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Multi-hop Hierarchical Heterogeneous Approach to Improve LEACH Routing Protocol

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ABSTRACT: An energy efficient routing protocol is the major concern in Wireless Sensor Networks (WSNs). This paper has described an energy efficient hierarchical routing protocol, developed from LEACH. The basic concept involved in increasing energy efficiency and hence lifetime is to keep radio communication distance as minimum as possible The new version of LEACH uses heterogeneous multilevel clustering approach based on the distance of base station from cluster heads. I have used three different types of nodes based on their initial energy level. They have played different roles depending whether they are the member nodes or the cluster heads. The proposed algorithm is successfully simulated in MATLAB and the results show that it is more energy efficient than homogeneous LEACH.

KEYWORDS*:* Energy, hierarchical, LEACH, routing, wireless.

I. INTRODUCTION

Recent advancement in wireless communication and electronics has enabled the development of low-cost, low-power multifunctional miniature devices for use in remote sensing applications [7]. Such sensors can be widely deployed for commercial, civil and military applications such as surveillance, vehicle tracking, climate and habitat monitoring intelligence, medical and acoustic data gathering. A WSN is composed of large number of sensor nodes, which consist of sensing, data processing and communication capabilities. Usually sensor nodes are scattered in the sensing field. They coordinate among themselves to get information about the physical environment. The information is routed to the Base Station either directly or through other sensor nodes. The BS is either a fixed or a mobilenode, which is capable to connect the sensor network to the internet where user can access and process data.The key challenge in sensor networks is to maximize the lifetime of sensor nodes because it is not feasible to replace the batteries of thousands of sensor nodes. Therefore, computational operations of nodes and communication protocols must be made as energy efficient as possible. Considering the challenges of WSN many routing protocols have been already proposed for WSN. They can be classified into flat, hierarchical and location-based network routing. Hierarchical routing protocols provide maximum energy efficiency[3][7][8].

II. HIERARCHICAL ROUTING PROTOCOLS

LEACH is one of the most popular clustering algorithms used in WSNs to increase the network lifetime [1]. LEACH is an adaptive, self-organizing and clustering protocol. It introduces the concept of Rounds. LEACH assumes that the BS is fixed and located far from the sensors, all sensor nodes are homogenous and have limited energy source, sensors can sense the environment at a fixed rate and can communicate among each other, and sensors can directly communicate with BS. The idea of LEACH is to organize the nodes into clusters to distribute the energy among the sensor nodes in the network, and in each cluster there is an elected node called a cluster head (CH). Each round in LEACH consists of two phases as shown in Fig.1[2].

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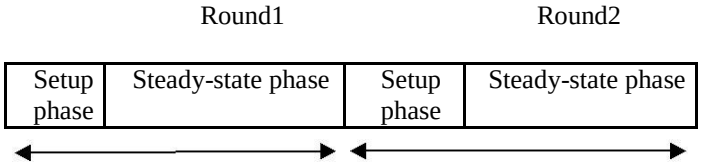

Figure 1. LEACH phases; setup and steady state phase

Clusters are formed during the set-up phase and data transfer occurs during the steady-state phase. The sub-phases included in the above are: Advertisement Phase, Cluster Set-Up Phase, Schedule Creation Phase (come under Set-up phase) and Data Transmission Phase (come under steady-state phase) [6].

A) Advertisement Phase:

It is the first step of the set- up phase. Here the decision of each node to elevate as a CH is made for the current round. Every single node picks a random number between 0 and 1[6], and then computes a threshold formula T(n). If the picked random number is less than the computed threshold the node becomes a CH. T(n) is computed as shown below [3][5].

Where,

$T(n) = p/1-(p \times r \bmod 1/p)$ if n € G

= 0 otherwise

n = given number of nodes.

p = the priori probability of a node being elected as a CH.

r = a random number between 0 and 1 that is selected by a sensor node.

G = the set of nodes that were not accepted as CH in the last "1/p "events.

If this random number is less than the threshold value T (n), then the respective node becomes the CH for the current round.Now each nominated CH starts advertise their own status to the rest of the nodes in the network. The non-cluster- head nodes must keep their receivers on during this phase to hear the advertisements of all the CH nodes[5].

