Energy Efficient Vice Low Adaptive Hierarchy Clustering Protocol:EEV-LEACH

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Summary
For many sensor network applications, minimizing the energy consumed as well as extending the network lifetime are the most important objectives to be achieved, these objectives have pushed the scientific community to propose new solutions to minimize the total energy consumed by the sensors without degrading the network performances, amongst the proposed solutions, the clustering techniques. In this work we focus on hierarchical routing protocols, more precisely clustering in wireless sensor networks. We propose an energy-efficient hierarchical routing protocol for WSNs called EEV-LEACH (Energy Efficient Vice Low Adaptive Clustering Hierarchy), which represents a new variant of the LEACH protocol. Our energy-efficient protocol aims to maximize the lifetime of the network, by minimizing the energy consumption of each sensors nodes and cluster-heads. Minimizing the wasted energy by each sensor node is achieved by minimizing the periodic selection of CHs in each round. Minimizing the periodic selection of CHs allows decreasing the association messages exchanged between the CH and the nodes, so the consumed energy and overhead are minimized. EEV-LEACH aims also to minimize the energy consumed by the cluster-heads (CHs) by using vice CHs , which will share the workload with the CHs in an alternative way. The performances of our protocol EEV-LEACH is compared to, LEACH, LEACH-S and TL-LEACH by using MATLAB simulator, the results show that EEVLEACH protocol extend the network lifetime and it minimizes the overall overhead versus LEACH, LEACH-S and TL-LEACH protocols.

Keywords:
Wireless Sensor Network, hierarchical Routing Protocol, Network Lifetime, LEACH, overhead, vice CHs.

1. Introduction

Wireless Sensor Networks (WSNs) are a new technology that has emerged as a result of huge technological advances in the development of smart sensors, powerful processors and wireless communication protocols. This type of network consists of a few/thousand sensors designed to collect environmental data, process it and broadcast it to the outside world[1]. Wireless sensor networks play an important role in realizing various applications in different types field [2][3]. Among the many key requirements of these networks is energy conservation which is a very important metric, as it directly affects the lifetime of these networks, for the reason that the sensors are equipped with a limited battery. WSNs are not perfect. In fact, given their small size, low cost, and deployment in hostile or hard-to-reach areas, sensor nodes suffer from several weaknesses [4], including limited network lifetime since sensor batteries are not typically rechargeable, low bandwidth, and reduced acquisition and communication capabilities. To overcome these limitations of the WSN, several research questions have emerged in recent years, mainly related to optimizing energy consumption in order to improve network lifetime [5][6] .Among these solutions, clustering. LEACH, is one of the best-known energy-efficient hierarchical clustering routing protocols, which takes place in rounds where each round is divided into two phases. In the first phase, the construction phase, CHs are selected from a number of nodes in a random manner and clusters are formed. And in the 2nd phase, the communication phase, the data are sending to the base station using TDMA schedules. In LEACH protocol, the cluster –head is changed in each round. the periodic selection of CHs conducts to formation of clusters again, leads to an overconsumption of energy caused by the exchange of association messages between CHs and nodes for each election of CHs. It also leads to an of exchanged messages and especially in the case of a dense network. In this paper a hierarchical routing protocol for WSNs is proposed. This later represents another variant of LEACH (Low Energy Adaptive Clustering Hierarchy) (LEACH) protocol that is one of the most popular hierarchical routing algorithms for wireless sensor networks, it is based on the clustering approach. Our energy-efficient protocol aims to maximize the lifetime of the network and to decrease the overall overhead. The proposed protocol is designed to achieve the following objectives: Minimizing
the energy consumption of sensor nodes: this goal is achieved by minimizing the selection of CHs in each round. When the periodic selection of CHs is limited, the association messages exchanged between the CH and the nodes are minimized also. So the consumed energy and the overhead are decreased.

Minimize the energy consumed by the cluster-heads (CHs) by using the vice CHs, which will share the work with the CHs in an alternative way. This can also minimize the overhead generated in CH. The remainder of this paper is organized as follow, Section 2 presents the most known LEACH variants, in section 3 the proposed protocol EEV-LEACH is introduced, in section 4 the evaluation of our protocol is presented and section 5 concludes the paper

Manuscript received October 5, 2024
Manuscript revised October 20, 2024
https://doi.org/10.22937/IJCSNS.2024.24.10.4

2. LEACH Protocol and its variants

LEACH is one of the widely used hierarchical clustering protocols in WSNs. LEACH has many advantages, but in addition to some advantages, there are also disadvantages. To overcome these shortcomings, many variants of LEACH protocol have been introduced, these are detailed later. LEACH is proposed by [7], which is one of the first energy efficient routing protocols and is still used as the leading protocol in WSN. The basic idea of LEACH is to select CH from a number of nodes by rotation so that the energy dissipation of the communication can be extended to all nodes in a network. The operation is divided into two phases, the setup phase and the steady-state phase. In the Set-up phase each node decides whether or not to become a Cluster-Head for the current node round which depends on the percentage of CH suggested and the number of times a node has been CH. A random number is chosen between 0 and 1; If the number is less than the threshold, described in equation 1, the node becomes a cluster-Head.

