

ENERGY EFFICIENT PIGEON INSPIRED OPTIMIZATION ALGORITHM BASED CLUSTERING AND ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

R.M. Alamelu¹ and K. Prabu

ABSTRACT. Owing to the advancement in recent technologies, Wireless Sensor Networks (WSNs) plays a vital role in today's real-world application. In WSN, energy efficiency is considered as the crucial process to conserve the energy and lengthen network lifetime. Most of the research has aroused in preserving energy with various enriched energy-efficient clustering and routing approaches. Therefore, the proper selection of cluster heads (CHs) and optimal route selection plays a vital role to achieve energy efficiency and prolong the network lifetime. In this work, we propose an optimistic approach for energy-efficient Pigeon Optimization Algorithm based Clustering and Dempster-Shafer (DS) for Routing called (PIOA-DS) Protocol for WSN. The PIOA-DS model involves two major phases namely PIO based clustering algorithm and DS evidence theory based Routing (DSET-R). The PIO algorithm derives a fitness function using residual energy, distance to base station (BS), and distance to neighbors. In addition to that, the non-cluster head nodes will join the respective CHs using the weight functions. Besides, the DSET-R algorithm finds an optimal set of routes based on three measures namely transmission power efficiency ratio, Idleness degree, and Energy density factor. The performance of the presented algorithm is tested extensively on various scenarios of WSNs. The observed results are compared with some existing algorithms to illustrate the superiority of the PIOA-DS work.

¹*corresponding author*

2020 *Mathematics Subject Classification.* 68M18.

Key words and phrases. Clustering, Energy efficiency, Routing, Pigeon optimization algorithm, WSN.

Submitted: 20.12.2020; *Accepted:* 06.01.2021; *Published:* 21.01.2021.

1. INTRODUCTION

Nowadays, wireless sensor networks (WSN) comprise several sensor nodes generally used for determining the physical parameters namely vibration, sound, moisture, density, humidity, temperature, and so on. The wider range of applications in WSN is armed forces, ecological observations, surveillance, etc, bio-medical system, health tracking approach, smart home observing model as well as inventory management technology [1]. Also, clustering [2] is joined with WSN which isolates the regional area as tiny sectors. The sensor nodes involved in WSN helps to share or divide the overhead equally for every node and one among them is declared as 'cluster head (CH)'. In WSN, the CH election is one of the primary objectives to compute the effectual data transmission.

Practically, CH is reconstructed at diverse rounds for attaining the significant performance. A typical cluster is enclosed with a CH with a massive number of Cluster Members (CM). The main aim of CH is to incorporate every node in the cluster [3]. Hence, an appropriate CH election [4] takes place with standard potentials for equalizing the level of the network's power efficiency.

2. THE PROPOSED PIOA-DS MODE

The working principle of the projected PIOA-DS approach is depicted in Fig 1. As depicted, the network undergoes random node deployment and initialization process takes place. Once the nodes are initialized, PIOA based clustering process is applied to select the CHs effectively. Then, the route selection process is done by the DSET-R algorithm for intercluster communication. After the routes are established by the DSET-R algorithm, data transmission has begun from CHs to BS.

2.1. Pigeon Inspired Optimization Algorithm based Clustering (PIOA) Scheme. The key procedure of the newly deployed approach is to select a vital CH over ordinary sensor nodes under the consideration of power efficiency. Hence, the lifetime of a network can be extended. To compute an effective CH election with energy efficiency, RE, distance to BS and distance to neighbors are used. The PIO method is evolved from pigeon homing nature based swarm intelligence (SI) optimization model which contains tremendous advantages.

