Fault Detection Mechanisms In Wireless Sensor Networks-A Review

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Abstract: Wireless Sensor Networks (WSNs) are vital apparatus for checking the discrete remote situations. As one of the key innovations engaged with WSNs, fault recognition is a basic in most WSN applications. Wireless sensor networks are self-organized networks that regularly comprise of an expansive number of sensing devices with severely restricted processing, storage and communication capabilities and limited energy supply. Wireless Sensor Networks are normally fault- prone and the reliability of WSN is influenced by faults that may occur, because of different reasons such as malfunctioning hardware and software glitches, separation or natural reasons. The primary point of this paper is to consider a variety of approaches of fault detection techniques in WSNs and its impending predictions. To accomplish this point, we reviewed many existing approaches and providing a broad outline of fault detection and fault tolerance in WSNs. At last, in this paper, the summary of existing fault detection techniques is given and furthermore examination is made to help sensor applications.

Keywords: Wireless Sensor Networks, Fault Detection, Fault tolerance.

I. INTRODUCTION

A Wireless Sensor Network is a cluster of small Sensor nodes, that nodes are organized into a supportive network. A WSN consisting of spatially disseminated independent devices using sensors to monitor the physical or environmental conditions. For example, temperature, light, sound, pressure, humidity, vibration etc. Sensors organize for the most part comprises of a few recognition stations known as sensor nodes, each of which is tiny, insubstantial and transportable. The nodes in the system are related by methods for remote correspondence channels. Every node can possibly detect information, process the information and send it to rest of the nodes or to base station. These systems are limited by the node battery span. Each sensor node is formed with a transducer, microcomputer, handset and power source. The transducer creates electrical signals in view of sensor physical impacts and Phenomena. The small- scale PC procedures and supplies the sensors yield. The transceiver which can be hard-wired or remote gets charges from a local PC and transmits information to that PC. The power for every sensor node is acquired from the electric solidarity or from a battery. Remote sensor organizes commonly have insufficient vitality and transmission limit, which cannot coordinate the transmission of a substantial number of information gathered by sensor nodes. WSNs are normally fault-prone and their unwavering quality is vigorously impacted by issues. A fault is essentially a sudden change in a framework, in spite of the fact that it might happen because of different reasons including battery exhaustion, radio impediment, de- synchronization, or separation. In general, there are mainly two sorts of node faults in WSNs. The primary type is function fault, in which the sensor node cannot convey the data packet suitably. The second type is data fault, in which the node can convey the information bundle effectively yet the information gathered by sensor node is off base.

SOURCES OF FAULTS

Data delivery in sensor nodes is intrinsically faulty and unpredictable. Failures in remote sensor systems can happen for different reasons. In the first place, sensor nodes are delicate, and they may fail because of consumption of batteries or destruction by an external event. Furthermore, nodes may catch and convey defective readings as a result of ecological effect on their detecting segments. Second, as in any specially appointed remote systems, links are failure- prone, causing system correspondence and dynamic changes in network topology. Connections may come up short when for all time or incidentally hindered by an external object or ecological condition. Packets might be corrupted because of the invalid idea of correspondence. Furthermore, when nodes are inserted or conveyed by versatile items, nodes can be removed from the scope of communication. Third, congestion may lead to packet loss. Congestion may happen because of countless synchronous progress from a power sparing state to a dynamic transmission state in reply of an event-of-intrigue. Besides, the greater part of the above blame situations are compounded by the multihop correspondence nature of sensor systems. It frequently takes a few jumps to convey information from nodes to the sink; along these lines, failure of a solitary nodes or connection may prompt missing reports from the whole area of the sensor network. Also, congestion that begins in a single neighborhood spread the distance to the sink and influence information conveyance from different regions of the system.

A NEED FOR FAULT DETECTION MECHANISMS

The primary motivation to think about the fault detection mechanisms for nodes in WSNs is as per the following:

1. Failure in sensor nodes happen more effectively than in different frameworks on the grounds that, Massive minimal effort sensor nodes are routinely conveyed in unmanageable and opposing situations.
2. WSNs are conveyed in a few events, for example, observing of atomic reactor where high security is required, because of its broadened nature, and fault

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identification for sensor nodes in this predefined application is of enormous significance.

