Appraisal of the Performance of Genetic Algorithm based WSN in comparison with LEACH

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Abstract- The main issue in wireless sensor networks is its the low lifetime. Here we have focused on the working of Wireless Sensor Network using the genetic algorithm for clustering. By using the genetic algorithm the energy dissipation is greatly reduced as well as the lifetime of the WSN has also increased. Genetic algorithms (GA) have been investigated and it has been functional in the routing protocol of wireless sensor networks (WSN), the emphasis has been mainly on the design of fitness function to boost network performance. The total communication distance can be minimized by grouping a sensor network into a number of liberated clusters using a GA, thus elongating the network lifespan. Simulations have shown the improvement in the lifetime of the sensor networks by the procedure of GA as compared to the basic LEACH protocol. After the simulation, it has been observed that there is almost 69-70% increase in the lifetime of the network after using the GA based protocol.

Keywords- WSN, Hierarchal routing, LEACH, chromosomes, genetic algorithm, crossover, mutation and fitnes function.

I. INTRODUCTION

A wireless sensor network (WSN) involves spatially dispersed self-governing sensors to witness physical or ecological circumstances and to concurrently pass their data through the network to a core location [1].The WSN comprises of nodes from a few to several hundreds or even thousands, where each node is associated to one (or numerous) sensors. A sensor node alter in size and may range from that of a box to the size of a sand grain. A sensor node has characteristically several parts like a radio transceiver, a microcontroller, an electronic circuit for interfacing with the sensors and a battery. The components of a sensor node are- microcontroller,transciever, sensor, power source (mainly batteries) and external memory.

The main purpose of a sensor is to gather the data and then direct it to the base station or sink. The sinks are one or more components of the WSN with much more computational energy and communication resources.

The nodes transfer data wirelessly and frequently self-organize after being organized. The most important technology of 21st century is the wireless sensor network. It has been valuable in medical treatments, military surveillance, atmosphere recognition, industry, home monitoring, sensing and avoiding natural disasters, equipment monitoring and other fields.

There are many benefits [1] of wireless sensor networks like low cost and small size. The only power source in WSN is batteries and replacing the batteries of so many nodes is a difficult task, so the main research area in the wireless sensor network is increasing its lifetime. To do so, a number of routing protocols has been proposed. In this paper, we will review some of them.

For the monitoring applications the cluster based approach of WSN is used. LEACH protocol is also a cluster based approach in which data collection is done by random areas known as clusters. The data transmission is done in a TDMA (time division multiple access) fashion. By using genetic algorithm (GA) the clusters are formed and cluster heads are choosen by using fitness function, thus increasing the lifespan of the wireless sensor network in comparison to the basic LEACH protocol.

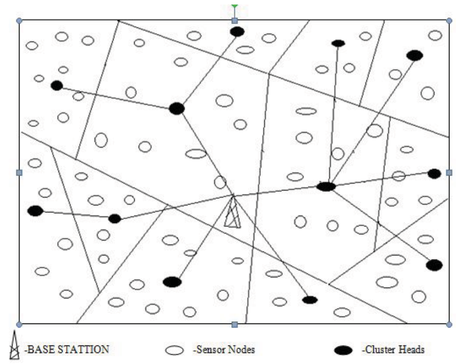

Figure1. Wireless Sensor Network [1]

II. LEACH PROTOCOL

LEACH (Low Energy Adaptive Clustering Hierarchy) [3] routing protocol is the conventional clustering communication protocol widely used in Wireless Sensor Networks. It is based on the low power consumption adaptive routing algorithm of WSN. In LEACH, in order to balance energy consumption of each node, nodes are selected as cluster head nodes circularly and randomly. This algorithm makes sure that every node gets a chance to become a cluster head.

LEACH operates in two phases which are as follows:

- *Setup Phase-*

Every round begins with a set-up phase when the clusters are organized. During the set-up phase, each sensor node tries to select itself as a cluster head according to probability model. For selecting a cluster head, each sensor node generates a random number between 0 and 1. If the δ is less than the threshold [3]*T (n),* the sensor node selects itself as a cluster head for current round, the threshold is presented as follows:

$$T(n) = \begin{cases} \dfrac{p}{1 - p \, mod \left[\frac{1}{p}\right]} & n \in G \\ 0 & otherwise \end{cases}$$

Where *n*as the total number of sensor nodes in the network, *p* is the number of cluster head nodes for each round, *r* as the number of the current round, and *G* is the set of nodes that have not been selected as cluster heads in the last *n/p* rounds.