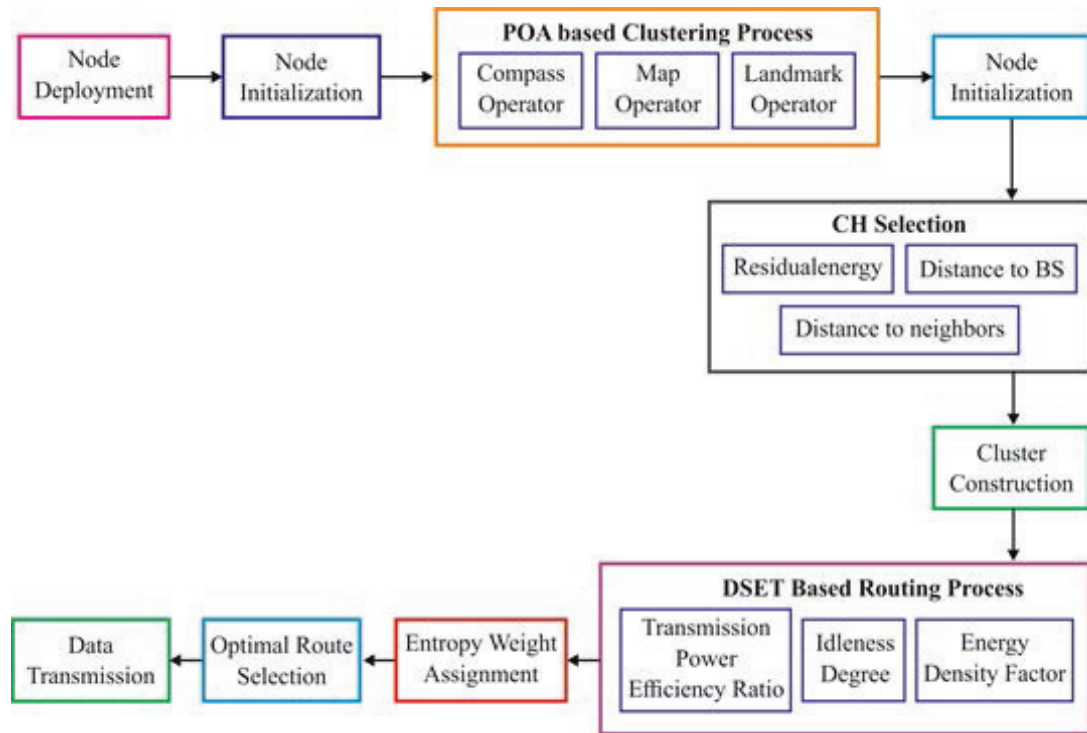


FIGURE 1. Block diagram of PIOA-DS model

Homing pigeons are capable of finding the home or native place with the help of 3 homing primitives they are:

- (1) Magnetic field
- (2) Sun
- (3) Landmarks

Here, a novel bio-centric SI optimizer PIO has been established. The novelty deployed model is composed of a map and compass operator which depends upon the Magnetic Field (MF) and sun, whereas landmark is relied on nearby shops, showrooms, well-known buildings and so on. The analysis of pigeons' capability to predict diverse MF illustrates that, the pigeons' attractive homing talents are based on small magnetic particles which are present in their beaks. In particular, the beaks of pigeons are filled with iron crystals that act as a nose for birds. The research work depicts that, the species have a mechanism such as the signals from magnetite particles are transmitted from nose to brain through trigeminal nerve. Sun plays a major contribution to pigeon direction, either

partially or wholly by means of pigeon's potential of differentiating variations in altitude from Sun at home and the flying point.

2.1.1. Derivation of fitness function. Here, the fitness function for the CH selection relies on three basic parameters namely distance to BS, distance to neighbors and residual energy. Assume that f_1 is a function of average intra-cluster and BS distance of CHs. It is essential to limit the f_1 for best CH election. Suppose f_2 is a function that is a reciprocal of the overall present energy of selected CH. In order to normalize both the objective functions the values should be within 0 and 1. These functions are employed for deriving the fitness function for the optimization algorithm as shown in the formula:

$$\min F = \alpha \times f_1 + (1 - \alpha) \times f_2$$

Subject to

$$dis(s_i, CH_j) \leq d_{max}, \quad \forall s_i \in S, \quad CH_j \in C$$

$$dis(CH_j, BS) \leq R_{max}, \quad \forall CH_j \in S$$

$$E_{CH_j} > T_H, \quad 1 \leq j \leq m$$

$$0 < \alpha < 1$$

$$0 < f_1, f_1 < 1$$

2.1.2. Individual representation in optimization algorithm. For selecting best CHs, few parameters like RE, distance from BS as well as neighborhood ratio. Any node with a higher weight is chosen to be CH. The solution is represented in Fig 2. The first row represented the CH with the corresponding sensor nodes in the second row and their respective positions in the third row. Every iteration indicates that the solution is changed from one position to another position which updates the CHs with the optimal CHs which holds better fitness value.

