Egyptian Informatics Journal 22 (2021) 439–445

Contents lists available at ScienceDirect

Egyptian Informatics Journal

journal homepage: www.sciencedirect.com

# An improved energy-efficient head election protocol for clustering techniques of wireless sensor network (June 2020)

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ARTICLE INFO

*Article history:*
Received 8 June 2020
Revised 22 November 2020
Accepted 20 January 2021
Available online 4 February 2021

*Keywords:*
WSN
LEACH
Clustering
Head election

ABSTRACT

Although wireless sensor networks (WSNs) have been utilized for over one decade, it is now heavily used by many modern applications such as medical observance, disaster management and environmental monitoring. This type of network suffers from limited energy and a short lifetime in addition to the low channel bandwidth. Bandwidth represents the major challenges of such systems due to the great impact of communication cost on the consumption of nodes power. Clustering has been proven to be one of the best techniques to conserve the energy of WSNs. LEACH (low energy adaptive clustering hierarchy) protocol is one of the most fundamental works of WSN clustering. However, this protocol suffers from some drawbacks, especially in the setup phase where CH is selected randomly. This work aims to enhance LEACH by identifying a cluster head according to the lowest degree of consuming energy. The results clarify the ability of this work to enhance LEACH while prolonging the lifetime and improving the performance of WSN.



## 1. Introduction

Continuous technological progress works to convert the distributed systems from large to small and tiny scales are known as Wireless Sensor Networks (WSNs) [1]. WSNs are gigantic systems composed of a large number of miniaturized, distributed and limited-energy sensor nodes. These nodes are usually spread over a certain region in order to collect various types of environmental data [2]. Many recent applications depend on WSN such as medical observance, disaster management and environmental monitoring. The collected data are always sent to a base station (called sink) for processing and analysis. This type of network suffers from limited energy and a short lifetime due to the limited non-rechargeable power of the small batteries in sensor nodes. The network lifetime is defined by the round when all nodes have died, and the sensor node is defined as dead when its energy is out [1]. The limited lifetime and low channel bandwidth are the major challenges of such systems due to the great impact of communication on the consumption of the power energy of nodes. Therefore, the efficient use of energy to face these challenges and to prolong the network lifetime is the most critical issue in WSNs [3].

Clustering as a reduction technique has been proven to be one of the good techniques to conserve the energy of WSNs. With clustering, sensor nodes are grouped into an optimized number of clusters with a lower number of nodes. As such, each cluster must have at least one node acting as a cluster header, which is often abbreviated as CH, which is responsible for receiving and aggregating the sensed data, then forwarding them to the base station. Consequently, the packets sent to the base station are reduced and the communication bandwidth is conserved as a result. The most important target is to reduce the energy used to receive and send more sensed data [4].

Several exertions with many strategies are introduced to cluster WSN for power reduction and extension network lifetime. LEACH [5] is the most fundamental protocol for clustering WSN. It groups the sensor nodes into several small-sized clusters. Each round of LEACH consists of two phases: (1) setup phase where the clusters are formed and the cluster-head of each cluster is elected. (2) steady state phase where the sensed data is sent to the base station via CHs. Randomly, LEACH elects one node to be CH for a round; each node selects a random number between 0 and 1. If that number is less than or equal to the threshold (T(n)), it becomes CH;

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Peer review under responsibility of Faculty of Computers and Artificial Intelligence, Cairo University.

https://doi.org/10.1016/j.eij.2021.01.003
1110-8665/

**Notation:**

N: number of nodes; BS: a base station$S_0$: Maximum size of cluster threshold$E_{Tci}$: Energy of transmission cost from $n_i$ to BS$H_0$ = Capability threshold$X_i$, $Y_i$ : Latitude & Longitude of $n_i$$d_0$ : distance threshold$Re_i$: Residual Energy of niK: the size of sensing packet

**Table 1**
The Simulation Settings.

| Parameter | Default value |
|---|---|
| Monitoring area | 100 m × 100 *m* |
| Number of nodes- N | 45–85 |
| Packet size | 6400 bit |
| $E_i$ | 0.5 |
| BS location | (50,50) |
| $e_i^R$ | $50 \times 10^{-9}$/ packet |
| $e_i^A$ | $5 \times 10^{-9}$/ bit |
| $e_i^S$ | $50 \times 10^{-9}$ /bit |

otherwise, a node will remain regular. The threshold is set as in equation (1): [5]

