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ORIGINAL ARTICLE

New scheme of WSN routing to ensure data communication between sensor nodes based on energy warning

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ABSTRACT

Among the different challenges related to the improvement of wireless sensor network (WSN) performance, the optimization of energy consumption takes an important place. Basically, sensor nodes in WSN are powered by limited battery. These batteries can allow sensor nodes to be functional for a limited period of time then sensor nodes turn out to be dead. Enhancing energy consumption and finding new manners to save sensor nodes' energy is becoming essential and more challenging. Improving energy consumption for each sensor nodes leads to enhance the lifetime of WSN. Clustering is among the outstanding strategies to reach this goal. In this paper, a new scheme of routing protocol in WSN will be presented in order to minimize the energy consumption and improve WSN lifetime. The new scheme is proposed in order to find the best selection of cluster head (CH) by taking in consideration the energy at each sensor node. It has been proposed based on Firefly Algorithm. We have compared the proposed scheme with LEACH, EAMMH, SEP, E-SEP, BRE, NEAHC and WEB protocol. Experimental results show that the proposed scheme yields better performance than the compared routing protocols in terms of better energy consumption and packet delivery between sensor nodes and base station. Results obviously prove that the proposed scheme could improve the WSN lifetime.

1. Introduction

Wireless Sensor Networks (WSNs) can be used for many purposes and they have been used over many fields [31,38]. In general sensor nodes are powered based on batteries and have limited resources in terms of data processing and transmission range. In addition, sensor nodes are small devices and sometimes are tiny. They have the ability to gather data from the sensing field like temperature, wind speed, etc. After that, the gathering data is sent to base station (sink nodes) through wireless transmissions. Unfortunately, sensor nodes' batteries are unchangeable and data transmission between sensor nodes and base station causes batteries discharge. If sensor nodes' batteries are discharged, the sensor nodes cannot operate and they become inactive. Communication in WSN needs to be optimized in order to improve the WSN lifetime [44,16].

WSN lifetime is an important concern and it must be improved based on different solutions. Among the solution, we find the architecture of sensor nodes, batteries technology and routing protocols [2,3,35]. Furthermore, routing protocols play a crucial role in the energy efficiency and performance of WSNs by determining the paths for data transmission between sensor nodes. Although there are a vast number of works that have solved different versions of the routing problem in WSNs, there is still a need for new routing protocol schemes that can improve network performance and minimize energy consumption. WSN routing protocols can be seen as two major classes, which are flat routing protocols and hierarchical routing protocols. In the first class, sensor nodes are deployed in the filed with the same level of energy and task. In this class of routing protocols, if number of sensor nodes increases, then the consumption of energy is increased automatically. In the other hand, hierarchical routing protocols [10] have been proposed based on clustering. They devise sensor nodes into clusters and each cluster has the mission to gather data from a specified area. Furthermore, every cluster has cluster head (CH), which is a sensor node with a mission to send

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Table 1
Table of notations.

Notation	Description
WSN	Wireless Sensor Network
CH	Cluster head
BS	Base station
FFA	Fireflies algorithm
n	Number of sensor nodes
N_{CHs}	Number of cluster heads
$T_{Energy-Cluster_i}$	Consumed energy by sensor nodes of cluster i
$\|Cluster_i\|$	Number of sensor nodes in cluster i
$EnergyLevel_j$	Residual energy of sensor node j
T_{energy}	Objective (fitness) function of the proposed scheme
E_{DA}	Energy for 1 bit of data aggregation
E_{elec}	The energy dissipation for transmitting or receiving 1 bit of data
ϵ_{fs}	The coefficient of energy dissipation in the free space (transmission coefficient amplifier)
ϵ_{mp}	The coefficient of energy dissipation in the multi-path attenuation model (transmission coefficient amplifier)
E_o	Initial energy of sensor nodes
$E_{Tx-elec}$	Transmitter electronics energy
E_{Tx-amp}	Transmit amplifier energy
$E_{Rx-elec}$	Receiver electronics energy
E_{Tx}	Energy consumed in transmission of data
E_{Rx}	Energy consumed in reception of data

data of its cluster to the base station (BS). This strategy leads to extend the WSN lifetime and to efficient energy consumption by sensor nodes. Routing protocols based on clustering are more scalable then flat routing protocols.

Routing protocols based on clustering can be very effective in WSN. For instance, they can improve the robustness, scalability, delay and reduced data retransmission. This improvement can lead to enhance and increase the WSN lifetime. In routing protocols based on clustering the selection of CHs is crucial task and it must be done in the right way in order to minimize energy consumption. In addition, the optimal number of CHs is still challenge and an open issue [5,12]. In this paper a new scheme of WSN routing protocol is proposed. The proposed scheme selects CHs from sensor nodes by taking in consideration the energy level at each cluster. The selection of CHs is done in the proposed scheme based on Firefly optimization algorithm by minimizing the proposed fitness function. Then, clusters will be created based on distance to CHs. CHs are the intermediate nodes between sensor nodes and BS in order to transmit the gathered data. In other words, the gathered data by sensor nodes is sent to CHs according to the created clusters and CHs send data to the BS.

This paper has a contribution that is summarized in the following points:

1. This paper presents a new scheme of routing protocol in WSN based on clustering by the selection of the optimal number of CHs from deployed sensor nodes.
2. CHs are selected in the proposed scheme by taking in consideration the energy at each sensor node in order to improve the WSN lifetime. Firefly optimization algorithm is used by the proposed scheme to select the optimal CHs by minimizing the proposed fitness function.
3. The proposed scheme has been compared with some existing schemes in terms of WSN lifetime, dead sensor nodes and energy consumption.

