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ENHANCING THE PERFORMANCE OF LEACH ALGORITHM IN CLUSTER-BASED HIERARCHICAL HOMOGENEOUS ROUTING PROTOCOL FOR LARGE AREA COVERAGE IN WSN

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ABSTRACT

Recently improved progress in wireless communication systems is the deployment of Wireless Sensor Networks (WSNs) for monitoring regular environmental conditions. WSNs involve low-power, low-cost, and simple sensor networks. The networks are developed to sense the environmental conditions, gather the data, process the gathered information, and drive the collected data/information to the Base-Station (BS) over the Cluster-Heads (CHs). The basic “LEACH (Low-Energy Adaptive Clustering Hierarchy) Protocol” is an efficient algorithm mainly used to solve the data gathering issues in WSN, where a small number of clusters are formed and deployed in a sensor network. This paper provides a definite analysis of the cluster mechanism in the LEACH-protocol. Likewise, the performance of the improved-LEACH protocol is analyzed and evaluated in terms of the lifetime of the network, calculation of the number of alive nodes, and dead nodes. “Energy-Efficient LEACH (EE-LEACH) protocol” offers a well-organized efficient routing in WSNs. The MATLAB simulation results show that the lifetime of a network of the LEACH-protocol is extended and the energy efficiency of the node is boosted.

Keywords: Deployment, Wireless sensor network, Cluster-Head, LEACH, Base Station, Hierarchy, Energy efficient.

INTRODUCTION

A large number of sensor nodes are randomly distributed in the wireless sensor network. The deployed sensor nodes are mainly used to detect, process, and transmit the data to neighbouring nodes and base stations in a highly focused area. In order to monitor the necessary action, the collected data should be transmitted to the base station by using a proper routing algorithm. Because of this requirement, routing has become a very important parameter for improving energy-related parameters in wireless networks. The routing protocol is designed to transfer the collected information efficiently from one node to another or from the base station. In the 21st century, the working of the WSN network has been compared with the latest technology and has been acknowledging for its improved performance. In the WSN, several decentralization techniques are proposed for the efficient use of available resources. The main goal is to achieve energy efficiency and maximize the life of the network. Clustering is the most commonly used approach in hierarchical routing to meet the desired requirement. Clustering schemes intentionally remove redundant

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messages from collected data and intelligently within clusters, the protocols are designed to select and resects the CHs depending upon the energy levels in every node.

Wireless Sensor Nodes are used to observe communication areas, later they will start collecting information, and finally, the collected information/data are reported to the base station. Gathering the data [2] is an efficient systematic approach for energy conservation in wireless sensor networks. The main feature of the data aggregation process is to reduce the redundant data from the information and transmitted energy will be saved. There are few data aggregation approaches, which are used to reduce the congestion in data transmission. Data broadcast in WSNs is controlled and achieved by the routing protocols [3]. Sensor nodes in a wireless network are well equipped with supply energy, and the regaining of energy might be difficult, so the system's lifetime is directly proportional to the energy factor in networks.

The LEACH protocol is [4] mainly works upon the time period (round) that is the time taken by the clusters for the reestablishment of the new clusters and cluster-heads in the entire sensor networks. Here, has been projected a relative analysis [5] of an “Improved-LEACH” protocol in order to resolve the problem accompanying with LEACH protocol. In the Improved-LEACH protocol, based on the energy level the cluster head will be elected. The node which has more remaining energy will be selected as new CHs. Therefore, the clusters with less amount of load can avoid energy consumption [6] and selects CHs in a cluster network. Simultaneously, overloading of the cluster head failure can also be avoided [7].

In LEACH-C [8], the process of selection of CH is based on several factors for example residual energy, distance from a node to CH, and area/locations [9]. BS gets the information about the status of each node and finally, CH is selected among all sensor nodes in a deployed network. The energy in the base station is used to select a node as CH which has maximum residual energy. This process increases the WSNs' lifetime.

