Economic Computation and Economic Cybernetics Studies and Research, Issue 3/2023; Vol. 57

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CLUSTER HEAD SELECTION ALGORITHM ON THE BASIS OF MASS DEFENSE OF BEES IN IOT

Abstract. *Clustering is one of the methods which bring about efficiency boost, energy reduction, and longevity in Internet of Things (IoT). One of the key challenges in IoT clustering is optimal cluster head selection. Unintelligent selection and improper distribution of cluster head selection are critical problems rooted in the random nature of classical methods. Thereupon, meta-heuristic methods are used to solve such problems. The present study presents a new clustering method as well as an optimal cluster head selection applying the Mass Defense of Bees algorithm. This method simulates honey bees' behaviour in fighting against the red bee invader, defending a hive, detecting the invader, resistance against the invader and displaying coordination performance. The proposed method achieves the optimal head selection through fitness function introduction. Compared to PSO and leach methods, the proposed simulation method demonstrates the IoT network clustering, around 9.45% energy improvement and 13.2% residual energy development, respectively.*

DOI: 10.24818/18423264/57.3.23.11

***Keywords**: Cluster Head, IoT, Mass Defense of Bees Algorithm, Reduction of Network Energy Consumption*

JEL Classification: C8, C88, L63, L86

1. Introduction

IoT1 is a thoroughly novel issue whose central idea lies in connecting all things to the Internet. In the absence of user-to-user or user-to-computer interaction, IoT can transmit data over a network. The IoT network differs from other networks as the nodes own limited bandwidth, storage volume, processing, and battery power. Altogether, energy consumption is dramatically serious concern in such devices (li et al., 2016; Sun et al., 2020.)

In IoT networks, abundant efforts are made to increase lifespan due to the limited energy and memory. Routing is the significant key issue to maximise nodes' lifetime in IoT (Xinlu et al., 2015). Fault-tolerant routing is highly essential to save energy for IoT applications (Hasan et al,2017; Petrov et al., 2018; Akba et.al., 2015). As battery-operated nodes cannot be replaced or charged, hence specific approaches should be taken to reduce their energy consumption (Gambhir et al,2018; Kumari et al, 2019 and Praveen et al., 2019).

A hierarchical routing approach is one of the optimal approaches to reduce nodes' power consumption and improve IoT network lifetime. In this approach, nodes are placed in separate groups, called clusters. Clustering of IoT nodes is an extensively effective factor to reduce energy consumption and lifetime improvement in IoT network. In the clustering approach, to transmit data, cluster head node is selected for each cluster (Agarwal et al., 2015 and Ding et al.,2019). In these algorithms, the cluster head node which tolerate extensive overload are prone to premature death due to high energy consumption (Praveen et al., 2019; Reddy et al., 2019 and Sahoo et al., 2021).

In clustering-based protocols, each cluster data is collected and sent to the base station. Meanwhile, in network, total sum of dispatch and receipt diminishes and duplicate data is removed before transmission to the base station. IoT network clustering aimed to minimise power consumption is a NP-Hard problem. Henceforth, cluster head selection and their arrangement are top challenges in IoT network clustering. Evolutionary and swarm intelligence algorithms which are significantly effective approaches to solve complex optimisation problems in various fields (Schranz et al., 2021), also used to solve clustering problem. Evolutionary clustering algorithms attempt to find the best possible solution with the least energy consumption rate (Janakiraman et al., 2018).

The proposed approach is an evolutionary algorithm studying collective factors essential to optimal cluster head selection in IoT. It aims to compute fit

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[1] Internet of Things

function as well as nodes operation, and select cluster heads based on desired parameters. Consequently, by applying the proposed algorithm, a compound (synthetic) head cluster selection framework is proposed in the IoT network.

The proposed approach is much more preferable than other approaches because of:

- Multi-criteria selection and high flexibility
- optimal exploration
- High speed to find optimal solution
- Network efficiency improvement

The current paper presents a literature review in Section 2. Section 3 introduces the proposed swarm intelligence algorithm. Section four demonstrates the simulations and analytical results. And the final section covers conclusions.