In this phase the clusters are also formed. The nodes chosen as cluster heads send a message to the nearby nodes to join them so as to form clusters. When the nodes respond to this message several small clusters are formed in the wireless sensor network.

- *Steady Phase-*

In this phase the nodes send the data to the cluster head which processes the data and further send it to the base station. When all the data reaches the base station then the round is complete and the next round begins.LEACH is the basis protocol but it has some restrictions like: stochastic selection of cluster heads, nodes are homogeneous and choosing low energy nodes as cluster heads.

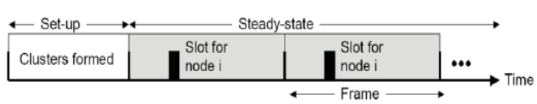

Figure 2. LEACH [2]

The energy dissipated by the nodes during the transmission of data of *k* bit packet is given by the equation [4]:

$$E_{TX}(k,d) = \begin{cases} kE_{elec} + kE_{fs}d^2 & d < d_o \\ kE_{elec} + kE_{mp}d^4 & d > d_o \end{cases}$$

where E_{elec} is the factor of electronics energy consumption, E_{fs} and E_{mp} are amplification coefficients of power amplifierand d_o distance between transmitter and receiver which is given as:

$$d_o = \sqrt{E_{fs}/E_{mp}}$$

Energy dissipation for receiving a *k* bit data is:

$$E_{RX}(k) = kE_{elec}$$

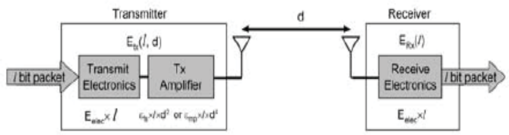

Figure 3. Data Transmission in LEACH [5]

III. GENETIC ALGORITHM (GA)

Genetic Algorithm executes fitness tests on new structures to choose the best population. Fitness regulates the quality of the individual on the base of the defined principles. In nature, an individual's fitness is its capability to pass on its genetic material. Anything that backs this capability contributes to the organism's total fitness. This capability contains characters that permit it to survive and additionally reproduce. In a GA, fitness is estimated by the function significant to the problem. The fate of an individual chromosome rest on the fitness value; the superior the fitness value more are the chances of survival. GAs explain design problems like that of natural solutions for organic design problems.

The basic outline of the genetic algorithm is:

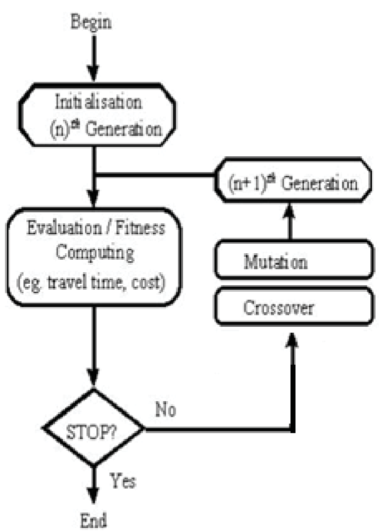

Figure 4. Genetic Algorithm [6]

The working of basic genetic algorithm (GA) is explained below:

1. Initialize Population

In the first step a population is initialized represented as P = (*C1* , *C2* ... *Cr*) [7] that is a collection of choromosomes. The population comprises of a collection of individuals known as chromosomes that symbolize a total solution to a well-defined problem. Every chromosome is an arrangement of 0s or 1s. The early set of the population is a arbitrarily created set of individuals.

2. Selection and Fitness

The selection [8] process governs which of the chromosomes amoung the existing population will mate to generate new chromosomes. The individuals with superior fitness values have superior chances of selection. These new chromosomes join the existing population. This combined population will be the basis for the next selection.
In a GA, fitness is calculated by the function defining the problem. The selection of an individual chromosome solely depends on the fitness value. The chances of survival are higher for better fitness values.

3. Crossover

Crossover [8] is also known as recombination of constituent materials owing to mating. It is a imitation of the reproductive process that is responsible for the transmission of genetic inheritance. The results of crossover are mainly governed by the selection of chromosomes made from the population. Crossover is a binary genetic operative acting on two parents. There are diverse crossover operators that have been established for various purposes. Ther easiest is the single-point crossover in which a point is selected arbitrary, and the two parent chromosomes exchange information after that point.

