A STUDY ON IMPLEMENTATION OF WSN IN OPTIMISATION OF ENERGY CONSUMPTION FOR MANUFACTURING UNITS

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Abstract: A great deal of attention has been paid to Genetic Algorithm (GA). As a method, the algorithm is a multi-objective method that can be used in areas like self-organizing wireless sensor networks. The method looks at the used parameters and the fitness function by looking at or taking into account all of the operational modes in the possible states that can be made. Most GA implementations of clustering algorithms only focus on optimizing a few parameters, such as coverage and energy use, which have a noticeable effect on the quality of the network. Keeping network coverage can be thought of as a mathematical programming problem with a lot of calculations to do. On the other hand, wireless sensor networks (WSNs) can be very dynamic. If this is the case, the network needs to be able to respond to events in the right way. If it doesn't, even the smallest decision made by management could have a big impact on the quality of the network. In this study, the Genetic Algorithm toolbox and custom codes are used along with MATLAB's hybrid method to solve this problem. The best solution was found using a mathematical algorithm that met all of the above criteria.

Keywords: Genetic Algorithm, Wireless Sensor Network, Coverage Maintenance, Energy Consumption, Network Optimization

I. Introduction:

Wireless Sensor Networks (WSN) are made up of many low-cost, low-power sensors that can only do a limited amount of computing and communication. The sensors are easy to set up in a WSN setting to do certain things. Wireless platforms are getting cheaper and more useful at the same time. This trend shows that the wireless system will be used more and more for things like health monitoring and military sensing. WSNs have inspired a lot of researchers all over the world [1, 2], just like other networks have.

One of the most important things about WSNs is their coverage, which is closely related to things like saving energy, staying connected, changing how the network works, how long it lasts, and so on. In this study, nodes are set up for a random sensor field. So, coverage is a big problem because it affects how objects are watched and tracked.

In general, you can talk about coverage from two points of view: the best and worst cases that can be seen. In the first method, the goal is to find the area with the most changes in observations and find the best areas for support and guidance. In the second case, however, the goal is to find the areas with less change in observation and the blind spots. In some cases, it's hard to get the sensors where you want them in the target field because it's almost impossible to do it by hand and it can be affected by things you can't control, like wind and obstacles [3, 4]. Fig.1 shows how a WSN network is set up in general [5].

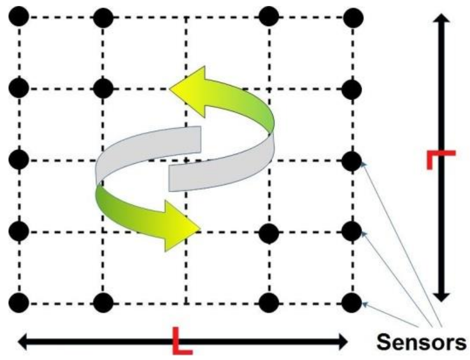

Figure 1. Network coverage concept in WSN

The most important challenge of WSN is making sure the network lasts as long as possible. This is because nodes with small batteries are in charge of putting together and sending monitored data to the base station. These tasks take a lot of energy, and it's not possible to replace or recharge the batteries.

Few algorithms and protocols have tried to keep a balance between the amount of energy used and the amount of coverage needed as a way to solve the lifetime problem. So, it's important to study how to spread the sensors out evenly so that they all use the same amount of energy coverage that is good enough. In any case, there is no way to get around the problem of coverage. As was already said, WSN coverage is used to describe the area that sensors cover, which has a big effect on how well they work. This makes a big difference in how much power is used.

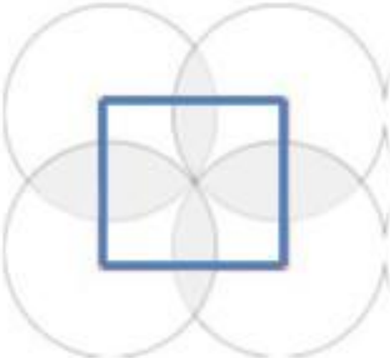

Figure 2. Coverage problem in WSN [2]

There may also be overlaps in the area the sensor can see (Fig.2). By reducing the overlaps, the network can cover a bigger area with fewer sensors. The "coverage problem" [6] is the problem of how sensors in a network share the space they cover. Another thing to worry about is the space that was left open between the covered areas (Fig.3). The spaces are called "holes" in computer terms, and since the network can't collect information about the holes, it's important to make them as small as possible.