2. Literature Review

Among the proposed protocols, the LEACH[2] protocol takes on a special importance (Nandan et al., 2021). The current protocol transmits data from sensors to the cluster head and from there to the base station. In the LEACH protocol, time is divided into sections known as cycles. Each cycle is also divided into two phases: start-up and stable states. In the start-up phase, clusters are constructed, and then data are transmitted in steady state phase. In start-up phase, network clusters are randomly formed, and network parameters such as residual energy and node positions are neglected (Grover et al., 2014).

In cluster heads selection for LEACH, each sensor selects a random number between 0 and 1. If the selected number is less than the threshold value, the sensor will be selected as a cluster head during that cycle. Similarly, other network sensors become the nearest cluster head’s members. Dynamic clustering is introduced in the LEACH protocol. Simply put, after each data dispatch and receipt operation cycle, the cluster head changes and another sensor randomly is selected as the cluster head.

It should be noted that in the LEACH algorithm, random cluster head selection may lead to improper distribution in the network. On the other hand, in one section of network, the cluster heads may be positioned closely while the other section is left without any cluster head. Similarly, the cluster heads may be positioned onto network edge, or ineffective cluster head node is wrongly selected.

In recent years, nature-inspired clustering algorithms have attracted the attention of many scholars. Likewise, diverse algorithms have been developed to improve proper cluster head selection. This section presents and investigates some of cluster head selection approaches objected to LEACH protocol optimisation in IoT network.

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[2]- Low-Energy Adaptive Clustering Hierarchy

In (Praveen et al., 2017), a synthetic approach comprised of GSA[3] and ABC[4] is proposed to select the cluster head. This approach has considered several parameters of IoT devices in cluster head selection process such as distance, energy, latency, load, and temperature.

A research group (Qiu et al., 2016) have introduced a multi-objective fractional gravitational search algorithm to provide cluster optimisation in the IoT network. Here, an algorithm was proposed to improve node lifespan. In this study, a fitness function named multi-objective FGSA (MOFGSA) was proposed for cluster head selection taking into account several objectives comprised of distance, latency, link lifespan, and energy.

Another study presented ant colony-based cluster head selection algorithm ACO[5] based on the traditional LEACH algorithm (Poonguzhali et al., 2020). This approach uses ACO-based cluster head selection based on the residual energy factor to select IoT devices with maximum residual energy. This algorithm consists of three phases. Initially, data is transmitted from cluster nodes to cluster heads. In the second phase, data is transmitted from cluster heads to the network administrator, and in the final phase, the network administrator transmits the data to the base station.

To optimise the energy distribution rate, a study presented an intelligent cat approach to reduce the distance between cluster head and inner clusters (Chandirasekaran et al., 2019). The operation of this algorithm relies on factors such as residual energy, signal strength, and cluster head distance.

Similarly, the geographical cluster method has been proposed for the cluster head selection based on the sink position in the network (Akila et al., 2019). In this study, a set of cluster heads was assigned to each cluster, and then relative secondary cluster heads were selected to each main cluster head. The simulation results displayed energy consumption reduction.

Keeping on evolutionary algorithms in clustering (Shankar et al., 2016), a synthetic ACO and PSO[6] program (ACO-PSO-CHS) has been proposed. This approach optimally performs the exploration process by the basic PSO parameters with no energy loss. This ACO-PSO-CHS approach emerged greatly effective in minimising energy consumption to extend network stability.

In addition, (Praveen et al., 2019), another study proposed a cluster head selection approach for IoT network using gravitational search algorithm and colonial rivalry approach (GSA-ABC-CHS). During the implementation of the GSA-ABC-CHS project, the percentage of alive nodes and network power were optimally determined. Several factors comprised of distance, latency, load, temperature, and energy are extensively used in this approach.

