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Cluster Based Fault Node Detection Algorithm for Wireless Sensor Network

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ABSTRACT: This paper proposes a cluster based faulty node detection system to enhance the wireless sensor network life time by detecting the non functioning sensor nodes. The algorithm dynamically and periodically clustered the entire sensor nodes, then creates the routing table using grade diffusion algorithm and detects the faulty nodes using modified genetic algorithm. In our simulation, the proposed algorithm reduces the false positive and false negative faulty node detection rate and increments the accuracy in node detection.

KEYWORDS: Genetic algorithm, Grade diffusion, Life time of network, Wireless sensor network

I. Introduction

Wireless sensor networks (WSNs) are today's widely accepted data sharing and data generating network, it generates massive amount of data by consuming high amount of energy [1]. These Networks are quickly gaining popularity due to the fact that they are potentially low cost solutions to a variety of applications [2][3]. Sensor networks are developed in many civilian application areas, such as fire detection, environment and habitat monitoring, health care, home automation, and traffic control applications, homeland security, pubic sensing for metro city etc [4].This network system comprised of hundreds or thousands of spatially distributed static or mobile devices using wireless sensor nodes with sensing and routing capabilities over a geographical area to monitor its phenomenon and collect its data [5]. These individual nodes are capable of sensing their environments periodically, processing the information data locally, and sending data to one or more collection points in a WSN through multi hops. Sensor nodes are extremely constrained in terms of memory, processor, and energy.

In wireless sensor networks, each sensor node has limited computational power to process and transmit the periodic data to the sink station or data collection centres [6], [7]. Network lifetime is considered as an important issue for many applications. The lifetime of the sensor networks purely depends on the battery power of the nodes because the sensor nodes have low level battery power and it is quite difficult to recharge node batteries. When the energy of a sensor node is exhausted or they have reached their operational threshold or otherwise they cease to function, then wireless sensor network leaks will appear, and the failed nodes can no longer sense the event data and cannot relay data to the other nodes or to the sink during transmission processing, such nodes are called faulty nodes. Thus, the other sensor nodes will be burdened with increased transmission processing and WSN will no longer function. , The power consumption of the sensor nodes and the chances of faulty nodes in WSNs are unavoidable. So only the effective detection and the replacement of the non functioning sensor nodes from sensor networks transmission processing is the beneficial way of improving the sensor network life time.

In this paper we focus on improving the life time of the wireless sensor networks by detecting the non functioning sensor nodes using a cluster based faulty node detection algorithm. The algorithm effectively and periodically clustered sensor devices and detects the faulty sensor nodes and results more reused routing paths for data transmission. The algorithm reduces the false positive and false negative faulty node detection rate and increments the accuracy in node detection.

The cluster based faulty node detection algorithm clustered the entire sensor nodes periodically, then creates the routing table using the grade diffusion algorithm and detects the faulty nodes using modified genetic algorithm.

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II. RELATED WORK

There are many system have been proposed till now for faulty node detection for wireless sensor networks. A series of routing algorithms [10], [14] [13] for wireless sensor networks have been proposed in recent years. The most used traditional routing protocols for wireless networks are direct diffusion and grade diffusion algorithm. Both direct diffusion [9] and grade diffusion [8] are efficient for wireless sensor network. The goal of the DD algorithm is to reduce the data relay transmission counts for power management. The DD algorithm is a query-driven transmission protocol. The collected data is transmitted only if it matches the query from the sink node. i.e., Sensor nodes send the data back to the sink node only when it fits the queries. But here we are using the grade diffusion algorithm, because the grade diffusion is appropriate for considering the type or grade value of the sensor nodes during the transmission processing. The Grade Diffusion (GD) algorithm [8] in 2012 to improve the ladder diffusion algorithm using ant colony optimization (LD-ACO) for wireless sensor networks [10].
The WSN may fail due to a variety of causes, including the following: the routing path might experience a break; the WSN sensing area might experience a leak; the batteries of some sensor nodes might be depleted, requiring more relay nodes; or the nodes wear out after the WSN has been in use a long period of time. The power consumption of the sensor nodes in WSNs is unavoidable. A Recovery Algorithm based on Minimum Distance Redundant Nodes (MDRN) were proposed in [11] By employing redundant nodes carefully, the recovery algorithm is deployed on the sink node with unconstrained energy consumption which knows the locations of all active nodes and redundant nodes in the WSNs. in this algorithm, by choosing appropriate number of redundant nodes, this algorithm will have great recovery accuracy and coverage quality, also achieve the purpose of prolonging the lifecycle of WSNs.
There is an [12] extended the cellular approach and proposed a new fault management mechanism to deal with fault detection and recovery of WSN. They proposed a hierarchical structure to properly distribute fault management tasks among sensor nodes by a self managing function. Sanam al Hasseini [15] explained that a wireless sensor network composed of many sensor nodes which are used to monitor unavailable and harsh environments. Because these nodes are too small and battery operated which have limited energy, faults may occur. Fault tolerance is one of the most important issues in wireless sensor networks and must be increased as much as possible to avoid faults. Also there is a faulty node recover algorithm [16] were proposed in 2013. That system used the genetic algorithm [18] in association with grade diffusion algorithm. But the system resulted out with a number of miss detection of faulty node due to the massive number of sensor nodes. The system suffered with the increased rate of false positive node detection and false negative node detection. Thus, the accuracy of the detection rate is decreased continuously with the increased number of nodes.
This can be overcome by applying dynamic clustering in sensor nodes. so we propose, a cluster based faulty node detection algorithm ,where we clustered the entire sensor node [17]and then applies the fault node detection algorithm.

