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Abstract

Wireless sensor network (WSNs) are networks of distributed autonomous devices aimed to monitor and record conditions at various locations to send the sensed data to a processing unit. It is not always possible to recharge or replace the sensor nodes in various applications such as in war fields. Therefore, sensor nodes energy depletion is a critical issue in wireless sensor networks. This paper presents a survey of energy efficient clustering techniques using a computational intelligence technique, Genetic Algorithm (GA) in which the power consumption problem is chiefly addressed.

Keywords: Cluster Head; Energy; Clustering; Genetic Algorithm; Wireless Sensor Network, Computational Intelligence

I. INTRODUCTION

Wireless sensor network (WSNs) are networks of distributed autonomous devices aimed to monitor and record conditions at various locations to send the sensed data to a processing unit. Sensor networks are widely used in many applications such as environmental monitoring, habitat monitoring. The network consists of high amount of small, low cost, as well as life-limited sensor nodes. After deployment, it is not always possible to recharge or replace these sensors especially when they are deployed in remote regions such as in war fields or inside the nuclear reactor. Once the battery is depleted, the network is declared dead. Therefore, sensor nodes energy depletion is a critical issue in wireless sensor networks [8]. Researchers have used various Computational Intelligent techniques in WSN to overcome various issues such as depletion of energy in WSN.

This paper presents a survey of energy efficient clustering techniques using one such computational intelligence technique, Genetic Algorithm (GA).

Clustering basically means division of sensor nodes in virtual groups (called clusters) which comprises cluster head and cluster member nodes. Clustering prolongs the network lifetime, reduces communication overhead and provides scalability. Figure 1(b) shows the basic clustered wireless sensor network.

In fig.1 (a) direct transmission from nodes to the sink is taking place which forms the traditional network and in fig. 1 (b) nodes are communicating with the sink via cluster heads. The basic clustering protocol is LEACH. LEACH [1] is a hierarchical, self-organizing, adaptive clustering protocol. It uses randomization for distributing the energy load among the sensors in the network. LEACH has two phases namely set up phase and steady state phase. Nodes transmit data to the cluster heads which transfers the collected data to the sink.

Rest of the paper is organized as follows: Section II provides an brief overview of Genetic Algorithm. Section III gives detailed view of different clustering algorithms using GA. Section IV summarizes this paper.

II. OVERVIEW OF GENETIC ALGORITHM

Genetic Algorithms (GAs) are adaptive heuristic optimization techniques based on the evolutionary ideas of natural selection. The basic techniques of the GAs follow the principles laid down by Charles Darwin i.e. “Survival of the fittest”. In Genetic
Algorithm fitness tests are performed on new structures for selection of the best population. Fitness is the quality of the individual based on the definite criteria. It is an evolutionary algorithm that uses a population of solution candidates called chromosomes. Each chromosome is in the form of a sequence of 0s or 1s. The chance of an individual chromosome depends on the fitness value. Genetic algorithms have three operations: selection, crossover and mutation [2].

The selection operation determines which of the chromosomes from the current population will create new offspring by doing the processes of crossover and mutation. Roulette-Wheel selection, Rank selection and Tournament selection etc are the various selection methods. Chromosome with better fitness has greater chances of selection. After selection process crossover is carried out.

A random crossover point is chosen and the two parent chromosomes exchange the information after that point. The sample of crossover is given in fig. 2.

Parent 1: 1111 | 0101
Parent 2: 1011 | 1110
Offspring 1: 1111 1110
Offspring 2: 1011 0101

Fig. 2: Crossover example

This generates two new child chromosomes (offspring). Crossover depends on the probability defined for it and is called crossover rate. It could be single point or multi point crossover. After a crossover process, mutation takes place. The new offspring only have the traits of their parents and no new genetic material is inherited in the offspring. By mutation there is introduced a new sequence of genes into a chromosome.

Original Chromosome: 11110101
Mutated Chromosome: 11010101

Fig. 3: A mutation example

Figure 3 shows the mutation effect. Here the third bit of offspring is changed from 1 to 0. Unlike crossover probability there is mutation probability by which it changes bit of the new child chromosome known as mutation rate. The chance of survival of that chromosome is more which has better fitness value.

### III. Clustering Techniques using Genetic Algorithm

Critical problem of energy consumption is addressed by clustering a wireless sensor network by various methods using genetic algorithm in following papers.

Genetic Algorithm based Energy efficient Clustering Hierarchy (GAECH) an algorithm for clustering is proposed in [3]. GEACH increases the different metrics namely First Node Die (FND), Half Node Die (HND), and Last Node Die (LND) which are there for analyzing lifetime of the network with a novel fitness function. This fitness function formed well-balanced clusters having considered the key parameters of a cluster, which in turn increased the lifetime and stability period of the network. GEACH have a feature of load balancing among the nodes in the sensor network that is also evenly important and which is generally overlooked by some of the well-known clustering techniques which in turn result in overloading of individual sensor nodes. The experimental results indicated better performance of GAECH over other algorithms.

A new genetic-based approach is presented in [4] that improved the performance of the LEACH protocol for clustering in wireless sensor networks. The proposed approach utilized the mobility feature of nodes for reducing the communication distances between the base station and cluster heads. For every round, new locations of the cluster heads were determined using a genetic algorithm. The results demonstrated that the proposed approach performed better than LEACH in terms of average remaining energy and network lifetime.

In [5] a genetic algorithm (GA) is used for creating energy efficient clusters for routing in wireless sensor networks. The fitness of a chromosome is determined by various parameters, such as energy consumption and node density. The investigation of gradual energy depletion in wireless sensor nodes is also done. The simulation results showed that the proposed hierarchical clustering technique is more energy efficient as compared to other cluster-based routing protocols.

