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Energy Efficient Routing Protocol Based On Adaptive Clustering For Multi-Hop Infrastructure-less Wireless Network

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Abstract

Wireless Sensor Networks (WSNs) are the infrastructure-less multi-hop network which can be self-configured. It monitors physical as well as environmental conditions. WSNs contain of a huge number of nodes and these nodes of WSN have capabilities of sensing, computation as well as communication and are normally multifunctional, low cost & low power. The sensor node sense the data where they are utilized perform computation on that particular data and later communicate it with other nodes. During this process a lot of energy is consumed. The batteries attached to the nodes provide power supply and it cannot be recharged or replaced in most cases, so the energy consumption is limited. Hence the efficient routing protocols should be developed in sequence to maximize networks lifetime energy. This paper focuses on various energy efficient routing protocols which are utilized in WSN and try to develop a new advanced protocol which will outperform all the previous existing protocols. This paper help to analyzes (LEACH) protocols and develops an advanced protocol for its up-gradation.

Keywords: Cluster Heads (CHs), Cluster Members (CMs), Full Node Dead (FND), Half Node Dead (HND), Improved Low Energy Adaptive Clustering Hierarchy (iLEACH), Low-energy Adaptive clustering Hierarchy (LEACH), Minimum transmission energy (MTE), Wireless sensor and actuator networks (WSAN), Wireless Sensor Networks (WSNs).

1. Introduction

WSN is an automatic configured as well as infrastructure slighter wireless network. It's also known as wireless sensor & actuator networks (J N Al-Karaki & Kamal, 2004; Wajgi, 2014). It monitors physical as well as environmental conditions like temperature, pressure, sound (Liu, 2012). WSNs networks not only sense but also compute the data which is transmitted between the various networks (Mohd Waes Siddiqui, 2016). WSNs interconnect various sensor devices in order to perform specific tasks. Some sensor nodes containing of four cardinal components: sensing unit (captures data from the environment), processing unit (responsible for the data processing that is being received from the sensing unit), and transceiver unit (performs the functionality of transmitter as well as receiver) and power unit (provides sufficient energy to power the system).

The sensor node can self-orientate to form the networks that can communicate with one another in a wireless way. Each node collects data from the network, exchanges the collected data with other nodes & finally sends the information to the destination node or to the base station. Generally, WSNs contains thousands of the sensor node and these nodes can transmission with each other with the help of radio signals. The equipment used in wireless sensor node are computing devices and sensing, power components and radio transceiver. After the utilization of sensor nodes, they

are accountable for self-orientation of an efficient networks infrastructure commonly with multi-hop transmission within them. After that collection of information starts via onboard sensors. The mode of working in a sensor node is either event driven or continuous. The energy consumption as well as designing routing protocols is major issues in the WSN. The choice of ways is selected by using routing algorithms (Manal Abdullah, 2014; Shraddha Fulkar, 2014). The routing protocols determine the communication of various routers in between the destination and source in a networks (Heinzelman et al., 2000). The following things must be considered before design a routing protocol:

- Resource limitation and energy
- Long life timing
- Loss of packet is less and delay
- Dynamic adjustability of networks

The better energy efficiency as well as longer life time is achieved by the clustering method used in WSNs. In the clustering algorithms the networks are divided into various clusters. In every cluster there is some root nodes which is known as cluster head & the endure nodes are called appendage of the clusters. In sequence to conserve the energy of networks sensors the clustering of sensors into smaller groups plays a vital role, and also increases network lifetime. In clustering, a large numbers of sensors are grouped into the small clusters and each cluster has a Cluster Head and all other sensors are Cluster Members. With the help of low-power short-distance transmitting technique sensors transmit the sensed data to their respective CH. Further CHs pile up the data and send the collected data to the destination using high-power long-distance transmitting technique therefore, CHs run out of energy earlier than other members of cluster (Claudio Silva, Rodrigo Costa, Adonias Pires, Denis Rosário & Kássio Machado, Augusto Neto, 2013). For the effectiveness of clustering, the proper scale and number of clusters is important else the network cannot enjoy the advantages of clustering. The large number of clusters results in a formation of CHs inside the network and those CHs has to communicate with the destination with the help of long-distance communication technique. On the other hand, a small number of clusters results in a formation of clusters with big diameters, due to which a large amount of energy is consumed in sending data from the CMs to CHs. In order to increase the effectiveness of clustering CHs should be distributed uniformly in the network. There are two types of operations in clustering protocol:

