Design of Energy Efficient Clustering Protocol for Wireless Body Area Networks

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Certificate

This is to certify that the thesis entitled ***Design of Energy Efficient Clustering Protocol for Wireless Body Area Networks*** by **Sailesh Kumar Upadhyaya & Ragini Patel** is a record of an original research work carried out under my guidance and supervision in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering.

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Abstract

The research in Wireless Body area Networks (WBAN) has taken an exponential growth in last decade. The advances in wireless communication among the invasive / non-invasive micro sensors along with the Micro Electro Mechanical systems (MEMS) technology have enabled the deployment of wireless body area networks (WBANs) in and around the human body for e-health monitoring. The main aim of WBANs is to improve the speed, accuracy and reliability of communication of sensors inside in the close proximity of the human body. Wearable WBAN in medical applications can be used either for disability assistance or human performance management. In case of wearable BANs, the sensor nodes may be deployed in a wearable device like a brain cap, chest jacket or even a bracelet etc. The sensors sense the body parameters and send it to the base station for further processing. The resource constrained, miniature sized sensors meet several challenges while communicating to the base station. A routing protocol basically decides the energy consumption in the network. So, designing a routing protocol that will extend the life of sensors and hence the life of WBAN is the main goal. This thesis proposes a distributed clustering algorithm that aims to provide a longer network life time by the fair distribution of energy consumption among the sensor nodes.

Keywords: *WBAN, Micro-sensor, MEMS, routing protocol, clustering.*

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Chapter 1

Introduction

1.1 Wireless Body Area Networks

A Wireless Body Area Network (WBAN), also referred to as Body Sensor Network (BSN), is a wireless network of wearable/ implantable small computing devices (bio-sensors). These devices are used for continuous health monitoring. They also provide real-time feedback to the medical personnel or user [1].

A typical structure of WBAN is shown in Figure 1.1.

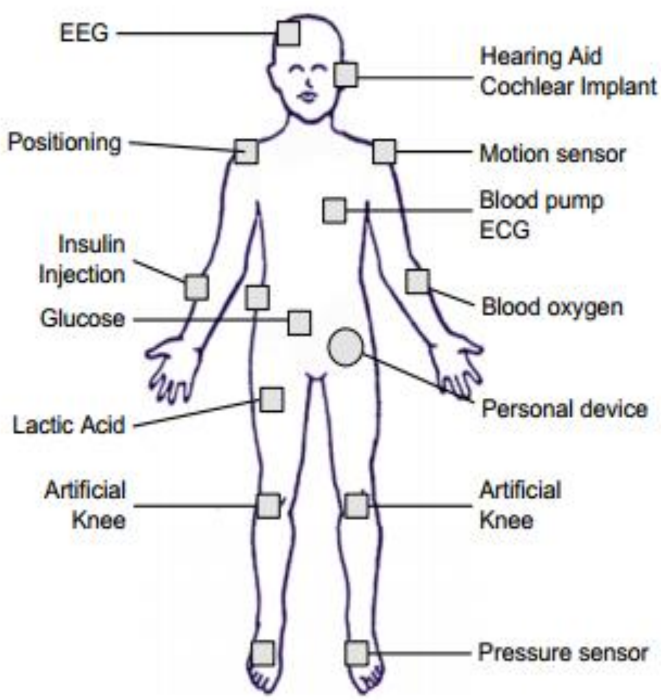

Figure 1.1: Wireless Body Area Networks

1.2 WSN vs WBAN

WSN (Wireless Sensor Network) is a network of spatially distributed autonomous sensor nodes which cooperatively monitor physical or environmental area and pass their data to main location i.e. Base Station (BS). Various techniques from ad hoc networks and Wireless Sensor Networks (WSNs) can be used for facilitating communication between WBAN devices. Differences between a WBAN and a WSN are as follows [7]:

- The devices/sensors have a very small form factor (often less than 1 cubic centimeter), so they have limited energy available. It is very difficult to change or recharge the batteries once implanted. So, devices which can last for decades are required. Hence, the available energy, computational power and available memory of the devices are limited for WBAN.

- The devices are added only when they are required for some application as all the devices have equal importance. So, no redundant devices are available in case of WBAN. Redundant devices can be available in WSNs.

- A very low transmission power per node is required to minimize interference. This can also cope with required health concerns.

- The waves must be attenuated before they reach the receiver because propagation takes place in lossy (human body) medium.

- The devices in WSN are static whereas in WBAN, devices can be in motion as they are located in the human body. Therefore robustness in WBANs is required in order to cope with frequent changes in network topology.

- High reliability and low delay is required as the data contains mostly medical information.

- High security mechanisms are required for ensuring the security of confidential information and private medical data.

- The devices are generally heterogeneous because they may have different demands and requirements. They may require different resources of the network in terms of power consumption, reliability and data rates.

1.3 First Order Radio Model

A simple radio model is shown in Figure 1.2[5].

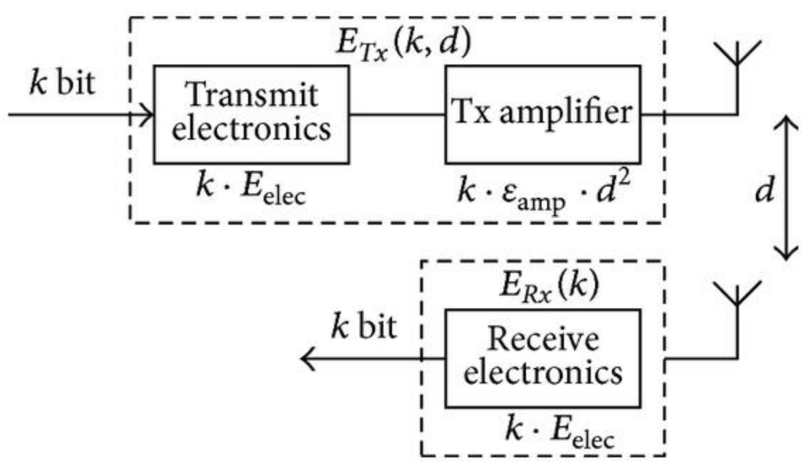

Figure 1.2: First Order Radio Model

So, energy used for transmitting k-bit message for *d* distance is given by:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) \qquad \longrightarrow \qquad (1)$$

$$E_{Tx}(k,d) = E_{elec} * k + \in_{amp} * k * d^2$$

And for receiving k-bit message, energy used is:

$$E_{Rx}(k) = E_{Rx-elec}(k) \qquad \longrightarrow \qquad (2)$$

$$E_{Rx}(k) = E_{elec} * k$$

1.4 Clustering

In this protocol, nodes are organized into groups called clusters. Each cluster has a local base station known as cluster head. The cluster forming mechanism is deployed to form virtual clusters and a cluster head for its cluster. These cluster heads broadcast a message to its cluster members denoting its id and a time slot. Cluster members send their data to cluster head on their respective time slots. Cluster head aggregates all the data collected from its cluster members removes the redundant data, and then transmit it to the base station. It minimizes the energy consumption in the network and number of messages communicated to the base station. It also reduces the number of active nodes in communication. Final result of clustering the sensor nodes is enhancing lifespan of the network. Fig. 1.3 shows a basic clustering sensor network.

