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Energy Efficient Clustering Method in WSN for Automated Intelligent Bio Fertigation Monitor and Control

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Abstract : Nowadays, numerous types of microcontrollers are designed and they quickly become man's invisible companion. The recent advancements in the digital system using microcontrollers enable us to do wonders in real time environment. One of the recent applications of using microcontrollers with wireless sensors (motes) is to automate the agricultural practices in order to make the process simple and improve the yield. The application of WSNs in automated precision farming assures high yields, good pest control, prevention from unauthorized access, limited power consumption, elimination of air pollution, control over water and fertilizer wastages, reduce manpower, avoid personal monitoring of field by farmers and manage fertigation and other control units remotely at a lower cost. This paper proposes automated fertigation system for farmers' farm field using WSNs. We propose two novel techniques using WSN to minimize the energy consumption of sensor nodes used in bio irrigation system thereby increasing the lifetime of the network. We have proposed an improved method for the Cluster Head (CH) election carried out in traditional LEACH protocol. We named the modified protocol as Assigned-LEACH (ALEACH) used to implement the above mentioned two techniques. The sensors monitor the field for attributes and based on these sensed values the mote triggers the fertigation equipment. Once the field receives the required amount of water and fertilizer, fertigation is stopped. Also the sensed values are sent to the Base Station (BS) frequently, which can be intimated to the farmer via SMS using GSM. On receiving this information, the farmer can control the necessary equipment without directly monitoring of the farm field thereby improving efficient crop management and reducing wastages and labour costs.
Keywords : Automated fertigation; WSNs; clustering; energy efficiency; network lifetime.

1. INTRODUCTION

Over the past few decades, the recent advancements in technology have shown considerable improvements in the world's agronomy. Especially the Microcontrollers find usage in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. These advancements have been used in various sectors and especially in the field of agriculture. Agricultural practices such as efficient management of water resources and equipment, effective utilization and control of fertilizers, efficient stock management, breeding etc., can be enhanced by adopting the recent techniques in WSNs. These advancements have brought transformation in the field of agriculture by implementing new agronomical practices. This has shown considerable increase in the yields. On the other hand, agriculture farming faces many challenges such as water insufficiency, crop deceases, unpredictable climatic conditions, non availability of labour etc. Hence, farmers prefer to use modern techniques such as automated irrigation systems to improve the productivity. These automated irrigation systems are made effective by using WSNs. WSN consists of several hundreds of sensor nodes which are deployed in the agricultural field, to collect

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data like temperature, humidity, plant height, nutrition level, fruit size, etc. These sensors provide the most accurate information and based on this information, the automated systems control the complete agricultural activities including the various agricultural devices. Automated irrigation systems are not only used for controlling the various devices but also used for decision making based on the collected information which is stored in its database. This data is then used by farmers to select the seasonal crops, the suitable fertilizers and their quantity and effectively manage water supply [1-5]. The main reason for using WSNs in agriculture is because the sensor nodes are wireless devices and hence, the need for laying connection cables in the field is totally eliminated. Replacing or repositioning the nodes from one place to another is very easy. As nodes are small in size, they occupy very less space and also the energy consumption of the nodes is very much reduced. Thus, implementing WSN in the field of agriculture is cost effective and eliminates the need for human intervention.

Sensor nodes operate with small battery backups. Solar cells can be used to renew the power of these sensors. Modern sensors have the ability to work in all climatic conditions. As each of these sensor nodes have a low battery capacity, a failure of even one node can affect the entire structure of the network causing the complete network framework to be restarted. This highlights that a network's lifespan is totally subject to the lifespan of every single node deployed within the network. In a network, every node consumes a considerable amount of energy as it performs the sensing, processing, transmitting, receiving and storing tasks. Hence optimized energy utilization is a major requirement when fabricating a WSN [5].

In WSN, many routing protocols are intended to increase the lifespan of a network by using the given sources in the most cost-effective way. Clustering is a mechanism used in order to extend the lifespan of a WSN. It is a method which splits the field into a group of sensors forming various clusters. The sensor nodes of a cluster are called the Member Nodes (MNs) of that cluster. Each cluster in a network elects one of its MNs as a Cluster Head (CH). On sensing any data, the MNs transmit the data to the CH, where it is aggregated and further transmitted to the BS. Optimized energy consumption of MNs can be achieved by the clustering technique since the distance required for a MN to transmit data is considerably reduced. This method ensures the effective utilization of bandwidth and energy as the data received at the CH is aggregated and sent to the BS thus removing redundant data in the network. LEACH protocol is the first protocol of hierarchical routing which has proposed data fusion technique and uses clustering method; it assumes greater importance in clustering routing protocol.

