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PRESENTING AN OPTIMAL ALGORITHM BASED ON FIREFLY ALGORITHM WITH SPECIFIC PARAMETERS TO SELECT THE CLUSTER HEAD IN WIRELESS SENSOR NETWORKS IN ORDER TO REDUCE ENERGY CONSUMPTION

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Resumen: Las redes de sensores inalámbricos tienen múltiples nodos con propiedades tales como pequeñas, de bajo costo y energía limitada que se utilizan para recopilar información de su entorno. Los métodos que intentan recopilar datos dentro de cabezas de clúster y enviarlos a través de la cabecera de clúster a la estación base mediante la realización de clústeres y la selección de la cabeza de clúster, se consideran uno de los métodos más eficaces para reducir el consumo de energía en dichas redes. En los métodos en los que se aplica la agrupación, la reducción de energía se produce más rápido que los nodos habituales debido a la mayor actividad de los cabezales del clúster, es decir, recopilar datos de los nodos habituales y luego enviarlos a la estación base. La muerte temprana de los nodos conduciría a la reducción de la cobertura en la red, por lo que disminuiría la vida útil de la red de sensores. Por primera vez, el algoritmo LEACH ha aumentado la vida útil de estas redes mediante el uso de enrutamiento y agrupación entre los nodos de la red de sensores inalámbricos. Dado que el problema de optimización del consumo de energía en la red de sensores inalámbricos es un problema NP-Hard y no hay ninguna solución determinística para tales problemas, podríamos intentar mejorar los resultados proponiendo algoritmos más óptimos. El algoritmo firefly es un algoritmo inspirado en la naturaleza. En este trabajo, se propone un algoritmo de luciérnaga optimizado con parámetros específicos para mejorar la búsqueda y aumentar la precisión en la búsqueda que tendría resultados más optimizados sobre los algoritmos anteriores. Los resultados de la simulación muestran que este algoritmo reduce el consumo de energía y aumenta la cobertura en estas redes en comparación con los métodos de la competencia.

Palabras clave: luciérnaga, agrupación, cabeza de racimo.

Abstract: Wireless sensor networks have multiple nodes with properties such as being small, low cost and limited energy which are used to collect information from their environment. Methods which attempt to collect data within cluster heads and send them through the cluster head to the base station by performing clustering and selecting the cluster head, are addressed as one of the most efficient methods to reduce energy consumption in such networks. In methods where clustering is applied, the energy reduction occurs fasters than usual nodes due to higher activity of cluster heads, namely collecting data from usual nodes and then sending them to the base station.

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The early death of nodes would lead to reduction of coverage in the network, so it would decrease the sensor network's lifetime. For the first time, the LEACH algorithm has increased the lifetime of these networks by using routing and clustering among wireless sensor network's nodes. Since the energy consumption optimization problem in wireless sensor network is a NP-Hard problem and there is not any deterministic solution for such problems, we could attempt to improve the results by proposing more optimal algorithms. The firefly algorithm is a nature inspired algorithm. In this paper, an optimized firefly algorithm is proposed with specific parameters to improve searching and increase the precision in searching which would have more optimized results over the previous algorithms. The simulation results show that this algorithm reduces energy consumption and increase the coverage in these networks compared with competing methods.

Keywords: firefly, clustering, cluster head.

1. INTRODUCTION

Wireless sensor networks have a lot of applications in military and civilian cases. These networks have been used widely in target tracking, security, natural disaster monitoring, medical applications, habitat monitoring and building management systems (Yick, Mukherjee, and Ghosal 2005). The sensor nodes sense and detect an environment for disaster prediction in natural disasters. In biometric application, the implanted sensors represent the patient's health status. In earthquake evaluation, sensors are placed in particular regions in order to detect volcano or earthquake (Lorincz, .Malan, J, T. R. F. Fulford-Jones et al 2004). The nodes of the wireless sensor networks have limited energy and battery replacement is almost impossible. Therefore, reducing energy consumption in nodes is a major problem and presenting energy consumption improvement methods is a vital issue for sensor nodes (Wener-Allen, Lorincz, Ruiz et al.,). Usually, wireless sensor networks monitor the given regions by using sensors and then these sensors send information to the base station. A typical wireless sensor network, created hierarchically, has been shown in figure 1. In the hierarchical structure, to save energy, some nodes are selected based on the objective function which act as cluster head and collect data from other nodes. Then, the cluster head sends data to the base station and reduces network overhead and consequently decreases energy consumption at each node. Unlike tradition networks, the wireless sensor networks have their own structure and architecture including limited energy, short transmission range, limited bandwidth and low processing power in nodes. According to the applied scheme, the network size varies based on environment size. One of the most important tasks in WSNs is data aggregation which collects data from neighbors and reduces their redundancy and then propagates them.

