LEACH Protocol Enhancement for Increasing WSN Lifetime

2020 11th International Conference on Information and Communication Systems (ICICS) 978-1-7281-6227-0/20/$31.00 ©2020 IEEE 10.1109/ICICS49469.2020.239542

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***Abstract*— Wireless Sensor Network (WSN) has become one of the most common techniques in different applications such as agriculture, factory monitoring, health care and fire track. WSN has many advantages such as low cost, small size, multifunctional, self-organized and able to be routed by WSN protocols. On the other hand, WSN has some backward which obstructs some applications such as low battery, short lifetime, area of sensor deployed and sensor energy consumption. In this paper, we propose a new approach to achieve better enhancement of WSN in terms of network lifetime and data transmission time represented by reducing the packet delay time. Then, we compare the simulated result of the proposed algorithm with the basic LEACH protocol with fixing parameters. The proposed algorithm achieved 128.80% improvement compared with the basic LEACH in the concept of network lifetime.**

***Index Terms*—WSN, LEACH Protocol, Secondary Cluster Head, Network Lifetime, Energy Efficient**

I. INTRODUCTION

Wireless Sensor Network (WSN) consists of a large number of very small sensors deployed in a specific area depending on the desired application [1]. Each sensor contains sensing, data processing, and communication components. These sensors form WSN nodes that transfer the sensing data to the Base Station (BS) or sink. In the BS, the data is processed and computed to give understandable results. The communication between BS and wireless nodes is arranged by different protocols. One of the energy-efficient protocols is the LEACH routing protocol. In this protocol, the network is divided into different clusters and each cluster has elected Cluster Head (CH) which connected with cluster member nodes and the BS, collecting data from the nodes and then sending the aggregated data to the BS [2][3].

As a cluster head has more functions than the other nodes, so it consumes its energy faster than the other nodes which leads it to die earlier [4][5]. In this paper, we propose a new algorithm called Secondary Cluster Head (SCH) which becomes a cluster head simultaneously with the death of the previous CH. So, all WSN cluster keep transmitting data even if some nodes dead which increase the network lifetime and performance.

LEACH protocol uses TDMA or CDMA routing protocols [6][7][8]. First, LEACH processes start with the setup phase then the steady-state phase. The cluster formation and then Head has been chosen are in the setup phase. We propose in this project to select the CH besides of Distance-Based Cluster Head (DBCH) algorithm that improvements combination with SCH approach would maximize the network lifetime, save energy, reduce delay time and increase the data transmission rate.

The remaining of this paper is organized as follows. Literature review and related work is given in *Section II*. The LEACH protocol, including the relevant theoretical background about the main components of the proposed system, is presented in *Section III*. Next in *Section IV*, the proposed algorithm is presented. The base line simulation is discussed in *Section V*. The experimental settings, results, and discussions are thoroughly given along with the supporting and illustrative figures are presented in *Section VI*. Finally, the paper is concluded in *Section VII*.

II. RELATED WORK

Wireless sensor technology is growing rapidly, especially with many new Internet of Things (IoT) applications. In another side, researches are coming out with diversities of approaches to enhance and improve this technology trying to cover the needs in this era. The drawback of sensor Technologies is the low battery and short lifetime. So, most of the following researches considering to sophisticate these weaknesses and suggest different algorithms and approaches overcome these issues.

Sharma [7] proposed novel LEACH protocol in the heterogeneous network and compared the simulation results with LEACH Homogeneous system; They chose 100 * 100 meters area to simulate the protocol. Sharma found that 10 nodes have more energy than the rest of 90 nodes which improves the system lifetime and enhanced wireless sensor network performance.

Naveen [8] explored fifteen different types of clustering wireless sensor protocols which considered more in energy-efficient and lifetime of the network system. They also compared them with various parameters such as stability, scalability, load balance and energy-efficient.

