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Routing Optimization for Wireless Sensor Network Using Genetic Algorithm

Kushagra Seth[(1)], Sumita Mishra[(2)], Pallavi Asthana
Department of Electronics and Communication Engineering, Amity School of Engineering and Technology, Amity University Uttar Pradesh - Lucknow Campus, Lucknow, India.

Abstract: *This paper discusses about various routing optimization methods employed in wireless sensor network with main focus on genetic algorithm based optimization.Wireless Sensor Network (WSN) is composed of various types of networks which are randomly distributed to process or transfer the data to another step or path. It is used commonly nowadays in industrial applications like street light, health care monitoring, water impurities measuring devices, weather prediction, soil condition etc. One of the important uses of WSN is in the area of machine monitoring like rotating machine where it is difficult for engineers to take measurement from hard wired sensors and more relevant to wired sensors, wireless sensors are much cheaper than them.*
Keywords:*Wireless Sensor Network, optimization techniques, genetic algorithm, Sensor Nodes.*

I. Introduction:

A sensor network is an establishment, enrolling, and correspondence parts that empower a manager to an instrument, watch and react to events and wonders in a predefined space. The hub regularly is a common, administrative, business, or mechanical element.[1] The terrain can be the physical world, an organic framework, or a data innovation structure. WSN routing protocols are designed to find a route between source and destination. These routing protocols decomposes the network in small and manageable pieces and then it first share them to its neighbors and then throughout the network.[1]

In WSN the range of transmission of each sensor node is limited and the sensed data is relayed to sink node by multiple hops.[2] Lots of routing exists simultaneously from one sensor to sink node and each node may become relay node.[3] Therefore selecting relay node to compose energy efficient routing is import issue for WSN.

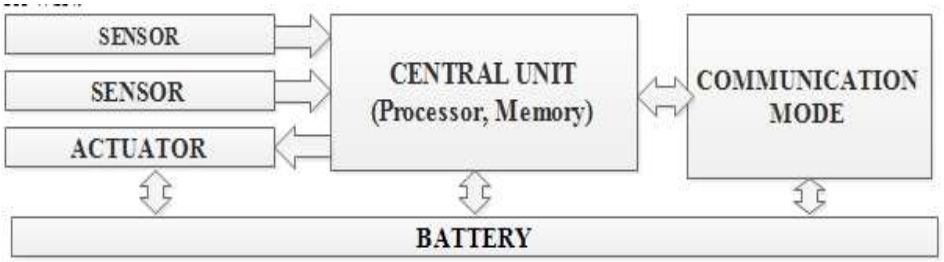

Figure 1: Sensor Node Structure

II. Operational Stages Of WSN

Node Placement- there is various ways of distributing a node including random, regular and grid distribution. In grid layout distance between each node can be determined and the gaps between nodes are fixed. [3]

Network Coverage- Poisson distribution is used for various types of phenomenon, it helps in generating estimated binomial.

probabilities which is used for detailed study on simulation of wireless sensor network and then the sensor are connected based on range on the services among which radio range and service domain are important part.[3]

Clustering- it is an important term in optimization of WSN. With the help of clustering the sensor nodes are into groups called as division cluster. Every cluster contains a cluster head which aggregates the information to the sink directly or step by step by victimizing very cluster head.[8] Therefore the nodes might cut back their communication heading compared with once information forwarded on to the sink. Clustering is basically used to save energy and to increases the lifetime of WSN.

Data aggregation and routing- the aggregation process reduces the spaces and communication overhead for both sink and sensor. This technique enables the sensor to secure, verify and collect back all the relatable data. The protocols in way help to increases working durability of a network but also consume more energy for cluster head. Therefore protocols guarantee implementation of efficient clustering algorithms.[7] A simple way of

transferring of data is direct way, where data between node and base station is directly transferred. Multistep transfer is limited to specific radius.

