Use of Genetic Algorithm for Optimal Node Placement in Wireless Sensor Networks

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***Abstract*— Wireless sensor networks (WSN) are now become an emerging technology and vastly use in engineering science, industries and military areas. To make this technology available commonly, many things requires attentions. In this study, the emergence, applications and problems of WSN has been discussed. Also some recent proposed architectures to optimize the major issues of WSN i.e. field coverage and network energy. This proposed architecture is the improvement of an already proposed architecture which is less complex. The proposed modified architecture has been proved by simulation process.**

***Keywords*— Genetic Algorithm, Wireless Sensor Networks, Node Placement and Network Configuration.**

I. INTRODUCTION

Modern science have able the industries to build such things which are not even imaginable in last two or three decades. Today's industries are automated and use robotics for manufacturing and productions. To use robotics in efficient way, sensor networks are used to sense such environmental variables more efficiently. This cannot be accessible by users. Enhancements and technology made these sensors wirelessly accessible and now these sensors are not only use in industrial applications but also in other fields of daily life.

A. Wireless Sensor Networks (WSN)

Typical wireless sensor networks consist of sensor nodes which are cheap, consume less power and perform various functions. Theses sensor nodes are in small in size and they also have other components like radio transceivers and microprocessor. That's why these sensor nodes have not only sensing capability but they are also able for data processing and data communication. WSN communicate over short distance through radio frequency RF channel and are useful in environmental monitoring, military applications, civilian and industrial applications [1]. The structure and characteristics depend on their electronic, mechanical and communication limitations but also on application-specific requirements [2].

B. Components OF WSN

There are four main components of WSN:

- Sensors: They are responsible for receiving, sensing or transmitting data from specific environment.
- Micro Controller: They are responsible for processing of data and control other functionalities of sensors.
- Transceiver/Receivers: They are responsible for communication among nodes and help for data transmission over wireless medium.
- Power Supply: Nodes require power energy for sensing, data communicating and processing.

C. Applications OF WSN

The applications of WSN are uncountable and no one can ignore these benefits. WSN play main role in different fields which are general engineering, environmental monitoring, civil engineering, military applications and health care applications. WSN used in sensing human interactions and social behavior [3]. It also provides lot of benefits in military field [4].

D. Limitations, Issues and Flaws OF WSN

The unique characteristics of WSN create lots of challenges in its design and its deployments.

- Energy Consumption: Sensor nodes use energy power for their sensing functions and transmission of data. They have limited energy capacity. This creates a big challenge for node deployment, their software and hardware placements and as well as challenge for architecture and protocols designs. To enlarge the life time of sensor networks energy consumption is critical issue. In existing sensor networks energy consumed by nodes in data processing is usually less than data transferring [5].
- Network Connectivity: Network connectivity is another design issue of WSN. It actually depends on protocol used for particular application. Mostly cluster based architecture is used for communication protocols. That include different issues like no of nodes in cluster, position of head node, load handling capability of sink node and ability of sensor nodes to reach these sink nodes [6].
- Network Coverage: Network converges is a major issue for WSN design. As WSN has limited range for communication. So placement of nodes and base station is main area of research in WSN. Position of nodes or base station should be like that it can cover whole specified area.

II. LITERATURE REVIEW

A. Genetic Algorithm

A genetic algorithm is an evolutionary algorithm used to solve optimization and search problems. It uses natural evolutionary logics for optimization that's why it is so called genetic algorithm. Genetic algorithm was developed by john Holland in 1992 [7]. Holland's goal was not to develop an algorithm to solve a specific problem but to study the natural process of evolution and tried to c`reate ways in which natural process of evolution can be incorporate into computer systems [8].

B. Components of Genetic Algorithm

The major terms of genetic algorithm (GA) explained in [2] and [8] are:

1) Population:

GA works on number of population. Each population has number series called chromosomes and in which data is stored in binary form. Solution is based on some parameters which are required to be optimized and theses parameters are represented in binary form.

2) *Fitness Function:*

Most important component of GA is Fitness function. Validity or invalidity of GA is determined through this fitness function. This function is designed on the basis of no of parameters of problem and requires more time for construction. This is raw information used by GA .That is why relation among parameters must be cleared.

3) *Selection:*

GA involves natural phenomena of reproduction and replication. So selection decides which chromosome is best according to fitness function or in other words it select no of chromosomes which are going to be replicated.

