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An Energy Efficient Scheme for Precision Agriculture Using WSN in Heterogeneous Environment

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Abstract : *The purpose of present paper is to provide the use of wireless sensor network technology in agriculture, which will show the new era of farming in rural areas by replacing the traditional techniques. Wireless sensor network presents a technology for low power measurement and control applications. By eliminating lead and wires, it provides a considerable amount of cost savings as well as improve reliability for monitoring applications. Generally, WSN comprised of many small sensor nodes having the sensing capabilities, computations capabilities, battery and wireless communication capabilities. In this paper, we proposed an energy efficient clustering scheme New LEACH (Low Energy Adaptive Clustering Hierarchy) for precision agriculture using WSN in the heterogeneous environment. In this scheme sink node divided the network field into different logical regions depending upon the location of sensor nodes in the network field. We placed BS (base station) far away from the network field and installed a rechargeable gateway node at the centre of the network field. Finally, we compare our proposed scheme with MODLEACH (modify LEACH) and simulation results make sure that less amount of energy will consume in the network by using New LEACH.*

Keywords*: Cluster head, clustering, LEACH, MODLEACH, routing protocols, WSN, Wireless sensor network*

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I. Introduction

The popularity of wireless sensor network increased at very great scale due to the vast potential of the sensor network to connect the physical world with the virtual world. Since agriculture sensor, soil sensor and crop sensors are rely on the battery power and placed in the hostile environments replacing them is a tedious task. Thus the improving energy efficiency of these networks is very important for the longer lifetime. An agriculture sensor node is one of the nodes in wireless sensor network which is capable to carry out information processing, gathering and communicating sensing information with other nodes in the network. The principle elements of a wireless sensor node are an external memory, a microcontroller, power source(battery), transceiver and one or more sensor.

In developing countries, farmers are facing with new problems in advancement in technology and progress every day. So far by using wireless sensor network in the field of agriculture makes farming easy and efficient for farmers. In this paper, we have developed an energy efficient scheme called New LEACH for both homogeneous WSNs and heterogeneous WSNs that achieve the good performance in terms of network lifetime, throughput and application perceived the quality of service. In this paper, we are focusing on cluster-based routing protocols for energy efficiency. Further, we compare modify LEACH (MODLEACH) [11] performance with our proposed New LEACH. MODLEACH performance is better than Low Energy Adaptive Clustering Hierarchy (LEACH) [4] protocol, it is the first clustering routing protocol or algorithm in wireless sensor network.

The major aim of this work is to narrow down the energy consumption of the sensor nodes in order to increase the network lifetime and decrease the overall system cost. For this purpose, we have divided our network field into different communication level. Nodes which are placed near to Base Station (BS) have direct communication with BS while nodes placed away from the BS have direct communication with rechargeable gateway node. The remaining nodes use clustering and send data through CHs to the gateway node. Gateway node aggregate all sensing information and transmit to BS. Our proposed scheme New LEACH in comparison with MODLEACH [11] performs better. It uses the metrics of cluster head formation, throughput and network lifetime. And finally, a brief performance analysis of MODLEACH and our proposed scheme New LEACH for energy efficiency is given in terms of throughput, network lifetime and even distribution of energy usage.

The remaining paper is categorized as follows. We present the detailed study of routing based clustering protocol[4-11] and their advantages and inefficiency in section II. Our proposed energy efficient scheme New LEACH based on clustering is derived in section III. Simulation results and analysis of New LEACH and MODLEACH has been done in section IV on the basis of various network parameters. At the end section V conclude the proposed work and gives the outline for the future work.

II. Related work

We have studied various energy efficient routing protocols. As shown in Fig. 1, all protocols are useful for increasing the energy efficiency of wireless sensor network can be categorized into three groups as follows.