HACO-ABC-CHS approach was an effort to concentrate on the efficient cluster head selection between IoT and WSN devices. This approach operates by

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[3]- Gravitational Search Algorithm

[4]- Artificial Bee Colony

[5]- Ant Colony Optimisation

[6]- Particle swarm optimisation

elimination problems in ACO and ABC optimisation algorithms (Janakiraman et al., 2018). Stagnation in ACO and convergence delay in ABC prevent their optimal performance.

3. The proposed method

Internet of Things (IoT) refers to an Internet from several irregular points to sum interactive points. Clustering is widely considered as the most efficient approach to solve routing problems in IoT networks. Each cluster consists of one cluster head. The clusters receive and collect data, then forward it to the base station called sink. The base station acts as a communication channel between the sensor network and the user. Data collection is performed to prevent redundancy and communication load as a result of multiple transmissions (Figure 1).

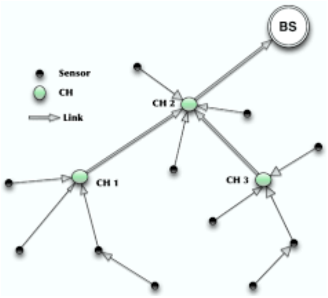

Figure 1. IoT Network Clustering

In recent years, several clustering protocols have been proposed to prolong lifetime of IoT network. Limited node resources can be considered as one of the limitations. Henceforth, power-aware routing protocol which is able to prolong network lifetime turns to a dramatically significant challenge in setting up IoT networks. Accordingly, the operation of the cluster head selection process using an efficient meta-heuristic algorithm with high-speed convergence in IoT seems essential.

Evolutionary optimisation and search algorithms are efficient methods to find optimal global solutions to problems. Such algorithms' random nature prevents them getting stuck in optimal local points. Some of these algorithms, such as the Mass Defense of Bees (MDB) algorithm, are inspired by biological systems (nature-inspired systems). Such algorithm has successfully appeared in global optimum achievement and beneficially converged to final solution.

In the proposed algorithm, initially the clusters are formed, and the power node rate is computed. Then, the objective key fitness function is operated to obtain efficiency. According to the proposed method, a node is selected as the main cluster head, until the maximum performance from network parameters is achieved. When the cluster head node power runs out, the phases will be reiterated.

3.1. Mathematical Model for the Proposed Method

Stochastic, evolutionary, and optimisation algorithms are extensively efficient methods especially used to find optimal global solutions for complicated problems. The random nature of these algorithms prevents them from getting stuck in local optimal solutions. In practical optimisation problems such as engineering designs, management of organisations, and economic systems, pivotal focus usually rests on obtaining global optimal solutions. Many of such algorithms are inspired by biological systems. The proposed algorithm is based on mass defense of bees against red bees [25]. The algorithm consists of 2 phases: defense phase and update (refresh) phase.

Applied evolutionary algorithm includes two phases: defense and update (refresh) phases

3-1-1 Defense phase (Chanpa et al., 2022): In this phase, the defending bees encircle (surround) the invader and vibrate their flight muscles to generate heat.

Increasing distance to radius of r, the heat intensity $\theta(i,j)$ decreases. The emitted heat $\theta(i,j)$ is directly related to vibrating bees' numbers (N_i). Hence, more bees generate more heat. Bee's generated heat dramatically affects their lifespan. In other words, the increased heat decreases bee's lifespan. As afflicted with heatstroke, they soon die. When bee's lifespan is indicated by L; Heat radiation gradually kills the invading bee. Heat is merely transmitted through radiation.

The population size parameter indicates the initial number of defending bees. Eq. (1):

$$\theta_0 = \frac{\mathrm{Fitness}(s_{\mathrm{best}})}{\mathrm{problem}_{\mathrm{size}}} \tag{1}$$

θ_0 : This parameter displays the initial heat rate for each bee.

$\mathrm{Fitness}(s_{\mathrm{best}})$: It forms on problem exploration.