Advantages of Clustering:

(i) Transmit aggregated data to the data sink
(ii) Reducing number of nodes taking part in transmission
(iii) Useful Energy consumption and efficient use of resources in WSNs
(iv) Scalability for large number of nodes
(v) Reduces communication overhead
(vi) Removes redundant data.

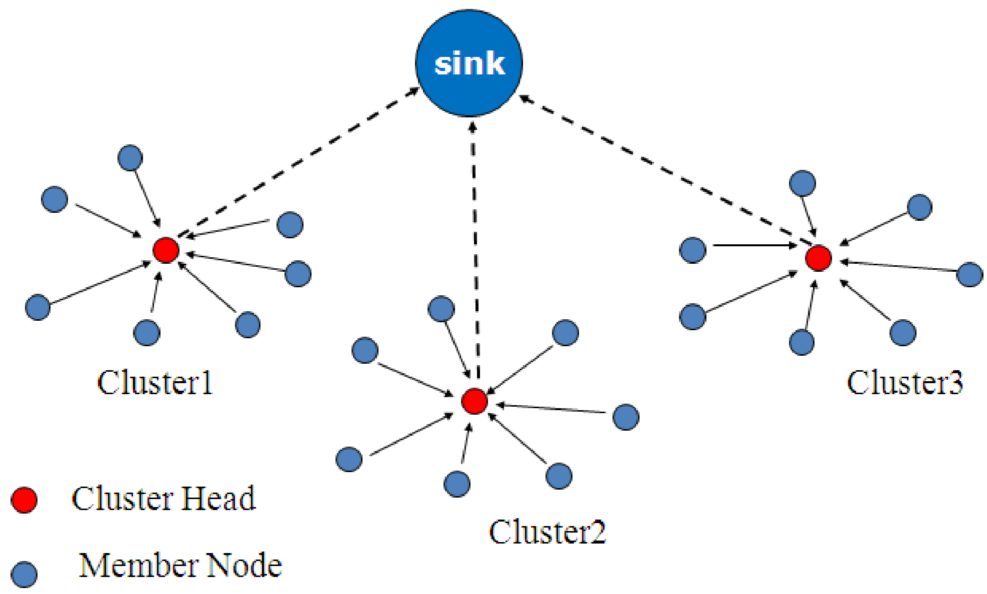

Figure 1.3: Clustering

1.5 Problem Statement

The main aim of this project is to find the more energy efficient protocol. Wireless body area networks are battery operated. Sensor nodes collect the data and pass them on to the network for further use. This passing and receiving of data utilizes most of the energy of the network. So for better operation and increase the lifetime of the network, energy consumption must be the major factor of concern. In this project, a new protocol has been proposed for the uniform distribution of cluster heads.

The objectives of proposed algorithm are as follows:

1. Minimize the energy dissipation of the network.
2. Increase the life time of the network.
4. Uniform distribution of cluster heads in the network.

The rest of the thesis is organized as follows. Chapter 2 provides a literature survey on the existing work in the area of wireless body area networks and the clustering protocols for micro sensors. Chapter 3 proposes the new protocol, Distributed Cluster Head Protocol, followed by its simulation results and analysis in Chapter 4. Finally, Chapter 5 concludes the thesis.

Chapter 2

Literature Survey

Biosensors in WBANs are a network of multiple battery operated devices having limited energy and computational capability, lacking robustness and scalability with a demand of continuous operation. Though the technology used for communication in biosensors do not match exactly with the conventional sensor network, but a brief review of the existing work in the related area would help in establishing the ground work of our proposal.

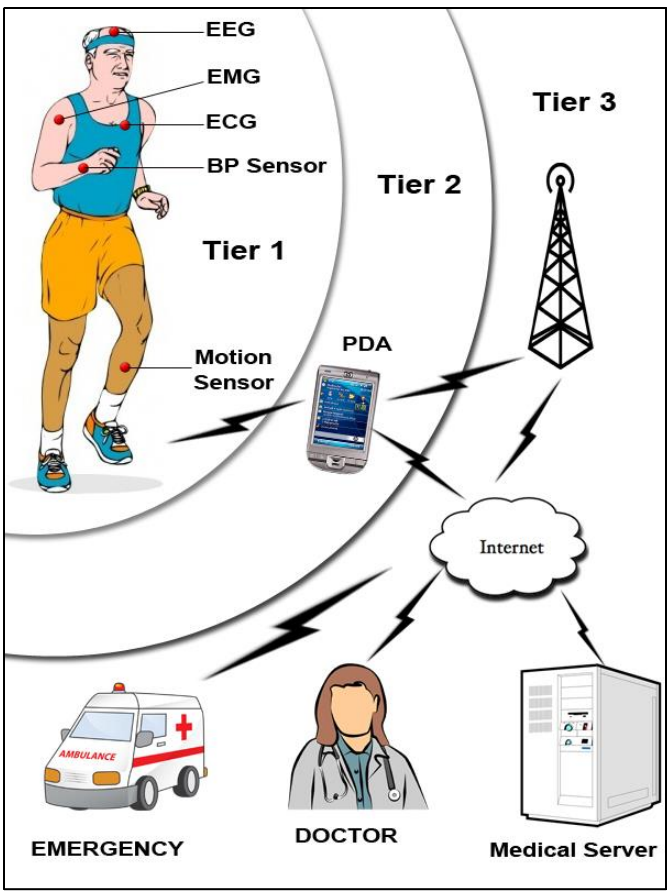

Figure 2.1: WBAN Architecture

The sensors in wearable WBANs for medical applications are capable of monitoring the sleep disorders of patients, sleepiness at work and drowsy drivers, monitoring allergic agents in air for asthma patients, assessing soldier fatigue and battle readiness in battle field, and glucose diagnoses of diabetic patients. The sensed data is collected into an intelligent node or a PDA that works as an interface between the patient and a remote server that stores the patient data. The current status of the patient is analyzed and diagnosed by the expert at the server side and appropriate medication is advised for the patient. The three layer architecture of such a wearable WBAN is provided Fig 2.1. [2]. Some of the issues involved in designing energy efficient protocols for WBANs are similar to that of between the biosensors on the wearable device and the PDA. Achieving a longer network life time for a sustainable communication between the sensors and the remote server has been a constant research issue during last few years.

Body Area Network (BAN) is a network of wearable or implanted wireless sensor nodes. Human body is composed mainly of water, which is the primary medium of transmission of information from sensor nodes to Base Station [4]. Ultrasonic waves are preferred as information carriers because of its low absorption, less heating effects in human tissue and less interference than any other electromagnetic waves. Ultra sonic waves are characterized by physical parameters such as Amplitude (A), Propagation speed(c), Pressure (p), Particle velocity(u),and Intensity(I). Attenuation of these waves in human body mainly occurs due to absorption and scattering. So, the pressure of the wave decreases with increasing distance.

Pressure at a distance d is governed by the following equation

$$P(d) = P_0 \, e^{-\alpha d}$$

Where, $\alpha = a \, f^b$

a and b are constants and f is the operating frequency.