$$Tn = \begin{Bmatrix} \frac{P}{1-P(rmod^{1}/_{P}))}, ifn \in G \\ 0 \qquad\qquad else \end{Bmatrix} \quad (1)$$

Where: P is the percentage of CHs, r represents the current round, and G is the member nodes that were not selected as CHs in the last $1/P$ rounds. The elected CH will advertise the other nodes and, based on the signal strengths, the nodes decide which cluster to join and send a membership message. To use energy efficiently, the role of CH is rotated. In the Steady-state nodes receive and transmit data to their CH, then CH aggregates and sends data directly to Base Station (BS). In order to avoid collisions, TDMA/CDMA MAC mechanism is used.

The authors of [8] proposes LEACH-C: (Centralized Low Energy Adaptive Clustering Hierarchy) . The difference between LEACH and LEACH-C is in the setup phase. The cluster-head is selected by the base station. Each node sends its current location and energy level to the base station and the base station uses this information to choose a cluster-heads. The base station selects only the node with sufficient energy level to be the Head of clusters and broadcasts this information to all nodes in the network. The advantage of this protocol compared to LEACH is the deterministic method of selecting the number of cluster head nodes in each round, which is predetermined at deployment. LEACH-C allows a better distribution of cluster head nodes in the network. But LEACH-C needs the current position information of all nodes using GPS, which is not reliable.

The authors of [9] present TL-LEACH (Two levels Low Energy Adaptive Clustering Hierarchy). Unlike LEACH protocol, the cluster head sends data directly to the base station in a single hop. The TL-LEACH protocol operates in a two-level hierarchical structure. The aggregated data from each cluster head is collected by the cluster head located between the cluster head and the base station, rather than directly sent to the base station. The advantage of this protocol the data transmission energy is reduced. Compared to other nodes far from the base station, the cluster head node is dead sooner. TL-LEACH improves energy efficiency by using a Head cluster as a relay node between Head clusters.

The authors of [10] propose Cell-LEACH (Cell level Low Energy Adaptive Clustering Hierarchy). In this protocol, the area is divided into 7 parts called cells where each cell contains nodes, among them; a node is selected as a Head of cell. Once formed, there is no reassembling. Each cell node sends data to the cell head in a slot of time by using TDMA schedule. The data aggregation function is performed by the Cell Heads and the processed data is sent to the Cluster Heads. Cluster Heads and Cell Heads transfer the data to the base station. After the first round, the Cell Head and the Cluster Head are determined randomly.

The authors of [11] present V-LEACH (Vice Low Energy Adaptive Clustering Hierarchy). In the LEACH protocol, the cluster Head consumes more energy than the normal nodes to send aggregated data to the base station (located at a long distance).As a result, the cluster head dies prematurely and the whole cluster becomes useless, causing data loss V-LEACH improves this drawback by having a vice-cluster Head in each cluster that takes the role of cluster Head. When cluster Head dies. This protocol reduces the overhead of selecting a new cluster Head each time when a cluster Head dies, and thus the network lifetime increases because the data will always reach the base station.

The authors of [12] present M-LEACH (Mobile Low Energy Adaptive Clustering Hierarchy) This protocol ensures the mobility of nodes that is missed in LEACH during the 2 phases. The nodes are homogeneous and the position of each node is calculated by GPS. The nodes with the lowest mobility and attenuation are selected as cluster head nodes and their role is broadcast to all nodes in its transmission range. The nodes with the lowest mobility and attenuation are selected as cluster head nodes and their role is broadcast to all nodes in its transmission range.

In [13] the authors discuss EE-LEACH (Energy-Efficient Low Energy Adaptive Clustering Hierarchy). This protocol takes into account the energy and position factors for each node in order to optimize the cluster head election and data transmission. The node with the highest residual energy will be elected as the cluster head. The cluster Head aggregates the data before sending it to the base station, remembering to transmit the nodes with the highest residual energy. In the data transmission phase, some of the neighboring cluster heads are chosen as relay nodes to balance the energy consumption of the communication. This protocol has better stability and longer network lifetime compared to LEACH.

In [14] the authors propose LEACH-B (Balanced Low Energy Adaptive Clustering Hierarchy). LEACH-B uses a decentralized approach to cluster formation, where each sensor node knows its own position and the position of its final destination, independent of the positions of other nodes in the network. LEACH-B is divided into three steps: cluster head selection, cluster formation and multiple access data transmission. Each node selects its cluster head based on the energy consumed on the path from the node to the final receiver. LEACH-B is more energy efficient than the LEACH protocol.