$\theta(i,j)$: Heat radiated from defending bees i to invader j.

Eq (2):
$$\theta(i,j) = \frac{\theta_0}{L_i} e^{-\gamma\pi r_{i,j}^2} \tag{2}$$

γ: Demonstrates heat absorption coefficient by invader. This variable equals to 1.

$\pi r_{i,j}^2$: Fitting the position in radius r.

The distance between defending bees i and invading bee j can be the Euclidean distance or any other distance in the radius r. Total radiated heat from all defending bees is achieved.

If the bee initially places itself in radius r, it likely moves at a distance xi from the circumference of the circle. The displacement rate of each bee toward circle's center with radius r is obtained from Eq. (3):

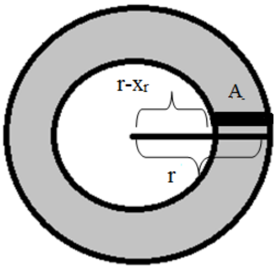

Figure 2. Movement of bees to circle’s center

$$A=\frac{\pi(r^2-(r-x_r)^2)}{\pi r^2}=\frac{r^2-(r^2-2rx_r+x_r{}^2)}{r^2}=\frac{2rx_r-x_r^2)}{r^2} \tag{3}$$

$$x_i^{t+1}=x_i^t-A$$

Update (refresh) phase
To refresh radiated heat rate, there is Eq. (4):
If a bee dies, soon it is replaced by other efficiently performer bee.

$$\theta(i,j)=(1-\rho)\theta(i,j)+\rho\Delta\theta(i,j) \tag{4}$$

If Li =0 then $\theta(i,j)=\theta(i,j)+\Delta\theta(i,j)$
ρ : Refresh rate coefficient equals to 0.1.
$\Delta\theta(i,j)=\text{Fitness}(s_{best})$ if $i \in N$

It is worthwhile to note that maximum efficiency achieves when the number of defending bees ($f_{population}$), their lifespan ($f_{lifetime}$) and their radiated heat ($f_{temperature}$) are high. Meanwhile, they are placed in lower distance ($f_{distance}$) from the center of the circle. Thereupon, there is Eq. (5).

$$F_1=f_{lifetime}+f_{temperature}+f_{population}$$

$$F=\frac{\alpha}{f_{distance}}+(1-\alpha)\,.\,F_1 \qquad ,\alpha \in [0,1] \tag{5}$$

3.2. IoT Cluster Head Selection based on MDB

The proposed method’s key objective is lifetime improvement of IoT network. A synthetic cluster head selection framework in the IoT network is proposed by applying a new swarm intelligence algorithm. The following section explains the approach:

Step 1: Optimal Cluster Head Selection

First, several higher energy nodes are selected as cluster heads. In the proposed algorithm, nodes percentage turning to cluster head is 5% of the total nodes’ number. For this purpose, the threshold energy is defined. If the selected number of nodes for cluster heads is small, then the threshold value should be reduced constant coefficient. Consequently, the cluster heads are selected.

When there is an energy-based cluster head selection, a high energy level node with a long distance from the sink may be selected as cluster head. Similarly, a high-energy level node with short distance to the sink may be chosen as cluster head, while its overload toleration and delay in data transmission will reduce throughput network. Several effective criteria in cluster head selection are considered based on the MDB approach. Accordingly, Eq. (6):

$$\theta j = l_j \, \theta_0 e^{-d_{i,j}^2} / \gamma\eta \tag{6}$$

θj: residual energy at cluster head j_{th}

l_j Parameter displays the cluster head lifetime jth and when its energy runs out over time, cluster head is removed.

When $l_j \rightarrow 0$ there is $\theta j = 0$, it means residual energy of cluster head turns zero and a new cluster head must replace it.

γ indicates the delay and η the network load. Put simply, when delay and load increase, consumption energy decreases.