“Two-Level LEACH protocol” [10] is designed based on CHs types in the sensor network. First-level CH sends the gathered information to the BS via Second-level CH. An “Energy-Efficient Clustering (EEC)” [11] [12] [13] protocol in WSNs selects CHs with high residual energy through local radio-communication. In “LEACH-M protocol” [14] the TDMA is scheduled in order to calculate the communication range between CHs. The first slot of the TDMA is a request message from CHs for data communication. Energy-Efficient LEACH [15] uses the leftover energy of sensor nodes for choosing CHs. CHs have a higher threshold of residual energy in T-LEACH [16].

In a wireless sensor network, all the distributed nodes are structured like a dynamic topology, which has a large number of sensor nodes. According to the requirement, the battery of the sensor nodes should be replaced or recharged. The lifetime of the network mainly depends upon the batteries. This mainly leads to the requirement for

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efficient energy routing protocols. Fig 1 shows the major blocks that a typical sensor node should consist of, like Sensing Unit, Transmission device, and processing unit. Sensors and the ADC (Analog-to-Digital Converter) are the main components used in the sensing unit [17]. The information from ADC is received by the Processing device and the further the processing of the data takes place in the processor module. The result of the processed data is stored in the storage unit. Transceiver modules are used to communicate with sink nodes or other sensor nodes in WSNs as per requirement. The other optional component of the sensor nodes are Mobilizer, Location finding system, and node power unit. A sensor network provides efficient services under a wide range of applications. They work like remotely monitored devices and the stored energy is a basic resource for node operation.

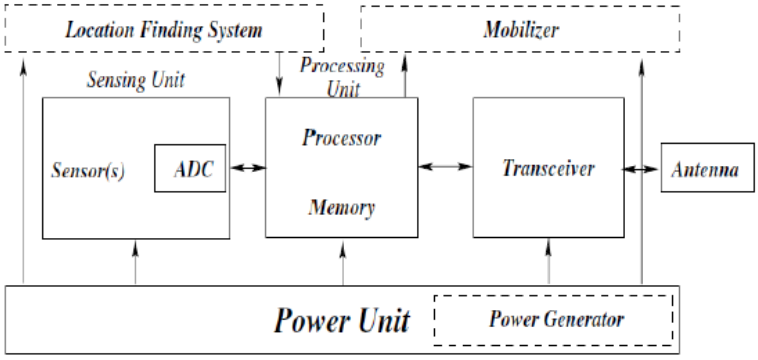

Fig. 1. General Hardware Architecture of a Sensor Node.

In WSN, because of resource constraints, proper routing is more difficult compare to other wireless networks. Different new approaches for clustering have been developed in order to fulfill the challenges in WSN. All the developed new algorithms basically have 2 constraints, one is the type of sensor node requirements and its need. The second one is the type of sensor architecture used. Enormous routing techniques have been developed in order to increase the overall lifetime of the network and to decrease the consumption of energy in each node. WSNs are classified into four categories: the network structure, based on the topology used, the routing scheme for reliability, and the model for communication.

All the sensor nodes are grouped into a cluster in a hierarchical method. As per the algorithm, cluster heads are chosen that are liable for routing. A two-layer approach has been employed sometimes in the hierarchical routing approach. Sensing of the physical atmosphere is done by one layer and proper routing is done by another layer. The lowest energy level sensors are used to sense the data/information. And highest energy levels usually perform collecting data, segregation of data, data processing, and finally transmit/forward the data to next the node within clusters or to next cluster-head. The cluster scheme is generally used practice for energy potency to realize measurability and effective communication.

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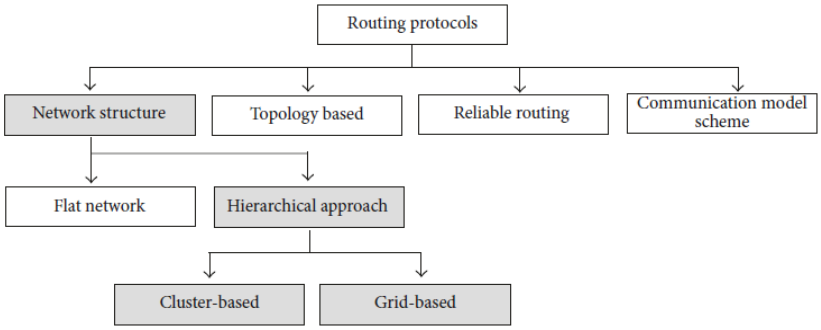