- Intra-cluster communication [Communication between different clusters]
- Inter-cluster communication [Communication within a cluster]

1.1 LEACH- A Cluster Based Routing Protocols

LEACH protocol is the first & most remarkable hierarchical routing protocols that provides the data fusion (Lalita Yadav, 2014). It is based on a round protocol and is self-organized as well as self-adaptive. Each protocol will be organized into the two phases i.e. Steady state and Setup phase. The setup stage is kept little than the stage of steady state (Gill & Sachdeva, 2018). The setup phase has advantages (Table 1) over a steady state stage as in the setup stage the sensor node itself elects the cluster heads randomly and different networks clusters are formed and later these cluster heads planned a TDMA plan for their members of cluster node.

Table 1. Advantages and disadvantages of LEACH protocol.

Advantages	Disadvantages
Improves the lifetime	It is unaware about the total numbers of cluster head in the full networks
Balances the energy consumption	If the cluster head die due to some reason the cluster become useless or headless

Reduces the traffic in the network	There is uneven distribution of clusters
Does not require a central node or coordinator	
To create cluster location information of nodes are not required	
It is completely distributed and doesn't require any global knowledge of the network	
It efficiently distributes the energy load to each sensor nodes	

1.2 Research Questions

How I Leach technique is reducing the energy dissipation in sensor nodes?

1.3 Literature Survey

"Routing Techniques in Wireless Sensor Networks: A Survey" research paper by Jamal N. Al-Karaki et al., Outlines the design issues for routing protocols in WSNs, moreover it also provides a comprehensive investigate of routing technologies and techniques. It discusses design trade-offs in between communication overhead and energy. This paper highlights the advantages as well as performance problems in each routing protocol. This article alss gives the outputs the feasible future research perspectives(Jamal N. Al-Karaki & Kamal, 2004).

"An Energy Saving Algorithm To Prolong The Lifetime Of Wireless Sensor Network" research paper by Monika Raghatate et al., focuses on improving lifetime of WSNs thereby reducing the energy consumption by developing an energy saving algorithm in which clusters are formed on the basis of a subset of high energy nodes as a CH and different subset of the powerful nodes are asked to go to sleep. When CH consumes all their energy then another subset of nodes becomes active & acts as a CH. The Proposed technique is executed in MATLAB and the Simulation results confirm that it successfully prolongs the networks lifetime as juxtapose to the LEACH protocols(Raghatate & W. Wajgi, 2014).

"A Survey on Clustering Routing Protocols in Wireless Sensor Networks" research paper by Xuxun Liu presents a comprehensive survey on clustering routing protocols in WSNs. This paper outlines the advantages as well as aims of clustering in WSNs & also develops a novel categorization of the WSN clustering routing techniques on the basis of complete clustering elements(Liu, 2012).

"Application of Alternate Energy Efficient Clustering Protocols for Heterogeneous Networks" research paper by Mohd Waes Siddiqui et al. analyzes the various heterogeneous routing protocol on the depend of clustering and also suggests an efficient approach towards attaining energy efficiency in the term of a hybrid energy well organized protocol(Mohd Waes Siddiqui, 2016).

"Routing Protocols for Wireless Sensor Networks: Classifications and Challenges" research paper by Manal Abdullah et al. classifies the routing protocols that are suggested for WSNs. The categorization is done on the basis of 5 main key elements: energy efficiency, routing objectives, operational models, route selection and networks infrastructure. Few of these basis is further categorized in detail. This paper also gives attentions some of the overlapping attributes of few protocols. The structure issues of WSNs are discussed along with its future application area(Manal Abdullah, 2014).

"Energy Efficient Resource Allocation in Wireless Sensor Networks" research paper by Shraddha Fulkar et al. Proposes mc-ACO (ant colony optimization) method along with SSMTT (sleep scheduling numerous tracking the target) algorithms. With the help of both the methods the sensor nodes are scheduled due to which it wakes from sleep mode to active mode whenever it is required. This not only gives better resource allocation of sensor nodes but also extend the networks lifetime(Shraddha Fulkar, 2014).