The ultrasonic waves used for carrying information to Base Station are propagated by an electrical transducer [3]. This transducer comprises of an active element, wear plate and a backing. The active element (a piezoelectric substance) is used to convert electrical signals to mechanical waves and vice versa. The backing absorbs the radiations generated from back surface of active element and the wear plate is used for protection of active element from corrosion. The energy consumption comes from mostly from the transducer. The transducer is composed of a parallel plate capacitor, and the power consumption occurs because of charging and discharging this capacitor. The power consumption is given by

$$P_c = f \, C_0$$

Where, f is repetition frequency and Co is the capacitance.

It can also be expressed in terms of maximum pressure of ultrasonic waves Pmax, Co and thickness of transducer which is expressed as

$$P_c = C_0 \ (g_{33} \ P_{max} \ t_h)^2 \ [W]$$

Where, g_{33} is a constant that relates mechanical pressure and electrical displacement.

LEACH (Low Energy Adaptive Clustering Hierarchy) is the first energy efficient cluster based hierarchical routing protocol proposed by W. R. Heinzelman et al. in 2000 [5]. LEACH gives the guarantee about the allocation of energy in sensor node homogeneously. TL-LEACH is a protocol based on LEACH proposed by V. Loscri et al. in 2005 [11]. TL-LEACH uses two level hierarchies for the formation of clusters. Based on the ideology of LEACH, Taewook Kang et al. proposed a centralized LEACH (LEACH-C) in 2007 [12]. LEACH-C uses high energy base station for selecting cluster heads in each round. In this section, we will review two main clustering algorithms: LEACH and LEACH-C.

LEACH is one of the cluster based protocol in which one of the sensor node in each cluster acts as a cluster head. Nodes in the clusters transmit their data to cluster-head that aggregates the data (DATA FUSION) and send the data to the base station. It gives the guarantee about the allocation of energy in the sensor node homogeneously. The selection of cluster head in LEACH is dynamic in nature. There is a randomized rotation of the cluster-head position such that it rotates among different sensors and hence does not drain the battery of a single sensor. Figure 2.2 shows a simple structure of LEACH. The operation of LEACH is divided into rounds, where each round begins with a set-up phase and a steady state phase.

In Set Up phase, every node in a cluster decides whether they want to become a cluster head based on a randomized formula. The nodes select a value from 0 to 1.If the number is less than the threshold value, then it becomes the cluster head for a particular round.

$$T(n) = \frac{P}{1 - \text{P x (r mod P}^{-1})} \qquad \forall n \in G$$

$$T(n) = 0 \qquad \forall n \notin G$$

Where,

n – Random number between 0 and 1

P – Cluster head probability

G - Set of nodes that weren't cluster heads the previous rounds

Each cluster head broadcasts an advertisement message and a TDMA slot to its cluster members.

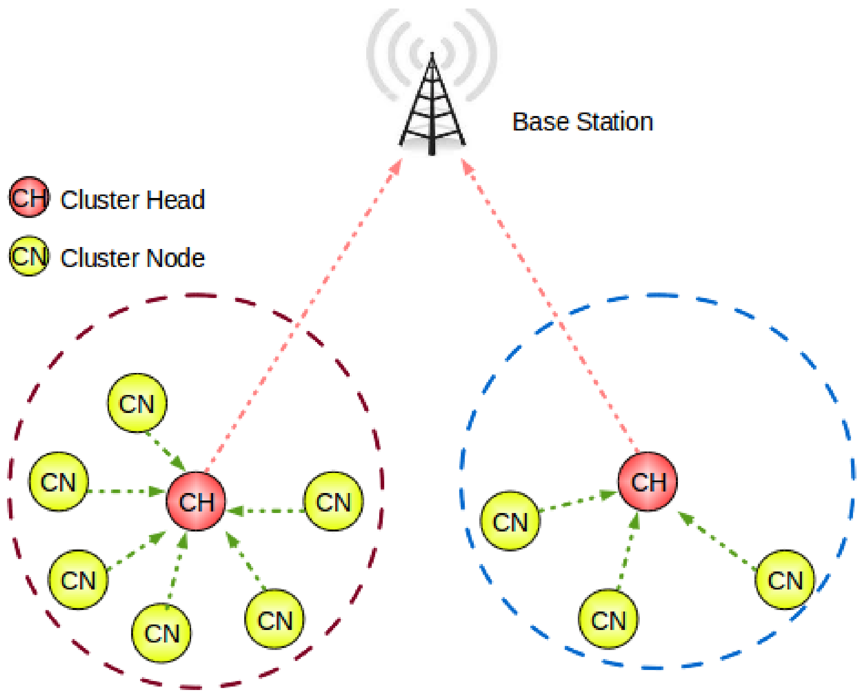

Figure 2.2: LEACH

Cluster members send their data to their cluster head on their respective time slots in the **Steady State Phase**. After receiving all its cluster members' data, it aggregates all the data received and transmit to the Base Station. This aggregation of data is called fusion which removes all the redundant and unnecessary data which saves a lot of energy required for transmission thus fostering the efficiency of wireless sensor network.

LEACH protocol is analyzed to have the following drawbacks:

- It stands on a peculiar assumption that all nodes are within the transmission range of each other and the base station, which is not feasible for most of the scenarios.

- Selection of random number of cluster heads and their random placements in the network. That is Cluster heads are not uniformly distributed.

- For cluster head sparse regions, sensor nodes have to transmit their data to long distance resulting high energy consumption.

- LEACH doesn’t consider energy consumption for cluster head selection. This may generate nodes with low residual energy as cluster heads which will lead to shorten the lifetime of network.

- Even if less number of nodes is available, then also these protocols select some definite % of members as cluster heads. So, this high frequency of selection of cluster heads even if less nodes are available wastes a lot of energy consumption.

This poor cluster set up was resolved by a central control algorithm LEACH-C that aimed to disperse the cluster heads throughout the network. This protocol differs from the LEACH only in the cluster setup phase. During this phase, the base station selects the cluster heads depending on their available battery power. But in LEACH-C, cluster heads are not uniformly distributed. Some cluster heads may be scattered in one particular region while some regions may not contain any cluster heads. So, for those **cluster head sparse regions**, sensor nodes have to transmit their data to long distance resulting high energy consumption which can be reduced if some of the cluster heads from **cluster head dense regions** were present.

After the cluster heads are selected it follows a similar procedure as LEACH to send data to Base Station. But in cluster head selection, each sensor has to transmit data to Base Station causing high energy consumption. Energy Transmission is given by

$$E_{trans}(k,d) = E_{elec} * k + \epsilon_{fs} * k * d^2 \qquad if\ d < d_0$$

$$E_{trans}(k,d) = E_{elec} * k + \epsilon_{mp} * k * d^4 \qquad if\ d \geq d_0$$

Here threshold,

$$d_o = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$$

The transmission energy of transmitting a k-bit message for the distance d will cost E_{trans}; ϵ_{fs} and ϵ_{mp} are the power consumption of transferring 1 bit of data in different condition. In LEACH-C, Base Station always selects sensor nodes with high residual energy as cluster heads, so the sensor nodes live for longer period as compared to LEACH.

Chapter 3

Proposed Algorithm

As once sensors are implanted in body, it becomes difficult to replace them. So, we are focusing mainly on increasing the life span of network. Thus we propose a protocol, Distributed Cluster Head Protocol that achieves the required goal by reducing average energy consumed in the network through uniform distribution of cluster heads.