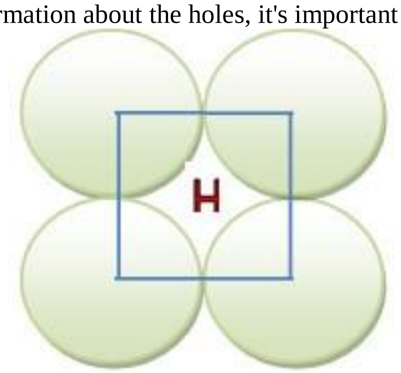

Figure 3. Coverage hole in WSN [2]

Even though the failure of a few nodes might not stop the network from working as a whole, this can have a big effect on the best way for the network to connect [7].

Cluster-based protocols are used more often because clustered nodes use the least amount of energy. Under cluster architecture, nodes are put into different groups based on their roles in the network and the goals of the cluster. A head node, also called a cluster head, oversees a group of nodes. The data that each member of the cluster sends to the sink is sent to the sink by the cluster head. The group's schedule can be set by the cluster heads based on Time Division Multiple Access (TDMA). Even though several algorithms [8, 9] have been shown, focusing on a single problem makes the design more complicated.

Genetic algorithm is one of the most promising heuristic ways to solve optimization problems (GA). The algorithm is based on the idea of "intrinsic selection," which is also a part of how living things change over time. The GA often and randomly changes a group of people to make them parents and use them to make the next generation. After that, the population changes over time to find the best solution through each generation. In other words, the main goal of this study is to find a way to solve the problem of coverage in WSNs while minimizing the effect of overlap. MATLAB was used to do the simulations.

The next part, section II, looks at the research on WMSN and network coverage. In Section III, the basic ideas, such as terminology and the hypotheses needed for the proposed method, are talked about. In section III, we talk about how the proposed algorithm solves the problem of coverage. In section IV, we talk about evaluating performance and simulating results. The end is in Section V.

II. Related Works

In most recent studies, sensor nodes are fixed, and a lot of extra nodes are put in to get the level of coverage that researchers want. This could cost a lot, and there's no guarantee that everyone will be covered since it's a random process.

There have been many ideas for how to design the best WSN, but each one has focused on a different issue and made the design more complicated. This part talks about some studies that have been done on the problems of optimizing network coverage.

Ref. [10] did a study that was one of the first in the field. He suggested a method of "blanket coverage" that used statistics to set up sensor nodes in a way that gave extra coverage.

Reference [8] proposed a GA-based method that used a repelling behaviour to spread the nodes over the desired area. The authors worked on a full model network that could only be built on further with offline planning. Reference [11] suggested an interactive method based on GA for finding the best solution for energy use, transmission schedules, and other things.

In Ref. [12], another way was shown to figure out and add to the multimedia coverage of each sensor. The method is meant to place the sensor automatically. As the method calls for, the coverage ratio of a certain number of nodes can be found, and reducing the number of nodes in the method makes it less effective. Ref. [2] came up with a new way to classify WSNs based on 3D geometric shapes. To find out how much space the sensors covered, they came up with an equation called "volume in the spherical coordination." This classification seems to be useful in places where the space is not very big.

at first glance [2].
Reference [13] used a step-by-step process to make the coverage problem easier to understand. With the help of mathematical modelling, theoretical analysis and formula derivation, classical geometric theories, and mathematical induction, the analysis formula for the minimum number of nodes in a WSN with complete and continuous coverage [13] was found.
Ref. [3] talked about the problem of mobility in sensor networks, where some of the sensors could move around. When a sensor finds gaps in coverage, it moves to a new spot based on rules. To make sensor mobility cheaper, they came up with a density mobility scheme (DMS) that could improve the system's coverage by moving the nodes to the nearest hole. Under the DMS, a mobile sensor can only move to a sparse area if the majority of the sensing area is covered by its neighbours' nodes [3].
As a way to solve the coverage problem, a genetic algorithm was used to come up with a new way to model the problem of coverage in wireless camera-based sensor networks.
Theoretical analysis of the problem has been used to cover an area as much as possible with as few overlaps as possible between the cameras.
In Reference [15], an interactive approach based on GA was shown for Mobile Sensor Networks. In this work, the fitness function was used to find the best way for a node to move, considering either how much of the target area it would cover or how much energy it would use.

III. Proposed Algorithm

The genetic algorithm is used in this study to find a better solution than the other methods. The GA has the following general steps:

- To start with a random population of M (0).
- To figure out and keep track of the fitness u(m) for each "m" in the current population M. (t).
- To figure out the selection probabilities p(m) for each member "m" in M(t) so that p(m) is relative to u. (m).
- To get M(t+1) by picking individuals from M(t) at random to create a new generation through crossover and mutation.
- Repeat step 2 until you get a satisfactory answer.

