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A Modified LEACH Protocol for Increasing Lifetime of the Wireless Sensor Network

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Abstract: *Many studies have been proposed on clustering protocols for various applications in Wireless Sensor Network* (*WSN*)*. The main objective of the clustering algorithm is to minimize the energy consumption, deployment of nodes, latency, and fault tolerance in network. In short high reliability, robustness and scalability can be achieved. Clustering techniques are mainly used to extend the lifetime of wireless sensor network. The first and foremost clustering algorithm for wireless sensor network was Low Energy Adaptive Clustering Hierarchy* (*LEACH*)*. As per LEACH, some Cluster Head* (*CH*) *may have more nodes, some other may have less nodes, which affects the network performance. The proposed method MaximuM-LEACH provides a solution by load balancing the number of nodes equally by fixing the average value N, so the life time of the network is increased.*

Keywords: *LEACH, modified LEACH, hierarchical cluster based routing, Wireless Sensor Networks* (*WSN*)*.*

1. Introduction

Recent advances in wireless technologies and the development of portable hardware will expand and support Wireless Sensor Network (WSN) applications. An WSN consists of thousands of sensor nodes which are deployed in sensing the field, for applications such as health care monitoring, agricultural monitoring, intruder tracking, traffic control, etc. During monitoring, data are routed through intermediate nodes to be communicated to a base station. The sensor network cannot communicate without power, supplied by a battery. Changing a battery in the sensing field is difficult in certain applications, for example, measuring the temperature of a volcanic field. Efficient battery use to increase the lifetime of the network is therefore desirable, but it can be a challenging task. Energy is consumed during idle listening; data transmission; and computing, processing and relaying the intermediate data. Idle listening can be avoided by periodically sending the node to sleep. Energy consumption can be minimized during data transmission and relay by

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an energy-efficient routing protocol. The routing protocol used in traditional wireless networks is not suitable to WSN, so designing an efficient routing protocol is a challenging task. Many such routing algorithms have already been proposed. Communication to the base station is generally achieved by one of two methods. One method is through direct communication. The problem with direct communication is that the farther a node is located from the base station, the greater the transmission power required, leading to greater energy consumption. The second method uses routing through intermediate nodes. Route establishment requires energy initially, though it generally uses less energy for communication than direct communication. Another drawback to this cluster-based second method is the difficulty in maintaining the network topology and links from source to destination. If the network consists of sensor nodes that are close to the base station, direct communication is the best choice. However, in a real time scenario, a huge number of sensors are widely deployed, making cluster-based hierarchical routing the best choice for effective and energy efficient communication.

The most extraordinary progressive routing protocols in WSN's are LEACH, PEGASIS, TEEN, EECS, HEED, etc. [13]. Among these all, LEACH is the least difficult routing protocol in WSN whose principle point is to spread the energy stack similarly among all sensor nodes in the system furthermore delay system life time. In this paper we look out on literature review. Section 2 describes LEACH, its types and their efficiency, comparative study tabulated and flow chart. Section 3 proposes a protocol. Section 4 consists of results and discussions. Section 5 contains conclusion.

2. Related work

Low Energy Adaptive Clustering Hierarchy, i.e., LEACH [1] is an energy efficient cluster-based hierarchical routing protocol. The main feature of LEACH is that it forms a local cluster and elects its own Cluster Head (CH) for communication with the base station. CH is responsible for all routing and communication in its given time period and aggregates local data before transmission. The CH is randomly chosen within some constraints. Generally, the node with the highest remaining energy will act as the CH because it can lead the group of nodes for a longer period of time than other nodes in the cluster. Once the CH is chosen, it will send the other nodes a message to join in that cluster. However, sensor nodes other than the CH will choose their own CH based on minimum transmission energy needed for communication. Once a cluster is formed, the CH determines the communication schedule for its nodes.

Various phases of LEACH are.