"Energy-Efficient Communication Protocol for Wireless Microsensor Networks" research paper by Wendi Rabiner Heinzelman et al. Proposes a LEACH protocol in which Simulations show that LEACH can attain a factors of

8 depletions in energy debauchery as compared to the standard routing protocols. Moreover, LEACH distributes the energy debauchery evenly to all the sensors, which results in doubling the lifetime of the battery(Heinzelman et al., 2000).

"A Cluster-depend Approach to supply Energy-Efficient in WSN" research paper by Claudio Silva et al. suggest an augmentation of LEACH protocol, called Cluster-based technique for Energy-efficiency in WSNs (CLENER). CLENER combines various metrics to overcome the above drawbacks regarding CH selection and cluster formation thereby balancing as well as reducing the energy consumption between the nodes. The CLENER provides energy efficiency by using a probability function for CH selection and fuzzy logic for cluster formation. Simulations show the benefits of CLENER as compared to LEACH and EECHS. Simulation results show that CLENER enhances the network lifetime by 19% and 18%, and also increases the packet delivery ratio of LEACH by 15% and EECHS by 14%(Claudio Silva, Rodrigo Costa, Adonias Pires, Denis Rosário & Kássio Machado, Augusto Neto, 2013).

Low Energy Adaptive Clustering Hierarchy in Wireless Sensor Network (LEACH)" research paper by Lalita Yadav et al. suggested a new improvised cluster algorithms of LEACH protocols which is focused on balancing the energy expending of the networks and enhancing the lifetime of the network.

"Study of LEACH Routing Protocol for Wireless Sensor Networks" research paper by Reenkamal Kaur Gill et al. analyzes LEACH protocol and its phases, advantages and disadvantages and also various types of attacks on the routing protocol. The result shows that LEACH protocols is vulnerable to several types of attacks and is explained in thorough in this proposed research paper(Gill et al., 2014).

The present study is based on various energy efficient routing protocols which are utilized in WSN and develops a new advanced protocol for its up-gradation which outperforms all the previous existing protocols. This paper overcomes the several issues present in the earlier studies like design issues for routing protocols which results in improving the lifetime of WSNs. It overcomes the drawbacks regarding CH selection as well as cluster formation which results in balancing and decreasing the energy utilization in between the nodes.

2. Methodology

2.1 Low Energy Adaptive Clustering Hierarchy Protocol

In LEACH protocols, the node in WSNs can take a resolution to become a clusters head considering the given expectation independently and then it elects the cluster heads as well as reorganizes the network after a specific time period. Due to this the energy consumed by cluster heads is decreased to prolong the networks lifetime. LEACH modify the clustering protocol in order to assign the energy utilization to the sensor node utilized in the networks. By following this method energy regulation of the wireless sensors networking model improves beyond the standard clustering architecture and it increase the life time of the networks. Wireless sensor networking nodes form several wireless networking models i.e. several local clusters LEACH protocol and in every local cluster, there is a node which acts as the cluster head or platform station. Therefore, each node in the local cluster sends the data to the cluster head in that particular local cluster. LEACH outperform the normal cluster architecture as it uses the highly efficient technique i.e. using the randomization clusters head selection techniques which depends on the energy left in the node, on the hand the nodes battery evacuates very quickly as in normal cluster architecture the cluster head is not selected randomly.

The cluster head is selected with some fixed probability, and in every local cluster the cluster heads broadcast their status to the sensor nodes using CSMA MAC protocol. As illustrated in (Figure 1) every sensor node chooses a cluster head which is closest to them based on the energy of the broadcast message from the various cluster heads. The sensor node consumes the minimum communication energy in order to join that specific cluster with its cluster head.