The authors of [15] present LEACH-S (Low Energy Adaptive Clustering Hierarchy for Sensor Network) . In the LEACH protocol, the nodes consume more energy, also an important overhead is generated in the network. LEACH-S improves these drawbacks by minimizing distributed energy and decreasing overhead by minimizing periodic cluster head selection. The difference between LEACH and LEACH-S is in the setup phase. From the 2nd round, the cluster Head checks its remaining energy if it is higher than a calculated threshold so it continues its activity as a cluster Head otherwise another cluster Head is chosen. The calculated threshold is presented in the following formula :

$$E_{moy}=\left(\sum_{i=1}^{i=n} E_i\right)/n \quad (2)$$

n: number of nodes

E_i : the residual energy of node in the cluster

In [16] the authors discuss MOD-LEACH (Modified Low Energy Adaptive Clustering Hierarchy). The differences between MOD-LEACH and LEACH are: in MOD-LEACH it is not necessary to change the cluster head as long as it does not have more energy than the required threshold. And MOD-LEACH does not amplify all signals to the same level. In LEACH the cluster Head is changed after each round, in order to avoid that the cluster Head dies prematurely, but in MOD-LEACH the current cluster Head is replaced by a new one only if the energy of the current cluster Head is not below the required threshold. This saves the energy consumed for cluster formation and transmission of routing packets in order to search a new cluster Head. In each round, if the residual energy of current cluster Head is more than the minimum threshold value, then the current cluster Head will remain the cluster Head for the new round. MOD-LEACH has classified the communication into three categories: (1) Intra-cluster communication (2) Inter-cluster communication (3) Data transmission from cluster head to the base station. The energy required for intra-cluster communication is different from that required for inter-cluster or cluster head to base station communication. Thus, different types of amplification are required for different packets depending on their type. Previously, in LEACH, all packets were amplified in the same way, regardless of the type of communication.

In [17] the authors suggest MH-LEACH (Multi Hop Low Energy Adaptive Clustering Hierarchy) . In LEACH, the distance between the base station and the CH has no effect. Data is transmitted from the CH to the base station in a single hop. As the network diameter increases, the distance between the cluster head (CH) and the base station also increases. So, battery power consumption increases with distance. MH- LEACH protocol reduces the power consumption. In this protocol the data broadcast from cluster Head to base station occur in a Multi-Hop communication manner, the data is transmitted from one cluster Head to another cluster Head, then to another cluster Head, until they reach the base station. the cluster Head that is close to the base station transmits all the data to the base station (BS). Cluster Heads perform data aggregation upon receiving data to reduce the total number of data transmission in the network.

In [18] the authors introduce IB-LEACH (Low Energy Adaptive Clustering Hierarchy). IB-LEACH is designed to reduce the intra-group communication cost and to minimize the CH load by dividing the task between the CH and its group members. IB-LEACH operates in multiple rounds and each round is divided into three phases: The set-up, the pre-stabilized and the stabilized step. The set-up phase (the build phase) is similar to the LEACH. In the pre-stable phase, the sensing nodes in a cluster are divided into three categories: the CH, the sensing nodes, and the aggregators. Sensor nodes sense the environment and send the sensed data to aggregators. The aggregators aggregate the received data and send it to the base station. This reduces the energy consumption of the CHs. The CHs maintain and manage the cluster activities. They create and broadcast the TDMA schedule to all cluster members. The CHs also select the aggregator nodes in a frame and broadcast their list to all cluster members. The steady state process is divided into frames. Each cluster member sends its data in each frame according to its time slots. The aggregator aggregates this data and sends it to the base station.

The authors of [19] propose H-LEACH (Hybrid Low Energy Adaptive Clustering Hierarchy). H-Leach divides the set of WSNs into a number of CHs and the LEACH protocol is used to select a CH in each partition based on a probabilistic method. This can conducts in a better distribution of CHs and a longer lifetime of WSNs.

The authors of [20] suggest LEACH-E (Energy Low Energy Adaptive Clustering Hierarchy). In the LEACH-E protocol, all nodes initially have the same energy and the same probability of becoming a cluster head. After the first round, the energy level of each node changes. Then, the amount of residual energy of each node is used to select the cluster heads. Nodes with the highest residual energy are preferred over other nodes. LEACH-E improves the lifetime of the network by balancing the energy load among all nodes in the network.