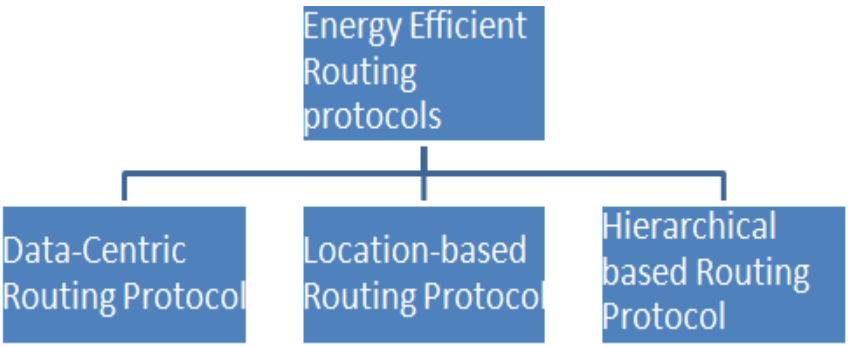

Figure 1. Classification of routing protocols

Cluster-based routing [18] comes under the hierarchical protocol. Cluster-based routing protocols [17], [18] and [19] are the most energy efficient for our application in agriculture field where cost and the network lifetime are main constraints. In cluster-based routing sensor network with central base station controlling the entire process is centralized in nature. The centralized version of LEACH [4] is a very good example of such a protocol. In the starting of each cluster formation phase, the centralized base station forms the cluster in such networks and passes the information to the nodes elected as the cluster heads (CHs). The distributed version is the more common example of clustering protocols [6], [19] and [20]. In the starting of the cluster formation phase the sensor nodes exchange information about the residual energy in [14] elect themselves a cluster head and announce it to their neighbors. The neighbor joins this node's cluster following the underlying protocol specifications. In adaptive clustering, cluster heads change as nodes move in order to keep the network fully connected. LEACH [4] being the parent clustering protocol is that it does not take into account the residual energy of the sensor nodes during the cluster head selection as well as the cluster formation phase. Threshold-Sensitive Energy Efficient Network (TEEN) [5] is a reactive clustering protocol. The cluster formation and cluster head selection of nodes in a network is similar to the LEACH [4] protocol. In the TEEN protocol, two threshold values are broadcasted by CH to it CM-hard threshold and soft threshold. In this protocol data transmission can be controlled by varying two threshold which improves the data efficiency. TEEN is well suited for time critical application. The major inefficiency of TEEN is whenever thresholds are not met, the sensor node cannot communicate with other nodes and the communication will stop. Hybrid Energy-Efficient Distributed Clustering (HEED) [6] is distributed protocol for homogeneous networks. In HEED dual parameters are used in the cluster formation process i.e. residual energy of the sensor node for cluster head selection and Intra-cluster communication cost is considered by the non-cluster head sensor nodes in deciding which cluster to join. The major inefficiency of HEED is while considering intra-cluster communication cost HEED consider the overall expenditure in the energy of the cluster head. Energy Efficient Clustering Scheme (EECS) [7] is a single hop distributed clustering protocol for homogeneous networks. The major inefficiency of EECS protocol is the sensor nodes do not take into account their own residual energy when they elect themselves as a cluster head. This lead to the sensor nodes with lower residual energy also becoming cluster head. Static clustering leads inefficient load balancing. Power-Efficient and Adaptive Clustering Hierarchy (PEACH) [8] protocol tackle two problems first one is overhead in the cluster formation phase: employs the use of overhearing by the sensor nodes to form efficient clusters. The second one is static clustering: makes use of adaptive multi-level clustering to reduce the load on far-off cluster heads. Clusters setup process is done instantaneously on each packet transmission. PEACH also suited for both the location-aware and unaware sensor nodes. Major drawbacks of PEACH is that there is no accountability of the residual energy of the sensor nodes, delay in the data packet being sent. Enhanced Stable Election Protocol (ESEP) [9] builds more load balanced network in the context of communication load and energy consumption. ESEP uses the dynamic sizing of clusters. Some of the drawbacks of ESEP is lots of overhead due to global information for communication and single hope communication consume lots of energy. Deterministic Energy Efficient Cluster (DEEC) [10], this algorithm tackles with overlapped sensing coverage

