# Energy Efficient Data Gathering in Wireless Sensor Network using Genetic Algorithm

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***Abstract-*** Wireless Sensor Network (WSN) is a collection of sensor nodes which sense, process and transmit data regarding any sensing area. Various energy-efficient protocols are of great importance in order to increase network lifetime during data gathering. The parameter that is important for protocols in a sensor network is its energy awareness. The factors that are causing unequal energy dissipation among the nodes are the distance of nodes from base station and inter nodal distances in the network. Thus the protocol designed should be energy efficient and robust to deal with. PEGASIS which forms chain using greedy algorithm provide elegant solutions to the problem. In this paper, first we implement PEGASIS using greedy chain and then we use Genetic Algorithm to construct data routing chain, which uses its crossover and mutation operators and find an optimized routing path for data gathering. Genetic Algorithm increases the network lifetime for same number of nodes. Extensive simulations are done and the results of PEGASIS and GA are compared with each other on the basis of energy consumption and number of rounds.

***Keywords:-*** *data gathering, PEGASIS, Genetic Algorithm.*

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## I. INTRODUCTION

Wireless Sensor Networks (WSN) are networks of small lightweight nodes that are arranged over large area**.** These nodes are capable of collecting, processing and transmitting the surrounding conditions such as temperature, humidity, vibration etc. Sensor node senses and processes the data. After processing, it routes that data to base station through a communication medium. Sensor nodes do not need to communicate directly to the nearest Base Station but only with their local peers [7]. There is no pre-deployed infrastructure *i.e.,* each sensor node becomes an active part of the overall infrastructure. These sensor nodes gather various types of data and collaborate to perform a high level task in the network.

From the sensing field the data is gathered by the sensor nodes and routed towards the sink or the Base Station as shown in Fig. 1. The network must possess self-organizing capabilities since the positions of the individual nodes are not pre-determined. Dominant thing in WSN is the cooperation among the nodes as these nodes cooperate to circulate the information gathered in the area of the user [8].

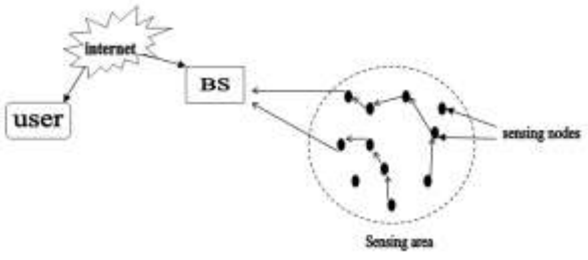


Figure 1 Structure of WSN

Network lifetime is an important parameter for WSN. It is determined by energy consumption of the nodes. In various situations, a network can become non-functional if large number of nodes are dead. So balancing the energy dissipation by the nodes of network is main factor of prolonging lifetime [1]. To enhance the lifetime of network energy must be consumed efficiently by using efficient protocols. Many routing protocols have been introduced in WSN based on a variety of different mechanism and optimization criteria [4]. In order to reduce energy dissipation the protocols used should be fault tolerant and scalable [2]. There are various protocols introduced. PEGASIS is the most elegant solution to the energy dissipation problem. This protocol implemented using Ant Colony Optimization (ACO) and Genetic Algorithm further improves the results by increasing the number of rounds for a specific number of nodes.

*PEGASIS*

PEGASIS is Power-Efficient Gathering in Sensor Information Systems. It is a chain based protocol that allows minimizing the energy consumption at each sensor node. PEGASIS is found to be more robust to node failures as compared to other protocols such as LEACH [6]. In PEGASIS, the nodes form chain and each node transmits the data to its nearest neighbor. The chain construction starts from the node farthest from the Base Station (BS) and is accomplished by using Greedy Algorithm. Nodes take turn transmitting to the BS so that average energy spent by each node per round is reduced [5]. In every data gathering round, each node fuses the data packet with its own data and passes it to the other neighboring node as shown in Fig. 2. The token passing approach is used which is initiated by leader for starting data transmission from the ends of the chain [3]. Global information of all the nodes is assumed to be possessed by each and every node. Already visited node should not be revisited during chain formation in each round. The chain is reconstructed when a node dies by bypassing the dead node. The solution to energy utilization problem is achieved by this protocol but this goal has not been fully achieved as the inter-nodal distances tend to become large while approaching the end of the chain. So these nodes tend to dissipate more energy in the process of data gathering and transmission to their neighbors and as a result those nodes die earlier.

$$\mathbf{N_o \rightarrow N_1 \rightarrow N_2 \leftarrow N_3 \leftarrow N_4}$$
$$\downarrow$$
**BS**

Figure 2 Basic Structure of PEGASIS

S. Lindsey et al. [5] proposed PEGASIS as one of the elegant solutions to data gathering. A near optimal chain based protocol, namely PEGASIS, is proved to be an improvement over LEACH and Direct approach by sensor nodes to the base station. A. Seetharam et al. [1] proposed that PEGASIS implemented using Ant Colony Optimization (ACO) shows improved results instead of that implemented with greedy chain. They showed significant improvement of results over LEACH. S. Hussain et al. [6] proposed that intelligent clustering can reduce energy consumption. They used Genetic Algorithm for creating clusters.