Fig. 2. Classification of Routing Protocol in WSNs

Motivation: Performance is one of the desires that should be satisfied by the sensor networks for the effective broadcast of the data/information. Designing/Implementing such algorithms that maintenance the efficient transmission with excellence in service is a foremost problem that mainly depends upon the mobile nature of the sensor nodes. Various routing protocols such as VELCT, MEC protocol, EM method, etc., are only concerned with evaluating a reasonable path regardless of the state of network traffic, end connections, tree density, and certain data/information collection. But, they do not inform about the status of the network in real-time issues. This intern reflects the performance of the WSN network and more wastage of energy. Thus energy-efficient routing protocol should be used for improving network lifetime.

Contribution: The main impact of the work is to provide a comparison between the existing hierarchical clustering methods of energy efficiency and, based on the structure of the network, they are classified into clustering and grid techniques.The main emphasis in this paper is to create a cluster network among all sensor nodes, selection of cluster head, cluster reformation if node energy goes down, and cluster head reselection taking into account the energy consumption in each round and their effects on the overall network lifetime, number of live node and dead node in LEACH protocol and its different optimizations methods.

Organization: The further sections of this article are organized as follows: Part II gives the literature reviews of the related work; Problem statement and Methodology are explained in Part III; Part IV list about the result analysis and Performance Evaluation for different types of LEACH; Conclusions are presented in Section V.

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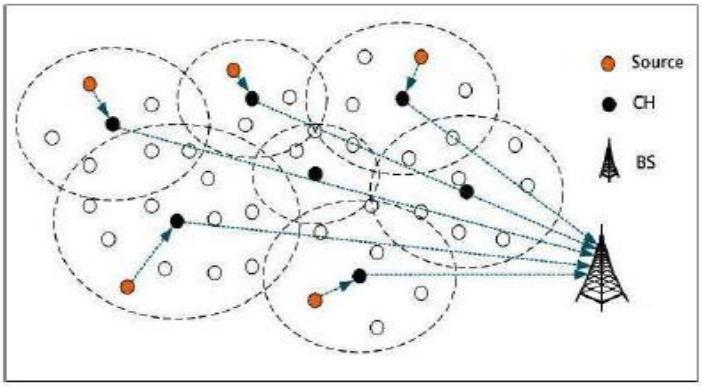

Fig. 3. Cluster Formation using LEACH Protocol in WSNs

LITERATURE SURVEY

Bilal jan et al., [1] introduced an idea about “Energy Efficient Hierarchical Clustering approaches in wireless sensor networks”. Different types of clustering methods have been explained neatly. This work tells about, state-of-the-art EE-based and grid-based techniques in WSN have been assessed by considering the following parameters: cluster formation metric, Consumption of energy for data transmission, and network lifetime. Arumugam et al., [2] have proposed an algorithm for “Energy-Efficient Data Gathering methods in WSN based on LEACH algorithm”. The testing results of the recommended protocol illustrate that the EE-LEACH gives good efficient results than the remaining energy-balanced routing-protocols (EBRP) and LEACH algorithm in terms of packet delivery ratio, slighter end-to-end delay, and energy intake.

Kalpavi et al., [3] have been explained the concepts on “Design Issues and Challenges in Hierarchical Routing protocols for WSN”. This survey gives a comparative analysis on different parameter issues in different routing protocols for increasing the lifetime of the sensor nodes. The parameters like improvement in network lifetime, consumption of energy, and transmission efficiency from every sensor node to sink node have been taken into consideration for further implementation. F. Xiangning et al., [4] have suggested different ideas on “Improvement on LEACH protocol for WSN”. These suggestions are helped for developing new ideas and also helped to identify the variations in the energy levels. X. G. Li, J.F. Wang et al., [5] have proposed an algorithm on “LEACH protocol and its improved algorithm in wireless sensor network”. In the improved algorithm, the authors suggested clearly about basic requirement of clustering in WANs. The selection of clustering in WSNs mainly depends on the applications.

