CCET JOURNAL OF SCIENCE AND ENGINEERING EDUCATION
(ISSN 2455-5061) Vol. - 3, Page-20-24, Year-2018

Energy Optimization in Clustering for Wireless Sensor Networks Using Firefly Algorithm

Yogesh Tamrakar

PhD Scholar, Computer Science & Engg, CSVTU Bhilai, Chhattisgarh, India,
yogeshtamrakar@gmail.com

Abstract

Nature-inspired algorithms are among the most powerful algorithms for optimization. Among the several algorithms, Firefly Algorithm is the motivation behind this paper. Fireflies are attracted to each other according to their light intensity which reduces as their distance increases. In Wireless Sensor Network (WSN) each sensor node consists of a battery, transmitter, receiver and a processor. Replacing or recharging the battery is not possible every time. So load balancing is a critical issue during communication. In this paper, Energy efficient clustering for wireless sensor networks using Firefly algorithm is implemented at the base station. A new cost function has been defined to minimize the distance between sensor nodes within a cluster to optimize the energy consumption of the network.

Index Terms: *Wireless Sensor Network, Clustering methods, Firefly algorithm, Centralized algorithm, Energy efficient clustering.*

1. Introduction

In a Wireless Sensor Network each sensor node is communicating each other using radio signals and deployed randomly or manually to sense any activity in the required area. Due to the limited power supply, designing of wireless sensor network protocol is difficult. Therefore energy efficient clustering algorithms have become a key part in the network lifetime of WSNs.

1.1 Clustering in Wireless Sensor Network

Here, the sensor nodes are divided into small groups, which are called clusters. Each cluster will be having a cluster head (CH), which will monitor the remaining nodes. Nodes in a cluster do not communicate with the sink node directly. They will collect the data and send to the cluster head [1]. Cluster head will aggregate this data and transmit it to the base station. So the energy consumption and number of messages transmitted to the base station will be reduced and number of active nodes in communication is also reduced. In this way the network lifetime is increased. One of the well-known techniques is LEACH (Low Energy Adaptive Clustering Hierarchy) [3]. LEACH is a distributed clustering algorithm, where nodes make decisions without any centralized control. All nodes have a chance to become Cluster Head to balance the energy spent per round by each sensor node.

Main approaches proposed so far are focused on making the changes at MAC layer and network layer. Two more major challenges are to fix the cluster heads over the grid and number of clusters in a network. To tackle with all these challenges clustering has been found to be the efficient technique. In this paper, a centralized, energy aware cluster-based protocol to extend the sensor network lifetime by using Firefly algorithm has been developed. It makes use of a high-energy node as a cluster head and produces clusters that are evenly positioned throughout the whole sensor field. The main idea in the proposed protocol is the selection of intra cluster distance between itself and the cluster member and optimization of energy management of the network.

Optimization problems based on swarm intelligence have features like self-organization, decentralized control, derivative free and easier implementation which lead to an emergent behavior overcoming the limitations of conventional methods. Real world optimization problems belong to a class of hard problems whose main objective is to find the minimum or the maximum of the D dimensional objective function [6] where D represents the number of variables to be optimized.

CCET JOURNAL OF SCIENCE AND ENGINEERING EDUCATION
(ISSN 2455-5061) *Vol. - 3, Page-20-24, Year-2018*

2. System Model

2.1 Network Model

In this section the network model is discussed. Assume that the network consists of N different sensor nodes which can sense, monitor and acquire information and are randomly deployed uniformly within an M×M square region. The following assumptions are made for modelling the network.
All the nodes in the network are stationary and energy constrained.

- Each and every node can perform sensing tasks periodically and always has the data to transfer to the sink (Base Station).
- A fixed base station can be presented inside or outside the network sensor fields.
- All nodes are capable of varying their transmitted power.
- All nodes are eligible to operate either in cluster head mode or cluster member mode.
- Data fusion is used to remove the redundant data.

Data communication is based on the single hop.