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

Where $p$ is the probability of the current node ($r$) to be CH, $G$ is the set of nodes that were not CH before. The remaining nodes in the cluster collect their targets and forward them to CH, which it is responsible to aggregate ~~for~~ and compress the received data before forwarding it to the base station. According to LEACH, each node has the same chance to be a header. As the node successes to become a CH, it broadcasts an invitation message to join its clusters. The target nodes then decide to join the cluster of sending a CH based on the strength of the signal by sending an acknowledgement message. Subsequently, the CH assigns each node a time slot in which it can transmit the sensed data according to a schedule. The node cannot be chosen as a CH more than once for the current round [5].

On the other hand, LEACH suffers from many defects due to the random selection of CHs. First, a low powered node has the same chance to be a CH as a high powered node, which can be the main source of energy depletion. Second, LEACH was not clear enough about any constraint on the number of CHs in the network. Finally, although all CHs must have the ability to immediately link to the base station (BS), LEACH did not consider any clustering features such as location, energy, communication cost, etc. between itself and the BS [6].

Based on the fact that the consumed energy increased due to the long distance, several efforts were introduced to enhance LEACH by eliminating the random election of CHs and identifying them according to suitable features. These efforts attempted to reduce the high energy consumption of nodes. However, most authors used shortest distance as the clustering criteria in order to decrease energy consumption by CHs [6,7,8,9], while others added the residual energy to the clustering criteria in an attempt to achieve more accurate results [10,11,12,13].

The communication cost is the major consumer of WSN energy. There are many factors other than distance that can affect the communication cost as stated by [14].; the present work decides to use the communication cost as the main criteria in the election of CHs instead of using any indirect factors that impact the communication cost.

The current work addresses the problem of a random election of CHs, which causes the dissipation of energy among sensor nodes. The **first** contribution of this work is to enhance LEACH by modifying the setup phase to elect CHs based on four parameters: communication cost with BS, residual energy, location and network size. In order to be more accurate and closer to reality, the selection process is not based on the highest energy as in [4] or the shortest distance as in [15]. Cluster heads are identified in this work according to the adequacy of residual energy to cover the needed communication cost in each round. So, we can effectively conserve the energy of the elected CHs and maintain the entire system's performance. Another source of the dissipation the energy of WSNs is the power that consumption holds in forwarding redundant information to BS by multiple CHs. The redundant information is produced due to the overlapped CHs in the same monitoring area where the distance between any two or more CHs overlay each other. The **second** contribution of this work is enhancing LEACH to avoid forwarding this redundant information by identifying one or more vices for each CH. The goal here is to find the set of headers that can compete each header (cover the same monitoring area). This work is based on the memetic algorithm [16] to define vices set for each header. The presence of the defined vices of the cluster header (candidate headers) drives this work to the **third** contribution of the scheduling mechanism to arrange the defined CH with its vices in the correct order. This work tries to achieve an efficient energy consumption of WSNs using the waking-sleeping scheduling mechanism for managing which head must wake-up to perform all tasks of receiving the collected data, aggregating them and sending them to BS.

The remaining part of this paper is organized as follows: Section 2 briefly reviews the previous related works to the present work. The proposed $IE^2$-LEACH protocol is presented in Section 3. In Section 4, the simulation results are revealed. Finally, Section 5 concludes the work and highlights future directions for other aspects of improvement in WSN.

## 2. Related work

Clustering protocols plays a significant role in prolonging the lifetime of WSNs. The LEACH protocol is introduced by [5] to reduce global communications among WSN by grouping the nodes into a number of small-sized clusters. The random election of CHs represents one of the main weak points of LEACH, the problem that this work tries to address. Consequently, many strategies have been introduced to face this problem.

Similar to this work, the following efforts are introduced to improve the setup phase of LEACH protocol using different strategies to enhance LEACH during the main task of the setup phase (to select CHs).