B.Wang et al., [6] have suggested analysis and improvement on LEACH protocol in WSN. The simulation results show that the improved LEACH protocol extends the network lifetime and successfully improves the energy and efficiency of the sensor node. V. Padmathilagam et al., [7] have given ideas on the study of different

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clustering approaches and their advantages and disadvantages. The author has clearly mentioned the drawback of cluster techniques with respect to data transmission. Sometimes there is a chance of forwarding wrong data in place of the original information. So this influences a research scholar for their research work in identifying original data/information among collected information. U. K. Chandrika et al., [8] have addressed “An Improved Leach Algorithm based on wireless sensor networks”. The improved computation algorithm is able to increase sensor life and this research work has been shown that a vital utilization of networks also improved. M. A. Gupta et al., [9] have proposed a “Clustering Approach for Enhancing Network Energy using LEACH protocol in WSN”. In this research paper, it has been proposed an algorithm which is a modified version of LEACH, and performance parameters are evaluated using MATLAB simulator. The parameters like sensor network lifetime, number of dead nodes, and number of alive nodes are compared with the existing protocol.

S. R. Ahmed et al., [10] have addressed “Wireless Sensor Networks Improvement using LEACH algorithm”. The author proposed a method for low-cost and low-energy sensor networks for WSNs. The main problem encountered here is depletion in the node nearer to the base station. M. Masdari et al., [11] have suggested “Analysis of Secure LEACH-Based Clustering Protocols in Wireless Sensor Networks”. This paper mainly describes the features related to security and its solutions. And also highlight the objectives, advantages, and limitations. D. W. Xu et al., [12] presented a comparative study for hierarchical routing protocols in WSN. The main focus is on the detection of live and dead nodes, and the amount of packets transmitted to the mobile sink node. The experimental results have been discussed on five different protocols.

M. Rajput et al., [13] presented an algorithm for "Performance analysis of leach-based approaches for large area coverage in wireless sensor network”. This article mainly focused on the coverage area, which helped me to deploy a homogeneous network using clustering techniques. Thapa R et al., [14] suggested “A Comparative Analysis of LEACH and SEP using NS2”. The different performance parameters like delay, throughput, and packet size are evaluated in this article. H. Liang et al., [15] proposed an optimized solution for “Research on routing optimization of WSNs based on improved LEACH Protocol”. Here, research scholar has proposed a method for routing in the case of multihop WSNs. A.W. Khan et al., [16] addressed sensor mobility schemes in WSNs. As the sink node mobility increases it leads to a major problem for identifying exact trajectory for better transmission. X. Q. Jiang et al., [17] designed “Development of a lifting wavelet representation for surface characterization” in WSNs. Node-related deployment for surface-level representation has been discussed here. B. Pithva et al., [18] have proposed methods for “Optimization of Leach Protocol in Wireless Sensor Network. The author developed a reduced energy consumption for a balanced network. With this architecture, we can develop or design efficient WSNs for homogeneous networks.

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LEACH PROTOCOL – Problem statement and Methodology

Problem Statement

For a given wireless sensor network with 'n' number of sensor nodes, distributed in an area of XxY, a set of sensor nodes are selected as a sources and destinations randomly. Depending up on the number of sensor nodes within the given range, formation of clusters will be done first. Then, the objectives are:

(i) To choose the cluster head depending up on the energy-level in each round.

(ii) Calculation of alive and dead node in each cluster.

(iii) Reformation of cluster if required.

(iv) To improve the network life time.

(v) To decrease end-to-end delay.

Selection of Cluster Head (CH)

The algorithm used to select the cluster head [2] uses based on the selection of random choice. The Cluster activities like: Synchronizing and Monitoring can be handled by CH and also transmits information to the base station. Energy requirements are considerably more compared to other nodes in a network. LEACH protocol minimizes the consumption of energy, the lifetime of the network is improved. The process of execution of LEACH is periodical in nature, and it also includes the cluster formation, data communication in each period. This period/cycle is known as a Round. The energy is preserved by providing a proper time scale in the data transmission phase and is always kept broader than establishment time.

