Energy Efficient Cluster Formation in Wireless Sensor Networks Using Cuckoo Search

Manian Dhivya[1], Murugesan Sundarambal[2], and J. Oswald Vincent[3]

[1] Department of Electrical and Electronics Engineering,
Anna University of Technology,
Coimbatore, TamilNadu-641047
saidhivya1@gmail.com
[2] Department of Electrical and Electronics Engineering,
Coimbatore Institute of Technology,
Coimbatore, TamilNadu-641014
mseeecit@yahoo.co.in
[3] SHV Energy Private Limited,
T.Nagar, Chennai, TamilNadu-600017
oswaldrocks@gmail.com

Abstract. Wireless Sensor Networks consist of wide range of applications to be discerned and researched nowadays. The foremost restraint of these Networks is to reduce energy consumption and to prolong the lifetime of the network. In this paper a meta-heuristic optimization technique, Cuckoo Search is used to aggregate data in the Sensor Network. In the proposed technique, the least energy nodes are formed as subordinate chains (or) clusters for sensing the data and high energy nodes as Cluster Head for communicating to the base station. The Cuckoo search is proposed to get enhanced network performance incorporating balanced energy dissipation and results in the formation of optimum number of clusters and minimal energy consumption. The feasibility of the scheme is manifested by the Simulation results on comparison with the traditional methods.

Keywords: Wireless Sensor Networks, Clustering, Cuckoo Search, energy efficiency, Network Lifetime.

1 Introduction

Wireless Sensor Networks (WSNs) are distributed systems, limited in power, memory and computational capacities. The design often employs approaches such as energy-aware techniques, in-network processing, multihop communication and density control techniques to extend the network lifetime. While traditional networks aim to achieve high Quality of Service (QoS) provisions; Sensor Network protocols must focus primarily on power conservation [1]. Hence minimization and conservation of energy is a critical and significant issue in the design of Wireless Sensor Networks. Clustering and classification techniques afford a new dimension to the Sensor Network paradigm. The cluster based routing techniques are viable for a wide variety

B.K. Panigrahi et al. (Eds.): SEMCCO 2011, Part II, LNCS 7077, pp. 140–147, 2011.

of applications in WSN because of their divide and conquer strategy. It is widely accepted that balancing the energy dissipation among the nodes of the network is the key factor for prolonging the network lifetime [2]. Hence efficient data clustering techniques must be used to reduce the data redundancy and in turn reduce overhead on communication [3].

In this paper, Cuckoo Search [4] a metaheuristic approach is used for effective data collection. The least energy nodes are allowed to form subordinate chains or clusters and transmit the collected data to the Cluster-Head. The Cluster-Head (CH) is selected from the best fit of the search process. The CH transmits the aggregated data to the base station. Hence the least energy nodes are first exploited in communication, and periodically the search is done to rule out the inefficiencies of imbalance energy dissipation. The objective is to fairly balance the energy consumption among the sensor nodes, according to their residual energy and to extend the longevity of the network. The obtained results are compared with conventional methods to show the efficacy of the proposed method.

The rest of the paper is organized as follows. Theoretical Background is elaborated in section 2. The network model and the problem are formulated in section 3. Overview of Cuckoo Optimization, Proposed Cuckoo Search, and Methodology is discussed in section 4. Section 5 describes the simulation results. Finally conclusions are drawn in section 6.

2 Literature Overview

Several review articles, survey articles, and techniques are proposed for the past one decade on the energy conservation of WSNs. Low Energy Adaptive Clustering Hierarchy (LEACH) is a distributed single-hop clustering algorithm [5] proposed for energy utilization problem in Sensor Networks. The cluster head's role is periodically rotated among the sensor nodes to balance energy consumption. But cluster head rotation requires that, all the nodes be capable of performing data aggregation, cluster management and routing decisions. This results in extra hardware complexity in all the nodes. Hybrid Energy Efficient Distributed clustering (HEED) is one of the effective data-gathering protocols for Sensor Networks [6]. Both LEACH and HEED are applicable for mobile and static data collection.

Traditional cluster based routing have been extensively exploited. Hence an energy efficient routing protocol should encompass robustness, scalability, minimum overhead or delay, reduce data redundancy, multihop communication and shortest path routing. Therefore parallel solution methods are more desirable for fast Computation. In some duality models the network's optimization problem can be solved by a primal Parallel algorithm for allotted rates and a dual parallel algorithm for shadow prices or congestion signals and energy optimization [7]. The Computational Intelligence techniques and biologically inspired techniques can be integrated to get improved parallel solutions. The previous approaches have constraints in selecting shortest path which might not be a minimum energy cost route, decreasing the energy consumption

by replacing the hop-count routing with minimum energy routing and unpredictable node deaths. Hence Hybrid techniques and novel optimization techniques are utilized to compensate the deficiencies of one algorithm with another and to bring out cooperative performance.

