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# Cuckoo Based Clustering Algorithm for Wireless Sensor Network

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**Abstract**

A significant challenge in wireless sensor network is the restriction of energy resources that influences network lifetime directly. Clustering is a technique that can be used to increase network lifetime. Recently, nature-inspired clustering approaches have attracted research community interests. In this paper, we introduce three variant of Cuckoo algorithm in which the energy of path length is considered as one important factor in cluster head selection. To prevent quick energy dissipation of the cluster heads, the role of cluster head should be circulated among different nodes. Thus, the proposed algorithms are aimed to avoid the selection of specific nodes as cluster head very frequently. In addition to this, the problem of lack of attention to the residual energy of sensor nodes during experimental clustering phase in well-known LEACH algorithm is resolved. Simulation results show that the proposed algorithms outperform LEACH algorithm in terms of energy consumption and network lifetime.

***Key words:*** wireless sensor network; clustering; Cuckoo algorithm; network lifetime; energy.

## 1. Introduction

Wireless sensor networks (WSN) consist of electronic sensor nodes that are capable of sensing the surrounding environment and forwarding the collected information towards base station, namely *sink* node. The type of information, including pressure, temperature, humidity, chemical materials, etc., depends on the application of WSN. But one common aspect in all of WSN applications is that sensors are powered by batteries with limited amount of energy.

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In case of deploying WSN in harsh or inaccessible environments, the network provider can hardly recharge or replace the batteries. Hence, one of the most significant challenges in WSNs is scarcity of energy resources that has impact on the network lifetime directly [1, 2]. To incorporate with this constraint, one approach is to partition the nodes into a number of small groups which is calling clusters. The process of grouping the sensor nodes into the clusters and choosing a cluster head (CH) is called clustering. The CH is in charge of collecting data from cluster members, processing them (consists of aggregation and compression), and finally transmitting the processed data towards the sink node. Clustering is an important technique which is used to evenly distribute the energy consumption among all the nodes and to extend network lifetime. Nowadays, the nature inspired meta-heuristic algorithms are applied effectively in the clustering problems [3]. The Cuckoo algorithm has some of the capabilities such as fast convergence and the accurate achievement to global optimal point [4]. To promote network life time, Cuckoo algorithm can perform as an appropriate candidate. In clustering with Cuckoo algorithm, ordinary nodes in the network treat CHs as the nests and try to select the best CH for transferring packets (laying eggs). Then, each node send a Join Request message to the chosen CH. This message is treated as the Cuckoo egg. In this paper, we propose three clustering algorithms after utilizing Cuckoo approach for wireless sensor networks. The proposed algorithms take the remaining energy of the nodes in to consideration for selecting the best CH. In order to proper distribution of the cluster head role, the random selection technique is used to prevent a node from frequently election as the best cluster head. The proposed algorithms are implemented with the network simulator OPNET 14.5 and the obtained results are compared with the well-known LEACH algorithm. Simulation results show that our proposed algorithms have better performance in terms of the proper distribution of energy consumption among all the nodes, the number of receiving of packets to the Base Station (BS) and increase of the network lifetime. The reminder of the article is organized as follows:

Section2 presents a description about some of the antecedent algorithms which were introduced to the clustering in WSNs. Section3 reviews the Cuckoo search algorithm. Section 4 describes the proposed algorithms with their details. Section 5 show simulation results. Finally conclusions are given in the section 6.

## 2. Related Works

Many clustering algorithms are suggested in recent years. The majority of these algorithms are different from each other in the method of cluster heads selection. In [5] LEACH algorithm was introduced in which the cluster head is selected randomly and sensor nodes have equal chance to become a cluster head. In HEED [6] algorithm the cluster heads are selected based on residual energy of node and intra-cluster communication cost.

EEUC algorithm [7] partitions all nodes into clusters of unequal size such that the smaller clusters can conserve much energy. In PEGASIS [8] clustering algorithm, sensor nodes form a chain from the source to the sink. Each node receives data from one neighbor, fuses data with its own, and transmits them to the other neighbor on the chain until all of data to be forwarded to the sink.