GA is usually used to solve problems that have a large search space and don't have to be exact. As our method says, the maximum area to be watched is covered by a minimum number of active sensors.
We will assume that the target field has a WSN with a lot of small, battery-powered sensor nodes. The sensor nodes check the temperature and other things in the environment every so often. This part defines a network and describes how it works.
Definition 1: A sensor's sensing range is the area of land where any event could happen.
The sensing neighbour is a group of sensors that are in range to sense.
Definition 2: A WSN is homogenous when all the sensors have the same initial energy, sensing range, and communication range. Otherwise, it is heterogeneous [4].
Definition 3: Fitness function is to evaluate the goodness of each solution, i.e. chromosome.
Considering real-world WSN applications, this study looks at hypothetical parameters A, B, and C for 2D fields. These parameters help us take a more practical approach. Researchers in the field use them all the time [16]. So, we have three kinds of sensors to look at different things. To make the problem easier to understand, it is assumed that the spatial variations of A, B, and C are shown as the number of sensors per area unit where the objects are being watched. This is shown as A > B > C. This idea looks at both the big picture and the details of special objective networks. Table 1 shows the simulation parameters.

Table 1. Simulation parameters

Area (N)	100*100
Number of Sensors(N)	200
Initial Energy	2J
Node energy	50 nj/bit
Base Station distance	200 m
Packet Size	200 bits
Sensing range	15 m

Assume squared Euclidean field with length l is divided into equal areas so that sensors at the lines where the fields meet can keep an eye on any area of interest. Many researchers use a method called "grid-based wireless sensor network layout."
The sensors are small, have limited power, can only send data over a certain distance, and have a "sensing-mode selection node" that can choose one of three modes of operation based on its capabilities and current state. Since A has the lowest density, it has the longest transmission range, while C has the shortest range. To get the most out of the energy used in this work, a clustering solution was used. Each cluster is made up of one or more sensors that are close to each other and have the same "cluster-in-charge" mode of operation. With multi-hop, each cluster talks to either the sink or the Base Station (BS).
A multi-objective algorithm is used to find the best way to balance two important parameters, like energy use and coverage. So, the problem was split into two smaller ones. The plan was as follows:

1. Using local search and the genetic algorithm, find the minimum number of nodes needed to cover the whole environment. This will help solve coverage and power consumption problems.
2. To make sure that connections are made between clusters-in-charge and member nodes of a cluster. The Kruskal algorithm was used to do this.

A new algorithm was used to come up with some possible best network topologies that minimised operational energy, the number of nodes that weren't connected, and the overlap of cluster-in-charge errors. Part of the genetic algorithm formula, which is an improved version of the Nakmura formula, was used to suggest an appropriate fitness function [17]: A is the given monitoring area, S is the set of sensor nodes, D is the set of demanded points, Ad is the set of sensors monitoring the demanded areas, NC is the penalty cost of not covering a demand point, AE is turning on the power, PC is the penalty cost of the path from every node to BS (obtained by Dijekstra's algorithm during a pre-processing phase) and it is given to every node to tell expensive nodes and model variables apart, and (when the demand point j is not covered). The model's different parts are:

- Xij = 1 when node 'i' covers demand point j and 0 otherwise
- yi = 1 when nodes 'i' is active and 0 otherwise
- hj = 1 when demand point 'j' is not covered.

The model can be formulated as:

$$\min \sum_{i \in s} (AE_i + PC_i) \times y_i + \sum_{j \in D} NC_j \times h_j \qquad (1)$$

Subject to:

$$\sum_{ij} (x_{ij} + h_j) \geq 1, \forall j \in D \,\&\, \forall ij \in A^d \qquad (2)$$

$$x_{ij} \leq y_i, \forall i \in S \,\&\, \forall ij \in A^d \qquad (3)$$

$$0 \leq x_{ij} \leq 1, \forall ij \in A^d, h_j \geq 0, \forall j \in D$$

$$y \in \{0,1\}, \{x, h\} \in \Re$$

The above formula reduces the number of active nodes that are needed, which increases network energy and the number of interested areas that aren't being used. Constraints 2 and 3 say that each required point is either being watched by a sensor or isn't being watched at all. They also say that only active nodes can sense. We improve our algorithm's Fitness Function (FF) by considering the penalty cost of overlapping cluster-in-charge errors and the energy consumption, which are shown below [18]:

$$FF = \min(Usage\_Cost + Penalty\_Cost)$$

$$Usage\_Cost = \sum_{i \in s} (AE_i + PC_i + EC) \times y_i$$

$$Penalty\_Cost = \sum_{j \in M} \sum_{k \in D} (NC_{jk} + OPCE_{jk}) \times h_k \qquad (4)$$