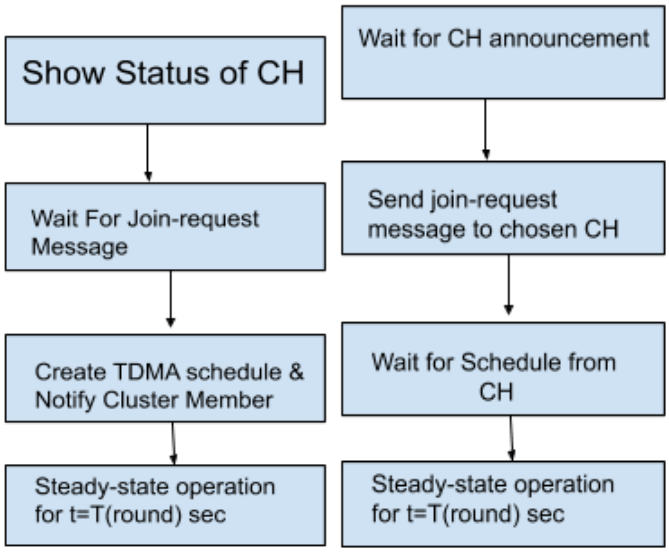

Fig. 1. Set-up stage: LEACH Protocol when node is a clusters head (left) when node is not a clusters head (right).

After the termination of the clustering stage the next phase is the setup stage, each CH schedules the node in its clusters. The clusters head generate a TDMA plan depend on the total numbers of node in the clusters which tells every node when it can transfer the data. It is assumed that the node always has the data set to transfer and it sends the data during their located time period to the clusters head. In order to increase the efficiency, every sensor node turns off the radio and waiting for their located time as demonstrated in (Figure 2). The efficiency can be increased more by implementing CSMA protocols by turning off/on the radio and waiting for their located time. After receiving the data, the clusters head implements defined information aggregation functions in order to flatten the data set into an individual signal. With the help of a fixed escalate code using the CSMA, the clusters heads transmit these data packets. This helps in avoiding the inter-cluster intervention by CSMA techniques as well as the intra-clusters interference by TDMA. According to this hierarchy of protocols, the CH receives data set from every sensor nodes and makes sure that the end user gets access to the data.

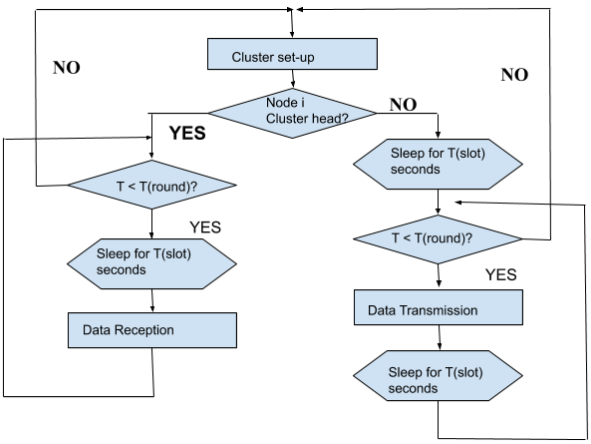

Fig. 2. Steady-state stage: LEACH Protocol

Some sensor nodes assume a numbers between 0 & 1 during the setup phase. If this assumed numbers is lower than threshold T [n] then the sensor nodes is CH. T [n] will be calculated as:

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

Otherwise,

$$T(n) = 0;$$

Where,

P = The aspired (%) to becomes a clusters head

r = The current roun

G = set of node which isn't preferred as a cluster head in the last 1/P rounds

After the cluster heads are selected, the CH informs all sensor nodes in their range with the help of CSMA MAC protocols that it is the new clusters heads. Once the sensor node receives the information, it determines the clusters to which it belongs on the basis of the signals strength of the information from the CHs to the sensors node. The sensor nodes then inform the relevant CHs that they will be a member of the cluster. After that the cluster heads allot the time based on a TDMA approach in which the sensor nodes can send data to the CHs. The sensor nodes sense as well as transmit data to the CHs during the steady-state stage. The clusters head also collects data from the nodes in their respective cluster before it sends those data to the base station. After a fixed period of time consumed in the steady-state stage, the networks go back to the setup stage again & another circle of selecting cluster heads is initiated. In the next cluster setup stage, the member node informs the CH that it has become a appendage of that particular cluster and sends an information message with the help of CSMA MAC protocol. In this round every non-cluster head node arbitrates its cluster head on the basis of received signal strength. Cluster arbitrate sends a join-request message to its selected cluster head with the help of CSMA MAC protocols. Cluster head nodes sets the TDMA schedule mechanism for the data communication within the clusters as demonstrated in Figure 3.