2.1.3. Steps involved in PIOA model. The steps in PIOA based CH selection are provided in the following.

- (1) Based on the environmental modeling, sensor nodes should be placed in a region and information with coordinates of nodes.
- (2) Upload parameters of PIO method like solution space dimension D, population size N_p , map and compass factor R , count of rounds N_{c1} max and N_{c2} max for 2 operators, and $N_{c2} \max > N_{c1} \max$.



FIGURE 2. Solution representation

- (3) Assign all pigeons with random velocity and path. When comparing the fitness of every pigeon, and identify the recent optimal path.
- (4) Compute map and compass operator. Initially, the velocity and path of pigeons are upgraded under the application of functions. Followed by, the fitness of all pigeons is compared and identify the novel and optimal path.
- (5) When $N_c > N_{c1max}$, terminate the map and compass operator, and start using the consecutive operator. Else, repeat Step 4.
- (6) Grade all pigeons based on fitness measures. A maximum number of pigeons that have minimum fitness would follow the pigeons with maximum fitness based on given function. Identify all centers of pigeons.
- (7) When $N_c > N_{c2max}$, terminate the landmark operator and start generating the outcome.

2.2. Dempster-Shafer (DS) evidence theory based Routing (DSET-R). Here, a new technique for energy effective as well as stable routing has been developed. It depends upon the DS evidence theory using multi-resource decision making model. It has been deployed with a node estimation function that assumes the resource of nodes in 3 indexes they are:

- (1) Transmission power efficiency ratio
- (2) Idleness degree
- (3) Energy density factor

To compute the efficiency of this model, the weight of all indices has relied on various coefficients of entropy values. Under the application of index values, the effective hop node can be selected for energy efficient stable routing. **Definition**

1: Next adjacent node: For estimating the evade data backhaul, it is important and ensures that the data is transmitted to BS. The forward adjacent node set is composed of adjacent nodes in forwarding semicircle area of node i inside a transmission range R . The forward adjacent node set can be expressed as:

$$FAN(i) = a | d_{ia} \leq R_i, d_{as} < d_{is},$$

where, FAN implies a forward adjacent node i , d_{ia} mimics the distance from node i to node a , d_{as} and d_{is} refers to the distances from node i and node a to BS correspondingly, R defines higher transmission range of node i .

2.2.1. DS Evidence Theory. This objective was coined by Dempster and Shafer that is mainly applied for data fusion as well as irregular inference. It has developed a single correspondence among a ratio and set, that is effectively used in data fusion, smart optimization, fault analysis, decision analysis and so on.

Standard probability assignment function: The frame of discernment θ is meant to be a collection of feasible measures of proposition A , $m(A)$ is defined as fundamental SPA function, which represents the degree of stability in proposition A . When $A_\delta \in \theta$, $m(A_\delta) > 0$, and A_δ is named as focal component. Hence, SPA function satisfies the provided demands:

$$\begin{cases} m(\varphi) = 0, \varphi \text{ is null} \\ \sum_{\delta=1}^n m(A_\delta) = 1 \end{cases}.$$

DS evidence fusion rules Let m_1 and m_2 are 2 SPA functions than a frame of discernment θ , as well as focal components are assumed in $A = \{A_1, A_2, \dots, A_f\}$. Followed by, the orthogonal sum of 2 pieces of evidence m_1 and m_2 is:

$$m(A) = (m_1 \oplus m_2)(A).$$

2.2.2. Entropy Weight Assignment. It is known for specific index, as higher the variation of V_{ab} , the smaller EN_b and larger the data provided by this metric, the maximum weight should be provided, hence the weight of an entropy index b is described in the following:

$$w_b = \frac{1}{1 - \frac{EN_b}{\sum_{b=1}^3 (1 - EN_b)}},$$

where $EN_b = -\frac{1}{\ln m} \sum_{a=1}^m \theta_{ab} \ln \theta_{ab}$

3. PERFORMANCE VALIDATION

In this section, a detailed experimental analysis of the presented model takes place under diverse aspects. The proposed method has been simulated using MATLAB tool. Besides, the performance measures used to examine the experimental results are network lifetime, network stability, number of alive nodes and number of dead nodes.

