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ALGORITHM FOR ENERGY EFFECIENCY AND LIFETIME OPTIMIZATION IN WIRELESS SMART SENSORS NETWORK

[1]LAGRAINI HAJAR, [1]CHHIBA MOSTAFA, [1]TABYAOUI ABDELMOUMEN, [1] LASBAHANI ABDELLATIF, [1]BAHRI MOHAMED, [1]KAMAL ADIL, [2]MOUHSEN AHMED

[1]RMI Laboratory, FSTS Hassan 1st University, 26000.Settat, Morocco

[2] IMII Laboratory, FSTS Hassan 1st University, 26000.Settat, Morocco
E-mail: [1]h.lagraini@uhp.ac.ma , [1]moschhiba@yahoo.com, [1]tabyaoui@uhp.ac.ma,
[1]abbdellatif.lasbahani@gmail.com, [1]m.bahri@uhp.ac.ma, [1]adilkamal.14@gmail.com
[2]mouhsen.ahmed@gmail.com

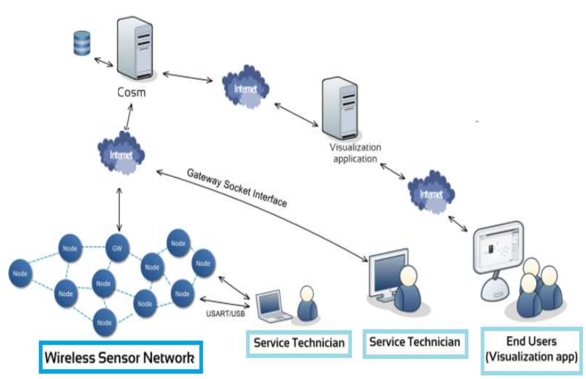
ABSTRACT

Wireless sensor network (WSN) is a wirelessly interconnected network; it has increased massively due to the vast potential of smart wireless sensors to connect the physical globe with the virtual globe. Sensor nodes are used for monitoring and tracking fields they sense many environment conditions such as vibration, temperature, speed and even pollution level and many other such environmental conditions. Thus it's quite common to deploy WSs in hostile environments where there are no electricity sources so SN get powered from its battery and this battery get evacuated with time. However decreasing power energy consumption in WSN is one of the most essential keys to challenge WSN lifespan, hence Low energy adaptive clustering hierarchical routing protocol (LEACH) has been suggested to enhance network lifespan. This protocol is based on clustering technique; each cluster of the network has cluster members CMs and one chief cluster named cluster head CH responsible for routing data to the BS. In this paper, we will present an algorithm based on LEACH to optimize energy efficiency level and improve life time of the WSN, Moreover, a comparison of this algorithm and the pure LEACH is being done. Finally simulation results shows that the proposed protocol beats pure LEACH in terms of network power consumption saving and network lifetime.

Keywords: *WSN, IOT, Clustering, Leach, Wireless Transmission, Power Energy Effeciency.*

1. INTRODUCTION

A WSN can be distinct as a group of sensor nodes (SN) that generally derive their energy from attached batteries [1]. WSN is composed of great number of smart nodes which are compactly used in an area required to be monitored. The basic purpose of a WSN is to collect the measurement of physical values (e.g. health monitoring, environmental monitoring, biological hazard detection, etc.), generate this data and communicate it directly or by multi-hopping way to the sink (BS).



transferring/getting information. Consequently several energy efficient techniques are considered, to decrease power energy consumption and increase network lifespan [2]. One of the furthermost techniques is the hierarchical routing, which presents the conception of clustering approach. Researchers approved that clustering of smart sensor in WSN is an operative method for energy conservation [3]. In WSN clustering it is utilized to diminish quantity of SNs that take part in long distance messages transmission to the sink, what causes fading in total power energy ingesting of the network [4]. Clustering approach diminishes the sum of transferred data by assembling homogenous nodes together and choosing one node as a chief cluster CH, where combination of data is implemented to circumvent redundancy and communication load, then forwarding the accumulated data to the sink, where it is treated, kept and saved. The principal aim of this approach is to manage power energy feeding of SNs efficiently by including them in multi-hop communication inside a specific cluster. The most conjoint hierarchical routing protocol is Low Energy Adaptive Clustering Hierarchy (LEACH) [5]. In the rest of this paper, section II gives related works, sections III gives a comparison study of hierarchical routing protocols and briefly discusses about working of LEACH clustering protocol, division VI presents details about simulation and results using MATLAB tool; in section V analysis of simulation results will be presented. And finally section IV accomplishes the paper by mentioning the effectiveness of enhanced LEACH over the basic LEACH.