The hierarchical algorithms are addressed as an efficient method in data aggregation. The LEACH algorithm performs nodes routing randomly, so it leads to load distribution among sensor nodes. The main idea in LEACH algorithm is that the nodes are selected as a cluster head. This algorithm has two phases. The first one is to create the cluster and the latter one is data relation (Thakar 2012).

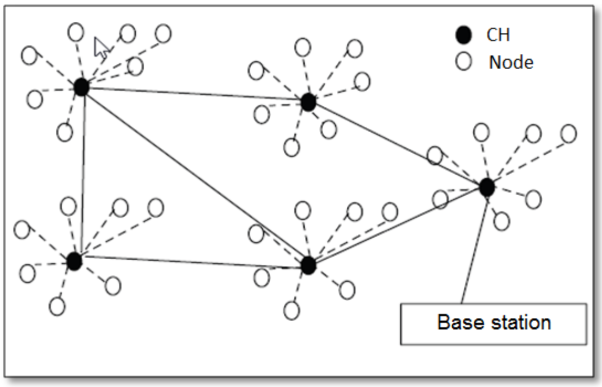

Figure 1. Sensor network with hierarchical clustering

In LEACH algorithm, a random number of nodes is selected and their energy is compared with the threshold energy t(n). If it is less than t(n), the node is selected as the cluster head and otherwise it remains as a normal node in that round. Threshold t(n) is expressed as the following:

$$t(n) = \begin{cases} \dfrac{p}{1 - p*(r \bmod (1/p))} & if \ n \in G \\ 0 & other \end{cases} \quad (1)$$

where p is a percent of cluster heads over all nodes. r is a random number. G is a set of nodes which have not been selected yet as a cluster head in 1/p round of algorithm's run.

To improve LEACH algorithm, many protocols have been presented in recent years. Numerous evolutionary algorithms such as genetic, particle swarms and bee colony algorithms have been presented in this field. In this article, an optimal evolutionary algorithm has been introduced based on firefly algorithm. A new firefly based algorithm is presented to avoid trapping in local optimum. The firefly algorithm works based on the light emitted from the fireflies. This amount of the generated light is applied on the objective function and fireflies move towards a firefly with higher light. In this article, a hybrid firefly algorithm is presented based on the following factors:

1. The power of continuing reproduction to select the firefly.

2. The firefly generated by using the presented method has the best gene among other fireflies.
The advantages of the presented algorithm are as the following:
1. Faster convergence over other methods
2. Avoid trapping in multiple local optima