problem and sensing hole problem. Some nodes in this DEC protocol can move to coverage area inside the cluster. Some of the drawbacks of DEC is that poor energy efficiency and the load balancing is not up to the mark. Modified LEACH (MODLEACH) [11], this protocol is the modification of the LEACH protocol. MODLEACH improves the network lifetime and throughput. The performance of MODLEACH protocol is better than the LEACH protocol. In this protocol, if the energy of the cluster head comes below a predefined threshold value then it will consider in CH and cluster formation process otherwise same node serve as a CH.

In an adaptive clustering hierarchic, there can be three kinds of communications with respect to distances.
a) Inter-cluster communication
b) Intra-cluster communication
c) Cluster head to base station communication,

This protocol also consume more energy in cluster head selection so for reduction of energy consumption and longer lifetime of network we proposed solution by reducing the overhead of cluster head selection. As the number of selected CH is reduced the amount of consumed energy will also reduced. In next section proposed solution explained in detail.

III. Proposed Work

In order to improve network lifetime and throughput, we decrease the number of cluster heads in network field by dividing the network into four logical regions. This sub-division of the network field has been done by using the coordinate system. Sink divides the nodes into four logical regions as shown in Fig .2
1. Sensor node region near to the base station (R2)
2. Sensor node region far away from the base station (C1, C5)
3. Sensor node region near to rechargeable gateway node (C2, C3, C4, C6)
4. Sensor node region around the gateway node (R1)

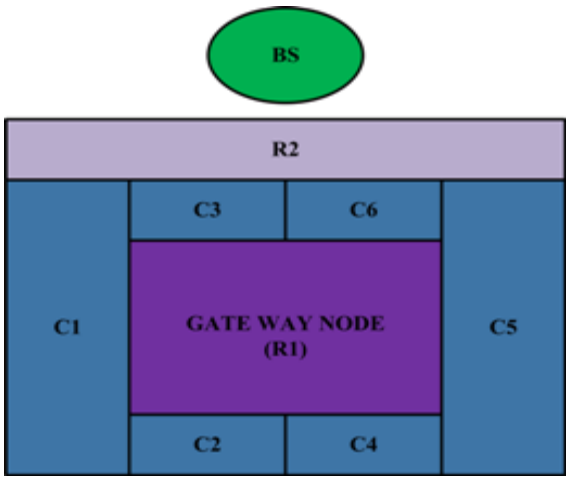

Figure 2. Network Field

A gateway node is placed at the centre of the network field. The function of this gateway node is to collect data from CHs and from nodes near to gateway node, aggregation of collected data from all nodes and sending to BS. We added this rechargeable gateway node at much cheaper price than the price of the sensor node. This reduces the overall system cost. Two regions (R1, R2) as shown in Fig .2 use direct communication and rest regions (C1, C2, C3, C4, C5, C6) use clustering technique. In this paper, we assume that N is the number of sensor nodes which in particular are deployed randomly to monitor the environment in the field. We assume that i-th sensor is represented by n_i and subsequent sensor node by the set N = { n_1, n_2 ..... n_n}. Also assuming the network field as shown in Fig .2 Following assumptions are made for configuring our network field.
1. The Base station is installed far away from the network field. The Base station and the sensor nodes stay stationary after the network placement.
2. In the same network field, a gateway node is placed at the centre of the network field.
3. The Gateway node is fixed at their position after placement and rechargeable.
4. Sensor nodes are homogeneous with similar computational and sensing capabilities.
5. Distinctive identifier (ID) is assigned to each and every node placed in the network.