4) *Crossover:*

Crossover is an operator which is used to create new generation. Children in new generation contain part of information of each parent. There are different forms of crossover like single point and multipoint crossover. In single point crossover position of chromosome is selected from both parents and break into two substrings and theses substrings are swapped to form two children. In multipoint each parent is break from many points and these substrings are swapped accordingly.

5) *Mutation:*

Mutation is a process in which some bits of chromosomes are flipped. In GA Probability of mutation is about 0.01 or 0.001. This low rate prevents good chromosomes from change.

C. Benefits of Genetic Algorithm

WSN is now become most popular technology and mostly use in industrial and other fields. The main issue in WSN is to optimize its field coverage and network energy. GA is most appropriate optimization process for WSN, majorly because of its self-organizing capability. Not only has that GA had other more advantages as given below:

- Genetic algorithm is used for optimization of large number of continuous and discrete variables.
- It can perform simultaneously direct and indirect search in large search space.
- GA algorithm can also perform optimization of complex variables in complex surface.
- This paper problem is related with wide search space and it is important to evaluate each and every point to find out optimum one. GA helps us to find most optimum point from various points.
- When one variable changes then all other variables are also affected by such change. To find out cost value on each change requires critical calculation and GA use natural evolution process and selection process for performing such calculations and gives best solution as minimum cost [9] .

D. Discussion and Analysis of Related Work

Many works has been done since late 80s in the field wireless sensor networks, where so many optimized solutions have proposed. Most of these solutions are based on optimization of field coverage and power consumption issues. But the gates of optimization in these fields are still open. Here I have discussed and analyze some of these most appropriate proposed solutions. Suen Y., used the first online genetic algorithm to solve deployment problem in mobile wireless sensor networks [10]. Also designed the algorithm focused on two domains: server and cluster domain. In this algorithm, server is responsible to assign a base station to each cluster, where default target coverage has decided at initial stage. Each sensor is responsible to send their information (id, coverage, power) to base station, where base station sort these information according to their knowledge. Then the GA Mutation process has applied to change this sorted order and evaluate the best possible results.

Bhondekar *et al.* [6], has proposed a multi objective genetic algorithm to solve network coverage and energy consumption problem. In their paper they have discussed three types of sensors, where each type differs from another in power consumption and their range. They have mentioned these sensors by X, Y and Z type sensors where Sensor type of X, provides large transmission range, Y provides medium transmission range and Z provides low transmission range. Their energy consumption is based on their ranges so X consumes more power than Y and Z. They have designed a fitness function based on different optimized parameters which include network energy, field coverage, number of sensors in each cluster and number of overlaps in clusters. With the help of genetic algorithm they optimized those factors through which overall cost will minimize. The problem of their work is that they have focused only on network connectivity.

Ferentinos *et al.* [2], *has* proposed adaptive design optimization and used application specific parameters. These application specific parameters include uniformity and density. They test their GA on agriculture problem and used cluster based architecture with two different type of clusters i.e. cluster head and sensors of both regular and irregular type. Their main focus is to optimize design characteristics which include clustering with appropriate cluster head, status of sensors (active/inactive) and transmission range of sensor nodes.

A positioning method was developed by Romoozi *et al.* [11] ,to solve coverage and energy consumption problem. They tried to find out best position of nodes in a network which gives good coverage in minimum energy then by using GA they arrange these nodes finally they used K-mean cluster algorithm to formalize clusters of nodes. Their proposed fitness function consists of energy transmission parameters and network coverage parameters. They compared their results with very basic algorithm LEACH (low energy adaptive luster hierarchy) [12]. By results they proved that their proposed network's life time is maximum than LEACH algorithm's network.

Another solution for the same problem was given by Buddha *et al.* [13]. They used gradient based genetic algorithm in their research. They proposed an algorithm to optimize network coverage and backbone connectivity. They used an ordinary proposed algorithm as their pre work which is quadratic optimization method for connectivity and coverage problem based on the square distance between neighbor nodes known as quadratic minimization problem [14]. They tried to solve quadratic minimization problem by using gradient approach.