In this paper, we propose two novel techniques to optimize the energy utilization thereby enhancing the network lifetime. These techniques are (i) A new methodology for CH selection for each round and (ii) Developing a scheme for optimizing the energy utilization of nodes. The techniques we propose improve the energy efficiency of the CHs and enhance the network lifetime.

A. Objective of the Proposed Work

The main objective of the proposed system is to automate the fertigation viz. irrigation along with fertilizer system using the WSNs which will monitor the various parameters needed for decision making and control. Clustering is used for efficient collection and transmission of data. These data monitored by each sensor are sent to the CH which will aggregate the received data and transmit it to the BS. The received data are used for analysis to make decision for efficient fertigation. Based on the monitored data, functions such as alert messages or activating alarms can be sent. Based on the alert messages received at the farmer's cell, an action can be automated by the farmer from any location he is present at the moment. This totally makes the system automated and hence efficient.

B. Scope of the work

The proposed system has a wide scope in a country like India where agriculture plays a vital role in the economy and for the survival of the nation. The proposed system works best in a protected crop culture such as a greenhouse environment which has benefits such as protection from UV rays, direct sun rays, pest control, contamination free high yielding etc. The proposed system is applicable for very large farm fields as clustering is used in the WSN.

2. RELATED WORK

A. Low Energy Adaptive Clustering Hierarchy (LEACH) [6]

This protocol was the first to implement the clustering mechanism in order to distribute the energy load evenly within the network by arbitrarily choosing a CH for every round. Every node in LEACH is self-sufficient to elect itself as the CH. This process is carried out by selecting an arbitrary value and comparing it with a pre-fixed (threshold) value. In case the selected value is lower than the pre-fixed value, that particular node becomes the CH for that round. The protocol ensures that a node elected as the CH for one round does not become the CH again in the following rounds thus giving all the nodes a chance to become a CH at least once. This helps the energy load to spread out evenly among all the nodes in the network. The major drawback of LEACH protocol is the uneven distribution of the CH selected, as they are chosen randomly.

B. Enhanced Low Energy Adaptive Clustering Hierarchy (E-LEACH) [7]

E-LEACH is an enhancement of LEACH protocol, where every node in this protocol is considered to have the complete knowledge of the remaining energy of all the other nodes. E-LEACH proposed a change that the required number of CHs may be increased to the square root of total sensor nodes, thus optimizing the amount of energy utilized. Every other feature of E-LEACH is similar to LEACH protocol.

C. LEACH- Centralized (LEACH-C) [8]

This protocol is the enhancement of E-LEACH. It addresses the issue of managing the entire network. In LEACH-C, the nodes send information to the BS regarding their positions and the energy levels. Based on the received data, BS creates clusters, decides the CHs and the member nodes. The remaining process is similar to that of LEACH protocol.

D. Two level hierarchy LEACH (TLLEACH) [9]

Effective use of energy is achieved in TLLEACH protocol. It uses two levels of CHs viz. primary CHs and secondary CHs. In this protocol, the member nodes send the sensed data to the secondary CHs where the data is synthesized. The processed data is then sent to the primary CHs which further synthesize the data. The primary CHs are responsible for transferring the data to the BS. All the other functions of this protocol are similar to LEACH. The significance of using this protocol is that it uses a few nodes to communicate with the BS, hence increasing the energy level of the network.

E. LEACH with Fixed cluster (LEACH-F) [10]

LEACH-F is the protocol which limits the overhead by fixing a specific size for the cluster. The nodes within the same cluster take turns to be CHs. The clusters are formed the same way as in LEACH-C protocol. The drawback of LEACH-F is that it cannot accommodate new nodes within a fixed cluster.

