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

Amira Bendjeddou*, Mouna Hemici†
University of Annaba, Algeria.

Abstract

The primary objectives for many sensor network applications are to reduce energy consumption and extend network lifetime. These goals have pushed the scientific community to develop new solutions to reduce total energy consumption while maintaining network performance, such as hierarchical routing protocols. This paper proposes an energy-efficient hierarchical routing protocol for Wireless Sensor Networks (WSNs) called EEV-LEACH (Energy Efficient Vice Low Adaptive Clustering Hierarchy) to improve the LEACH protocol. The EEV-LEACH protocol aims to extend the network lifetime by reducing energy consumption at each sensor node and cluster-head (CH). Minimizing the wasted energy by each sensor node is accomplished by minimizing the periodic selection of cluster heads (CHs) in each round; thus, the number of association messages exchanged between the CH and the nodes is reduced, reducing consumed energy and overhead. EEV-LEACH also reduces the energy consumed by CHs by employing vice-CHs, which share the workload with the CHs in an alternative way. The MATLAB simulator simulation demonstrates that the EEV-LEACH protocol extends network lifetime and reduces overall overhead compared to the LEACH, LEACH-S, andTL-LEACH protocols.

Key words: Wireless Sensor Network, hierarchical Routing Protocol, Network Lifetime, LEACH, overhead, vice-CH.

1 Introduction

Wireless Sensor Networks (WSNs) represent a relatively new technology that has emerged due to tremendous technological advances in developing smart sensors, powerful processors, and wireless communication protocols. This type of network comprises a few/thousand sensors that collect, process, and broadcast environmental data to the outside world [1]. WSNs are useful for various field applications [2][3]. However, energy conservation is the primary requirement of these networks because it directly affects the lifetime of network nodes. In fact, because of their small size, low cost, and deployment in hostile or difficult-to-reach areas, sensor nodes have several flaws [4], including limited network lifetime because sensor batteries are not typically rechargeable, low bandwidth, and limited acquisition and communication capabilities. Several research questions, primarily related to optimizing energy consumption to improve network lifetime, have emerged in recent years to address these limitations [5][6].

LEACH is a well-known energy-efficient hierarchical clustering routing protocol that operates in rounds of two phases. In the first phase (construction phase), CHs are chosen randomly from a pool of nodes, and clusters are formed. The data is forwarded to the base station (BS) using TDMA schedules in the second communication phase. The CH is changed in each round of the LEACH protocol. The periodic election of CHs results in excessive energy consumption. The exchange of association messages between CHs and nodes causes each CH election. It also causes overhead, particularly in dense networks. A hierarchical routing protocol for WSNs is proposed in this paper. This latter is a variant of the LEACH (Low Energy Adaptive Clustering Hierarchy) protocol based on the clustering approach. LEACH is one of the most popular hierarchical routing algorithms for WSNs.

The proposed energy-efficient protocol aims to increase the network's lifetime while decreasing overall overhead. Minimizing the selection of CHs in each round reduces the energy consumption of sensor nodes. When the periodic selection of CHs is limited, the number of association messages exchanged between the CH and the nodes is also reduced. The result is a reduction in energy consumption and overheads. Energy consumption by CHs can be reduced by using vice-CHs, who will share the workload with CHs in an alternative way. This can also help to reduce the amount of overhead generated in CH. The rest of this paper is structured as follows: Section 2 describes the most well-known LEACH variants, and Section 3 describes the proposed protocol EEV-LEACH. Section 4 evaluates the proposed protocol, and Section 5 concludes the paper.