In paper [6], a Genetic Algorithm based method is proposed that optimizes heterogeneous sensor node clustering. The proposed method extends the network life with balanced energy consumption which allows the sensor energy to deplete evenly. The network lifetime is improved with respect to second best performance based on the last-node-die and first-node-die and is 13%, and 33.8% respectively.

In [7], an efficient protocol CFGA (Clustered wsn using fuzzy logic and genetic algorithm) is introduced to increase life expectancy of the network. Here, single - step method is used for intercluster communication and multi – step method is used for intercluster communication. Firstly, in the beginning of each round, fuzzy module is checked by each node, and based on output of the fuzzy module, if the node is capable to be cluster head, it would be ready, after which at the base station by using the location of cluster heads based on minimum energy consumed and genetic algorithm, the optimum network nodes are determined. The existing network energy in the kth period fitness function is as in equation (1) that is minimized.

\[
\text{Fitness} = |E_{\text{net}}^k - E_{\text{net}}^{k-1}| \quad (1)
\]

In this learning, energy consumption for nodes which are not capable of becoming cluster head is prevented.
In paper [8], a genetic algorithm (GA) with hierarchical clustering is incorporated for reducing the long-distance communications. The fitness function used is given as in equation (2).

\[ f = w \cdot (d - \text{dist}_i) + (1 - w) \cdot (n - h_i) \]  

(2)

Here \(d\) is summation of distances of all nodes to sink, \(d\) is the total number of nodes, \(w\) and is predefined weight. The results indicate that this approach is efficient as it decreased the long-distance communications and energy consumption.

In paper [9] there is proposed a method based on genetic algorithms (GAs) for solving a sensor network optimization problem. In this the problem of drainage of the energy of sensors because of long communication distances between the sensor nodes and a sink in a wireless sensor network is addressed. A sensor network is clustered into a number of independent clusters using a Genetic Algorithm to minimize the total communication distance between sink and cluster heads. Here one-point crossover is used. Fitness or F function is given as in equation (3).

\[ F = \frac{100}{E_{\text{essential}}} + \frac{(d_{\text{sink}} - d_{\text{nodes}})}{d_{\text{sink}}} + 10 \cdot \frac{n - c}{n} \]  

(3)

where \(E_{\text{essential}}\) is the essential energy for sending information from cluster to sink, \(d_{\text{sink}}\) is total distance of all the nodes to sink, \(d_{\text{nodes}}\) is the total distance of Regular nodes to clusters and the total distances of all the clusters to sink, \(n\) and \(c\) are number of nodes and clusters respectively. Simulation results showed that proposed algorithm quickly finds a good solution.

In paper [10], there is developed a centralized cluster-based protocol which extends the WSNs lifetime by using global simulated annealing genetic algorithm (GSAGA). Main idea in the proposed method is the selection of a cluster head that could minimize the maximum intra-cluster distance between itself and the cluster members, and the optimization of energy management of the network. Here the genetic selection, two-point crossover and annealing mutation are performed. Simulation results showed that GSAGA had better performance of prolonging the network lifetime under the special environment of applications.

In [11], genetic algorithm based method (GABEEC) is proposed which follows clustering approach like LEACH. The network lifetime is maximized by the means of rounds by using genetic algorithm. There are 2 phases which are Set-up and Steady-state phase. In the set-up phase, the clusters are created which are remained unchanged throughout the network. In every round, there are static clusters with changing cluster heads. The fitness function in genetic algorithm has three parameters namely the round which first nodes dies, the round which last node dies and the cluster distance. The results showed that the proposed GABEEC method is found to be more efficient than LEACH.

In [12] the authors have studied and analyzed the shortcomings of LEACH protocol and then have put forward the improved LEACH-SAGA (low energy adaptive clustering hierarchy- Simulated Annealing and Genetic Algorithm) protocol. In this protocol, there is used the simulated annealing and genetic algorithm to cluster the sensor nodes then calculated the cluster center of each cluster. If the node energy in the cluster is higher than the clusters average energy, it becomes the candidate for cluster head; at last the candidate cluster head becomes the cluster head according to distance from the cluster center of the cluster. Simulations show that it can balance the wireless sensor network load balance and extend the lifecycle of wireless sensor network.

A hybrid algorithm based on Genetic Algorithm and Particle Swarm Optimization is proposed in [13] overcome the clustering problem in WSN. This is done by finding the number of clusters, the cluster heads and the clusters members. We utilize GA is utilized to determine the number of cluster heads and therefore choosing the best ones and PSO is there to select the clusters’ members. Simulation results revealed that algorithm outperforms LEACH and Genetic Algorithm based clustering scheme.

In [14], an efficient clustering technique is developed in which cluster heads (CH) are formed and sends the data to the BS and the role of CH is changed in each rotation. The finalization of the CH is based on the energy distribution. Cluster heads are selected on the basis of its residual energy and GA is used, as a result the load is well distributed and balanced among the nodes. The results show that with this approach the stable operating period is increased.

IV. SUMMARY

First and foremost, introduction to wireless sensor network along with the basic definition of clustering is stated. This paper provides the description of the basics of fuzzy logic. Various clustering algorithms which use the concepts of Genetic Algorithm in wireless sensor network are given in this paper. Applications of Genetic Algorithm in wireless sensor networks are also mentioned in the paper. Furthermore, Genetic Algorithm along with other computational techniques forming hybrid techniques for energy efficient clustering are also stated in this paper.

REFERENCES


