

A Survey on Fault Tolerance in Wireless Sensor Network Using Genetic Algorithm and Artificial Neural Network

Sonit Rathi¹, Utkarsh Agarwal², Sangeeta Roy³, Prof. Bappa Sarder⁴, Prof. Anindya Jyoti Pal⁵

U.G. Student, Department of Information Technology, Heritage Institute of Technology, Kolkata, India¹

U.G. Student, Department of Information Technology, Heritage Institute of Technology, Kolkata, India²

U.G. Student, Department of Information Technology, Heritage Institute of Technology, Kolkata, India³

Assistant Professor, Department of Information Technology, Heritage Institute of Technology, Kolkata, India⁴

Associate Professor, Department of Information Technology, Heritage Institute of Technology, Kolkata, India⁵

ABSTRACT: The main concern in Wireless Sensor Networks is how to handle with their limited energy resources. The performance of Wireless Sensor Networks strongly depends on their lifetime. As a result, Dynamic Power Management approaches with the purpose of reduction of energy consumption in sensor nodes have drawn attentions of many research studies.

I. INTRODUCTION

Wireless sensor networks (WSNs) are composed of massive, small and low-cost sensor nodes deployed in a monitoring region, forming a multi-hop self-organized network system through wireless communication. Sensor node is the basic unit in WSN which contains on-board sensors, processors, memory, transceiver and power supply. Sensor is a transducer which converts physical phenomenon e.g. heat, light, motion, vibration, and sound into electrical signals. Sensors have low power, limited memory, energy constrained due to their small size. Wireless networks can also be deployed in extreme environmental conditions and may be prone to enemy attacks. Although deployed in an ad hoc manner they need to be self organized and self healing and can face constant reconfiguration.

Wireless sensor networks, being made up of small sensor nodes are prone to faults. Fault can be caused by any external or internal factors. As the network is deployed in those areas where human surveillance is not possible like deep forests or active volcanoes etc, so the networks are prone to get damaged with time or get depleted of their energy. The process by which we can make our networks tolerant to faults that is, even after the occurrence of a fault, the system continues to provide the desired output is called a **fault tolerant system**.

Artificial Neural Network is an electronic models based on the brain's neural structure. As brain learns from past events in the same way artificial neural network undergoes training in order to gain the learning. Animals are able to react adaptively to changes in their external and internal environment, and they use their nervous system to perform these behaviours.

An appropriate model/simulation of the nervous system should be able to produce similar responses and behaviours in artificial systems.

The nervous system is build by relatively simple units, the neurons, so copying their behaviour and functionality should be the solution.

Genetic Algorithm also has a biological inspiration as it is based on the Darwin's principles of Natural Selection and Survival of the Fittest. Here, a chromosome is referred to as a solution. And then a population is created which nothing but a set of possible solutions. And then after the process of mutation and crossover, the solutions are fed into a fitness function which further lowers the set of solutions. Thus, after successive iterations, we get a nearly optimal solution.

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- 1) At first chromosomes which are nothing but the solution of the problem is formed.
- 2) A population that is a number of chromosomes or solutions are generated.
- 3) Mutation and crossover is performed on randomly chosen chromosomes.
- 4) The resultant population is then fed into a fitness function. This fitness function gives the fittest chromosomes as output which is less prone to faults.
- 5) The process is repeated until we get the same results repetitively and thus we get a nearly optimal solution.

II. REVIEW ON PREVIOUS WORKS

[1] presents a neural model for reliable and fault tolerant transmission in Wireless Sensor Networks based on Bi-directional Associative Memory(BAM). The proposed model is an attempt to enhance the performances of both the cooperative and non cooperative Automatic Repeat Request. BAM has been used at both receiver and sender end. Before sending the sender passes the packet through the bi-directional associative memory which returns an associated packet which is then sent to the receiver which is short and communication-friendly. The receiver receives it and passes it through the BAM at its end to get the original packet which the sender intended to send thus reducing the communication overhead. It also uses a activation function which helps overcome faults occurring during transmission of packets.

The lifetime of WSN is increased. It leads to lower communication cost and wastage of energy. It, thus, gives an analogy between ANN and WSN. It retrieves correct original packet despite of corrupted packets. The relationship between scalability, deployment, reliability, power, efficiency, mobility is sophisticated which if unbalanced can cause the network to suffer from overheads that negates its applicability. The advantage of the approach is that it is a Communication friendly setup (i.e, less communication cost) which increases the level of fault tolerance of the network. It is more reliable and timely than the normal cooperative and non-cooperative ARQ. Fault tolerance power can be further improved by including BAM structure with a recurrent network in an asynchronous mode.

In [2] proposed a method to optimize the energy consumption based on Self Organizing Map. SOM learning algorithm is used for training the neural network. The nodes which fall in the routing path of many nodes to the base station node are referred to as a hotspot. These hotspots are used for route discovery and energy conservation. Neural Network is also used for sensor data prediction, sensor data fusion, and cluster formation. Three inputs – x-coordinate, y-coordinate and the energy of each node are provided to the SOM structure which first normalizes the inputs and then processes the parameters of all the nodes and a cluster using Energy Based Clustering Self organizing map(EBCS) is formed by mixing the lower and higher energy nodes to get a balanced cluster. This output is then passed to a K-means algorithm to get reduced number of clusters. A minimum separation filter is kept between the outputs of the SOM. SOM also provides an efficient routing path. The sensor data prediction, data fusion, cluster formation performed by SOM helps in conservation of energy and increases fault tolerance.

It conserves energy for the network (WSN), follows the shortest route and has less communication cost. Sometimes the clusters formed might be the balanced one but not the most efficient collection of clusters. The most energy conserving algorithm can be devised which further reduces energy requirement of WSN. Secondly the time complexity can be improved.

