (d_{i+1}<d_i)]

Then node with greater energy value and having less distance from BS is selected as Cluster-Head.

Case 2:

If [(E_i=E_{i+1})] and [(d_i<d_{i+1}) or (d_{i+1}<d_i)]

Then compares distances of all nodes in a cluster from BS and a node having less distance from BS is selected as Cluster-Head

Case 3:

If [(d_i=d_{i+1})] and [(E_i>E_{i+1}) or (E_i<E_{i+1})]

Then a node having greater energy value is selected as Cluster-Head without considering distances of nodes.

Case 4:

If [(E_i=E_{i+1}) and (d_i=d_{i+1})]

Then any node in the cluster can be selected as Cluster-Head.

Case 5:

If [(E_i>E_{i+1}) and (d_i>d_{i+1})] or [(E_i>E_{i+1}) and (d_{i+1}>d_i)]

Then node with greater energy value can be selected as Cluster-Head.

4.2 Packet transmission using chaining

This scheme checks the distances of all nodes from the BS and their energies to select a Cluster-Head in each round.

- Suppose depending on above five cases, a node is selected as Cluster-Head.
- Now if any node has data to send BS then it checks its table and finds the node with shortest distance and sends data towards that node.
- Similarly this node checks its table and finds the one node with the shortest distance from itself and sends its aggregated data towards that node.
- This process continues until data is sent towards the selected Cluster-Head 1.
- Now this Cluster-Head check its table and find that it has the shortest distance from Cluster-Head 2 as compared to BS so, it sends aggregated data towards the Cluster-Head 2.
- This process continues until one finds the shortest distance from the BS and sends the aggregated data to it.

4.2.1 Chaining Within Cluster

We can explain this with the help of a simple example given below in Fig 3.3. Consider we have a Cluster with having 25 randomly distributed nodes as shown below, having different energies.

We assume that all nodes not only have their location knowledge but also have global knowledge of the network and employ the greedy algorithm.

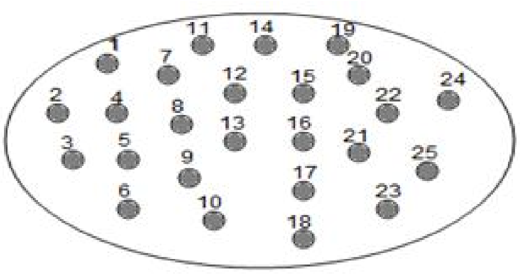

Fig 3.3 Nodes distribution within cluter

Each node in the Cluster has the following Table 3.1. This table has the record of node location, node energy, its distance from BS and, and node distances from all other nodes in the Cluster.

Table. 3.1 Node ID,its location,its distance from BS, and its initial energy

Node ID	Node location	Distance from BS	Initial Energy
1			
2			
3 " " 25			

Suppose a node with ID 25 is selected as Cluster-head above as it has the highest energy and less distance from the Base Station. This Cluster-Head selection is shown below in Fig 3.4.

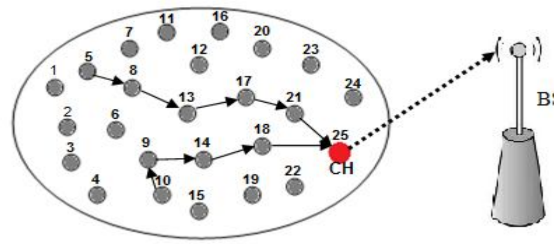

Fig 3.4: Chaining within Cluster

In this example we describe the two rounds of data sending within the Cluster. In the first round a node with ID 5 has a data packet to send. This node checks its table and finds that it has less distance from the node with ID 8 as compared to any other node in the Cluster so it sends data packet to node 8. Now node 8 checks its table and find the shortest distance from node 13. Node 6 aggregates the received date and sends towards the node 13. Now node 13 checks its table and finds the shortest path from node 17. Node 13 sends the aggregated data to the node 17 where this data is aggregated again and sent towards the node 21. Now node 21 finds the shortest distance from node 25 which is the Cluster-Head node, finally data is aggregated here and send to the Cluster-Head. In the second round a node with ID 10 has some data to send. This node proceeds in the same manner as in the first round and finally the node with ID 18 forward the aggregated data towards the Cluster-Head.

4.2.2 Chaining between Cluster-Heads

Now we explain chain construction between Clusters with the help of Fig 3.5 as given below. Chain construction between Clusters depends only on distances of Cluster-Heads from Base Station not on the energy values of nodes. According to this chaining process the Cluster-Head nearest to the Base Station collects data from its neighbor Cluster-Heads, aggregate this collected data with its own data and sends towards the Base Station in each round.