2. RELATED WORKS

With specificity that had been given to the WSNs, the problem that arises is the adaptation of routing method used with the huge number of existing nodes in an environment characterized by the modest capacity of calculation, and limited reserves of power energy and memory capacity. In this regard, optimizations of the efficiency of the sensor networks have been anticipated with constraint of severe resources. As we mentioned before among those, the clustering algorithms have acquired greater importance in the increase in lifetime of WSNs, due to cluster-head (CH) selection approach and data gathering, great solutions for energy-efficiency are proposed [6-9].

2.1 Different Routing Protocols

In this section the main routing protocols in WSN will be presented.

A. Hybrid Energy Efficient Distributed Clustering

In Ref [8] authors propose a method which takes into account the energy of the SN and intra-cluster communication while electing CHs in multi hop sensor networks.

B. Flooding

The transmitter sends data to all its neighbors. Each neighbor in turn sends data to all its neighbors and so on. The nodes will therefore obtain the similar message several times from diverse neighbors.
To prevent the message is multiplied in the network, each node returns only once [10].
To do this, each message sent to flood a unique identifier. Nodes that re-diffuse the message note the identifier. If they receive a message with again this ID, they do not return it.

C. Gossiping

In this technique, derived from the flooding technique, the smart sensor node does not broadcast messages received to all its neighbors, but it sends them to a single, randomly selected. Indeed, each SN in the network randomly selects a node from its neighbors to communicate the received data, once the neighbor node receives this information; it selects a different node in a random manner to transmit these data in turn. While this approach evades the problem of implosion in having a single copy of the message at each SN, it takes much longer to propagate messages throughout the network [11].

D. SPIN

The idea behind the SPIN is to name data using high-level descriptors or Meta given.
Before transmission, the metadata are switched between the sensors by a data advertising mechanism. Each node receiving new data, the announcement to its neighbors and those interested retrieve data by sending a request. Communications in SPIN are made in three steps: When a node wants to direct a given, it first sends a message containing ADV a description of the data element concerned.

A node receiving ADV message consults its database of interest. If you are interested in this information, it sends a REQ message to its neighbor. Receiving REQ message, the transmitter diffuses the data to the person concerned as a DATA message [12].

E. Power-Efficient Gathering in Sensor Information Systems

It is considered an optimization of LEACH offers by Lindsey and others 2002 [9]; PEGASIS includes network nodes form a long chain founded on the principle which states that a SN can only communicate with the nearest node to it. Thus, he adjusts his radio to a short broadcast to save energy. To contact the wells, the process is organized in rounds; during each round only one node is authorized to communicate directly with the well. This privilege is granted to all network nodes a turn. Better energy conservation is achieved, too, by aggregating data on each network node.

F. LEACH

LEACH is the most popular in hierarchical routing protocols. Its main advantage is to diminish power energy ingestion of network elements. In this protocol the network is separated into clusters and each cluster has a master node called cluster-head. The latter supports the management of its cluster. It is periodically elected from the nodes forming the cluster, depending on the state of its battery [13].

In Ref [14] authors compared energy dissipation in homogeneous and heterogeneous networks, they also analyzed how a single-hop and multi-hop network performs.

Therefore, Leach protocol has been selected as representative of homogeneous networks and they compared it with a single-hop heterogeneous network. Authors considered that the use of single-hop communication between the members of a cluster and their consistent CH might not be the right choice when the index K 'loss of spread' is large (k > 2) for intra-cluster communications [13] and when the distance increases between the CH and the base station, as it has been mentioned in [15]. To resolve this matter multi-hop Leach was proposed in [16]. However, like any other routing protocol Leach has limits.

Thus, several studies have been exposed based on pure leach protocol in order to overcome its disadvantages and many improvements have been suggested. But these improvements have not been able to illuminate all the problems of the basic Leach.

According to LEACH Protocol, the training of new CHs in each round is necessary. If a CH has not used a great part of its energy during the previous round, there is a probability that it will be replaced by a node that has the lowest energy level during the process of CHs election for the next round, which leads to a loss of information.