In [3] the researchers have tried to consider fault tolerance at all the five different layers, physical, hardware, system software, middleware and the application layer. At the physical layer software radios can be used as an extension to the programmability which helps in adhering to the channel conditions. The encoding and modulation schemes can be used with the available hardware resources when a part of software malfunctions and leads to fault tolerance towards noise. In the hardware parts the tolerance is increased for the storage components by using volatile memory like DRAM and non-volatile memory like flash. As rechargeable battery is the basic source of energy, to increase the fault tolerance backup battery is used. At the system software fault tolerance is maintained by using a variety of software and running each program on different versions in parallel as all versions won't have identical bugs. For the middleware ways are used to replace the readings of one type of nodes with another type of nodes during fault occurrence. At the application layer a combination of biometric features can be used to identify a particular person without any error.

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As the fault tolerance is achieved at all the different levels it is a very efficient approach towards fault tolerance. But achieving it at different layers makes it a very complex algorithm which is really difficult to debug. In future the lifetime of WSN can be improved by placing a subset of nodes in sleep mode. Some fault resiliency methods for sensor fusion, data filtering and data aggregation will be a key for future.

[4] deals with the dynamic selection of cluster heads by optimizing the energy consumption and improved k-means clustering algorithm is used to form the clusters. In the field of application during target tracking, it is necessary to have a network which is fault tolerant and does not affect the desired work. As sensor nodes have limited energy resources, it is much necessary to optimize the usage of energy and thus comes the concept of clustering. Genetic Algorithm is being used to find optimal use of sensor nodes and recover from fault as quickly as possible so that target detection won't be disrupted. The chromosomes are formed which include the nodes in each cluster, according to the distance between each sensor node and their residual energy. A population is thus created having all the possible solutions. And after crossover and mutation, the solution passes through a fitness function which discards the chromosomes having less residual energy or more scattered topology.

$$F(n)=E_{\max} + \min(A/N)$$

Where, E=residual energy of the cluster

A=Area covered by the cluster

N=number of nodes in the cluster

During object tracking if a cluster head is not functioning due to depletion in energy, another cluster head is chosen according to the energy requirement and which is less prone to faults. The process continues till all the nodes in that cluster have been exhausted.

In [4] as the cluster head with highest residual energy is chosen, it is less prone to faults due to energy depletion and thus, the energy consumption due to the process of appointing a new cluster head is reduced considerably. The network's lifetime is thus increased.

In [5] a genetic approach is taken such that, without the help of re-clustering, the existing nodes of the cluster are individually assigned to the nearest cluster head of another cluster. Energy efficiency is the key in WSN. To reduce the energy consumption the concept of clustering was introduced, so that there are a certain number of nodes in a cluster and a cluster head which receives information from the nodes and communicates directly with the base station. And, if a cluster head goes down the whole cluster becomes useless and re-clustering has to be performed which can take up a lot of energy. The algorithm in [5] deals with this problem so as to minimize the chances for re-clustering. The algorithm takes into account the maximum range of transmission of the nodes and the cluster head to which it is to be assigned and as well as the residual energy and number of nodes the cluster already has. GA is used to first assign each node to a cluster head randomly and each set represents a chromosome. A population of such solutions is created taking into account the transmission range of both the node and the cluster head. Then after applying crossover and mutation to certain chromosomes taken randomly, the result is fed to a fitness function to take the better solution set and discard the ones prone to fault. The fitness function used in this genetic algorithm is-

$$F(n)=[1/\text{distance}+ 1/\text{members} +\text{energy}]$$

The proposed algorithm in [5] has greater efficiency as three parameters are taken into account compared to those that deal with one of the parameters. However, being a dynamic process the proposed algorithm takes up a lot of time giving only the nearly optimal solution. Furthermore, signal to noise ratio, an important parameter, is also not taken into account.

Priyanka *et al*, in [6] also focus on the consumption of energy and reducing the wastage of residual energy. When a data packet is being transmitted via a node, if the node goes down due to depletion of energy, the data packet gets lost and further loss of such data packets causes error in data transmission. The main motive is to increase the lifetime of the network even after some nodes are depleted. In [6] two algorithms, Fuzzy logic and Genetic algorithm are used. Fuzzy logic is used to get a set of nodes which passes the set of rules set according to the algorithm. The set of rules may include nodes according to their residual energy, energy bandwidth etc. Thus we get a set of nodes which are high in residual energy and will not deplete during the transmission. Further Genetic algorithm is used to select an optimal path with the selected nodes for the transmission of data. GA generates a population of solutions that is different

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number of paths that can be taken. And the fitness function used, being the path with least number of hops and highest amount of residual energy.

$$F(n)=\max(E\text{of the path})+\min(\text{no of hops})$$

[6] uses an efficient way to reduce the number of lost data packets considerably, as it will choose a path where the nodes are least likely to deplete of their energy and thus increasing the lifetime and efficiency of the network and making it less prone to faults.

III. CONCLUSION

We have prepared this report after studying various research papers. Though these papers provide a very efficient way to implement Fault Tolerance in Wireless Sensor Networks, yet there are some limitations. BAM, genetic algorithm, artificial neural networks that are used are very complex structures which increase the time complexity and energy consumption of the network. The genetic algorithm used in the above papers is mostly applicable on a static network which is not practical in nature. Faulty nodes can be detected only if a certain message or an acknowledgement is not received in a specified time, but, if a node sends faulty or distorted messages, it cannot be known.

A hybrid model can be formed which uses the artificial neural network as its base to form the structure of the wireless sensor network as in [2] and applying genetic algorithm on it to make it further tolerant to faults and optimization of energy as used in [4], [5] and [6].

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