LEACH-F (Fixed number of cluster Low Energy Adaptive Clustering Hierarchy) is proposed by [21]. LEACH-F uses a centralized approach to cluster formation like the Leach-C protocol. Once the cluster formation process is complete, there is no re-clustering phase in the next round. Clusters are fixed and only rotation of cluster head nodes within its clusters is possible. LEACH-F has reduced the overhead of the LEACH construction phase because once the fixed number of clusters is formed. They are maintained throughout the network. But this protocol does not allow nodes to be added or removed once clusters are formed, and nodes cannot adjust their behavior in the event of node death.

Table 1: A comparative table representing LEACH variants

Protocols	***Data transmission***	***Mobility of BS***	***Homogenous***	***Need for location information***	***Scalability***	***Distributed***	***Auto-organisation***
LEACH	Single-Hop	Fixed	Yes	Yes	Limited	Yes	Yes
LEACH-C	Single-Hop	Fixed	Yes	Yes	Good	No	Yes
TL-LEACH	Multi-Hop	Fixed	Yes	Yes	Very good	Yes	Yes
Cell-LEACH	Multi-Hop	Fixed	Yes	Yes	Very good	Yes	Yes
V-LEACH	Single-Hop	Fixed	Yes	Yes	Very good	Yes	Yes
M-LEACH	Single-Hop	Mobile	Yes	Yes	Very good	Yes	Yes
EE-LEACH	Single-Hop	Fixed	Yes	Yes	Very good	Yes	Yes
LEACH-B	Single-Hop	Fixed	Yes	Yes	Good	Yes	Yes
LEACH-S	Single-Hop	Fixed	Yes	Yes	Very good	Yes	Yes
MOD-LEACH	Single-Hop	Fixed	Yes	Yes	Good	Yes	Yes
MH-LEACH	Multi-Hop	Fixed	Yes	Yes	Very good	Yes	Yes
IB-LEACH	Single-Hop	Fixed	Yes	Yes	Good	Yes	Yes
H-LEACH	Single-Hop	Fixed	Yes	Yes	Good	Yes	Yes
I-LEACH	Single-Hop	Fixed	Yes	Yes	Very good	Yes	Yes
F-LEACH	Single-Hop	Fixed	Yes	Yes	Limited	No	No
LEACH-E	Single-Hop	Fixed	Yes	Yes	Very good	Yes	Yes
LEACH-K	Single-Hop	Fixed	Yes	Yes	Good	Yes	Yes
EEM-LEACH	Multi-Hop	Fixed	Yes	Yes	Good	Yes	Yes

The authors of [22] design I-LEACH (Improved Low Energy Adaptive Clustering Hierarchy). I-LEACH is designed with two important changes; first, residual energy is used to select the CH (Cluster Head) instead of the probability used in LEACH, so that it can be used for sensor nodes with different initial energy. Second, coordinates of nodes are used to form clusters so that there must be one CH near to each sensor node, as there is no certainty in LEACH about the location of CHs.

The authors of [23] propose LEACH-K (K-medoids low energy adaptive clustering hierarchy). LEACH-K is proposed to eliminate the drawback of LEACH, mainly the random selection of CHs, which sometimes leads to very poor cluster formation. The K-LEACH protocol improves the cluster and head cluster selection procedure in the 1st phase, because at the very beginning of each round, it uses the K-medoids algorithm for efficient cluster formation, and then selects the head cluster using the Euclidean distance to the nearest or very center of each cluster. It uses the maximum residual energy (MRE) until we get unique cluster heads for each cluster. The steady state of LEACH-K is the same as that of LEACH.

EEM-LEACH (Energy Efficient Multi-Hop Low Energy Adaptive Clustering Hierarchy) is proposed [24]. It aims to reduce the problems of direct communication from the cluster Heads to the BS and the wrong selection of the cluster Head in LEACH protocol. EEM-LEACH protocol is characterized by:

1) Cluster Head selection based on residual energy and average energy consumption of nodes.
2) Multi-Hop inter-cluster communication which selects a Multi-Hop path with minimum communication cost from each node to the base station.
3) Direct communication by nodes close to the base station (if the communication cost is minimal). Using relay nodes with more residual energy and minimized communication cost per packet. This can improve the network lifetime. We summarize the cited protocol in the related work in the following table

3 The proposed Protocol

3.1. Motivation

LEACH Protocol is one of the most prominent hierarchical routing protocols. It is known for its energy efficiency in homogenous wireless sensor networks. LEACH protocol is divided into rounds and each round is composed of two phases: set up and steady phase. The election of cluster head is done periodically and randomly for every round, so a new cluster formation is needed. This leads to excessive energy consumption due to association messages exchanged between nodes. Also, this generates additional and unnecessary overhead in both cluster heads and base station. In the other hand, if a cluster head has not spent a large amount of energy in the previous round, there is no need to elect a new CH. Thus, an energy efficient cluster head replacement based on residual energy of current cluster head is required By considering the residual energy of cluster heads, the reelection of cluster heads is limited hence the number of association messages is reduced therefore the consumed energy and the overhead are decreased. Many variants of LEACH protocol are proposed in order to minimize the consumed energy generated by the periodic election of cluster head, some of them propose vice cluster head, it replace cluster head when this latter died. However, this vice cluster operates only when the cluster head exhausts its energy and there is no reelection of cluster and vice cluster when both of them died. Other protocols aim at replacing the cluster head only when its energy is less than a fixed threshold, this is can increase the network lifetime but it can generate an overhead at cluster head specially in homogenous network, so the residual energy of this latter is exhausted rapidly.
To deal with the above cited problems, we propose an energy efficient clustering protocol called EEV-LEACH (Energy Efficient Vice Low Energy Adaptive Clustering Hierarchy)