Cluster head selection algorithm is the main factor of getting better performance in clustering wireless sensor network, as reported by Prasad [9]. Prasad suggested an improved energy-efficient leach protocol (IEE-LEACH) for MANET aiming to

minimize energy consumption and enlarge network lifetime by picking CH which exhausted high remaining energy and nearest distance to the BS. Prasad simulated LEACH using TDMA routing protocol. Also, they surveyed the previous approaches for selecting CH and improving the WSN performance such as Euclidian Distance from a node to BS, remaining energy and number of nodes in the same cluster.

Increasing the number of dead nodes in the cluster would be the reason for shortening the WSN lifetime. Nandi [10] implemented a new protocol for choosing an optimal place for the BS, which overcomes the issues of delivering data and they compared the simulation result with the basic LEACH protocol with TDMA technique. Commonly when the BS located far away from the node, then transmitting data from a node to BS will cost more energy in the node, which leads to reduce the node lifetime and therefore reduce the network lifetime [10]. Moreover, packet delivery time would be reduced when the sink positioned in the center near the nodes [10].

In [11] the authors compared three different WSN protocol, direct transmission protocol, LEACH and EEE LEACH in terms of data communication time and throughput. EEE LEACH has better data transmission time and DTx has minimum throughput [11]. In [12], the authors proposed an algorithm called Distance Based Cluster Head (DBCH) which the threshold value measured by the following equation :

$$\mathrm{T}(n) = \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)} + (1-p)\frac{D_{max}-D_{i\ to\ BS}}{D_{max}-D_{min}}\left(\frac{E_R}{E_0}\right) \quad (1)$$

where E_R is the residual energy of the node for the current round and E_0 is the initial energy. This algorithm proposes to select the closest node to the BS as a cluster head. This enhancement considered on two-parameter energy and distance. In addition, it considers the distance from the node to cluster head base station and compared the distance from node cluster head and BS. This study simulated the suggestions on a homogenous network, where all nodes have the same amount of energy.

III. LEACH PROTOCOL

LEACH protocol or low-energy adaptive clustering hierarchy protocol suggested for wireless sensor networks by MIT's Chandrakasan [13]. LEACH is a self-adaptive cluster formation protocol. The nodes are randomly deployed then one node is selected to be a cluster head which will play a role as a gateway for all nodes in the cluster to the BS. All nodes in the cluster have the same probability to be a cluster head based on the equation (2). The cluster head election occurs in the setup phase of each round in the LEACH protocol. Each node generates a random number between 0 and 1, when the generated number is less than the threshold T(n), then the node would be selected as a cluster head. After that, the cluster head node informs all nodes in the same radio range (each node join the CH based on Received Signal Strength Indicator RSSI [13][14]) that it's the cluster head for the current round and the cluster form. The threshold is defined as in the following equation [15]:

$$T(n) = \begin{cases} p/(1-p\times(r \bmod(1/p))) & n \in G \\ 0 & otherwise \end{cases} \quad (2)$$

where p is the probability of a node to be a cluster head, r is the number of rounds, G is the set nodes that have not been selected in the last $1/p$ rounds. As the cluster head is known for each node in the cluster and the cluster head form the TDMA slots for each node in its cluster (to prevent interference). Then the steady-state stage of the LEACH protocol process starts. Next, all nodes send the data packet to the cluster head then the cluster head integrates the data packets and sends the fused data to the BS. We have noticed that the cluster head missions are more than the ordinary nodes, so the cluster head consumes more energy than the others which one of the drawbacks of the LEACH algorithm. LEACH disregards the BS and cluster head geographical positions, energy consumption, and instability in the case of cluster head death.