2.2 Radio Energy Model

The energy model for the sensor nodes is implemented based on the first order radio model, which is used in [5]. Here the energy dissipation of transmitter is due to running the radio electronics and power amplifier while the dissipation of energy in receiver is because of radio electronics as shown in Figure 1. The energy dissipation is directly proportional to the square of the distance. For longer distances the energy consumption is proportional to where d is the distance between sender and receiver nodes. In order to attain an acceptable SNR for transmitting an l bit message over a distance d, the radio spends the energy given by:

$$E_{TX}(l,d) = E_{TX-elec}(l,d) + E_{TX-amp}(l,d) \quad (1)$$

$$= \begin{cases} l.E_{elec} + l.\varepsilon_{fs}.d^2 \;\; if\, d < d_0 \\ l.E_{elec} + l.\varepsilon_{mp}.d^4 \;\; if\, d \geq d_0 \end{cases} \quad (2)$$

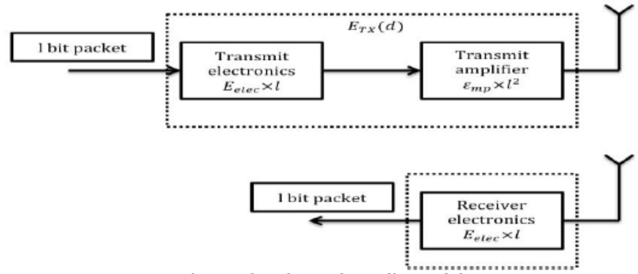

Fig. 1: The First order radio model

While receiving an l bit message, the radio spends:

$$E_{RX}(l,d) = l.E_{elec} \quad (3)$$

Where ETX is transmitter radio energy dissipation, ERX is the receiver radio energy dissipation, is the energy consumption per bit to run the transmitter or the receiver circuit ε_{fs} , ε_{mp} and depend on the transmitter amplifier model used and d0 is the threshold transmission distance which is given by

$$d_0 = \sqrt{(\varepsilon_{fs} / \varepsilon_{mp})} \quad (4)$$

2.3. Protocol Description

Firefly Algorithm (FFA): Firefly algorithm is one of the Meta-heuristic algorithms developed recently by Dr. Xin She yang at Cambridge University in 2007, modeled after the flashing behavior of fireflies. The aim of Firefly Algorithm is to find the particle position that results in the best evaluation of a given fitness function. In this algorithm, there are three main rules [2]:

- All fireflies are unisex i.e. a firefly will be attracted by other fireflies regardless of their sex.
- Firefly's attractiveness is directly proportional to its brightness and it decreases as the distance increases.
- The objective function gives the brightness of a firefly.

The pseudo code for the Firefly algorithm can be prepared based on these three rules.

2.4 Attractiveness and Light Intensity

The light intensity varies according to the inverse square law. The light intensity can be determined as shown below

$$I(r) = I_0 \exp(-\gamma r^2) \quad (5)$$

Where $I(r)$ is the light intensity at a distance r and I_0 is the intensity at the source, γ is the absorption coefficient of the medium. The attractiveness of a firefly is proportional to the light intensity seen by the adjacent fireflies. So the attractiveness β of a firefly is given by the equation (6)

$$\beta = \beta_0 \exp(-\gamma r^m) \quad (6)$$

Where β_0 is the attractiveness at r = 0. $r_{i,j}$ is the distance between any two fireflies i and j, which are located at x_i and x_j respectively. The Cartesian distance is given by the equation:

$$r_{i,j} = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \quad (7)$$

Where $x_{i,k}$ is the k^{th} component of the spatial coordinate x_i of the i^{th} firefly and d is the number of dimensions. The movement of a firefly *i* towards more attractive (brighter) firefly j is given by

$$x_i = x_i + \beta_0 e^{-\gamma r_{i,j}^2}(x_j - x_i) + \alpha\epsilon \quad (8)$$

Where the second term is due to the attraction while the third term α is the randomization parameter.