3.1 Distributed Cluster Head Protocol (DCH)

As discussed by the authors of [1], wearable WBANs are somehow similar to MANET with respect to group based movement rather than the node based movement. There exist several routing protocols for MANET [1] and WSN [1]. However, those are not suitable for the WBANs as the network is more energy constrained in comparison to the others. The proposed algorithm aims to achieve a longer network life time in order to avoid frequent recharge or replacement of the nodes in the wearable WBAN device.

Basics of the algorithm

The proposed algorithm has three stages in a round. The **cluster head selection** phase, in which virtual cluster heads are selected evenly distributed throughout the network, the **cluster formation** phase, in which the cluster members affiliate to the cluster heads and the **steady state** phase, in which the data transmission takes place. Each of these stages has been described in detail.

Assumptions for the proposed algorithm:

- Every node has a distinct ID.
- Base Station has infinite amount of energy.
- All the sensor nodes are capable of sending and receiving data by adjusting their transmission power.
- All the sensor nodes have the ability to put themselves in sleep state when no data is available to transmit.
- All the sensor nodes may or may not be in the communication range of the base station.
- All the sensor nodes are static.
- All the sensors are time synchronized by the base station and start the cluster head process at the same time.

Cluster Head Selection: The entire WBAN is divided into number of logical clusters. Every cluster has a cluster head that works as the local coordinator for that cluster. The base station selects the cluster heads depending on its degree of connectivity and its available battery power. The weights of each node are calculated as:

$$w_i = w_1 * |n_i| + w_2 * energy_{avail} \quad (1)$$

The degree of connectivity $|n_i|$ decides how many members can be served by a cluster head A higher degree of connectivity is preferred to reduce the number of cluster heads in the network and for uniform distribution of cluster heads in the network. $|n_i|$ ensures the cluster heads are formed where density of nodes is high. Reducing the number of cluster heads will reduce the aggregation cost of the same data sensed by the nearby sensors. However, too less or too many numbers of members result in poor performance of the network. So this number needs to be optimized in future work.

$energy_{avail}$ is the currently available energy of the node. This decides the life time of a node. A node having higher available energy is preferred to become the cluster head so that it does not die out while forwarding the data from its members.

w_1 and w_2 are weighing factors for degree of connectivity and residual energy respectively, such that, $w_1 + w_2 = 1$

Higher value of w2 is preferred in order to give more weightage to energy factor as compared to connectivity factor because life span of network is very much significant in case of WBAN.

Once the nodes compute their corresponding weight, they transmit to the IPDA along with their IDs. Being an intelligent device the IPDA has the knowledge of the sensor locations. After receiving the weight information from the sensors, the IPDA finds the node having the highest weight. During the initial cluster head selection phase, the node having the highest weight is selected as the first cluster head. In case of tie, any node could be chosen randomly as the cluster head. This is understood that, during initial cluster setup phase a node having the higher connectivity is selected as the cluster head as all the nodes have equal battery power initially. This stage is followed by the cluster formation phase.

Cluster Formation: As the initial cluster head is selected, the base station broadcasts the ID of the cluster head. The node having the same ID makes its status as a cluster head and its immediate neighbors affiliate to the cluster head as members and set their status accordingly. Thus the cluster head selection and formation takes place for rest of the nodes in the network till all the nodes abstain the status as either a cluster head or a member node.

The subsequent cluster member affiliation stage works as follow:

If neighbor of 1 CH then affiliate

Else if neighbor of > 1 CH then affiliate to the one with highest available energy.

Steady State: This stage is the last stage of the round. The members of the cluster forward the sensed data to the cluster head during their TDMA time slot. The TDMA mechanism allows the idle nodes to enter into sleep state during their slot by further saving the energy. Finally the cluster head aggregates the data and removes the redundant data from the nodes of the same cluster before sending to the base station or the PDA. The elimination of the redundant data reduces the data size to be transmitted to the base station. This reduces the amount of energy consumed by the cluster head. Factors that results to energy consumption by the cluster head is defined by the equation is as:

Energy Consumption by non-cluster heads:

$$E_{non-CH} = bE_{elec} + b \in_{fs} (d_{to\_CH})^2 \tag{2}$$

Where, d_{to_CH} is the distance from the node to the cluster head. E_{elec} is transmission electronics energy per bit. $\in_{fs}$ and $\in_{mp}$ are transmission amplification energy per bit per area.

Energy Consumption by non-cluster heads:

$$E_{CH} = b\, E_{elec} \left(\frac{N}{k} - 1\right) + bE_{DA}\, \frac{N}{k} + bE_{elec} + b \in_{mp} (d_{to\_BS})^4 \tag{3}$$

Where, b is the number of bits in each data message, d_{to_BS} is the distance between the cluster head and the BS. E_{DA} is aggregation energy per bit, N is the total number of nodes and k is the number of clusters.

So,

Total Energy Consumed by a Cluster:

$$E = E_{CH} + (\frac{N}{k} - 1)E_{non-CH} \tag{4}$$

Total Energy Consumed by Network:

TE = E * k

$$= b(E_{elec}\, N + E_{DA}\, N + k\ \epsilon_{mp}\ (d_{to\_BS})^4 + E_{elec}\, N + \epsilon_{fs}\ (d_{to\_CH})^2\, N) \quad (5)$$

Optimal number of clusters, k_{opt} , can be found by setting $\frac{d(TE)}{d(k)} = 0$

Hence, $$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}\ \frac{M}{(d_{to\_BS})^2} \quad (6)$$

Where, M x M is total area of the network

At the end of every round the available energy is recomputed as follows:

$$Energy_{avail} = energy_{avail} - energy_{consumed} \quad (7)$$

3.2 How DCH Protocol is Advantageous?

The fixed transmission range distributes the cluster heads uniformly on the whole area which minimizes energy consumption. It means the whole area is divided into various overlapping transmission ranges. So there is a cluster head at every distance of transmission range. So the maximum energy spent by any sensor node will be the energy required to transmit data for a distance of transmission range saving a lot of energy consumption.

Every node transmits their data to the cluster head which falls in its transmission range only so no transmission is lost. Their data reaches to its respective cluster head error free.

If little number of nodes is available, only required number of cluster heads are formed which reduces the frequency of clustering thus reducing energy consumption. If fewer nodes are available and closer to each other, then also the previous protocols would have made the fixed % of cluster heads which is not required. In our protocol, this doesn't happen as the closer nodes will fall under one transmission range creating only one cluster head for those nodes. This reduces the frequency of clustering saving a lot of energy.

Our protocol is also better than LEACH protocols in terms of cluster head selection process as in our protocol, Base station selects the cluster head based on the residual energy of sensor nodes not on the randomized function as in case of LEACH. This ensures that higher energy nodes always become the cluster heads enhancing the longevity of sensor nodes.

Chapter 4

Simulation Results and Analysis

Comparison between LEACH protocol and LEACH-C protocol has been simulated using MATLAB. Table 4.1 shows the simulation parameters. The nodes are randomly distributed between (0, 0) and (400, 400).