* †LRS Laboratory, Department of Computer Science
*Amira.bendjeddou@univ-annaba.org

2 LEACH protocol and its variants

LEACH is a popular hierarchical clustering protocol in WSNs. LEACH has many advantages, but there are also some disadvantages. Many variants of the LEACH protocol have been introduced to address these shortcomings; these are discussed further below. [7] proposes LEACH, one of the first energy-efficient routing protocols and still the leading protocol in WSNs. The basic idea behind LEACH is to select CH from a number of nodes by rotation to extend the communication's energy dissipation to all nodes in the network. The operation is divided into two phases: set-up and steady-state. During the set-up phase, each node decides whether or not to become a CH for the current node round, which is determined by the percentage of CH proposed and the number of times a node has been CH. A random number between 0 and 1 is chosen; if the number is less than the threshold described in Eq. (1), the node is designated as a CH:

$$Tn = \begin{cases} \frac{P}{1-P(r \bmod \frac{1}{P})}, & if n \in G \\ 0 & else \end{cases} \quad (1)$$

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 the nodes will decide which cluster to join and send a membership message based on the signal strengths. The role of CH is rotated to maximize energy efficiency. The steady-state nodes receive and transmit data to their CH, aggregating and transmitting data to the Base Station (BS). The TDMA/CDMA MAC mechanism is used to avoid collisions. The authors of [8] proposed LEACH-C (Centralized Low Energy Adaptive Clustering Hierarchy). The primary distinction between LEACH and LEACH-C is in the set-up phase. The BS chooses the CH. Each node transmits its current location and energy level to the BS, which uses this information to select a CH. The BS chooses the node with the highest energy level to be the cluster's leader and broadcasts this information to all nodes in the network. The deterministic method of selecting the number of CH nodes in each round, which is predetermined at deployment, gives this protocol an advantage over LEACH. LEACH-C improves the network's distribution of CH nodes. LEACH-C, on the other hand, requires current position information from all nodes via GPS, which is unreliable.

[9] introduced TL-LEACH (Two Levels Low Energy Adaptive Clustering Hierarchy). In contrast to the LEACH protocol, the CH sends data to the BS in a single hop. The TL-LEACH protocol is organized in a two-level hierarchy. Instead of being sent directly to the BS, the CH collected the aggregated data from each CH located between the CH and the BS. This protocol has the advantage of reducing data transmission energy. The CH node dies faster than other nodes farther from the BS. TL-LEACH improves energy efficiency by using a Head cluster as a relay node between Head clusters.

The authors of [10] proposed Cell- LEACH (Cell level Low Energy Adaptive Clustering Hierarchy). In this protocol, the area is divided into seven cells, each containing nodes; one is chosen as the cell's head. There is no reassembling once formed. Using a TDMA schedule, each cell node sends data to the cell head in a time slot. The cell heads perform the data aggregation function, and the processed data is sent to the CHs. Data is transferred to the BS by CHs and cell heads. Following the first round, the cell and CHs are randomly chosen.

V-LEACH (Vice Low Energy Adaptive Clustering Hierarchy) was described by [11]. The CH uses more energy than the normal nodes in the LEACH protocol to send aggregated data to the BS (located a long distance away). As a result, the CH dies prematurely, rendering the entire cluster inoperable and resulting in data loss. V- LEACH mitigates this disadvantage by having a vice-CH in each cluster who takes over as CH when the latter dies. This protocol reduces the overhead generated by selecting a new CH each time a CH dies, increasing network lifetime because data is always delivered to the BS. M- LEACH (Mobile Low Energy Adaptive Clustering Hierarchy) is presented by the authors of [12]. Contrary to LEACH, this protocol ensures node mobility in the second phase. The nodes are homogeneous, and each node's position is calculated using GPS. The CH nodes are chosen based on their low mobility and attenuation, and their role is broadcast to all nodes within their transmission range.

In [13], the authors discuss EE-LEACH (Energy-Efficient Low Energy Adaptive Clustering Hierarchy). This protocol optimizes CH selection and data transmission by considering each node's energy and position. The node with the greatest residual energy will be chosen as the CH. Before sending the data to the BS, the CH aggregates it. It also sends the status of the nodes with the most residual energy. During the data transmission phase, some neighboring CHs are chosen as relay nodes to balance the communication's energy consumption. Compared to LEACH, this protocol is more stable and has a longer network lifetime. The authors propose LEACH-B (Balanced Low Energy Adaptive Clustering Hierarchy) in [14]. LEACH-B employs a decentralized approach to cluster formation in which each sensor node is aware of its position and the position of its final destination, regardless of the positions of other nodes in the network. LEACH-B is divided into CH selection, cluster formation, and multiple access data transmission. Each node chooses its CH based on the energy consumed between the node and the final receiver. LEACH-B uses less energy than the LEACH protocol.

