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Improved LEACH protocol for increasing the lifetime of WSNs

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ABSTRACT

Recently, wireless sensor network (WSN) is taking a high place in several applications: military, industry, and environment. The importance of WSNs in current applications makes the WSNs the most developed technology at the research level and especially in the field of communication and computing. However, WSN's performance deals with a number of challenges. Energy consumption is the most considerable for many researchers because nodes use energy to collect, treat, and send data, but they have restricted energy. For this reason, numerous efficient energy routing protocols have been developed to save the consumption of power. Low energy adaptive clustering hierarchy (LEACH) is considered as the most attractive one in WSNs. In the present document, we evaluate the LEACH approach effectiveness in the cluster-head (CH) choosing and in data transmission, then we propose an enhanced protocol. The proposed algorithm aims to improve energy consumption and prolong the lifetime of WSN through selecting CHs depending on the remaining power, balancing the number of nodes in clusters, determining abandoned nodes in order to send their data to the sink. Then CHs choose the optimal path to achieve the sink. Simulation results exhibit that the enhanced method can decrease the consumption of energy and prolong the life-cycle of the network.

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1. INTRODUCTION

Recently, information technology has seen enormous progress in all domains, everything has been digitized. WSN offers a better solution for efficiently gathering data from anywhere, even difficult areas where human activity is impossible [1]. Various domains use WSN to ameliorate their production or quality of service (QoS) [2]. Each sensor node has at least one sensor that serves to collect data. These micro-sensor nodes characterize by self-configuration and self-adaptation, generally, they are alimented by non-rechargeable batteries. Numerous applications use the WSN by reason of the weak-cost, the self-organization of nodes, the sensing ability of sensors, the miniature dimension of the node which allows it to be deployed in hard environments to supervise different types of physical and environmental conditions, easy in positioning, scattering over an large region and giant fault tolerance [3–5]. However, the WSN faces several issue related to the power source.

The great use of energy in the various units of the sensor node limits the lifespan of these batteries, which limits the lifespan of the entire network because batteries are the principal reasons for the lifetime of

the sensor node [6]. Consequently, the major constraint within the WSN is energy consumption. Therefore, it is requisite to conserve energy in order to prolong the network life cycle. For this reason, numerous research problems are defined as optimization issues referred at discovery useful design strategies, like deployment coverage issue, data routing problem, cluster-head selection [7]. Thus several routing protocols have been scheduled by researchers to reduce the energy consumption of network nodes [8, 9].

Routing protocols are divided mainly to 3 classes: hierarchical, data-centric, and location [9] as we can see in Figure 1. Each class contains several protocols, such as LEACH [10], SPIN [11], HEED [12], MG-LEACH [13], EDMHT [14], MBER [15], BRE-LEACH [16], and so on. Among the existing and the famous routing protocols, there is LEACH protocol. LEACH has been the first and the oldest algorithm, it has been considered as it is an energy-efficient clustering protocol which partitions the network to many groups of sensor nodes. Thus, in any group, there are common nodes responsible to collect data and a randomly elected cluster head which aggregates cluster data, compresses it then transmits it toward the collector. Even if LEACH aims to extend the duration of the network, it remains limited by many constraints, such as the random selection of CHs, single-hop between CHs and the sink regardless of the space and the remaining power. To improve the energy efficiency in WSN various energy efficient routing protocol are proposed, such as EESRA [17], O-LEACH [18], BPA-CRP [19], and so forth.

In this work, we suggest an ameliorated efficient-energy routing approach based on the clustering method. This work is different from other existing studies because it is based on the remaining energy to select CHs, it limits the number of nodes in each cluster which serves to balance the energy of the CHs, determines abandoned nodes that can not join any cluster in order to send their data to the sink. Then every CH chooses the optimal path to achieve the sink. Our enhanced protocol serves to prolong the life cycle of the network more than LEACH by minimizing energy consumption.

The organization of the content of the present document is as pursue: the second part exposes the related work. The third part introduces the proposed work. The fourth part exhibits the simulation results of our protocol compared with the LEACH algorithm. A discussion of results is given in the fifth part. Finally, the sixth part presents a conclusion of the paper.