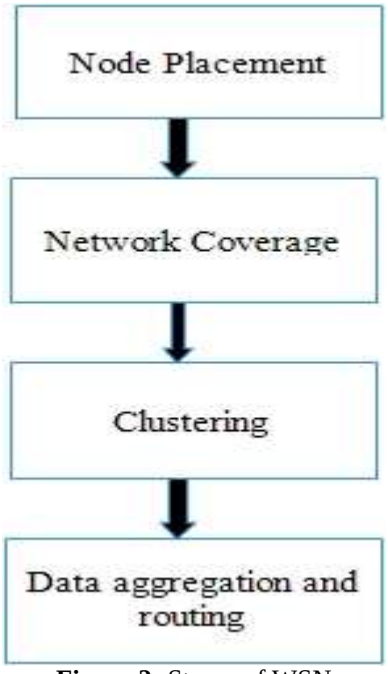

Figure 2: Stages of WSN

III. Optimization Model

1. **Network Model**- his mode assumes that device node is distributed uniformly in monitoring area with density. The network contain large number of homogenous sensor nodes and only one sink node located at fixed position outside the monitoring area. The number of sensor nodes depends upon the size of application system. The transmission range of all sensor nodes is identical. The original energy of each sensor node is same and after getting deployed it can't be supplemented.

- Energy consumption for wireless sensor node receiving K bit data is:

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

Where, E_{elec} represents energy consumption for one bit data

2. **Routing Model-**this model is used to find the suitable and efficient part from multiple routing for one sensor node to the sink. For WSN system with N sensor nodes, the number of possible routing from one sensor node to another is $p(N)=2^{N-1}-N+1$.Therefore selecting suitable is very essential for WSN system.[3] A large amount of resources and power will be used for selecting suitable routing from all the possible routing in traditional way. Therefore various optimization techniques are used for finding routes like Evolutionary algorithms (EA) and Swarm optimization [6] are two classifications of nature enlivened algorithms. EA endeavours to re-enact the marvel of regular development. In common development, every species scan for valuable adjustments in an ever-evolving condition. Genetic algorithm (GA)[8][9] and differential development (DE) calculations are the case of EA. Swarm optimization techniques incorporate Ant Colony optimization, Honeybee colony optimization, and Particle Swarm Optimization.[7]

a. Particle Swarm Optimization

It is derived from the natural insect swarm and is a part of artificial intelligence. These frameworks comprise of basic associating operators sorted out in little social orders, called swarms, which display qualities of insight, for example, the capacity to respond to natural dangers and basic leadership limits. PSO gives a populace-based pursuit technique in which people baptized subdivisions adjust their location (state) with time.[6] In Particle Swarm Optimization (PSO), atoms hover around in a multidimensional pursuit planetary. Amid flying, every molecule utilizes its personal involvement, and knowledge of a neighbouring molecule, to change its location by bearing in mind the best situation experienced by it and its neighbour, a Particle Swarm Optimization utilizes together nearby inquiry strategies and in addition worldwide inquiry techniques.

b. Artificial Bee Colony (ABC) Optimization

Its computation was proposed by Karaboga in 2005. Simulated Honey Bee Province (ABC) enhancement is fake awareness (a swarm-based) count which is stirred via astute rummaging behaviour of bees.

The Artificial bee colony (ABC) optimization figuring includes 3 bumble bee social occasions also support bases.[6] The circumstance of a sustenance source implies a possible response for the change issue and the nectar measure of a sustenance source addresses the quality (wellbeing) of the related game plan. The three sorts of bumble bees are onlookers, scouts, and used bumble bees. The bumble bee which finishes sporadic chase is known as a scout. The honey bee which is taking off to the sustenance source which is passed by it as of now is used bumble bee. Honey bee which is paying special mind to the move an area is an onlooker honey bee.

