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Cluster Formation based Comparison of Genetic Algorithm and Particle swarm Optimization Algorithm in Wireless Sensor Network

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Abstract—Wireless Sensor Network is a network of small sensor nodes which sense the environment for various monitoring purposes of real life applications like military or commercial, which are required to be deployed in areas with no connectivity to the outside world. But, these nodes come with a limitation of having short battery life which needs to be recovered by applying various optimization techniques. In this paper, we are comparing two optimization algorithms that are Genetic algorithm and Particle Swarm Optimization algorithm, on the basis of their cluster head selection and cluster formation techniques to solve the problem of energy consumption by sensor nodes. We are experimenting with the different number of clusters to check the efficiency of each algorithm in MATLAB (simulation tool).

Keywords— Genetic Algorithm Clustering, Energy efficiency, Particle Swarm Optimization, Wireless Sensor Networks

I. INTRODUCTION

A sensor network is a collection of sensors which are nodes that sense the environment and compute the values, then sent to a specific base station for administration and observation of that particular area. Some of the applications of sensor network are data collection, surveillance and monitoring.

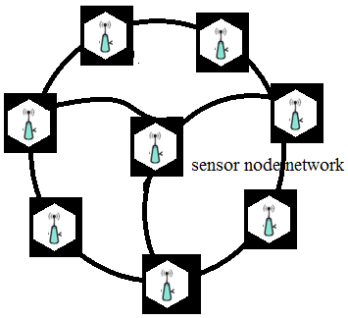

Figure 1. Sensor Node Network

Figure 1 depicts the sensor node network containing nodes as sensors interconnected with each other.

Wireless Sensor networks or WSNs are the collection of wireless sensor nodes which are of compact size and measure the environment conditions and send the useful data to a base point for appropriate processing of data. WSNs can communicate with the neighbouring nodes and perform basic computations on the data. They are inexpensive and durable. They can be deployed in a uniform or random nature, on land or underwater or places which are difficult to reach. They work without being affected by the geographical area in which they are installed.

Each wireless sensor is equipped with a battery that has a limited life. Thus the lifetime of the sensor node is highly dependent on life of its battery. It is not always possible to use a power source close by to provide power to the nodes. The main power drain is through the three important operations which are sensing, computation and communication. Sensing is the capability of the node to produce a measurable response to change in a physical condition like temperature or pressure. Computation is the task of processing the data and controlling the other components in the sensor node. But most of the node's energy is used in communication. The more the distance

between the communicating nodes, more the energy is consumed. The death of one node soon is succeeded by the death of others and nodes isolation. Therefore, managing energy consumption is an important in WSN [2].

For efficient collection of data from all the nodes of the network, the nodes are grouped in such a way that each group has a limited number of nodes which sense the data from environment. Such grouping of nodes into clusters is known as clustering. Each cluster has a head which combines the data from every node and forward it to the base station. It is known as Cluster-Head (CH). It is selected such that it has better resources in terms of energy and sensing capability.

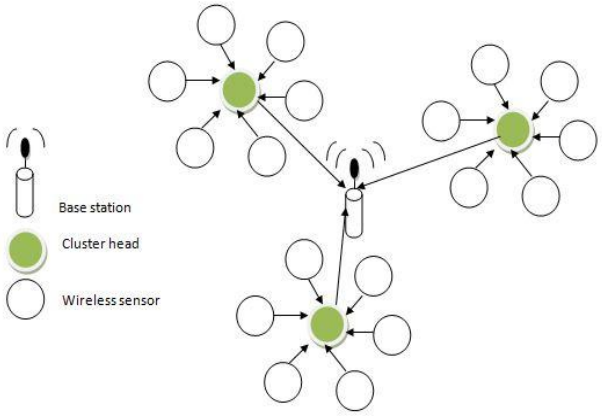

Figure 2. A Clustered WSN

There are certain advantages of clustering like:
1. It minimizes communication overhead
2. Enhances resource use. For example, non-neighbour clusters can use the same communication frequency.
3. Scalability; nodes can join or leave the group without affecting the entire network.