LEACH-S (Low Energy Adaptive Clustering Hierarchy for Sensor Networks) was introduced by [15]. The LEACH protocol causes nodes to consume more energy, resulting in significant network overhead.

LEACH-S mitigates these drawbacks by reducing distributed energy and lowering overhead by reducing periodic CH selection.

The primary distinction between LEACH and LEACH-S is in the set-up phase. The CH checks its remaining energy in the second round to see if it is greater than a calculated threshold. In this case, it continues its activity as a CH; otherwise, another CH is chosen. The calculated threshold is shown in Eq. (2):

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

where, n is the number of nodes and E_i is the residual energy of the node in the cluster.

In [16], the authors discuss MOD-LEACH (Modified Low Energy Adaptive Clustering Hierarchy). The following are the primary distinctions between MOD-LEACH and LEACH: changing the CH in MOD-LEACH is unnecessary as long as it does not contain more energy than the required threshold. MOD-LEACH also does not equalize the amplitude of all signals. In LEACH, the CH is changed after each round to prevent the CH from dying prematurely, whereas, in MOD-LEACH, the current CH is replaced by a new one only if the energy of the current CH is greater than the required threshold. This reduces the energy required for cluster formation and the transmission of routing packets to a new CH. If the current CH's residual energy exceeds the minimum threshold value in each round, the current CH will remain the CH for the next round. MOD-LEACH categorizes communication into three types: intra-cluster communication, inter-cluster communication, and data transmission from CH to BS. The energy required for intra-cluster communication differs from that required for inter-cluster communication and communication from a CH to a BS. As a result, different types of amplification are required depending on the packet type. Previously, regardless of the communication type, all LEACH packets were amplified similarly.

The authors of [17] proposed MH-LEACH (Multi-Hop Low Energy Adaptive Clustering Hierarchy). LEACH has no effect on the distance between the BS and the CH. Data is transmitted from the CH to the BS in a single hop. The distance between the CH and the BS grows as the network diameter grows. As a result, energy consumption rises with distance. This protocol broadcasts data from the CH to the BS using Multi-Hop communication. The data is passed from one CH to the next, and so on, until it reaches the BS. The data is transmitted to the BS by the CH located near the BS. When CHs receive data, they aggregate it to reduce the total amount of data transmitted by the network. The authors introduce IB-LEACH (Low Energy Adaptive Clustering Hierarchy) in [18]. IB- LEACH is intended to reduce intra-group communication costs and CH load by dividing the task among the CH and its group members. IB-LEACH operates in rounds, each divided into three phases: set-up, pre-stabilized, and stabilized. The LEACH phase is similar to the set-up phase (the build phase). During the pre- stable phase, cluster nodes are classified into CH, sensing nodes, and aggregators. Sensor nodes sense their surroundings and transmit the information they gather to aggregators. The received data is aggregated and sent to the BS by the aggregators. This process reduces the CHs' energy consumption. The cluster activities are maintained and managed by the CHs. They develop and distribute the TDMA schedule to all cluster members. The CHs also choose the aggregator nodes in a given frame and broadcast the list to all cluster members. There are frames in the steady-state process. Each cluster member sends data in each frame according to its time slot. This data is aggregated by the aggregator and sent to the BS.

H-LEACH (Hybrid Low Energy Adaptive Clustering Hierarchy) is proposed by the authors of [19]. H-Leach divides the network's nodes into clusters, and the LEACH protocol is used to select a CH in each partition using a probabilistic method. This can lead to better CH distribution and a longer network lifetime. The authors of [20] proposed LEACH-E (Energy Low Energy Adaptive Clustering Hierarchy). In the LEACH-E protocol, all nodes start with the same amount of energy and the same chance of becoming a CH. Each node's energy level changes after the first round. The residual energy of each node is then used to select the CHs. The nodes with the highest residual energy are prioritized over others. LEACH-E extends the network's lifetime by balancing the energy load across all nodes. [21] proposes LEACH-F (Fixed number of cluster Low Energy Adaptive Clustering Hierarchy). LEACH-F, like LEACH-C, employs a centralized approach to cluster formation. After the cluster formation process is completed, there is no re-clustering phase in the following round. Only the rotation of CH nodes within its clusters is possible because clusters are fixed. LEACH-F reduces the overhead of the LEACH construction phase by forming a fixed number of clusters maintained throughout the network lifetime. However, once a cluster is formed, nodes cannot be added or removed, and nodes cannot adjust their behavior despite the death of nodes.