3. It is troublesome and not practical to physically investigate whether the nodes are working appropriately.
4. Correct data cannot be acquired by the control focus in radiance of the fact that failed nodes would create erroneous information. What's more, it might bring about fall of the whole system in serious cases.
5. In WSNs, more often than not nodes are battery-controlled and the vitality is constrained. Along these lines, it is normal for shortcomings to happen because of battery consumption.

II. FAULT TYPES CLASSIFICATION IN WSN

1. Data-Centric viewpoint

The data-centric viewpoint describes faults that are related to the data readings. More specifically, this viewpoint does not have a description of the underlying cause of each fault and it is easier to define a fault by the characteristics of the sensor reading behavior.

2. System-Centric viewpoint

The system centric viewpoint mostly includes faults, which are directed to the malfunction of the sensor node. In detail, it describes malfunctions, conditions or faults with a sensor and mentions what kind of consequences it will have on the data.

3. Fault-Tolerant Distributed System viewpoint

In fault-tolerant distributed system viewpoint, we see a different classification based on the behaviour of the failed component. It may be due to crash, omission or incorrect computation and timings.

4. Duration viewpoint

The duration viewpoint is based on its duration. It classifies the fault types based on its duration. It may be Permanent fault like software and hardware faults; Intermittent means a temporary fault, and also Transient, a fault that are external faults, and temporary faults.

5. Component Viewpoint

This Component Viewpoint is based on its components, it classifies into three kinds of faults, functional faults on malfunctioning sensor nodes, informational faults on incorrect sensor readings and communicational faults on networking malfunctions. The below table Summarises all the Fault types in Wireless Sensor Networks that are discussed above. The table shows different fault types with respect to viewpoints:

Viewpoints	Fault types
Data-Centric	Outlier, Spike, Stuck-at, Noise
System-Centric	Calibration, Connection or Hardware, Low Battery Centric Environment out of Range, Clipping
Fault-Tolerant Distributed System	Crash, Omission, Timing, Incorrect Computation Fail-Stop, Authenticated Byzantine, Byzantine
Duration	Transient, Intermittent, Permanent
Components	Functional, Informational, Communicational

Table.1: Fault Types in WSNs

III. FAULT DETECTION MECHANISMS

Some of the Fault detection mechanisms are discussed as follows:

A. Centralized Approach

This approach is used to identify and confine failure nodes in WSNs. Typically a base station, middle coordinator or administrator, sink are used to monitor and tracing the faulty node in the system. The states of system concert and individual sensor nodes can be taken back by adopting an active detection model in the central node, by regularly injecting queries to the system. Central approach analysed this in order to identify the failed nodes. The drawback of this approach is that central node may easily become data traffic concentration in the network, which further causes a high message traffic and quick energy utilization in certain regions of network specially node closer to base station. In [11] authors apply the Distributed Fault Detection (DFD) algorithm in a True Time simulator based on clustering model where the cluster head or the sink node detects the suspicious nodes by exchanging messages in active manner. By analysing the information that is collected, the failed nodes can be recognized by the Cluster heads, according to a pre-defined failure detection rule. By using the DFD algorithm, the above drawback can be overcome and solvethe message traffic problem. The main advantage of this centralized approach is, it is easy for accurate and fast identifying of faulty node. The drawback of this approach is Central node may become a single point of data traffic attentiveness and causes high volume of message and quick energy depletion. In [18] Authors proposed two different architectures to incorporssate the multi-sensor data based on extended Kalman filter (EKF) data fusion algorithm. The distributed combination employments the state-vector union process, at the same time the centralized coordination plan will be in view of the Output Augmented Fusion (OAF) system. In centralized approach, data from all local sensors are brought together; that information starting with every last one of nearby sensors will be nourished under a single data-fusion focus. Over information combination center, every one of procedure estimations are transformed centrally toward the

EKF information combination algorithm will yield those global process state evaluate. This strategy makes utilization of all raw measurement estimation data to their first manifestation without any measure diminishment. The main advantage of this is, it may be relevant altogether sorts for circumstances such as different sensors whose estimation matrices may a chance to be for diverse sizes. Furthermore also, its computational load builds with including a greater amount sensor.