2. RELATED WORKS

In (Hussain, Abdullah , Awan, Ahsan, and Hussain 2013), a large classification of cluster head selection algorithms in wireless sensor networks has been presented by using comparative analysis. In (Hu,. Han, Wei, and . Chen 2015), a multi hop homogeneous clusters based optimization algorithm[1] has been presented which reduces the number of cluster heads and improves energy consumption by 16.7%. In (Peng, Liu, Li, and Guo 2013), a clustering algorithm has been proposed to decrease energy consumption during broadcasting which increases the network lifetime. In (Bencan, Tingyao, Shouzhi, and Peng 2013), an energy homogeneous clustering system[2] has been presented which allows the alteration in the initial energy of nodes based on distance to the resource in order to save energy. In (Kuila and. Jana 2014), a PSO based algorithm has been given to select the cluster head by using multi-purpose function which takes energy consumption of cluster heads and latency in packet transmission into account. In this algorithm, each domain of the existing particles is equal to the number of sensor nodes within the network. In (Natarajan , Arthi , and Murugan 2013), the combination of LEACH and PSO algorithms has been used to optimal and energy aware selection of clusters and cluster heads. In (Ma, Ma, Huang, and Xu 2013), the dual cluster heads method has been proposed which uses niche particle swarm optimization method[3] with two cluster heads including master and slave cluster heads. In (Ma, Ma, and Xu, 2013), an auxiliary adaptive clustering method with niche particle optimization has been presented to improve system lifetime and data delivery by optimizing energy consumption in the network. In (Hoang , Yadav, Kumar, and Panda 2014), a harmonic search algorithm has been presented to develop cluster based protocols by minimizing the distance of inner cluster across the members of their clusters and head clusters. According to the stated literature, we could observe that the evolutionary algorithms have been used significantly to select the cluster head in wireless sensor networks. The genetic algorithm has good local search features, however it has weak coverage. Considering weights in PSO algorithm is an advantage, so search is limited to local or global space. In this paper, a meta-heuristic method based on firefly life is presented which finds the solution related to the local optimum with coverage fast and presents significant improvement strategy. In (Yang (2009), (2013), it has shown that the PSO method acquires a good global optimum for optimization functions over GA, but the firefly algorithm has higher power over PSO and genetic algorithm in factors such as efficiency and success rate. Also, (Łukasik and Zak 2009) has shown the power of firefly algorithm in optimization in comparison with PSO algorithm. In (Fister, Yang, and Brest (2013), applying firefly algorithm has been studied in different application areas. In this paper, it has represented that the firefly algorithm could manage multiple problems significantly. In (Fister, Yang, and Brest (2013), a set of sensor nodes as S= {S1, S2 … SN} has been considered. Then, a low percent of these nodes are selected as cluster heads. Afterwards, the other nodes are connected to the cluster heads. Next, the cluster heads are selected by using meta-heuristic algorithm and mutation and crossover operators. In (Potthuri, Shankar, Rajesh 2016), a harmonic search algorithm has been introduced which performs clustering based on random search in wireless sensor network. This algorithm has low homogeneity rate and the operations of cluster head selection and clustering is done with lower speed.

3. THE PROPOSED FIREFLY ALGORITHM TO SELECT OPTIMAL CLUSTER HEADS

The firefly algorithm works based on firefly lights (luciferin). The intensity of light radiation helps fireflies to move towards bright places and present an optimal solution within the search space. The algorithm's standardization is explained for some of the firefly features as the following:
1. Each firefly could be attracted by its opposite sex.
2. Attractiveness is proportional to their brightness, and for any two fireflies, the less bright one will be attracted by the brighter one. If the firefly is not able to find a brighter neighbor, it would move randomly.
3. In mathematical model, the brightness of the firefly can be stated as an objective function

In this paper, a new fitness function, energy, end to end latency and packet loss rate are considered as eq. (2).

$$F(x) = \frac{(P_d / P_t) \times (E_i^r / E_{init})}{\exp^{-e_d / e_m}} \quad (2)$$

where p_d is the number of lost packets, p_t is the total number of sent packets, E_i^r is the remaining energy in node i, and E_{init} is the initial energy. e_d is an end to end delay and e_m is the maximum available delay. In the firefly algorithm (Tarachand Amgoth, Prasanta Jana 2015), the changes in brightness and the problem formulation in attractiveness components are important as the objective function. The light intensity is shown as γ. The constant light attraction coefficient and the light intensity I could be calculated in terms of distance r as eq. (3):

$$I = I_0 \ e^{-yr} \quad (3)$$

where I_0 is the original light intensity. The eq. (3) could be stated as equation (4) with an approximation and by using Gaussian rule:

[1] *MHCOA*
[2] *EHCS*
[3] *DCH-NPSO*

$$I(r) = \beta_0 e^{-yr} \quad (4)$$

The attractiveness β for firefly is calculated as eq. (5):

$$\beta(r) = \beta_0 e^{-yr^2} \quad (5)$$

Where β_0 is the attractiveness at $r = 0$. In two-dimensional space, the distance of two fireflies could be stated as an Euclidian distance, $r_{ij} = \sqrt{(x_i + x_j)^2 + (y_i + y_j)^2}$. The firefly i moves to the attractive firefly j using eq. (6):

$$x_i = x_i + \beta_0 e^{-yr}(x_j + x_i) + \alpha(rand - \frac{1}{2}) \quad (6)$$

Table 1. A sample solution of the proposed algorithm

Firefly 10	Firefly 9	Firefly 8	Firefly 7	Firefly 6	Firefly 5	Firefly 4	Firefly 3	Firefly 2	Firefly 1	firefly
1	1	1	1	1	1	0	0	1	0	Solution 1
0	0	1	0	1	1	0	1	1	0	Solution 2
0	1	1	0	1	0	1	1	0	0	Solution 3

Table 2. The new generated solutions after applying crossover and mutation over the previous solutions

Firefl y10	Firefl y9	Firefl y8	Firefl y7	Firefl y6	Firefl y5	Firefl y4	Firefl y3	Firefl y2	Firefl y1	firefly
0	0	1	0	1	0	0	0	1	0	New Solution 1
1	1	0	1	0	1	0	1	1	0	New Solution 2
0	1	0	0	1	1	0	0	1	1	New Solution 3
1	1	0	1	1	0	0	1	0	1	New Solution 4

3.1. Steps of firefly algorithm

1. Generate an initial population of fireflies
2. For each firefly i

For each firefly j

3. If Ii < Ij (j is better than i)

Generate Xi' according to attraction formula

4. Evaluate the new fireflies
5. Determine the best found result
6. Repeat from step 2 until the termination conditions are met

3.2. The application of chaos mapping in the proposed algorithm

A mutation coefficient has been used in the presented algorithm to make diversity and convergence. This mutation coefficient must be altered at each step to obtain better diversity.

One way to change this coefficient is to use linear alteration.

Table 3. the applied network parameters

Parameter	Value
The number of nodes	100
Network size	100*100 m2
BS location	At the centre of network
Initial energy of nodes	1 J

The assumed radio model to transmit messages in the network is the basic model of the presented researches on wireless sensor network clustering. Therefore, we have used eq. (8) to send a message from a node to the BS and eq. (9) to send the message to the other nodes.

In the proposed algorithm, the fireflies are ranked and the best one is selected by racing selection. The selected fireflies reproduce by crossover and mutation. One solution of the proposed algorithm has been represented in table 1. This table shows the general solution for the best obtained fireflies based on the existing selections. After applying the crossover and mutation, the generated fireflies have been presented in table 2. The new solutions are also added to the firefly system and the next iteration runs.

The formulation of the mutation coefficient linear alteration is as eq. (7):

$$\alpha(t) = \alpha_0 + (\alpha_\infty + \alpha_0)\frac{t}{T} \quad (7)$$

In this equation, zero is the initial value and an extreme is a final value to be reached.

We could consider t over T as a coefficient in the range of zero and one. This case is initialized with chaos mapping in the proposed algorithm. The main goal is to decrease alpha per step. Alpha is considered to make diversity in the result; however it must obtain convergence gradually, so we should reduce it gradually in order to reach the final convergence.

4. SIMULATION RESULTS

4.1. Parameters for network simulation

The performance evaluation of the proposed algorithm has been done by MATLAB. The base station in placed in distance 50m from (0,0). This base station has unlimited energy. The following assumptions have been considered in the performed simulation.

1. The nodes are static and there is not any change in their location after placement.
2. All nodes have the same energy during placement.
3. The base station is out of the network.
4. Each node has a unique ID.
5. The transmission power varies in the node in terms of the distance among communication media.