Cuckoo Search is applied for both cluster formation as well as routing of gathered information to the base station. The research problem is divided into two perspectives, as follows: i) Cluster Formation phase and ii) Communication Phase from cluster head to base station. The traditional Cuckoo Search is modified as per the requirements of the proposed problem. To the best of the literature analysis done, this is the first paper incorporating Cuckoo Search technique for Wireless Sensor Networks.

3 Proposed Model

All nodes remain stationary and are initially charged with some base energy. Multihop situation is allowed for better communication link. Nodes can be arranged randomly in the two dimensional space. Constraints required for the base station from the nodes are neglected when the base station is located away from the network area. GPS devices which are used to sense the network nodes are neglected. Noise interference, signal fading and other losses are neglected during communication linkage. The distance between the '*n*' sensors from the base station from the point P (x_i, y_i) is given in (1).

$$d(i, j) = (x_i - x_n)^2 + (y_i - y_n)^2 . \tag{1}$$

$$E_{TX} = \{l.Electrical + \varepsilon_{fs}.d^2 (for\, 0 \le d \le d_{crossover}) \} \tag{2}$$

(or)

$$E_{TX} = \{l.Electrical + \varepsilon_{mp}.d^4 (ford \ge d_{crossover}) \} \tag{3}$$

The amount of energy consumed for transmission E_{Tx}, of *l*-bit message over a distance *d* is given in (2) and (3).

$$E_{RX} = l.Electrical \tag{4}$$

where $Electrical = 50nJ/bit$ is the amount of energy consumed in electronic circuits, $\varepsilon_{fs} = 10\text{pJ/bit/m}^2$ is the energy consumed in an amplifier when transmitting at a distance shorter than $d_{crossover}$, and $\varepsilon_{mp} = 0.0013\text{pJ/bit/m}^4$ is the energy consumed in an amplifier when transmitting at a distance greater than $d_{crossover}$. The energy expended in receiving a *l*-bit message is given in (4). The assumptions for the Sensor Network are adopted from Aslam et al., [8] and the radio model is considered as stated in LEACH.

4 Cuckoo Search

The significance of optimization techniques had led them in the application of dynamic optimization problems like data aggregation and fusion, energy aware routing, task scheduling, security, optimal deployment and localization in Wireless Sensor Networks [9].

```
begin
Objective function f(x), x = (x1, ..., xd)^T
Generate initial population of
      n host nests xi (i = 1, 2, ..., n)
while (t <MaxGeneration) or (stop criterion)
       Get a cuckoo randomly by Levy flights
            evaluate its quality/fitness Fi
      Choose a nest among n (say, j) randomly
      if (Fi > Fj),
            replace j by the new solution;
      end
      A fraction (pa) of worse nests are abandoned and
      new ones are built;
      Keep the best solutions (or nests with quality
      solutions);
      Rank the solutions and find the current best
end while
Postprocess results and visualization
end
```

Fig. 1. Pseudo Code for Cuckoo Search via Levy Flights

Cuckoo search (CS) is an optimization algorithm developed by Xin-She Yang and Suash Deb in 2009. It is a novel algorithm which is inspired by the obligate brood parasitism of some cuckoo species by laying their eggs in the nests of other host birds of other species. In the multi dimensional space where the optimal solution is sought, the CS is carried out for a maximization problem, where the quality or fitness of a solution can simply be proportional to the value of the objective function. Cuckoo Search has similarity to the hill climbing algorithm [10].The CS is based on three idealized rules:

1. Each cuckoo lays one egg at a time, and dumps its egg in a randomly chosen nest.
2. The best nests with high quality of eggs will carry over to the next generation.
3. The number of available host's nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability P_a. In our experiment it is considered as 0.2 for 100 number of nests. The worst nests are discovered and dumped from further calculations.

The pseudo code for cuckoo Search is given in Figure 1.It can also be written in biased way with random step sizes. Equations (5), (6), and (7) give cuckoo search's biased random walk. Step size is determined as given below.

$$\text{Step size} = \text{rand}*(\text{nest}(\text{randperm}(n), :) - \text{nest}(\text{randperm}(n), :)); \quad (5)$$

$$\text{new\_nest} = \text{nest} + \text{stepsize}.*K \quad (6)$$

$$\text{where;} \quad K = \text{rand}(\text{size}(\text{nest})) > pa \quad (7)$$

4.1 Proposed Cuckoo Search

Step 1: Initialization
Select the number of sensor nodes, cuckoo nests, eggs in nests to start the search. Each nest has multiple eggs representing a set of solutions. Initialize the location and energy of nodes and the location of base station.

Step 2: Formation of Clusters using Cuckoo Search

$$f(dfi) = \sum_{i=1}^{n-1} (100 * di) \quad (8)$$

The probability of choosing the best egg or quality egg is done by random walk. Step size and Levy angle is updated. In turn the nests are updated.