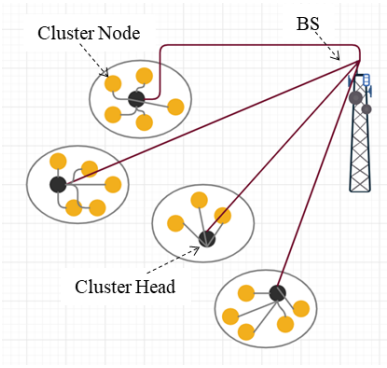


Figure 1: LEACH infrastructure

IV. PROPOSED ALGORITHM

On breaking down the properties of LEACH protocol, cluster head selection plays the main role in enhancing and improving the network lifetime, data transmission and energy-efficient. We propose a new algorithm to improve the lifetime of the network by selecting Cluster Head (CH) and Secondary Cluster Head (SCH) in the sensor setup phase of each round. According to previous researches, the nearest the distance between CH and BS, the better lifetime and energy-efficient the network is. Basis equation (1) we choose to select the closest node to the BS as CH and the closest node to the CH as SCH, with considering on energy and distance parameters of the node. Depending on this suggestion, if the CH dead the cluster will not cut off the communication with the sink and the secondary cluster head replace the dead cluster head and pronounces itself as a cluster head. Rather than that, the cluster continuously connecting the sink as long as the active node alive in the cluster.

The threshold in the proposed method is defined as follows:

$$T(n_i) = \begin{cases} \frac{p}{1-p*(r \bmod \frac{1}{p})} + \left(\sqrt{2} - \frac{dis(st)}{\left(\frac{x+y}{4}\right)}\right) / \alpha \\ 0 \end{cases} \quad (3)$$

The threshold is defined above because we want node energy criteria and node-sink distance to be effective in determining CH and SCH. Although Select secondary cluster head costs more time in the setup phase for the same round, it keeps the cluster communicate with the BS in case it has alive nodes. Equation 4 what we call the distance coefficient,

$$\sqrt{2} - \frac{dis(st)}{\left(\frac{x+y}{4}\right)} / \alpha \quad (4)$$

increases the likelihood of nodes being shorter than the sink. *dis(si)* compute the distance of the node *i* to the sink. This value can be calculated by relying on the Euclidean distance (the distance between two nodes is the line length between them) and as shown in equation (5)

$$d(\mathbf{p}, \mathbf{q}) = \sqrt{(q_1 - p} \quad (5) \quad \overline{p_2)^2}.$$

Where, points $p = (p_1, p_2)$ and $q = (q_1, q_2)$ are the locations of the two nodes. The number of CH should equal the number of SCH (one SCH for each CH) at the beginning of the round.

Returning to reducing data transmission time, we suggest that the position of BS should be in the center of the WSN as shown in Figure 2 surrounding with four equal-area squares in order to optimize energy consumption for communicating between clusters and BS.

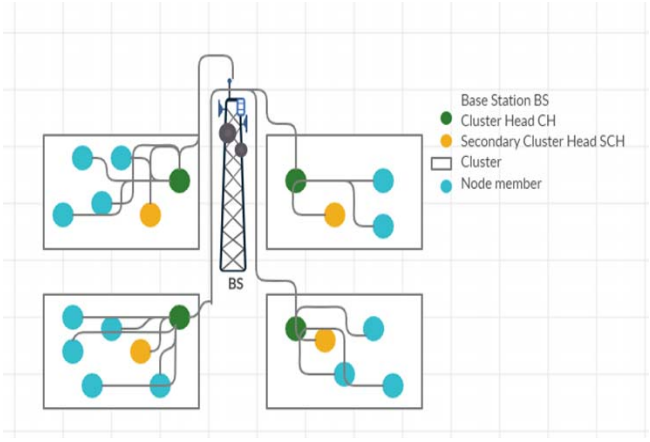


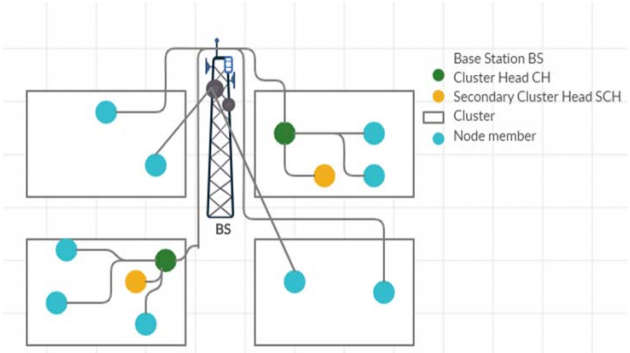
Figure 2: Architecture platform of the proposed algorithm

From the perspective of making the network with high latency. we applythe algorithm of node density in the cluster.Some nodes are not able to join the cluster because they have not the range ratio of any cluster, So they connect to BS directly without electing CH by the protocol which called Direct transmission (DTx), where (we assume Figure 3 illustrates this algorithm.