The rest of the paper is set as follows; section 2 presents related works about WSN routing protocols. Section 3 describes the proposed scheme of routing protocol based on clustering. Simulation and results are presented in section 4. Finally, section 5 concludes the paper. Notations that have been used through the paper are given in Table 1.

2. Related work

In this section, we will present some routing protocols for WSN based on energy aware. Many schemes have been proposed over years. Schemes based on clustering are the most effective routing protocols in terms of energy consumption and data transmission. The most known protocol in this category is Low Energy Adaptive Clustering Hierarchy Protocol (LEACH) [15]. It has been proposed by Hillzaman et al., and many new routing protocols have been developed based on LEACH. CHs are randomly selected in LEACH and every sensor node in WSN has an opportunity to be a CH. LEACH-Balanced (LEACH-B) [43] is a decentralized algorithm, which enhances clustering by trying to select the best CHs. I-LEACH [7] elects CHs based on residual energy and sensor nodes location. Another protocol based on LEACH is LEACH-C [14], which is a centralized approach of clustering. Mobile LEACH (LEACH-M) [20] takes in consideration the mobility of sensor nodes in WSN. Mobile Enhanced-LEACH (LEACH-ME) [21] is the improvement of LEACH-M. VH-LEACH [6], LEACH-T [9], TB-LEACH [18] are examples of routing protocols based on clustering. Vie-CH-enabled routing protocol [29] could minimize the network overhead based on clustering process. In [28], authors proposed a routing protocol for WSN based on Ad-Hoc routing protocols. It reduces energy consumption by reducing number of hops between sensor nodes. Some routing protocols have been proposed based on distance in order to cluster sensor nodes in WSN. For instance, Improved-LEACH [4], EADCR [30], BN-LEACH [13] and Wireless Energy Balancing protocol (WEB) [36] are examples of clustering based on distance. BRE-LEACH [11] chooses sensor nodes to be CHs with high energy level and near to BS. Stable Election Protocol (SEP) [41] considers two types of sensor nodes, which are advanced and normal sensor nodes. SEP gives more chance to advanced sensor nodes to become CHs. SEP tries to manage energy consumption by keeping normal sensor nodes away from being CHs. An enhanced stable election protocol (E-SEP) protocol [1] considers three types of sensor nodes. E-SEP devises sensor nodes into advanced, normal and intermediate sensor nodes. Modified Stable Election Protocol (M-SEP) [40] is improvements of SEP. Sensor nodes with higher energy levels have more opportunity to play the role of CH with M-SEP. A prolong stable election routing (P-SEP) [27] is proposed based on SEP. P-SEP selects CHs based on threshold, which is estimated by taking the residual energy level at sensor node, to avoid CHs with a lower level of energy. Energy-Efficient Clustering Algorithm (DEEC) [32] is routing protocol based on clustering, which is made by selecting sensor nodes to be CHs according to a limited threshold. Sensor nodes' energy level and multi-hope have been combined together to cluster sensor nodes in EAMMH routing protocol [26]. Energy aware hierarchical cluster-based (NEAHC) routing protocol [19] aims to reduce energy consumption by sensor nodes and make sure the energy is equally consumed between sensor nodes. Tang et al. [42] proposed an energy-efficient algorithm for constructing a minimum connected dominating set (MCDS) in WSNs. The proposed algorithm is based on a combination of node density and connectivity, and it aims to minimize energy consumption while ensuring connectivity between nodes. The proposed scheme, named RISA [17], aims to improve the network performance and reliability of IoT networks by selecting the most efficient routes for data transmission. Minimizing movement in mobile sensor networks while maintaining both target coverage and network connectivity has been proposed in [22]. The proposed algorithm is based on the concept of virtual forces, which are used to control the movement of sensor nodes.

Routing protocols in WSN have been also proposed based on optimization algorithms. These optimization algorithms use heuristics and metaheuristics in order to find solutions for complex problems. Many schemes of routing protocols based on optimization algorithms have been proposed. For instance, a particle swarm optimization (PSO) based energy-efficient coverage control algorithm for WSNs has been proposed [46]. The proposed algorithm aims to optimize the deployment of sensor nodes in order to maximize the coverage area of the network while minimizing the energy consumption of each node. In [37] a new cluster-based data transmission scheme for wireless sensor networks that uses a combination of black hole and ant colony algorithms. The proposed scheme aims to improve the energy efficiency and performance of WSNs by reducing the communication overhead and minimizing the number of hops between sensor nodes. Fuzzy logic based distance and energy-aware routing protocol for delay-tolerant mobile sensor networks has been proposed in [25]. The protocol aims to improve the network performance and energy efficiency by considering both distance and energy factors in the route selection process. The paper of [24] proposed a data aggregation tree structure for WSNs that based on cuckoo optimization algorithm. The proposed structure aims to improve the energy efficiency and performance of WSNs by reducing the amount of data transmitted and minimizing the communication overhead. A reliable data dissemination scheme for the IoT using the Harris hawks optimization algorithm (HHO) has been proposed in [39]. The proposed scheme aims to improve the packet delivery ratio and reduce the energy consumption in IoT networks by optimizing the node placement and transmission power. In [45] an optimal coverage multipath scheduling scheme with multiple mobile sinks for wireless sensor networks (WSNs) has been proposed. It aims to improve the coverage area and network lifetime of WSNs by scheduling the movement of multiple mobile sinks and selecting the optimal paths for data transmission. Some protocols of WSN have been proposed based on MANET protocols [47,33,23].