3.1. Alive Node Analysis of PIOA-DS Protocol. Fig 3 examines the network lifetime analysis of the presented model interms of alive node analysis under the node count of 100. The figure exhibited that the FFOA model has shown a reduced network lifetime and the number of alive nodes gets significantly decreased. At the same time, the GOA algorithm has attained a slightly higher network lifetime over the FFOA and has more number of alive nodes. Followed by, the ALO algorithm has tried to exhibit moderate network lifetime and has attained a certainly higher number of alive nodes. At last, the PIO algorithm has reached to maximum network lifetime and has offered highest number of alive nodes.

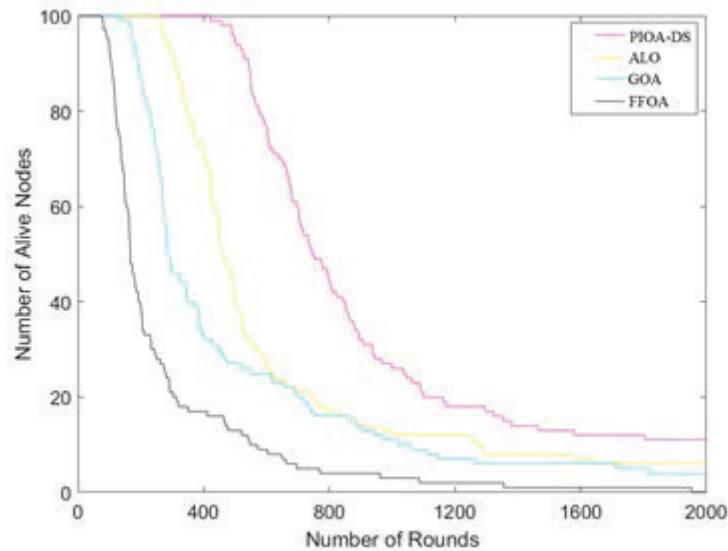


FIGURE 3. Alive Node analysis of PIOA-DS algorithm under node count of 100

3.2. Dead Node Analysis of PIOA-DS Protocol. Fig 4 determines the network lifetime analysis of the proposed approach with respect to dead node analysis under the node count of 100. The figure implied that the FFOA technology has implied the lower network lifetime and count of dead nodes are improved vastly. Simultaneously, the GOA model has accomplished gradual network lifetime than the FFOA and composed of number of dead nodes. Besides, the ALO model has

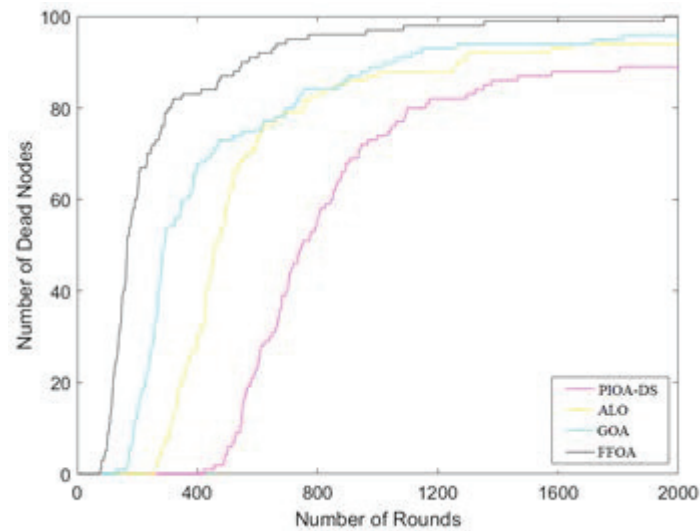


FIGURE 4. Dead Node analysis of PIOA-DS algorithm under node count of 100

tried to show a considerable network lifetime and reached a minimal number of dead nodes. Consequently, the PIO model has attained to higher network lifetime and provided lower number of dead nodes.