III. CLUSTER BASED FAULT NODE DETECTION SYSTEM

Our cluster based faulty node detection system is based on the energy efficient grade diffusion algorithm combined with modified cluster based genetic algorithm. The fig shows the processing view of the proposed system.
The Fig.1 shows the step by step processing of the cluster based fault node detection system. The hybrid wireless sensor network is composed with both static and mobile sensors. So the entire sensor nodes in the sensor area are clustered periodically for accurate node detection. Grade diffusion algorithm is applied for each clustered nodes for the balanced routing. Then the faulty nodes are detected by using the modified genetic algorithm.

3.1. Dynamic Clustering

A hybrid wireless sensor network is composed with hundreds or thousands of both stationary and mobile sensor devices. The faulty node detection will be difficult and inaccurate for such sensor networks due to the movement of the sensor devices. It's difficult to manage the entire sensor nodes together and it will reduce the accuracy of faulty node detection algorithm. So in order to make the algorithm, work efficiently, the entire sensor devices are grouped in to predefined number of clusters. Here we are using a dynamic cluster algorithm, for periodic clustering. So in each period of time the mobile and stationary sensor devices will automatically clustered according to its position in the sensor area.

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In dynamic clustering, the entire sensor area is firstly clustered in to number of clusters. Then after each small period of time, the cluster is dynamically changed according to the movement of the sensor devices. The clustering done automatically, according to the position of sensor devices. Periodically the number of cluster reduced to the user predefined number of clusters.

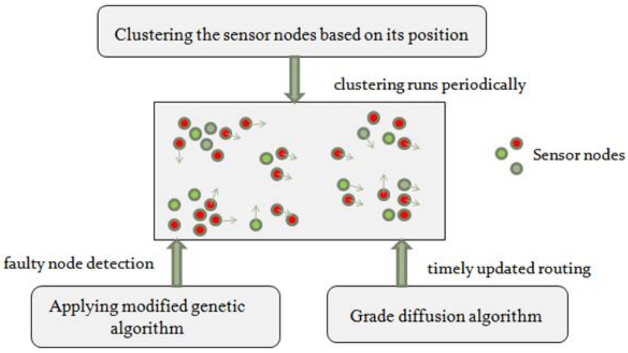

Fig.1 Block Diagram of Proposed System

3.2 Grade Diffusion Algorithm

The grade diffusion algorithm is the energy efficient routing algorithm for the wireless sensor networks. The algorithm efficiently solves the transmission problem and sensor nodes loading problem in wireless sensor networks by to arrange the sensor nodes routing. Grade diffusion can increments the sensor nodes life time and sensor nodes transmission effect. Also the sensor nodes can save some backup nodes to reduce the energy for the relooking routing by the grade diffusion in case the sensor nodes routing is broken. It has less data package transmission loss and hop count.

GD creates the routing for each sensor node and also it balances the sensor nodes loading by identifying a set of neighbour nodes. The GD algorithm can also record some information regarding the data relay. Each sensor node can select a node with a lighter loading or more transmission energy, from the set of neighbour nodes when its grade table lacks to perform extra relay operation.. That is, the GD algorithm updates the routing path in real time; it can send the data package to destination node quickly and correctly. Using GD's grade tables the history of each success packet relay can be taken out for the processing of genetic algorithm to find out faulty nodes.