There are various routing protocols developed for WSNs, such as hierarchical, flat, location-based, data-centric, and QoS-based protocols. In this section some routing protocols based on clustering have been presented. Each protocol has its own advantages and limitations in terms of network lifetime, energy consumption, scalability, and reliability. In addition, metaheuristic algorithms are capable of optimizing complex problems and finding near-optimal solutions. In WSN, the use of metaheuristic algorithms can lead to efficient and effective routing protocols that can extend the network lifetime by minimizing energy consumption, improving data transmission and reducing congestion. The main advantage of using metaheuristic algorithms for routing protocol design is their ability to adapt to network conditions, where sensor nodes may fail, energy levels may vary, and new nodes may join the network. Furthermore, metaheuristic algorithms can optimize an objective issue very well, such as energy consumption. In this study, a new scheme of routing protocol has been proposed based on Fireflies algorithm in order to optimize energy consumption in WSN and improve its lifetime.

3. New WSN routing scheme

The proposed scheme ensures routing in WSN by taking in consideration the consumption of energy. It will be presented in this section. At the beginning, the optimization method of Firefly will be illustrated. Then, the proposed scheme will be given and clarified.

3.1. Firefly optimization algorithm

In nature we can find some amazing fireflies. According to scientist, more than two thousand firefly species exist. Generally, these fireflies have the ability to produce short flashes, which are unique for each species. These flashes are happened by bioluminescence process. Basically, the produced flash has a mission to attract partners or to warn others and it can also be used to find prey. In generally, these flashes can be seen as a way of communication between flayers. Each species' flash has some unique features like rhythmic flash, rate, and period of time. Furthermore, like any light its intensity decreases with the distance. Based on this rule, fireflies can be visible only for a certain distance (some hundreds of meters) at night in order to communicate. Based on this process an optimization algorithm has been proposed in [48].

Steps of firefly optimization algorithm can be summarized in Algorithm 1.

Algorithm 1: Fireflies algorithm.

Data: Objective function to be optimized $f(x)$, $x = (x_1, ..., x_d)^T$
Result: X^* the best solution

1 Generate initial population of fireflies $x_i (i = 1, 2, ..., n)$;
2 $f(x_i)$ represents the flash intensity I at x_i;
3 γ is the light absorption coefficient;
4 **while** $t \leq Number\ of\ iterations$ **do**
5   **for** $i = 1 : n$ *and n is number of fireflies* **do**
6   **for** $j = 1 : n$ **do**
7   **if** $(I_j > I_i)$ **then**
8   i moves towards j;
9   Estimate a new solution and update light intensity;
10   Find the best solution;

First of all, Algorithm 1 starts by an initialization step. In this step, the population of fireflies is randomly generated within the search space. The fireflies are assigned an initial attractiveness value that represents their fitness level (steps 1 and 2 of Algorithm 1). Each firefly moves towards another firefly with higher attractiveness, which is represented by γ (step 3 of Algorithm 1). Steps 5 to 9 stand for attraction, intensity and updating attractiveness in order to find the best solution (step 10). The attractiveness of a firefly is determined by its fitness level or objective function value $f(x)$. Fireflies with higher fitness levels are more attractive than those with lower fitness levels. The intensity of light emitted by a firefly is proportional to its attractiveness value. The intensity of light decreases with increasing distance between fireflies. The attractiveness of a firefly is updated based on the distance between the fireflies and their respective intensities of light I. Fireflies with higher intensities of light are more attractive than those with lower intensities. Finally, the optimization process stops when a maximum number of iterations is reached (step 4 of Algorithm 1, which is the loop while).

3.2. New routing protocol scheme

The proposed scheme ensures data transmission between sensor nodes in WSN and reducing energy consumption. It performs clustering of sensor nodes into clusters and for each cluster assigns a certain role to one sensor node. This new role will make a sensor node to become a CH. CHs have a mission to gather data from sensor nodes of theirs cluster, and then send it to BS. In generally, the transmission pattern of all sensor nodes in WSN relies on a uniform distribution, where data is evenly spread across the network based on the maximum radio range. Furthermore, BS is different from sensor nodes and it has no limited resources like data processing capacity and energy. Sensor nodes are supposed to have the same radio range and data is transmitted in electromagnetic waves [27]. Where, electromagnetic waves are waves that consist of oscillating electric and magnetic fields and can propagate through space. In the context of WSN, radio waves, which are a type of electromagnetic wave, are used for data transmission. These radio waves typically have frequencies in the range of several hundred megahertz to several gigahertzes. The specific frequency band used for data transmission in WSN depends on the application requirements and regulatory restrictions of the region. Furthermore, the frequency of electromagnetic waves used for data transmission in WSN is typically not in the range of visible light frequency. Fig. 1 illustrates an example of WSN architecture consisting of a BS and clusters of sensor nodes. BS serves as a central node that collects and processes data from sensor nodes in the network. The clusters of sensors are formed to reduce energy consumption and prolong the network's lifetime, as nodes within the same cluster communicate with each other through CHs rather than directly with the BS.

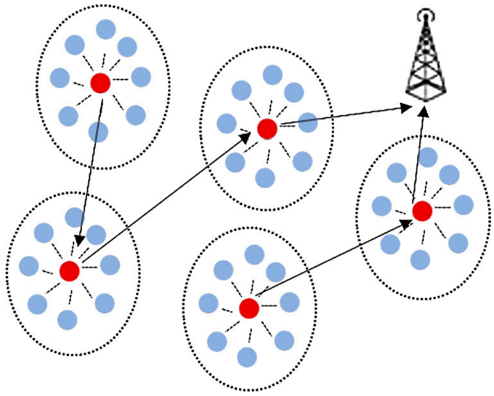

Fig. 1. Example of WSN's sensor nodes clustering.

The proposed scheme clusters sensor nodes of WSN by selecting the most optimal number of CHs and sensor nodes to become CHs. It has three basic steps. These steps are startup, setup and transmission step. In the first step, the installation of WSN is made by deploying sensor nodes in predefined area of $(M \times M)$ meters. Then, sensor nodes are clustered into some clusters and CHs are selected in the second step. Finally, the last step represents the transmission process between sensor nodes, CHs and BS.

