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Faulty Sensor Detection for Wireless Sensor Networks

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Abstract— Due to the increasing growth in wireless networks in different areas, reinforcing and developing faults management in wireless sensor networks will have an important role in effective use of them, so we must identify and put aside faulty sensors so that they won't affect the entire network performance. these faults may be transient, permanent or intermittent .The proposed method covers any defects in the sensor nodes and each sensor in a self-constructive, distributed and local manner in such a fashion that the value received from the environment periodically sends data to all its neighbors, and all sensors make decisions about this point as if the sensor is faulty based on information received from the neighbors or not. This algorithm optimizes sensor energy sources, enhances detection accuracy and reduces the error percentage in detecting faulty wireless sensor networks.

Keywords— wireless networks, Fault detection, Fault distributed, Fault management, fault detection techniques.

1. Introduction

Wireless sensor networks consists of a large number of much smaller sensor nodes, which are randomly distributed in the environment. Each sensor network is independent of the other sensor networks, and receives Information from the environment and sends it to the sink through the proper protocol, which is used for specific goals. Unlike ad hoc networks, which at the first glance may seem similar to sensor networks, nodes in sensor networks, usually do not have unique addresses. These sensor networks can be used for various purposes such as war, identifying the contaminated environment, monitoring environmental analysis of the construction of buildings, in the intelligent roads and highways and in medical fields and so on [1][17].

In the design of wireless sensor networks there are some constraints such as low cost, small size, low power, low bit rate, data received from the environment, nodes being autonomous, and has the versatility to change the possibility of adapting to changes that can be mixed with various errors and make the sensor nodes faulty and unreliable, that the networks should identify the faulty nodes which probably don't reflect the status of processes and eliminate them to ensure the quality of the network. The main challenge in wireless sensor networks is the detection of sensor nodes' faults including faults in communication or the energy constraint [13][15]. One of the most effective ways of reducing the energy consumption of nodes is managing and conducting appropriate packets in the network. We should make plans for managing and identifying the faulty nodes. The wireless sensor network covers the occurring of any fault in the nodes and continues its activities in similar favorable position, all by itself. Since the specific topology of wireless sensor networks are not used, a rapid method is adopted to detect the error distribution of each sensor individually to ensure that its neighbors are healthy. Each sensor contains a certain number of its neighbor nodes deployed in an environment in order to send periodic messages. The analysis results determine which node is faulty or healthy [2][3].

In general, a node in wireless sensor networks is in two modes: "Normal" or "faulty". Nodes fail for various reasons. In general, the fault is any defect or deficiency in the subsystem or its components which makes improper performance of the system, and causes failure in its functioning. These failures are developed in three levels in wireless networks: node, network and Sink, which will be explored by such techniques as fault in performance, capacity and sustainability [4].

In sensor networks, each node has one or more sensor or actuator. Each sensor is used for receiving parameters such as temperature, light, distance, vibration or noise, radiation, humidity. The sensors are physically very small and have limited processing power and memory capacity. Each sensor node can identify and test its error condition based on the local data received from a sensor with a certain threshold [5][16].

Sensor fault detection management system being distributed and local would be useful due to the small amount of energy needed by the sensors. The aim of fault detection system is to involve all nodes in detecting faults .The more nodes participation in the process, the more accurate the results and the less need to send data to the central node, which results in lower power consumption and better functionality. Nodes make decisions based on information received from the neighboring ones and a majority vote. Unlike centralized systems, the band width of the above system and also signal processing core are reduced upon approaching Sink [6][14].

This paper will proceed as follows: in Section 2, studies related to fault detection in distributed wireless sensor networks are investigated. Then the system model and fault model for the proposed algorithm are presented in Section 3. Then in Section 4 we explain the details of the proposed algorithm. Finally, Section 5 concludes the article.