As it is mentioned above to resolve this problem we suggest a new algorithm of CH selection by considering the energy measurement part by fostering the nodes that have more left over of power energy to become CHS.

2.2 Low-Energy Adaptive Clustering Hierarchy Overview

LEACH (Low Energy Adaptive Clustering Hierarchy protocol), is an energy-conserving routing protocol for WSNs that works in round, it plays a key role in routing algorithms of WSNs, LEACH was firstly announced by Heinzelman in 2000.

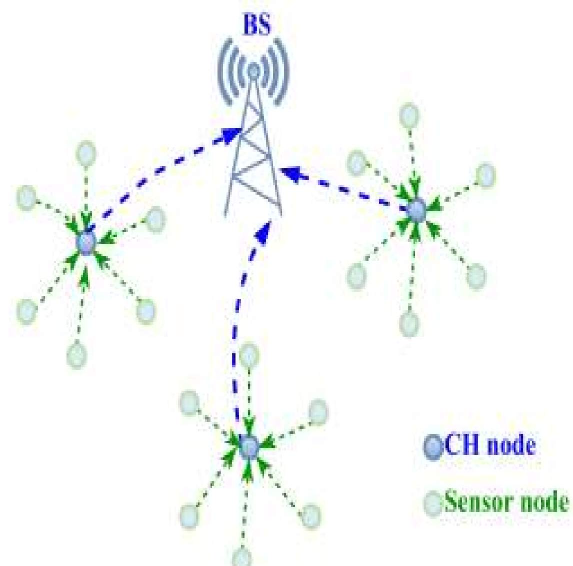


Figure 2: Illustration of LEACH Protocol

The defined operation of LEACH can be alienated into two parts: Set up phase, in which CHs are organized, and steady state phase, in which data are diffused to the sink. The Threshold is set as follow:

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

However in this equation (1), p is the probability of selecting nodes as a CH node, r is the number of the current round, $(r \bmod \frac{1}{p})$ is on behalf of the number of SNs which was designated as CH in the round r, G is defined as the set of SNs that have not been CHs in the last $(\frac{1}{p})$ r.

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As it is mentioned above the process of LEACH protocol is divided into rounds and each round is subdivided into two segments namely as:

➔ Set up phase:

An arbitrary number is created between 'zero' and 'one' by each node. This number is then compared with the Threshold value T (n). If this number is less than T (n), node is chosen as the CH. The elected node proclaims itself as a CH by sending a broadcast message to the whole network. Each node resolves which cluster to connect according to received signal strength and transmits a request message to the contiguous CH. CH announces them as the members of clusters on receiving all the messages by nodes.

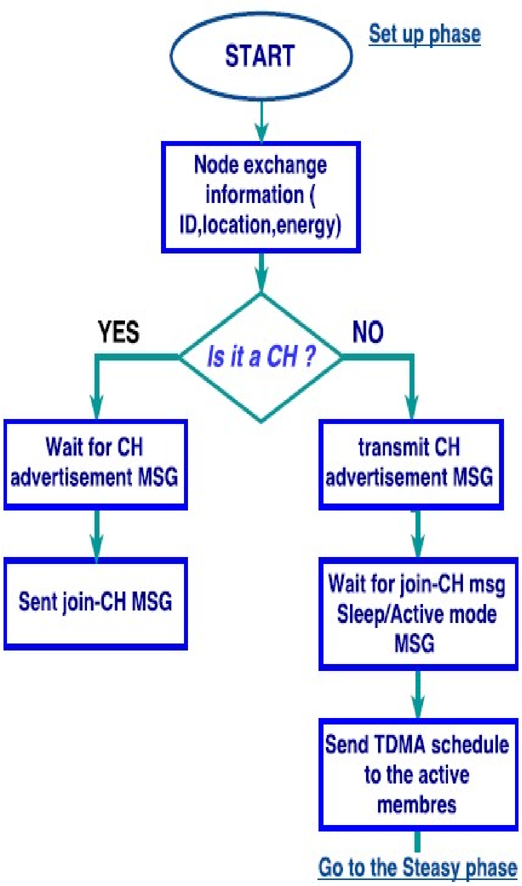

Figure 3: Flowchart of LEACH protocol in Set-up phase

➔ Steady state phase:

All the members of the clusters transfer information to the CH. Then CH gathers the collected data and forwards this bonded data to the BS. The conventional LEACH has lot of weaknesses. LEACH algorithm picks the CHs arbitrarily.