- Advertisement phase
- Cluster setup phase
- Schedule creation phase
- Data transmission phase

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Advertisement phase. During the cluster formation time, if a node wants to be a cluster head, it can choose a random number between 0 and 1. If the random number chosen by the node is less than the threshold value $T(n)$, it will be elected as CH. The procedure to calculate $T(n)$ is

$$T(n) = \begin{cases} \dfrac{x}{1 - x\left(r \bmod \dfrac{1}{x}\right)} & \text{if} \quad n \in S, \\ 0 & \text{otherwise,} \end{cases}$$

where n is number of nodes, x= 0.05 is the defined percentage of the cluster, r is the current round, and S is the set of nodes not elected as CH in the last $1/x$ rounds. When r = 0, all the nodes are eligible to be a CH. Once a node has acted as CH in r = 0, it will not be eligible for $1/x$ rounds, so the probability of being a CH of will increase for other nodes. Once the CH is selected, all CHs nodes advertise at the same signal strength. The non-CH nodes receive the message and choose a CH based on signal strength, where higher signal strength indicates closer proximity to the CH. Higher signal strength/closer proximity requires the least transmission power to CH.

Cluster setup phase. Based on the received signal strengths, a node chooses its own CH and sends the reply message to the CH, of which it is a member.

Schedule creation phase. The CH maintains its member list, sets a Time Division Multiple Access (TDMA) for its nodes and relays the communication schedule to its members.

Data transmission phase. Cluster members communicate to the CH until the radio is turned off. Once the CH has received all the data from its members, it compresses it to a single signal and communicates it to the base station.

Disadvantage. The uniform distribution of cluster members is not satisfied in LEACH because some clusters will have more members, requiring the CH to wait longer to receive all data from cluster members. This leads some CH nodes to fail sooner than others. The general cluster stricter is shown on Fig. 1. LEACH-C (LEACH-Centralized) defines during the setup phase of LEACH-C, each node reports its current location and residual energy to the base station. The base station calculates the average energy of the nodes. The nodes with above average energy will act as cluster heads for next time period, and this message is communicated to the other nodes in the network. Otherwise, the communication phase is identical to LEACH [2].

Solar aware LEACH (sLEACH) focuses on improving lifetime by providing solar power nodes in LEACH. The Base Station (BS) chooses k cluster heads plus three highest residual energy nodes and then removes potential cluster heads based on various criteria, such as minimum distance from other nodes. This process removes any CH that is close to another. By choosing and removing an unsuitable CH that consumes more energy, this method is more energy efficient than LEACH [3].

F a n X i a n g n i n g and S o n g Y u l i n [4] introduce a protocol with two strategies to improve the performance of LEACH:

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1. In LEACH, CH nodes are chosen randomly. The new strategy gives a node with high remaining energy the chance to be elected CH more often. This prevents the choice of a node with low energy, increasing its useful lifetime.

2. Instead of communicating directly from the CH to the BS, the CH can communicate through another CH in a multi-hop method. These two strategies improve the energy efficiency over LEACH.

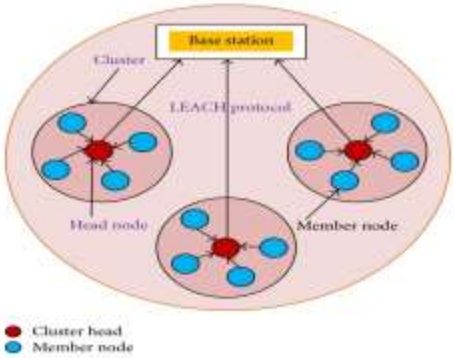

Fig. 1. LEACH protocol clustering structure

J. Islam, M. Islam, N. Islam [5] define an advanced version of sLEACH with a fixed BS placed away from the solar sensors and battery powered sensors. The BS selects a solar powered node as the CH and broadcasts the CH-ID message to every node in the network as an advertisement phase. Communication scheduling is as in LEACH. The major change is data aggregation based on First-In-First-Out priority.

Mittal et al. [6] propose an improved LEACH protocol that maintains the two CH nodes. One main cluster head receives data from members, aggregates it and sends it to the BS. The other CH is a Sub-CH kept in reserve, which acts as CH if the main cluster head dies. This Sub-CH is then responsible for all data transmission to and from the BS.