At the beginning and after the deployment of n sensor nodes, the proposed scheme groups sensor nodes into clusters by selecting the most optimal set of sensor nodes. The selecting of CHs is done at the BS, such as the location of sensor nodes is sent to BS. Then, the firefly optimization algorithm (FFA) is used to optimize the proposed fitness function. This fitness function takes in consideration the energy level and the distance of each sensor nodes. The proposed fitness function is as follows:

$$T_{energy} = \sum_{i=1}^{N_{CHs}} T_{Energy-Cluster_i} \tag{1}$$

In this function the total of residual energy in WSN is the sum of residual energy at each cluster, which means that the residual energy at each cluster has been taken in consideration in order to minimize the energy consumption. The number of clusters, which equals to the number of CHs, is represented by the variable N_{CHs}. The total residual energy at each cluster i is represented by the variable $T_{Energy-Cluster_i}$. It is estimated based on the amount of residual energy at each sensor node of cluster i. $T_{Energy-Cluster_i}$ is estimated as follows:

$$T_{Energy-Cluster_i} = \sum_{j=1}^{|Cluster_i|} EnergyLevel_j \tag{2}$$

where j stands for a sensor node in cluster i and its residual energy is $EnergyLevel_j$.

Once the CHs have been selected the ID of CHs will be broadcasted to sensor nodes. Then, sensor nodes can choose the right CH in order to be in one cluster based on the distance. In other way, each sensor node will be related to the nearest CH. At the end, the step three of transmission can be started by sending data from sensor nodes to BS through CHs.

All these steps represent one round. Simulation is repeated many rounds. The flowchart of the proposed scheme is shown in Fig. 2.

4. Simulation and results

Ealuation of the proposed scheme is presented in this section. The proposed scheme has been compared with some well-known routing protocols. It has been compared with LEACH [15], EAMMH [26], SEP [41], E-SEP [1], BRE [11], NEAHC [19] and WEB [36] protocol. Parameters of simulation are presented in Table 2. The model of energy dissipation that has been used to evaluate routing protocols is according to [34] (see Fig. 3). If a message with a size of l bit is transmitted/received between sensor nodes, then the energy expense is given as follows:

Table 2
Simulation parameters.

Parameter	Value
Sensing area	100 m^2
Number of sensor nodes	200
Packet size l	4000 bits
Energy for 1 bit of data aggregation E_{DA}	5 nJ/bit
The energy dissipation for transmitting or receiving 1 bit of data E_{elec}	50 nJ/bit
The coefficient of energy dissipation in the free space (transmission coefficient amplifier ϵ_{fs})	10 pJ/bit/m^2
The coefficient of energy dissipation in the multi-path attenuation model (transmission coefficient amplifier ϵ_{mp})	0.0013 pJ/bit/m^4
Initial energy of sensor nodes E_o	0.1 J

$$E_{Tx}(l,d) = E_{Tx-elec}(l) + E_{Tx-amp}(l,d) = \begin{cases} lE_{elec} + l\epsilon_{fs}d^2, d < d_0 \\ lE_{elec} + l\epsilon_{mp}d^4, d > d_0 \end{cases} \tag{3}$$

$$E_{Rx}(l) = E_{Rx-elec}(l) = lE_{elec} \tag{4}$$

where d stands for the distance between sensor nodes, d_0 is a threshold for sending a message based on distance, in generally is estimated according to the following equation:

$$d_0 = \frac{\epsilon_{fs}}{\epsilon_{mp}} \tag{5}$$

In this model E_{elec} represents the electronics energy consumed by sensor node. For a distance greater than d_0 the consumed energy by the transmitter amplifier is ϵ_{mp}. However, if the distance is less than d_0, then the consumed energy by the transmitter amplifier is ϵ_{fs}. The needed energy for data aggregation is E_{DA}. Values of $E_{elec}, l, \epsilon_{fs}, \epsilon_{mp}$ and E_{DA} are presented in Table 2.

The coefficient of energy dispersion in free space (ϵ_{fs}) is expressed in square meters because it represents the area over which the energy is dispersed from a point source in all directions. The energy is dispersed over the surface of a sphere, and the surface area of a sphere is proportional to the square of its radius, which is equivalent to the square of the distance from the point source. However, the coefficient of energy dispersion in multi-path attenuation (ϵ_{mp}) is expressed in squared square meters because it represents the area of a surface that is perpendicular to the direction of propagation and the distance traveled by the signal. Since the signal can take multiple paths in a multi-path environment, the energy is dispersed over multiple surfaces. The area of each surface is proportional to the square of the distance traveled, and since there are multiple surfaces, the total area is proportional to the square of the square of the distance traveled.

Results of simulation have been presented in term of rounds. In the simulation of WSN routing protocols, "rounds" typically refer to the number of times the network is evaluated or the number of cycles that the protocol is executed. Each round of simulation involves the collection of data from sensor nodes, forwarding the data to the BS, updating the network topology and routing table based on the collected information. The number of rounds may vary from protocol to another. Typically, the more rounds that are executed, the more accurate the evaluation of the protocol's performance will be.