The Cuckoo search algorithm has already used to solve the problems such as data aggregation and node positioning in WSNs [9,10]. The parameters such as residual energy of sensor nodes, distance of the sensor nodes from each other, the energy of the path length and etc., are used for clustering in WSNs. In [11] one clustering approach based on Cuckoo behavior has been introduced to which we refer as "Cuckoo" algorithm in this paper. In "Cuckoo" algorithm, the nodes select the best cluster heads based on equation (1):

$$F= fit\_number / [(\beta * d^2) + (\gamma * d_0{}^2)] \quad (1)$$

Where F is the fitness of a nest (CH). In fact the node which has the most of value for F function is selected as a cluster head. In (1), fit_number denotes the residual energy of cluster head, $d_0$ represents the distance between the ordinary node and the CH, and d is the distance between the cluster head(CH) and the Base Station(BS). In (1), the cluster heads are selected only according to the residual energy of cluster head. So the function F in (1) does not consider the residual energy of ordinary nodes.

In other hand function F in (1) does not consider the energy of the path length. This study attempts to improve the idea of previous clustering (clustering only according to the residual energy of cluster head). In this paper, we propose a new fitness function for the selection of cluster heads.

The proposed function selects a best cluster head according to the energy of the path length and leads to the improved network lifetime. Our proposed algorithms select the cluster head node not only based on residual energy of the CH, but they also consider residual energy of the ordinary node. Similar to the majority of the clustering algorithms, LEACH algorithm forms the basis of our proposed algorithms in this paper.

## 3. Cuckoo algorithm

The Cuckoo algorithm [11, 12] is one of the metaheuristic algorithms that has been inspired from life style of a bird called Cuckoo. The Cuckoos have some eggs which lay in some other bird's nest. Each Cuckoo starts to lay in some of the random nets inside her egg laying radius.

When all the eggs laid in host bird's nests, some of them that have less similar to host bird's own eggs, are detected and thrown out of the nest. Rest of the birds grow in host nests. Then the young Cuckoos are growing and turning into mature Cuckoos. They live in their own habitat for sometimes and at egg laying time, they form some groups or the clusters.

To determine the groups of Cuckoo, k-means algorithm is applied, then they immigrate to optimal point (goal point). Each Cuckoo attempts to find the best position in search space that is known as the main concept of immigration in Cuckoo algorithm [13].

## 4. The proposed algorithms

In this section we explain the details of the proposed solutions.

### *4.1. Radio Model*

We utilize heinzelman's Radio Model [7] which is a classical Model for wireless sensor networks. The block diagram of the Radio Model is represented in Fig1. In order to transmit L bits of data between two nodes with distance "d", the energy consumption is computed based on (2):

$$E_{tx} = (L_p + E_{tx}) + (L_p * E_{amp} * d_n) \quad (2)$$

And to receive L bits data, the radio expends energy according to (3):

$$E_{rx} = (L_p * E_{rx}) \quad (3)$$

Both, $E_{tx}$ and $E_{rx}$ describe the consumed energy for communication of one bit.

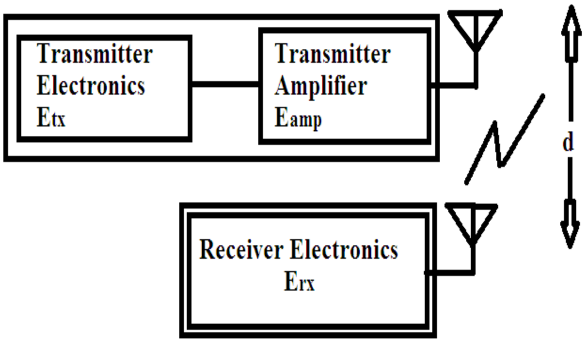


**Figure 1:** Radio Model for WSN[11]

ASR parameter: ASR shows the geographical position of sensor nodes in network [14]. ASR is defined by(4):

$$ASR=(S,D)-d(R,D) \quad (4)$$

Where S depicts the source node, D is the destination node and R is relay node. Since the control packet moves from source(S) to destination(D), ASR is considered higher than zero(ASR>0), but if the control packet moves from destination(D) to source(S), ASR is considered lower than zero(ASR<0).

### *4.2. Assumptions*

1) In all the proposed algorithms, the sink position is not changed.

2) The Base Station has enough energy and processing power.