Number of Nodes	100
Network Size	400m x400m
Base Station Location	(200,200)
Initial Node Energy	0.5J
Number of Cluster Heads	10
Maximum no. of Rounds	2500

Table 4.1

Figure 4.1 shows the comparison between LEACH and LEACH-C. X axis represents number of rounds of simulation and Y axis represents number of sensor nodes alive.

4.1 Case Study analysis for different locations of Base Station

Whole Sensor Network Area is divided into 4 regions, having different priorities. Here priority is related to frequency in use i.e. higher priority region is used more frequently to communicate with Base Station. More sensors are deployed in higher priority area than a less priority area.

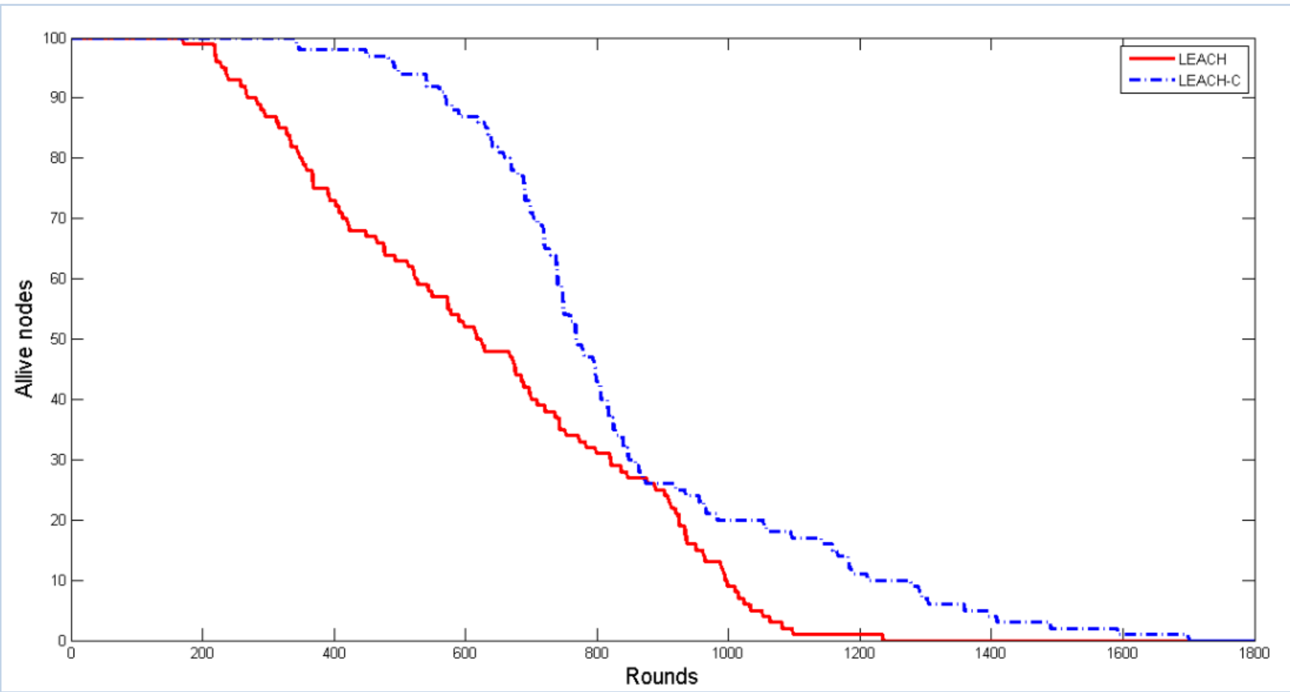

Figure 4.1: LEACH vs LEACH-C

Figure 4.2 shows four regions. A whole network area is divided into four regions with different specifications.

We have taken two cases:

Case 1: Base Station Location is nearer to one of the regions

Here Base Station is at (450,200) i.e. nearer to Region 1 and Region 4. This case is simulated using MATLAB with simulation parameters as in Table 4.2.

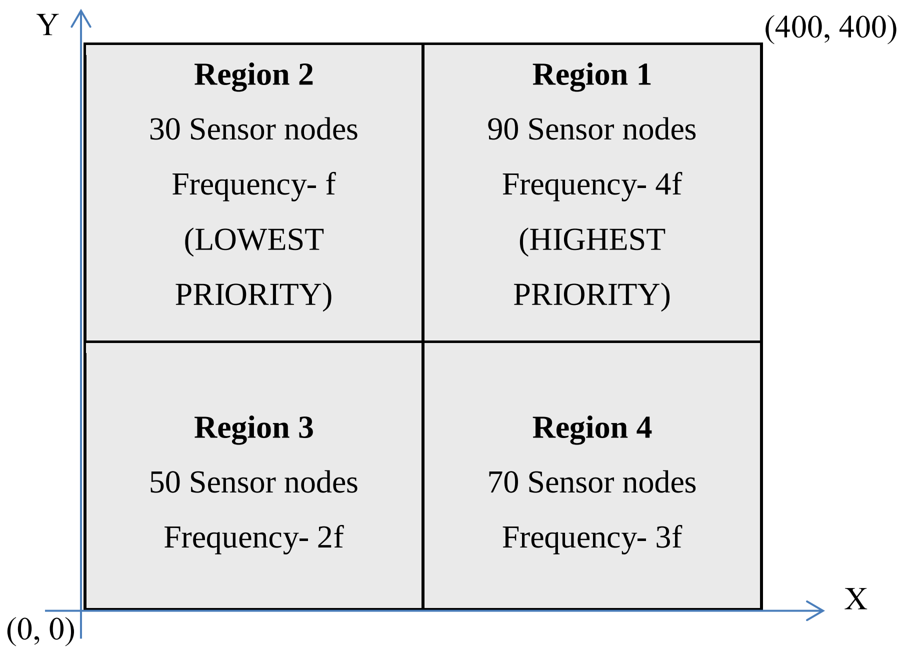

Figure 4.2: Four Regions

Network Size	400m x400m
Initial Node Energy	0.5J
Number of Cluster Heads	10% in each region
Maximum no. of Rounds	2500

Table 4.2

$$\textbf{Time for which nodes are alive } \alpha \frac{\textbf{No of Sensor Nodes}}{(\textbf{Frequency In Use} \times \textbf{Distance From BS})}$$

which is shown evidently from Figure 4.3 having X axis as number of nodes alive and Y axis as time steps.