Figure 3: Nodes density in a cluster; LEACH protocol connection and DTx protocol connection with BS

V. BASE LINE SIMULATION

Considering the major issues of the Wireless Sensor Networks, We focus on the most common algorithm. LEACH protocol, which enhanced the performance of the WSN such as Energy efficient, Transmission time, transmission rate, optimal position of the sink, the optimal position of the cluster head, node density and network lifetime. These are the main performance enhancement factors that we figure out in this paper. Figure 4 shows the initial LEACH protocol with homogenous network topology using MATLAB (Version: 9.2.0,518641) with an area of *100* × *100m*. BS is in the center of the network *(50,50)*, with *100* nodes are deployed randomly and certain nodes are randomly selected as cluster heads. We fixed a maximum number of clusters to be *10*, a maximum number of rounds is *5000* and the initial energy equal *0.5Joules.*



Then, we set the data packet size equal to *4000 bits* and the number of packets from each node to be *10* each round. We prefer to save the same parameters for all algorithms to gain fair comparison.

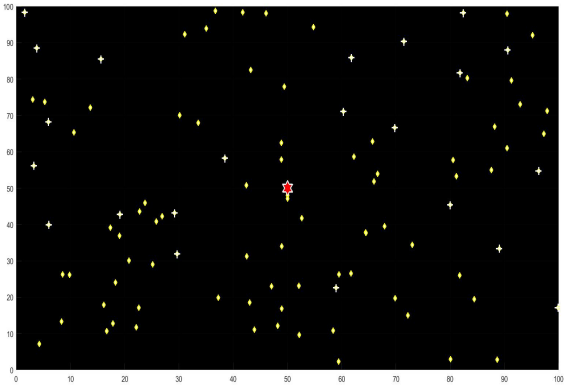


Figure 4: LEACH protocol topology in Matlab, where all the nodes are alive

First issue is choosing the cluster head and to build our baseline, we explore the basic LEACH protocol simulation with respect to the fixed parameters and we found that the first dead node is in round 1428, and the last dead node is in round 1934 as shown in the Figure 5. The red dots are the dead nodes

in contrast with round value. The process in LEACH protocol is divided into two phases. First, elect the Cluster head which form the clusters (setup phase). Second, data communication start between ordinary nodes and their cluster head and between cluster heads and base station (steady state phase). Because randomly selection of cluster head, all nodes have the same probability to be a cluster head, which increases the energy consumption. As soon as the cluster head is elected, the CH node warns the other nodes that it is the CH. The nodes sense the data and send packets to the CH in the same cluster, CH collect the data from nodes and transmit it to the base station. Data communication is conducted by TDMA routing protocol. Each node takes slot time to send its data packet.

Figure 5 illustrates a snapshot of the network during the last period. The small red nodes denotes the dead nodes in the network. While, Figure 6 shows a snapshot of network, while communicating and transferring the data packets.

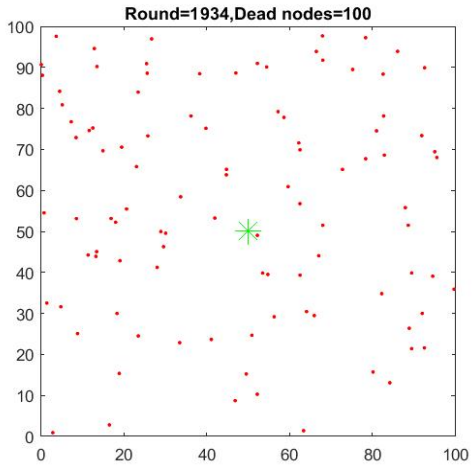


Figure 5: Snapshot of the network during the last period. red dots (small ones) denote the dead nodes