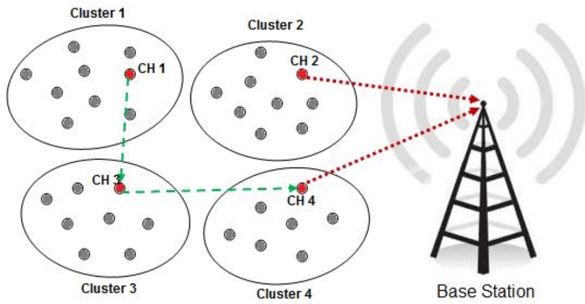

Fig 3.5: Chaining between Cluster-Heads

Each Cluster-Head node in the cluster has the following Table 3.2. This table has the record of Cluster-Head ID, distances of all Cluster-heads from BS and the number of nodes in each Cluster.

Table. 3.2: Cluster-Head ID,its distance from BS and nodes in the Cluster

Cluster-Head ID	Distance from BS(m)	Nodes in the Cluster
CH01		
CH02		
CH03 " " CH04		

In this Fig Cluster-Head node (CH 1) in Cluster 1 checks its table and finds the shortest distance from CH 3 node in the Cluster 3 as compared to any Cluster-Head node or BS. CH 1 node sends the aggregated data of Cluster 1 to the CH 2 node in the Cluster 2. CH 2 again do the same step and finds that CH 3 node In Cluster 4 is closets node to it, hence sends the aggregated data to CH 4. Now CH 4 finds that BS is close to it as compared to any other Cluster-Head node, hence sends its data towards the BS. Cluster-Head (CH 2) node directly sends its aggregated data to the BS, as it has a shortest distance from the BS than any other Cluster-Head node in the network.

5 SIMULATION RESULTS AND EVALUATION

This section presents the performance analysis of CBRNA.To evaluate the performance of CBRNA, we simulated CBRNA using random 21node network. The initial energy per node is random within range of 0.1J-1J. similarly distances of nodes from BS is also randomly taken within range of 10m-100m. For simulation simplicity we consider only one Cluster at a time.This simulation consists of data for 4 rounds, where In each round starting node is different.

Table.5.1 Simulation Parameters

Parameters	Value
Number of the nodes	25
Initial energy of the nodes	0.1 Joul~1 Joul
Initial energy of the selected Cluster-Head	0.950222J
Distances of nodes from BS	10m~100m
Distance of the selected Cluster-Head from BS	16m
Time taken for one move	1 unit
Sleep mode energy	0.000000 J
The energy dissipated in electronics for 1 bit Transmission and reception	50 nJ/bit
Energy consumed in power amplifier in the free - space model	10 pJ/bit/m2
Energy consumed in power amplifier in two-ray propagation model	.0013pJ/bit/m4
The total energy spent by a node n a given data transmission roun for useful work	$0.01 \leq E_t \leq 0.1$

5.1 Graphs

These graphs are drawn for different data samples taken from different clusters. Fig 5.1(a) given below shows the plot of the initial energy of nodes and Residual energy of nodes after four rounds for Cluster 1 while Fig 5.1(b) shows the plot of the Initial energy of nodes and Residual energy of nodes in each round.

5.1.1 Cluster 1

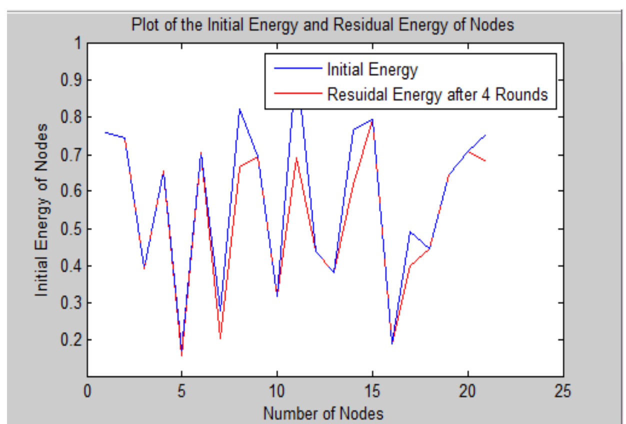

Fig 5.1(a): Plot of the Initial energy and final energy of nodes

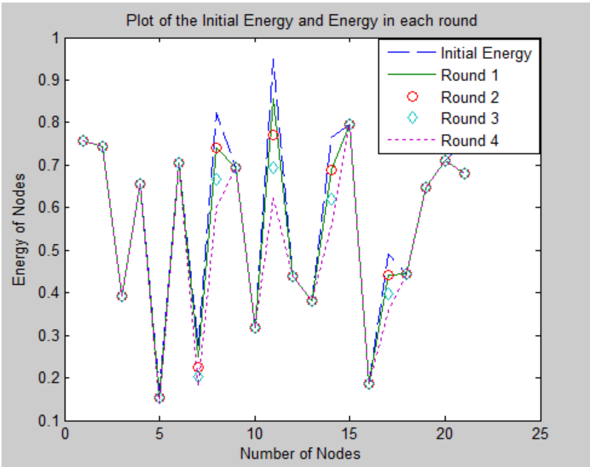

Fig 5.1(b): Plot of the Initial energy and energy of nodes in each round

5.1.2 Cluster 2

Similarly Fig 5.2(a) as given below shows the plot of the energy of nodes after four rounds of data transmission for cluster 2 while Fig 5.2(b) shows the plot of the energy of nodes and Residual energy of nodes in each round. For Cluster 2, Cluster-Head (CH2) is selected with the following energy and distance values 0.910648J, 61m.