3) All the sensor nodes can communicate with each other and the BS directly.

4) In all proposed algorithms, we assume that sensor nodes are randomly distributed in the space of network.

5) Also we suppose that there is a single hop from the source node (ordinary node) to the cluster head and the cluster head to the Base Station.

**Table 1:** Simulation parameters

| Parameter | Value |
|---|---|
| **Number of nodes** | 100 |
| **Initial energy of the node** | 0.5 J |
| **Range of radio Minimum** | 25m |
| **Range of radio maximum** | 105m |

### *4.3. Description of the first proposed algorithm*

All the proposed algorithms are composed of three phases:

1) Experimental clustering phase

2) Clusters formation phase

3) Transmission of information phase

#### *4.3.1. The experimental clustering phase*

In experimental clustering phase, an initial clustering is done based on LEACH algorithm. In cluster formation phase, the sensor nodes select the best cluster head according to a new proposed fitness function which is suggested in this research and then ordinary node is jointed to its chosen CH. Transmission of information phase is done after cluster formation phase and the selection of the best cluster heads. During this phase, the transmission of information happens between the ordinary nodes and cluster heads (CHs) and also between CHs to BS.

- First, the Base Station (BS) broadcasts the percentage of the CHs requirements for the total of the network. The desired percentage to become CH is represented with P. Also BS broadcasts the location information of all the nodes to the network whole.
- After receiving this information, each node produces a random number in [0,1] and compares it with T(n) given by (5). If random number is less than the threshold value T(n), the node is chosen to become a cluster head for the current round otherwise the candidate node is known as ordinary node.

$$T(n) = \begin{cases} \dfrac{P}{1 - P\left(r \bmod \dfrac{1}{P}\right)} & if \quad n \in G \\ 0 & otherwise \end{cases} \qquad (5)$$

In equation (5) P is the desired percentage to become a CH, r is the current round number and G denotes the group of sensor nodes that are not CHs in the previous 1/p rounds. In the end of this phase according to the mentioned conditions some of the tentative CH (N nests) are determined (since the number of these cluster heads are not predetermined, we represent the number of created experimental cluster heads with parameter N)

#### *4.3.2. The cluster formation phase*

In this paper, the best cluster heads are selected among the experimental CHs based on the proposed fitness function in (6). After the experimental clustering phase some of the cluster heads are determined. These cluster heads broadcast a control packet to attract ordinary node in the network. The packet includes the residual energy of the cluster head.

The ordinary nodes in the network treat CHs as the nest and tries to select the best CH for laying egg. The ordinary nodes select the best cluster heads based on the proposed fitness function by (6):

$$F=(Energy_{\mathrm{CH}}+Energy_{Node})/distance_{CH,Node} \quad (6)$$

Where $Energy_{\mathrm{CH}}$ depicts the amount of remaining energy of CH, $Energy_{Node}$ is the residual energy of the source node (the ordinary node) and $distance_{CH,Node}$ is the distance between the ordinary node and the cluster head. Since the proposed algorithms are implemented as single hop, the energy of the path length is the sum of residual energy of the source node and residual energy of the cluster head.

The attention to the parameter of distance causing the node which has a distance shorter to cluster head than other nodes to be taken in the cluster. In other hand if the distance of the node to CH is less than other node, that node has more chance to become member of that cluster.

The candidate node compares the F value of its cluster head ($F(n_{own\_ID})$) with the F value of other cluster heads(F(n)). The node with highest F value is selected as the best cluster head.

Each ordinary node forward its packets to the selected best cluster head. Each ordinary node transmits the packet if:

a) The maximum F value of the other cluster head(F(n)) to be more than the F value of its cluster head ($F(n_{own\_ID})$).
b) The distance between the ordinary node to CH is lower than 25 meter (dist<=25) and ASR>0. The intuition is to prevent transmission of packets of source nodes to far away cluster heads. The distance of the source node to cluster head is considered to be less than 25 meter. This amount is the minimum of the radio range. Since the control packet is moved from the source node to the destination node, ASR is considered to be positive.

#### *4.3.3. The transmission of information phase*

The transmission of information is done after the information of clusters phase and also after the selection of the best cluster heads. In this phase, the cluster head aggregates the data according to TDMA scheduling and forwards the aggregated data to the Base Station directly. The details of the first algorithm is shown in Fig 2.