In this paper first PEGASIS is implemented using Greedy chain and then using Genetic Algorithm. The results are compared with each other and ACO [1]. This paper is organized in four sections. Section II presents implemented scheme, section III presents simulations and results and section IV concludes the results.

## II. IMPLEMENTED SCHEME

The work done includes the PEGASIS protocol implementation. The protocol is implemented using Greedy Chain which is the conventional method of implementing PEGASIS. It is then implemented using Genetic Algorithm. The greedy chain starts the chain formation from the farthest node from the base station. The next node is selected which is at a smaller distance from the others. So the inter-nodal distances are calculated and the nodes are selected. During this process the distances start increasing towards the end of the chain which leads to more energy dissipation.

### *A. Genetic Algorithm*

Genetic Algorithm is a heuristic search algorithm based on the concepts of natural selection and evolution [6]. Genetic algorithms are evolutionary algorithms (EA) which provide solution to optimization problems using genetic operators like mutation, selection and crossover. In a genetic algorithm a population of chromosomes is developed, the candidate solution (fitness value) is generated [4]. The population of chromosomes is generated randomly. Various terms related to GA are described as follows-

***a. Population-*** It is a collection of chromosomes. It consists of *r* chromosomes.

***b. Genes and chromosomes-*** We represent our data routing chain by means of a chromosome, which contains information for the Genetic Algorithm. A chromosome is a group of genes and each chromosome represents a particular arrangement of the nodes in the routing chain for a given network.

***c. Parent Selection-***The parent selection process of Genetic Algorithm determines which two parents out of the total population of *r* chromosomes will take part in mating to create an offspring.

***d. Generation-***A new generation is created using crossover and mutation operations. The population size remains same for all the generations.

***e. Crossover*** – Crossover indicates the combination of two parent chromosomes to produce an offspring. For example if C1 = {2,1,4,5,3,6} and C2 = {1,2,3,4,5,6} are two parent chromosomes selected for crossover. The slot {3,4,5} is randomly chosen from C2 and inserted in the same position in C1. Thus the offspring produced is O1 = {2,1,3,4,5,6}.

***f. Evaluation and Fitness*** – In any evolutionary computation scheme, a function is needed to compare and evaluate the fittest of a candidate from a generation of candidates. The fitness of a candidate is calculated by the function of the optimization problem.

The chromosomes with best fitness values are selected on the basis of fitness function given by

$$f(c) = \sum_{i=1}^{N} d_i^2$$

it calculates the energy of a chromosome C containing *N* genes and $d_i$ denotes the distance between the (*i*+1)th node (or, gene) and the *i*th node in the data gathering chain. The greater value of the chromosome energy indicates a longer chain and corresponds to an inferior solution.

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*B. Energy Model*

The radio model for energy is used as in [1,5]. In this model $E_{elec}$=50nJ/bit, where $E_{elec}$ is the energy required for transmitter or receiver circuits and $E_{amp}$=100pJ/bit/m$^2$, where $E_{amp}$ is the energy required for transmit amplifier. For transmitting a k-bit message over a distance d, the energy spent is:

$$E_{TX}(k,d)=(E_{elec} + E_{amp}*d^n)*k$$

where $n$ is called the path loss exponent (usually, $2.0 \le n \le 4.0$). For receiving the packet

$$E_{RX}= E_{elec} * k$$

*Assumptions:-*

The channel is assumed to be symmetric so that energy dissipated in transmission from node i to j is same as from node j to i.

All sensors are deployed randomly over an area. Every node has the global information of the position of another node.

Figure 3 shows the flowchart of the implemented scheme.

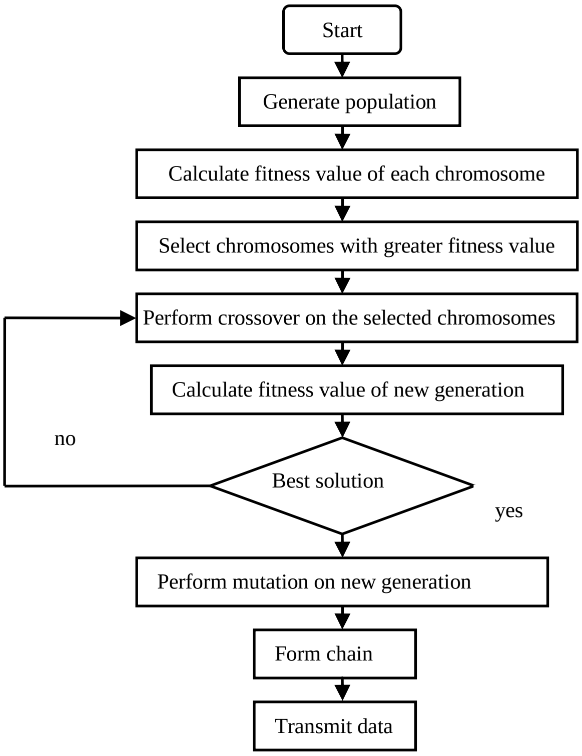


Figure 3 Flowchart of implemented scheme

## III. SIMULATIONS AND RESULTS

All simulations were done on a 100m*100m area and nodes were randomly distributed in this region. The implemented protocol PEGASIS is simulated using 100 nodes. The chain construction is done in PEGASIS using greedy approach and Genetic Algorithm. The simulations are done to determine the number of nodes when 10%, 30%, 60%, 90% of nodes die. Each node has same initial energy level.