3.3 Modified Genetic Algorithm

The genetic algorithm used here to find out the faulty nodes by using genetic operations. Cluster based faulty node detection algorithm applied in each dynamic clusters and it results the non functioning nodes of each cluster. The algorithm works continuously with the periodic clustering.

Here the modified genetic algorithm used to finding out the non functioning sensor nodes in the sensor networks. The genetic algorithm is a search algorithm that is routinely used to generate useful solution to a search or optimization problem. Genetic algorithm mainly have 3 operations selection, cross over and mutation.

The modified genetic algorithm used six stages of genetic operations for the best result. Here the genetic operation round starts with Initialization operation where we arbitrarily choose the combination status of every sensor nodes. The initialization step is followed by selection, evaluation, and cross over, mutation and ends with the best phase. Each round results a best combination status of the sensor nodes, status shows whether the node should be replaced or not. In the proposed algorithm we can set the number of genetic operation rounds to detect the faulty nodes in accordance with the wireless sensor network application. After the predefined number of genetic rounds, the algorithm results the faulty nodes that should be replaced. This result directly forward to the initial phase of next set of genetic operation round. The faulty node detection algorithm works continuously with a predefined sleep time interval and finds out each node, whenever it fails.

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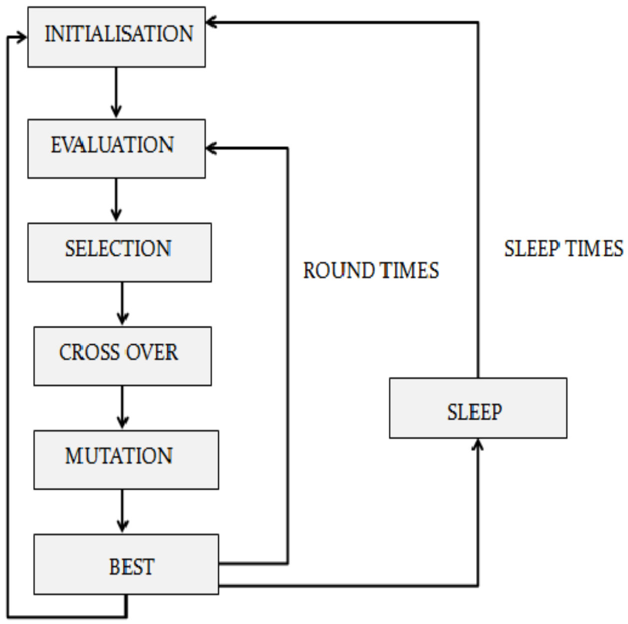

Fig.2 Flow Chart of Genetic Algorithm

Description of steps follows,

3.3.1 Initialization

The algorithm generates chromosomes in the initialization phase, each chromosomes is an expected best result of the algorithm. We can predefine the number of chromosomes based on the population of sensor area. The chromosomes are the combination of random status of sensor nodes that shows whether it is faulty or not. The chromosome length is equal to the total number of sensor nodes in the corresponding cluster. The elements in the gene are either 1 or 0. The 1 means the node is faulty and 0 means the node is not a faulty node.

9	7	10	81	23	57	34	46	66	70
0	0	1	0	1	1	0	1	1	0

Fig.3 Initialization of Genetic Operation

Here the chromosome length is 10, i.e. there are totally 10 sensor nodes in the cluster and the genes are 0 and 1. The 0 and 1 bits are assigned randomly. In initialization the predefined number of the chromosome with different elementary combination of sensor nodes are created.

3.3. 2 Evaluation

After the initialization process the evaluation of each chromosome is carries out. During evaluation phase the rank or fitness value of each chromosome is calculated and compared for the next selection stage. The rank of chromosome is calculated using the weight of each gene element in the chromosome.
i.e.

Rank = *weight of the chromosome sequence / Total number of nodes in the chromosome*

The weight of the chromosome sequence is calculated by considering weight of each gene element in the chromosome sequence and the weight of each gene is finding out by comparing the elementary gene with the history data of each packet delivered in the network.

