Energy and Trust Aware Clustering based on Genetic Algorithm for Wireless Sensor Networks

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ABSTRACT
Wireless Sensor Networks (WSNs) are gaining a lot of recognition, since it has extensive areas of applications. These networks consist of tiny sensor nodes, powered by a battery source having less power and computational capabilities. These nodes are mostly deployed in remote areas where it is very difficult to replace their batteries.

As battery power is a crucial parameter in the algorithm design, a system based on clustering using a genetic algorithm has been proposed to maximize the lifespan of sensor nodes. In this clustering algorithm, energy is distributed and network performance is enriched by choosing cluster heads on the basis of (i) the remaining energy of sensor nodes (ii) nearest hop distance between the sensor nodes and (iii) trust of the sensor nodes.

To further enhance the network lifetime, the proposed algorithm additionally implements a multihop routing mechanism from source sensor nodes to destination sink using intermediate cluster heads.

To prove the effectiveness, this proposed algorithm has been simulated using Matlab and compared with "Design and Implementation of a New Energy Efficient Clustering Algorithm using Genetic Algorithm for Wireless Sensor Networks"(DINEECAGA)[11]. From the result analysis, it has been shown that the proposed algorithm is far better in terms of energy efficient than the (DINEECAGA) [11].

Keywords
Genetic Algorithm, Cluster Head, Clustering, Wireless Sensor Network, Trust, Multihop.

1. INTRODUCTION
WSNs arecollection of a large number of tiny sensor nodes with the ability of sensing the surrounding information, processing and wireless communication. The sensed data is transmitted through intermediate sensor nodes (Cluster Heads (CHs)) to the sink. WSN is one of the fastest growing technologies in today's era having a wide range of applications in the field of health science, hospitality, agriculture, monitoring, military etc. [1]. One of the most challenging issues is the insufficient battery power of the sensor nodes. Designing of WSN algorithms needs to focus on the parameters to amplify the life span of the sensor nodes and in turn the entire network. Cluster based routing and data aggregation methods are the most admired techniques in WSNs for energy efficiency [2]. The proposed system was inspired by Darwin's theory of evolution [3]. Darwin suggested that the individual who is the fittest will continue to exist in the context of survival [4] [5].

A Similar theory has been used by Genetic Algorithm (GA) based CH selection. Here also, a fittest entity is considered to be the candidate for CH selection. The proposed system first checks the fitness of the sensor nodes using GA and the sensor node with highest fittest and more energetic sensor node becomes the CH, and then the CH forms a cluster of member sensor nodes considering the shortest distance from CH [6][12]. The sensed data is then transferred from the source sensor node (CH) to the destination node (Sink) through multihop routing algorithm considering the intermediate CH nodes to form the route.

The rest of the paper is focused on examining the related work in section 2, and describing the proposed system in section 3. Section 4 illustrates the Implementation and Results of the proposed algorithm and at last the conclusion and future scope is discussed in detail.

2. RELATED WORK
In this paper [7], Abbas Karimi proposed a method of fitness function calculation, which is dependent on difference of energy of chromosomes in the current and previous round. Chromosome with least difference gets selected. The proposed method is successful in increasing the lifetime of the network. The other parameter considered is the number of messages received at the base station. As the number increases, it prolongs the network's lifetime.

In this paper [8], Sudakshina Dasgupta presents a new approach of clustering in WSNs using genetic algorithm. Here a GA is applied by the base station. The basic idea is to evaluate the fitness of chromosomes. Depending upon the fitness value, the next generation can be found, that means chromosomes with higher fitness can be used to produce off springs for the next generation. As a result of GA, clusters are determined and the network details are broadcasted to all the nodes and clusters are formed accordingly. Performance was compared with Low Energy Adaptive Clustering Hierarchy (LEACH) [9] and the method was found more efficient than LEACH.