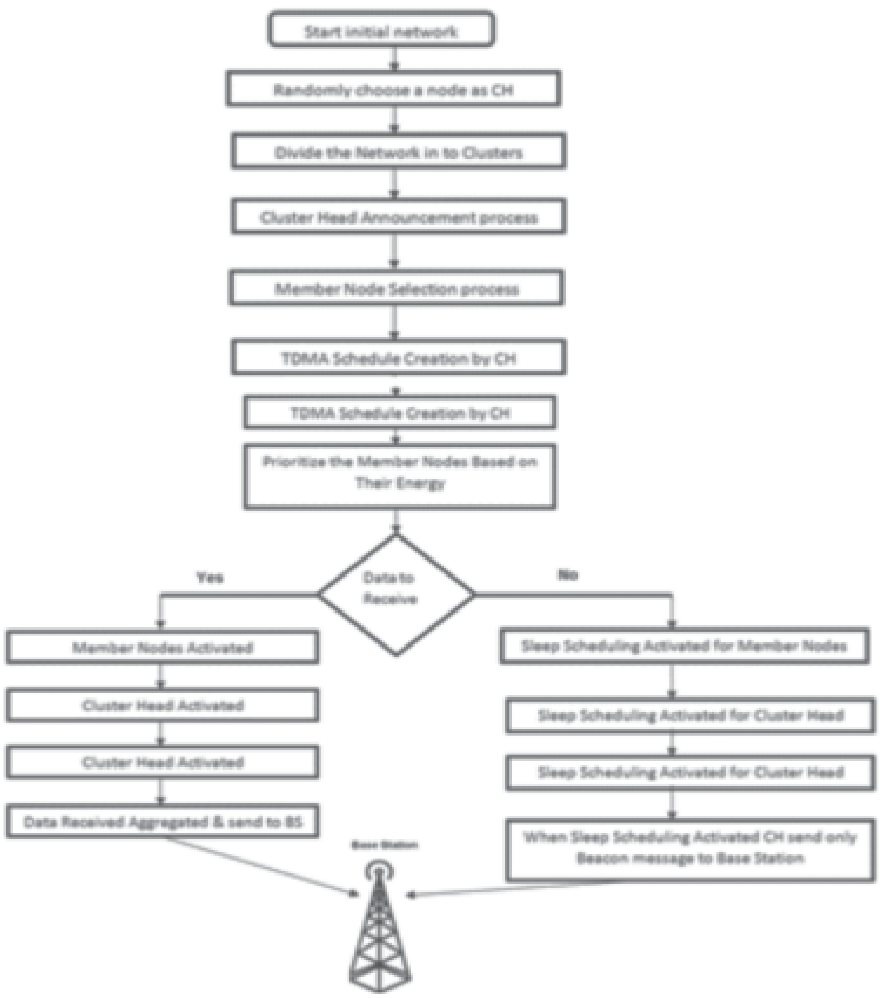
3. PROPOSED WORK

Two new techniques have been proposed in this paper for minimizing the energy utilization of the sensor nodes in the WSN which can be favourably used in bio fertigation. For implementing these two techniques, we propose a protocol namely Assigned-LEACH (ALEACH) which is a modification of the standard LEECH. The first of these proposed techniques, proposes the idea of scheduling the CHs. The nodes are deployed randomly on the farm field. A beacon message is sent from BS to all the nodes within the network. This message carries the information of BS-id and its location details. One hop hello messages are exchanged between the nodes within the network. These hello messages carry information of the node id, its energy level, and its position details. Those nodes that receive these messages update their neighbour tables. For the 1st round, CHs are randomly elected based on the probabilistic method. The elected CHs send an announcement to all the nodes that are at one hop distances. Those nodes that reply to the CH become the MNs of the cluster for which the randomly selected node will be the CH. The reply messages sent by the nodes carry information about their ids and levels from the BS and their residual energies. Based on this information, a schedule is prepared listing the nodes which will be the CHs for the consecutive rounds. This schedule is then sent to all the MNs. Assigning CHs for the future rounds is done in the first round itself. It eliminates the need for preforming the CH election process at each and every round. Thus, this technique can effectively reduce the computation time and energy consumption of the nodes within the cluster.

The second technique proposes a sleep schedule for the nodes within the cluster. Traditional methods are programmed to change only the member nodes to sleep mode when there is no requirement for monitoring the sensing field. The CHs in such networks are always kept in the active state even though the member nodes are in sleep mode. In such cases considerable energy is consumed by the CHs as they remain active throughout the network life period, thus leading to a rapid decrease in the lifespan of the network. Hence, slots are assigned for every MN in the cluster and also for the CHs. Each MN is given a slot for transmitting data and CH is given a slot for receiving data and sending it to the BS. The slot details are sent to the MNs along with the schedule table. Each node updates its own slot time and its CH slot time. When a node senses data, it checks for its slot and the CH's slot, and if both slots are available, then data is transmitted to the CH, else it waits until it receives a slot and then transmits data. The CH wakes up only during the given slot, meanwhile it is kept in the hibernate (half sleep) state. In order to know whether a CH is alive or dead, the CHs send only beacon messages at regular time intervals to the BS. The second technique improves the network lifetime significantly when implemented thus increasing the network lifetime to an extent of 20%.