The amount of energy consumed for sending message is calculated by eq. (10):

$$ET_{ij} = 1Ee + 1\varepsilon s\ d_{ij}^2 \quad (8)$$

$$ET_{ib} = 1Ee + 1\varepsilon l\ d_{ib}^4 \quad (9)$$

$$ER = 1Ee + 1E_{BF} \quad (10)$$

In these equations, let l as the message length, ET_{ib} as energy to send a message between the node i and base station. d_{ib} represents the distance between node i and BS. ET_{ij} is energy to send message between node i and node j. d_{ij} is the distance between node i and node j. E_{BF} shows the cost of beam formation, εs is the consumed energy of amplifier to send in close distance, εl is the consumed energy of amplifier to send remote and Ee is the energy consumed in electronic circuits to receive and/or send a message, where all used values are given in table 4.

Table 4. Radio model parameters

Parameter	Value
εs	10 pJ/bit/m2
εl	0.0013 pJ/bit/m4
Ee	50 nJ/bit
EBF	5 nJ/bit
L	Bit

It is assumed that all computations of the presented algorithm are performed in BS and the result of the best clustering and configuration is sent to all the network nodes. BS propagates messages containing complete details on the configuration of sensor network nodes. Nodes receive these messages and clustering is performed. After clustering phase, data transmission phase starts. Nodes send data to their own cluster head, and then the cluster head forward them to the BS or other cluster heads.

The simulations have been done by using Modified HAS, DESA, firefly, EEHC, LEACH and the proposed algorithm. The LEACH algorithm has been used to compare with the proposed algorithm due to its popularity in the previous researches and applying random method.

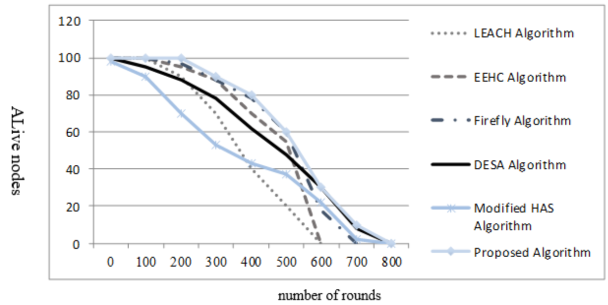

Figure 2. The lifetime spent as a percent of live nodes for different clustering algorithms

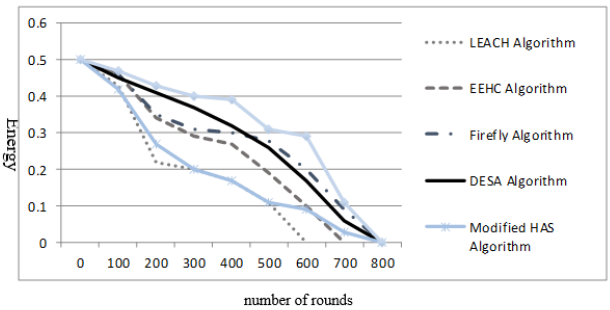

Figure 3. The remaining energy for different clustering algorithms

Figure 2 represents the lifetime of the wireless sensor network. The proposed algorithm minimizes the end to end delay compared with other algorithms and usual firefly algorithm. Figure 3 shows the lifetime spent as a percent of live nodes for different clustering algorithms with 100 nodes. it is observed that the proposed algorithm increases network lifetime in comparison with firefly algorithm.

5. CONCLUSION

In this paper, a new clustering algorithm is presented based on firefly algorithm to select the optimal cluster head in wireless sensor networks. In the proposed algorithm, the best fireflies selected by racing algorithm are allowed to reproduce with crossover and mutation. The proposed algorithm
has higher convergence rate and avoids trapping into multiple local optima. Furthermore, it improves the network lifetime. As a future work, some other particular parameters could be initialized in the firefly algorithm more optimally.

REFERENCES

Bencan G, Tingyao J, Shouzhi X, and Peng C (2013), *An energyheterogeneous clustering scheme to avoid energy holes in wireless sensor networks*, International Journal of Distributed Sensor Networks, vol. 2013,Article ID 796549, 8 pages.

D. Ma, J. Ma, B. Huang, and P. Xu (2013), *Energy-aware clustering protocol with dual cluster heads using niching particle swarm optimization for wireless sensor networks*, International Journal of Advancements in Computing Technology, vol. 5, no. 5, p. 127.