2.5 Cluster setup using Firefly algorithm

The protocol is a centralized algorithm in which the Base Station runs Firefly Algorithm to determine the best K CHs that can minimize the cost function, which is defined as

$$cost = \beta \times f_1 + (1-\beta) \times f_2 \quad (9)$$

$$f_1 = \max_{k=1,2,\ldots K} \left\{ \sum_{\forall n_i \in C_{p,k}} \frac{d(n_i, CH_{p,k})}{|C_{p,k}|} \right\} \quad (10)$$

$$f_2 = \frac{\sum_{i=1}^{N} E(n_i)}{\sum_{k=1}^{K} E(CH_{p,k})} \quad (11)$$

Where f_1 is the maximum average Euclidean distance of nodes to their associated cluster heads and | $C_{p,k}$ | is the number of nodes that belong to cluster C_k of particle p. f_2 is the function which is the ratio of total initial energy of all the nodes (n_i , i = 1, 2…. N) in the network to the total current energy of the cluster head candidates in the current round. The constant value β is a user defined constant to weigh the contribution of each of the sub-objectives. For a sensor network with N nodes and K predetermined number of clusters, the wireless sensor network can be clustered as follows:

1. Initialize *S* particles to contain *K* randomly selected cluster heads among all the eligible cluster head candidates.
2. Calculate the cost function of each particle:
a. For each node nodes (n_i , i = 1, 2…. N) calculate the distance d(n_i , $CH_{p,k}$) between node n_i and all cluster heads $CH_{p,k}$
b. Assign node n_i to cluster head $CH_{p,k}$
where: $d(n_i, CH_{p,k}) = \min\{d(n_i, CH_{p,k})\}$ for $k = 1$ to K
3. Rank the fireflies and find the current best.
4. Update the position of the particle and limit the change in the particles position value.
5. Map the new updated position with the closest (x, y) coordinates.
6. Repeat the steps 2 to 5 until the maximum number of iterations is reached.

The base station has identified the optimal set of cluster heads and their associated cluster members.

3. Simulation Results

The performance of the Firefly algorithm is evaluated using MATLAB. The simulated network is for 100 nodes in a 200m×200m network area and the base station is located at the center of the area. The following table gives the data considered during the simulation of the network. The performance of proposed protocol is compared with the previously proposed algorithms Particle Swarm Optimization-Centralized (PSOC) [7] and LEACH [3]. The number of clusters is set to be 5 percent of the total number of sensor nodes. The simulations continued until all the nodes consumed all their energy.

CCET JOURNAL OF SCIENCE AND ENGINEERING EDUCATION
(ISSN 2455-5061) Vol. - 3, Page-20-24, Year-2018

Table-1: Summary of parameters values

Parameter	Value
E_{elec} , E_{DA}	50*nJ/bit*, 50*nJ/bit/signal*
ε_{fs} , ε_{mp}	10*pJ/bit/* , 0.0013*pJ/bit/* m^2
l	4000 bits

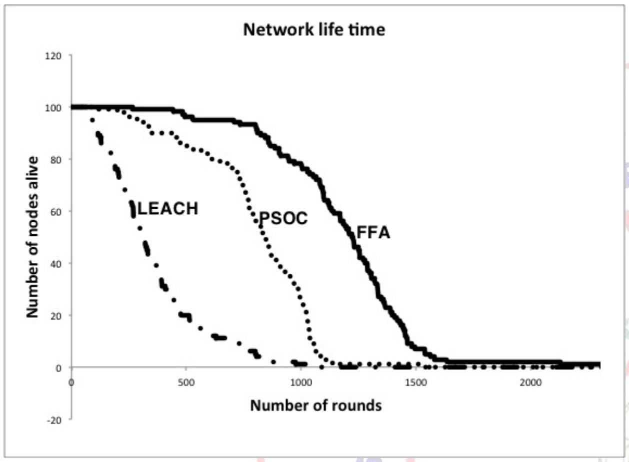

Fig-2: Network lifetime for the nodes with non-uniform energy

Figure 3 gives the network lifetime of nodes having homogeneous energy. From the results it can be clearly understood that Firefly algorithm gives better network life time when compared to other two protocols.