Tan et al [7] propose an energy efficient routing protocol called LEACH-DE that calculates the average residual energy of all nodes. In the first round, all the nodes in the network have the same energy level. Subsequently, a node that is closer to the BS will consume less energy than a node farther from the BS. Once the average residual energy is calculated, a node of higher than average energy close to the BS will be considered as a CH. After the CH selection procedure, the CH advertises its message to its potential members, members reply and cluster is formed.

In [8] Singh and colleagues describe a new LEACH, which for the first round follows the same set up procedure as LEACH. Subsequently, it checks the remaining energy of the CH; if it is greater than the threshold, the node can continue as CH. The remainder of the process is the same as LEACH. The comparison of various enhanced LEACH protocols is listed in Table 1 referred from Madheswaran and Shanmugasundaram [9]. The data flow methods of various enhanced LEACH techniques are defined in Fig. 2 [10].

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Table 1. Comparison of various modified LEACH protocol

Author	Algorithm proposed	Communication pattern	Energy efficiency	Advantages	Limitations
Sharma and others	PEGASIS	Chain based	High	No of rounds are 100 to 200% higher than LEACH	Excessive delay for distant nodes
Khan and others	Ad-LEACH	Single hop	High	The network life time is 66% more than LEACH. Increases the number of rounds around 1500-2500 rounds	Instability region is 40% more than LEACH
Dakshayini and others	E-LEACH	Single hop	Very high	Reduced the radio communication range by proper selection of CH. No of rounds are 200% higher than LEACH	The network should equipped with GPS for monitoring the position of the nodes and CH
Nguyen and others	LEACH-C	Chain based	Very high	Number of data received at base station is 8% more than LEACH	Not give good performance if the nodes are mobile
Dembla and others	EE-LEACH	Single Hop	Very high	Energy consumed is reduced up to 43% for 100 nodes and 44% for 200 nodes	CH need to be distributed uniformly
Taneja and others	TLHCLP	Multipath model	High	Life time is improved from 20-42% for 100 nodes	Algorithm should ensure that all nodes become cluster members
Gupta and others	LEACH-A	Chain based	Very high	Life time of the network increases 80% and throughput increases 1.2 times than LEACH	A multi path route algorithm based on energy hops is proposed to reduce the energy consumption
Bhadeshiya and others	LEACH sub CH	Single hop	High	Fixed number of CH increased throughput and reduced the energy consumption significantly	Optimum number of clusters must be selected for best results
Mao and others	EECS	Single hop	Very high	Life time increases 135% and energy utilization is 93% more than original LEACH	Future work should include multi hop communication
Nguyen and others	M-LEACH	Multi hop	Very high	Throughput is 8 times greater than LEACH-C	Velocity threshold and round time models should be developed. Location monitoring is an overhead
Mu Tong and others	LEACH-B	Single hop	High	Residual energy of nodes is considered for CH selection and 25% efficient than LEACH	Other parameters like node degree, distance are yet to be considered for best CH selection

In [11] it is described the changed adaptation of LEACH convention with altered groups and turning group heads. Here bunches are shaped once and altered, and the bunch head’s position pivots among the hubs inside the group. As bunches are shaped just once so there is no situated up overhead at the start of each round. Filter F does not permit new hubs to be added to the framework and does not modify their conduct in view of hubs passing on. Version of LEACH (V-LEACH) [12] is another rendition of LEACH

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Protocol, which minimizes the energy consumption. Hierarchical LEACH (H-LEACH) [13] is proposed to minimize the energy level using minimization of the transmission distance (more distance-more power, less distance-less power). H-LECH performs its first round like LEACH. For further clustering a Master Cluster Head is chosen for optimal transmission distance to base station [14].