D.Ma, J. Ma, and P. Xu, (2013) *An adaptive assistant-aided clustering protocol forWSNs using niching particle swarm optimization*, in Proceedings of the 4th IEEE International Conference on Software Engineering and Service Science (ICSESS '13), pp. 648– 651, May.

Fister Jr. I, Yang X.-S., and Brest J. (2013) *A comprehensive review of firefly algorithms*, Swarm and Evolutionary Computation, vol. 13, pp. 34–46.

Hoang D. C, Yadav P, Kumar R, and Panda S. K, (2014) *Real-time implementation of a harmony search algorithm-based clustering protocol for energy-efficient wireless sensor networks*, IEEE Transactions on Industrial Informatics, vol. 10, no. 1, pp. 774–783.

Hussain K, Abdullah A. H, Awan K. M, Ahsan F, and Hussain A, (2013) *Cluster head election schemes forWSNandMANET: a survey*, World Applied Sciences Journal, vol. 23, no. 5, pp. 611.

Kuila P and. Jana P. K (2014) *Energy efficient clustering and routing algorithms for wireless sensor networks: particle swarm optimization approach*, Engineering Applications of Artificial Intelligence, vol. 33, pp. 127–140.

Lorincz K, .Malan D. J, T. R. F. Fulford-Jones et al (2004). *Sensor networks for emergency response: challenges and opportunitie*s, IEEE Pervasive Computing, vol. 3, no. 4, pp. 16–23.

Łukasik S and Zak S (2009). *Firefly algorithm for continuous constrained optimization tasks*, in Computational Collective Intelligence. SemanticWeb, Social Networks and Multiagent Systems, vol. 5796 of Lecture Notes in Computer Science, pp. 97–106, Springer, Berlin, Germany.

Natarajan M, Arthi R, and Murugan K (2013) "Energy aware optimal cluster head selection in wireless sensor networks," in Proceedings of the 4th International Conference on Computing, Communications and Networking Technologies (ICCCNT '13), pp. 1–4, IEEE, July.

Peng J, Liu T, Li H, and Guo B, (2013) *Energy-efficient prediction clustering algorithm for multilevel heterogeneous wireless sensor networks*, International Journal of Distributed Sensor Networks, vol. 2013,Article ID 678214, 8 pages.

S. Hu, J. Han, X.Wei, and Z. Chen (2015), *Amulti-hop heterogeneous cluster-based optimization algorithm for wireless sensor networks*, Wireless Networks, vol. 21, no. 1, pp. 57–65.

Sweta Potthuri, Shankar T, Rajesh A, (2016) *Lifetime Improvement in Wireless Sensor Networks using Hybrid Differential Evolution and Simulated Annealing (DESA*), Ain Shams Engineering Journal.

Thakar V. B. (2012), *Performance evaluation & augmentation of LEACH using a novel clustering hierarchy*, International Journal of Darshan Institute on Engineering Research & Emerging Technologies, vol. 1, no. 1,

Tarachand Amgoth, Prasanta K. Jana (2015), *Energy-aware routing algorithm for wireless sensor networks*, Computers and Electrical Engineering 41

Wener-Allen G, Lorincz K, Ruiz M et al., (2006). *Deploying awireless sensor network on an active volcano*,IEEE Internet Computing, vol. 10, no. 2, pp. 18–25.

Yang X.-S. (2009), *Firefly algorithms formultimodal optimization*, in StochasticAlgorithms: Foundations andApplications, vol. 5792of LectureNotes in Computer Science, pp. 169–178, Springer, Berlin, Germany.

Yang X.-S. (2013), *Multiobjective firefly algorithm for continuous optimization*, Engineering with Computers, vol. 29, no. 2, pp. 175–184.

Yick, J Mukherjee. B, and Ghosal. D (2005). "Analysis of a predictionbased mobility adaptive tracking algorithm," in Proceedings of the 2nd International Conference on Broadband Networks (BROADNETS '05), pp. 809–816, IEEE, October.