An algorithm based on GA was developed by Yipeng. Qu and Stavros V. Georgakopoulos for relocating wireless sensor nodes [15]. Yipeng also proposed multi objective genetic algorithm based sensor relocation algorithm. In which base station needs to know location of each sensor node and then run optimization algorithm to decide where sensor node should move to achieve maximum coverage and minimum traveled distance. They tried to optimize final position of sensor nodes and as well as travelled distance. The best thing of this algorithm is that it can be used for sensor network healing. They calculate area that can be uncover and traveled distance. Finally by combing these terms they calculate fitness function.

E. Discussion and Analysis of Pre-Work

Many algorithms which have been proposed so far for the purpose of optimization of network coverage and energy consumption. From these proposed algorithms [10-14], which have already been discussed in previous section..In their research they have used three types of sensors X, Y and Z and they assumed that variation of X in field is less than Y and variation of Y is less than Z. Node can operate in one of three operate modes i.e. X sense, Y sense and Z sense The nodes in X sensing mode have high transmission range whereas nodes in Y and Z sensing nodes have medium and low sensing ranges respectively. They have used simple cluster based architecture and those nodes which operates in X sensing mode are access point or cluster-in-charge and are able to communicate with base station by using multi hop communication. They proposed multi-objective genetic algorithm by using three categories of optimized parameters i.e. deployment parameters, energy related parameters and connectivity parameters. Their designed fitness function consists of five optimized parameters.

- In application specific parameters there is field coverage which shows area to cover by each sensor.
- In connectivity parameters there are three parameters :
  - Sensor-per-cluster-in-charge: shows no of sensors in each cluster.
  - Sensor-out-of-range error: shows no of sensors which are out of range.
  - Overlaps-per-cluster-in-charge error: shows no of overlaps of cluster-in-charge.
- Energy related parameter: shows how much energy is required by each sensor.

Their basic idea was to design fitness function which will minimize constraints such as operational energy, number of overlapping cluster-in-charge range and number of unconnected sensors. Whereas the parameters such as, field coverage and number of sensors-per-cluster-in-charge are to be maximized [6].

They have conclude that for communication purposes use high number of sensors to achieve low energy consumption, rather than having low number of sensors which consume high network energy. They also conclude that uniformity of sensors optimal design was satisfactory. But using large number of sensors will also result in increasing their buying cost and will consume more operational and communicational energy, because the power consumption of X, Y and Z mode sensors are relatively increases. They have used four X nodes or access points and all other sensor nodes are connected with these access points so their architecture is centralized WSN architecture which causes overlaps per cluster-in-charge-error and sensor out of range error.

III. PROPOSED ARCHITECTURE AND ITS ANALYSIS

In previous section it is discussed that Bhondekar *et al.* [6], proposed solution based on centralized. A proposed WSN architecture is based on considering Bhondekar *et al.* [6] as initial research.

In this study, IEEE standard 802.15.4d which supports the distributed architecture are used. Wireless sensors complying IEEE standard 802.15.4d supporting 2.7 GHz frequency and can support up to 16 to 24 channels with respect to power consumption. Furthermore FFD (fully functional devices), so each node can work as sensor node and access point or sink node. In proposed solution using 100 sensor nodes consist of three types that are X type nodes, Y type nodes and Z type nodes. X types of node are representing access point which is only one in my proposed architecture, while Z type of nodes can work as sink nodes as well as regular sensor nodes. When Z type of nodes start working as sink nodes then they are called Y type nodes otherwise they are called Z type nodes.

As pre-work [6], proposed algorithm is multi objective genetic algorithm and it optimizes application specific parameters, energy parameters and connectivity parameters. In [6], they used five optimizing parameters, while due to architectural change, only three parameters which are field coverage, sensors-per-cluster-in-charge and network energy.

Optimization is achieved by minimizing energy consumption, minimizing number of sensors-per-cluster-in-charge and Field coverage.