Chromosome1	**1100 | 0001**
Chromosome2	1001 | 1111
Offspring1	**1100** | 1111
Offspring2	1001 | **0001**

Figure 5. Crossover

4. Mutation

Mutation [9] takes place after the crossover is accomplished. Mutation alters every bit of the new offspring chromosome in order to ensure that the individuals are not exactly the same. Mutation is quite easy. One can go through all the alternative forms of genes of all the individuals, and if a particular alternative form of gene is selected for mutation, one can either modify it a little bit or swap it with a new one. Modification of the selected alternative form of gene is based on what is necessary. Mutation is integral to ensure the genetic diversity within the population.

Original Offspring	1 1 0 0 **1** 1 1 1
Mutated Offspring	1 1 0 0 **0** 1 1 1

Figure 6. Mutation

5. Generation of new population

Based on the fitness of the chromosomes the best ones are selected which further mates and generate the new population. From that new population, again best and fittest chromosomes are choosen that transforms into future generation.

6. Repitition

Repeat steps 2-5 till the terminating condition comes across.

IV. GA BASED WSN

In genetic algorithm based wireless sensor networks the clustering is done using genetic algorithm. In this, the nodes are denoted as bits of chromosomes as shown in figure 8. From this population of chromosomes the fittest chromosomes are choosen to generate the next population.In GA-WSN, the cluster head nodes are symbolized by 1's and the member nodes are symbolized by 0's.

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
0	0	0	1	0	0	0	0	1	0

Figure 7. Network Chromosome [12]

A network of *m* nodes is characterized as chromosomes of *m* numbers. The fitness function is designed in such a way the energy consumption is minimized as well as the network revenue (lifespan) is maximized. In addition to stabilize the energy ingestion among the cluster heads, clusters with irregular size are produced. There are two phases in the protocol which are set-up phase and steady-state phase.

1. Setup Phase:

In this phase clustering is done by making the use of Genetic Algorithm. In this protocol the fitness of the nodes is checked with respect to the cluster distance. The cluster distance [10] is the sum of the distances from the nodes to the cluster head and the distance from the cluster head to the base station. In this step using genetic algorithm fittest CH are chosen according to the fitness function [11] equations:

$$F = Af_1(Cl_p) + Bf_2(Cl_p) + Cf_3(Cl_p) + Df_4(Cl_p)$$

where $f_1(Cl_p) = \sum_{j=1}^{\beta}\left[\left(\sum_{i=1}^{\alpha_j} d_{ijhj}\right) + d_{hjbs}\right]$; $f_2(Cl_p) = \sum_{j=1}^{\beta}\left[\sum_{i=1}^{\alpha_j} ST(ij) / ST(hj)\right] / k$

$f_3(Cl_p) = \sum_{j=1}^{\beta}\left[d_{hjbs}\right] / \beta \sum_{j=1}^{\beta}\sum_{i=1}^{\alpha_j} d_{ijhj}$; $f_4(Cl_p) = 1/\sum_{j=1}^{\beta}\left[\left(\sum_{i=1}^{\alpha_j} E_{TX}(1, d_{ijhj})\right) + \alpha_j E_{RX}(1)\right]$;

The fitness function [11] defined above simultaneously reduce the intra-cluster distance between nodes and their cluster heads, computed by f_1; and of increasing the cluster head's energy sustainability in its cluster computed by f_2; and of creating clusters with uneven size computed by f_3; and also of enhancing the energy dissipated within clusters computed by f_4. The GA result identifies the cluster heads for the network. The base station allocates member nodes to every cluster head by means of the minimum distance approach. The base station transmit the whole network specifications to the sensor nodes. The transmission message contains: the number of cluster heads, the member nodes of each cluster head, and the number of communications for this arrangement. These packets transmitted by base station are recieved by the nodes and clusters are organized consequently. This completes the cluster formation phase.

2. Steady Phase

In this step the data is transmitted from nodes to cluster heads and further from cluster heads to the base station. At the end of each round the energy of all the nodes is updated and then again cluster heads are choosen for the next round of data transmission.

V. SIMULATION AND RESULTS

To evaluate the execution of genetic algorithm based wireless sensor network, we use MATLAB to simulate the protocol. The parameters being taken for the simulation are given in table 1. Here both LEACH and the genetic algorithm based protocol are simulated and compared with respect to the two parameters.

- R_{FND} (First node dead)
- R_{LND} (Last node dead)

Where R_{FND} is the round in which first node dies and R_{LND} is the round in which all nodes are dead. The comparison results drawn are detailed in table 2. R_{FND} as mentioned above is the time when the first node will die this indicate the sustainability of the network. R_{LND} is the time when the whole network goes down after execution that is all nodes are dead and it indicates the total lifespan of the network.