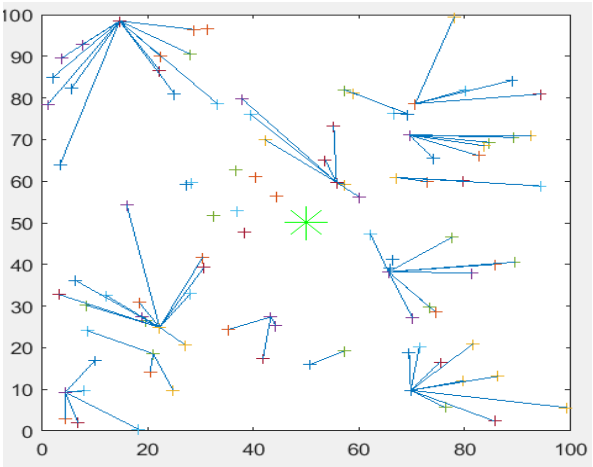


Figure 6: Snapshot of network while communicating and transferring packets

Alive nodes counting in contrast with a number of rounds are illustrated in Figure 7. The figure shows alive node analysis of basic LEACH protocol. As shown in the figure, the nodes start dead during round 1547, and then all nodes are dead in round 1934.

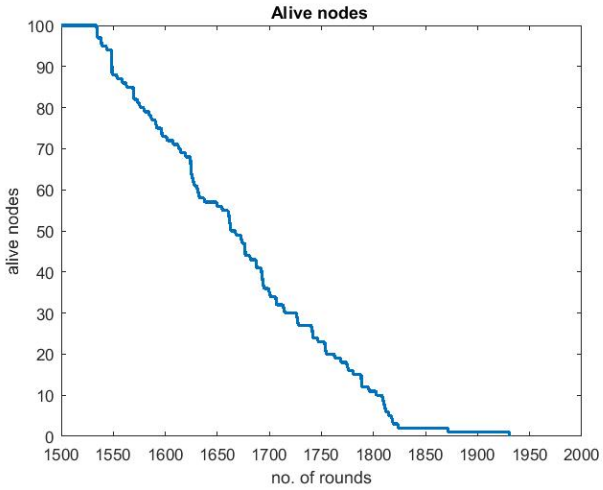


Figure 7: Alive node analysis of basic LEACH

The network lifetime influenced by the energy consumption of each node. When the consumed energy increases, network lifetime decreases. Figure 8 illustrates the basic LEACH with average consumed energy in each round.

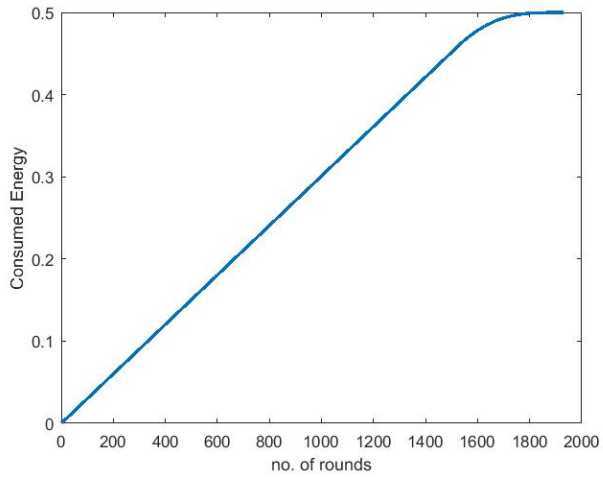


Figure 8: Average consumed energy of basic LEACH

Next section, we discuss the simulation results of the proposed algorithm and compare the result with the basic leach protocol.

VI. Proposed Algorithm Simulation Results

Prolong network lifetime still a major issue in wireless sensor networks [16]. So, we tend to extend the network lifetime and implement the proposed algorithm with the same parameter used for the basic LEACH protocol. Parameters values are chosen relying on previous researches who analyzes the WSN parameter to choose the optimal values for simulation and experiments and as demonstrated in [16], [17], [18], [19] and [20]. The proposed S-LEACH protocol simulation parameters are shown in Table 1. We used

MATLAB (Version: 9.2.0,518641) simulation tool with a simulation time of 2002.291161 seconds.