While electing the CH it does not take into account the remaining of energy level of the SN. Thus if a node having the lower energy is designated as the CH, it may fall short of energy of the node and henceforth demise. Thus this node will become invalid. As the number of dead nodes growth there will be a damaging impact on network performance which will definitely shorten the network battery life.

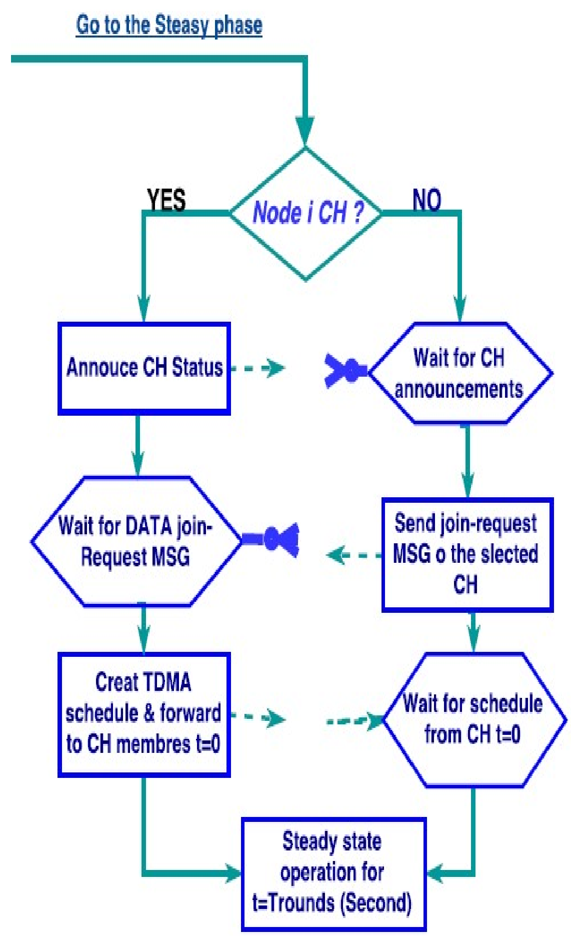

Figure 4: Flowchart of LEACH protocol in Steady phase

LEACH protocol has the following advantages:

➢ The hierarchy, routing data and path selection are rather simple, and the SNs do not need to store large amounts of routing information, and do not need complex functions. The CH node is haphazardly designated, the chance of each node is the same, and the load of the WSN is balance [17].

However, there are a several weaknesses in LEACH protocol, such as:

- For the reason that the CHs in LEACH protocol are arbitrarily generated, energy consumption can be consistently distributed in the network. However, the CH alternations do not take into account the residual energy of SNs. Therefore, it is possible for a sensor node that has low left over energy to be designated as a CH. This can provide the cluster useless due to the rapidly shattered battery power of the CH.
- In addition, LEACH does not analyze the distance between SNs and the BS. Consequently, if the geographic position of the CH is far from the sink and the geographic position of the cluster members is far from their CH, it will devour a lot of energy transmitting and receiving data. Subsequently it leads to exhaust the energy speedily in SNs [18].

2.3 DERIVATION OPTIMIZATION OF LEACH ALGORITHM

Most of suggested optimizations have been improved by including power energy parameter into the threshold criteria equation T (n), for example, M-LEACH [19], LEACH-T [20], A-LEACH [21], LEACH-HEM [22], LEACH-C [23] ,E-LEACH [24]and Q-LEACH[25].

A. M-LEACH

In LEACH protocol the information is communicated from CH to the sink or (BS) node over single hop communication no matter the distance between BS and CH. Energy consumption will be more if distance is outlying [19]. M-LEACH protocol adjusts LEACH allowing SNs to utilize multi-hop communication within the cluster in order to upsurge the energy efficiency of the protocol.

This work extends current solutions by permitting multi-hop inter-cluster communication in WSNs in which the direct communication between CHs or the sink is not possible due to the distance between them. Thus, the focal of the proposed solution here is that the multi-hop method is followed in the inside and outside of the cluster. CHs can also perform data fusion to the data receive, allowing a reduction in the total transmitted and forwarded data in the network [19].