The basic parameters required for the simulation of WSN include E_o; the initial energy of all the sensors in the network (simulation is done over different initial energies), E_{elec} is the amount of transmitting and receiving energy, E_{DA} is the energy required for data aggregation, E_{fs} is the amplification energy for short distances and E_{mp} is the amplification energy for long disatances.

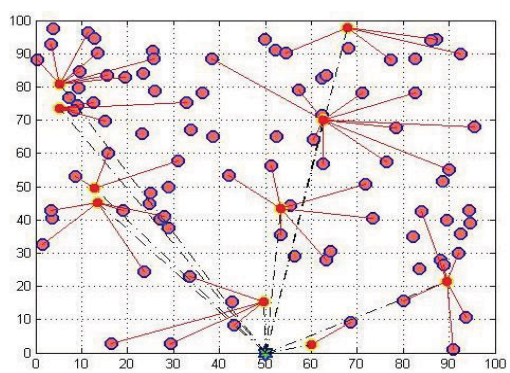

Figure 8. Genetic Algorithm based WSN

Table -1 Simulation Parameters [13]

Parameter	Value
Network size	100x100
No. of nodes	100
Sink location	(50,0)
E_{elec}	50nJ
E_{fs}	10pJ/bit/m2
E_{mp}	0.0013pJ/bit/m4
E_{DA}	5nJ/bit/signal

After the execution of the both the protocols (at E_o=0.01J) the resultant graphs of the number of dead nodes with respect to the total life time i.e. number of rounds are as following:

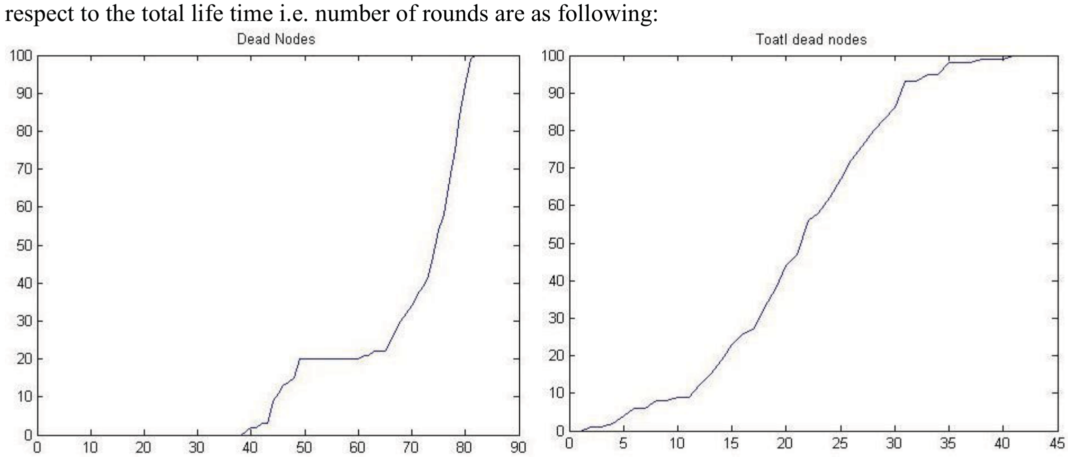

Figure 9. (a) Dead nodes in GA-WSN (b) Dead nodes in LEACH (at E_o=0.01J)

In case of both the protocols we have taken 4 values of initil energy (E_o) as 0.01J, 0.05J, 0.1J and 0.5J.
The comparison is as follows:
CASE 1- Initial Energy, E_o= 0.01J

Table -2 Result when E_o= 0.01J

	LEACH	GA-WSN
R_{FND}	1	38
R_{LND}	40	81

CASE 2- Initial Energy, E_o= 0.05J

Table -3 Result when E_o= 0.05J

	LEACH	GA-WSN
R_{FND}	42	184
R_{LND}	152	392

CASE 3- Initial Energy, E_o= 0.1J

Table -4 Result when E_o= 0.1J

	LEACH	GA-WSN
R_{FND}	118	362
R_{LND}	241	787

CASE 3- Initial Energy, E_o= 0.5J

	LEACH	GA-WSN
R_{FND}	793	1431
R_{LND}	1836	4320

Table -4 Result when E_o= 0.5J

VI. CONCLUSION

WSNs have been a range of interest owing to its low battery life and many protocols have been developed to prolong its lifetime. In this paper, we have simulated the basic LEACH protocol and a genetic algorithm based protocol. The simulation results at different initial energy of the sensor nodes have shown that GA-WSN have greatly improved the lifetime of the network as compared to the basic LEACH protocol. The lifespan has increased more than four times by making the use of genetic algorithm in wireless sensor networks. The GA-WSN increases the lifespan of WSN to 69-70% as compared to the basic LEACH.