3.2. Description of EEV-LEACH Protocol

In this work we propose a hierarchical routing protocol which represents a new variant of LEACH. Our protocol is executed on rounds and each round is composed of two phases: the set up and the steady phase. Our contribution is mainly focused on set up phase. In the first round we choose two cluster head, the main cluster head and vice cluster head. Both of them work in turn. From the second round, the replacement of cluster head and the vice cluster head is done based on some criteria. For every next round, the residual energy of cluster head or vice cluster head, responsible for this round, is compared to a calculated threshold. If this latter is less than a required threshold, a new cluster head /vice cluster head is chosen. The details of our protocol are given bellow

3.2.1. Protocol Functioning

We describe only the set-up phase; the steady phase is the same as LEACH protocol.

In the first round
The cluster head is chosen as in the LEACH protocol. Once a cluster formation process is done, the cluster head chooses among its members an assistant cluster head (vice cluster

head). It chooses the nearest member to the base station as assistant.
The chosen assistant takes place in the second round as CH.

From the second round
The cluster head and the vice cluster head work in turns, if he cluster head is active for the current round, the vicecluster will be active for the next round.
From the second round the residual energy of the cluster head or vice cluster head is compared to a calculated threshold (ENTR), if it is less than the required threshold, a new cluster head /vice cluster head is chosen (the cluster head /vice cluster head with maximum residual energy).
The required threshold is represented by the following formula:

$$ENTR = ((Et + Er) * n)nbrcluster \quad (3)$$

Such as:
Et: the necessary energy for transmitting a packet.
Er: the necessary energy for receiving a packet.
N: the number of nodes in the network.
Nbr cluster: the number of formed clusters.
The following pseudo-code summarizes the steps of the proposed protocol.

3.2.2. Pseudo-code of the proposed protocol (EEV-LEACH)

1st round: (r=0)
Begin
While the nodes are alive **do**
Begin
Random selection of the CHs
The elected CH sends a message to the other nodes
Nodes decide which cluster to join
CH chooses the nearest node to the base station as assistant (vice-CH)
Nodes collect and forward data to its CH
CH aggregates and sends data directly to BS
2nd round (r=1)
Begin
If (r mod 2! = 0)
Begin
If (Evch >= ((ET+ Er) * n) /nb cluster)
Stay as VCH
Else
Choose a new VCH
End if
Nodes collect and transmit data to its V-CH
The VCH aggregates and sends the data directly to BS
End else
Else
Begin
if (Ech >= ((ET+ Er) * n) /nb cluster)
Stay as CH
Else
Choose a new VCH
End if
. Nodes collect and transmit data to its current CH
The CH aggregates and sends the data directly to BS
End else
End
End while
END

4 Results and Discussions

In this section we present the performance evaluation of our protocol. The evaluations are conducted by using MATLAB simulator. For that, a number of nodes are distributed randomly over an area of 100m*100m. All nodes are static and homogenous. They are equipped with 0.5 joules of battery. The base station is situated in the center of the area. Simulation parameters are summarized in table.

Table 2: Parameters of simulation

Parameters	***Values***
E0 (the initial energy of nodes)	0.5 J/node
E elec	50 nJ/bit
E fs	100 pJ/bit/m²
E mp	0.0013 pJ/bit/m4
E ag (energy of aggregation)	5 nJ/bit /signal
P (the desired percentage of CH)	0.1
Packet size in the Set-up phase « node-CH »	400 bits
Packet size in the Steady phase « CH-node »	1000 bits
Packet size in the Steady phase «CH-BS »	4000 bits
D0	0.000000005 Joule
Network size	100m *100m
Range	50
BS coordinates	X=50 ; Y= 50

Our protocol is evaluated by taken into account the following metrics:

The consumed energy:
We are interested in the energy consumed at reception and transmission. The consumed energy is calculated using the following formulas (Kirankumar & Katageri, 2014):

- Consumed energy for transmission :

$$ETxs, d = ETxelecs + ETxamps, d \quad (4)$$
$$ETxs, d = ETxelec{*}s + (Eamp{*}s{*}d2) \quad (5)$$

- Consumed energy at reception :

$$ERxs = ERx\ elec{*}\ s \quad (6)$$
$$ERxs = ERxelec{*}s \quad (7)$$

Where:

Eelec and Eamp represent the electronic transmission energy and amplification energy, respectively.