Network lifetime is presented in Fig. 4 in term of dead sensor nodes. It is very easy to notice the best performance of compared routing protocols. From this figure, we can notice that the proposed scheme performs better than LEACH, EAMMH, SEP, E-SEP, BRE, NEAHC and WEB protocol. Sensor nodes started to die at early round with the proposed scheme, exactly at round number 29. However, this did not affect the performance of the proposed scheme. It managed to find the best

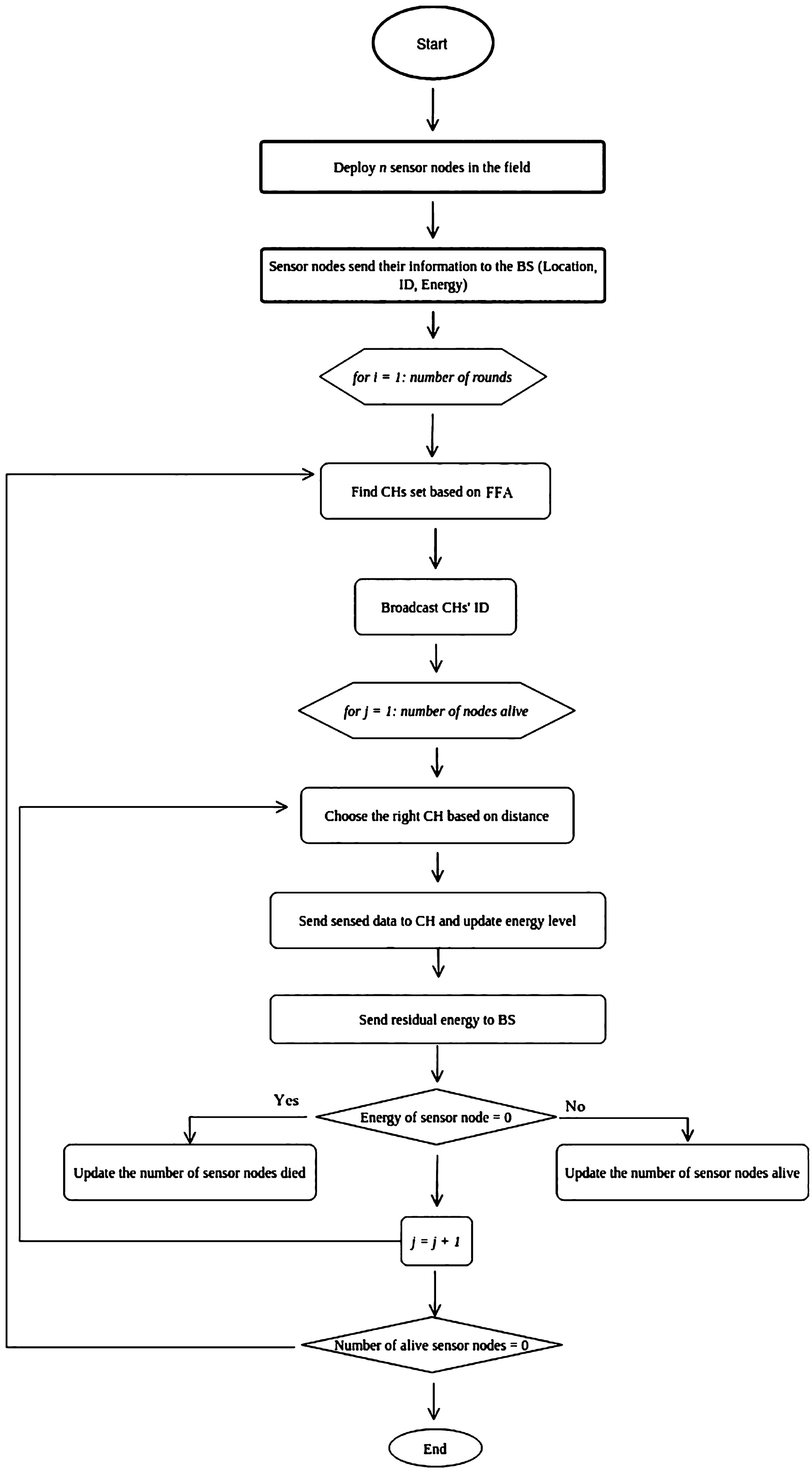

Fig. 2. Flowchart of the new scheme of routing protocol in WSN.

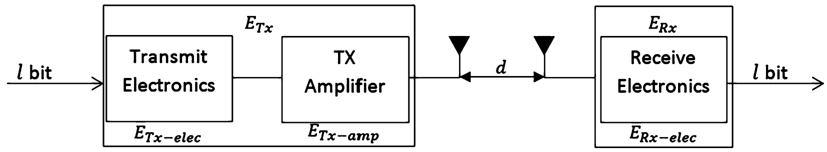

Fig. 3. Energy dissipation model.

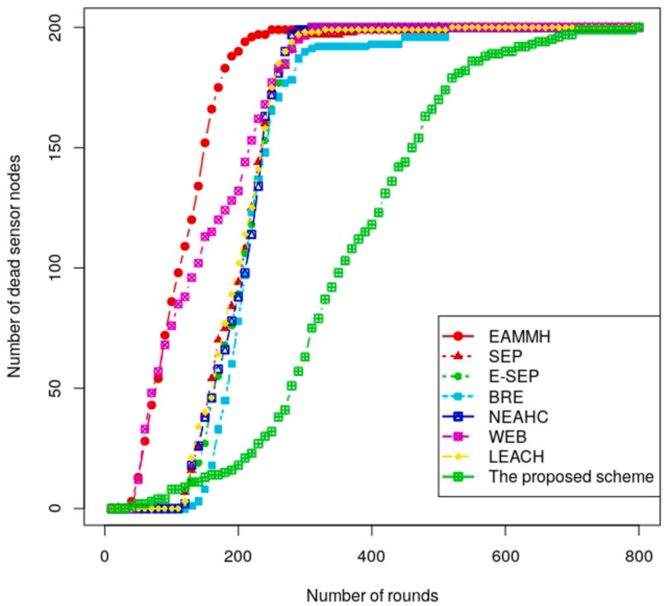

Fig. 4. Network lifetime in term of dead sensor nodes.