A. Application Specific Parameters

- Field coverage: This shows area to cover by each sensor node. As node of X type (Sink node) is assumed to be single node in WSN and when a node of Z type (Sensor node) work as both type of nodes i.e. Z type and X type, supposed to be node type of Y. Therefore the field cover by node of Y type is equal to node of X type. For the node type of Z, it is assumed that either it will be inactive or active. In first condition, there is no need to calculate field coverage for such nodes, otherwise it will

$$FC = \frac{(2*X\_Type\_of\_Nodes + 2*Y\_Type\_of\_Nodes + Z\_Type\_of\_Nodes) - inactive}{Total\_nodes}$$

  half of X type of nodes

B. Connectivity Parameters

- Sensors-per-cluster-in-charge: This shows no of sensors in each cluster. As X type nodes and Y type nodes can be part of cluster-in-charge. So calculating possible number of sensors in each clusters excluding inactive nodes. The proposed architecture can support 16 to 24 channels as per IEEE standard 802.15.4d.

$$SPCi = \frac{((Y\_Type\_of\_Nodes + Z\_Type\_of\_Nodes) - ninactive)}{No\_of\_channels}$$

C. Energy Related Parameters

- Network Energy: As node of X type (Sink node) is assumed to be single node in WSN and when a node of Z type (Sensor node) work as both type of nodes i.e. Z type and X type, supposed to be node type of Y. Therefore, X type node and Y type node consume equal power that is twice of power consumed by Z type of node. For the node type of Z, it is assumed that either it will be inactive or active. In first condition, there is no need to calculate network energy for such nodes, otherwise it will half of X type or Y type of nodes. Therefore, the finalize network energy consumption may be defined as:

$$NE = \frac{(Z\_Type\_of\_Nodes + 2 * Y\_Type\_of\_Nodes + 2 * X\_Type\_of\_Nodes)}{Total\_Nodes}$$

Simulation Parameters and Assumptions

Simulation process using genetic algorithm under 3000 generations to verify the outcomes in MATLAB . Proposed architecture considering the field of 10 x 10 units of area. In order to optimize field coverage, using a total of 100 nodes which include one X-type sensor node, forty Y-type sensor nodes and remaining are of z-type sensor nodes. Sensors which will not in use in simulation process will be considered as inactive nodes. As node of X type (Sink node) is assumed to be single node in WSN and when a node of Z type (Sensor node) work as both type of nodes i.e. Z type and X type, supposed to be node type of Y. It is also assumed that sensors used in this simulation process, is IEEE standard 802.15.4d compliant. Therefore these sensors can support up to 2.7 GHz frequency and maximum 26 channels In this case very few numbers of sensors can cover the required field.

- ***Field Coverage:***
  Figure 1 shows optimization of field coverage with 200 generations and depicted from the figure that initially some scattered data within 20 generations. But after 20 generations was constant data. It is also depict that that proposed architecture has covered up to 0.82(82%) area of field.

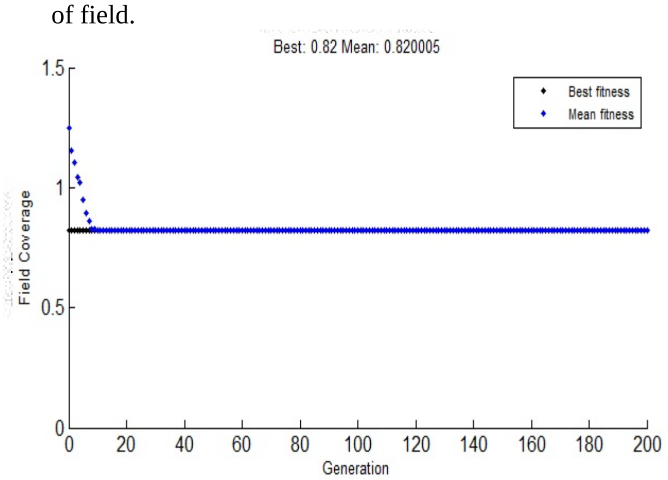

Figure 6: Optimized Field Coverage (FC) parameter

- Sensors Per Cluster In Charge:
  In order to optimize Sensors-per-cluster-in-charge, three channels are used, fixed number of Y-type sensor nodes and Y-type sensor nodes. Sensors which will not in use in simulation process will be considered as inactive nodes. Figure 2: shows optimization of sensors-per-cluster-in-charge (SPCi) with 200 generations. It could depict from figure that constant data from 1 to 200 generations. It is also observed that the proposed architecture minimizes SPCi up to 13.33.