The work of [7] introduces the HEED approach, which selects the nodes with high residual energy to be the CHs through an iteration of CH election scheme, according to the current and the initial battery levels. The work of [8] proposed FLEC to improve LEACH employing the high energy nodes to become a cluster

**Table 2**
Cluster Lifetime Of The Proposed Work And Most Related Works.

| Average | IE2-LEACH | E-LEACH | LEACH |
|---|---|---|---|
| Number of Heads/Cluster | 4 | 1 | 1 |
| Cluster density of | 6.5 | 18 | 28 |
| Number of rounds/ CH | 125 | 15 | 13 |

header and combine the data of their cluster aspects and transmit it BS. In order to support LEACH for minimizing the consumed time and energy for selecting a new cluster head when one is damaged [9], a new mechanism should be introduced to assign each cluster with a vice cluster head.

The work by [17] elaborates LEACH with a fixed count of the cluster (LEACH-F) protocol by a centralized cluster representation. This protocol has a difficult drawback as it has no flexibility for adding or removing nodes once clusters are formed, and nodes cannot modify their activity on node damaging.

Furthermore, the work of [18] showed that an energy-balanced clustering algorithm based on the LEACH protocol relies on the remaining energy and distance agents, which improve the strategies of selection and not the selection of the cluster head.

In addition, [19] proposed K-LEACH using k-medoids. They partially elected CHs randomly only after almost 50% of round operations of the network, instead of totally random CHs election in LEACH.

The work of [6] uses the distance of the node from BS to the cluster LEACH protocol in prolonging the lifetime of the network. Moreover, for reduction, other transferences are conducted in the current LEACH protocol.

The works of [20] and [21] both address the energy consumption problem and present clustering by considering the energy and distance. In order to select the CHs in the setup phase, the first work calculates the distances between all the nodes. A node with the minimal distance and higher residual energy is designated as CH. The node is considered as a high power node if the calculated residual energy is higher than the threshold. In the second work, the CH selection is based on the optimal number of clusters confirmed by the lower energy dissipation.

As all clustering works in WSN, [15] aimed to reduce the power consumption in cluster head nodes and prolong the lifetime of the whole network. They introduced an enhanced LEACH protocol by randomly identifying a CH according to the shortest distance from BS.

In order to balance the energy consumption of WSN, the work by [16] introduced ESACC scheduling mechanism which monitors the network performance to ensure that only some redundant nodes are scheduled to work while the others sleep. Sleeping nodes are awakened to replace the dead nodes and maintain network performance. Their main objective is to find a minimum set of working nodes that succeed to reduce the consumption of power and maintain the coverage area.

The work of [22] is most related to the present work because of the common primary objective of improving the cluster head selection of LEACH. They have introduced an Improved Energy Efficient Cluster Head Selection protocol (IEECHS-WSN) by selecting dual cluster heads in a separated cluster based on the distance. The first CH transfers the information to the sink node, and sink node then accepts the data and that sent via the second CH. As such, the energy usage for connection with the sink is distributed between the dual CHs.

In the context of scheduling, we benefit from the work by [23], which introduces a novel cluster based task scheduling method called Algorithmic Critical Path Formulation (ACPF) to minimize the execution energy by separating task requests into clusters based on a set of defined parameters in order to apply the appropriate load balancing upon them.

## 3. The proposed improvement of LEACH

As previously stated, LEACH is a most popular clustering protocol, which, in WSN, has many weak points due to the random selection of cluster heads. The proposed work tries to address the main problems of LEACH in the setup phase including the sources of energy depletion:

1) The random selection gives an equal chance for lower-powered nodes and high-powered nodes to be cluster heads. This increases the probability of decreasing the lifetime of the network.
2) The physical properties of the connection with BS are ignored during the selection of cluster heads.
3) There is no constraint to avoid the selection of overlapping or competitive CHs.

The main contribution of this work is to introduce IE$^2$-LEACH as an effective selection algorithm for cluster headers to overcome the previously mentioned problems. Although IE$^2$-LEACH is introduced to maintain the properties of LEACH, it is designed mainly to prolong the lifetime network; therefore, it can be adapted to any other clustering technique that includes a step of CH election.

The proposed algorithm (IE$^2$-LEACH) introduces a new method for identifying the cluster heads instead of selecting them randomly in LEACH. Moreover, identifying CHs according to the accurate bases is one contribution of IE$^2$-LEACH for power saving. As proved before in [24], the transmission cost is the biggest consumer of the WSN power. Many factors can impact the transmission cost between two points. The work by [14] lists these factors as the number of transmitted packets, the properties of transmission medium, physical distance, the number of nodes in the transmission path, etc. The identifying CHs based on some of these factors (with their indirect effect on consuming power) to achieve power saving is not accurate. We see that the usage of the factors that have a direct effect on power consumption can be more suitable. Therefore, using the distance as a parameter in cluster head selection as in LEACH may not be enough. There are many factors other than distance that can affect the transmission cost, which is the main energy consumer and impact the role of distance itself.