Subject to:

$$M \in \{A, B, C\}$$

EC is measured by a number, and the number depends on how the sensor network is set up. Since the "A" mode sensor node has a long communication range, it makes sense that it uses the most energy. Modes B and C are next in terms of energy use. In what comes next, it is assumed that A mode uses four times as much power as C mode and that B mode uses twice as much power as C mode. EC comes from:

$$EC = \frac{4n_A + 2n_B + n_C}{\sum_{i \in S} n_i} \qquad (5)$$

In the fitness function, OPCE calculates wasted energy to keep track of errors caused by clusters-in-charge that overlap.

IV. Evaluation and Results

A genetic-based algorithm finds a lot of the best solutions, even though it doesn't consider how the nodes are connected. This shows the flow of information from the BS to the BS. In the second part of ECEP, the network connectivity was looked at with the help of the Kruskal algorithm. The proposed process has four steps. The network is thought of as a graph G, with an edge between vertices x and y when the maximum communication range between two nodes x and y is greater than the distance between them. By using the Kruskal algorithm, a minimum spanning tree (MST) is made so that each pair of nodes has a shorter path between them for routing aggregated data. When the number of MST tree edges is equal to the number of vertices minus one, connectivity with specific shortest paths is achieved. If this isn't the case, inactive nodes are turned on (this explains shorter transmission range than communication distance for some nodes). Kruskal technique is used on nodes that have just been turned on or turned off. This makes a new tree that is the lightest. Each disconnected node's shortest path to the BS is found, and the internal sensor nodes on those paths are added to the set E. Any newly activated node that isn't on the list in E is turned off. This helps save energy on the network, but the quality stays the same. Lastly, one or two network types were made based on how far nodes could send data and where sensor nodes were placed. The network(s) that got the most network coverage had the best coverage and used the least amount of energy. To use the new method, a square LL field was used, where the areas of the squares were about the same. Each node is at the intersection of two subareas, and it can have one of four values: 1: inactive = 00; 2: mode "A" active = 01; 3: mode "B" active = 10; and 4: mode "C" active = 11. Figure 1 shows the network encoding method. 4.

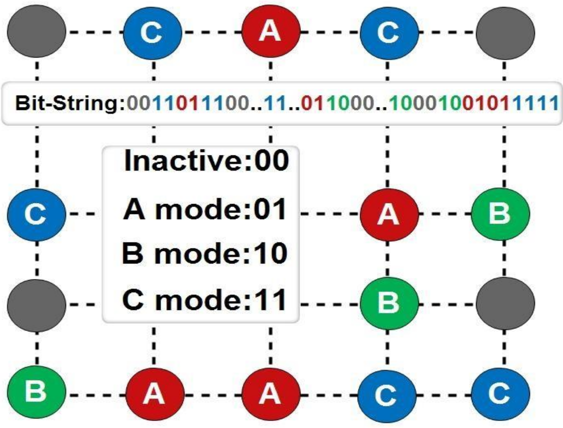

Figure 4. Network with represented encoding

The setting of all the nodes in a network can be shown by gen, and a specific chromosome is made up of an ordered set of gen. In this way, encoding is 2.L2 bits for a network with L nodes (L.2 gens that need 2 bits to explain the mode of corresponding node). The genetic algorithm technique is based on a set of chromosomes, called the population, that get better with each generation [18]. To put it another way, the algorithm copies nature based on the data it is given and the primary population that is chosen at random. After the process of generation, the developed population or the result is the best solution to the main problem. Crossover, scoring, selection, and mutation are all parts of the generation process that help things get better. By "crossover," we mean a production function with a set rate that mates two chromosomes that are different to make a new population. From all the ways to cross over, single point was chosen for this work. The key to a genetic algorithm that is affected by the problem is how it scores or assigns points based on the fitness function [19].

At this point, the algorithm gives each chromosome a weight based on what it contains. In other words, each chromosome stands for a solution that is built up over time. The better chromosome that makes it to the next generation has a higher fitness value. Most of the time, the fitness function is designed based on the problem, and most of the time, researchers focus on showing intelligent fitness functions to tell qualified people apart. During the selection process, the better chromosome is used to create a new population. This is done by using the mutation technique so that only certain chromosomes are passed on to the new generation.