The Table 1 shows the energy analysis of the above schemes. The numbers of rounds completed by various schemes are compared with each other corresponding to the percentage of alive nodes for the same initial energy level.

Table 1 Number of rounds when 10%, 30%, 40%, 50%, 60%, 70%, 80% of nodes die

| ENERGY | PROTOCOL | Percentage of alive nodes | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 90 | 70 | 60 | 50 | 40 | 30 | 20 |
| 0.25 | PEGASIS | 700 | 710 | 730 | 750 | 780 | 790 | 800 |
| | PEG ACO | 1400 | 1520 | 1580 | 1600 | 1780 | 1900 | 2100 |
| | PEG GA | 2500 | 2750 | 2800 | 3050 | 3150 | 3200 | 3300 |
| 0.5 | PEGASIS | 1400 | 1430 | 1490 | 1500 | 1520 | 1600 | 1650 |
| | PEG ACO | 2084 | 2097 | 2105 | 2110 | 2119 | 2124 | 2200 |
| | PEG GA | 2700 | 3050 | 3150 | 3300 | 3500 | 3650 | 3800 |

The chain formation using Greedy Algorithm results in inferior chain quality. The greedy chain selects the next nearest node to transmit data in which the inter-nodal distances tend to increase at the end of the chain resulting in more energy dissipation and earlier node deaths. ACO bypasses the problem and constructs the chain within the threshold. However Genetic Algorithm shows better energy performance as compared to ACO. The simulations are carried out using 0.25j and 0.50j as initial node energy. Fig. 4 indicate energy analysis when initial energy is taken as 0.25j.

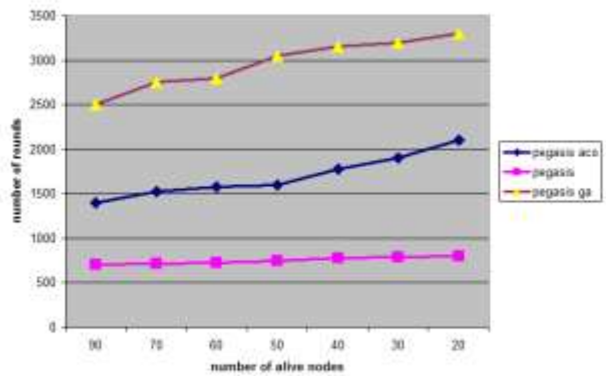


Figure 4 Comparison of the schemes when energy is 0.25j

The results show better performance in case of PEGASIS implemented using GA. The number of rounds completed in case of GA are 3300 when 80% of nodes are dead whereas in case of ACO and Greedy Chain, the number of rounds are 2100 and 800 respectively. Therefore, PEGASIS when implemented using GA shows almost 1.5 times better results than ACO. Fig. 5 indicates energy analysis when initial energy is taken as 0.5j.

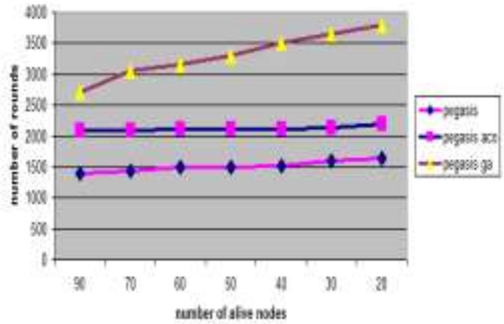


Figure 5 Comparison of the schemes when energy is 0.5j

The above results show that for a 100m*100m area the performance of GA is better as number of rounds completed by GA are 4500 when 80% of nodes are dead whereas in case of ACO it completes only 2550 rounds at the same time. Therefore PEGASIS when implemented with GA in sensor network can provide us information for considerably long period of time. With less nodes dead, the quality of information would also be good as compared to conventional Greedy chain and ACO.

## IV. CONCLUSIONS AND FUTURE WORK

The PEGASIS protocol considered ensures that a near energy utilization occurs thereby increasing network lifetime. PEGASIS implemented using Greedy chain shows some drawbacks like the gradual increase in inter-nodal distances while reaching the end of the chain which is overcome by implementing PEGASIS using Ant Colony Optimization (ACO) and Genetic Algorithm (GA). The simulations are carried out in MATLAB which are compared with each other on the basis of energy consumption which is carried out in the form of distance travelled. The results of GA are better as compared to ACO. It enhanced the lifetime of sensor network by optimizing routing paths.

Further many schemes could be implemented like Particle Swarm Optimization (PSO) on PEGASIS and compare it with ACO and GA. Packet losses could also be considered and existing model be modified to get desired results under the given circumstances.

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