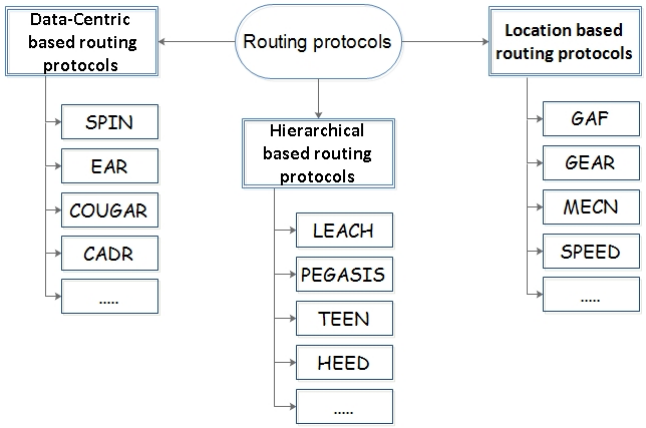


Figure 1. Routing protocols classification

2. RELATED WORK

LEACH is the fundamental and the oldest protocol of hierarchical routing protocols, focused on clustering [20], suggested by Heinzelman *et al.* in 2000 [10]. LEACH is characterized by the self-adaptation as well as the self-organization; nodes organize themselves into clusters [21]. LEACH generates clusters in the network and it provides a turn conception. Each turn includes two main stages. In the first stage, CHs are selected randomly according to the threshold function defined in (1), then clusters are established in self-adaptation [22]. In the second stage, it includes communication between normal nodes and their corresponding CHs, thus communication between CHs and the collector. So, this last stage presents data transmission.

In the cluster formation, LEACH adopts a probability function to elect CHs. Each sensor node makes choice an aleatory value betwixt zero and one. This node turns into a CH in the present period if the random

value is inferior to the threshold function described in (1). Otherwise, it becomes a normal node [23]. Thereby, normal nodes are looking for their CHs depending on the received signal from CHs.

$$T_L(s) = \begin{cases} \frac{P_L}{1-P_L*(i \ mod(1/P_L))}, s \in C \\ 0 \qquad\qquad \text{else} \end{cases} \tag{1}$$

Here P_L represents the CHs probability in the network, i is the number of the period; C is the number of the sensor nodes that have not become CH in the previously $1/P_L$ iterations.

In the stable stage, Once CHs are elected and clusters are formed, the data transfer begins. Every normal node gathers its environment information, forward it to its CH. When data achieve CHs, these latter aggregate their cluster data, then send them to the sink.

LEACH-centralized (LEACH-C) [24] is a centralized clustering algorithm. It is an enhancement of the conventional LEACH approach. With similar to LEACH, LEACH-C splits every round into a set-up and steady-state phase. In the beginning phase, unlike LEACH, in LEACH-C the base station (BS) selects CHs at the hand of the average energy of nodes and the location. Based on this information, alone the nodes with higher energy can be a CH.

Balanced residual energy-LEACH (BRE-LEACH) [16] selects CHs in terms of the remaining energy. Then, it selects the CH that has the remaining energy more than the average remaining energy and the distance to the BS less than the average distance as a root CH. This root is responsible to aggregate all CHs data and sends them to the BS. Thereby, in the BRE-LEACH, CHs use the multi-hop technique to achieve the root CH.

3. THE PROPOSED PROTOCOL

In the LEACH protocol, the aleatory choice of CHs in the network results in an energy imbalance of nodes, and not all nodes have the same opportunity to become CH. Thus, in the LEACH, the LEACH-C, and the BRE-LEACH algorithms, the number of nodes in clusters is not the same, which creates an energy imbalance, CHs with more cluster members can exhaust their energy early than others. Thereby, in these protocols, nodes determine their clusters according to the power of the received signal from CHs. So, data of nodes that have not accessed any cluster cannot achieve the BS.