B. T-LEACH

R. Hou et al. [20] proposed T-LEACH which considered the residue power of SNs in order to balance network loads and changes the round time by presenting a novel probability (Phead), the ideal number of clusters over all nodes instead of that used in the basic LEACH algorithm. This probability took the distance between SN and BS into account including the area coverage (M is the length of node distributing field) and the number of existing nodes as follows:

$$T(n) = \begin{cases} \frac{p_{head}}{1-p_{head}\times(r \bmod \frac{1}{p_{head}})} \times \frac{E(t)}{E_{total}(t)}; if\ n\ \in G \\ 0 \qquad ; otherwise \end{cases} \quad (3)$$

$$\text{While; } P_{head} = \frac{\sqrt{n}}{\sqrt{2\pi}} \times \frac{\sqrt{\varepsilon fs}}{\sqrt{\varepsilon mp}} \times \frac{M}{d_{to\ BS}^2 \times N}$$

C. A-LEACH

In [21] proposes a new CH selection algorithm that allows choosing the greatest node for CH. A-LEACH uses distributed algorithm to form cluster heads, where the decision is made autonomously by SNs without any centralized control. Sensor node with more left over energy has a bigger probability to be a CH as follows:

$$T(n) = \begin{cases} \frac{K}{N-K\times(r \bmod \frac{N}{K})} \times \frac{Ecurr}{Emax} \times \frac{K}{N} \quad ; if\ n\ \in G \\ 0 \qquad ; otherwise \end{cases} \quad (4)$$

D. HEM-LEACH

In [22] controls the probability of CH based on remaining energy. Greater the value of residual energy, upper is the possibility of becoming the CH. If (r) is the reference energy compared with remaining energy of node then,

$$Pi = p_{opt} \times \left[\frac{\bar{E}(r)-Ei(r)}{\bar{E}(r)}\right] = p_{opt} \times \frac{Ei(r)}{\bar{E}(r)} \quad (5)$$

Popt is defined as the optimal percentage of CHs (Popt is replaced by Pi),(r) is the average power energy of the whole network in round 'r', and threshold for each sensor node in each round is assumed as follow:

$$T(Si) = \begin{cases} \frac{p_i}{1-p_i\times(r \bmod \frac{1}{p_i})} & ; if\ Si\ \in G \\ 0 & ; otherwise \end{cases}$$
(6);

E. LEACH-C (Centralized LEACH)

In this protocol a centralized cluster head selection approach is used, all nodes direct their physical location and their energy level to the sink. Base station will track the location of nodes and check the energy level of the SNs.

Then the base station select the CHs from the nodes on the basis of the power energy level of SNs, the node which has enough energy level will be selected as cluster head.

- → Advantage: There is predetermined selection of the CH nodes which will effect in the better distribution of the nodes in the network.
- → Disadvantage: It requires physical location information of the entire node, which is robust [23].

F. E-LEACH

This protocol is based on LEACH algorithm to balance the energy ingesting of smart sensor nodes in order to solve the excess of energy depletion problem. E-LEACH implements the identical round idea with the pure LEACH. In hierarchical routing algorithms, the quantity of cluster-heads is the fundamental element that influences the performance of routing protocols. If the number of CHs is fewer, each CH needs to cover grander area, this will chief to the problem that some CH-members get distant from their cluster-heads and consume much more energy. As the announcement between CHs and the sink needs considerably additional energy than common sensor nodes, the unnecessary number of CHs will Growth the power energy ingesting of the entire network and abbreviate the network lifetime. Therefore, it is essential to select optimum CH number to make the energy depletion least. In the E-LEACH lowest spanning tree between CHs is utilized; choose the CH which has more outstanding energy as the root node [24].

G. Q-LEACH PROTOCOL (Quadrature LEACH)

In Q-LEACH the entire network is shared into four identical quadrants which will result in the batter distribution of the SNs in the whole network [25]. All the SNs direct their physical location information to the sink, based upon their location information base station divide the entire network into four quadrants, in which strict spreading of the nodes are defined. CHs will broadcast message to the SNs and nodes receive CH advertisement select CH according to their signal strength..

- → Advantage: It gives a better energy utilization of SNs than the conventional leach protocol. Proper distribution of the nodes into the network will result in better coverage of all the SNs in the network.
- → Disadvantage: The CH which is distant from the sink will consume more energy and will die faster.