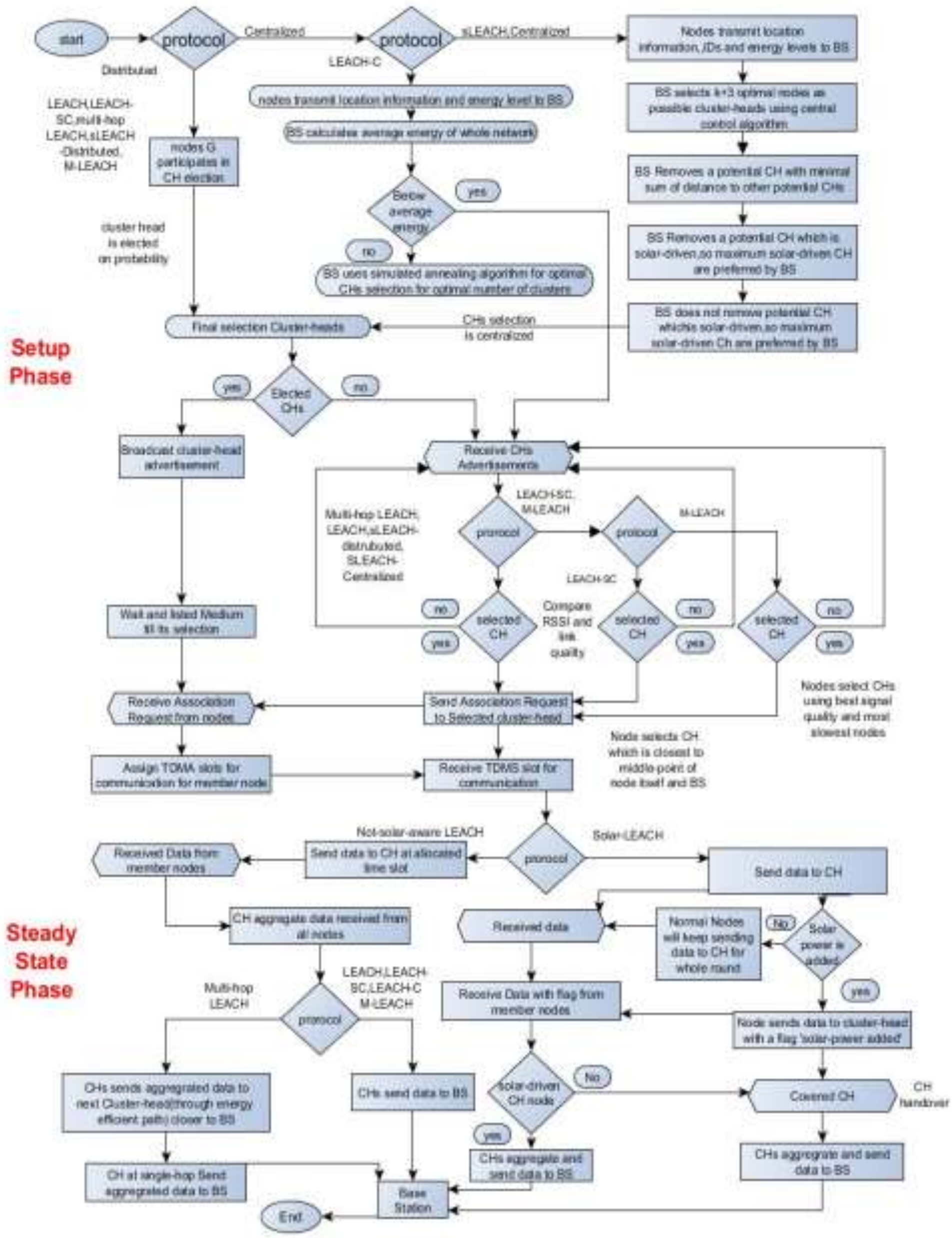

Fig. 2. Flowchart of LEACH protocol and its types

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Luan et al. [15] proposes an algorithm based on LEACH by consolidating Node Degree and Remaining Energy of WSNs. The CH is elected based on the number of connected nodes and the maximum remaining energy. Taneja and Bhalla [16] proposed an improved version of LEACH: Three Levels Hierarchical Clustering LEACH Protocol (TLHCLP) for Homogeneous WSNs. Base station is considered as the location center and a predefined radius is utilized. Nodes are ordered as inside nodes. Mao Ye et al. [17] propose an Energy Efficient Clustering Scheme (EECS) for periodical information gathering application. At the election stage for CHS, a fixed number of hopeful nodes are chosen based on the remaining energy holds by the nodes and executing the load balancing to achieve the minimum energy consumption. Gupta et al. [18] propose low energy utilization chain-based routing protocol LEACH-CC. LEACH-CC uses a centralized clustering algorithm; to minimize energy, delay to increase the lifetime of network. Fig. 2 shows the comparative study of various LEACH protocol.

3. Proposed method

When the distribution of nodes is uneven, one cluster may have many nodes while others may have very few. The cluster head of a large number of nodes may die faster. This phenomenon affects the efficiency of the network. Both LEACH and LEACH-C fail to solve this problem. To overcome this problem, we propose another algorithm that uses the concept of LEACH-C. The principal new strategy is to allocate nodes to the nearest cluster head only if the number of nodes already allocated to that cluster head is less than a particular number N. If the number is greater than N, a node is allocated to the second-nearest cluster head, and so on. N is calculated by dividing the total number of nodes by the number of cluster heads.

The modified algorithm consists of two phases: the setup phase and the steady state phase. In the setup phase, the base station knows the energy status and location of all the nodes. The base station calculates the average energy of the network. All the nodes with energy greater than the average energy are selected as cluster heads. The base station then allocates nodes to the nearest cluster head only if the number of nodes already allocated to the cluster head is less than N. If it is greater than N, the base station then calculates the second-nearest cluster head. If the number of nodes of the second cluster head is also greater than the number N, the base station finds the third-nearest cluster head and the process continues. Once the nodes are allocated to the cluster heads, the base station sends to each node the identifier of their cluster head. The equal energy drain on the cluster heads also increase the efficiency and lifetime of the network.