In order to prolong the lifetime of CHs, IE$^2$-LEACH avoids selecting the redundant CHs (headers that are very close to each other, cover the same monitoring area and expected to be overlapped in their roles) and defining them as vices of CH. Therefore, the geographic location of each header is considered as a parameter by IE$^2$-LEACH in order to identify the vices of CHs. Subsequently, a sleeping-waking scheduling mechanism is used to decreases the death probability of CHs and optimize the energy consumption by minimizing the redundant information that have to be forward to BS.

### 3.1. Network model

The IE$^2$-LEACH protocol suits WSNs under the following suppositions:

- All nodes are randomly distributed to collect data about environmental parameters
- The physical location of each node is fixed; therefore, the distance of any node and BS can be calculated
- The packet size of collected data from each node is equal
- Each node may act as a sensing node or a cluster head but not both in each round
- All sensing nodes are responsible for only collecting data and forwarding them to their corresponding cluster header
- CHs are responsible for receiving data from sensing nodes, aggregating them and forwarding to BS
- BS is responsible for performing all calculations in each round, and it is power-equipped enough for this task

- Each node uses the same level energy, and it is possible to calculate the residual energy of each node at BS using power transferring and the transmission cost
- As in LEACH, the cluster-head node is responsible for the creation of Time-Division Multiple Access (TDMA) schedule, which determines when the sensor nodes can transmit each time slot.

### 3.2. Energy model

The energy model of the proposed protocol is similar to the first order energy model of LEACH. The energy needed to send data through the cluster head is formulated as follows:

Each sensor node ($SN_i$) in IE$^2$-LEACH has a set of periodic tasks = {$C_i$, $S_i$} where $C_i$ is the collecting data, and $S_i$ is sending them to CH (sink). While the cluster head node ($CH_i$) also has a set of periodic tasks = {$R_i$, $G_i$, $S_i$} where $R_i$ is the receiving data from sensor nodes, $G_i$ is the aggregating of the received data, $S_i$ is sending the received data to BS.

Let $e_i^c$(k), $e_i^g$(k) denote the energy consumption by collecting and aggregating respectively, while $e_i^s$(k, Tc) denotes the energy consumption by sending the number of data units (k) with the transmission cost (Tc) between the sensing node and CH or between CH and BS. Moreover, $e_i^r$(k) is the energy consumption by receiving the number of data units (k).

Thus, the residual energy $E_i$ at any node $n_i$ can be obtained by Eq. (2) if it is a sensor node, or by Eq. (3) if the node acts as cluster head.

$$E_i^{SN} = E_i - (e_i^c + e_i^s) \tag{2}$$

$$E_i^{CH} = E_i - (e_i^r + e_i^g + e_i^s) \tag{3}$$

where, $E_i^{SN}$ is the residual energy of sensor node and $E_i^{CH}$ is the residual energy of cluster header node.

$$e_i^s = \begin{cases} k \times E_{Tc}, \frac{Tc_{n2CH}}{E} > Th_0 forSn \\ k \times E_{Tc}, \frac{Tc_{CH2BS}}{E} > Th_0 forCH \end{cases} \tag{4}$$

where, $E_{Tc}$ is the dissipated energy for each data unit that depends on many factors such as the characters of signal (digital coding, modulation and spreading), the distance, etc. as mentioned in previous sections.

According to Eq. (4), the dissipated energy of cluster header can be minimized; therefore, maximizing the network lifetime by minimizing the energy of aggregating ($e_i^a$), receiving ($e_i^r$) and sending ($e_i^s$). Moreover, ($e_i^a$) and ($e_i^r$) are already reduced by reducing the number of communicating nodes as a result of clustering. In order to minimize ($e_i^s$), the communication cost between CH and BS must be minimized.

### 3.3. Proposed algorithm description

The method of this work is the same as of LEACH, in that it consists of two phases: setup and steady state. The significant difference from LEACH occurs at the setup phase as this work tries to face the problem of CHs selection randomly. In our setup phase, the CHs are selected and their vices are identified. In order to determine whether or not any sensor node can be a CH with minimum threats on its lifetime, IE$^2$-LEACH introduces a header selection method that considers the impact of the transmission cost between that node and BS on its residual energy during the selection decision.