In short, the cluster head selection is based on distance, energy, delay, and work load. When there is a distance-based cluster head selection, the selected node must be at a certain distance from the sink. In an energy-based cluster head selection, the power rate should be maximised. In the same way, the delay and work load of the nodes should be minimised. Thereupon, a swarm intelligence model is introduced to overcome such challenges. The key objective of this model is cluster head selection along with node energy maintenance, distance and delay minimisation, and work load balance in IoT devices. The prominent goal of the proposed algorithm is to obtain maximum efficiency from Eq. (7). α and β are constant coefficients between [0,1]. Accordingly, the effect of each parameter on cluster head selection can be determined through this.

$$\begin{aligned} F_1 &= f^{energy} / f^{load} \\ F_2 &= \alpha / f^{distance} + (1-\alpha) F_1 \\ F_3 &= \beta F_2 + (1-\beta) / f^{delay} \end{aligned} \tag{7}$$

Whenever α is closer to zero, higher residual energy will affect cluster head selection.

Step 2: Clustering

When node distance to the sink is less than its distance to the nearest cluster head, it can transmit data directly to the sink.

Otherwise, each node will move to a closer cluster head Eq (8).

$$d_{ij}^{best} = \begin{cases} \text{if } d_{ij} \leq d_{ij+1} & d_{ij} \\ \text{elseif } d_{ij} > d_{ij+1} & d_{ij+1} \end{cases} \tag{8}$$

$$d_{ij} = d_{ij}^{best}$$

d_{ij} Parameter indicates distance between node i and cluster head j.

Node i examines its distance from cluster head j and j + 1. And then selects the nearest cluster head.

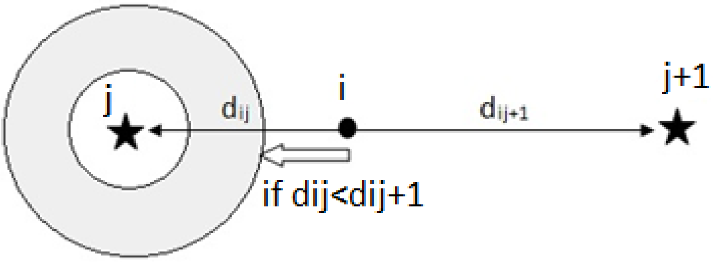

Figure 3. How to select distance-based cluster head

It is the strength and suitability of the cluster head that determine nodes' division between clusters. The aforementioned criteria in the first step make nodes select their cluster head.

The proposed algorithm will be operated and the fitness function will be recomputed for nodes and cluster heads in each round. Whenever a node has more fitness to its cluster head, it will be replaced. When a specific position requires the node to join another cluster, it will happen. Also, energy-depleted nodes will be removed from cluster. Then the efficiency parameters for each node are updating (refreshing). The algorithm performs these steps consecutively for several rounds until it reaches the termination states. One of the significant advantages of this algorithm is its appropriate fit speed in finding an optimal solution.

4. Simulation and Illustration of Results

The current study significantly represents the application of the MDB algorithm to develop clustering protocols and select cluster head in the IoT network. The cluster head selection is extensively based on pivotal factors of distance, energy, delay and work load.

The proposed method beneficially provides optimal exploration and efficiency, the two significant key success factors in swarm intelligence approaches. In this algorithm, several different parameters are considered in cluster head selection. Henceforth, such a feature, i.e., multi-criteria selection, leads to high flexibility of algorithm. One of the effective advantages of the proposed method is its appropriate fitting speed in finding the optimal solution. In energy-based cluster head selection, energy consumption should be minimised. To prolong network lifetime, the energy in selected cluster head must be at the least minimum, and also distance, delay, and work load at the maximum height.

To perform the proposed algorithm, the present study has applied the MATLAB 2020 software. The simulator is performed on a computer with Intel Core i5 CPU, 16 GB RAM and Windows 7. The total area of the IoT network is 100 × 100 meters with a central base station. The proposed algorithm is compared to the traditional PSO and LEACH algorithms.