Table 1: Simulation Parameters

Parameter	Value
Sensor deployment area	100 × 100 m
Base Station Location	(50,50)m
Number of nodes	100
Data packet size	4000 bit
Control packet size	100 bit
Initial energy of sensor	0.5 J
Probability of node to become CH	0.1
Maximum round (rmax)	5000

Network lifetime measurement factor is used to monitor the network life cycle, in this paper we focus on the last dead node in the whole network concurrently with data packet transmission through the network. The alive nodes of the proposed LEACH algorithm in contrast with the number of rounds are illustrated in Figure 8. As shown in the figure, by using our proposed algorithm, the last dead node was in round 4425 (after ten times of simulation). While in basic LEACH (as shown in Figure 6), the last dead node was in round 1934. It turns out that the proposed S-LEACH approach increased network lifetime by 128.80% compared with basic LEACH.

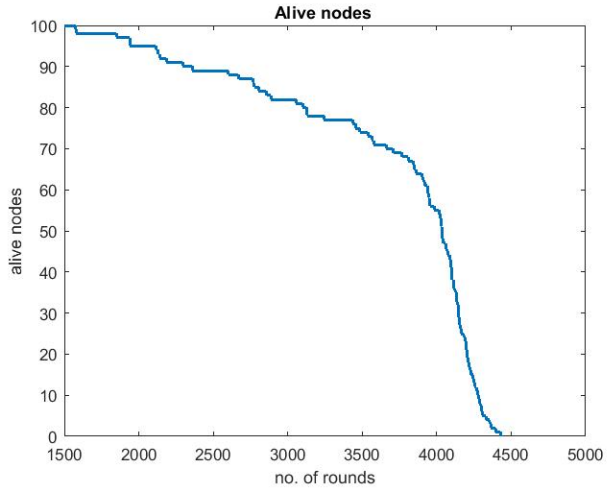


Figure 9: The Alive node in the network of the proposed algorithm

The reflection also appears on energy consumption. The network lifetime is increased due to the efficient way of energy consumption by transmitting the data packet in our proposed algorithm. Figure 10 shows the energy consumption of the proposed algorithm. As shown in the figurefor example, the average consumed energy in round 1000 was 0.12J compared with 0.3J in the basic LEACH algorithm. In addition, the network with our proposed algorithm run for 4425 rounds compared with 1934 in basic LEACH as we discussed before.

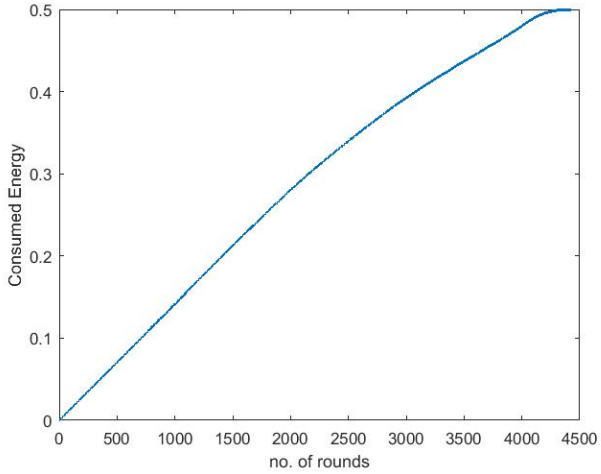


Figure 9: Energy consumption of proposed LEACH protocol

VII. Conclusion

The wireless sensor networks are widely used in different areas. LEACH protocol is one of the most popular approaches in WSN. In this paper, we proposed a new algorithm called Secondary Cluster Head (SCH), which becomes a cluster head simultaneously with the death of the previous CH. Therefore, all WSN cluster keep transmitting data even if some nodes dead, which increase the network lifetime and the network performance. It is shown thatthe last dead node in the proposed algorithm was in round 4425, which increased the network lifetime by 128.80% compared with the basic LEACH protocol.Also, that increased the number of transmitted data packet in the network with the same network settings compared with the basic LEACH protocol. As future work, it would be worth to apply the proposed S-LEACH algorithm in different WSN routing protocols to minimize network traffic and the best path for data to travel from cluster to sink.

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