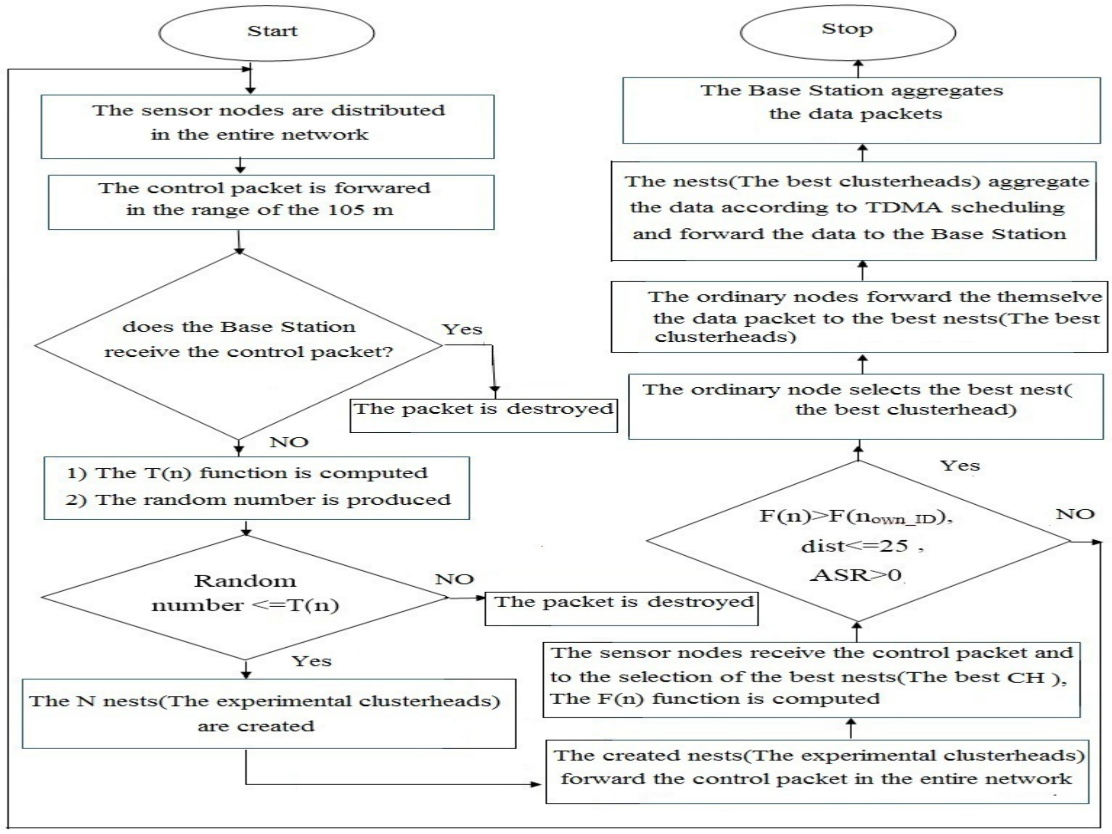


**Figure 2:** The flowchart of the first proposed algorithm

### *4.4. Description of the second proposed algorithm*

Whether the first proposed algorithm is implemented a good algorithm for clustering, but in this algorithm the cluster head is selected as deterministic. Its benefit is the simplicity. But as in the Cuckoo algorithm, all the Cuckoos don't select the optimal nest. It's better that the selection of the best cluster head by the proposed fitness function to be randomly, for example the best cluster head can be selected with the probability of 0.8 and with the probability of 0.2 an other cluster head would be selected. The flowchart of the second proposed algorithm is shown in Fig 3.

For this work, after experimental clustering phase, each nest (experimental cluster head) produce a random number in [0,1] and this random number is inserted into the control packet. The created nest forward the control packet in the total of the network.

The ordinary nodes receive the control packet, each ordinary node generates a random number between 0 and 1.

Then the random number of node is compared with the random number of the packet, if the random number of node is smaller than the random number of the packet and also the maximum F value of its cluster head ($(F(n_{own\_ID}))$) is more than the F value of the other cluster heads (F(n)) then the candidate node is adopted as the best cluster head.