2. PROPOSED ALGORITHM

Our proposed algorithm is an improvement over the existing LEACH, LEACH-C algorithms. The basic LEACH algorithm is not too energy efficient in cluster foundation. It might choose a sensor node whose residual energy is not adequate to sustain the cluster and consequently lead nodes fading. LEACH-C [26] improves LEACH by considering the residual energy of the nodes and matching it with the threshold average energy. But it too suffers from the problem of uniform distribution of cluster heads. Our suggested algorithm eliminates the probability factor of LEACH. For CH's election, two metrics: Distance and Energy are considered.

In this work, we will modify the pure LEACH algorithm, by adding two metrics to the threshold formula thus the sensor node selected as CH may have a better behavior in WSNs. As an objective for cluster heads selection, proposed algorithm choses the closest node to the BS and also the one with more residual of energy.

Table 1: Simulation Environment Specifications

PARAMETRE	VALUE
Simulator	MATLAB
WSN area / m^2	100x100
Number of nodes	150
Number of rounds	2500
Initial energy of node : Ei	0.5 Joules
Desired percentage of CHs : P b	0.05 0.8

Transmitter Amplifier Energy $\begin{cases} Emp \\ Efs \end{cases}$	0.0013 pJ/bit/m4 10 pJ/bit/m2
Data Aggregation Energy E_{agg}	5 nJ/bit
Electric energy	50 nJ/bit

At the beginning of setup phase, each node chose a random number from 0 to 1 and compares it to a threshold T (n), which is calculated as follow:

$$T(n) = \begin{cases} \left[\frac{En}{Ei}\right] \times C \times \left[\frac{Dm-D}{Dm+D}\right] & ;\ n \in G \\ 0 & ;\ \text{otherwise} \end{cases} \quad (7)$$

$$\text{While; } C = \frac{p}{1-p\times mod\left[r, round\frac{1}{p}\right]}$$

Where p is the desired percentage of CHs, r is the current round, G is the set of nodes that have not become the CH in last $(\frac{1}{p})$ rounds, $\left[\frac{En}{Ei}\right]$ is the node's energy divided by Initial energy to select the node with the more residual of energy.

$\left[\frac{Dm-D}{Dm+D}\right]$: Dm represents the highest distance between the sensor node and the sink and D is the distance between the sensor node and BS. This function T(n) choses the node with more residual energy to become the cluster head, thus balancing the energy consumption of the network.

3. LEACH PERORMANCE AND EVALUATION

We used version 2016 of MATLAB as a simulator tool to evaluate the performances of the improved LEACH protocol based on our new Algorithm. Important parameters for our simulation are given in Table 1. For evaluating and comparing the performance of our Algorithm with the basic LEACH Algorithm, we consider the following metrics:

- Network lifetime (number of live and dead nodes in 2500 rounds),
- Data packets delivered to the sink
- The remaining energy of sensor nodes in the wireless network.

4. RESULTS AND DISCUSSION

We explore network lifetime of the proposed algorithm and LEACH protocol. We examine the way the amount of alive and vanished nodes fluctuates as network evolves. Fig. 5 and Fig. 6 show the network status after 2500 rounds of the basic and the proposed protocol, it's crystal clear that the proposed protocol has improved lifetime than the basic LEACH protocol. Our algorithm has 45% and enhanced lifetime.

The election of the closest node to the sink as CH and also the one with the more residual of energy have significantly minimizes communication cost and prolongs the network lifetime.

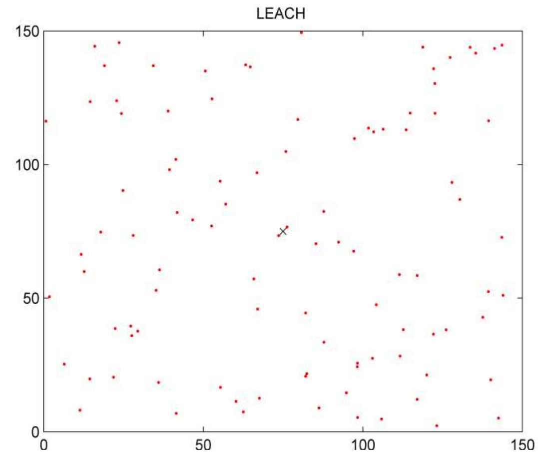

Figure 5 : The state of the network after 2500 Rounds using basic leach Algorithm

