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Fault Tolerance Approach in Distributed Sensor Networks using Genetic Algorithm

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***Abstract*— Nature has always been a great source of inspiration to all kind of researches so far. Genetic Algorithms (GA) were invented to mimic some of processes observed in natural evolution by John Holland in 1970s. GA simulates "survival of fittest" among individuals over consecutive generation for solving optimization problems. In this paper considering Fault tolerance as one of the important issues in Distributed Sensor Networks, the Genetic Algorithm has been proven to be the best. The Distributed Sensor Networks are interconnection of tiny, low cost, low-powered and multi-functional sensor nodes. However these DSNs (sensors) are highly prone to malicious attacks, faults due to energy depletion and sometimes due to link failure. When energy in some of the sensor nodes reduces or gets depleted the implementation of Genetic Algorithm have proven to be the masterpiece for development of healthier network than any other algorithms. As we know prevention is better than cure. This paper aims to prevent the sensor nodes from occurring failure. Thus the main objective of the current work is to generate energy efficient DSNs and a way towards fault tolerance.**

***Keywords*— DSNs- Distributed Sensor Networks, GA-Genetic Algorithm, Natural evolution, Energy Depletion, Link Failure.**

INTRODUCTION

The Distributed Sensor Networks (DSNs) are one of the active research areas today as they have thrived the progress of mankind. DSNs are such networks which are deployed in hostile environment where human intervention is profusely impractical. A considerable amount of attention and research has been devoted in recent years to the deployment of Distributed Sensor Networks (DSN) for example space exploration, battle field surveillance, search and research, costal and border protection, today such networks are used in many industrial and consumer applications and environmental conditions monitoring and so on. Energy efficiency, network or topology control and fault tolerance are the most important issues in the development of next-generation DSNs.

A DSN is a high level distributed set of sensors that are interconnected by a communication network in the environment. The sensors in the network have the unique feature of self configuring among themselves in unattended areas and have the ability to communicate with each other. DSNs may suffer from certain possible conditions as follows:

- Malicious activity, or by extended use.
- Extensive operation may drain some of the node power.
- Hazards may change devices positions over time.

This may need to deploy additional sensors to fix the network. Instead the Genetic Algorithm is applied in order to solve these conditions. The current working is all about Distributed sensor Networks (DSN) framed with Genetic Algorithm (GA). The main objective of this work is to provide fault tolerance mechanism by using GA.

RELATED WORK

Several related works are discussed in this section. A fault node recovery algorithm has been proposed [8] to enhance the lifetime of a wireless sensor network when some of the sensor nodes shut down. They have used Grade Diffusion Algorithm (GD) and Directed Diffusion Algorithm (DD). The next paper is about Mobile Ad-hoc Network [5] which ensures check pointing at each node for the fault tolerance approach. The trust factor has also been defined for the same. Prof. Rewagad [6] has considered the security issues in Wireless Sensor Networks. They have given Trust aware routing framework based on trust values of sensor nodes proved effective for preventing identity deception attacks. The work given in [9] presents the models of GAs and types of crossover operator. The work presented in [3] depicts a minimization of total energy consumption using Genetic Algorithms.

EXISTING WORK DONE

In the existing system, the Wireless Sensor Network was deployed and Genetic Algorithm was implemented for the overall network performance. The simulation model was showing the comparison of other traditional algorithms such as LEACH (Low Energy Adaptive Clustering Hierarchy) and GA. The performance graph was the result of the simulation. It concluded that how GA proved to be the best than any other traditional algorithms for example

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we have taken LEACH. We have calibrated the performance of our approach by proving that GA quickly converges to the optimal solution. For large networks, the GA generates solutions that significantly extend the lifetime of the network, compared to the conventional routing strategies.

BACKGROUND KNOWLEDGE

This paper aims to improve the lifetime of the Distributed Sensor Networks (DSNs) in combination with the Genetic Algorithm (GA). As a result in the existing work, GA has proved to be the best heuristic technique for solving such optimization problems for larger work space. The Genetic Algorithms are meta-heuristic inspired search based algorithms evolved from large class of evolutionary algorithms. It is frequently used to find optimal or near-optimal solutions to solve difficult problems and is used most probably in the research and machine learning.
The Genetic Algorithm was invented to mimic some of the process carried during natural evolution. The basic phases in GA are: 1. Population Generation, 2. Genetic Representation, 3. Fitness Function Declaration, 4. Selection (Best solution) using some technique, 5. Crossover and mutation for new offspring generation, 6. Elitism, 7. Termination condition if satisfactory level has achieved. It is essential to specify the basic terminologies before implementation. The terms used are:
Population: It is the set of possible solution on which GA operates. It is similar to the population of human beings. Here the possible solution is considered as the population instead. In distributed Sensor Networks the Set of Sensors deployed in the simulation graph is considered as population.
A Chromosome: Chromosomes are grouped into population and is one such solution to the problem. The particular set of sensors in the population is a chromosome in DSN.