c. Fuzzy Logic and Ant Colony Optimization

Fuzzy logic is used to determine the important points which determine the best route for a packet to be sent from sensor node to gateway.[3] The network controller in the sink node is used to setup the route for sensor node. With the help of fuzzy logic sink node is used to determine the cost of each sensor node o reach sink node. It asks all the sensor nodes to send the status of their cost and traffic. Ant colony is important for heuristic algorithm.[5] It is the part of swarm intelligence and as its name suggests it finds a shortest path which is used aster the fuzzy system as detected the optimum node value and as soon as optimum path is selected sink node will send out the signal for routing schedule.[10]

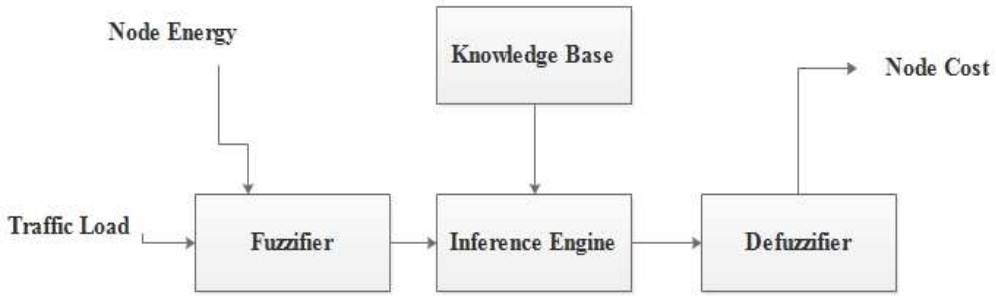

Figure 3: Fuzzy System

d. Genetic Algorithm

Genetic Algorithm (GA) it is also called as Global Heuristic Algorithm is "survival of the fittest" in natural upgrade and can solve efficiently large scale optimization errors.[9] Its rule start with an elementary population having random chromosome comprising of genes sequencing having 0's and 1's after which it leads to achieve optimum solution by repetition of process having crossover and operator selection. There are various optimizing techniques but on comparison with GA, GAs is considered as more efficient. There are two ways to make new individuals:

- Steady-State Genetic Algorithm
- Generational Genetic Algorithm

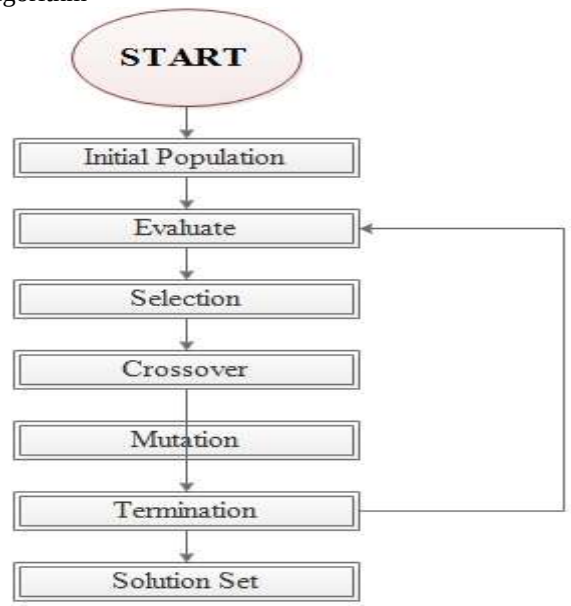

Figure 4: Flow Chart of Genetic Algorithm

1. Fitness Function

It is the process of scoring of each chromosome based on their qualifications. By use of fitness function GA's evaluation is extended to continuous or discrete problems.[3] Therefore designing a suitable fitness function is very essential for the performance of GA. To analyze the function we take all possible individuals and an individual routing from node to sink and a relay node. Therefore factors affecting the choice of individual include the remainder left from energy function each node, the distance function of the edges between adjacent nodes (dist(e)) and there energy consumption(ene(e)), communication delay of each node(delay(id_1)) and relay hops of each and every routing (hop(p_j(id_i,s))). The higher the fitness value represents the best suitable path.