2. Related Works

In Algorithm [7], local and distributed methods are presented for detecting wireless sensor failures that use neighboring nodes for determining the status of each node, and those sensors are considered neighboring sensors if they will be within the transmission range of each other. Given the data record, the sensor is regarded faulty if more than half of the neighbors of that sensor are considerably different with it. This algorithm does not require for each sensor to know its geographic position resulting in increasing of the costs. Another advantage of this algorithm is its lower complexity. But the disadvantage of this algorithm is high operational overhead which can only detect and identify permanent faults and is incapable of detecting and identifying transition faults.

Due to resource constraints on sensor nodes and wireless networks and their deployment in harsh and inaccessible environments, Sensor nodes may be prone to failure. Thus, fault management is essential in these networks. Otherwise, faulty nodes are used as intermediate nodes and cause disturbances in the routing process and expected operations. In most fault diagnosis algorithms, each sensor compares its data with those of their neighbors'. The status of sensors is diagnosed using the results of this comparison. If more than half of the neighboring nodes are faulty, most of the comparison-based methods will not work correctly and will fail to recognize the failures normally.

In Algorithm [8], a new fault detection method is proposed to solve the aforementioned problems. In this method four states happen which are discussed, and a query message is used to reduce incorrect decision makings. The results of this algorithm show that the detection accuracy and false alarm rate are acceptable comparing to existing algorithms even when nodes are probably faulty.

In Algorithm [5] test diagram and communication have been defined for the first time and the relationships of wireless sensor networks have been shown in a graph G (V, E). This algorithm uses two thresholds and emission testing criteria to help identify faulty nodes and fault-free nodes. When a node distributes its decision to its neighboring nodes using threshold value to determine the situation, if the decision is based on the results of the comparison of data collected in a given time, transient faults may occur after that time so the time of redundancy is used to cope with them in which, decisions are made based on data received from the collection in q times consequently. As a result, a sliding window is used to eliminate the redundancy scheme delay. This algorithm is more efficient and accurate in detecting faulty nodes, but can't properly detect common-mode failures and if failures are not independent of each other, it can't function properly.

The aim of algorithm [11] is to use the similarity test between two neighboring nodes for detecting faults of wireless sensor networks. This test is based on the similarity between nodes, sensor flawed test based on the similarity of neighboring nodes and dissemination of the decision made at each node which are known to be faulty. By using Time and space relationships jointly among neighbor sensor nodes, the proposed algorithm can efficiently find the sensor failures. The advantages of this algorithm are high detection accuracy and low false alarm rate and the cost savings. However, the operational overhead and common mode failures can't be detected correctly.

In Algorithm [9] the voting method is used to better detect faults. In the very algorithm, the initial state of the sensor is good, and each sensor sends its received value (X_i) along with its current state (T_i) to all the neighbors and after receiving data from the neighbors, sensors make decisions about neighboring states based on their existing ones (T_i) using the amounts received by the neighbors (X_j). In this algorithm, there are three threshold values θ_1, θ_2 and θ_3. Determining threshold values for proper application of algorithm is very important. Threshold value θ_1 is used to determine the minimum values received by the sensors to illustrate the differences between sensors which depends on the accuracy of the sensors and the value measured by them. Sending the status of each sensor is performed along with the received value, which reduces the data transmission, and therefore reduces energy waste. The algorithm increases network lifetime by reducing the frequency of receiving and transmitting data, but can't detect the common mode faults correctly.

Intermittent and transient failures are the biggest source of failure for sensor networks.

In algorithm [10] a method for detecting permanent, intermittent and transient faults has been offered using graph topology, and this algorithm identifies faults in the system by using discrete-time repeated and then makes decisions about them. This algorithm covers both hard and soft faults, the results of this false detection rate algorithm is well under control while maintaining a high detection accuracy indication. This fault detection algorithm is highly accurate for identifying strong alternating faults and also a wide spectrum of other faults.

3. Network Model

Suppose we have n nodes in the intended network. If all sensors are deployed randomly in a geographical region (x, y) so that sensors can cover the whole considered region, and all sensors have the ability to convey a message in a given range (Figure 1) this region is in the rectangular form. Black circles represent the faulty sensors and gray circles represent the sensors are intact .It is likely that all nodes in a region have been corrupted like the figure which is called the common mode failure.