Since the much closed neighboring nodes collect the same data (redundant data), the geographic information about the location of the CH is needed to determine the vices of the selected CH in preparation to apply the sleep-wake technique in order to save the power consumption by CHs and prolong their lifetime. The formation of the cluster in the second phase is expected to be as in LEACH by distributing the remaining nodes on the suitable selected CHs.

Module1: Cluster Header Selection for the Setup Phase

In order to identify all nodes that can act as CHs without exhausting energy for at least one round, the Weight Decision Value (WDV) in Eq. (5) is used. These nodes are then divided into two groups: strong and weak candidate CHs, which are calculated by the Headers Decision Value (HDV) in Eq. (6). Eq. (7) is used to identify all vices. The pseudo code for manipulating the process of the last three steps of the proposed setup method is presented below in algorithm 1:

$$\mathrm{WDV(Ni)} \begin{cases} 1 Z_i \geq 1 \\ 0 Z_i < 1 \end{cases}, \wedge^{i \in N} \tag{5}$$

$$\mathrm{HDV(Nj)} \begin{cases} \mathbb{C} PDV_j(HW_j) \geq H_0 \\ \bar{\mathbb{C}} PDV_j(HW_j) < H_0 \end{cases}, \wedge^{j \in w}, \mathrm{wisthesizeofHW} \tag{6}$$

$$\mathrm{CDV(Si, Si+1)} \begin{cases} viceofHeadi, loc(S_i, S_{i+1}) \geq d_0 \\ clusterHeader, loc(S_i, S_{i+1}) < d_0 \end{cases} \tag{7}$$

**Algorithm 1:.** *Cluster Header Selection for the Setup Phase*

1. Number of clusters M = N/$S_0$
2. For each Node i
3. Exchange a message with size = k announcing itself to BS
4. Calculate $E_{Tci}$, $Re_i$, $X_i$ and $Y_i$
5. Calculate the number of possible rounds $Z_i$ = $Re_i$, /$E_{Tci}$
6. If ($Z_i \succ 1$), then add $n_i$ to {HW}, //{HW} is set of High weight nodes
7. End for
8. For each Node $n_i$ in {HW}
9. If ($HW_j \geq H_0$) then
10. add $n_i$ to {ℂ}, C is set of strong candidate CH
11. else add $n_i$ to {$\bar{\mathbb{C}}$}, $\bar{\mathbb{C}}$is set of weak candidate CH
12. End if
13. End for
14. For each node $n_i$ in {ℂ}
15. Queue {H[i]}.push($C_i$), Create new header queue for each cluster
16. For j = i + 1 to length($C$)-1 do
17. If($X_i|Y_i$ – $X_j|Y_j \leq d_0$) then {$C$}.pop($n_j$) {H[i]}.push($n_j$), add nj to c vices s of CH[i]
18. If($\sum_C$ < M) then {$C$}.push({$\bar{\mathbb{C}}$}.pop()), first node of{C} to end of{$\bar{\mathbb{C}}$}.}
19. End if
20. End if
21. End for
22. End for

Module2: Select the Sleeping and Waking Cluster Headers

Due to unknown events, some nodes are gradually depleted of energy. Therefore, this work introduces a wake-up-sleep scheme to coordinate the work of each CH with its vices so that only the most efficient-powered header is awakened while others remain asleep. The ability of the residual energy of the current CH to cover required tasks is assessed at the beginning of each round. If it does not have enough energy, it will be removed from the header set and converted to a normal sensor node. It will be replaced by the first candidate in the vices queue (the highest in the residual energy). Fig. 1 shows the flowchart of Algorithm 2 and the wake-sleep scheduling mechanism of each round divided to two stages. The decision-making stage is responsible for monitoring the power level in the working head and evaluating its ability to cover the needed energy for the next round. In the processing stage, the selected CH performs all tasks of receiving the collected data from sensing nodes (R), aggregating them (A) and forwarding them to BS (S).