Step 3: Communication to the Base Station
In Cuckoo Search the cuckoo tries to find the optimal path by minimum levy angle and random walk. Cuckoo traverses from a source node (Cluster) to the base station by travelling through neighbor clusters.

5 Simulation Results and Discussion

The simulations are carried out in MATLAB (7.11.0.584). A detailed survey and analysis of previous works is carried out and the simulation parameters are chosen in advance. The lifetime of the network is measured in iterations. The traditional methods HEED and LEACH are compared with the proposed scheme, with regard to the parameters relevant to network lifetime and energy consumption. Since the comparison models are LEACH and HEED, the network operation model similar to them is taken for analysis. In the analysis each round consists of a clustering phase followed by a data collection phase. Figure 2 shows the percentage of active nodes versus the number of iterations. In Table 1, the Simulation parameters are listed.

Table 1. Parameters

S.No	parameters	
1	Sensor deployment area	100 m *100m
2	Base station location	(50m,150m)
3	Number of nodes	100-200
4	Number of nests	100
5	Number of eggs in a nest	1-3
6	Data Packet size	100 bytes
7	Number of Rounds	100

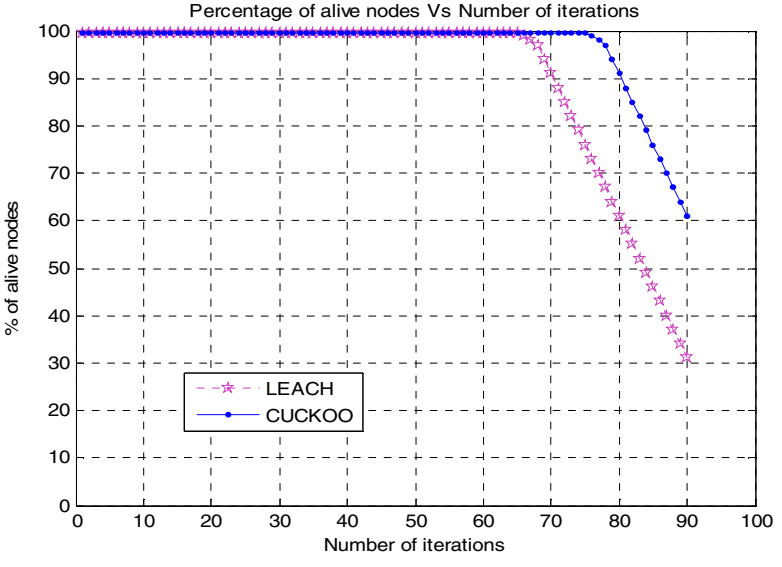

Fig. 2. Network lifetime of 100 nodes vs. iterations

In Figure 3 the network lifetime is compared with regard to the iterations until the first node dies. The life time of a network is usually defined by the number of the nodes alive or percentage of nodes die. Figure 4 shows the number of rounds until the last nodes die versus number of nodes. The time the first node and last node dies are significant in determining the lifetime of the network. Cuckoo Search produces comparable results mainly due to search process in chain formation.

In practical environments, the technique is adaptive to communication and operation management, as the power consumption dominates a node's power budget. Depending on the application, the power break-down and topology of the nodes are varied. The proposed work can be applied for any application entailing unequal energy distribution. For example, in Mobile object tracking, mobile source should track the designated target and retain target track information. Cuckoo Search can be applied for this scenario to form a cluster organization, and chase the object at ease by maintaining track route along a shortened path.