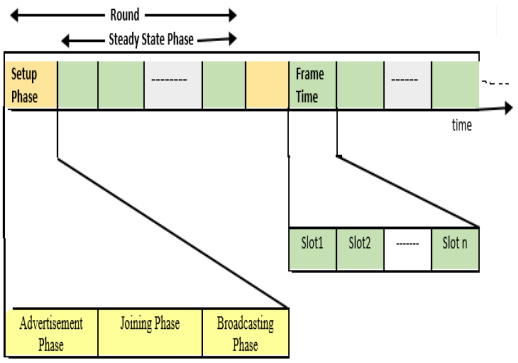

Fig. 4. Different Phases in LEACH Protocol

The Round mechanism is given as: A node will produce a random number between 1 and 0 (together with 1 and 0) during the set-up phase of the cluster [8] in WSNs as shown in figure 4. If the selected random number is less than the threshold T(n),

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then that sensor node will be nominated as a CH. The value of T(n) [10] is calculated using equation (1).

$$T(n) = \begin{cases} \frac{P}{1-P*\left(r \bmod \frac{1}{P}\right)}; & if\ n \in G \\ 0; & otherwise \end{cases} \quad (1)$$

In the equation given, p indicates the percentage of cluster nodes, which tells the probability of selection of nodes as a CH; r refers to rounds number, n represents the number of sensor nodes present in WSNs, and G is the fixed number of nodes that are not selected as a CHs in the 1/p round [8]. In stable data transmission mode, node member in a cluster (non-cluster sensor nodes) transfers the observed and collected information to related CH in the allotted time gap. LEACH is one of the greatest standard hierarchical-routing approach for WSNs. The routing protocol is basically categorised into rounds and each round consists of two phases as shown in Fig 4:

1. Installation phase or Set-up Phase: which includes, Advertisement and Cluster Set-up Phase.
2. Steady State Phase: Performs creation of schedule and transmission of data.

The phase of stable transmission is subdivided into various frames and each frame length is given by the total number of nodes in the cluster network. Information transmitted by individual nodes in its particular time gap is a part of the frame. CH and Clusters are re-elected [9] at the end of each phase and also for each round in the network.

Formation of Cluster [9]

Sensor nodes identify the CHs for the following round. This CH communicates with all other nodes in the network regarding its new role by sending a message through a “Non-Persistent CSMA protocol” [13]. Each node receives an announcement, and they directed that to which cluster they belong. This can be done, depending upon the strength of the signal used for an announcement from the CH to sensor nodes in WSNs. Then node informs the CH that they are the members of the cluster in a network. Based on the TDMA approach, CHs allocate the time on which the nodes can transmit the data to the CH. The CH begins a communication strategy for its cluster and transfers this strategy to every node in the same cluster. Once the setup-phase is completed, it initiates the establishment for the steady-state phase.

Advantages of LEACH-Protocol

LEACH and Improved LEACH protocol increase the lifetime of WSNs by 15% [16] when compared with the general and static routing protocols.

- LEACH-protocol supports data-fusion while data transmission, thereby reducing the redundant data and preserves the energy.
- LEACH-protocol applies the method of MAC-layer depending on CDMA [9], successfully removing signal intervention when communicating the data among the

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clusters. Whereas in the cluster, generally, the algorithm approves the mechanism of the MAC layer with TDMA to avoid data disturbance referred by sensor nodes and nodes will go to sleep when they are not allotted with any work in their own time slot so that energy can be saved.

- LEACH protocol begins with a round [8]. At every round, the algorithm will re-select the cluster nodes from the network and creates new clusters. Accordingly, every single node in the sensor network has the proficiency to become a CH, and the network load will be equally distributed on every node.