The steady state phase is similar to the steady state phase of the LEACH and LEACH-C protocols. The nodes send data to the cluster head. The cluster head

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aggregates the data and forwards it to the base station. After some predefined time, the next round begins and the setup and steady state phases start over.

Table 2. Simulation parameters

Parameters	Values
Coordinates of x_m and y_m	(400, 400)
Sink node location	(200, 200)
Total number of nodes	100
Initial energy	0.5 J
T_x and R_x energy for each node	50×10^{-9}
Data aggregation energy	5.0×10^{-9}
Total number of rounds	2500

MM-LEACH procedure

Step 1. Initialise the simulation parameters as shown in the Table 2.

Step 2. Distribute nodes randomly and evenly to the total area and store the locations of all nodes.

Step 3. Assume all the nodes are initially normal.

Cluster forming: Initialize number of cluster heads to zero.

Step 4. First round: Cluster head selection is similar to LEACH.

Step 5. Second round: The base station calculates the average energy,

If the node's energy is more than the average, the node is elected as cluster head

Else the node is a member node

If energy is =Zero

Then the node is a dead node.

Step 6. Setup phase

//Find the number of nodes for each cluster

number_of_nodes = (nodes – cluster+1) / (cluster – 1)

The total number of non-CH nodes is divided equally among the CH nodes.

if distance is less than min_distance and number of nodes allocated is less than number_of_nodes min_distance = distance

min_distance_cluster_head= current_cluster_head,

else

nodes to nearest CH, if it has less than the allotted number of nodes

If there are any remaining nodes, it will choose its neighbour CH.

Step 7. The Communication Phase is as it is in LEACH.

MM-LEACH procedure

Advantages:

1. The cluster heads are not selected randomly. They are selected on the basis of the existing energy of the nodes, making the new algorithm more energy efficient than LEACH.

2. Every cluster has equal number of nodes, so there is an almost equal amount of energy drain on all the cluster heads. This also increases the efficiency and lifetime of the network. The given modified algorithm is based on the LEACH and LEACH-C protocols. The parameters and variables used in MATLAB coding are given below.