Hereby the best cluster heads are selected randomly but the residual energy has also affected the selection. Also this mechanism causing the proper distribution of the cluster head role and prevention of the frequent selection of cluster head that leading to early death of CH.

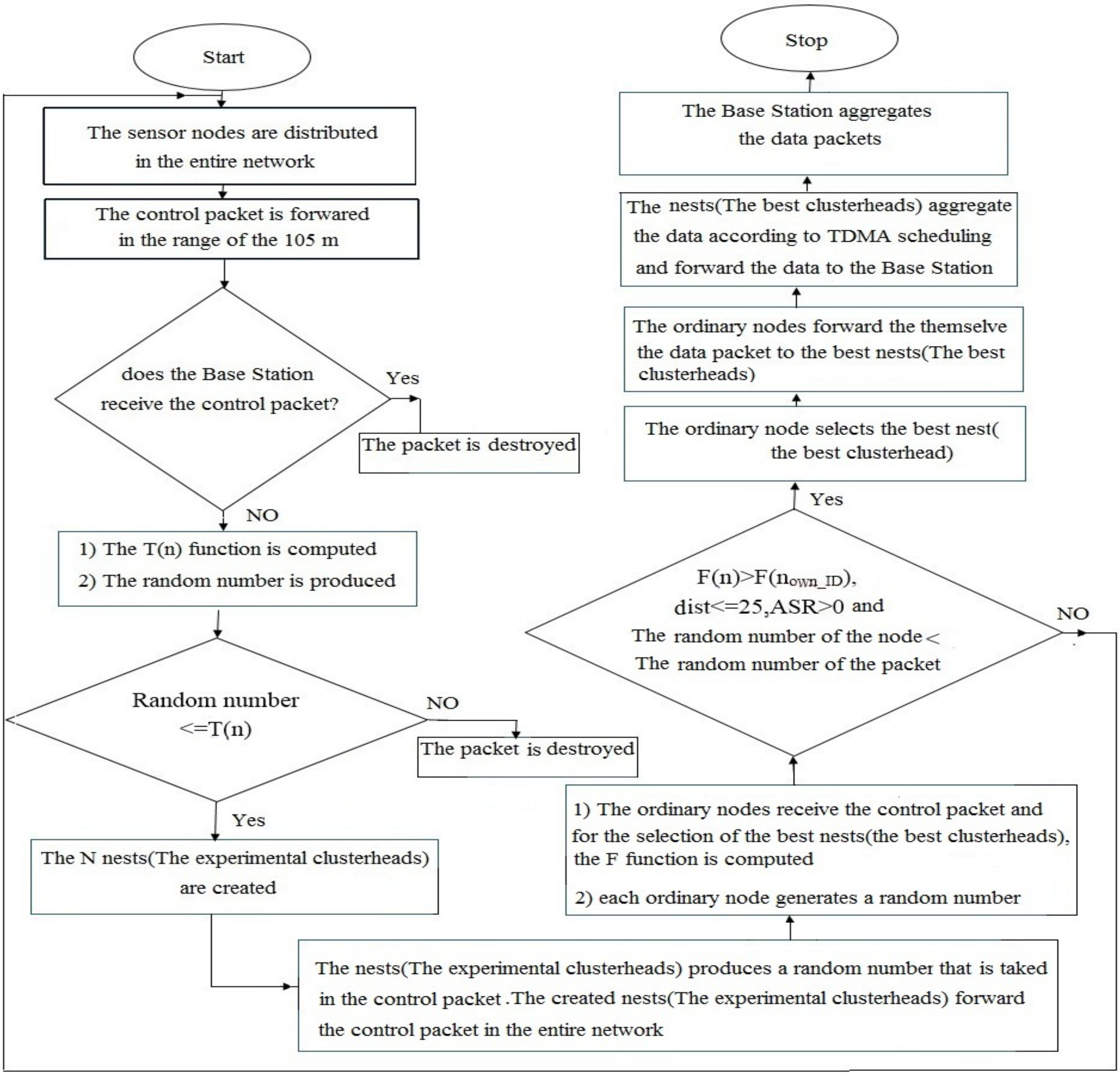


**Figure 3:** The flowchart of the second proposed algorithm

### *4.5. Description of the third proposed algorithm*

The LEACH algorithm is one famous algorithm that is known as the basis of the many other clustering protocols. However, one drawback of LEACH is lack of attention to residual energy of nodes at selection time of the cluster heads.