For these causes, we propose in this paper a new LEACH-based routing protocol, it aims to minimize energy consumption and extend the network lifetime. This approach is a new approach for picking out CHs in the network depending on the residual energy of the sensor nodes and establishing clusters. Thereby, the abandoned nodes that can not reach any cluster, can also send their data to the sink. Furthermore, it proposes the multi-hop technique between CHs to choose the optimal route to the BS or the single hop directly to the sink if it is the optimal path. The proposed approach supposes that in each round, there are clusters. The proposed protocol introduces two phases:

3.1. First phase

The initial phase concerns CH selection and clusters formation. To save energy in the WSN, this new approach proposes to select the CHs according to the remaining power of nodes. Thus, it forms clusters based on a determined amount of nodes. The CH formation will be every round. At the starting of every iteration, each sensor node designates an arbitrary value at interval zero and one. In case that, the chosen number is more than the threshold function defined in (2), which is proposed in [16, 25], then this sensor node will be as a common node (CN). In the other case, the sensor node will be picked out as a CH in the current iteration.

$$T_{pr}(s) = \begin{cases} \frac{P_L}{1-P_L*(i \ \%(1/P_L))} * \frac{E_{rem}}{E_i}, s \in C \\ 0 \qquad\qquad \text{otherwise} \end{cases} \tag{2}$$

Here P_L represents the CHs probability in the network, i is the number of the period; C is a set of sensor nodes that have not become CH in the previously $1/P_L$ iterations. E_i presents the beginning energy of nodes and E_{rem} is the remaining energy at the i iteration.

Once CHs are elected, common nodes are looking for their corresponding CHs according to the power of the received signal from CHs. The number of nodes in each cluster is determined N_{cl} in terms of the total amount of nodes in the network and the number of CH desired.

Each common node constructs its table of CHs according to the received announcement message from CHs. This table contains the distance between this node and the CHs. For selecting the CH corresponding, the proposed approach suggests that the distance between the sensor node and its CH belongs will be less than the threshold distance do defined in (3), and this CH has a number of nodes less than N_{cl}. In this way, the node forwards a message to join the CH with the lowest distance in its table if there is a frame available in the TDMA. On the other hand, when the first cluster in the table is filled, the node does the same procedure to the second CH with the lowest distance, and so forth.

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \tag{3}$$

Where, E_{fs} is the energy consumed by the amplifier in the free space, and E_{mp} in the multipath propagation.

Once clusters are established, nodes with distances in their tables equal to or greater than do, or the availability on the TDMA schedule is not available, they can not join any cluster. These nodes called abandoned nodes (ANs).

3.2. Second phase

Once the clusters are formed and ANs are determined, the second phase starts. This phase presents the data transmission phase. Each CH receives data from the cluster member (that collects information from the surrounding environment) and aggregates it. Then, every CH uses the multi-hop technique between CHs to choose the optimal path to the BS or the single hop directly to the sink if it is the optimal route. Furthermore, ANs can also send their data to the sink through the single hop. Finally, the closest CH to the sink sends its own information with the aggregated packet of others CHs to the sink. Figure 2 illustrates the flow diagram of the proposed protocol.