In this paper [10], Shiuyan Jin proposed a GA based clustering technique. The author has explained the scaling window concept. If individuals have similar fitness value, then which one to select as cluster head becomes problematic. Hence, for selection of a better individual as a CH, the minimum fitness value was subtracted from the fitness value of each individual. i.e. fit(i)=fit(i)-fitmin. The 2D environment was used with 100 nodes. Two different sink positions (0,0) and (100,100) was attempted. The value of certain parameters did not change throughout like population size, selection type, crossover rate, crossover type, mutation rate and generation size.

Moslem Alfrashteh Mehr et al [11] has proposed a method to form energy efficient clusters. Proposed system found the optimum number of CHs. Various parameters used were energy, distance, number of sensor nodes and number of cluster heads. The method was more energy more efficient than LEACH.

3. GENETIC ALGORITHM

Inspired by Darwin's theory, GA starts with a set of solutions (represented by chromosomes) called a population. Solutions from one population are taken and used to form a new population. This is motivated by a hope that the new population will be better than the old one. Solutions which are selected to form new solutions (offsprings) are selected according to their fitness - the more suitable they are the more chances they have to reproduce.

The fundamental fragments of a GA are explained below.

3.1 Crossover

In crossover, two parents are selected based upon the fitness. They are used to reproduce a new offspring. It is assumed that the offspring will inherit the good characteristics of both the parents and will have better characteristics than its parents. For example consider the below scenario where two parents are taking part in the one point crossover, where a random crossover point is selected and bits of the parents' chromosomes are swapped at that point to create a new offspring [2,3,9].

The below example shows the results, before and after cross over.

Before crossover

Parent 1: 100010j**010**

Parent 2: 001000j**110**

After crossover

Offspring 1: 100010j**110**

Offspring 2: 001000j**010**

3.2 Mutation

In mutation, a bit, which is 0 becomes 1 and the bit which is 1 becomes 0. Mutation is applied at mutation probability. After mutation, regular node may become a cluster head and a cluster head may become a regular node. When a CH becomes a regular node, members of that cluster join nearest CH and if a regular node becomes the CH, the nodes which are close to it join this cluster [4, 5].

3.3 Selection

Selection is used to select chromosomes for mating process i.e. crossover. Mating process reproduces new chromosomes, which join current population. This is thencalled as a new generation.

3.4 Fitness function

This is the function of various fitness parameters used to evaluate the fitness of the chromosomes. Fittest chromosomes are used to create a new population.

4. PROPOSED SYSTEM

The proposed system adapts GA parameters to determine the CH and then forms the cluster around it based on the shortest distance between CH and member sensor nodes. Two parameters are considered for the selection of CHs. The first parameter is where the fitness of all the nodes is calculated and then genetic operators such as crossover and mutation on the chromosomes are applied.

The second parameter is based on the trust of that node, which is calculated by the number of successful and unsuccessful events that passed through it. Once both the parameters are fulfilled, the node with the highest energy and highest trust becomes the CH. Once the CHis selected, it clusters and then the sensed data are transferred from CH to CH to Sink through multihop routing protocol, which helps to reduce energy consumption and in turn increases the network lifetime. The proposed system is shown in Fig.1