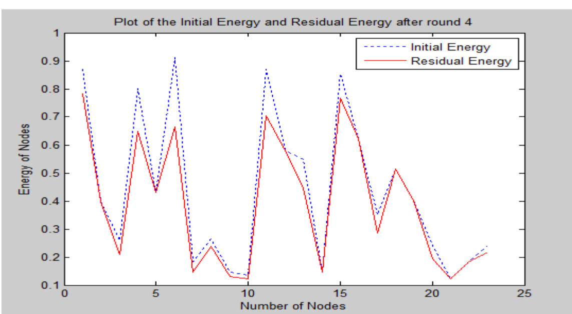

Fig 5.2(a): Plot of the Initial energy and final energy of nodes

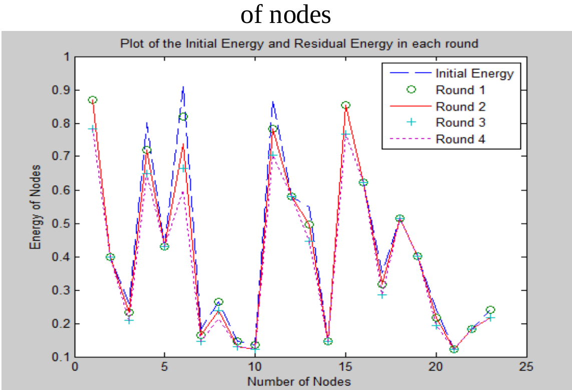

Fig 5.2(b): Plot of the Initial energy and energy of nodes in each round

Simulation in MATLAB verifies the enhanced lifetime of the nodes. We have used the distance as the key parameter while data transmission takes place. The scheme is efficient as when there are large number of nodes, chaining will take very less time and as well as energy to transmit the data to Cluster-Head. We have further applied an external chaining among Cluster-Heads of different clusters. With the applied limitations and suggested resources such as additional processor, it works well in relaying process.

6 Conclusion and Future Work

Due to the bidirection nature of the modern Wireless sensor networks, their capability to control and improve sensor activity leads to a need for a better and energy efficient hierarchy to increase the network lifetime span. During the thesis time period, we discussed a number of superlative problems that are important for Placement and Assignment of Relay Nodes in Wireless Sensor Networks in order to overcome the topic relating issues by using a hierarchy of energy efficiency. Mainly we focused on the optimization problem of RNA in similar networks upon the objective of enlarging the network lifetime span, and making network performance better by using these additions. In this work we studied two major algorithms PEGASIS & LEACH and then designed a new algorithm. Our algorithm Cluster Chain Based Relay Nodes Assignment (CCBRNA) is chaining based algorithm that first selects a Cluster-Head then starts data transmission using an internal chain of nodes according to the distances of nodes from BS. The given simulation results show that the network lifetime has been increased due to chaining; hence energy utilization is efficiently done. Finally it is concluded that, still we need to optimize the Relay Nodes Assignment in WSNs to make network performance better. Below in Table. 6.1 we have given attributes comparison of different schemes with respect to our scheme (CCBRNA).

Here we consider the sparse distribution of sensor nodes in the network, hence nodes does not have equivalent distances from each other but in future work we consider a dense network in which all sensor nodes would have equivalent distances from each other. However, the high density of nodes in the Network imposes challenges to the simulation. Therefore, there is a need for new approaches and algorithms for fast simulations in future.

Table. 6.1 Attribute comparision of differen Cluster-Head Schemes

Algorithms	CH Selection	Cluster Size	Network Type	Hierarchical	Clustering	Centralization	Hoping within Cluster
LEACH[11]	Threshold probability	Uneven	Homogenous	Yes	Yes	No	Single-hop
LEACH-C	Residual energy	Uneven	Homogenous	Yes	Yes	Yes	Single-hop
Hybrid LEACH[20]	Threshold probability	Uneven	Heterogeneous	Yes	Yes	No	Multi-hop
Uneven Clustering Routing[3]	Threshold probability	Uneven	Homogenous	Yes	Yes	No	Multi-hop
CCBRNA	Remaining Energy and Distance	Uneven	Homogeneous	Yes	Yes	No	Multi-hop

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