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4. Results and discussions

The simulation is executed using MATLAB. The various network parameters and their values are defined in the algorithm. Fig. 3 clearly shows the cumulative number of packets transmitted to the BS as a function of the number of rounds. The performance curve of MM-LEACH matches that of LEACH for small numbers of rounds. Towards the middle of the total number rounds, the performance curves deviate, but the performance of MM-LEACH is good at minimizing the number of dead nodes.

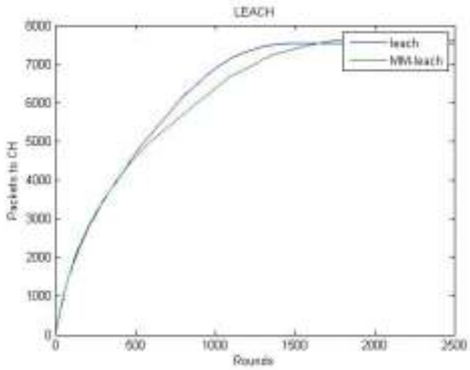

Fig. 3. Packets to CH for various rounds

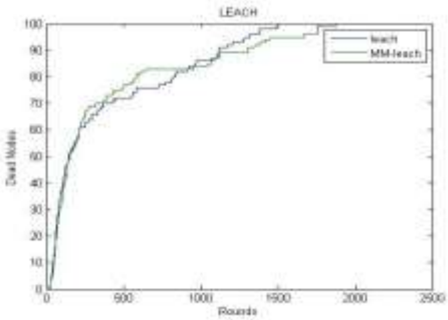

Fig. 4. Dead nodes vs rounds

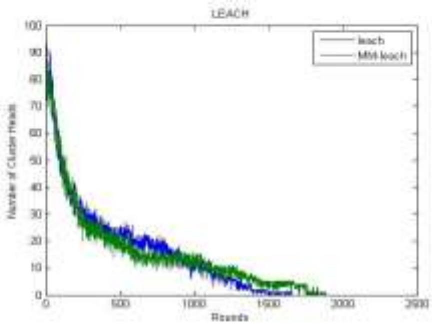

Fig. 5. Number of cluster heads vs rounds

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Fig. 4 relates the number of dead nodes to the number of rounds, showing that the number of dead nodes is smaller for MM-LEACH than for LEACH. At round 1600, all LEACH nodes are dead, but some of the nodes remain live at round 2000 in MM-LEACH. The lifetime of the network is increased in MM-LEACH. As shown in Fig. 4, because the lifetime of network is increased by the presence of the remaining live nodes, CH selection is also executed until round 2000 in MM-LEACH, as is clearly plotted in Fig. 5. Fig. 6 demonstrates that the proposed protocol delivers a greater number of packets to CH compared to LEACH.

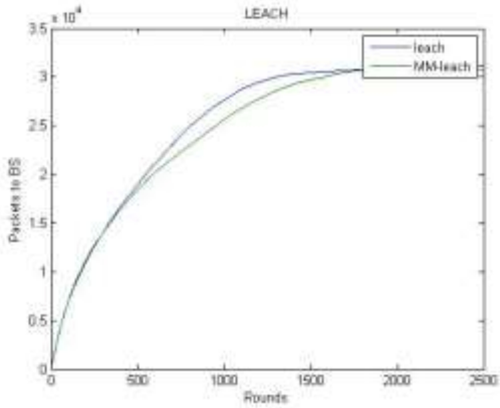

Fig. 4. Packets to BS

5. Conclusion

In this paper, the advantages and limitations of different modifications of the LEACH protocol are discussed. Table.1 lists the communication pattern, energy efficiency and the limitations of different modifications made to the LEACH algorithm. Each proposed variation of the LEACH routing protocol is examined to assess the improvement in energy efficiency and throughput. Research on performance improvements to the LEACH protocol is ongoing. Our research is also focused on improving LEACH performance to minimize the number of nodes stranded as the cluster heads die and on increasing network lifetime and throughput via load balancing.

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