**Algorithm 2:.** *Selection of Waking and Sleeping Headers*
Inputs: Queue of CHs set sorted in descending order by $Re_i$

1. Sleep All;
2. Current CH = CHs.peek(); // choose the first node
3. Wake up Current CH
4. **For** each round r
5. **Do** while ($E_{current} > E_{needed}$)
6. Perform all round activities
7. **Loop**
8. Sleep Current CH
9. Current CH = CHs.next(); // choose the Highest power
10. **Loop** r

## 4. Simulation and results

The present approach is introduced mainly to enhance the LEACH protocol with three contributions. Since being a cluster-head drains the battery of that node [5], the first contribution is to introduce a novel selection method for the capable nodes (that can be CHs). In the second contribution, we proposed an efficient method to define the vices of each CH to avoid sending redundant information. The third contribution aims to balance the energy usage among the vices of each header. The objectives of these contributions are to prolong the lifetime of WSN, while improving its ability to transfer and extend.

In this section, we evaluate the performance of IE$^2$-LEACH by comparing it with the mentioned related work. We investigate the LEACH protocol [5] as the main related work in addition to the work by [15], which we referred to as E-LEACH for the first contribution. Furthermore, the IEECHS-WSN protocol by [22], which already outperforms the work of [9] is investigated for the second contribution and the ESACC algorithm [16] and ECH protocol [21] for the third contribution.

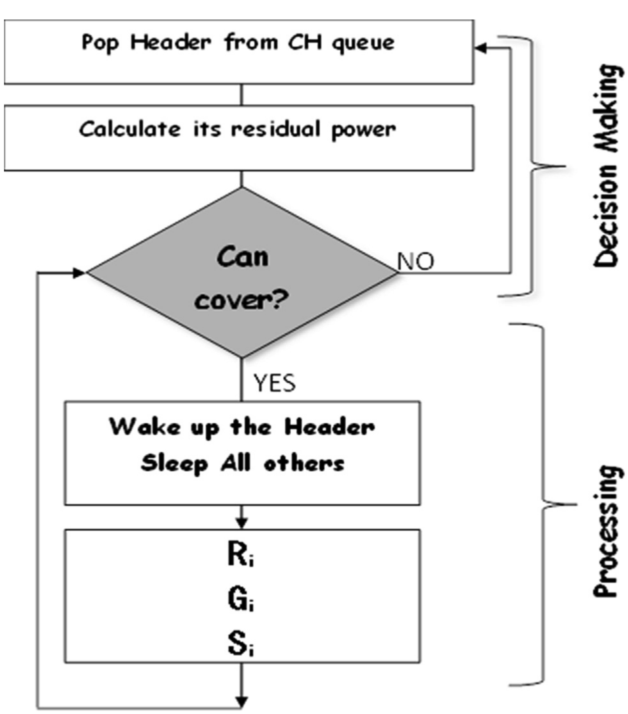


**Fig. 1.** Header wake-sleep mechanism flowchart.

For the sake of comparison, we consider the survivability and transfer capability to evaluate the proposed protocol with its mentioned related works.

To make the results from the experiments more objective, we use the same environment and parameters as the related works. Table 1 summarizes the set of parameters and the baseline settings for the simulation. The used simulation is MATLAB Environment guided by the simulation by the works of [25] and [26]. We evaluated the performance of the proposed IE$^2$-LEACH through extensive simulation tests.

### 4.1. The survivability

We use the following metrics to evaluate the survivability of the proposed approach compared to the related works.

- **Energy depletion:** measures the consumed energy during HNA
- **Network Lifetime:** measures the number of rounds until the end (all nodes are dead)

#### 4.1.1. Energy depletion

In order to evaluate and compare the performance of the proposed work with its related works, the network lifetime metric is used in the form of the number of rounds. Fig. 2 shows the comparison of the network lifetimes with three algorithms: LEACH [5], E-LEACH [15], IEECHS-WSN [22]. As seen in the figure below, in terms of average network lifetime, the IE$^2$-LEACH outperforms the others; it is 20–45% better.

#### 4.1.2. Energy dissipation

Fig. 3 reveals the average power consumption compared at different times for various nodes in 8 rounds. Fig. 3 depicts the result of energy depletion in CHs in LEACH, E-LEACH compared to energy depletion in the proposed approach (IE$^2$-LEACH). The simulation results show the outperformance of the proposed approach over the related works, especially with the higher number of nodes. In other words, the proposed approach consumes less power than its related work. This minimization of power consumption is due to the selection of CHs according to the lowest power cost where the extra transmission is omitted.