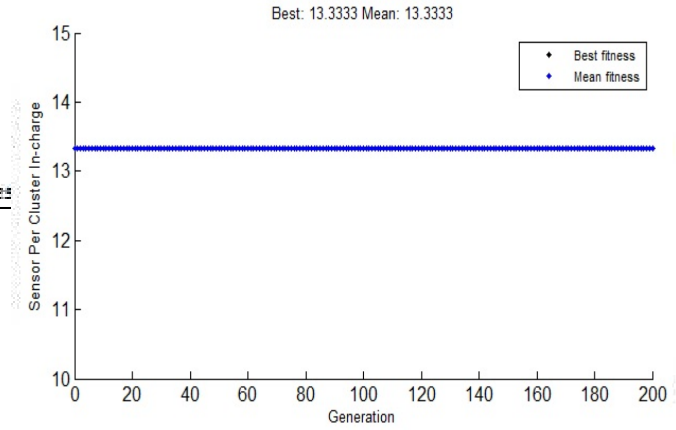

Figure 7: Optimized SPCi Parameter

- Network Energy:
  In order to optimize network energy parameter have used fixed number of X-type sensor node and Y-type sensor nodes while number of Z-type sensor nodes are varying. Due to this total number of nodes are also varying. Figure 3, shows optimization of network energy (NE) with 200 generations. This figure showed scattered result in initial generations but after 30 generations constant result is observed. Figure also depicts that Network energy is optimized up to 1.88.

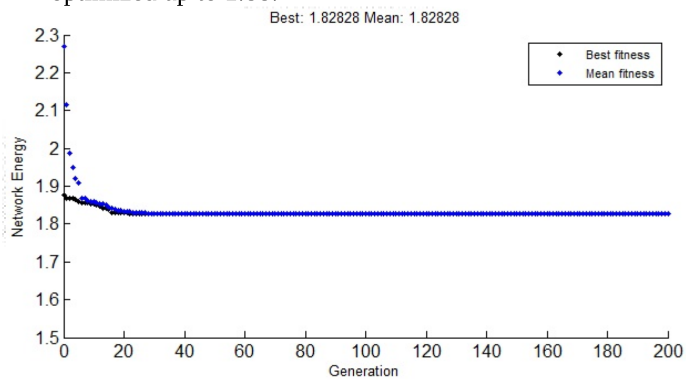

Figure 8: Optimized Network Energy (NE) Parameter

IV. COMPARISON BETWEEN MY PROPOSED ARCHITECTURE AND PRE WORK

In [6], they used five optimizing parameters, while due to architectural change, only three parameters field coverage, sensors-per-cluster-in-charge and network energy are used.

It could be observed that field coverage in pre work is about 0.8 (80%) [6], while my proposed architecture provide field coverage about 0.82 (82%). In this study FFD enables sensors to cover some area all the time so there is no any out of range sensors. Due to this reason my proposed field coverage is better than pre work's FC [6] .

In this paper aim is to minimize number of sensors-per-cluster-in-charge, so overall no of sensors are reduced and they consume less energy.), it is proved that SPCI of pre-work is greater than SPCi of my proposed architecture, which is 13.33 where in pre work it was examined as 21.5 [6] . This result show very big difference. Also achieved minimum no of sensor nodes in each clusters. In pre work Bhondekar *et al.* [6], tried to maximize number of sensors-per-cluster-in-charge because they shave used only four access points so they tried to connect more and more sensors to achieve better field coverage. But in my case, it is other way around. Hence sensors can work like access point as well as regular sensor nodes, so here it doesn't require maximizing number of sensor per cluster in charge.

It is observed that Network Energy in pre work is about 2.24 [6], while proposed architecture provide Network Energy about 1.828. Result proofs that proposed architecture can produce better field coverage with minimum network energy consumption. Main reason of minimized network energy is no of sensors per cluster in charge as in my case SPCi is reduced which ultimately causes less energy consumption.

V. CONCLUSION

Even though, wireless sensor networks are now used vastly in major industrial areas, but the gates for academic R&D are still open to ensure its common availability. My proposed WSN architecture is the modification of architecture proposed by Bhondekar *et al.* [6]. Proposed architecture is verified by simulating it on MATLAB. The result shows that proposed architecture is better than the pre-work's [6] architecture. The observed field coverage, network energy and sensors per cluster in-charge of proposed architecture is better than the proposed architecture by [6]. Based on simulated results, it can be concluded proposed architecture, by using less number of sensor nodes good field coverage can be achieved with less power consumption and also observed that FFD sensor helps in covering area for sensing as well as in achieving good field coverage.

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