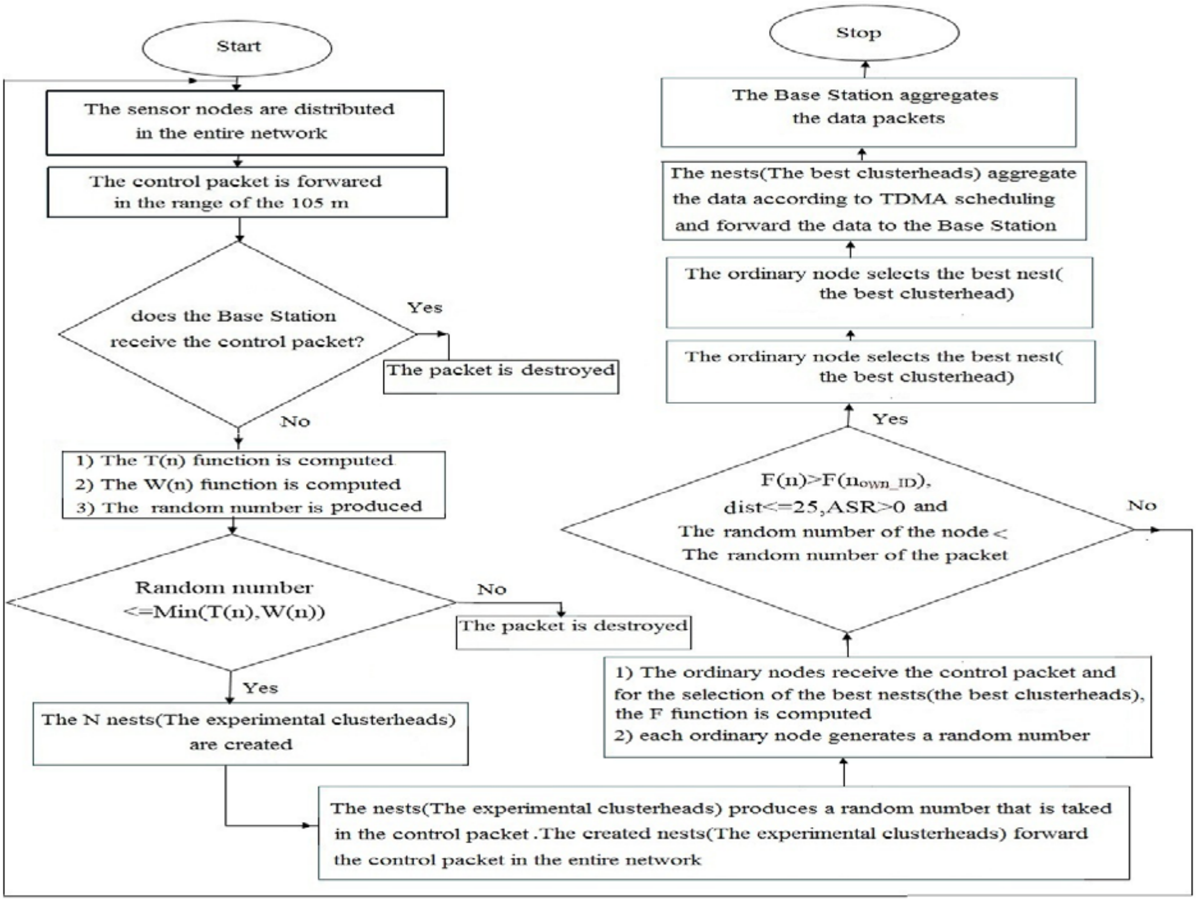


**Figure 4:** The flowchart of the third proposed algorithm

In all the proposed algorithms and also in the "Cuckoo" algorithm, first in the formation of cluster phase, an experimental clustering is done based on LEACH algorithm which in this phase, the experimental ordinary nodes and the cluster heads are selected randomly and LEACH algorithm does not consider the residual energy of nodes in the selection of the ordinary nodes and cluster heads. To resolve this problem, and for improvement of the "Cuckoo" algorithm and also improvement of the first and second proposed algorithms, the third algorithm is introduced. In this proposed algorithm, in the experimental clustering phase each sensor nodes computes a W(n) function. Then each sensor node produces a random number between 0 and 1 and compares its generated random number with Min[(T(n),W(n)]. If the generated random number is less than Min[T(n),W(n)], the candidate node is considered as cluster head otherwise this node is considered as the ordinary node. W(n) function is defined by equation (7):

$$W(n)=\frac{\text{Residual energy of Node}}{\text{residual energy of node+ residual energy of neighbor nodes}} \quad (7)$$