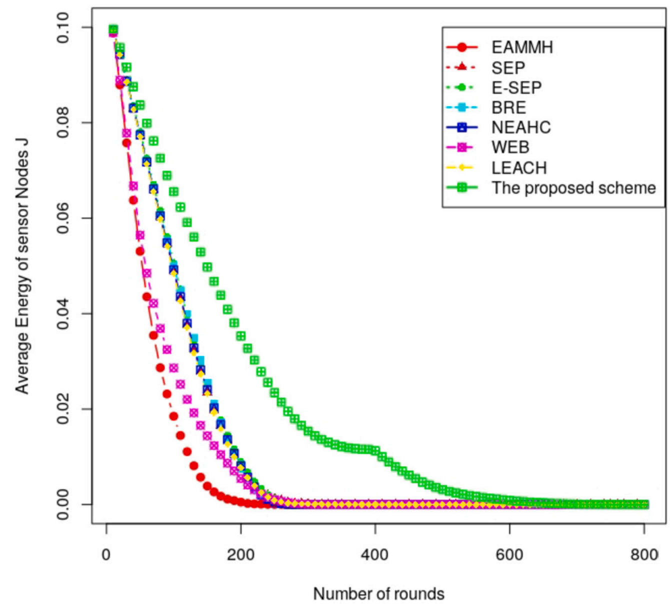

Fig. 5. Total residual energy of sensor nodes in WSN.

set of sensor nodes to be CHs by taking in consideration the amount of residual energy at each sensor node and estimating the amount of energy that would be consumed by each cluster. In the other side, the rest of protocols lost many sensor nodes before round number 200 and they could not extend the lifetime of WSN.

Fig. 5 illustrates the network total residual energy at each round of simulation. All routing protocols tried to save the energy of sensor nodes. From this figure, we can see that the proposed scheme saved more energy than the rest of protocols. The proposed scheme selected CHs based on the distance between sensor nodes and their energy level. This result proves that the proposed scheme managed very well the energy consumption, which allowed the WSN to exist for a long time. However, the compared routing protocols lost all sensor nodes' energy before round number 250.

The proposed scheme outperformed the other WSN routing protocols in terms of energy consumption and improving of the network's lifetime. The proposed scheme was designed based on Firefly optimization method. This method of optimization tried to strike a balance between exploration and exploitation of the search space. This means that it efficiently explored different routes while also exploiting promising paths. As a result, the proposed scheme could discover optimal or near-optimal routes in WSN. In addition, the optimization method took in consideration the change of network topology, energy levels, and traffic patterns, which allowed the proposed scheme to respond to these changes. It could quickly adjust the routing decisions by considering the current network conditions, leading to improved performance compared to the other routing protocols. Firefly can find optimal or near-optimal solutions. In the context of WSN routing, this means that the proposed scheme could discover routes that are close to the optimal solution in terms of the defined objective, which is energy efficiency.

The proposed scheme has been proposed based on clustering and the most important point in clustering is the number of clusters. In other words, the optimal number of CHs, how it will be chosen? Each routing protocol has its strategy in order to choose the right number of CHs. Fig. 6 represents the number of CHs, which has been chosen by each routing protocol for each round. In the proposed scheme the number of CHs was fixed based on the thumb rule of clustering [8]. Many studies used the number of clusters $c_{max} \leq \sqrt{n}$ and n is the number of features; in WSN n is the number of sensor nodes. In addition, the maximum number of CHs created by the proposed scheme was $\sqrt{200}$. This strategy allowed to create a reasonable number of CHs and to manage WSN in better way than the rest of protocols. However, for the rest of protocols the maximum number of CHs was between 55 and 70 except of WEB protocol, which has not created CHs. From this result, we can notice that the number of CHs has an important influence on the energy consumption and creating many clusters is not all the time the best option to save energy.

Number of packets sent to CHs and to BS is illustrated in Fig. 7 and 8 respectively. The data was sent to CHs from sensor nodes then CHs sent it to BS. All sensor nodes in the proposed scheme sent their data to CHs, which means that the clustering by the proposed scheme allowed all sensor nodes to participate and being connected with CHs. In addition, CHs sent data to BS where the number of packet sent to BS in the proposed scheme is fewer than the rest of routing protocols because the proposed scheme created few number of CHs. However, the rest of protocols generated an important number of CHs which led to more packets sent to CHs and more packets sent from CHs to BS.

5. Conclusion

In this paper we have presented a new scheme to ensure data transmission in WSN with aware to energy consumption. The proposed scheme is based on clustering strategy. It selects the best set of sensor nodes to become CHs based on residual energy at each sensor node.