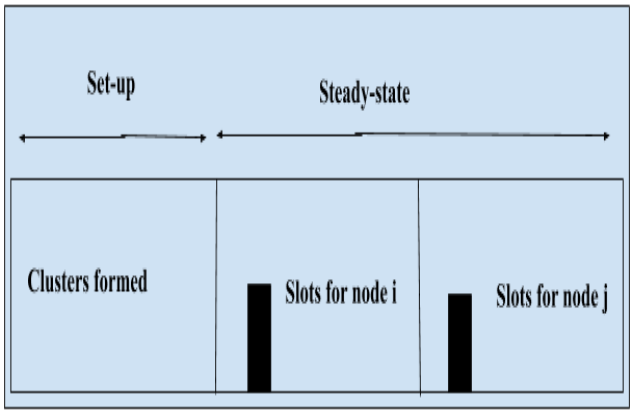

Fig. 3. Leach operation cycle

When the data communication is initiated the node send the data the CH only during their located TDMA slot. This communication technique consumes a lesser amount of energy. The radio and waiting of every non-clusters head nodes is revolving off until or unless the nodes are allocated a TDMA slot, thereby reducing energy evaporate to greater extent in these node. When the data set is received, the clusters head makes a bundle of these data & further sends it to the platform station. The LEACH clusters head is capable of gathering data in every clusters head in sequence to decreases the range of data as well as copy of data which is meant to be communicate to the platform station.

2.2 Improved LEACH Protocol (iLEACH)

LEACH deploys randomization in order to rotate the cluster heads which helps in achieving an improvement in i.e. low energy utilization. LEACH is juxtaposing with minimum transmission energy (MTE) routing technique in which the intermediary node is selected in such a way it minimizes the sum of suborn distances between the adjacent node. The

simulation results prove that the LEACH provides 10 times higher dataset than MTE routing technique for the common number of node deaths.

This paper suggests an enhancement of LEACH's CH algorithm selection in order to minimize energy utilization in which an appropriate cluster head algorithm selection increases lifetime of WSN depend on the LEACH structure. Ameliorate (iLEACH) protocol is an automatic as well as adaptive clustering protocols which uses randomization technique to contribute the energy consumption equally thorough the sensors utilized in the networks. In iLEACH, the node arranges themselves into the local clusters in which one node acts as the CH. If the cluster heads are chosen on a theoretical & fixed probability depend throughout the systems lifetime, the inaccurate sensors selected as cluster heads dies quickly and results in wasting the lifetime of every node which belong to that clusters, therefore iLEACH amends suddenly rotation of higher energy CH location in such a way that it circular among the different sensors in sequence to minimize draining of the battery to a greater extent. The suggested technique establishes the CH as well as cluster members in the WSN in the similar way as it is established in LEACH protocols. The 1st approach to improve for lifetime of the LEACH WSN is by including the endure energy level which is available in every node. It is achieved by decreasing the value of threshold T[n] which is denoted in the LEACH Equations. Therefore, T[(n] is multiplied by a factors which represents the remaining energy levels of the nodes in the below equation:

$$T(n) = \frac{P}{1-p*(r \bmod \frac{1}{p})} * \frac{En\_current}{En\_max}$$

The changed of the threshold equations by multiplying it with the endure energy that has a major disadvantage i.e. after an unquestionable round the networks is stuck, despite of the available nodes with sufficient energy to transfer data to platform station. The main cause behind this is the low threshold of CH due to the remaining node having very lower energy levels. In this proposed theory the approach is to expand the lifetime of a LEACH networks by modifying the threshold equations. It is further amended by an element that expand the threshold of every node which is not the CH for the last 1/P rounds. Instead of using the present as well as maximum energy level of the networks we have proposed the modified energy level.

The following algorithm is used in our proposed algorithm and is given as:

$$E' = E_0 * \left(\frac{1-\frac{round}{r_{max}}}{n} \right)$$

Where,

Eo = The initial energy of the nodes

Round = The present round consists of the system as well as steady state stage.

r_max = The maximum no. of rounds favored for the information transmission and sensing.