Formula for Fitness Function are-

$$F1 = \frac{\sum c \in pj\,(idi,s) dist\,(e)}{\sum c \in E dist\,(e)} \quad (1)$$

$$F2 = \frac{\sum c \in pj\,(idi,s) ene\,(e)}{\sum c \in E ene\,(e)} \quad (2)$$

$$F3 = \frac{\sum id\,1 \in pf(idf,s) delay\,(id\,1)}{\sum id\,1 \in P(idf,s) delay\,(id\,1)} \quad (3)$$

$$F4 = \frac{hop\,(pj(idi,s))}{\sum hopdist\,(P(idi,s))} \quad (4)$$

2. Selection

During each ordered generation, a new generation is developed through adopting members of the present generation to mate on the basis of their fitness. The individuals having higher fitness score have high chances of being selected. Most of the functions are designed stochastically for small amount of less fit individuals to avoid decrease in population.[8] There are various methods but Roulette-Wheel is used to find best probability of-

$$Pi = \frac{Fi}{\sum_{j=1}^{n} Fi} \quad (5)$$

Where F_i and 'n' are fitness chromosome and size of population. Each individual is assigned 0 and 1 according to this formula. We choose 50% individuals having higher fitness value because of the ideology for propagating to subsequent generation.

3. Crossover and Mutation

It is used for complete range which is practically not possible for WSN's as the sensor node transmission range is limited and nodes cannot exchange data with other node outside the transmission range.[9] For the crossover operation, the algorithm check for crossover point and if same with other individual or it belong to neighbor set of corresponding precedent, the crossover is conducted else the operation is discarded. For mutation process the algorithm checks the neighbor set and if it belonged to both succeeded and precedent and select it.[10] Then selected gene is replaced from mutation gene.

Algorithm to Improve Crossover and Mutation

Input- Individual before mutation and crossover

Output- Individual after mutation and crossover

1. **For** (each pair of individuals)
2. **If** ($p_j\_id^b_c == p_k\_id^b_c$)
3. take crossover of p_j and p_k;
4. **elseif**($p_j\_id^b_c$£ NE($p_k\_id^b_c$)& ($p_k\_id^b_c$£ NE($p_j\_id^b_c$)))
5. take crossover of p_j and p_k;
6. **else**
7. Don't take crossover of p_j and p_k;
8. **Endif**
9. **Endfor**
10. **For** (each individual)
11. **If** (id_n£($NE_{id}{}^b{}_m \cap NE_{id}{}^a{}_m$)
12. Take id_n to replace id_m
13. **Else**
14. Don't take mutation
15. **Endif**
16. **Endfor**

IV. Design Issue

A. Design Objective-As per today's demand most of the sensor network are of different specification, thus there are points on which design of a sensor depends,[14]

1. **Node Size-**Since sensor node are mainly used in difficult and different situation in large quantity, thus decreasing its size can effectively effect the cost of a sensor and will also reduce its power consumption.
2. **Scalability-**the quantity of sensor nodes is in terms hundreds and thousand's. Therefore network protocols designed should be scalable with different sizes.
3. **Reliability-**correction mechanism and error control must be provided by network protocol to ensure data is transferred reliably over various distortions in medium.
4. **Channel Utilization-** due to limitation in bandwidth of sensor network they must work in bandwidth channel provided to them.
5. **Security-**a sensor network must always keep on updating its security protocols to effectively keep the data safe from unauthorized access and leakage of data.