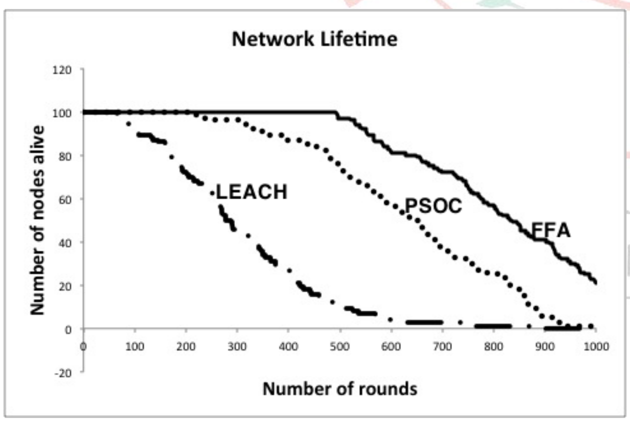

Fig. 3:Network lifetime for the nodes with uniform energy

4. Related Work

N.A.Latiff, et al presented [3] the energy aware clustering for wireless sensor networks using Particle Swarm Optimization (PSO) algorithm, which is implemented at the base station. The aim of PSO is to find the particle position that results in the best evaluation of a given fitness function. During each generation, each particle uses the data about its earlier best individual position and global best position to update its candidate solution.

V. Kumar et al proposed [4] an algorithm to maximize network lifetime in Wireless Sensor Networks (WSNs). The paths for data transfer are selected in such a way that the total energy consumed along the path is minimized. In order to support high scalability and fine data aggregation, frequently sensor nodes are grouped into non-overlapping; disjoint groups or subsets, which are called clusters. Clusters will create hierarchical Wireless Sensor Networks, which develop efficient utilization of limited resources (power) of sensor nodes, so that they extend lifetime of the network.

Wei Cheng el al [5] studied the impact of nodes heterogeneity, in terms of their data amount and energy. They proposed a novel distributed, adaptive, energy efficient clustering algorithm an Adaptive Energy Efficient Clustering (AEEC) for wireless sensor networks, which suits better for the heterogeneous wireless sensor networks.

Lot of work towards clustering is done, but none has studied the application of Firefly algorithm to choose the optimal number of cluster heads.

5. Conclusion

In this paper an energy aware cluster based protocol for wireless sensor networks using Firefly algorithm is implemented for the first time. A new cost function is mentioned, which can take the maximum distance between the cluster head and cluster members and the remaining energy of the cluster head candidates into the account. Results from the simulations indicate that clustering using Firefly algorithm gives a better network lifetime when compared to LEACH [3] and PSOC [7]. Future scope includes the implementation of hybrid optimization technique for clustering in wireless sensor networks.

References

[1] I. F. Akyildiz et al., “Wireless Sensor Networks: A Survey”, Elsevier Sci. B.V. Comp.
Networks, vol. 38, no. 4, Mar. 2002, pp. 393–422.
[2] W. R. Heinzelman, A. Chandrakasan, and B. Hari, “Energy-efficient communication protocol for wireless

micro sensor networks", Proc. 33rd Hawaii Int'l. Conf. Sys. 2000.

[3] N. A. Latiff, C. Tsimenidis, and B. Sharif, "Energy-aware clustering for wireless sensor networks using particle swarm optimization", in Personal, Indoor and Mobile Radio
Communications. PIMRC 2007. IEEE 18th International Symposium 2007, pp. 1–5.

[4] V.Kumar, S.Jain,S.Tiwarietal.,"Energy efficient clustering algorithms in wireless sensor
networks: A survey"," IJCSI International Journal of Computer Science Issues, vol. 8, no.
5, 2011, pp. 259-268

[5] W. Cheng and H. Shi, "AEEC: An adaptive energy efficient clustering algorithm in sensor
networks", in Industrial Electronics and Applications. ICIEA. 4th IEEE Conference on.
IEEE, 2009, pp. 3950–3954.

[6] MA Sasa, Xue Jia, Fang Xingqiao, Liu Dongqing, "Research on Continuous Function Optimization Algorithm Based on Swarm Intelligence", 5th International Conference on Computation, 2009, pg no. 61-65

[7] I˜naki Navarro, Ezequiel Di Mario and Alcherio Martinoli, "Distributed vs. Centralized Particle Swarm Optimization for Learning Flocking Behaviors" Distributed Intelligent Systems and Algorithms Laboratory, School of Architecture, Civil and Environmental Engineering, Ecole Polytechnique F´ed´erale de Lausanne ´ {ezequiel.dimario, inaki.navarro, alcherio.martinoli}@epfl.ch

.