B) Cluster Set-UpPhase:

After receiving this advertisement message the non-cluster- head nodes decide suitable cluster for them. They will choose the CH which sent the message with the largest signal strength heard [11]. This fact means the election of the CH to whom the minimum amount of transmitted energy is needed for communication [6]. When the non -cluster-head nodes take this decision, then they will inform their respective CH by a message using CSMA MAC protocol that they want to be member of thecluster.

C) Schedule Creation Phase:

After receiving all messages from the non-cluster head nodes, each cluster head include them to their respective cluster. For each node the CH creates TDMA schedule which indicate that they can transmit data.

D) Data TransmissionPhase:

When the TDMA schedule is fixed for each node, then according to the allocated schedule each node can transmit data to their respective CH. The CH nodes must keep its receiver on to receive all the data from the nodes in the cluster [6]. When they receive all the data from the nodes, they perform aggregation mechanism to compress the amount of data,andnext this data is sent to the base station. After a certain time, a new round begins with the Advertisement Phase.

II. DRAWBACKS OF LEACH

Although LEACH protocol prolongs the network lifetime in contrast to plane multi-hop routing and static routing, it still has problems. The cluster heads are elected randomly, so the optimal number and distribution of cluster heads cannot be ensured. The nodes with low remnant energy have the same priority to be a cluster head as the node with high remnant energy. Therefore, those nodes with less remaining energy may be chosen as the

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cluster heads which will result that these nodes may die first. The cluster heads communicate with the base station in single-hop mode which makes LEACH cannot be used in large-scale wireless sensor networks for the limit effective communication range of the sensor nodes.Since LEACH has many drawbacks, many researchers have been done to make this protocol performs better.

A) LEACH-F

It is the modified version of LEACH protocol with fixed clusters and rotating cluster heads [7]. Here clusters are formed once and fixed, and the cluster-head's position rotates among the nodes within the cluster. As clusters are formed only once so there is no set -up overhead at the beginning of each round. LEACH-F does not allow new nodes to be added to the system and do not adjust their behavior based on nodes dying.

B) LEACH-C

W. B. Heinzelman et al. proposed application specific protocol architecture for WSN which is known as LEACH- Centralized (LEACH-C) [8]. It is an enhancement over the LEACH protocol. LEACH-C, uses a centralized clustering algorithm and the same steady-state phase as LEACH. LEACH -C is more efficient than LEACH because LEACH - C delivers about 40% more data per unit energy thanLEACH.

C) E-LEACH

Energy-LEACH (E-LEACH) [9] improves the CH selection procedure in LEACH. It makes residual energy of node as the main metricwhich decides whether the nodes turn into CH or not after the first round. The operation of E-LEACH is divided into rounds, in the first round, every node has the same probability to turn into CH, that mean nodes are randomly selected as CHs, in the next rounds, the residual energy of each node is different after one round communication and taken into account for the selection of the CHs. Thatmean nodes have more energy will become a CHs rather than nodes with less energy.

D) V-LEACH

V-LEACH [10] is a new version of LEACH Protocol which aims to reduce energy consumption within the wireless network. The main concept behind V- LEACH is that besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies. By doing this, cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies which will extend the overall network life time.

E) H-LEACH

Hierarchical LEACH (H-LEACH) [3] is proposed by WairaguG. Richard considering the concept by minimizing the communication distance between nodes to conserve energy. It employs the same clustering approach as LEACH during initial phases and later it extends LEACH by further clustering the cluster heads and nominates one of the cluster head, which then acts as the Master Cluster Head (MCH), to forward data to the base station. In H-LEACH finally only one MCH is involved to transmit all compressed data to base station, so central point of failure situation may occur when the MCH will bedead..