B. Routing Issues-with the presence of various types of wireless network devices, routing and designing a protocols have always been very challenging. There are few issues among all the devices-[13]

1. **Limited Energy Capacity-** as senor works on battery they have limited storage of battery. Therefore energy is very important in any environment, moreover when a sensor reaches its threshold, the sensor will not work properly which will affect the device.
2. **Limited Hardware Resources-** due to less storage space and storage a sensor can only perform limited functions which effect the software development and upgrading of network protocols.
3. **Network Characteristics And Unreliable Environment-**as the sensor operate in different atmospheres whose conditions as are dynamic and un favouring sensors therefore sometime communication links between sensor becomes faulty due to rapid changes of sensors like adding or removing, damages or energy leakage.
4. **Data Aggregation-** sometime due to failure a sensor node might generate redundant data containing similar packets from various source which can be collected together to reduce the number of transmission.
5. **Diverse Sensing-** sensor network have a long range of applications and a single protocol is not sufficient for all of its application, therefore routing protocols must ensure data transferring to sink node without leakage and keep on checking sensor from time to time.

I. Routing Protocols

Routing in WSN is far different from routing in fixed sensor network due to lack of a structure in WSN.[11]

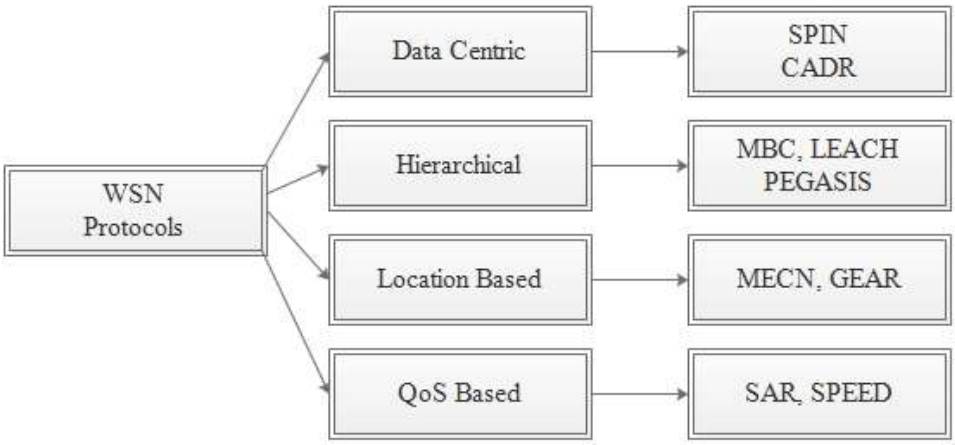

Figure 5: Categories of WSN routing protocols

a) **Data Centric Protocol-** sink node receives data from each sensor node in an appropriate way independently. When source node sends data to sink node, in meantime, the intermediate sensor can collect data from various sources and transfer them to sink node.[12]

- Sensor Protocol for Information via Negotiation (SPIN) - these are used to determine the energy consumption by sending, computing and receiving of a data over the network. This protocol is based on two important terms resource and negotiation.[15]
- Constrained Anisotropic Diffusion Routing (CADR) - it uses direct diffusion technique. The main purpose is to route the data network in such a way that the information received is maximized and delay in the bandwidth is minimized.

b) Hierarchical Protocols- clustering is an energy saving process which is used to send the report of data to sink node.[12]

- Mobility-Based clustering (MBC) - this protocol takes its estimated time to construct more dependent path based on the stability or availability each link in between non-cluster head sensor node and cluster-head sensor node. In this protocol node itself decide it as a cluster head depending up-on the energy consumption and mobility to achieve balance.
- Low-Energy Adaptive Clustering Hierarchy (LEACH) - in this clustering is done by nodes depending upon the time duration and direct communication is used by cluster head to move the data to base station. It is based on aggregation technique that combines the original data of smaller size comprising of only valuable intel. The LEACH have two process-[11]
  - the network is organize in to cluster head through setup phase organization
  - data aggregation from steady-state and compression and transmission to sink node.
- Power-Efficient Gathering in Sensor Information System (PEGASIS)- it is the extension of LEACH protocol in which chains are formed from sensor node so that each node sends and receives data from neighbor and among them only one node is used to send the data to base node. In this cluster formation is avoided and node in the form of chain is used to end data to sink node.[11] In this protocol it is assumed that sensor has all the knowledge about network and when a sensor becomes faulty another sensor is made by bypassing the same data.