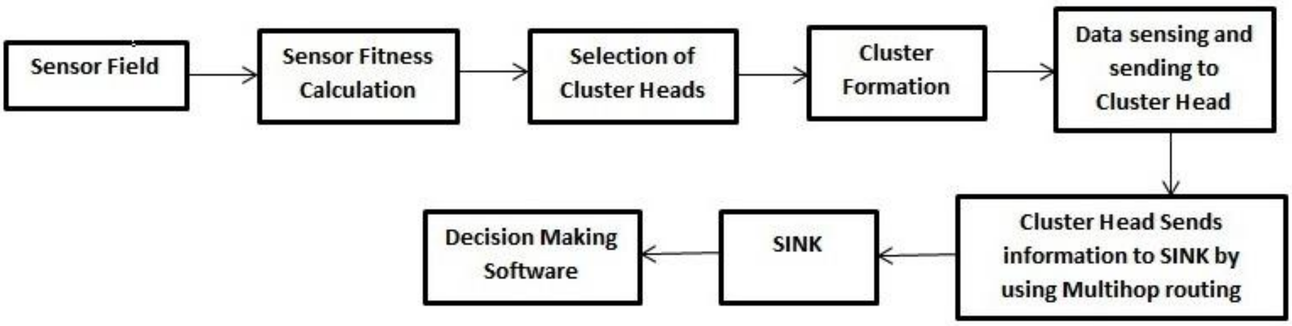

Fig 1: Proposed system diagram

4.1 Energy Computation of Nodes

1. Energy consumption in single non CH node is calculated

$E_{nch} = E_{etx} \times L_c + E_{amp} \times L_c \times d^2_{toch}$

2. Energy consumption in single CH

$E_{ch} = (n/k -1)(E_{erx} \times L_c + (n/k) \times L_c E_{ad} + E_{etx} \times L_a + E_{amp} \times L_c \times d^2_{tobs})$

3. Energy consumption in a single cluster of nodes

$E_{nch} \times (n/k -1) = (n/k -1)(E_{etx} \times L_c + E_{amp} \times L_c \times d^2_{toch})$

Total Energy (TE) = $E_{nch} + E_{ch}$

4. Energy consumption of Multihop transmission

$E_{mhop} = E_{etx} \times L_a + E_{amp} \times L_a \times m^2 + E_{erx} \times L_a + E_{etx} \times (L_a + L_b) + E_{amp} \times (L_a + L_b) \times m^2$

Where E_{etx} : Transmitter Electronics

E_{erx} : Receiver Electronics
E_{amp} : Transmit Amplifier

d^2_{toch} : Distance between CH & Member nodes

L_c / L_a / L_b: Data

n : Number of nodes

k : Number of clusters

(n/k -1) : Number of possible nodes in cluster

E_{ad} : Energy cost for data aggregation

d^2_{tobs} : Distance between CH & BS

m^2 : Distance between CH to CH to BS

4.2 Algorithm for the proposed system

1. Generate random population.
2. Calculate the fitness of all the sensor nodes.
3. Apply crossover and mutation operations.
4. Select sensor nodes with high energy, fitness and trust as CH.
5. Member sensor nodes join the nearest CH based on the distance formula.
6. Member sensor nodes sense data/information and transmit the sensed data/information to the CH.
7. Each and every CH finds its nearest CH and forwards the data/information to sink through multihop routing method.

5. IMPLEMENTATION AND RESULTS

The proposed algorithm was simulated using MATLAB R2009b and compared with DINEECAGA [11]. Table 1 shows the simulation parameters along with their values.

Table 1. Simulation Parameters

Parameters	Values
Number of sensors	20
Area	200m X 200m
Initial Population	20
Initial Energy	1 Joule
Crossover type	1 Point
Crossover rate	0.5
Mutation rate	0.1
Number of Rounds	100

The proposed algorithm has used the random deployment model for the WSN topology setup. The base station was placed in the location (650, 40) away from the sensor field.

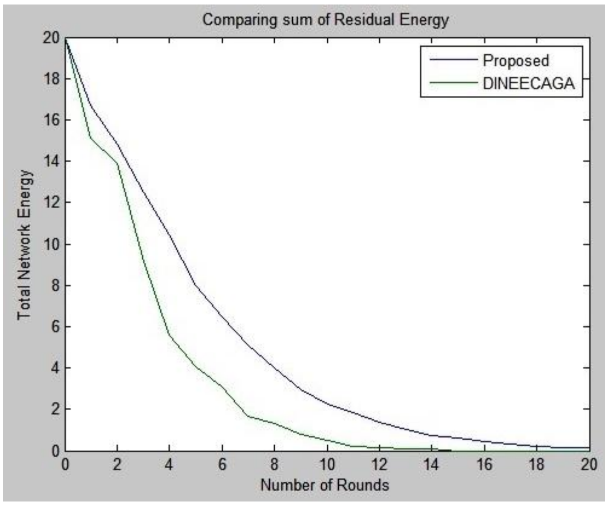

Fig 2: Comparing the sum of residual energy

Table 2. Data for different protocols for total network energy

	Total Network Energy	
Number of Rounds	**Proposed Method**	**DINEECAGA**
0	20	20
5	8.01	4.07
10	2.26	0.51
15	0.64	0
20	0.12	0

Fig.2 shows the total network energy with respect to the number of rounds. Initially it started with 20 Joules as shown in the graph. In the 16^{th} round, the proposed algorithm had0.64% more than DINEECAGA, which had completely exhausted. From the graph it clearly depicts that the proposed algorithm is better in terms of the total network, energy, i.e. residual energy of each node.