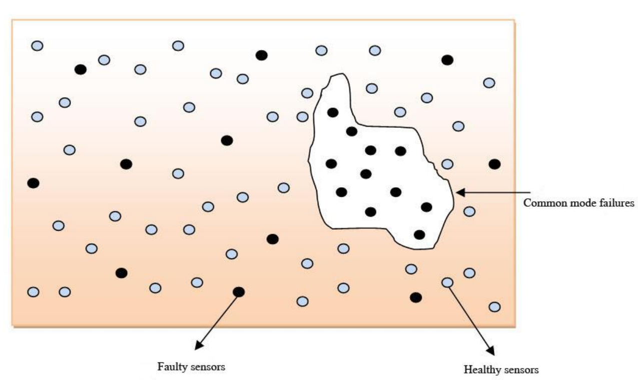

Figure 1. Network Model and Fault Model

Most voting assume each sensor node has at least three neighboring nodes. Since a large number of wireless nodes are interested in forming wireless networks, this situation is simply achieved.

4. The Proposed Algorithm

4.1. Introducing Fault Detection Algorithms

In this paper, sensors are randomly distributed in the environment, thus faults of each sensor are independent of the other ones. Each sensor receives information from the environment and sends them to the Sink with proper protocol. The proposed algorithm investigates the performance of distributed failure detection system. The aim of the algorithm in detecting failures is the participation of all nodes in identifying the faults. The sensors may be mixed with a variety of faults, which are divided into two categories in terms of levels: "soft Fault " and "hard faults". Hard faults occur due to failure in one of the main sensors, which cannot connect with other nodes. If a node is confronted with a hard fault, it will be inactivated completely and can no longer send data or receive messages from other nodes. It is possible to simply identify faulty nodes by sending a message to the nodes which have been confronted with hard faults. But when confronted with soft faults, defective nodes can communicate with other nodes, but the sent data are not correct which the most important type of failure is. The proposed algorithm covers all faults.

In the proposed algorithm, each sensor has five states based on its neighboring ones which are: Good, Bad, Localy Good, Localy Bad and Unknown. At first, the modes of all the sensors are good which periodically send their T_i values to neighboring nodes and decide about the states of the neighbors using and receiving the Values of X_j neighbors.

- ✓ **Failure Detection Algorithm**

Theorem 1: In the proposed algorithm, each sensor mode after step r is T_i=FT يا T_i=GD .

Proof: It is enough for us to prove the following arguments:

Sentence 1: For each sensor to the step r-1 If $Neighbors(V_i) \prec \beta$ is, then T_i= Unknown.

Table 1: Describing the Elements of Algorithm

C_{ij}	Status of each sensor
V_i	Sensors
β	Threshold value for the number of neighbors for each sensor
T_i	Includes FT, GD, LF, LG
θ_1 and θ_2	The threshold value

It is a fact that in the first phase, each sensor calculates the number of its neighbors and then compares it with a predetermined value .If the number of its neighbors is fewer than a predefined value, the sensor will not make any decision about its situation because given the low number of neighbors, the sensor may make an incorrect decision, thus resulting in its own mistakes and other sensors', and to the r-1, sensor and its state will remain Unknown.

Sentence 2: After r-1 Step for each sensor if $Neighbors(V_i) \succ \beta$ then $T_i = FT$ or $T_i = GD$.

In this sentence, the first phase of each sensor, if you have $Neighbors(V_i) \succ \beta$ then it initializes its state with respect to its neighbors that is either $c_{ij} = 0$ or $c_{ij} = 1$. Secondly, given the initial state of the neighbors, it will recognize its potential ($T_i = LG$ or $T_i = LF$), and then in the next step finalizes its state based on their status of possible neighbors. As a result, each sensor or $T_i = FD$ is identified as defective or $T_i = GD$ (normal) and its situation will be finalized.

Sentence 3: In stage r, the situation of none of the sensors is Ti = Unknown.