3.3. Network Lifetime Analysis of PIOA-DS Protocol. Fig 5 shows the comparative analysis of the PIOA-DS model interms of stability period, HND and network lifetime. The figure depicted that the PIOA-DS method has attained better network stability over the compared methods. Besides, the PIOA-DS method has delayed the HND to a maximum extent compared to existing methods. In overall, the PIOA-DS method has exhibited a higher network lifetime. From the above mentioned experimental results, it is apparent that the PIOA-DS model is found to be effective over the compared methods under varying node count.

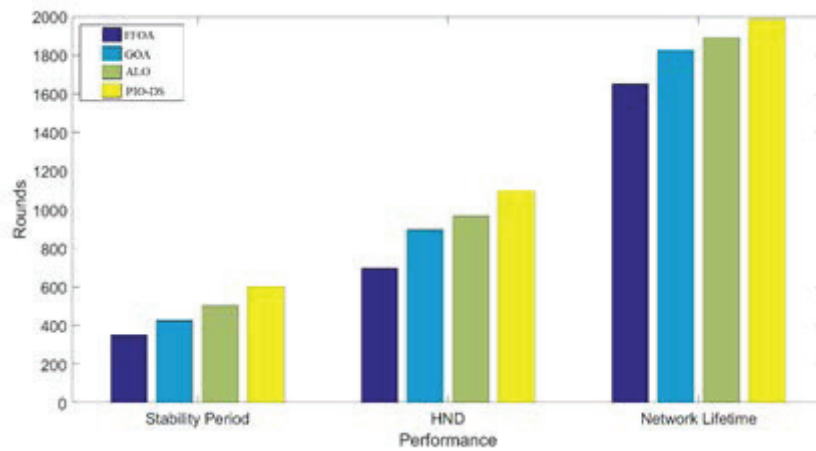


FIGURE 5. Network lifetime analysis of the PIOA-DS method

4. CONCLUSION

In this paper, an energy efficient Pigeon Clustering and Routing protocol named PIOA-DS for WSN has been presented. Once the nodes are initialized, PIOA based clustering process is applied to select the CHs effectively by the use of fitness function involving residual energy, distance to BS and distance to neighbours. Then, the route selection process is done by the DSET-R algorithm for intercluster communication based on three measures namely Transmission power efficiency ratio, Idleness degree and Energy density factor. After the routes are established by DSET-R algorithm, data transmission has begun from CHs to BS. An extensive experimentation is carried out to investigate the effective network lifetime analysis of the presented model. The obtained performance ensured the betterment of the PIOA-DS model over the compared methods in a considerable way.

REFERENCES

- [1] DATTATRAYA, K.N. AND RAO, K.R., 2019: *Hybrid based cluster head selection for maximizing network lifetime and energy efficiency in WSN*. Journal of King Saud University-Computer and Information Sciences.
- [2] ZHU, E., MA, R., 2018. : *An effective partitional clustering algorithm based on new clustering validity index*. Appl. Soft Comput. 71, 608–621.

- [3] ZHANG, D., WANG, X., SONG, X., ZHANG, T., ZHU, Y., 2015. : *A new clustering routing method based on PECE for WSN*. EURASIP J. Wireless Commun. Network. 162, 1–13.
- [4] SINGH, S.K., SINGH, J.P., 2018.: *An energy efficient protocol to mitigate hot spot problem using unequal clustering in WSN* Wireless Personal Commun. 101 (2), 799–827.

PG AND RESEARCH DEPARTMENT OF COMPUTER SCIENCE

SUDHARSAN COLLEGE OF ARTS AND SCIENCE, PUDUKKOTTAI- 622104, TAMILNADU, INDIA.

Email address: alamuinfo@gmail.com

PG AND RESEARCH DEPARTMENT OF COMPUTER SCIENCE

SUDHARSAN COLLEGE OF ARTS AND SCIENCE, PUDUKKOTTAI- 622104, TAMILNADU, INDIA.

Email address: kprabu.phd@gmail.com