Disadvantages of LEACH-Protocol

LEACH-protocol [12] possess some disadvantages they are:

- The probability of selection of CH in the LEACH protocol is random in nature, and it didn't take the residual energy of the cluster node.
- If a sensor node is elected as a CH with less energy, the gathered data cannot be sent out.
- As time increases, the rate of T(n) [8] [13] will also rise and in turn, more nodes in a network become a CH.
- The nodes which are not joining the cluster group need to be isolated or else simply they waste the resources of the networks. These issues can't be handled by LEACH properly.
- In LEACH-protocol some of the hostile nodes become a CH, and tries to send the wrong data which destroys the collected data.

RESULT ANALYSIS and DISCUSSION OF LEACH BASED APPROACHES

The research work shows the following short-comes in the LEACH algorithm [11][7][15]:

- LEACH-protocol has CHs failure issues.
- CH when changes, they create extra overheads.
- Not efficient in some cases when network is dynamic large area networks.
- Inter-cluster interaction is not provided
- CH sharing is not suitable for some networks.
- The selection of CHs is random in process, where energy consumption, the trajectory from the sink and, many other parameters will not be considered.

To assess and improve the LEACH algorithm, few basic parameters are taken into account and a comparative analysis has been made as shown in table 2. [10]

Network Simulation Environment [14]

The settings for the network simulation environment are given with the following assumption. The sensor node and the sink node can interact directly and these sensor nodes do not have the mobility in WSNs. In the first round, all nodes have the same and limited initial energy. The wireless channel used here is symmetric in nature. Because the energy consumed for transmitting data from node 1 to node 2 is always equal to the energy taken for the communication of data/information from

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node 2 to node 1. The position of the mobile or sink node is fixed and has sufficient energy to supply.

Table 1.

Settings of Simulation Environment

Parameters	Its Value
Area of wireless sensor network, (m X m)	150m x 150m
Nodes Number	120
Probability of selection of CH in / %	20
Node's Initial energy / J	1
E_{elec} / (nJ * bit $^{-1}$)	40
E_{amp} / (nJ * bit $^{-1}$ * m $^{-4}$)	0.0013
E_{fs} / (pJ * bit $^{-1}$ * m $^{-2}$)	15
Data-package size / bit	100
Simulation-time/s	350

Results and Comparison

Fig 5 gives the comparison for LEACH-Protocol and Improved Leach-Protocol in terms of the data package. As shown in the graph, initially there is not much discrepancy between both the protocols in terms of the data package. But as time keeps on increases, we can see that amount of information transmitted by Improved-LEACH [7] slowly increases [5][3].

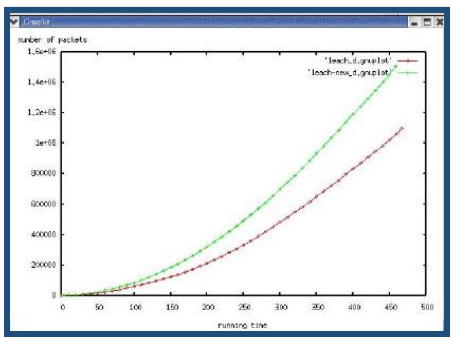

Fig. 5. Comparison with Data Transmission Rate.

Fig 6 gives the details about the number of alive nodes between two protocols. If the number of alive nodes is more than the stability of the network also good. And indirectly improves the lifetime of the sensor network. As shown in Fig 6, it can be observed that when time reaches to 250s, some of the nodes start to die in LEACH-

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Protocol [7], whereas in the second case at 400s the nodes are started to die. According to the developed LEACH algorithm at 400s all nodes died in WSNs.

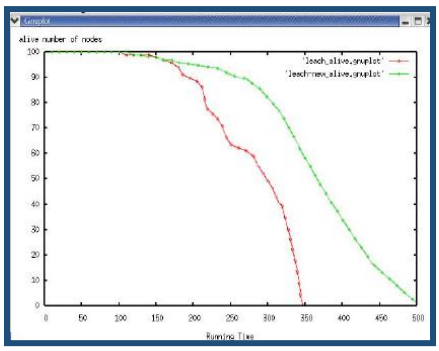

Fig. 6. Detection of Number of Alive Node in each Network.