At Stage r-1 if the sensor is $Neighbors(V_i) \succ \beta$ then its status is certain. Then it distributes its state to the other nodes whose states are $Neighbors(V_i) \prec \beta$ and T_i= Unknown. If the state of neighboring sensor $T_i = GD$ and the sensor value is similar to the sensor, its state is set to $T_i = GD$ and $T_i = FT$ would be otherwise.

After using sentence 1, sentence 2 and sentence 3, Theorem 1 is easily proved.

4.2. The Example Proposed Algorithm

In this section we will give an example of the algorithm based on Figure 2. A Part of a

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collection of sensor nodes in wireless sensor networks have been shown with some faulty nodes connecting with two nodes in the worst case.

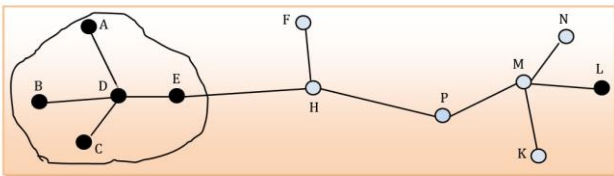

Figure 2. Wireless Sensor Network with a Common Mode Fault

In the beginning ,each sensor with respect to the threshold value will determine the value and C_{ij} obtained from the test results for all its neighbors, of course in this example $\beta = 3$ is defined, then the sensors A, B, C, E, F, P, N, K , L won't make any decision about their situations until the third stage, because it is $\beta \prec 3$. This position will reduce sending and the sensors D, H, M will check their status simultaneously on the second step of D and M to arrive H. in this step H and M sensors are identified as normal and D is detected as a faulty sensor. At the end these sensors send their situation to $\beta \prec 3$ sensors and they identify their situation by comparing their value with that of their neighbors.

Table 2. Fault analysis in Figure 2.

S_i	S_j with C_{ij}=1	S_j with C_{ij}=0	T_i in Iterations		
			0	1	2
A	D	-	-	-	FT
B	D	-	-	-	FT
C	D	-	-	-	FT
D	A,B,C,E	-	LG	FT	FT
E	D	H	-	-	FT
F	-	H	-	-	GD
H	E	F,P	LG	GD	GD
P	-	M,H	-	-	GD
M	L	N,K,P	LG	GD	GD
N	-	M	-	-	GD
K	-	M	-	-	GD
L	-	M	-	-	FT

5. Conclusion and Future Work

In this paper, a distributed new approach was proposed for fault detection improvement to address the fundamental problem of identifying faulty nodes (soft and hard) in wireless sensor networks. This algorithm is a simplified model for the detection of faulty sensor nodes with high accuracy for a wide range of faults noted, while the proposed method reduces the energy consumption, and improves network lifetime and fault tolerance by sending fewer messages. Even if half or more than half the sensors are faulty, the algorithm correctly detects the fault. With the increment in the number of sensors, the fault detection accuracy will be higher.

This approach can detect common mode failures by covering transient and permanent failures (problem algorithms Lee). As a future study, an intelligent diagnostic technique is proposed for self-diagnosing of sensor nodes with less operational overhead.

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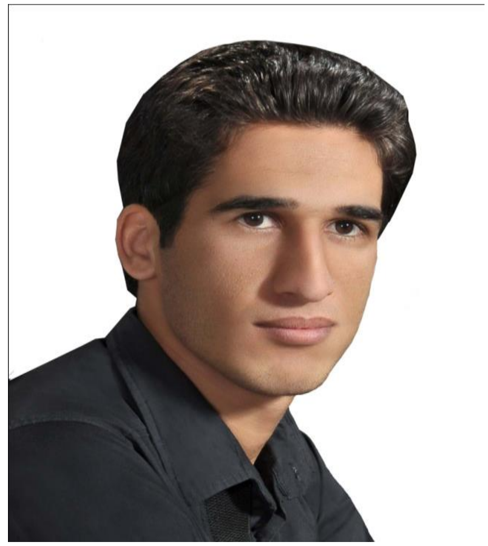

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