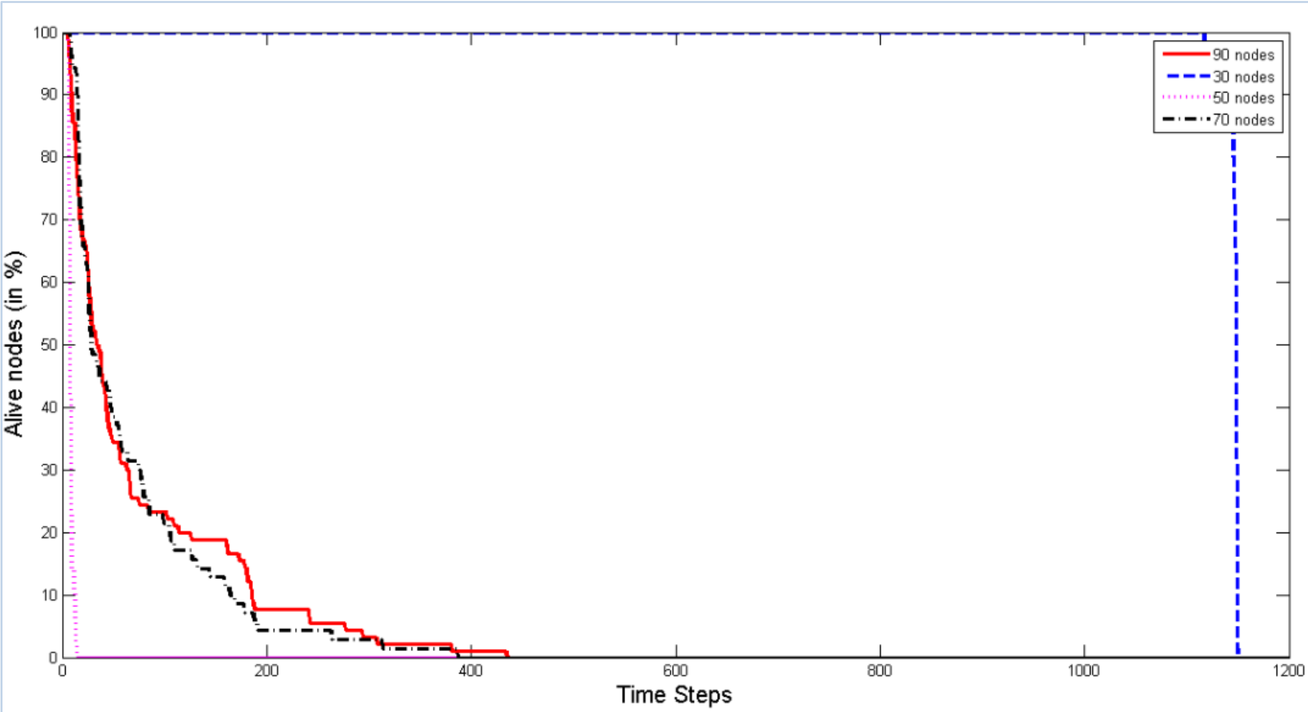

Figure 4.3: Location of BS is nearer to one of the four regions (Case 1)

Case 2: Base Station Located in center

Here the regions are divided same as according to Fig 4.2, with only difference that Base Station is located at center (200,200) i.e. equidistant to all the regions.

So,

$$\textbf{Time for which nodes are alive } \alpha \frac{\textbf{No of Sensor Nodes}}{\textbf{Frequency In Use}}$$

It is simulated in MATLAB having the simulation parameters as Table 4.2. As we can see that Figure 4.4 follows the above equation.

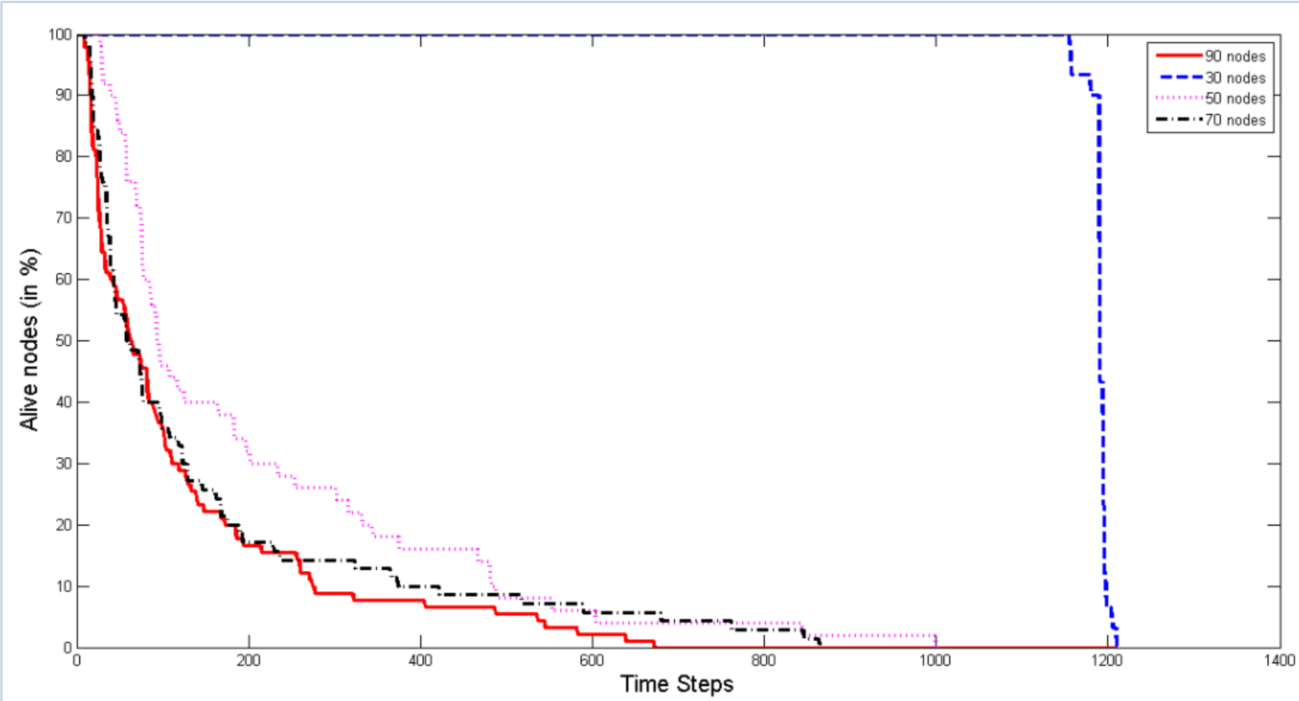

Figure 4.4: Location of BS is at the center (Case 2)

4.2 Simulation of DCH Protocol

Simulation for the proposed protocol is done in MATLAB with the parameters given in Table 4.3. The nodes are randomly deployed in a simulation area of 400 X 400. Considering the nodes to communicate to a PDA, it is located at a distance 500 X 500 for the simulation.

Number of Nodes	100
Network Size	400m x400m
Base Station Location	(200,200)
Initial Node Energy	0.5J
W_1	0.4
W_2	0.6

Table 4.3

The reason for considering a higher value for w_2 than that of w_1 is to give a higher weightage to the available battery power than the number of nodes to be served by a node if selected as a cluster head. Fig. 4.5 indicates the % of nodes being selected as cluster head when the transmission range of the nodes is varied for different values. It is seen that as the transmission range of the nodes are increased, the number of clusters takes a gradual decay as the degree of connectivity of the nodes increases. This is in contrast to the existing LEACH, and C-LEACH protocols, where a fixed % of nodes are selected as the cluster heads. Typically 5% as indicated for 100 nodes. And 5% corresponds to 95m transmission radius as from Fig. 4.5. 95m is taken for further simulations.