### 4.2. The transfer capability

We use the clustering lifetime as a metric to evaluate the transfer capability of the proposed approach compared to the related works. We measure the number of rounds covered by each CH and its vices

Toward more accurate results, we investigate the impact of the second and third contributions by the number of rounds covered by each CH and the vices as indicators about the cluster age. Table 2 and Fig. 4 reflect the light on the outperformance of the introduced work **IE$^2$-LEACH** and its ability to reduce the energy dissipation from CHs, as well as conserve the cluster alive. This can enhance the entire system's lifetime.

From Table 2, it can be easily to notice that the number of CHs of the present work is greater than that of the other protocols in the experiments. In detail, when running approximately 500 rounds, E-LEACH outperforms LEACH. This demonstrates that the present work can maintain better information transmission performance.

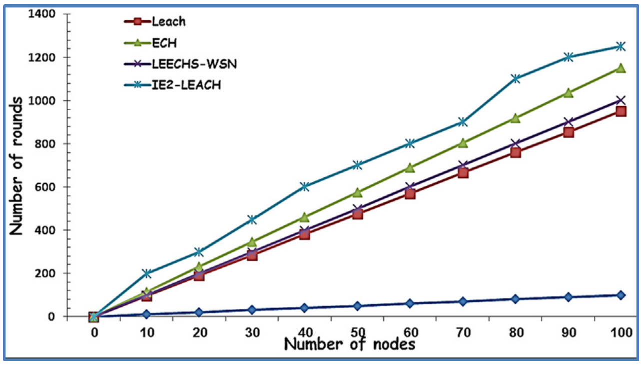


**Fig. 2.** The energy lifetime by LEACH, E-LEACH, IEECHS-WSN and IE2-LEACH.

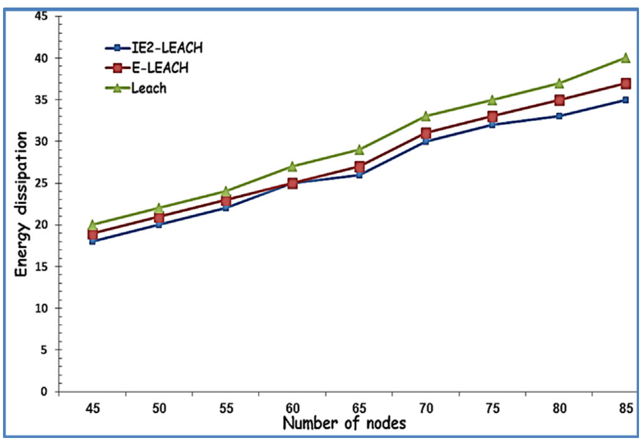


**Fig. 3.** The energy dissipation by cluster head in LEACH, E-LEACH and IE2-LEACH.

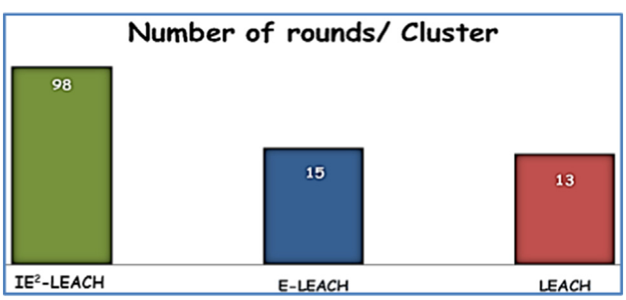


**Fig. 4.** The cluster lifetime of proposed work and related works.

## 5. Conclusions and future work

The LEACH protocol is fundamental for WSN clustering. However, it suffers from some drawbacks, especially in the setup phase where the selection of CH is random. In a trial to recruit the clustering techniques to confront these drawbacks, this work introduced an enhanced energy efficient cluster head identifying method in WSN according to the lowest degree of energy consumption. This work is introduced as an improvement on the LEACH protocol as we modify the method of CH selection in LEACH. The head selection is based on balancing between the communication cost and the residual energy. In addition, this work defines the vices of each CH to avoid sending redundant information. The present work also proposes a sleeping-waking up scheduling algorithm to conserve the power consumption. The simulation results show a better performance of IE$^2$-LEACH compared to many related works in terms of minimizing power consumption and maximizing network lifetime. In future, the proposed clustering technique should be extended to include the steady state phase.

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