I- LEACH (Improved Low Energy Adaptive Clustering Hierarchy) was designed by the authors of [22]. I-LEACH is designed with two significant changes. First, instead of the probability used in LEACH, residual energy is used to select the CH, allowing it to be used for sensor nodes with varying initial energy. Second, nodes collaborate to form clusters, with one CH located near each sensor node. The LEACH protocol does not specify this criterion. LEACH- K (K-medoids low energy adaptive clustering hierarchy) was proposed in [23]. LEACH-K is proposed to eliminate the disadvantages of LEACH, specifically the random selection of CHs, which can result in very poor cluster formation. The K-LEACH protocol improves the cluster formation and head cluster selection procedures in the first phase because it uses the K-medoids

Protocols	*Data transmission*	*Mobility of BS*	*Homogenous*	*Needs 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

algorithm for efficient cluster formation at the start of each round and then selects the head of clusters using the Euclidean distance to the nearest center of each cluster. The maximum residual energy (MRE) is used until each cluster has a unique CH. LEACH-K's steady state is the same as LEACH's. [24] proposes EEM-LEACH (Energy Efficient Multi-Hop Low Energy Adaptive Clustering Hierarchy). It addresses the issue of direct communication between CHs and BSs and poor CH selection in the LEACH protocol. The EEM-LEACH protocol is distinguished by:

1) The selection of CH is based on residual energy and node average energy consumption.
2) Multi-hop inter-cluster communication chooses the shortest multi-hop path from each node to the BS.
3) Direct communication by nodes near the BS (if communication costs are low). Utilize relay nodes with higher residual energy to reduce communication costs per packet. This has the potential to increase network lifetime. Table 1 summarizes the protocols cited in the related work.

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3 The Proposed protocol

3.1 Motivation

LEACH Protocol is a well-known hierarchical routing protocol. It is well-known in homogeneous wireless sensor networks for its energy efficiency. The LEACH protocol is divided into rounds of two phases: set-up and steady. The cluster head is elected randomly every round, forming a new cluster. Because of the association messages exchanged between nodes, this results in excessive energy consumption.

Furthermore, this adds unnecessary overhead to CHs and BS. If a CH did not expend much energy in the previous round, there is no need to elect a new CH. As a result, an energy-efficient CH replacement based on the current CH's residual energy is required. By taking into account the residual energy of CHs, the reflection of CHs is limited; as a result, the number of association messages is reduced; as a result, the consumed energy and overhead are reduced. Many LEACH protocol variants have been proposed to reduce the energy consumed by the periodic selection of CH. Some of them proposed the vice-CH position. When CH died, it took his place. However, this vice cluster only operates when the CH's energy runs out, and there is no reflection of the cluster or vice cluster when both die. Other protocols seek to replace the CH only when its energy level exceeds a certain threshold. This can increase network lifetime but generate an overhead at CH, especially in a homogeneous network, so residual energy is quickly depleted. This study proposes EEV-LEACH (Energy Efficient Vice Low Energy Adaptive Clustering Hierarchy), an energy-efficient clustering protocol to address the aforementioned issues.

3.2 EEV-LEACH protocol description

This work presents a novel hierarchical routing protocol, which is a new variant of LEACH. The proposed protocol is carried out in rounds, which include the set-up and steady phases. This contribution is primarily focused on the initial set-up. Two CHs are chosen in the first round: the main CH and the vice-CH. They both work in tandem. Based on certain criteria, CH and vice-CH are replaced in the second round. The residual energy of CH or vice-CH, who is responsible for this round, is compared to a calculated threshold for each subsequent round. If this latter value is less than the required threshold, a new CH/vice-CH is selected. The following section contains the specifics of the proposed protocol.