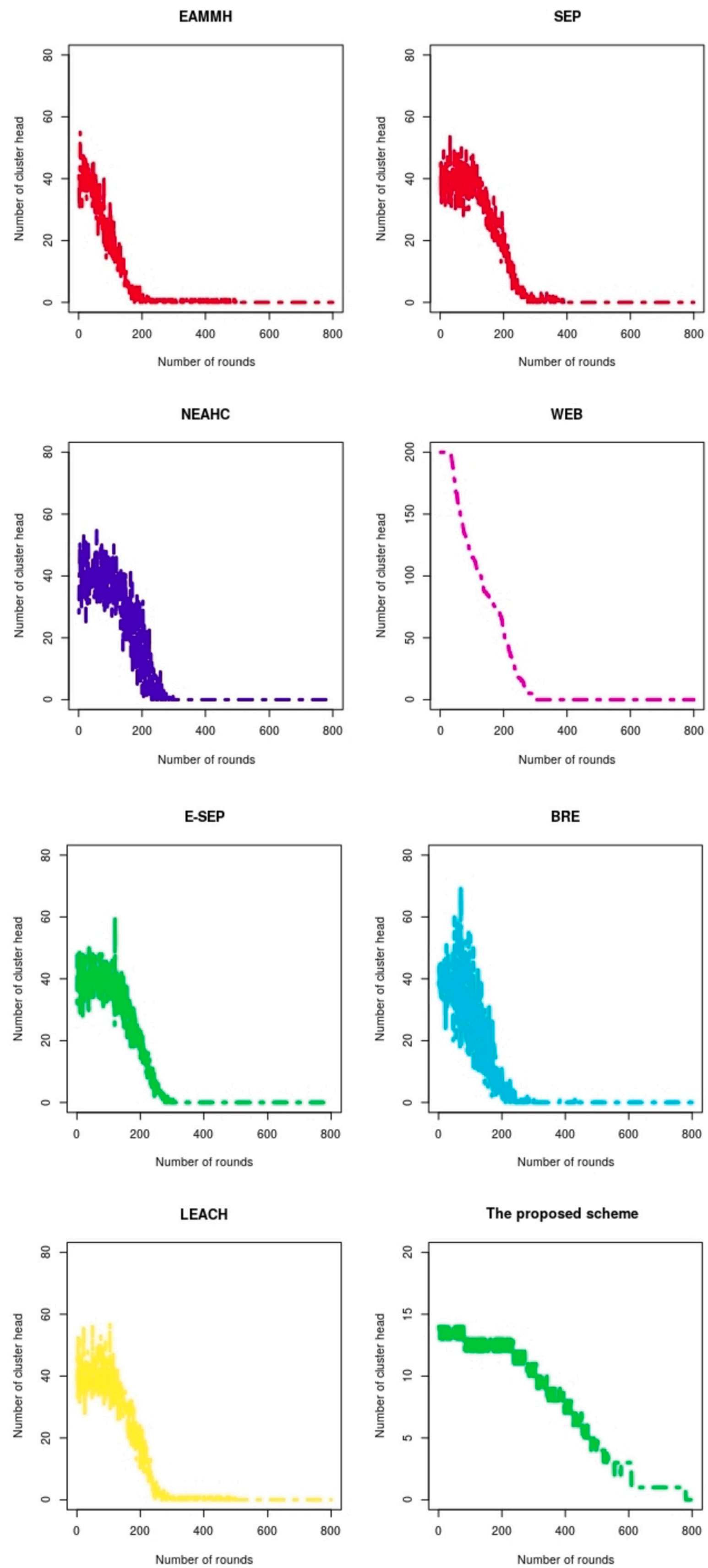

Fig. 6. Number of cluster heads created by each routing protocol.

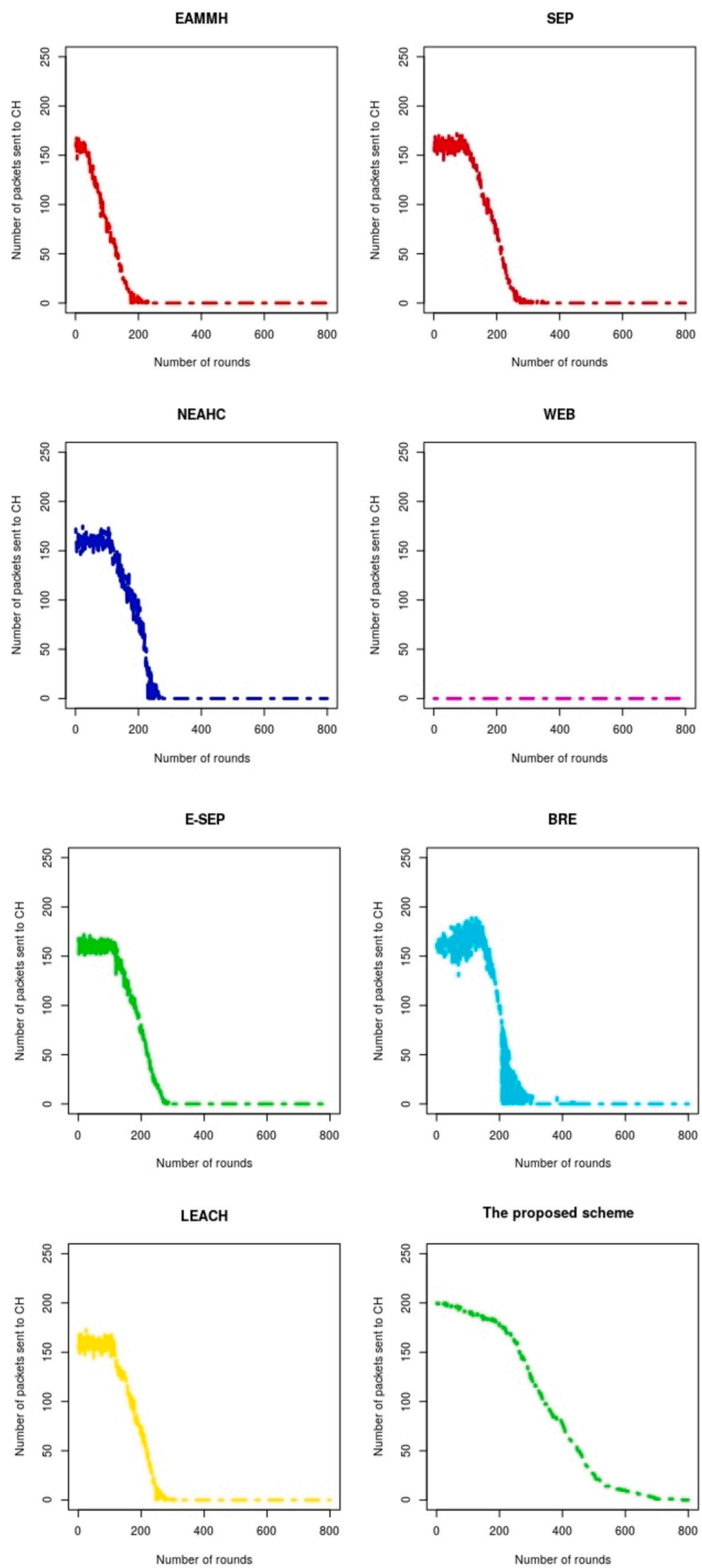

Fig. 7. Packets sent from sensor nodes to CH.