According to Fig 7, a comparison can be made with respect to Energy-Consumption between the two protocols. Up to the 200s, the energy consumption is merely the same for both. As time increases it can be observed that for the LEACH protocol the energy-consumption is very high. When time is equal to 400s all sensor node's energy will be used completely in LEACH, but energy is still remaining in Improved-LEACH protocol [7]. And finally, figure 8 gives the energy utilized in each round.

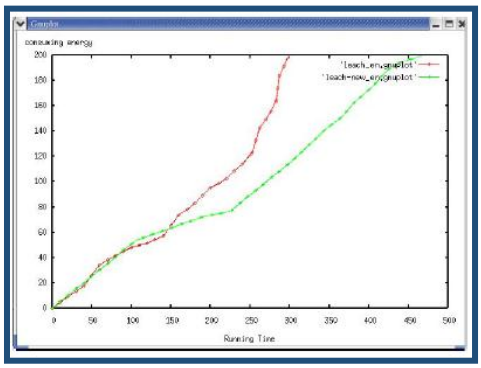

Fig. 7. Energy Consumption Level between Two Protocols.

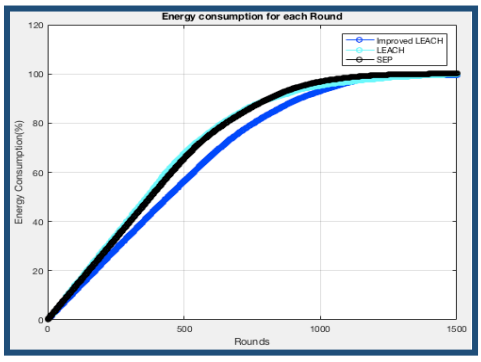

Fig. 8. Energy Consumption for Each Round

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Table2:
Comparison Between Different Routing Protocols [13] [1].

Routing Protocols v/s it's Parameters.	EEFL-CH "Energy-Efficient Fuzzy Logic CH"	GAICH "Genetic Algorithm Inspired Clustering Hierarchy"	LEACH-DT	MZ-LEACH	YA-LEACH	LEACH Protocol
Network lifetime.	Network life time is Increased Compare to LEACH.	It prolongs the network-lifetime, but the sensor node energy consumption is reduced.	It has been proposed A balancing approach between communication load and life-time is improved.	Stability time of sensor node is maintained constant and also network-life time is good.	Node dies in shorter time but it improves network life time.	All nodes communicates with CH within its own cluster and operation of set-up phase also controlled.
Energy consumption.	Reduced energy consumption.	Data collection is done at faster rate. Therefore energy saving is more.	Residual energy is more when compared with LEACH.	More CHs are generated. The energy consumption of CH is reduced.	Here CH rounds can be reduced by minimizing the amount of set-up phases.	Only CH node aggregates the collected information by every node thereby minimizing data redundancy.
Cluster heads vs. other nodes	Every sensor node transmits the gathered data to its own CH in the cluster network. Then, CH assembles the gathered data and sends it to the Base Station.	It uses more CHs than LEACH, without aggregation the data packets are send to BS.	In all the segments of the network, it can be observed that the difference in energy (Emax-Emin) is always less.	During each round, the associated nodes influences the CH for consumption of energy.	Centralized cluster formation is allowed and it is more efficient. CH can be managed in various rounds.	Energy consumption is less. Depends on predefined probability. CHs are elected randomly but equal probability has been given for every node.
Type of Network	WSNs	WSNs/ Added Networks	WSNs	WSNs	WSNs	WSNs

CONCLUSION

This paper gives the study and inferences about the network clustering techniques of the LEACH-protocol in WSNs. The comparison indicates that the LEACH-protocol

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sets a constant time-slot for choosing CHs throughout the complete sensor network instantaneously without getting the details about consumption of energy and the difference in load between different clusters. It has been proposed a new cluster-formation mechanism for increasing the performance of the protocol applied. The test results show that an improved-LEACH protocol can improve the lifetime of the sensor network and improves node energy effectively. There are few shortcomings in the algorithm like the environmental set-up used for simulation is too ideal, the segregation of alive node and dead node, the process of selection of CHs is improved and trusted, and so on. This results in further research for the improvement of the LEACH protocol in a hierarchical routing algorithm.

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