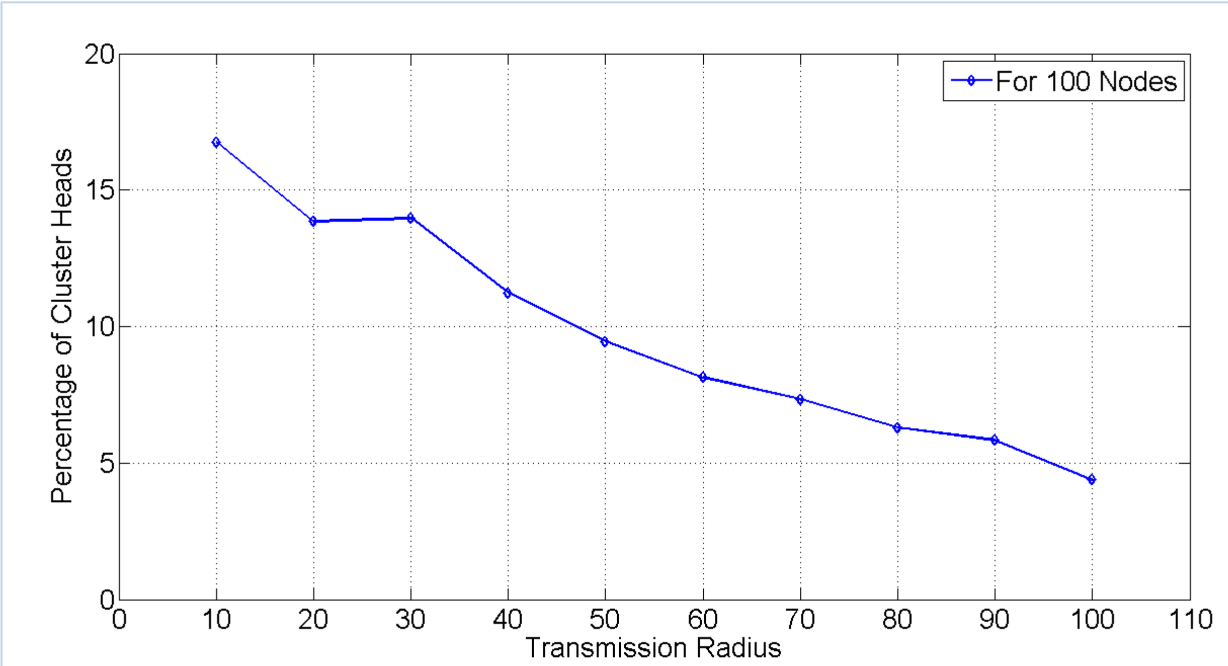

Figure 4.5: Percentage of clusters for different transmission ranges

Fig. 4.6 indicates the distribution pattern of the sensors in the clusters. In LEACH, the cluster heads are selected randomly irrespective of their position of deployment in the network. The result shows that the average number of members affiliated to a cluster per round is less in case of our proposed algorithm. This is due to the uniform distribution of the members in all the clusters.

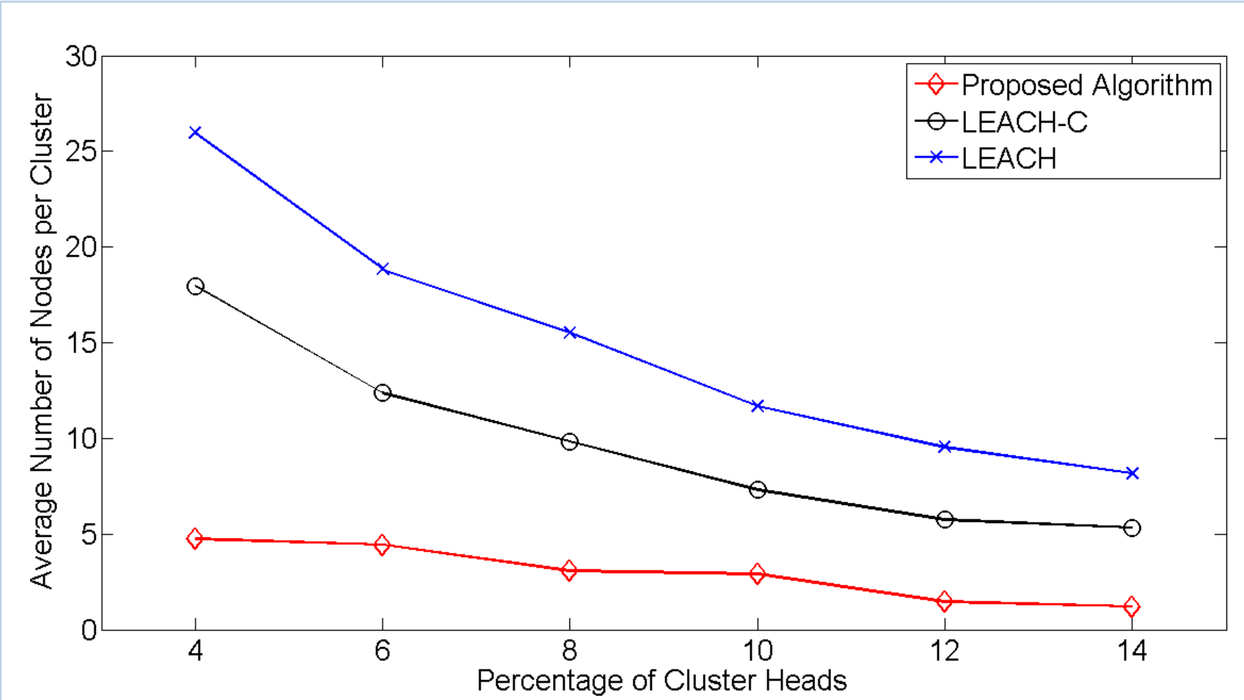

Figure 4.6: Distribution of sensors per cluster

It is understood that the sensor nodes consume energy while transmitting or receiving or aggregating the data. The member nodes consume energy only when transmitting the sensed data to the local cluster head. Thus their energy consumption could be calculated as below:

$$E_{non-CH} = bE_{elec} + b \in_{fs} (d_{to\_CH})^2 \tag{1}$$

Where d_{to_CH} is the distance between a node and the cluster head. E_{elec} is transmission electronics energy per bit which is set as 50 nJ/bit. $\in_{fs}$ and $\in_{mp}$ are transmission amplification energy per bit per area.

ϵ_{fs} = 10pJ/bit/m2 when $d < d_o$

ϵ_{mp} = 0.0013pJ/bit/m4 when $d >= d_o$

Where d_o is threshold distance,

$$d_o = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$$

The scenario is different for a cluster head. It receives the data from the local members, aggregates the data to eliminate the redundancy and forwards the data to the base station. So the equation for the energy consumption equation by the cluster head has three components as receiving energy, aggregation energy and transmitting energy as below: (2)

$$E_{CH} = b\ E_{elec}\ \left(\frac{N}{k} - 1\right) + bE_{DA}\ \frac{N}{k} + bE_{elec} + b\ \epsilon_{mp}\ (d_{to\_BS})^4$$

Where b is the number of bits in each data message, d_{to_BS} is the distance between the cluster head node and the BS. E_{DA} is aggregation energy per bit which is set as 5nJ/bit.

Fig. 4.7 indicates the comparison of average energy consumption per cluster in the protocols. It is seen that the proposed algorithm consumes the least energy per cluster. The reason for such result is the uniform distribution of the clusters throughout the network and load balance among the cluster heads while serving the members.