3.2.1 Protocol functioning

This paper only describes the set-up phase, as the steady phase aligns with the LEACH protocol.

In the first round

The CH is chosen in the same manner as in the LEACH protocol. After the cluster formation process is completed, the CH selects an assistant CH (vice-CH) from among its members. As an assistant, it selects the member closest to the BS. The chosen assistant serves as CH in the second round.

From the second round

The CH and vice-CH work in tandem; if the CH is active in the current round, the vice cluster will be active in the following round. The residual energy of the CH or vice- CH is compared to a calculated threshold (ENTR) in the second round. A new CH/vice-CH (the CH/vice-CH with the highest residual energy) is chosen if it is less than the required threshold. The required threshold is represented by Eq. (3):

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

where, *Et* is the necessary energy for transmitting a packet, *Er* is the necessary energy for receiving a packet, *N* is the number of nodes in the network, and *Nbr cluster* represents the number of formed clusters.

The following pseudo-code summarizes the steps of the proposed protocol.

3.2.2.1 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 BS as an assistant (vice-CH)

Nodes collect and forward data to their 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 their current CH

The CH aggregates and sends the data directly to BS

End else

End

End while

END

4 Results and discussion

This section describes the proposed protocol's performance evaluation. The evaluations are carried out with the help of a MATLAB simulator. A number of nodes are randomly distributed over a 100m*100m area. Every node is static and homogeneous. They are powered by a 0.5 joule battery. The BS is located in the area's center. Table 2 summarizes the simulation parameters. The proposed protocol is evaluated based on several metrics.

Consumed energy:

We are interested in the energy consumed during reception and transmission. The following formulas are used to calculate the consumed energy (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.

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

Network overhead:

We are interested in the overhead generated at CHs and the overhead generated at the BS. It is represented by the number of packets sent to the CH and BS.

Network lifetime:.

It presents the amount of time until all nodes in the network die.

4 The consumed energy

4.1.1 The consumed energy per round

Figs. 1-3 show the results of 120 nodes' energy consumption for LEACH, LEACH-S, TL-LEACH, and EEV-LEACH. The simulations are performed during 100, 200, 500, 700 and 1000 rounds.

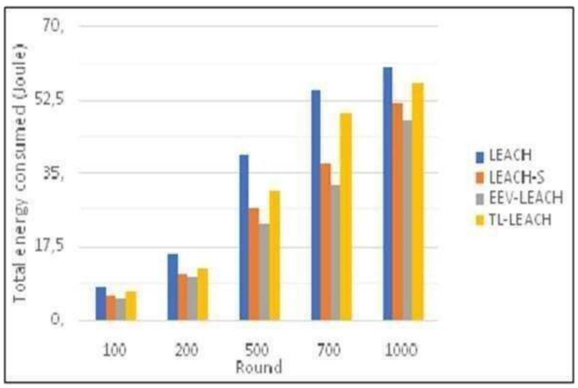

Fig 1. Total energy consumed/round

Fig. 1 represents the total energy consumed in the 4 protocols. Compared to LEACH, LEACH-S, and TL-LEACH during different rounds, the proposed EEV-LEACH protocol consumes less total energy in the network.

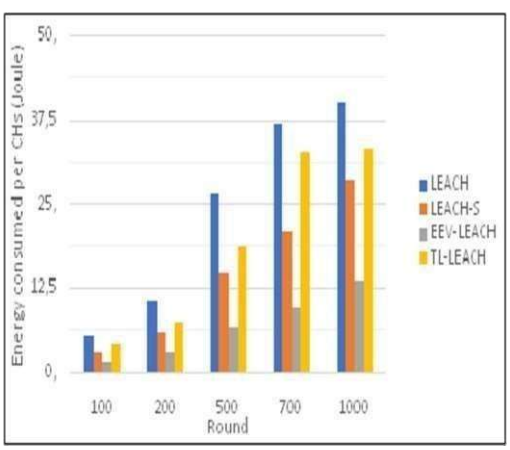

Fig. 2 Energy consumed per CH/round

Fig. 2 shows the energy consumed by the CHs in the 4 protocols. Because the CHs' role is shared with the assistants in an alternative way, the proposed EEV- LEACH protocol consumes less energy than LEACH, LEACH-S, and TL-LEACH during the different rounds.