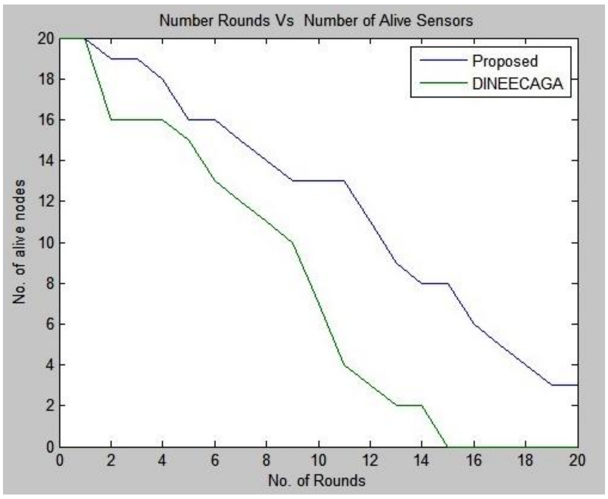

Fig 3: Number of alive nodes

Table 3. Data for different protocols for alive nodes

	Number of alive nodes	
Number of Rounds	**Proposed Method**	**DINEECAGA**
0	20	20
5	16	15
10	13	7
15	8	0
20	3	0

Fig.3 presents the number of alive nodes with respect to the number of rounds. Initially, all the sensor nodes were alive and at 15th round, the proposed algorithm was able to save 8 sensor nodes which could go on for few more rounds. It clearly depicts that the proposed algorithm is better in terms of number of alive nodes.

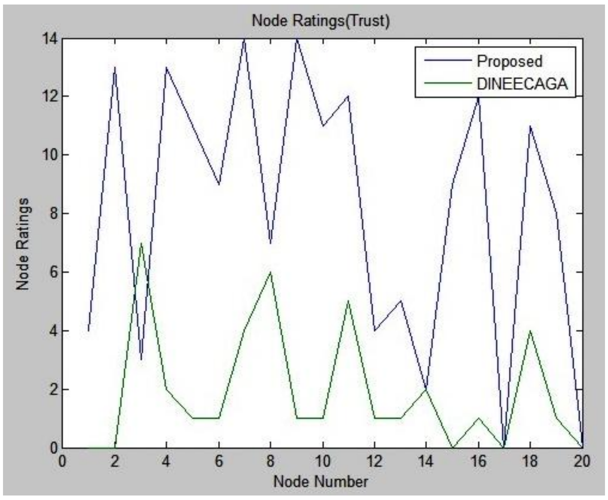

Fig 4: Trust of sensor nodes (in terms of rating)

Table 4: Data for different protocols for nodes ratings

	Node Ratings	
Node Number (Node ID)	**Proposed Method**	**DINEECAGA**
1	4	0
5	11	1
10	11	1
15	9	0
20	0	0

Fig.4 shows the trust of each sensor node. As compared to DINEECAGA, the proposed system had more trusted nodes and was able to route the data with great ease. From the above figure, it is clear that this proposed algorithm has more trusted nodes than DINEECAGA.

6. CONCLUSION AND FUTURE SCOPE

In this paper, a novel algorithm has been proposed based on the dynamic formation of clusters, CH and trust of the sensor nodes using Genetic Algorithm. Cluster information is broadcasted to each of the sensor nodes and thus routing mechanism could be formed. The results of this simulation study indicate that the proposed method conserves more energy than the existing ones. In future work, the focus will be to improve the scalability and trustworthiness of the network by considering a wide range of simulation parameters.

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