If the residual energy of the node is higher than the residual energy of neighbor nodes, the candidate node has more chance to become a CH.

**5. Simulation Results**

In order to evaluate the validity and the efficiency of the proposed algorithms, we have used the network simulator OPNET 14.5. The modeled wireless sensor network consist of similar sensor nodes that are randomly distributed in a square 100m*100m area. Simulation conditions are mentioned in table1. The proposed algorithms are compared with LEACH algorithm and "Cuckoo" algorithm. Simulation results exhibit that our proposed algorithms have better performance than two another algorithms in terms of the proper distribution of energy consumption, the number of receiving packets to the BS and increase of the network lifetime (based on the first node death time of a network).

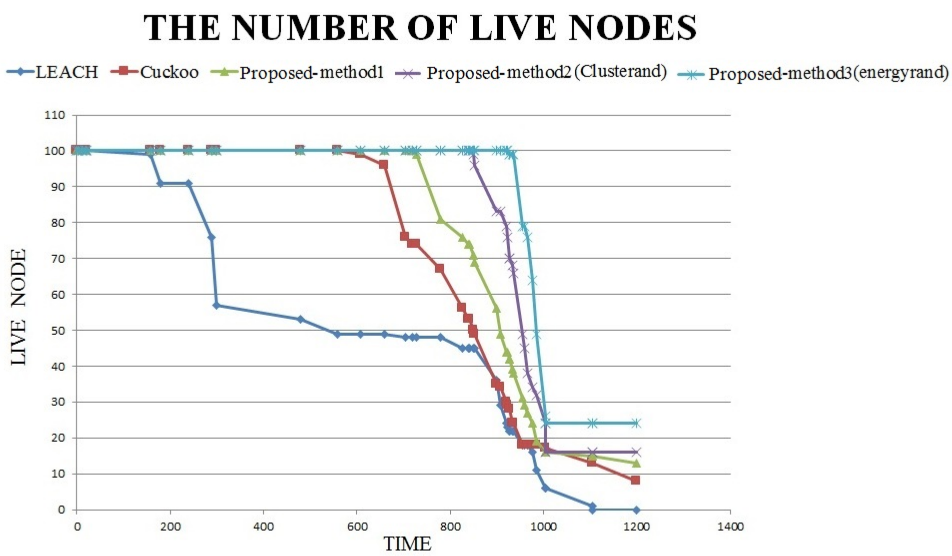


**Figure 5:** Comparison of the proposed algorithms with LEACH and Cuckoo in terms of network lifetime

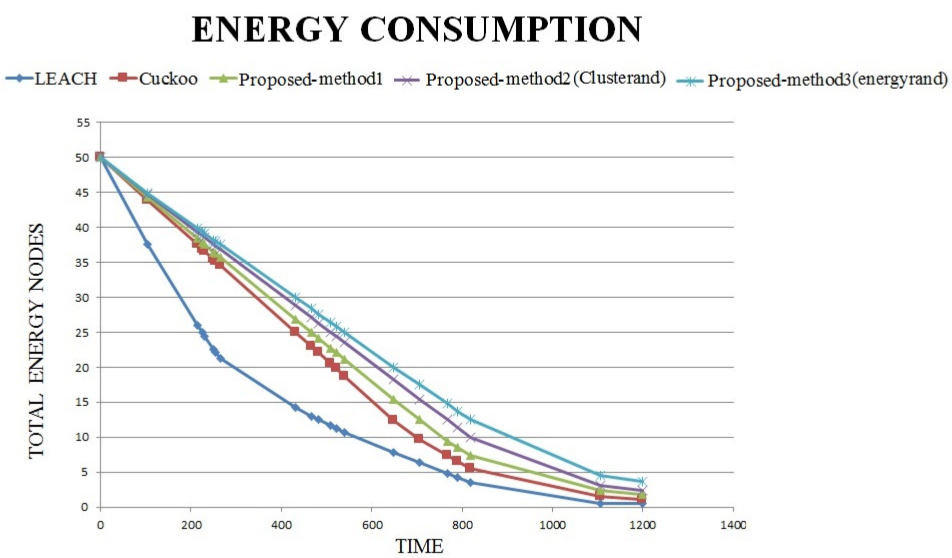


**Figure 6:** Comparison of the proposed algorithms with LEACH and Cuckoo in terms of the energy consumption

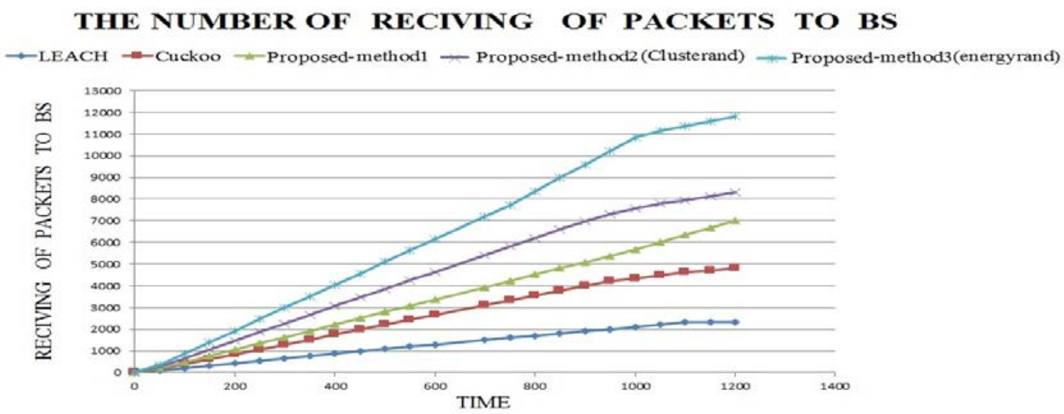


**Figure 7:** Comparison of the proposed algorithms with LEACH and Cuckoo in terms of the number of received packets to BS

**Table2:** Comparison of the proposed algorithms with LEACH and Cuckoo in terms of the first node death time

| Algorithm Name | the first node death time |
|---|---|
| **LEACH** | 158 |
| **Cuckoo** | 608 |
| **Proposed-method1** | 727 |
| **Proposed-method2 (Clusterrand)** | 850 |
| **Proposed-method3 (Energyrand)** | 928 |