A Clustered WSN is a network made up of clusters containing wireless sensor nodes.(Figure2).If a central node fails in WSN then the entire network will suffer its consequence and hence there is no reliability in centralized clustering mechanism. However, in distributed clustering mechanism, the nodes are reliable, serve better collection of data and provide backup in case of node failure. Since there is no centralized body to allocate the resources, they have to be self-organized. Distributed clustering is the mechanism in which, there is no fixed central CH and the CH keeps on changing from node to node based on some pre-assigned parameters[1,5].

Wireless sensor network is a network of sensor nodes which work in a wireless state to sense the environment. It consists of the following components:

1) Sensing unit-sensors that measure data from the surroundings
2) Processing unit-it processes the data collected from the neighboring nodes.
3) Transceiver -it sends and receives data using communication media.
4) Battery- unchangeable and irreplaceable limited battery.

We are comparing two optimization algorithms which help in better cluster head selection and cluster formation that are Genetic Algorithm and Particle Swarm Optimization algorithm. The comparison of both the algorithms is done in MATLAB on the basis of their fitness functions and their energy consuming capacity. Rest of the paper is organized as Section I contains Introduction to Wireless Sensor Networks and its limitations. Section II contains the research objective of the paper. Section III contains the Genetic Algorithm and its pseudo code. Section IV contains the study of PSO algorithm and its flow chart. SectionV contains simulation of the results in MATLAB and bar graphs. Section 00000000VI contains the conclusion with future scope.

II. RESEARCH OBJECTIVE

In this paper, we are comparing the two optimization algorithms- Genetic and Particle Swarm Optimization algorithm on the basis of cluster head selection and cluster formation techniques in wireless sensor network. Both the algorithms use different operators which are to be examined to find how they affect the algorithms and results.

III. GA ALGORITHM

Genetic Algorithm (GA) is a swarm intelligence based algorithm that focuses on natural selection. This technique finds the optimal solution to optimization and search problems. It uses techniques based on natural selection like inheritance, mutation, selection and crossover [3].

The problems starts with the randomly generated population of individuals and the population is evaluated by its fitness function which should be the best for optimized solution to the problem (Figure3).In each iteration, a small portion of population is selected to breed a new generation. This process is called selection process. The next step is to choose from the second generation generated from operators like mutation and crossover which develop the offspring's. For each new solution to be produced, a pair of parents are selected from a pool and a child is created using methods of mutation and crossover which results in next generation of chromosomes population completely different from initial generation. This process continues until a termination state is reached.

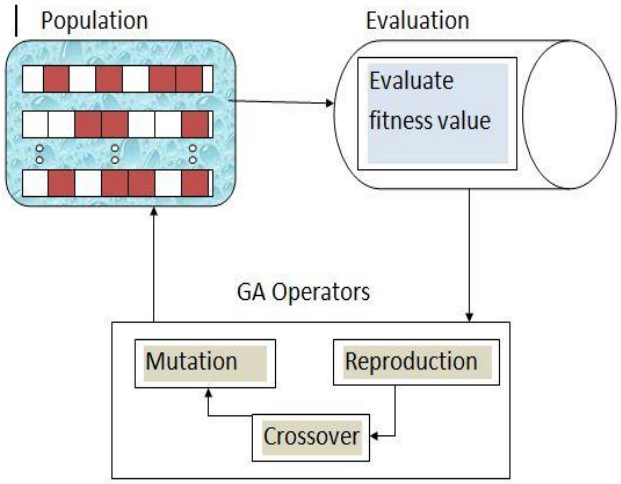

Figure 3. GA Evolution Flowchart

The process terminates when the satisfactory value of fitness function is normally achieved.
The Pseudo code for a Genetic Algorithm is as follows:

1. Begin
2. u=0;
3. initialize population [P(u)];
4. evaluate population [P(u)];
5. while(termination conditions are unsatisfied),do
6. begin
7. Create new solution P'(u)=Variation[P(u)];
8. Evaluate the new solution with variants ,P'(u)
9. Apply genetic operators to generate next generation population, P(u+1)
10. u=u+1;
11. end
12. end

IV. PSO ALGORITHM

Particle Swarm Optimization is an algorithm that works on a group of particles just like a swarm of bees or a flock of birds. It optimizes the problem by computing the particle's velocity and position. It works on a population of particles and moving them in a search space with their positions and velocities. Each particle position is influenced by its local best position but also by the better positions given by other particles known as best positions in search space[8].

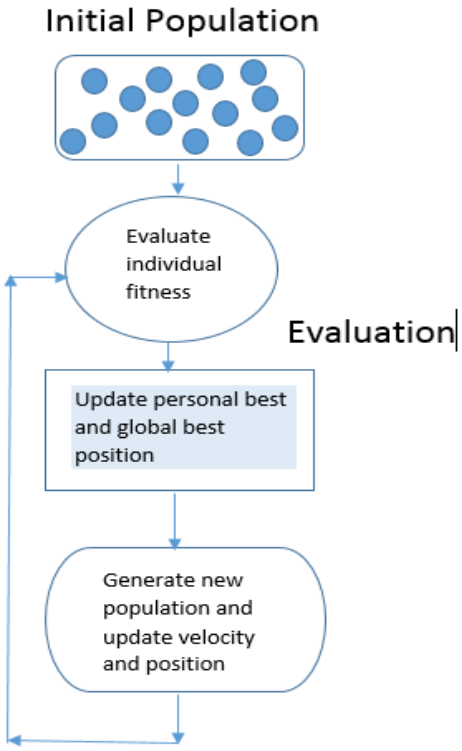

Figure 4. PSO Algorithm Flow Chart

The basic PSO algorithm consists of three steps, namely, generating particles positions and velocities, velocity update, and finally, position update. Here, a particle refers to a point in the design space that changes its position from one position to another (Figure4).

There is a global best position which is close to the target, and followed by all the birds with their local best positions. In every single iteration, velocity and positions are evaluated and updated according to the global best position the particles. The entire process is repeated until the global best position is obtained or the number of maximum iterations is reached.

The global best position of particle changes when its local best is closer to the target than the global best.

The Pseudocode for PSO algorithm is as follows:

1. Begin
2. t=0;
3. initialize particles P(t);
4. evaluate particles P(t);
5. while(termination conditions are unsatisfied)
6. begin
7. t=t+1;
8. Update weight

9. Select pBest for each particle
10. Select gBest from P(t-1);
11. Calculate particle velocity P(t);
12. Update particle position P(t)
13. Evaluate particles P(t)l
14. end
15. end

V. SIMULATION AND RESULTS

The results are obtained by using cluster head selection and cluster formation techniques of GA and PSO in MATLAB R2013a. The results are optimized on the basis of following parameters of both algorithms:

A. NUMBER OF CLUSTERS

CASE 1. When k (number of clusters) = 3

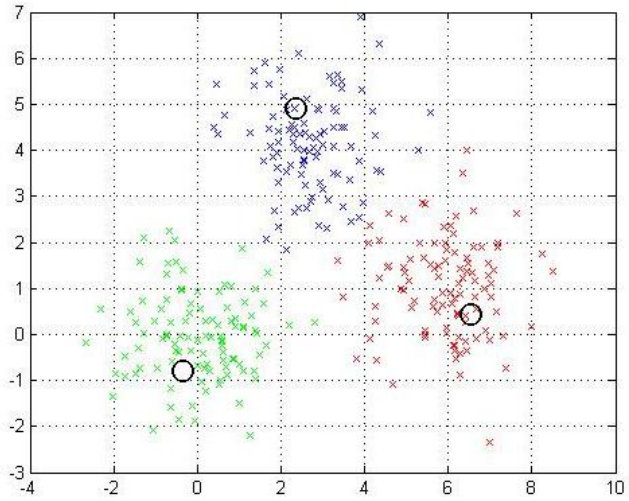

Figure 5. Clusters with cluster heads = 3

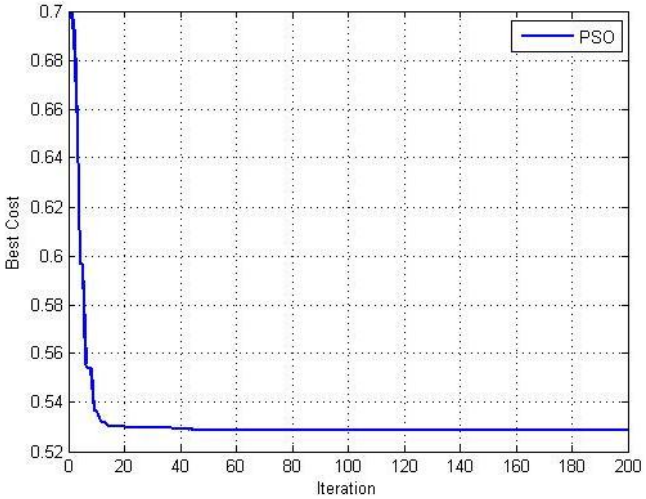

Figure 6. PSO Best Cost vs Iteration

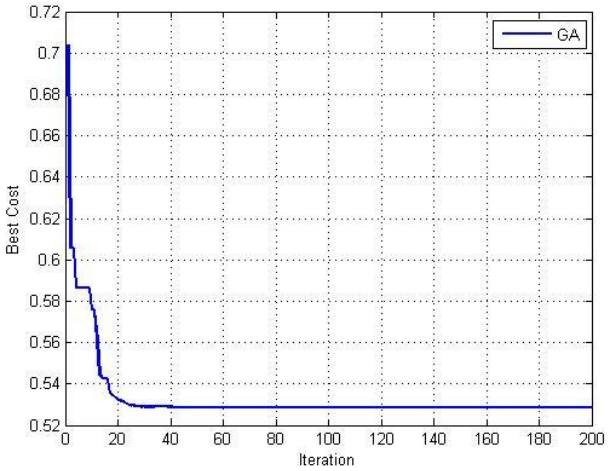

Figure 7. GABest Costvs. Iteration

In the figure5, 3 clusters are formed according to the value of k, and their clusters heads are identified with small circles. Figure6 and Figure7. Gives the graph of Best costvs. Iterations. Here, Best cost is considered as the sum of the Euclidean distancesi.e. the sum of distance between the nodes and the cluster heads in their respective clusters. Initially, Best cost is high because clusters heads are selected randomly, therefore the distances will be more than assigning cluster heads near the nodes after 200th iteration. So, the Bestcost keeps on decreasing and reaches the stable value till termination criteria is fulfilled [4].

A fitness function is determined which is to be maximized or minimized according to the required scenario. In this case, fitness function is defined as 1/u where u= sum of Euclidean distance between the nodes and the cluster head. Since, sum of nodes should be minimized so that the distance between the nodes is less and there is less consumption of energy of sensor nodes for better transmission of data. Therefore, the fitness function will be maximized to optimize theWSN.
In this case, the number of clusters are 3 in a population of 100 particles, therefore, both the algorithms perform equally and the Best Cost remains same as 0.52874. The lesser the best cost, better is the algorithm.Now, we can take for more number of clusters.