IV. PROPOSED PROTOCOL

A lot of simulation works / experiments are going on in the research field of WSN to make routing protocols more and more energy efficient. In this paper, we propose a modified version of LEACH called Improved LEACH that can increase energy efficiency than original LEACH. The basic concept involved in increasing energy efficiency is to keep radio communication distance as minimum as possible [3]. The popular technique used to minimize communication distance is the formation of clusters between nodes rather than direct communication [3] but as the distance between the CH and BS go beyond a certain level single hop communication concept of LEACH routing protocol is not suitable. For this we propose Heterogeneous Multi-hop LEACH routing protocol to increase the energy efficiency ofWSN.

LEACH considers all sensors in the network have the same amount of initial energy i.e. they are homogeneous with respect to energy which is not realistic approach. So the nodes which directly communicate with the BS (i.e. the CHs) will die earlier than the normal cluster member nodes, decreasing the overall lifespan of the network. To

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make the network more energy efficient we classify the sensors into three types: normal node, intermediate node and advanced node depending on their initial energy level. The advanced node has the highest energy level while the normal node possesses the lowest level of energy. The normal nodes will be the cluster members. They send their data to their CH which will be elected from the group of intermediate nodes. The intermediate nodes will also sense data from the environment. They will aggregate the sensed and received data and either send it to one of the advanced nodes located nearer to BS or send directly to the BS if no such advanced node is found. The advance node communicates directly with the BS. It also senses data and aggregates all the data it received from different intermediate nodes with its own data. Finally it transmits the data directly to the BS.

The routing protocol allows two types of communication operations: intra-cluster and inter-cluster. In former type of communication, when whole network is divided into multiple clusters, then each cluster has one CH (intermediate node). This CH is responsible for communication for all nodes in the cluster. CH receives data from all nodes at single-hop, aggregates and transmits directly or indirectly through advanced nodes to sink. In later type of communication, when distance between CH and BS is large then CH uses advanced node to communicate with BS.So our proposed algorithm selects the best path with minimum hop-count between CH and BS. It also provides scalability feature due to its multi-hop communication option for CHs.The whole process can be summarized into two basic phases: Set-up Phase and Steady-state Phase:

A) Set-up Phase:

1. There are three types of nodes: normal, intermediate and advanced having different energylevels.
2. Initially Cluster-heads are selected as in LEACH from the set of intermediatenodes.
3. After cluster formation each CH will broadcast a short message containing its ID to find itsneighbors.
4. Each non-cluster-head node from the set of normal nodes determines to which cluster it belongs by choosing the cluster-head that requires the minimum communication energy, based on the received signal strength of the advertisement from eachcluster-head.
5. The selected CH will create a TDMA schedule defining the time slot for each member in its cluster to forward data toit.

B) Steady-statePhase:

1. Like LEACH all the cluster members (normal nodes) will send data to their corresponding cluster-heads (intermediatenode).Unlike LEACH after aggregation cluster-heads will send the aggregated data to an advanced node which is closer to the BS than the CH. To find such a node CH will compare the distance between advanced node and BS with that between itself and the BS. Whichever is smaller will be used to transmit data to the BS. If no such advanced node is found then it will send the data directly to the basestation.
2. The advance nodes will again aggregate the sensed data and the data received from the CHs. After that it will forward the result to the base stationone part of the entire proceedings, and not as an independent document. Please do not revise any of the currentdesignations.

V. ENERGY EFFICIENCY OF PROPOSED PROTOCOL

Proposed algorithm provides betterconnectivityand successful data rate as compare to LEACH. The reason behind this enhancement is multi-hop communication adopted by cluster-heads. As member nodes save energy by sending data to cluster-head in LEACH instead of Base station, similarly in Improved LEACH cluster-head at longer distance from Base station transmit data to advanced nodes closer to the Base station instead of direct transmission to Base station. It is more effective energy efficient routing protocol when network diameter is larger. Energy efficiency of Improved LEACH can be better elaborate with the example of linear network having two cluster heads A and B which are communicating to Base station. A is at a distance 'm' from B and B is at a distance m from the Basestation.