3.1 Protocol stage: Our proposed energy efficient clustering scheme New LEACH has three phases.

3.1.1 Cluster formation phase: Clusters with the minimum amount of energy utilization are formed from the already existing clusters using different distributed and centralized approaches. In our proposed work we use distributed approach, in the starting of the cluster formation phase the sensor nodes exchange information about residual energy and elect themselves a cluster and declare it to their neighbours. The neighbour joins this node's cluster following the underlying protocol specifications.

3.1.2 Cluster head selection: In a heterogeneous network, each group of nodes in a cluster chooses its cluster head from amongst themselves. Cluster heads are selected from the group of higher energy nodes.

- CHs are elected based on the remaining energy of node and probability p.
- Each node elects itself as a CH once every 1/p rounds.
- A node generates a random number between (0,1)
- If the generated random number is less than a predefined threshold T(s) value the node become CH.
- The threshold value is calculated

$$T(s) = \begin{cases} \Pr/(1 - \Pr(rd \bmod(\Pr)^{-1})) \\ 0 \qquad\qquad \text{For all s Ɛ G} \end{cases}$$

where,P = the desired percentage of CHs and r = the current round, C = set of nodes not selected as CH in present round.

3.1.3 Information accumulation phase: This is the steady state phase in this cluster nodes gather information about the environment and send to CH. CHs send information to gateway node and gateway node sends all aggregated data to BS in one or more hopes depending upon the level of hierarchy in the network.

IV. Results

After simulating our proposed energy efficient scheme New LEACH on MATLAB Tool we have shown that network lifetime and energy consumption improved with the expense of adding gateway node. In our proposed scheme the optimal CH number is smaller than MODLEACH. A high number of cluster head may deplete energy quickly.

4.1 Simulation Setting: For the simulation, the network field deployed in a 100m X 100m field having 100 nodes which are placed randomly in the network field and the rechargeable gateway node is placed at the centre of the network field and base station is installed far away from the monitoring area. We have been considering the packet size of 4000 bits (500 bytes) and each node has 0.5 joule energy. Detailed network parameters used in the simulation are given in TABLE 1. The simulation has been done on MATLAB Tool.

The energy needed for the transmission of a data packet of 'k' bits at a distance 'd' and to receive a data packet of 'k' bits, is given as:

$E_{Tx}(k, d) = E_{Tx-elec}(k) + ETx-amp(k, d)$

$E_{Tx}(k, d) = E_{elec} \times k + Eamp \times k \times d2$

$E_{Rx}(k) = E_{Rx-elec}(k) E_{Rx}(k) = E_{elec} \times k$

$E_{Rx}(k) = Eelec \times k$

where, E_{Tx} : Transmitter electronics

E_{Rx} : Receiver electronics

Eamp : Transmit amplifier

$E_{o:}$ a node has 0.5 joule energy

The total energy of 100 node network is 50 joule.

Table 1: Network Parameter

Network Parameters	**Value**
Network Size	100*100 M^2
Initial Energy Present In The Sensor Network	0.5 Joule
Size Of The Packet	4000 Bits
Idle State Energy Consumption Of Transceiver	50 Nj/Bits
Required Amplification Energy For (Cluster To Bs)	E_{fs}=10pj/Bit/M^2
Required Amplification Energy For (Cluster To Bs)	E_{amp} =0.0013j/Bit/M^2

4.2 Performance Parameter: In the section below, we have been presented the performance of our energy efficient scheme New LEACH. In our proposed work, we have been evaluated following performance parameters-Network lifetime, throughput and even distribution of energy usage and residual energy which is given below.