The PSO algorithm is a dramatically powerful algorithm in global search. Likewise, the higher convergence speed is its prominent advantage. On the other hand, the PSO algorithm has a high ability to escape local optima. Application of PSO algorithm in LEACH optimisation significantly improves this protocol.

Nonetheless, the proposed algorithm performs optimally better than PSO in terms of performance speed, efficiency, and optimisation. It also requires less memory. Furthermore, network lifespan, defined by nodes' number increases over time. The proposed algorithm operates remarkably well. What's more, comparing to PSO and LEACH algorithms, it improves network lifespan. In addition, it efficiently performs network clustering to the state that an optimal distribution of cluster head across network emerges. Moreover, the energy loss in each node has been reduced.

The evaluation of parameters is presented below:

Network residual energy: In the network in each cycle, this criterion has computed the energy consumption. When the connection between sensor nodes and the sink starts, the total network energy gradually declines. Energy efficiency can be improved by using efficient routing. Such efficient routing covers much more rounds and extends network lifespan.

Throughput: Throughput refers to the number of successfully dispatched packets to the sink per each time unit. It is considered the most significant key criterion for measuring network reliability. High network throughput demonstrates remarkable network reliability and high-qualified services.

Number of clusters: Formed cluster numbers in networks must be in approximately constant range in each round. It means that cycle variations should be minimal. This parameter determines the cluster head numbers in each cycle in the networks.

Figures 4 to 12 display the simulation results.