**Table3:** Comparison of the proposed algorithms with LEACH and Cuckoo in terms of the number of received packets to the BS

| Algorithm Name | The number of received packets to the BS |
|---|---|
| LEACH | **2328** |
| Cuckoo | **4822** |
| Proposed-method1 | **7028** |
| Proposed-method2(Clusterrand) | **8327** |
| Proposed-method3(Energyrand) | **11821** |

## 6. Conclusion

In this paper, three proposed algorithms with the base of Cuckoo algorithm are introduced. The first proposed algorithm selects the best cluster head according to the energy of path length. To properly distribute the role of cluster head among different nodes and to avoid quick energy dissipation of cluster heads, the second algorithm is introduced. This algorithm selects the cluster heads (the best cluster heads) randomly and it will prevent of too early death of cluster heads. In the third proposed algorithm the problem of lack of attention to residual energy of the nodes during the experimental clustering phase was resolved. The simulation results and the obtained values in Table 2 and Table3 prove that the proposed algorithms will improve network lifetime between 47% to 64% compared to LEACH algorithm and between 10% to 27% compared to "Cuckoo" algorithm. Also the average of energy consumption is decreased 18% to 21% in comparison to LEACH algorithm and 3% to 7% in comparison to "Cuckoo" algorithm. The reason for those enhancements is the proper distribution of energy consumption among the nodes. In the proposed algorithms, the number of received packets to the BS are improved 67% to 80% in comparison to LEACH algorithm and 31% to 59% in comparison to "Cuckoo" algorithm.

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