The entire sequence of the proposed system is given in the accompanying flowchart.

Flowchart showing the proposed system.



4. PERFORMANCE EVALUATION

A. Simulation Environment

With the nodes being deployed, some assumptions are made concerning the node features and they are as follows :

- All nodes start with the same initial energy;
- Nodes are static;
- Member nodes transmit directly to their respective CH within a particular cluster and
- CHs use multi-hop routing to relay data to data sink.

In this simulation, we have considered a total number of 52 nodes deployed randomly within a space of 100 m × 100m. Fig. 1 shows the simulated environment of the 52 nodes that are utilized. The simulation results are given in Figs. 2

Fig. 1. Deployment of 52 Sensor Nodes.

B. Simulation Results

The CHs are selected for each round in the initial process itself when the nodes exchange their energy level information among their neighbours.

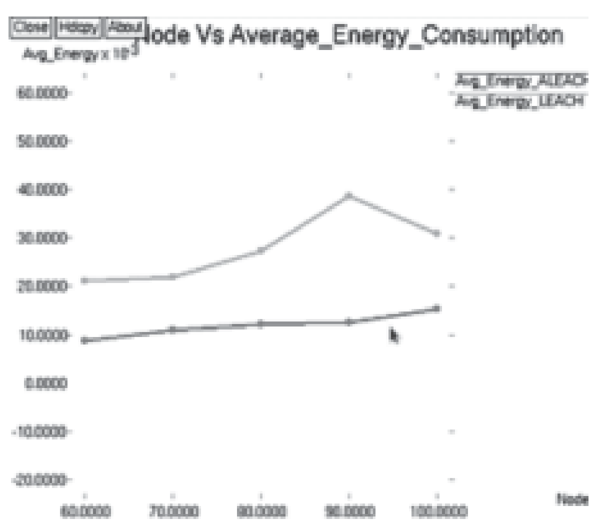


Fig. 2. Average Energy Consumption.

Simulation results show that CH scheduling and CH hibernation techniques contribute to a noticeable improvement in increasing the network lifetime by optimizing the energy consumption.

Fig. 2 shows the graph of nodes' average energy consumption. From the plot it is evident that the energy consumed by a node in ALEACH is significantly lower than the nodes in LEACH.

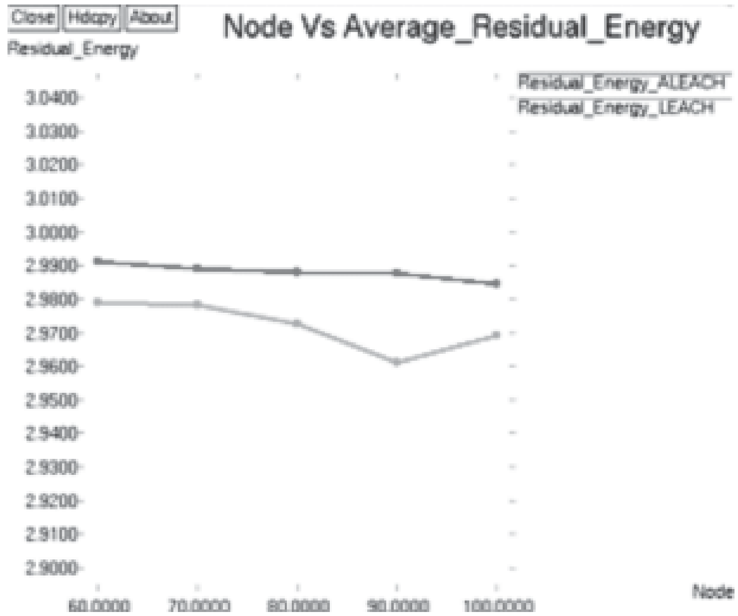


Fig. 3. Average Residual Energy.

Fig. 3 depicts the graph for the average residual energy of a node in ALEACH. In the Fig. 3 above, the average residual energy of a node in ALEACH is found to be higher than in LEACH.