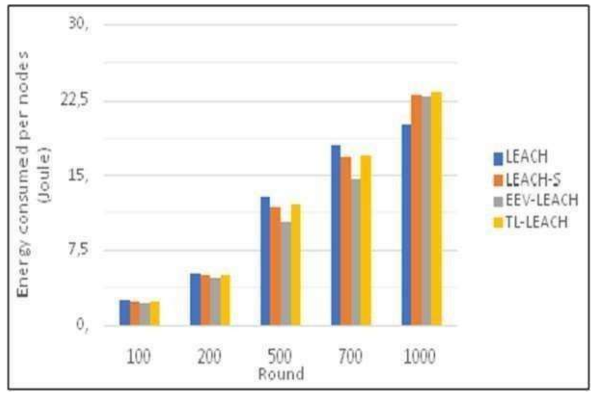

Fig. 3. Energy consumed per node/round

Fig. 3 represents the energy consumed by the nodes in the 4 protocols. The proposed EEV-LEACH protocol reduces node energy consumption. We have minimized the periodic selection of CHs in each round by comparing LEACH, LEACH-S, and TL-LEACH during the different rounds, decreasing the association messages between CHs and nodes and minimizing the energy consumed by nodes.

4.1.2 Energy consumed/number of nodes

Figs. 4-6 show the energy consumption results for 100 rounds of the four protocols with densities of 50, 100, 150, and 200 nodes.

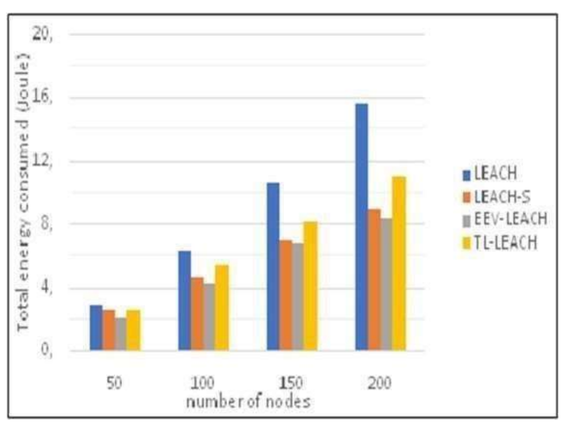

Fig. 4. Total energy consumed/number of nodes

Fig. 4 shows that the proposed EEV-LEACH protocol consumes less total energy than the three LEACH, LEACH-S, and TL-LEACH protocols with varying densities.

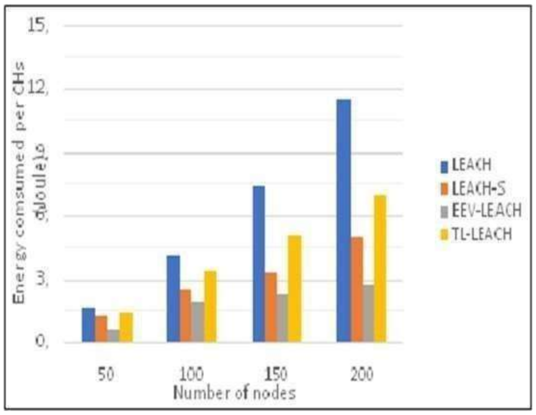

Fig. 5. Energy consumed per CH/number of nodes

Because the work of the CHs is shared with the assistants in an alternative way, the energy consumed by the CHs of the proposed EEV-LEACH protocol is lower than that of the LEACH, LEACH-S, and TL-LEACH protocols in different densities, as shown in Fig. 5.