c) Location-Based Protocol-location is used to address the sensor node and by means of location energy consumed is determined.[13]

- Minimum Energy Communication Network (MECN) - it is used to achieve minimum energy to setup a network with mobile sensor. It can maintain sensor connectivity irrespective of its mobility, hence referred as self-reconfiguring protocol.
- Geographic and Energy-Aware Routing (GEAR) – it is used to target regions in sensor fields is works like GPS system. They uses geographic forwarding algorithm to send the packet in the target region.

d) Quality of Service Based Protocol (QoS) – it is essential to provide better service with the energy consumption in terms of delay, fault tolerance and reliability.[12]

- Sequential Assignment Routing(SAR)- it is one of the first routing protocols of WSN that introduces the criteria of quality in routing. In this routing factor depends upon: energy resources, QoS on each path and priority level of each packet. Recovery of a senor is done by consistency routing table between higher and lower node and for local failure automatic path recovery program is enabled.
- Speed- in this real-time end to end sensor network is guaranteed and uses geographic locations to find paths.[12] This protocol ensures the speed of each of each packet so that end to end delay by distance and speed is estimated before making decision. The routing module available inn this is called Stateless Non-Deterministic Forwarding Geographic (SNFG).

Protocol	Category	Mobility	Power Usage	Scalability	Over-heads	Traffic	QoS
SPIN	Data Centric	Possible	Limited	Limited	Low	Low	Low
CADR		No	Limited	Limited	Low	Moderate	Low
MBC	Hierarchical	Possible	Limited	Good	Low	Low	Low
LEACH		Fixed	Maximum	Good	High	High	Low
PEGASIS		Fixed	Maximum	Good	Low	Low	Low
MECN	Location Based	No	Maximum	Low	Moderate	Low	Low
GEAR		Limited	Limited	Limited	Moderate	Moderate	Low
SAR	QoS Based	No	High	Limited	High	High	High
SPEED		No	Low	Limited	Low	High	High

Figure 6: Comparison of WSN Protocol

V. Results

The hybrid and LEACH protocols are compared having 100 nodes which are randomly arranged Figure 7 shows WSN arrangement. Figure 8 shows the performance while figure 9 represents outcomes of genetic algorithm and the optimization results.