With the help of the above modified equations of energy levels (E') a new probability of becoming a CH is evaluated which further integrates the modified energy level E', energy of the network, current energy level of nodes & I associate to the single node.

$$P_{new} = \frac{P\ n\ (node(i).E\ )}{E_0\ E'}$$

The above change probability equations are used to find out the new threshold of the networks which uses the changed LEACH probability equations as shown below, which further decrease the threshold in such a manner that sensor nodes choose any random numbers between 0 & 1 during the setup phase. If the chosen random numbers are less than the threshold T(n) new, then the sensor nodes are selected as a cluster head. The T(n) new is deliberate as:

$$P_{(n)\,new} = \frac{P_{new}}{1 - P_{new} * mod(r, round\frac{1}{P_{new}})}$$

Where,

P = The admire (%) to becomes the cluster head

r = The present round.

Sensors elect themselves as CH at any point of time using the modified probability (Pnew) as shown in the above equation. These CH nodes send their position to other sensor nodes in the networks. Each sensor nodes selects the cluster in which it needs to fit by selecting the CH demands minimum transmission energy. After the organization of every node into the clusters, every CH initiates a TDMA plans for all the node in its cluster. This helps the radio elements of every non-CH nodes to be rotate off every time except the transmit time, thus it minimizes the energy dissolute in each sensor. Once the CH has received all the data from each nodes, the CH nodes compresses the data & after that it sends the squeeze information to the platform station.

Being a CH evacuate the battery of that particular nodes, therefore this energy utilization is spread over various nodes, the CH node are not fastened instead it varies its position at different intervals of time. Thus the set of G nodes selects themselves CH at time [t1], but at the time [t1 + 1] a new set of G0 nodes selects themselves as CH, as manifest in the below (Figure 4) & (Figure 5). A node is choosed as CH on the basis of the amount of energy left at that particular node.

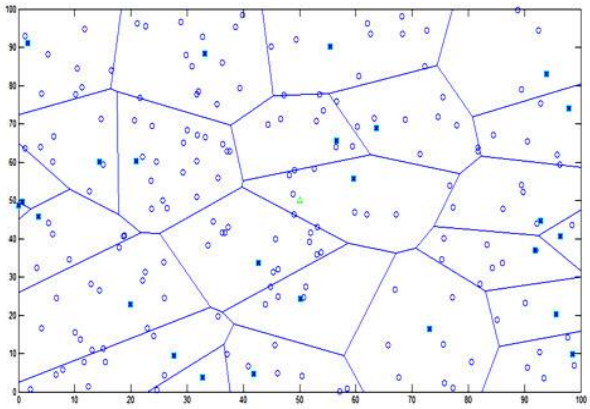

Fig. 4. Cluster head (CH) evolution at time (t1).

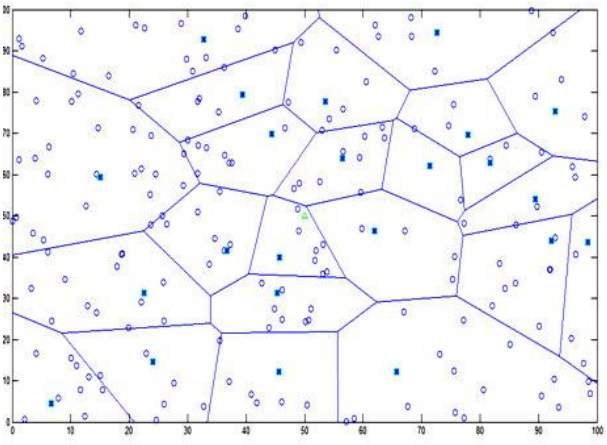

Fig. 5. Cluster head (CH) evolution at time (t1+1).

3. Result And Discussion

The results are presented which shows the relationship between network lifetime and the various system parameters. MATLAB software is used to perform simulation and the obtained results are reported in this section. The simulations presume the radio attributes and is mentioned in the below (Table 2). In this proposed theory the homogeneous sensor networks is defined with 200 numbers of sensor nodes which are distributed suddenly in the 100 ×100 m^2 areas, as shown in (Figure 4) and (Figure 5). The normal node is denoted with 'o' & cluster head with '⊡'. The platform station is denoted with 'Δ' and is placed at point (50, 50). The values used for the 1st sequence radio models are shown in (Table 2).