In this paper, the population size was 400, the productive function was a single point, and the mutation rate was set at 0.5. In Table 2, you can see the GA parameters that were used to model the environment. You can pick the candidate chromosomes at random because it won't change the final results. This is because any candidate individual will tend toward the best solution. The number of times the process is repeated is always 100.

Table 2. GA parameter Values

Number of candidate individuals	400
Length of Chromosome	20
Crossover Rate	.5
Mutation Rate	.2
Iteration	100

Because of stochastic bases of GA, repetitive runs of the algorithm eventuated in different solutions with different performances. Thus, average of the results of runs was reported. By using WSN simulator, appx. of the implemented proposed algorithm achieved 100% coverage on the designated area. Power consumption, number of active nodes, and live packet over time are listed in Table 1. The starting number of 18 packets delivered to the BS was increased to 83 packets after second 01.18.

Table 2. Observed values in the early times of network

Time (Nanosecond)	Power	Active Sensors / 35	Live Packets
00:35.090	20718	27	18
00:49.330	15332	27	60
01:08.107	8031	20	53
01:18.182	6739	18	83
01:36.719	5333	14	30

01:48.626	4368	12	36
02:02.956	3354	10	38
02:09.666	3123	8	38
02:18.048	2897	8	47
02:46.709	2032	7	54
02:55.352	1860	6	52

Table 3 indicates the last time the network which died in 5:13:781. In addition, the number of live packets gradually decreases as the number of active sensors approaches 0.

Table 3. Observed values in the last times of network

Time (Nanosecond)	Power	Active Sensors/35	Live Packets
03:22.821	1096	5	87
03:45.804	616	4	89
03:58.382	421	3	75
04:15.196	307	2	33
04:39.882	122	1	25
05:13.781	0	0	0

Figure 5 shows how the number of times the genetic algorithm is run affects how long a network lasts. Iterations 50 and 57 show that adding more people does not always make the solution better. In other words, it's enough to meet the stop criterion to get the best solution.

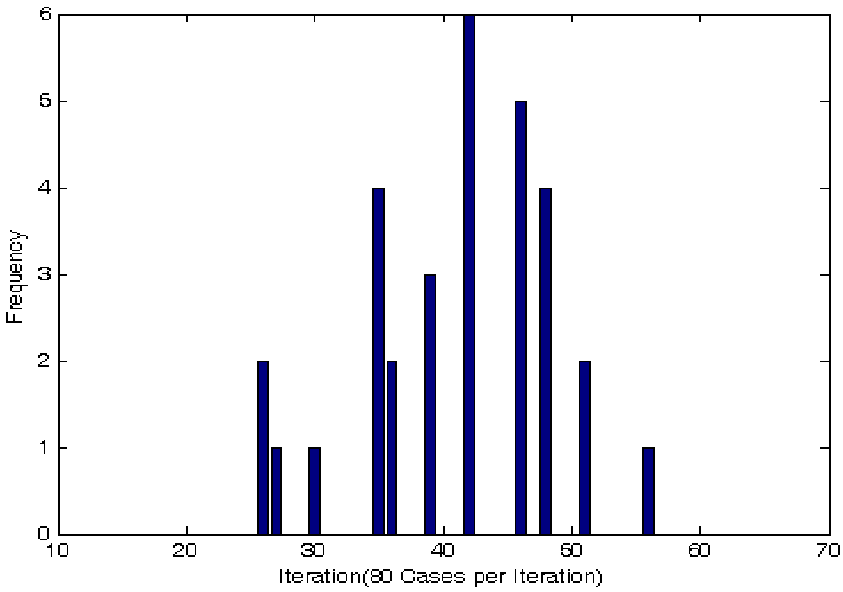

Figure 5. Network lifetime in specified scale

V. Conclusion

GA is one of the solutions that people often use when they need to search over a large area and don't care much about how accurate the results are. Using the method that was suggested, the widest area possible was covered with the fewest number of active sensors. In this study, the main problems of WSN, such as coverage and energy use, were solved with a hybrid method. Two genetic algorithms and Kurskal techniques were used to make this happen. In the GA-based part, both coverage and the best way to use energy were taken into account. The most important thing that this study showed was that a general algorithm can be used to solve the coverage problem in WSNs. In the simulation, three types of sensors with high, medium, and low transmission ranges were used to keep an eye on a grid-based environment. Simulations showed that using many low-power sensors for communication is better than using a small number of sensors that use a lot of energy.

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