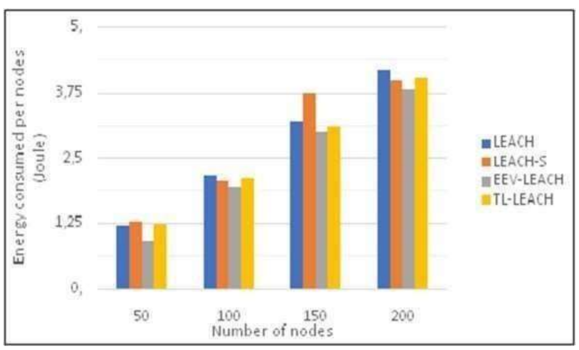

Fig. 6. Energy consumed per node/number of nodes

Fig. 6 shows that the proposed EEV-LEACH protocol consumes less energy than the three protocols LEACH, LEACH-S, and TL-LEACH in different densities because we minimized the selection of the CH in each round, which decreases the association messages between the CHs and the nodes and thus the energy consumed by the nodes. As a result, the proposed protocol reduces the energy consumed by nodes and CHs with varying network densities.

4.2 Network overhead

4.2.1. Network overhead/round

Fig. 7 and Fig. 8 show the number of packets sent to BS and CHs. This simulation employs 120 nodes and runs for 100, 200, 500, 700, and 1000 rounds, respectively.

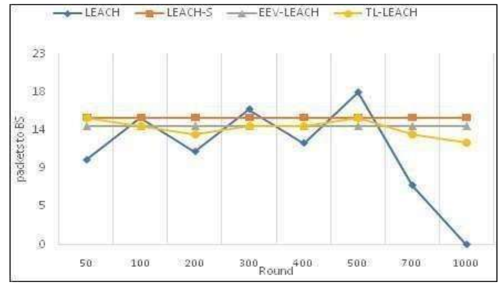

Fig. 7. Packets to BS/round

Fig. 7 depicts the packets sent to the four protocols' BS. The proposed EEV-LEACH protocol reduces the number of packets sent to BS compared to LEACH, LEACH-S, and TL-LEACH during different rounds, thereby minimizing network overhead.

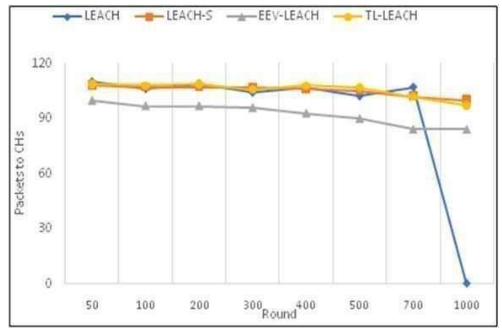

Fig. 8. Packets to CHs/round

Fig. 8 depicts the packets sent from nodes to CHs in the four protocols. Compared to LEACH, LEACH-S, and TL- LEACH during different rounds, the proposed EEV- LEACH protocol sends fewer packets to CHs. Reducing the number of CHs chosen can reduce the number of association messages between nodes and CHs. As a result, the overhead is reduced.

4.2.2 Network overhead/number of nodes

Fig. 9 and Fig. 10 show the number of packets sent to BS and CHs for 100 rounds of the four protocols at different densities of 50, 100, 150, and 200 nodes.

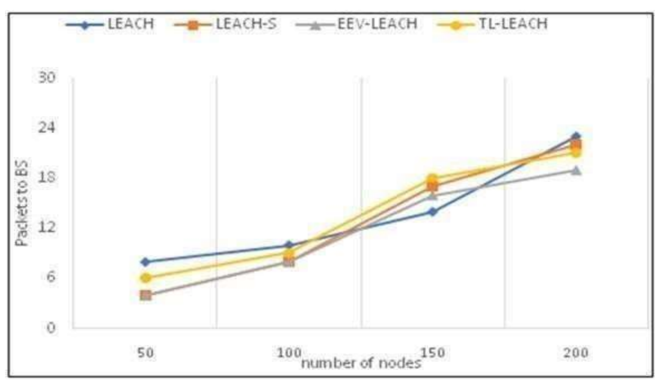

Fig. 9 depicts the packets to the BS in the four protocols at various densities.

Compared to LEACH, LEACH-S, and TL-LEACH during different rounds, the proposed EEV-LEACH protocol reduces the number of packets sent to BS; thus, the proposed protocol minimizes network overhead. Fig. 10 depicts the packets to the BS in the four protocols at various densities. The proposed EEV-LEACH protocol reduces the number of packets sent to BS compared to LEACH, LEACH-S, and TL-LEACH during different rounds, thereby minimizing network overhead.