4.2.1 High Network Lifetime: For a sensor node, the lifetime can be defined as the period of time (possibly the number of rounds) after which it is unable to transfer any information for a network. The can be designated by the death of the first node or 10, 20 or 100% of the nodes. one of the primary aims is the extension of the network lifetime by the reduction in the energy usage between member nodes and the cluster heads. For this routing protocols help in keeping a track of residual energies of the sensor nodes and dynamically adapt the clusters to these values. We can see from the Fig .3(plotted graph between No. of rounds and dead nodes) in our proposed scheme New LEACH, after 500 rounds nodes started to dying and after 2500 rounds all nodes are dead on the network whereas in MODLEACH after 1600 rounds all nodes are dead in the network. Now we can see from the Fig .4(plotted graph between No. of rounds and alive node) in our proposed scheme New LEACH, till 500 rounds all nodes are alive after that alive node fall to decrease and up to 2500 rounds all alive nodes get zero whereas in MODLEACH after 1600 rounds all alive nodes get zero. So our proposed scheme New LEACH has been obtained longer lifetime than MODLEACH.

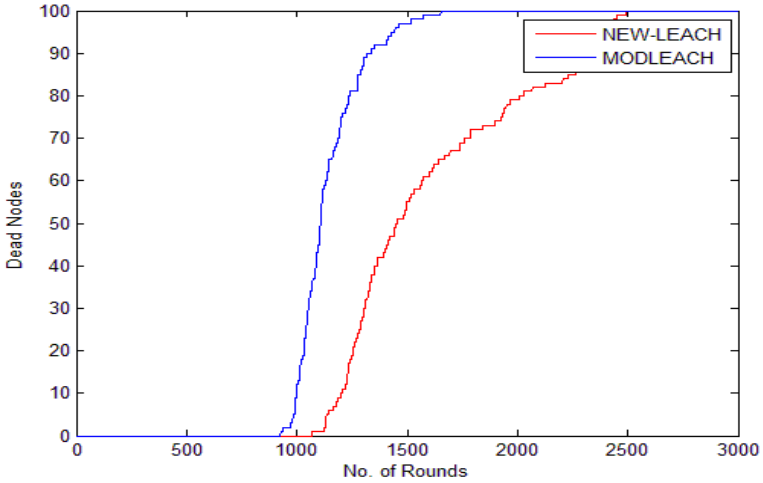

Figure 3. Comparison plot- Analysis of network lifetime(Dead node)

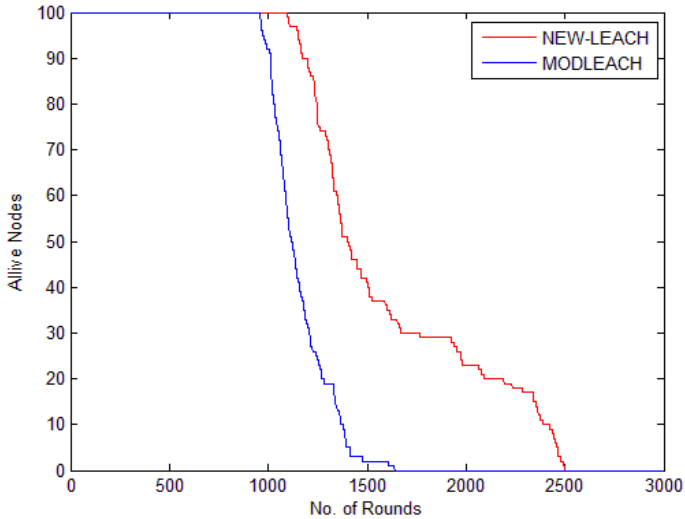

Figure 4. Comparison plot- Analysis of network lifetime(Alive node)

4.2.2 Throughput: Throughput is the measure of the number of messages received by the BS. Simulation results demonstrate the increased value of throughput. Plotted the graph of our proposed scheme New LEACH and MODLEACH in Fig .5 clearly illustrate the performance. After the simulation, it is clear that an increase of 5 times than MODLEACH in throughput. Gateway node region R1 and near base station region R2 uses direct communication consume less amount of transmission energy hence sensing nodes will stay alive for the larger period of time. Maximum alive nodes ensure the transmission of more packets to BS in the network.