The network overhead: We are interested in the overhead generated at cluster heads and the overhead generated at base station. It is represented by the number of packets send to the CH and base station.

The network lifetime*:* presents the elapsed time until the death of all nodes in the network

4.1. The consumed energy

4.1.1. *The consumed energy per round*

Figures 1, 2 and 3 represent the obtained results of energy consumed by 120 nodes for LEACH, LEACH-S, TL-LEACH and EEV-LEACH. The simulations are performed during 100/ 200/ 500/ 700 and 1000 rounds

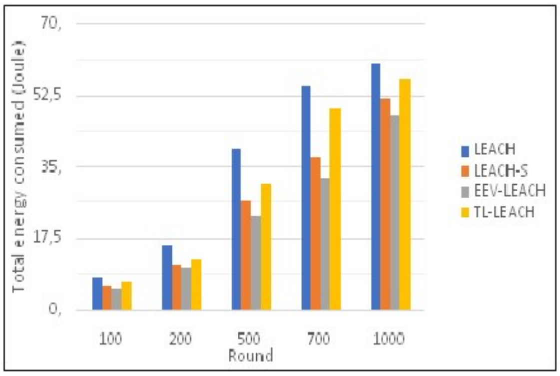

Fig 1. Total energy consumed/ round

Figure1 represents the total energy consumed in the 4 protocols. Our EEV-LEACH protocol reduces the total energy consumed in the network Comparing to LEACH, LEACH-S and TL-LEACH during different rounds

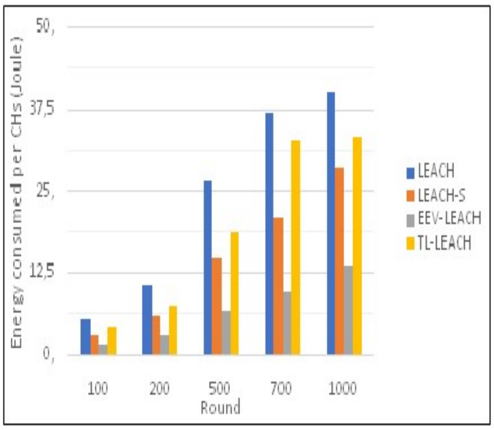

Fig. 2 Energy consumed per CHs / round

Figure 2 shows the energy consumed by the CHs in the 4 protocols. Our EEV-LEACH protocol minimizes the energy consumed by the cluster-heads (CHs) compared to LEACH, LEACH-S and TL-LEACH during the different rounds, because the role of the CHs is shared with the assistants in an alternative way

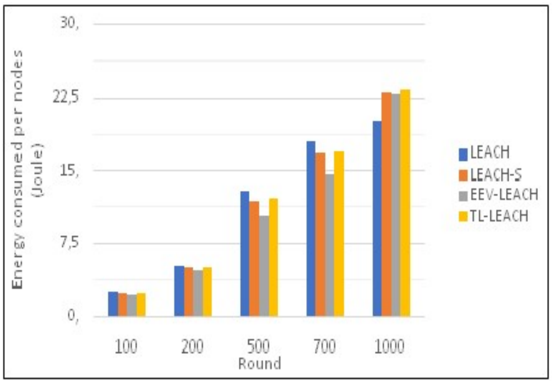

Fig. 3. Energy consumed per nodes / round

Figure 3 represents the energy consumed by the nodes in the 4 protocols. Our EEV-LEACH protocol minimizes the energy consumed by the nodes. Comparing by LEACH, LEACH-S and TL-LEACH during the different rounds because we have minimized the periodic selection of CHs (cluster head) in each round and this decrease the association messages between CHs and nodes and minimizes the energy consumed by nodes

4.1.2. Energy consumed / number of nodes

Figures shown below represents the results of energy consumed with different densities 50, 100, 150, and 200 nodes for 100 rounds of the 4 protocols

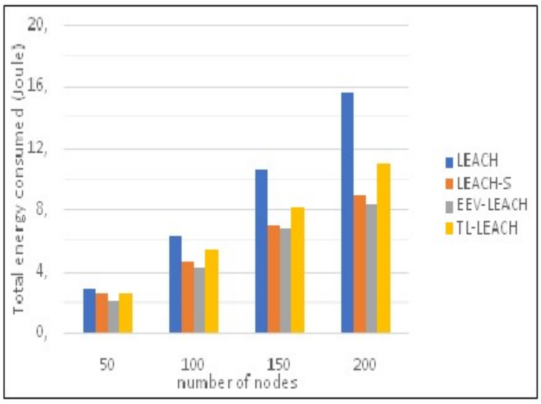

Fig.4. Total energy consumed / number nodes

Figure 4 represents that the total energy consumed by our EEV-LEACH protocol is lower than the 3 LEACH, LEACH-S and TL-LEACH protocols with different densities. Figure 4 represents that the total energy consumed by our EEV-LEACH protocol is lower than the 3 LEACH, LEACH-S and TL-LEACH protocols with different densities