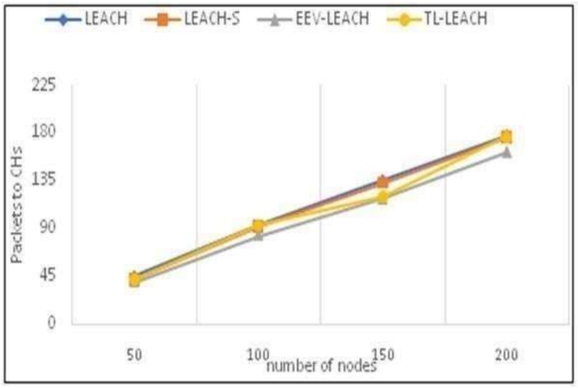

Fig.10. Packets to CHs/number of nodes

Fig. 10 depicts the packets sent from nodes to CHs in the four protocols at various densities. Compared to LEACH, LEACH-S, and TL-LEACH during different rounds, the proposed EEV-LEACH protocol sends fewer packets to CHs, reducing network overhead. This is due to reducing the number of association messages between nodes and CHs by minimizing the periodic selection of CHs.

4.3. Network lifetime

The network lifetime represents the time it takes for all nodes to die. The simulation is run with 120 nodes to evaluate the network lifetime.

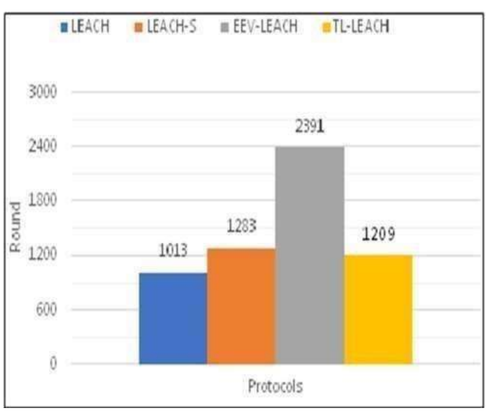

Fig. 11. Round of death of all nodes in the network for LEACH, LEACH-S, TL-LEACH and EEV-LEACH

Fig. 11 depicts the round in which all the nodes are dead. All nodes are dead in round r = 1013 of the LEACH protocol. All nodes are dead in round r = 1209 of the TL-LEACH protocol. All nodes are dead in round r = 1283 of the LEACH-S protocol. All nodes are dead in round r = 2391 of the proposed EEV-LEACH protocol. According to the results, the EEV-LEACH protocol outperforms LEACH, LEACH-S, and TL-LEACH regarding network lifetime.

5 Conclusion and future work

This paper introduced EEV-LEACH, a new hierarchical energy-efficient protocol. It is a new version of the LEACH protocol. The proposed protocol addressed the LEACH protocol's limitations. The objective is to minimize the overall energy consumption, thus extending the network's lifespan, by reducing the number of CHs selected on a regular basis in each round.

Additionally, the overall overhead can be reduced by reducing the number of association messages. Another goal of the proposed protocol is to reduce CH overhead by using an assistant CH in addition to CHs. Regarding consumed energy, overhead, and network lifetime, the simulation results show that EEV-LEACH outperforms LEACH, LEACH-S, and TL-LEACH. However, this work does not consider the topology changes and network coverage. These two drawbacks will be considered in our future works. In addition, more simulations will be performed to compare EEV-LEACH with other variants of LEACH protocols to better evaluate the performance of the proposed protocol.

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Biographies

1. Amira Bendjeddou

Amira Bendjeddou is an Assistant Professor at the University of Badji Mokhtar, Annaba, Algeria. She is a member of the LRS laboratory. Bendjeddou obtained her Ph.D. in Computer Science in April 2015 from the Computer Science Department of the University Badji Mokhtar, Annaba, Algeria. Her research interests focus on energy preservation in wireless sensor networks, coverage optimization and network security.

2. Mouna Hemici

Mouna Hemici received a master's degree in networks and security in 2022 from the Computer Science Department, University Badji Mokhtar, Annaba, Algeria. Her research interests focus on energy wireless sensor networks and security.