To further extend the lifetime of WSN energy harvesting [11] conception can be used. Also we can make the WSN a reactive network that will save energy during the steady phase also and make the network a reactive network like the HEER protocol [14]. By making the network a reactive one the transmission of data is reduced and further the energy deplition also gets lessen. This is very beneficial for the time critical applications.

REFERENCES

[1] Jaipreet Kaur “Retrospection of Hierarchal Routing Protocols For Wireless Sensor Networks.” *International Journal of Advanced Research in Computer Science and Software Engineering 4(5), May - 2014, pp. 1149-1154.*

[2] Lu, Yingqi, et al. "Improvement of leach in wireless sensor networks based on balanced energy strategy." *Information and Automation (ICIA), 2012 International Conference on*. IEEE, 2012.

[3] Yang, Zhiming, Junyi Liu, and Xuhui Chen. "An optimal mechanism of LEACH protocol for wireless sensor networks." *Computing, Communication, Control, and Management, 2009. CCCM 2009. ISECS International Colloquium on*. Vol. 4. IEEE, 2009.

[4] Jia, Jian-guang, et al. "An energy consumption balanced clustering algorithm for wireless sensor network." *Wireless Communications Networking and Mobile Computing (WiCOM), 2010 6th International Conference on*. IEEE, 2010.

[5] Liu, Jenn-Long, and Chinya V. Ravishankar. "LEACH-GA: Genetic algorithm-based energy-efficient adaptive clustering protocol for wireless sensor networks." *International Journal of Machine Learning and Computing* 1.1 (2011): 79-85.

[6] Kamali, Shahin, and Vahid Safarnourollah. "A Genetic Algorithm for Power Aware Minimum Connected Dominating Set Problem in Wireless Ad-Hoc Networks." (2006).

[7] Chakraborty, Ayon, Swarup Kumar Mitra, and Mrinal Kanti Naskar. "A Genetic algorithm inspired routing protocol for wireless sensor networks." *Int. J. of Computational Intelligence Theory and Practice* 6.1 (2011).

[8] Hussain, Sajid, Abdul Wasey Matin, and Obidul Islam. "Genetic algorithm for hierarchical wireless sensor networks." *Journal of Networks* 2.5 (2007): 87-97.

[9] Heidari, Ehsan, and Ali Movaghar. "An efficient method based on genetic algorithms to solve sensor network optimization problem." *arXiv preprint arXiv:1104.0355* (2011).

[10] Bayraklı, Selim, and Senol Zafer Erdogan. "Genetic Algorithm Based Energy Efficient Clusters (GABEEC) in Wireless Sensor Networks." *Procedia Computer Science* 10 (2012): 247-254.

[11] Wu, Yin, and Wenbo Liu. "Routing protocol based on genetic algorithm for energy harvesting-wireless sensor networks." *IET Wireless Sensor Systems*3.2 (2013): 112-118.

[12] Shurman, Mohammad M., et al. "Hierarchical clustering using genetic algorithm in wireless sensor networks." *Information & Communication Technology Electronics & Microelectronics (MIPRO), 2013 36th International Convention on*. IEEE, 2013.

[13] Jia, Jian-guang, et al. "An energy consumption balanced clustering algorithm for wireless sensor network." *Wireless Communications Networking and Mobile Computing (WiCOM), 2010 6th International Conference on*. IEEE, 2010.

[14] Javaid, Nadeem, et al. "HEER: Hybrid Energy Efficient Reactive protocol for Wireless Sensor Networks." *Electronics, Communications and Photonics Conference (SIECPC), 2013 Saudi International*. IEEE, 2013.

[15] Sastry, Kumara, David Goldberg, and Graham Kendall. "Genetic algorithms. *Search methodologies*. Springer US, 2005. 97-125.

[16] He, Jing, et al. "Genetic-algorithm-based construction of load-balanced CDSs in wireless sensor networks." *MILITARY COMMUNICATIONS CONFERENCE, 2011-MILCOM 2011*. IEEE, 2011.

[17] Karimi, Mohammad, Hamid Reza Naji, and Shahrzad Golestani. "Optimizing cluster-head selection in Wireless Sensor Networks using Genetic Algorithm and Harmony Search Algorithm." *Electrical Engineering (ICEE), 2012 20th Iranian Conference on*. IEEE, 2012.