In order to calculate the transmitting energy cost of cluster heads A and B, which are directly transmitting to Base station will be [3]:

$$E_{dirAB} = E_{eleTX} * L_A + E_{amp} * L_A * 2m^2 + E_{eleTX} * L_B + E_{amp} * L_B * m^2$$

Where EdirAB is total energy cost of cluster-heads A and B, LA is aggregated data transmitted by cluster-head A and LB is aggregated data transmitted by cluster-head B towards Base station and m is equal distance among cluster heads and Base station. This happens in case of LEACH when every cluster-head has to communicate directly

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to Basestation.

Similarly total transmitting energy cost can also be calculated when multi-hop communication is taking place. Our proposed protocol utilizes multi-hop communication. In this linear network if cluster-head A transmits data to B instead of Base station then B has to transmit not only its own data but also has to transmit cluster-head A's data to Basestation.

$$EMulti\text{-}hop = EeleTX * LA + Eamp * LA * m^2 + EeleRX * LA$$

$$+E_{eleTX} * (L_A + L_B) + E_{amp} *(L_A + L_B) * m^2$$

Where EMulti-hop is total transmitting energy cost of both cluster-heads in case of multi-hop communication of Improved LEACH. Advanced nodes near base station has more traffic burden but still they perform efficiently since they possess the highest energy level. The cluster-head which is at longer distance from Base station has benefits because it has to transmit at small distance and increase its lifetime. So the proposed protocol is more efficient in case of large network diameter and LEACH is suitable when network diameter is small.

VI. SIMULATION RESULTS ANDANALYSIS

For simulation of LEACH and Improved LEACH to make efficient analysis. Simulation parameters are shown in table 1. This simulation is implemented by using MATLAB. 100 nodes are scattered randomly in region of 100m × 100m.

A)Simulation Parameter

Table: 1Simulation Parameter

Parameter	Value
Network Size	100m * 100m
Number of nodes	100
Packet Size	2000 bits
Initial Energy	0.5j
Number of rounds	5000
TransmitterElectronics (ETX)	50nJ/bit
ReceiverElectronics (ERX)	50nJ/bit
DataAggregation Energy	5nJ/bit