CASE 2. When k (number of clusters) = 7

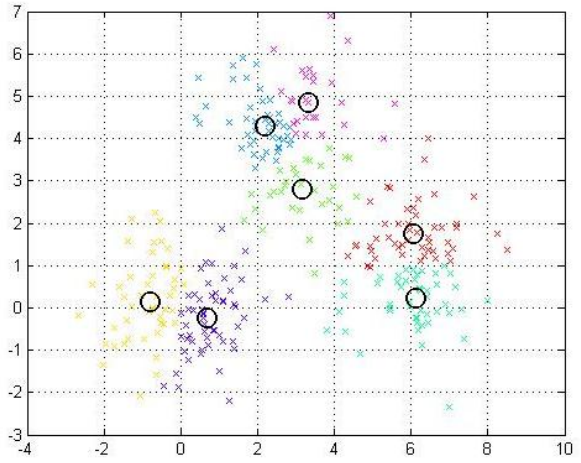

Figure8. Clusters with cluster heads = 7

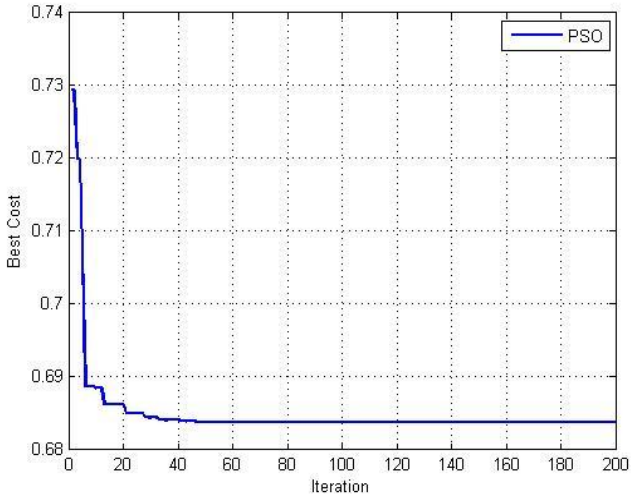

Figure9. PSO Best Costvs. Iteration

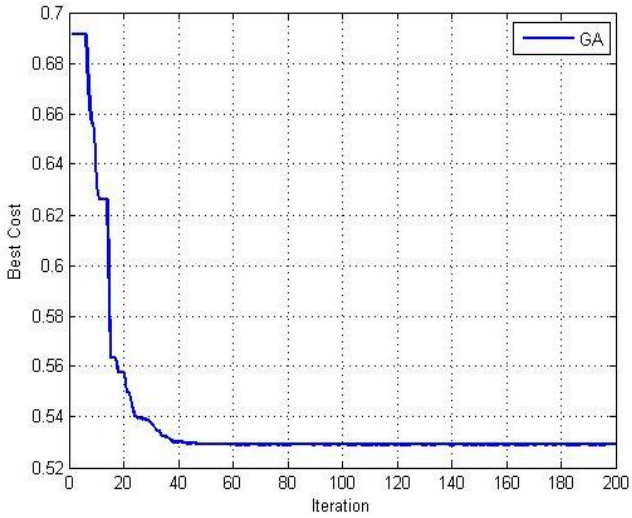

Figure 10. GA Best Costvs. Iteration

From Figure9 and Figure10, where the number of clusters = 7, we can infer that the Best Cost of GA is 0.52918 and the Best Cost of PSO is 0.6823 which is greater than that of GA. But for our fitness function to be maximized, we know that the Best Cost must be minimized, so in this case, GA is better than PSO.