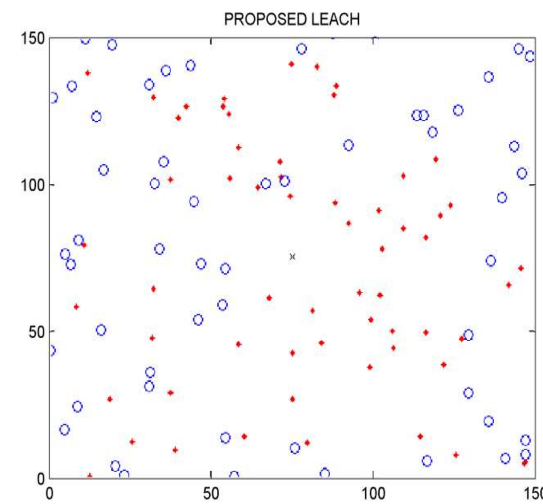

Figure 6 : The state of the network after 2500 Rounds using the improved version of leach algorithm

consider that network's lifetime of basic LEACH protocol has been improved, this shows that the new suggested formula of CH's election in our algorithm has succeeded in expanding the network's lifetime. As well nodes that do not comply with the two previous conditions (energy and distance) will simply send data to their CHs to which they are affiliated. This allows optimizing the energy consumption of the Nodes thus allowing prolonging their lives.

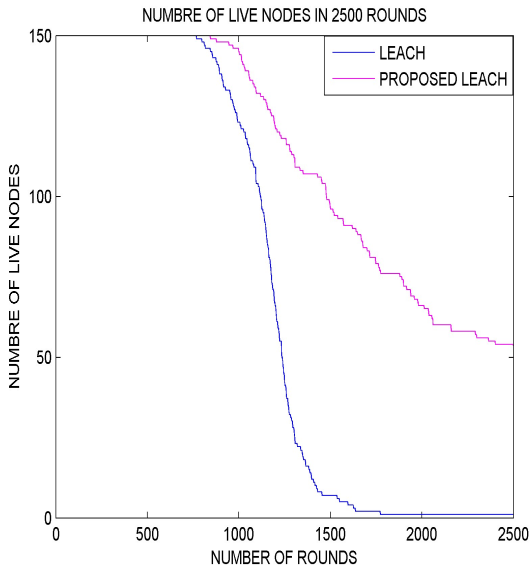

Figure 7: Comparison of live nodes in 2500 Rounds

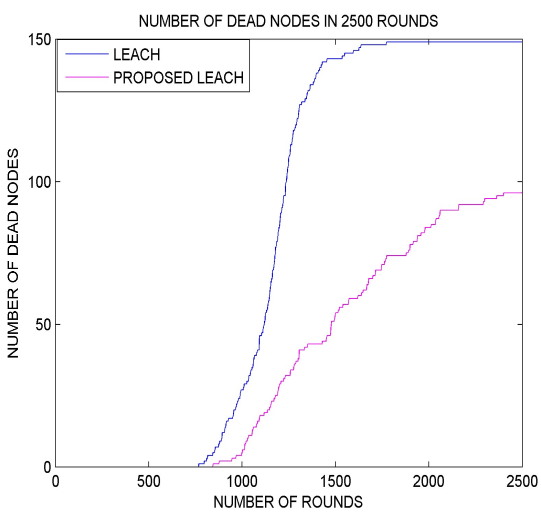

Figure 8: Comparison of dead nodes in 2500 Rounds

Results in Fig. 8; shows that nodes in proposed LEACH have a longer network battery life than the basic LEACH algorithm. Here, the Y axis designates the number of SNs and the X axis indicates the lifetime of the SNs in the wireless sensors network according to the simulation time.

In addition according to Figures 7 and 8, proposed LEACH is better than basic LEACH in terms of network lifetime. The reduction in power consumption of proposed LEACH is measured by comparing it with that of the basic LEACH algorithm. We observe on figure 7 that sensor nodes of basic algorithm start to die approximately at 720 rounds. However, the proposed LEACH nodes start to die at 860 rounds. We can also clearly notice that the network lifetime of proposed algorithm prolonged and surpass 2500 rounds, whereas that of basic LEACH ended at 1800 rounds.

This result shows the capability of proposed LEACH to improve power consumption of the total energy consumed by the smart sensor nodes to transmit data to the base station.