Table 2. The values used in the first order radio model

WSN System Parameter	
Parameters	**Value**
Number of Nodes	200
Network Size	100m*100m
Base station Location	(50,50)
Number of rounds	5000
Cluster Head Probability	0.05
Initial Energy	0.5j
Data packet size	4000 bits

The criteria to assess the execution of routing protocols in sensor networks are lifetime. The lifetime is measured in phrase of the rounds i.e. when the 1st node and half number of the node die. The iLEACH technique distributes energy consumption to all the node in the networks in such a way that the node dies randomly at the same rate which results in successfully reducing energy dissipation. LEACH is simulated in the existence of the homogeneous attributes. LEACH as well as the suggested protocol is replicate in the existence of several heterogeneity attributes which are present in the networks. The outputs of suggested algorithm as well as LEACH simulations are shown in below (Figure 6) and (Figure 7).

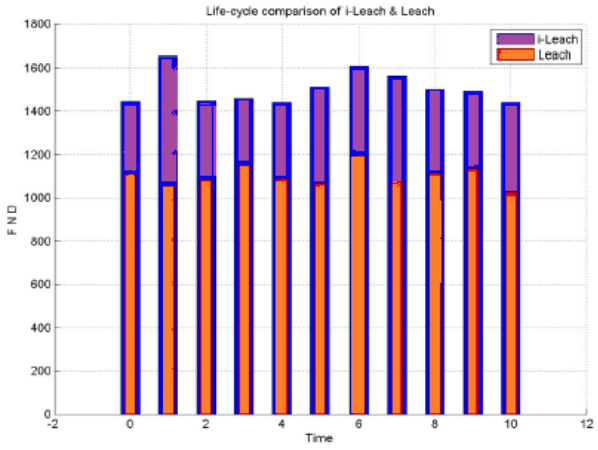

Fig. 6. The comparisons of Life cycle for full node dead (FND).

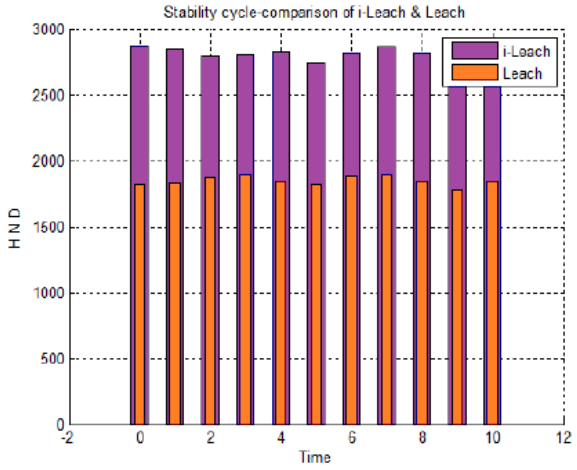

Fig. 7. The comparisons of Stability cycle for half node dead (HND).

The 1st node dies earlier in cases of LEACH as shown in (Figure 6). It also demonstrates that in LEACH the nodes endure alive for a few more circular before the 1st node dies as juxtapose to the suggested theory. Due to which it extends the lifetime as well as stability of the network. Half Node Dead (HND) is indicated in (Figure 7) which also demonstrates the networks lifetime which is enhanced in this proposed protocols.

4. Conclusion

The performance of suggested theory is compared with a LEACH considering the networks lifetime which is assessed using FND and HND metrics. iLEACH protocol is an automatic configured as well as adaptive clustering protocols which utilize randomization techniques to contribute the energy consumption equally amid the sensors utilized in the networks. The proposed theory distributes the consumption energy among the sensor nodes & thus enhancing the networks lifetime to a higher extent as juxtapose to the LEACH routing protocols. In this theory CH is not fixed rather it varies their position among the sensor nodes and thereby avoiding the issue of battery draining of the CH node. Therefore, the proposed iLEACH theory not only provides significant enhancement in networks life time but also the better networks stability. Providing such an energy efficient, Multi-Hop Infrastructure-less Wireless Network with distributed routing protocol will help in innovation for future micro sensor networks. The sight of WSNs in future is to use various distributed the devices to control as well as interrelate with physical world occurrence. These nodes interrelate with each other to design a networks that performs high levels tasks.

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