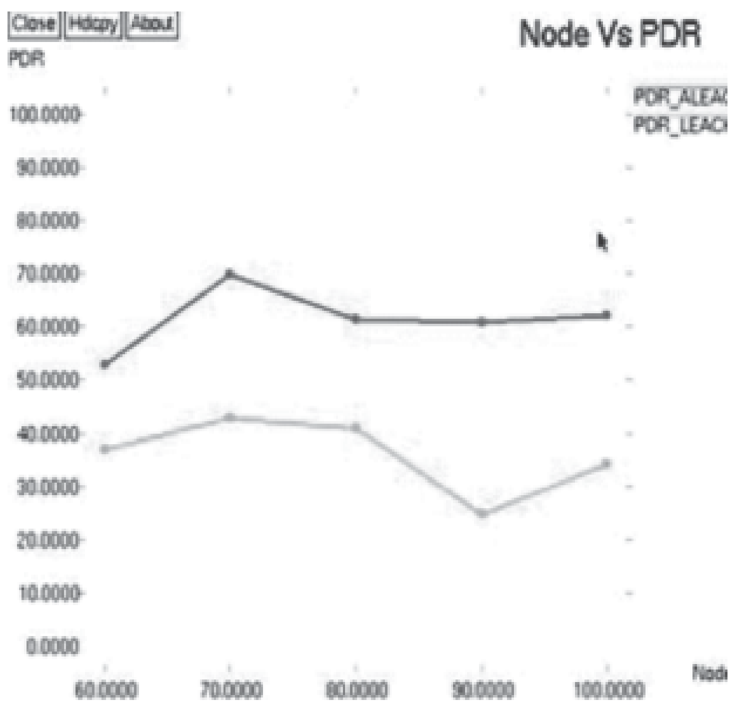


Fig. 4. Packet Delivery Ratio.

In Fig. 4, we can infer that the packet delivery ratio of the nodes in ALEACH protocol is much higher when compared to that of LEACH protocol as shown in Fig. 4.

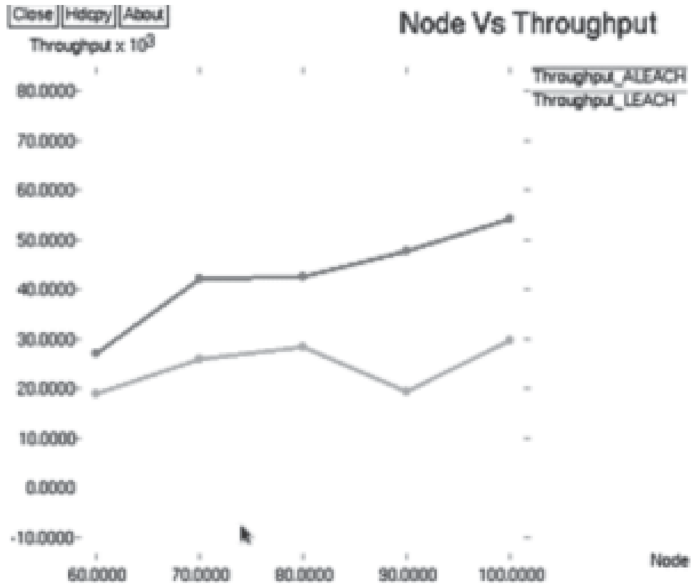


Fig. 5. Throughput.

And finally, Fig. 5 compares the throughputs of LEACH and the proposed clustering based protocol, ALEACH. It is evident from the plot that the throughput achieved in ALEACH is much higher than that in LEACH.

5. CONCLUSION

A modified protocol namely ALEACH, derived from LEECH protocol, has been proposed in this paper. In the proposed ALEECH two novel techniques have been introduced for minimizing energy in cluster based routing, we have shown that the proposed techniques effectively optimize the energy utilization of WSN and improve the network lifetime considerably. These techniques when employed in the bio fertigation of agricultural farming, reduces the total cost and totally avoids the need for human intervention. Also it has been shown that the energy consumed by each node in ALEACH is significantly lower than the nodes in LEACH. The average residual energy of a node in ALEACH is found to be higher than that in LEACH. The packet delivery ratio of the nodes in ALEACH is also higher when compared to that of LEACH protocol. Further it is evident from the simulation results that the throughput achieved in ALEACH is much higher than that of in LEACH.

In the future work, the implementation of the ALEACH protocol in a real-time application environment can be accomplished so that the benefits of the fully automated bio fertigation can be put into effective use by farming community.

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