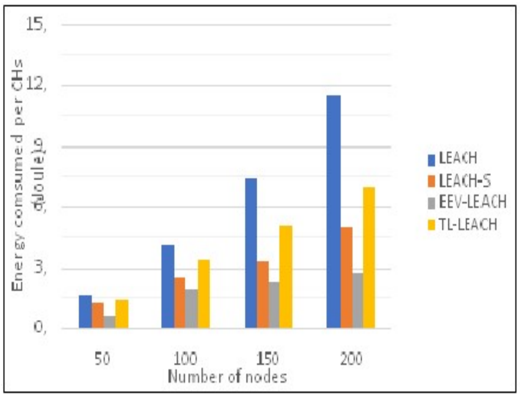

Fig.5. Energy consumed per CHs / number of nodes

Figure 5 shows that the energy consumed by the cluster heads (CHs) of our EEV-LEACH protocol is lower than that of the LEACH, LEACH-S and TL-LEACH protocols in different densities, because the work of the CHs is shared with the assistants in an alternative way

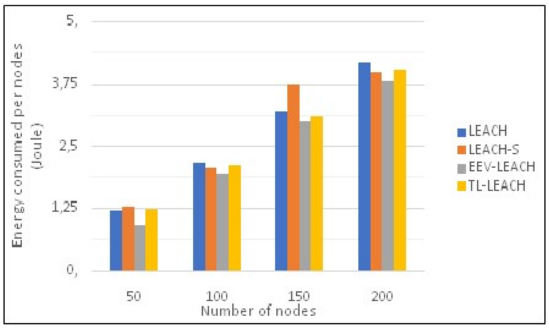

Fig. 6. Energy consumed per nodes / number of nodes

Figure 6 shows that the energy consumed by the nodes of our EEV-LEACH protocol is lower than the 3 protocols LEACH, LEACH-S and TL-LEACH in different densities, because we have minimized the selection of the CHs (cluster head) in each round and this decreases the association messages between the CHs and the nodes and minimizes the energy consumed by the nodes.

So, our protocol minimizes the energy consumed by the nodes and by the CHs with different densities of the network.

4.2 Network overhead

4.2.1. Network overhead/ round

Figures shown below represents the numbers of packets send to BS and CHs. For this simulation 120 nodes are used and its is executed for 100/ 200/ 500/ 700 and 1000 rounds respectively

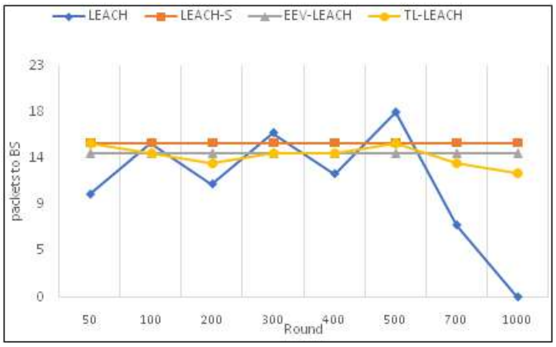

Fig. 7. Packets to BS /round

Figure 7 represents the packets to the base station (BS) in the 4 protocols. Our EEV-LEACH protocol decreases the packets sent to BS comparing by LEACH, LEACH-S and TL-LEACH during the different rounds so our protocol minimizes the network overhead

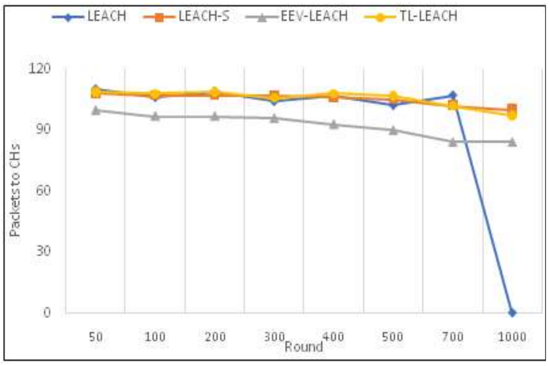

Fig. 8. Packets to CHs / round

Figure 8 represents the packets send from nodes to CHs in the 4 protocols. Our EEV-LEACH protocol decreases the packets sent to CHs comparing by LEACH, LEACH-S and TL-LEACH during different rounds. Minimizing the selection of CHs allows decreasing the association messages between nodes and CHs. Hence, the overhead is minimized