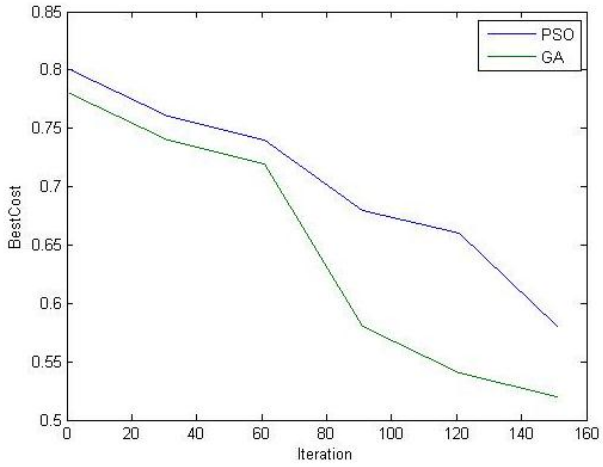

Figure 11. Best Cost PSO vs. GA

We get to know that fitness function also depends upon the number of clusters. More the number of clusters, less is the fitness value because use of more clusters is not feasible as energy consumption of cluster heads is more than that of the nodes (Figure11).

Figure11 shows the comparison of Best Cost between GA and PSO in which the value of Best Cost for GA decreases more than that of PSO.

We have experimented with the various values of number of clusters as k=3, 7,11,15,19etc. and got the following BAR graph.

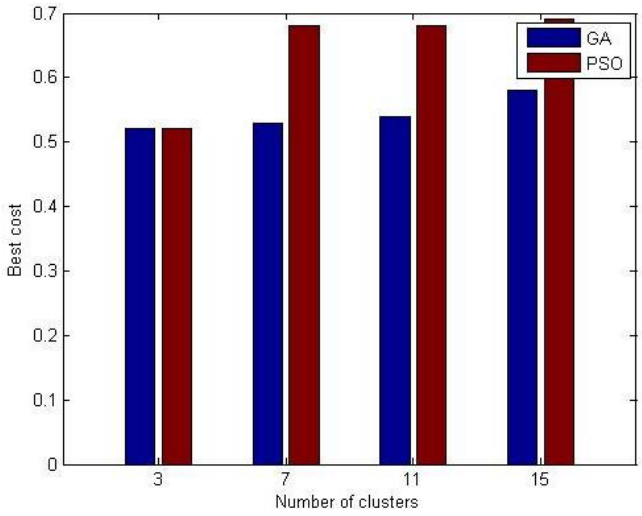

Figure 12. Comparison of GA and PSO on the basis of fitness value

From the bar graph in Figure12, we can clearly see that as the number of clusters are increasing, Best Cost of PSO is increasing than the Best Cost of GA and overall also, the Best Cost of both the algorithms are increasing due to more requirement of handling clusters(Figure12).
Comparison table is as follows:

TABLE 1. PSO VS. GA

No of clusters i.e. K	No of iterations	Population size	Best cost for PSO	Best cost for GA
3	200	100	0.5284	0.5284
7	200	100	0.6812	0.5361
11	200	100	0.6923	0.5436
20	200	100	0.7399	0.70275

It clearly defines that on the basis of fitness value, the Best Cost by GA is less than PSO(Table1).
However, if we increase the number of clusters like 20, then the cost of both algorithms will increase because more clusters lead to more management of the WSN.

B. EXECUTION TIME

PSO and GA algorithms are also compared on the basis of their execution time i.e. how much time each algorithm takes to find the optimum cluster head and cluster formation [1].

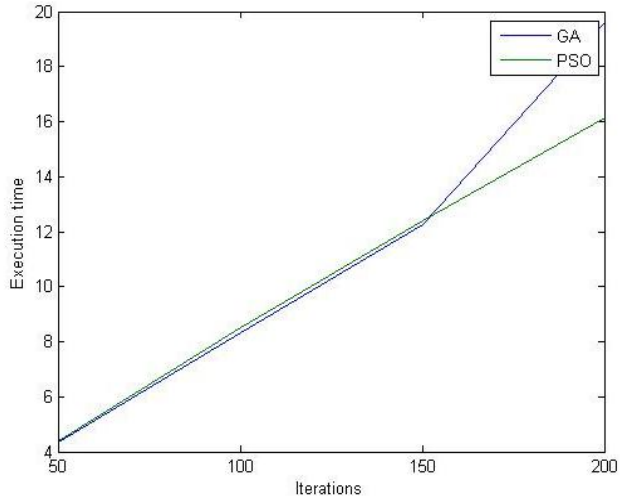

Figure13. Execution time based Comparison

From this graph, Figure13, we can see for less number of iterations, both PSO and GA take equal time but for more iterations, i.e. more optimized solution, GA takes more time than PSO [7].
We can infer that GA has more number of operators such as selection, mutation and crossover which takes more time to execute the Best Cost of the individuals in comparison to the parameters of PSO that are velocity and position(Figure13).