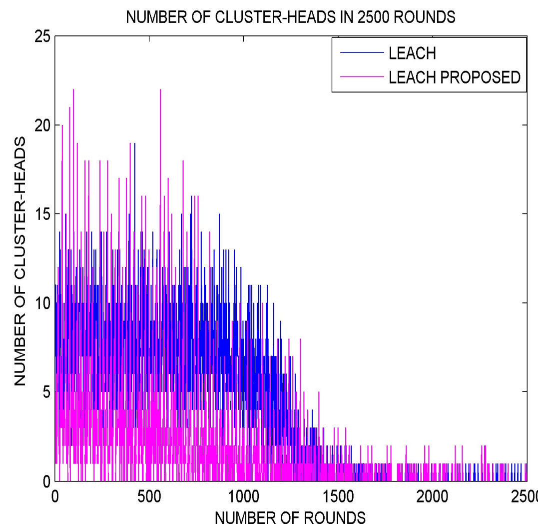

Figure 9: Number of CH created in 2500 Rounds

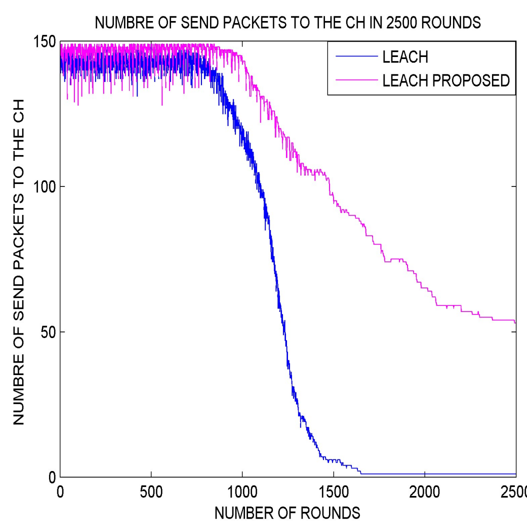

Figure 10: Number of transmitted packets to the CH in 2500 Rounds

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In Fig. 9 number of created CHs in 2500 rounds of the modified protocol is so much higher than the number of created CHs in 2500 rounds using the basic formula of CHs election; also in Fig. 10 Information packet transport is greater for our proposed protocol than the basic LEACH.

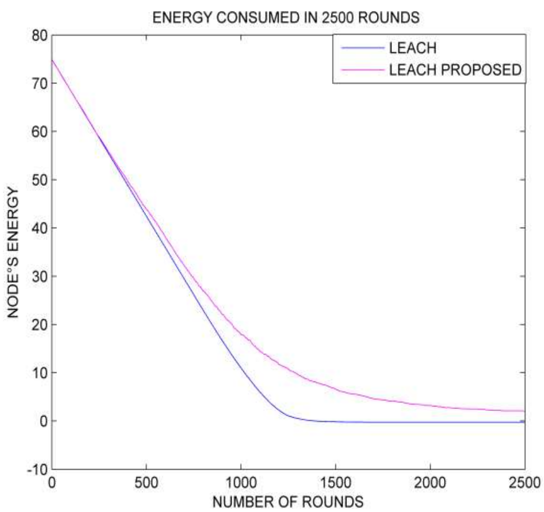

Figure 21: Energy consumption by the network based on LEACH and new LEACH algorithm

5. CONCLUSIONS AND FUTUR WORK

We presented in this paper an improved version of LEACH algorithm for WSNs, the focus was to increase the energy efficiency and extend the network lifetime.

In our algorithm, CH is selected based on two fundamental metrics: Energy and Distance, in order to select the node with more left over energy and the closest one to the BS to become the CH. In the improved LEACH energy dissipation and the network lifetime have been optimized. Simulation results illustrate that there is major progress in those parameters compared with the basic LEACH algorithm.

Although the results of the simulation confirmed that new LEACH outperforms LEACH in extending WSN battery life, whereas this work can achieve performance improvements, still many aspects of its design need to be explored since there are other metrics that may influence the energy consumption, comprehensive simulation and analysis could be additionally examined.

Our future work directions are to take the nodes themselves as solar aware nodes which recapture energy it selves, so that our protocol will be more energy sufficient. And another provision is to make our algorithm in to hierarchal protocol by forming "TOP clusters" out of the cluster head nodes and TOP clusters will process all the information from the CHs. Therefore the energy dissipation of every CH will be condensed to transfer data to the sink. This enhancement will make the modified LEACH effective for an extensive range of wireless smart sensor networks.

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