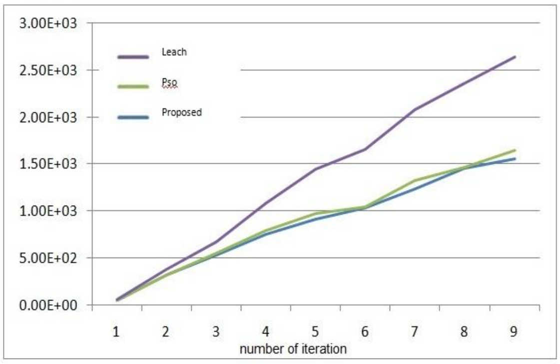

Figure 4. Number of dead nodes

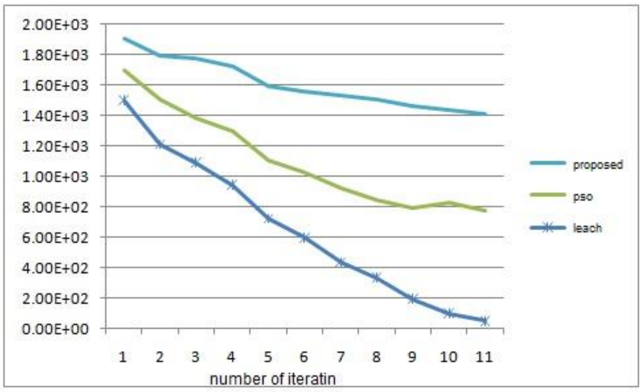

Figure 5. Number of Alive nodes

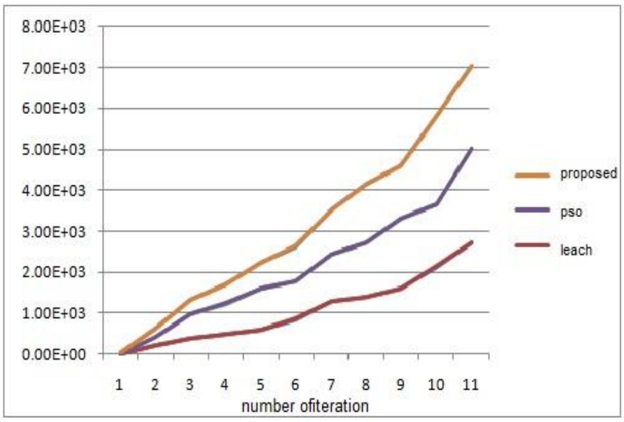

Figure 6. Number of packets reached Base Station

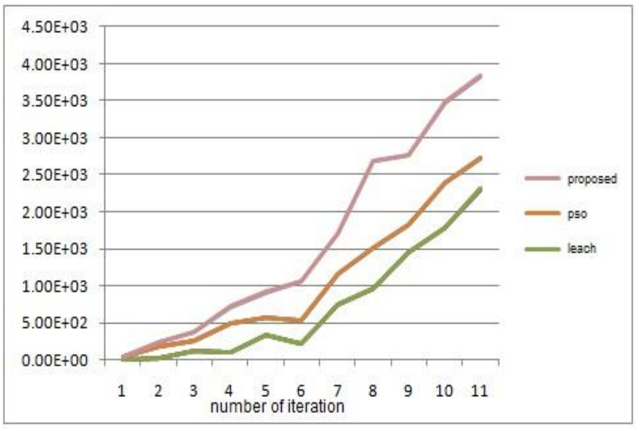

Figure 7. Number of packages reached to the cluster Head

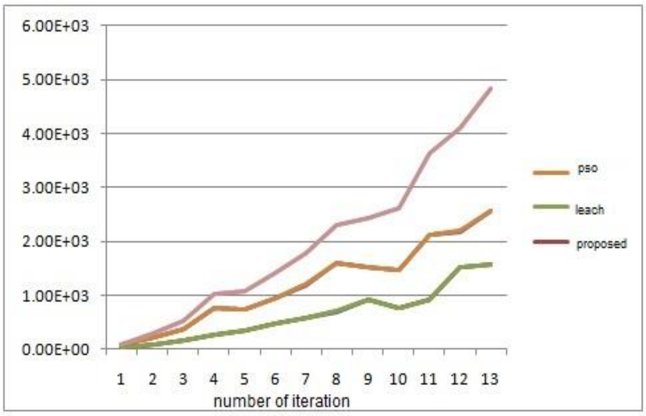

Figure 8. Throughput

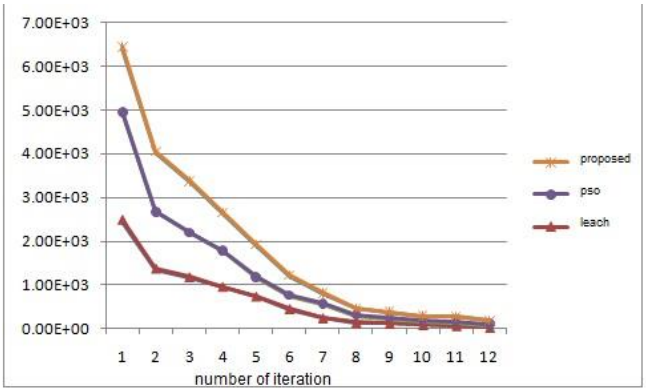

Figure 9. Average residual energy

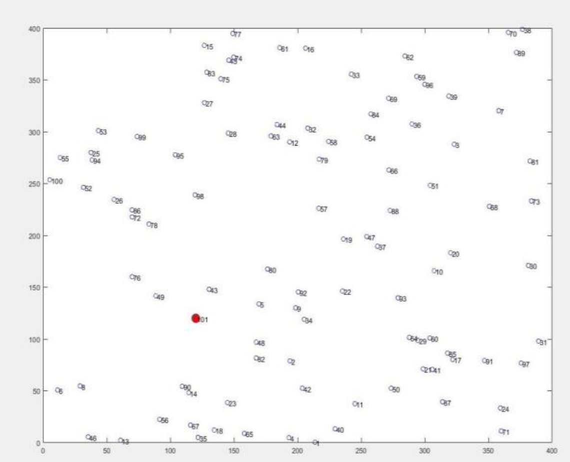

Figure 10. Random distribution of nodes and Cluster head position in Leach

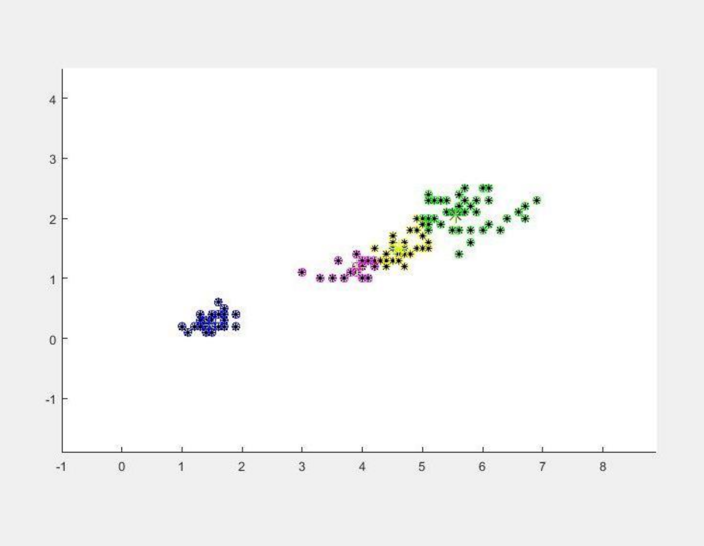

Figure 11. Leach optimisation with pso

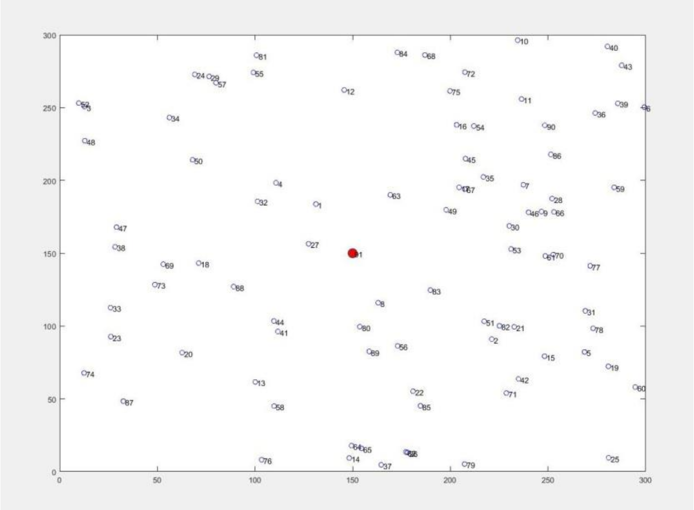

Figure 12. Random distribution of nodes and Cluster head position in MDB

Figures 4 to 12 display the simulation results for the LEACH protocol, the optimisation of the LEACH protocol with PSO, and the optimisation of the LEACH protocol with MDB.

The proposed algorithm demonstrated energy consumption reduction risen from short distance between non-cluster head and cluster head nodes. However, in two other algorithms, it is observed that some nodes have to travel longer distances to reach the cluster head. Considering optimisation and data transmission, comparing to other two algorithms LEACH and PSO, the proposed approach is able to transmit much more data and displays more optimisation. Likewise, it emerges efficiently in high-energy-level node selection by surveying all candidate nodes. Since the cluster head possesses adequate energy to complete stable phase, henceforth it is capable to transmit much more data. Another key feature that prioritises the current approach is the nodes with the highest residual energy. Regarding lifespan, the created network takes longer lifespan as all efficient parameters are actively involved in the cluster head selection.

5. Conclusions

The present study attempted to represent the optimal model of cluster head selection in the IoT network applying a new biological algorithm called MDB. Having considered the finest cluster head selection as an optimum criterion, the opted nodes are premier and carry higher residual energy than others. Both the simulated protocol and the obtained results successfully proved that this approach is beneficially capable to improve network lifespan and transmit higher data than the PSO and LEACH approaches. Moreover, by efficiently equal distribution of cluster head throughout the network, the current approach improves the IoT lifespan.

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