C. ENERGY CONSUMPTION REDUCTION

We have calculated the reduction in energy consumption with the number of clusters. Energy consumption is the energy consumed by the nodes while forming the clusters. Therefore, reduction in energy consumption to find the optimum solution with increasing number of iterations is a must.

Reduction in energy consumption is calculated by the formula:
= ((best cost)-(worst cost))/ (worst cost)

Since, the worst cost is always more than the optimized cost, the answer is in negative so as the reduction required.

More the reduction in energy consumption, better is the performance of the algorithm. In this case, we got the results as follows:

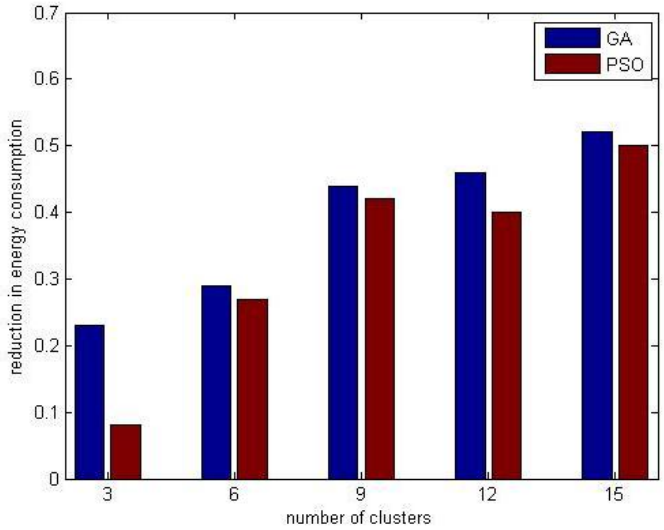

Figure14. Reduction in energy consumption

TABLE 2. SHOWING REDUCTION IN ENERGY CONSUMPTION BY BOTH THE ALGORITHMS

No of clusters i.e. K	No of iterations	Population size	Reduction in energy consumption for PSO	Reduction in energy consumption for GA
3	200	100	8%	23%
7	200	100	42%	44%
11	200	100	46%	48%

Initially, the number of clusters is less, so GA reduces energy consumption more than PSO and increase in clusters lead to same reduction eventually (Figure14).Since, more the

reduction % , the less energy is consumed by the nodes to form the optimized clusters by selecting the best value for Cluster head which can communicate between all the nodes thus using less energy for more reliable transmission of information to the base station[6].

VI. CONCLUSION

In this paper, we compared two algorithms- Particle Swarm optimization and Genetic algorithm on the basis of their fitness functions calculated by the Euclidean distances. Performance evaluation is done in MATLAB and simulation graphs were recorded and discussed to find the better algorithm for cluster head selection and cluster formation. The results prove that GA is better than PSO in maximizing fitness value and reduction in energy consumption by the nodes of the network. However, the execution time of GA is more than PSO with increase in number of iterations but that can be managed to get the optimized results of the problems.
In WSN, cluster head selection is an important task to connect the rest of the nodes because nodes have limited energy and short battery life. GA does it better though taking more time than PSO.

VII. FUTURE SCOPE

In this paper, we compared PSO and GA on the basis of reduction in energy consumption by the nodes, fitness functions and the execution time taken by both. In future, more parameters can be considered such as load balancing factor among the sensor nodes and burden balancing cluster head selection which can be used to get more optimized results of cluster formation in wireless sensor networks.

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