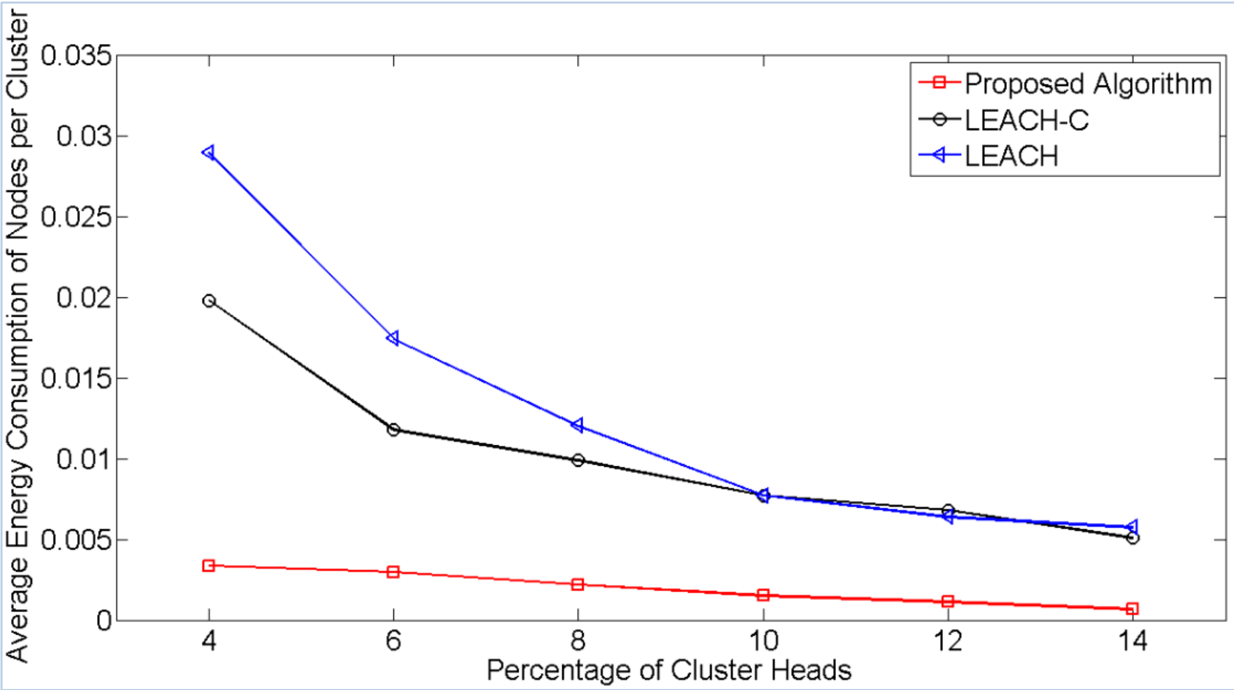

Figure 4.7: Comparison for average energy consumption

We take different radius of transmission range and simulated the protocol and compared the results with LEACH-C. The Fig. 4.8 shows total number of nodes that remain alive for the simulation time of 2500 rounds.

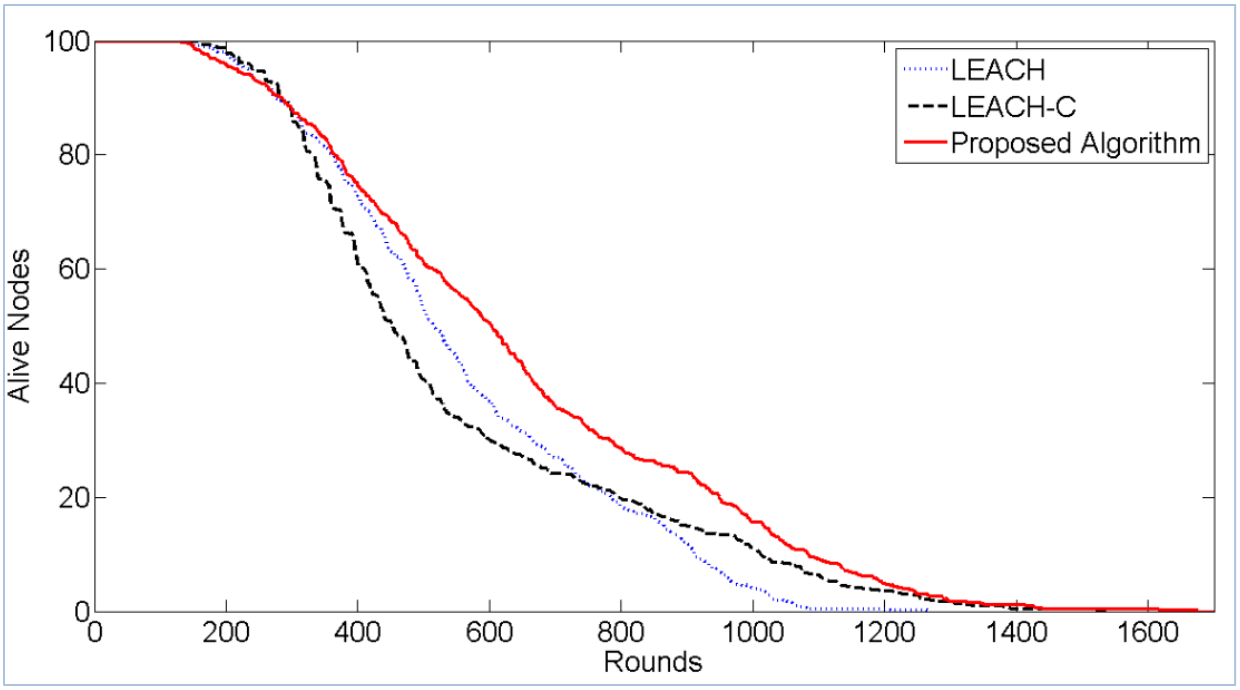

Figure 4.8: Comparison of algorithms for number of alive nodes in different rounds of simulation

Chapter 5

Conclusion

From the above simulation, it can be seen that the proposed algorithm shows better results than LEACH and LEACH-C. As the number of nodes per cluster in proposed algorithm is very less as compared to other protocols for same percentage of cluster heads, the average energy consumption per cluster is less which increases the lifetime of whole sensor network. Same as LEACH, it also distributes the load over network uniformly by rotation of cluster heads in each round. But the transmission radius factor in cluster head formation process in the proposed algorithm ensures the distribution of cluster heads remains uniform in the whole network thereby escalating the efficiency of network which may not be the case in other protocols. It also ensures that every sensor node falls inside the transmission radius of some cluster head, so there is no possibility of transmission loss thus saving energy consumption as compared to other protocols. Also this scheme allows more number of nodes to be alive till the end of network lifetime. Simulation is done MATLAB. From the results and analysis, it can be concluded that DCH routing protocol provides better performance in energy efficiency and hence increases the lifetime of wireless sensor networks.

Dissemination

S. Upadhyaya, R. Patel, S. Chinara, and M. Sarkar, “Design of Energy Efficient Protocol for Wearable WBAN”, IEEE Global Communication Conference (GLOBECOM 2015), San Diego, USA (Communicated 15th April, 2015).

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