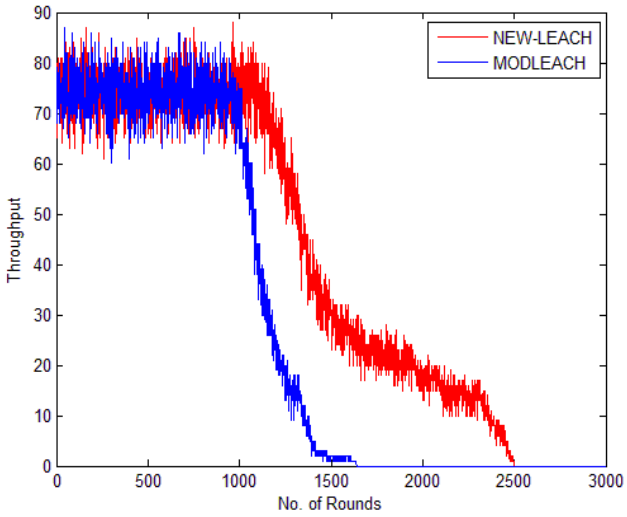

Figure .5 Comparison plot- Analysis of Throughput

4.2.2 Even Distribution of Energy Usage: Another aim is closely related to the high network lifetime is the even distribution of the residual energy of the sensor nodes. The main idea is that total energy of the network is a fixed quantity, even distribution of the sensor node energies will help lengthen the network life. A network in which all the sensor nodes die around the same time reflects a better protocol design than in which nodes steadily die at a constant rate. Fig .6 shows the amount of average energy of network in every round. Each node in the network has 0.5 joule energy. Therefore the total amount of energy of 100 node network is 50 joule. After simulation, it is observed that our proposed energy efficient scheme New LEACH gives less energy consumption than MODLEACH protocol in the given network field. Plotted graph clearly ensure that our proposed scheme gives better results than the MODLEACH in terms of total energy consumption. Placement of rechargeable node at the centre of sensor network makes sure that less amount of energy will consume in the network.

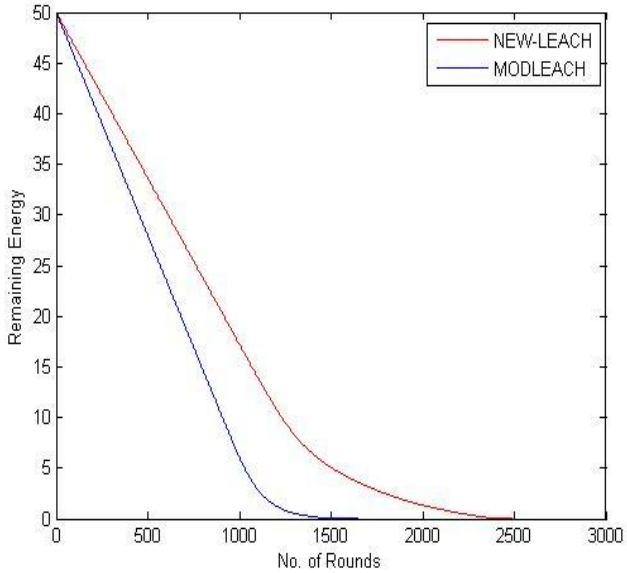

Figure .6 Comparison plot- Analysis of Remaining Energy

IV. Conclusion and future work

In this paper, we proposed a new energy efficient scheme New LEACH in order to improve network lifetime and throughput of WSN and reduce the system cost. As we tend to adapt this work in the real-world application as in precision agriculture for farming. So we tend to adapt wireless sensor technologies and mini senor devices in farming for automatic environment monitoring and controlling the agricultural parameters. It's our hope that this scheme will give additional insight into optimizing WSN energy consumption in real-world

situations. As a future scope of this work may be used as coping with the quality of the nodes and can be deal with mobile sensors which can move in network field with the higher energy efficiency.

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