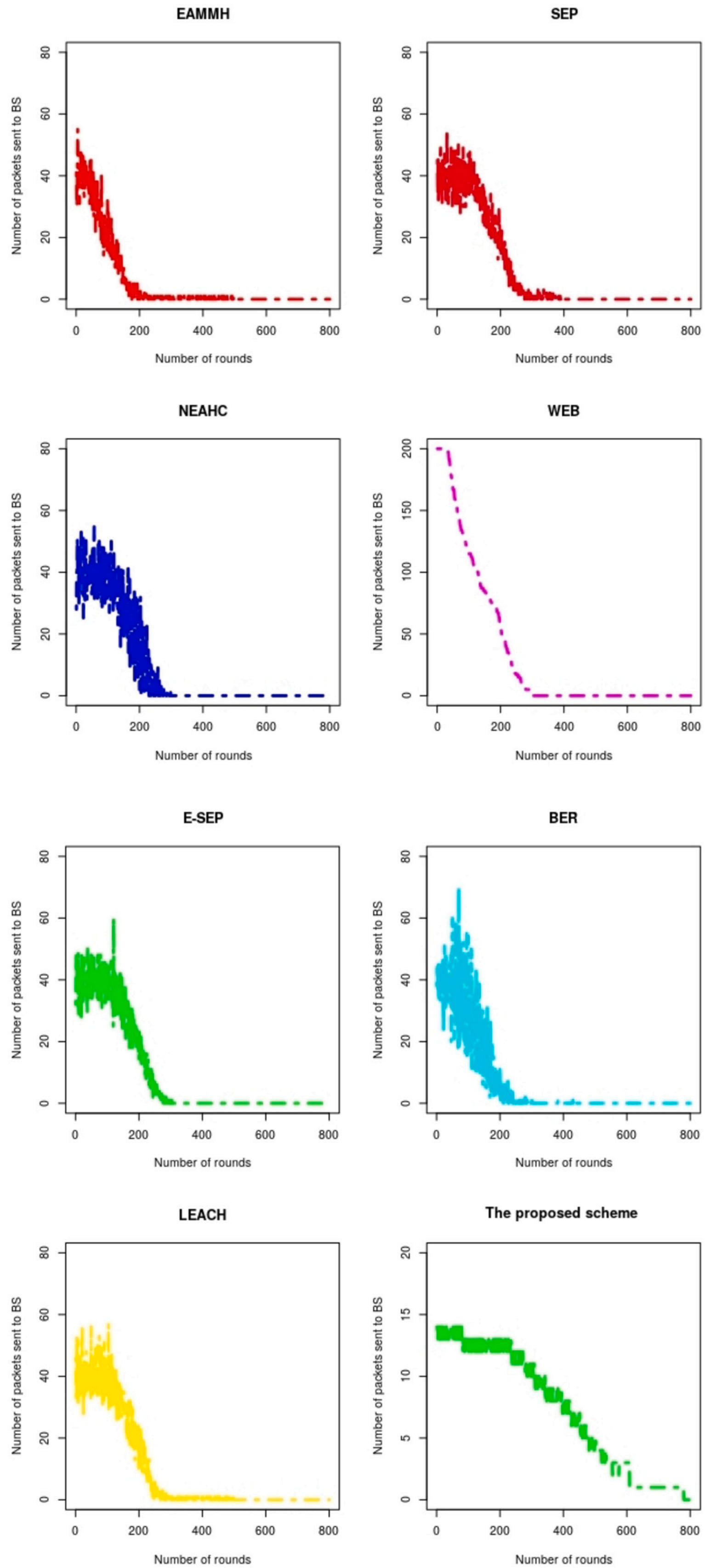

Fig. 8. Packets sent from CHs to BS.

The proposed scheme used Firefly Optimization algorithm to find the best set of CHs. The proposed scheme can minimize the consumption of energy by sensor nodes and extends the WSN lifetime. The selection of CHs set and the number of CHs are a difficult task. The proposed scheme can find optimal or near-optimal routes in WSN. It has exploited the advantage of Firefly optimization method, which took in consideration the change of network topology, energy levels, and traffic patterns. By taking all these parameters in consideration the proposed scheme can respond to changes and discover the best set of CHs. Results of comparison of the proposed scheme with some well-known routing protocols showed the effectiveness of the proposed scheme in terms of data transmission and energy consumption. The proposed scheme overcame LEACH, EAMMH, SEP, E-SEP, BRE, NEAHC and WEB protocol. It had a great management of energy, which led to extend the WSN lifetime. From results of simulation maximizing the number of CHs could not be the best solution all the time. The proposed scheme could be enhanced by adding more variables to the fitness function like transmission delay, sensor node activation time, etc. It may be tested on other WSN topology like WSN with mobile sensor nodes or mobile BS.

Future research could focus on exploring different optimization techniques to improve the protocol's efficiency and robustness, as well as analyzing its behavior in dynamic and unpredictable network environments. Additionally, investigating the impact of the protocol on network security and privacy could provide valuable insights into its potential vulnerabilities and help identify possible solutions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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