4.2.2 Network over Head/ number of nodes

Figures shown below represents the number of packets to BS and CHs on different density 50, 100, 150, and 200 nodes for 100 rounds of the 4 protocols

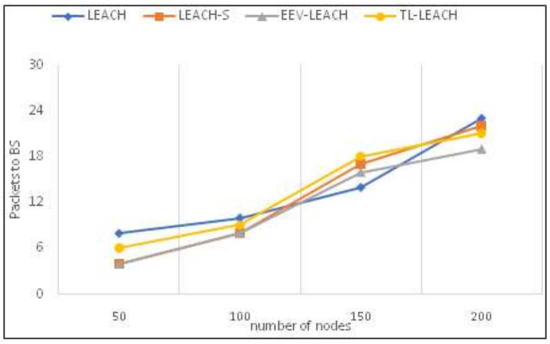

Fig.9. Packets to BS / number of nodes

Figure 9 represents the packets to the base station (BS) in the 4 protocols in different densities. Our EEV-LEACH protocol decreases the packets sent to BS comparing by LEACH, LEACH-S and TL-LEACH during different rounds thus our protocol minimizes the network overhead. Figure (15) represents the packets to the base station (BS) in the 4 protocols in different densities. Our EEV-LEACH protocol decreases the packets sent to BS comparing by LEACH, LEACH-S and TL-LEACH during different rounds so our protocol minimizes the network overhead

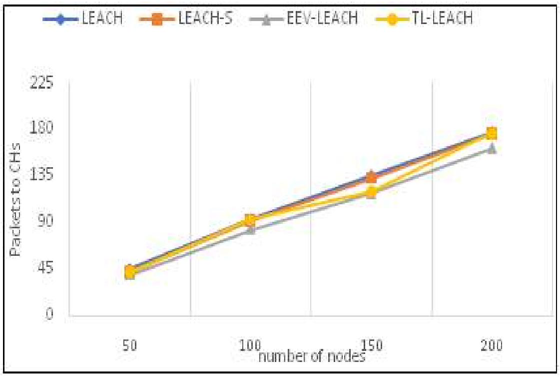

Fig.10. Packets to CHs / number of nodes

Figure 10 shows the packets sent from nodes to CHs in the 4 protocols in different densities. Our EEV-LEACH protocol decreases the packets sent to CHs comparing by LEACH, LEACH-S and TL-LEACH during different rounds thus our protocol minimizes the network overhead. This is due to the minimization of the periodic selection of CHs which decreases the association messages between nodes and CHs

4.3. Network lifetime

The network lifetime represent the elapsed time until all nodes are dead. In order to evaluate the network lifetime the simulation is executed using 120 nodes

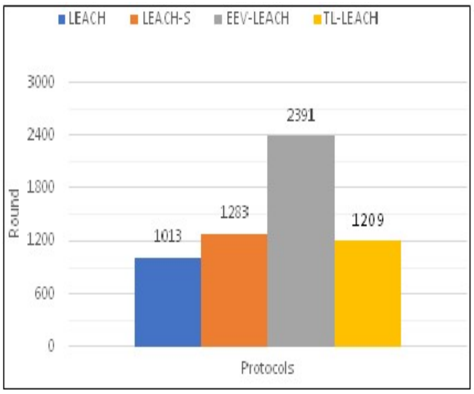

Fig.11. Round of death of all nodes in the network for LEACH, LEACH-S, TL-LEACH and EEV-LEACH

Figure 11 represents respectively the round where all the nodes are dead.

- In the LEACH protocol all nodes are dead in the round r = 1013.

- In the TL-LEACH protocol all nodes are dead in the round r = 1209.

- In the LEACH-S protocol all nodes are dead in round r = 1283.

- In our EEV-LEACH protocol all nodes are dead in round r = 2391.

From the obtained results, EEV-LEACH protocol increases the network lifetime compared to LEACH, LEACH-S and TL-LEACH

5 Conclusion and Future work

In this work, a new hierarchical energy efficient protocol called EEV-LEACH is proposed. It represents a new variant of LEACH protocol. Our protocol deals with the limits of LEACH protocol. It aims at reducing the total consumed energy hence the network lifetime is increased. This can be achieved by minimizing the periodic selection of cluster-heads in each round.

Also, the overall overhead can be decreased by reducing the number of association messages. Another objective of our protocol is to reduce the overhead generated in cluster heads by using an assistant cluster head in addition to cluster-heads. The simulation results show that, EEV-LEACH outperforms LEACH, LEACH-S and TL-LEACH in terms of consumed energy, overhead and network lifetime. In the future work, and in order to evaluate more the performance of the proposed protocol. More simulations will be conducted by comparing EEV-LEACH with the other variants of LEACH protocols

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