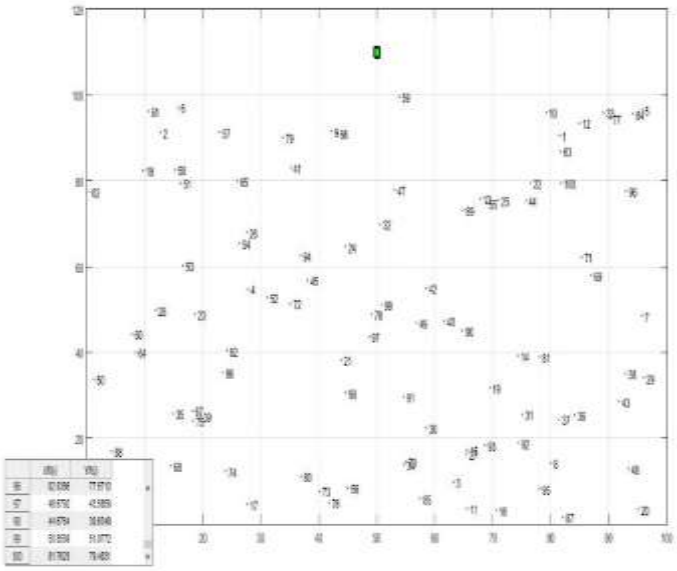

Figure 7:WSN Arrangement

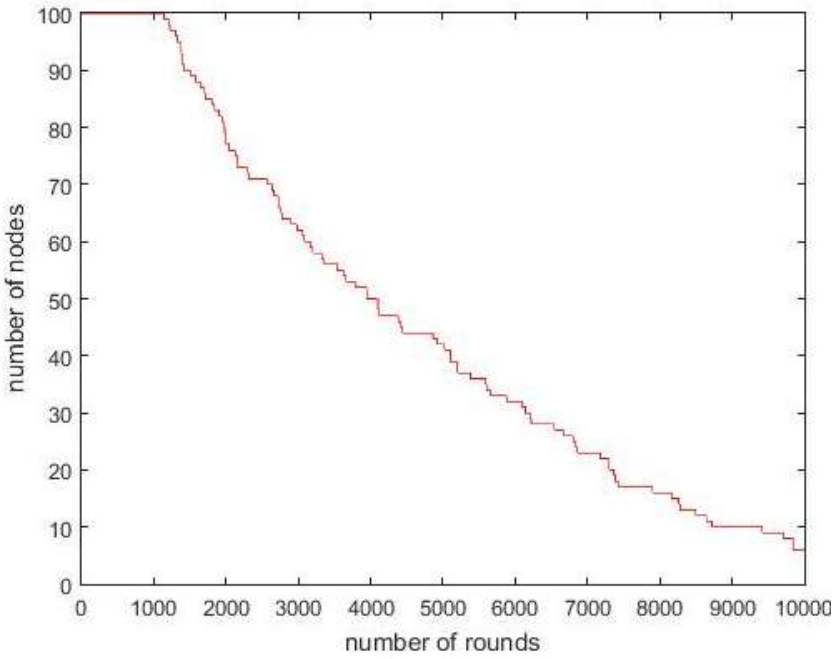

Figure 8: Hybrid Protocol

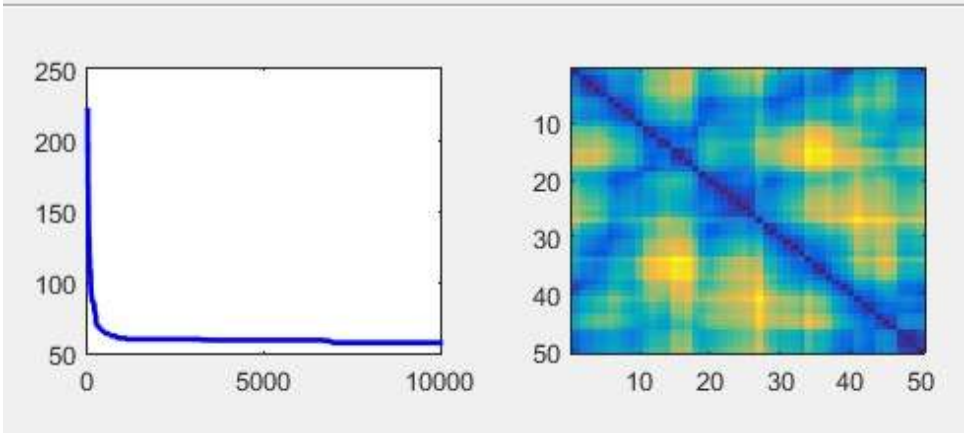

Figure 9: Genetic Algorithm Output

VI. Conclusions

Wireless Sensor network are useful to mankind in almost all the field from biomedical to military wireless networks are being used. In today's era wireless networks can be used in everywhere like using them in deep oceans, dense forests or in areas which are being hit by volcanoes. This paper reviews the important methods for optimizing a Wireless Sensor Network. there are various protocols and optimizing techniques for wireless network but this paper emphasizes more on Genetic Algorithm. Genetic algorithm is a powerful tool to optimize various routing protocols. It can be used alone or with other algorithms. In this paper we have shown that GA is more useful and efficient optimizing technique as compared to others, to minimize the power consumption at the transmitter side and taking shortest route and minimizing the effective cost of the network. Though genetic algorithm can be used in any wireless sensor network but it is more preferable for the sensor nodes, situated in remote place such as nuclear power plant and volcano. These types of places are very far away so that battery replacement or charging cannot be done.

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