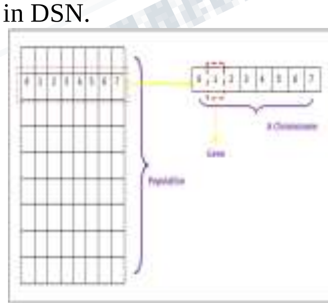

Fig.1 Chromosome Structure

A Gene: It is one of the elements in the chromosome. Here the sensor node acts as a gene in the simulation network.
Phenotype: It is the set of solutions considered in the real world situations. The actual search space in the DSNs can be in the areas where human intervention is risky. So needs to be converted or simulated.
Genotype: The solutions can be represented in symbolic way or they are mapped from the real world situations in order to simulate it.
In short, the phenotype is encoded to get Genotype and the Genotype is decoded to get phenotype. In this work, the Genotypes are encoded as Id's allocated to each sensor nodes which is its chromosome representation. The Genetic Algorithm is such a brief algorithm to be explained in basic background knowledge section. Its classification can be shown as follows:
The Genetic Algorithm always starts with its initial phase population generation. This phase can be classified into two stages either random population generation or heuristic one. Then genetic representation phase in which one can choose the genotype solution in many ways such as binary, real coded, integer, and permutation representation. Furthermore this classification extends up to termination condition.
The overall Basic Structure can be explained as

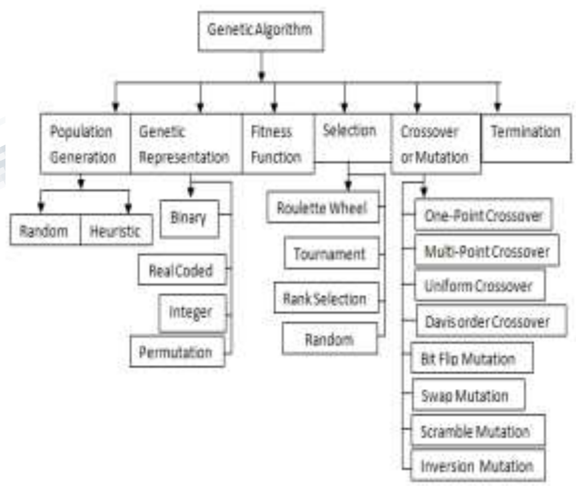

Fig.2 Basic Classification of GA.

In the current work the DSNs are framed with GA. Initially the population is generated in heuristic manner. Each sensor nodes are assigned with the node Ids as in the chromosome structure it is integer type of genotype. In this way the GA gets started.

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Proposed Work:

1. Node Deployment: This is the first module in which nodes are deployed in metaheuristic way. The sensor nodes will take their position in the simulation graph.
2. Keep Track of Routing Records: After the node deployment phase, there is need to find out the shortest path from the source to destination. Thus the easiest algorithm is applied known as Dijkstra's shortest path routing algorithm. It calculates the distance of neighboring nodes and tracks the possible solutions or ways to reach the destination. The routing tables are maintained while implementing the Dijkstra's Algorithm. As we know the DSNs have the ability to communicate and establish the link among the nodes.
3. Genetic Algorithm Implementation

The very first phase population generation and genetic representation (Chromosome structure) are discussed earlier. The next phase is

4. Stating the Fitness Function:

GA performs the fitness test on the population to find out best fittest individual. GA simulates the theory stated by Darwin- Survival of the fittest. The individual's fitness is the ability to pass on its genetic material to next generation. This ability includes traits that enable it to survive and further reproduce. The chances of survival are higher for better fitness values.

The proposed fitness formula is applied on the individual sensor node and not for the overall network. This will increase the fault tolerance of the network. The parameters in the fitness function are energy of each node and the strength of link established in the network. Two more parameters to be considered are path and obstacle. Path is the variable which shows that whether the path exists up to destination or not. The obstacle is also like flag which states that route is free from obstacle or not. One important thing to be taken care is that the value of any of these factors must not be negative. Thus it is clear that if any obstacle occurs the flag is set to -1 if not then 1. Similarly if path exists then 1 otherwise -1. The formula can be stated as:

Fitness Function:

$$(\text{Chromosome})=\sum 8\ E * \sum 8\ L * P * O$$

Where,

E= Energy in joules,
L= Strength of Link
P= Path
O= Obstacle

The fitness value of the chromosome must be positive.