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B)Results

Fig2: shows the dead nodes in LEACH protocol

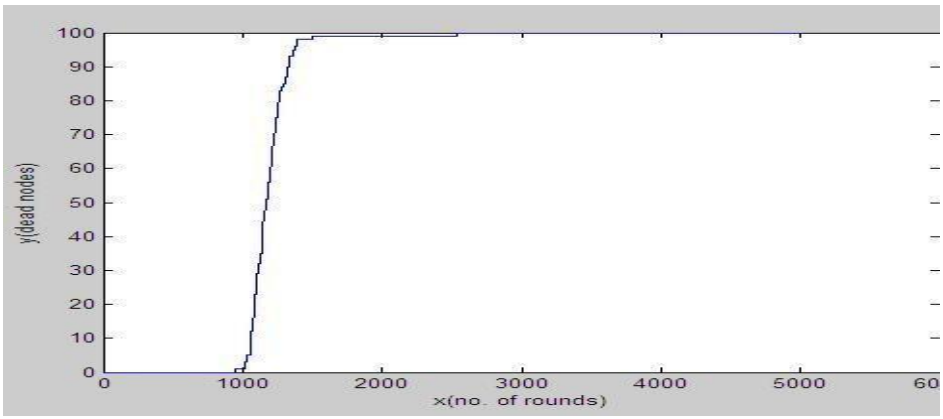

Fig3: shows the dead nodes in proposed protocol

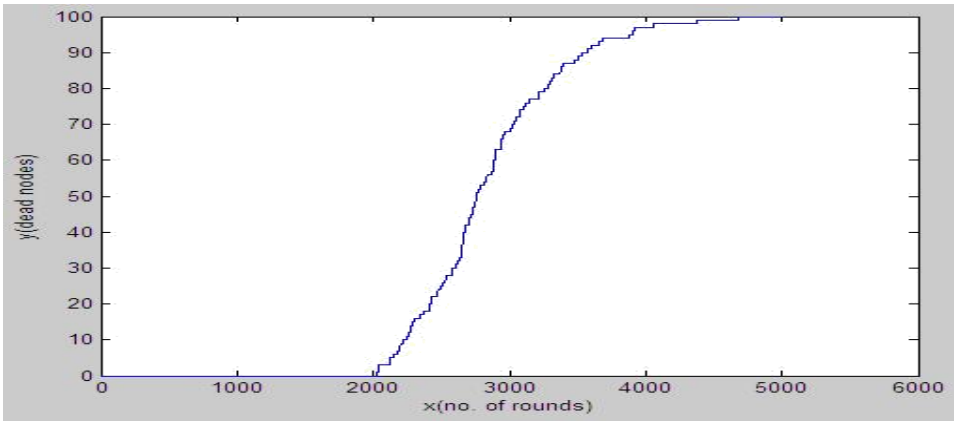

Fig4: shows the alive nodes in LEACH protocol

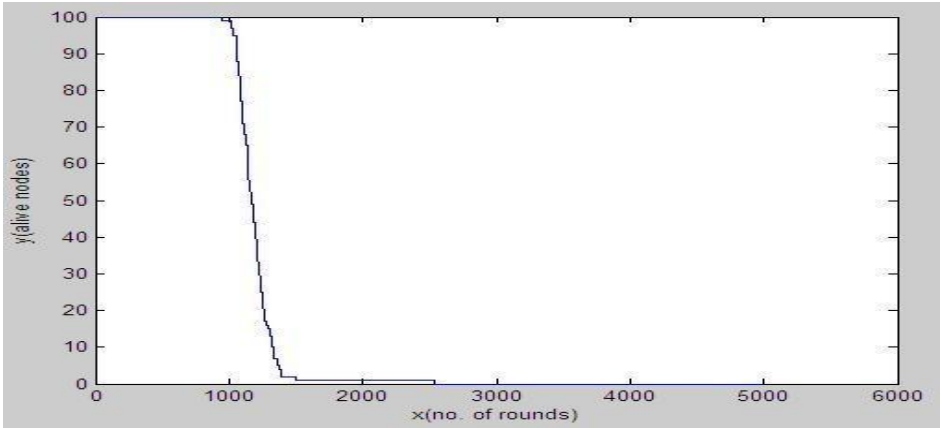

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Fig5: shows the alive nodes in proposed protocol

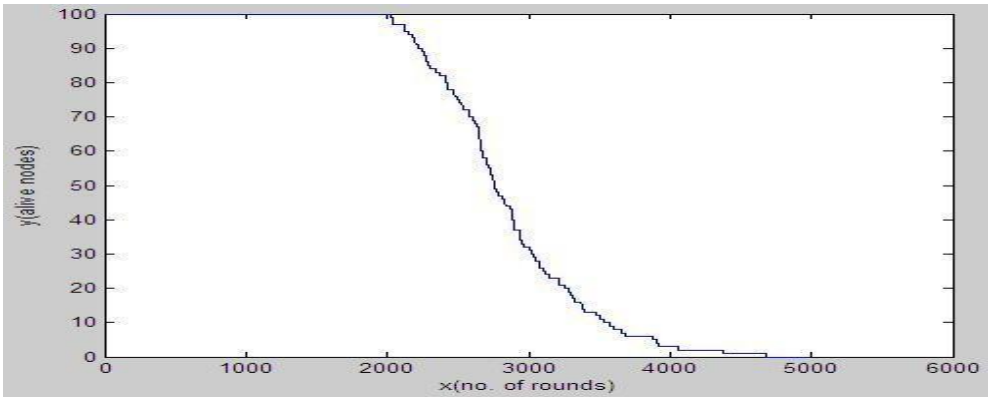

Table-2		
Protocol	Rounds when nodes start dying	Rounds when all nodes are dead
LEACH	950	2550
Improved LEACH	2020	4680

VII. CONCLUSION

In this paper, we considered a well known WSN routing protocol called Low Energy Adaptive Clustering Hierarchy (LEACH) protocol and proposed a newversion of LEACH protocol called Improved LEACH. Then the proposed protocol is successfully simulated and compared with LEACH protocol. From the simulation results we can draw the conclusion that improved LEACH is more energy-efficient than LEACH with greater network lifetime.

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