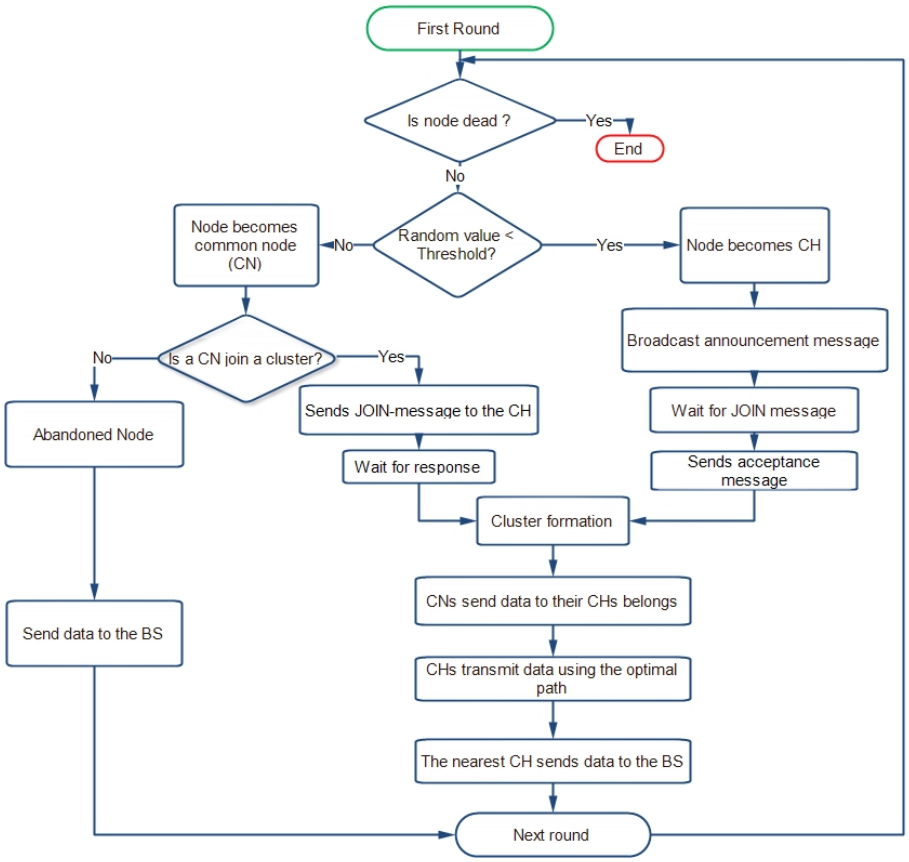


Figure 2. The flowchart of the proposed protocol

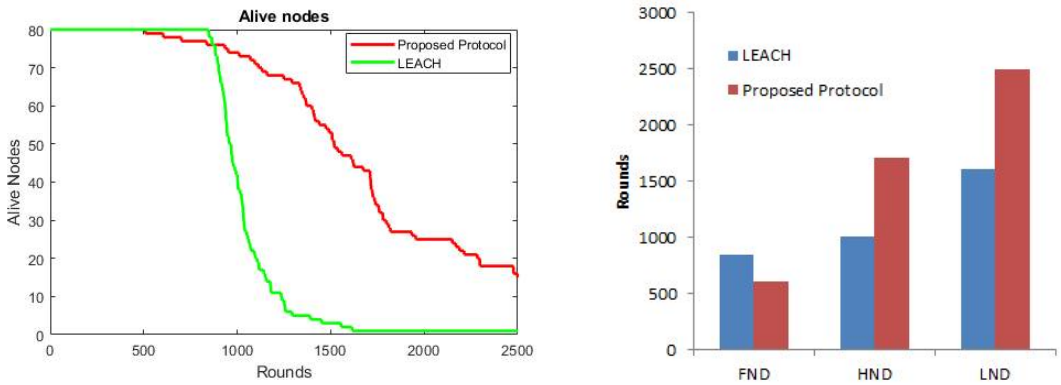
4. SIMULATION AND RESULTS

In that part, we are used simulation to analyze and simulate the proposed protocol performance. Matlab simulator is used to evaluate the proposed protocol and LEACH to put up a comparative analysis between the proposed algorithm and the conventional LEACH algorithm. We considered 80 sensor nodes are distributed haphazardly in the space of 100*100 m^2. The cluster probability is 5%, and the initial energy is 0.5 Joule. We considered one BS that located outside the network with coordinates (50, 150), nodes and the BS are static, then sensor nodes are homogeneous (having the same initial energy). Table 1 summarizes the simulation parameters that we have made in evaluating the LEACH and the proposed protocol.

Table 1. The simulation criterion value

Parameter	Value
Sensor nodes Number	80
Area	100 m*100 m
The cluster probability (P_L)	5%
Initial energy (E_i)	0.5 J
BS location (x,y)	(50,150)
$E_{Tx} = E_{Rx}$	50 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
Energy of data aggregation	5 nJ/bit
Size of packet	4000 bits
Number of rounds executed	2500

Figure 3 (a) shows the simulation results of the suggested approach as well as those of the original LEACH according to the network lifetime metric. From these results, we drew the diagram depicted in Figure 3 (b). The chart above shows a significant enhancement in the proposed protocol. In LEACH, the first node die (FND) at the iteration 846th while in the proposed protocol, the FND at the turn 609th. Furthermore, at the round 1003rd, only the half of nodes that stay alive in the LEACH protocol, whereas in the developed algorithm, the half node die (HND) at the 1714th iteration. Thereby, In LEACH, at the turn 1615th just one node stills alive, so the network is almost finished, while at this round, more than the half nodes stay alive in the proposed protocol (46 nodes). Finally, from the round 2499th, 15 nodes remain alive in the proposed approach, on the contrary, the network in LEACH is finished.