We can compute the value of Energy(E) by

$$E = Ei * D$$

Where, Ei is the energy consumed per packet transfer and D is the distance.

$$L= C/E$$

Where, C is the channel capacity and E is the energy of chromosome in joules

5.Selection

Selection is the process in which the best fittest individual is selected for producing new chromosome. As shown in fig.2 there are several different methods of selecting the best individuals. In this work, The Roulette Wheel Selection is used which is fitness based selection. In this method each sensor node of the population is assigned a segment of the wheel, with size proportional to its fitness, such that fitter individuals are more likely to be selected for the next generation reproduction.

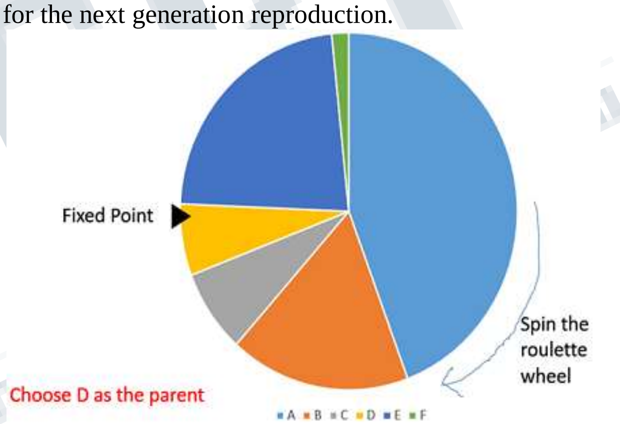

Fig.3 Roulette Wheel Representation

A fixed point is chosen on the wheel circumference and wheel is allowed to spin. The area of the wheel which comes in front of the fixed point is chosen as the parent. For the second parent, the same process is repeated.

6. Crossover Or Mutation

There are two genetic operators one is Crossover and the other is Mutation. We can apply both or one of them can be applied either. It is analogous to biological reproduction. In the proposed work, the single point crossover is used. One point crossover is a method in which a random point is selected usually from middle of the solution. The remaining halves are swapped to get new off-springs. The single point crossover can be illustrated as follows:

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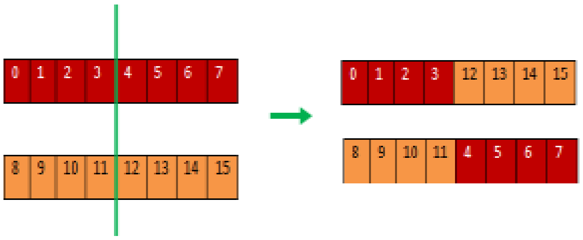

Fig.4 Single Point Crossover of two Chromosomes

7. Termination:
Termination is the last stage of the algorithm and is terminated when some specific conditions are met. In the proposed work termination is the condition when particular generations are reached. If not the then same procedure is iterated as GA is the iterative algorithm. What if fittest nodes in the previous generation get lost? The Elitism concept is introduced to regain such nodes.

8. Elitism:
The current fittest node in the population is always propagated to the next generation. Hence the stronger individuals in the previous population are not lost.

Expected Outcome:
The proposed simulation work consists of sensor nodes (chromosomes) deployed in first module according to the simulation environment. After the node deployment module, the Genetic Algorithm can be successfully implemented. When the Dijkastra's algorithm is applied, it gives shortest path as output and other paths in the record. The GA verifies each path by sending packet from every possible route. Consequently the initial energy of the sensor nodes in the network will get reduced up to some extent. Further the fitness function is calculated for all the sensors individually. Then best fittest sensors are selected using roulette wheel selection. The new healthier off-springs are created and the possibilities of occurring faulty nodes have almost reduced. As we know prevention is better than cure, the proposed work has prevented the sensors in the DSNs to get faulty. Thus it has been proved that using GA we can extend the lifetime of the DSNs and maintain energy in the nodes.

Time Complexity of GA:
It is the mathematical representation of size of function to define its time consumption. When one point crossover, roulette wheel selection a Genetic Algorithms is combined complexity found to be O (g (nm + nm + n)) with g the number of generations, n the population size and m the size of the individuals. Therefore the complexity is on the order of O(gnm)).

CONCLUSION

The Distributed Sensor Networks has brought forth many new issues and challenges as they are vulnerable to the malicious attacks and due to environmental factors some nodes usually gets shut down. So in order to before such conditions may occur we must prevent it. Thus the proposed work is way towards fault tolerance. The implementation of Genetic Algorithm has really proved to be the best option as it has got many advantages such as its robustness, its self repair quality and fast calculation of optimal solution in the large search space.

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