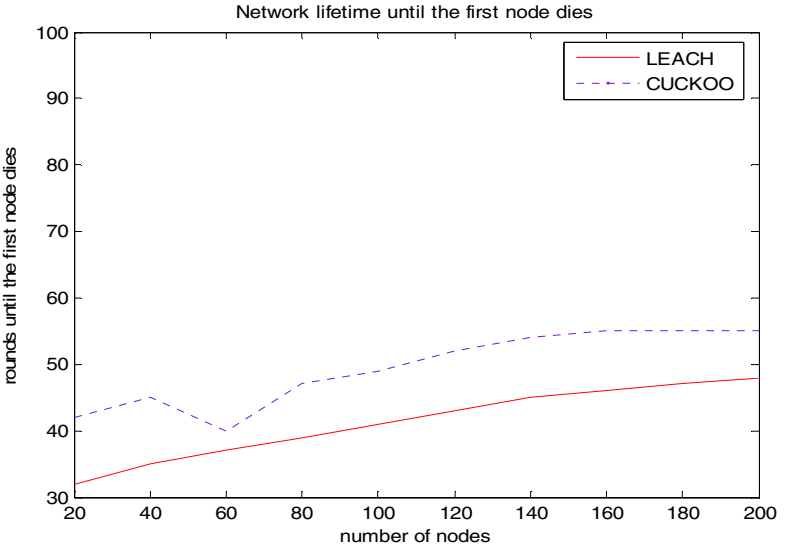

Fig. 3. Network lifetime until the first node dies

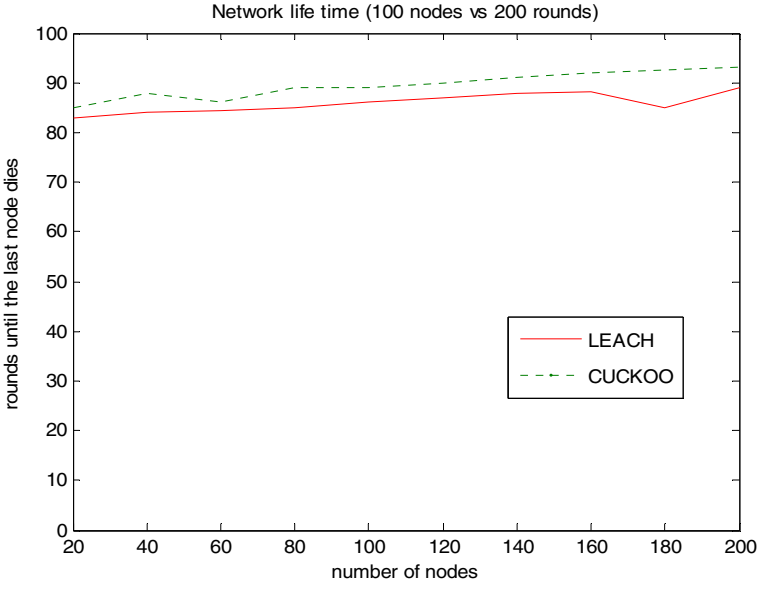

Fig. 4. Network lifetime until the last node dies

6 Conclusion

In this paper Cuckoo Search is applied for balancing the minimal energy dissipation among the Sensor nodes. All the nodes are utilized with equal importance to balance the energy dissipation. This approach incorporates two significant metrics that makes it favorable with respect to energy efficiency when compared to the original Cuckoo search. The proposed Cuckoo Search is compared with the standard LEACH protocol. The simulation results exhibits that, Cuckoo Search enhances the proportion of active nodes by minimum of fifteen percent. Future research will encompass the application of proposed Cuckoo for solving Swarm intelligence techniques combined with cross-layer design and Parameter.

References

1. Akyildiz, I.F., Su, W., Sankarasubramaniam, Y., Cayirci, E.: Wireless Sensor Net-works: a survey. Computer Networks 38, 393–422 (2002)
2. Akojwar, A.G., Patrikar, R.M.: Improving Life Time of Wireless Sensor Networks Using Neural Network Based Classification Techniques with Cooperative Routing. International Journal of Communications 2(1), 75–86 (2008)
3. Chakraborty, W., Chakraborty, A., Mitra, S.K., Naskar, M.K.: An Energy Effi-cient scheme for data gathering in Wireless Sensor networks using Particle Swarm optimization. Journal of Applied Computer Science 6(3), 9–13 (2009)
4. Yang, X., Deb, S.: Cuckoo Search via Levy flights. Paper Presented at the Proc. of World Congress on Nature & Biologically Inspired Computing, (Nabic), pp. 210–214. IEEE, India (2009)
5. Heinzelman, W., Chandrakasan, A., Balakrishnan, H.: An application-specific Protocol architecture for wireless microsensor networks. IEEE Transactions on Wireless Communications, 660–670 (2002)
6. Younis, O., Fahmy, S.: HEED: a hybrid, energy-efficient, distributed Clustering approach for ad hoc sensor networks. Transactions on Mobile Computing 3, 660–669 (2004)
7. Sundarambal, M., Dhivya, M., Anbalagan, P.: Performance evaluation of Bandwidth Allocation in ATM networks. Inderscience, International Journal of Business In-formation Systems 6(3), 398–417 (2010)
8. Aslam, N., Phillips, W., Robertson, W.: A Unified Clustering and Communication Protocol for Wireless Sensor Networks. IAENG International Journal of Computer Science 35(3), http://www.iaeng.org/IJCS/issues_v35/issue_3/IJCS_35_3_01.pdf
9. Dhivya, M., Sundarambal, M., Anand, L.N.: Energy Efficient Computation Of Data Fusion in Wireless Sensor Networks Using Cuckoo Based Particle Approach (CBPA). Int. J. Communications, Network and System Sciences (April 2011), doi:10.4236/ijcns.2011.44030
10. Yang, X.-S., Deb, S.: Engineering optimization by cuckoo search. Int. J. Mathematical Modelling and Numerical Optimization 1(4), 330–343 (2010)