(a) (b)

Figure 3. The network lifetime in the LEACH and the proposed protocol, (a) Alive nodes in the network, (b) Diagram of dead node in the network

Figure 4 compares the proposed solution against LEACH according to the remaining energy metric. The remaining energy is the difference between the initial energy and the consumed energy. From these curves, we can see that the remaining energy of total sensor nodes in the proposed protocol is gradually decrease compared to the classical LEACH approach. Then, at the round 1200, it is almost null in the LEACH while in the proposed protocol, it is still more than 15% of the initial energy of all the network nodes. From these

results, we can see that the proposed protocol in this paper can optimize the energy consumption and extend the stability of the network better than the original LEACH protocol.

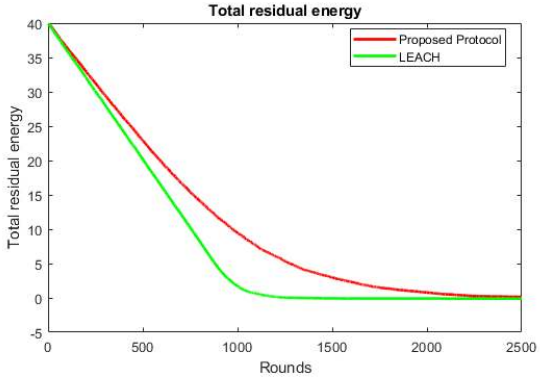


Figure 4. Total remaining energy of nodes in LEACH and the proposed protocol

5. DISCUSSION OF RESULTS

The LEACH protocol ameliorates the energy-efficiency compared to classical protocols used in WSN. The LEACH-C uses the centralization method to improve the traditional LEACH approach by enhancing the CH selection. The BRE-LEACH enhances the conventional LEACH algorithm by selecting CH according to the residual energy, and picks out a root. But each of these protocols has several limitations. Table 2 illustrates the advantages and disadvantages of the discussed protocols.

Table 2. The advantages and disadvantages of the proposed protocol with others protocols

Protocol	Advantages	Disadvantages
LEACH	Improves the life-cycle of the network through using the TDMA schedule.	Selects CHs aleatory/ Uses the single hop.
	Decrease energy dissipation of nodes.	The number of nodes in clusters is randomly.
	Decreases the no. of transmission packets.	Abandoned nodes can not send their data to the BS
LEACH-C	The centralization provides a better distribution.	The centralization method needs an extra energy.
	Achieves a large no. of turns in a minor area	Uses the single-hop technique.
	CH selection in accordance to remaining power.	The number of nodes in each cluster is unbalanced.
		Abandoned nodes data can not achieve the BS.
BRE-LEACH	Enhances the network lifetime.	No. of nodes in clusters is unbalanced.
	CH choice depending on the residual energy.	Abandoned nodes can not send their data to the BS.
	Chooses a root CH according to the residual energy and the distance to the BS	All CHs send aggregated data to the root even if the BS is closer than the root.
The Proposed Protocol	CH selection according to the remaining energy.	
	No. of nodes in cluster can not exceed a maximum.	Abandoned nodes send data directly to the BS.
	Abandoned nodes can send data to the BS.	Does not consider other QoS parameters.
	CHs use either the single or the multi-hop to choice the optimal path.	

6. CONCLUSION AND FUTURE WORK

In the present work, we have suggested a new approach for improving the performance of the conventional LEACH protocol. Instead of selecting CHs randomly in LEACH, the developed protocol uses the remaining energy to decide which nodes become as CH in the monitoring area. Furthermore, in LEACH, the total amount of nodes in the clusters is not the same, which leads to an energy consumption imbalance, the proposed protocol determines the maximum amount of nodes in every cluster. Rather than forwarding the aggregated packets by CHs to the BS in a single hop, the proposed solution uses the multi-hop technique. The result of simulation illustrates that the proposed approach prolongs the life-cycle of WSNs and decreases energy consumption. For future extensions to this work, we intend to compare this protocol to other enhanced-LEACH protocols. Thereby, we hope to make various enhancements in the present work such as determining the optimal number of clusters in the network, enhancing the throughput, and other quality of service parameters.

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