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The history array of the packet delivery is created using the history provided by grade diffusion algorithm. During the weight calculation of elementary gene sequence, the elementary gene is compared with the history array, and it generates the success and failure prediction rate array.
i.e.

$$\sum_{i=0}^{\text{number of nodes}} X[0]/X[1]$$

Here X [0] is the success prediction rate array element and X [1] is the failure prediction rate element. The success and failure rate array is created using the comparison between the elementary gene data or random status and the packet history,
i.e.

$$\sum_{j=o}^{\text{number of nodes}} \quad \sum_{i=0}^{\text{history length}} \text{if } (gene[j] == history[i][j])$$

By comparing those result, the prediction rate array X[0] and X[1] are created for each sensor node.

3.3. 3 Selection

Selection step eliminates the chromosome with high rank, i.e. the high ranked chromosomes are worst chromosomes that are a miss prediction. We keep half of the chromosomes with low rank i.e. good predictions. The worse chromosomes will be deleted, and new chromosomes will be made to replace them after the crossover step.
The rank generated using evaluation step is used here for the chromosome selection. In this phase we get good chromosomes or solutions for follow up processing. This is the first filtration step which filters out the good solutions from set of solutions. The upcoming best phase also includes the selection scenario for the best solution.

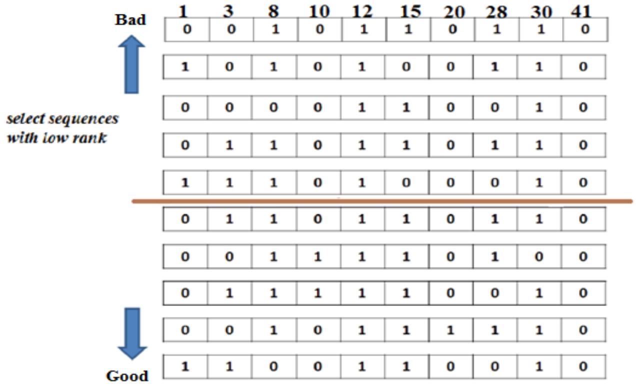

Fig.4 Selection Phase of Genetic Operation

3.3. 4 Cross Over

Cross over is used to change the individual chromosomes, and generate new chromosome sequence. It takes more than one parent chromosome and producing a child solution from there. By recombining portions of good solutions, the genetic algorithm is more likely to create a better solution. Here one point cross over is used to create the new chromosome sequence. The one point cross over is efficient for mating the chromosomes and to generate new sequence. Two individual chromosomes are chosen from the mating pool to produce two new children. A crossover point is selected between the first and last genes of the parent individuals. Then, the fraction of each individual on either side of the crossover point is exchanged and concatenated. The rate of choice is made according rank of chromosome.

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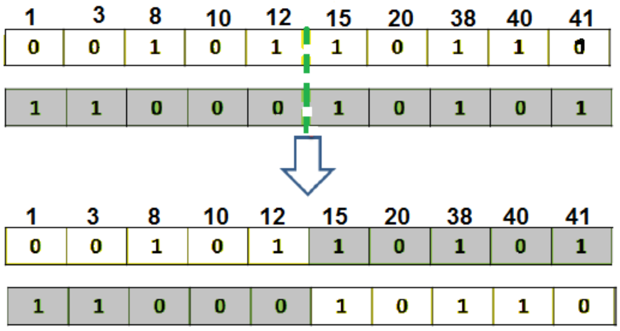

Fig.5 Cross Over Phase of Genetic Operation

3.3. 5 Mutation

The mutation step encourage the genetic diversity amongst solutions and attempts to prevent the genetic algorithm converging to a local minimum by stopping the solutions becoming too close to one another. In mutating the resulting solution may change entirely from the previous solution. By mutating the solutions, a genetic algorithm can reach an improved solution. In this algorithm, we simply flip a gene randomly in the chromosome.

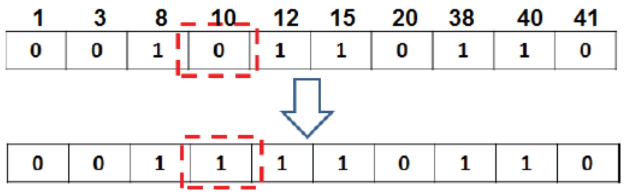

Fig.6 Mutation Phase of Genetic Operation

3.3. 6 Best

After mutation the sequences will forwarded to best phase, where we again calculates the ranks of the sequence. It will result out the best sequence with the lowest rank. This sequence is known to be the solution of the corresponding round of genetic operation. The sequence will be directly forwarded to the next round of genetic operation. Best phase composed of evaluation and selection phase scenarios for best solution.

The genetic operations continue up to predefined number of round. Each set of round gives the list of faulty nodes in the network.

IV. EXPERIMENTAL RESULT

The system is simulated with the help of one simulator, and the simulation result showed that how accurately the system detects the faulty or non functioning sensor nodes. The accuracy of the system is compared with the existing faulty node recovery system based on the comparison of the rate of false positive and false negative detection of the system with existing model.

The false positive rate and false negative rate of detection is compared by considering the number of sensor nodes. The two results helped to find out the detection rate changes with the sensor network size or population.

From the simulated graph of false positive detection with the network size shows that, the accuracy in detection become less when the size of network increases for traditional FNR algorithm.

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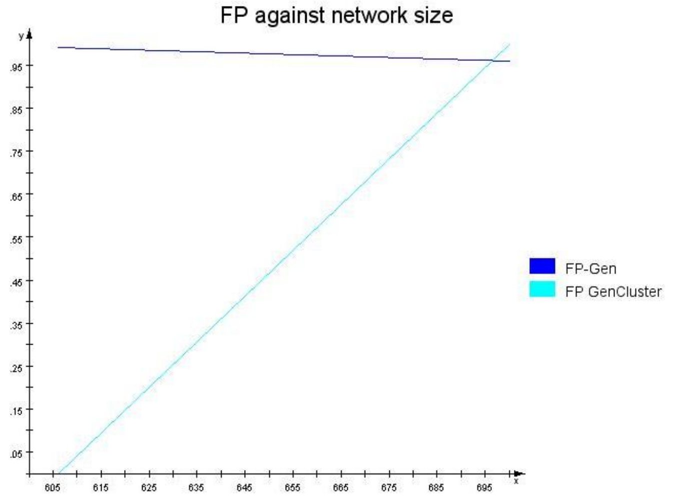

Fig.7 False Positive Detection Rate Comparison

The false positive graph in fig.7 shows the false positive detection rate of faulty nodes by using the traditional approach and the proposed system. The FNR algorithm results high false positive rate in small sized network and very high sized network. But for the cluster based detection system the accuracy increases with the sensor networks size.

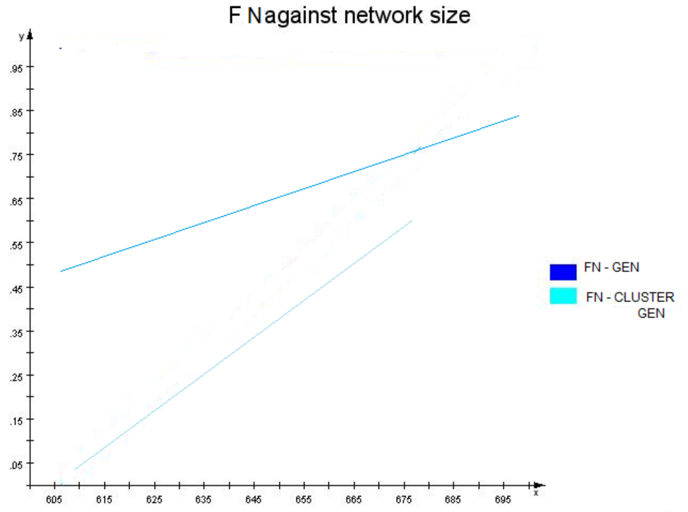

Fig.8 False Negative Detection Rate Comparison

The false negative graph in fig.7 shows the false negative detection rate of faulty nodes by using the traditional approach and the proposed system. The FNR algorithm results high false negative rate in small sized network and very high sized network. But for the cluster based detection system the accuracy increases with the sensor networks size.

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V. CONCLUSION

Wireless sensor networks, each sensor node have limited energy source to process .The life time of wireless sensor network highly depends on the limited energy resource of the sensor nodes. So In addition to the routing, it is important to consider the faulty or non functioning sensor nodes detection and its replacement. This paper proposes a cluster based faulty node detection system to detect the non functioning sensor nodes and to increase the life time of the sensor networks. The proposed algorithm uses dynamic clustering in combination with grade diffusion algorithm for routing and genetic algorithm for faulty node detection system. The simulation results of system showed the system decreased the false negative and false positive detection rate and increased the accuracy in faulty node detection.

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