B. Distributed Approach

This approach is used mainly for confined decision-making, which uniformly distributes defect management to the network. The aim of this approach is to take secure levels of judgment prior to communicating with the central node by allowing a node. It believes that if the decision made by that is more, then a lesser amount of data leads to be supplied to the principal node. In [10] authors proposed the a algorithm called as distributed fault detection algorithm for wireless senor networks based on Hidden Markov Model (HMM). A HMM is introduced to characterize the tendency of each node to be faulty. Hidden Markov models are especially used in the applications like sequential configuration acknowledgment such as speech, writing, gesticulation, part- of-speech tagging, musical score following, restricted releases and bio-informatics. In [15] Authors proposed the method called as an Uncertainty-Based Distributed Fault Detection (uDFD) mechanism for WSNs. The uDFD mechanisms can be used to solve the problems like (i) information missing earlier than exchanging readings; (ii) misjudgements caused by indeterminacy situations. The hassle of missing records due to communiqué faults will have an effect on the determination accuracy whilst comparing neighbour's measurements. To resolve the facts loss, a faulty sensing node have to to fill inside the lacking measurements to provide the reference. Secondly, the represented algorithm adopts the automobile-correlated check outcomes to describe the popularity of variations between exclusive days. Subsequently, the ones undetermined appearances may additionally arise inside the above-stated segment. The records entropy and the diploma of disagreement characteristic combined in proof fusion concept are advanced as a result to assist to deduce their real states. Similarly, the usage of information entropy in the proof fusion can lessen evidence conflicts and increase detection accuracy. The disadvantage of this mechanism is whenever the sensor's communication unit has failed, the acquisition unit is active, and then the results cannot seem by the sensor. So, once a neighbour's data is missing, it will affect the exactness of fault diagnosis. The advantage of this mechanism is, it gives privileged detection of accuracy in spite of lower connectivity environment or changing fault ratios. In [1] Authors used the Threshold tuning based technique to detect the sensor fault. Using this protocol, the Anomalies like false alarms are detected. They used the Bayesian Network based method for fault detection of sensor nodes. The drawback of this method is that, a BSN adopt a very limited number of sensors for vital information collection, lacking the information redundancy provided by densely deployed sensor nodes in traditional WSNs. To avoid the false alarms they used the Bayesian Network model based sensor fault detection scheme which relies on historical training data for establishing the conditional probability distribution of sensor readings, rather than the redundant information collected from a large number of sensors. The Bayesian Networks (BNs) can be defined as Graphical Models (GM), used to represent knowledge about an undetermined domain. Every node in the GM stands for a random variable and every edge for a probabilistic dependence between the regarding random variables. BN can be described better with a GM structure called directed acyclic graph (DAG). This interpretation is used for representing and calculating the Joint Probability Distribution (JPD) in an accurate and fast manner. The fault detection techniques for distributed approach are discussed as follows:

- **Node Self-Detection**

A self-recognition is fundamentally used to inspect the breakdown of the significant segments of a sensor node through both equipment and programming interface. Self-Identification of node failure is by one means or another obvious on the grounds that, the node directly watches the paired yields of its devices by contrasting and the pre-characterized blame simulations. In information conveyance conventions which convey expansive sections of information to the whole or part of the system, the goal of these nodes are in charge of identifying the missing packets or the window of missing packets, and imparting the input to the source utilizing NACK informing. In [4] Authors proposed software based liability recognition scheme for wireless sensor network. Generally, the wireless sensor networks are likely to supply uninterrupted, unattended service for a considerable length of time or even years. But, hardware reliability represents a noteworthy test to this desire. To overcome from this issue, a software-based negligible-overhead fault detection strategy to detect failures in various hardware components is proposed. This fault detection scheme has been actualized in the SOS kernel on the sensor nodes. In this paper, a software based fault management scheme conspires with respect to the SOS part is utilized to the processor disappointments and I/O blame identification. The primary preferred standpoint of this technique is that with the exception of the memory get to trap, most disappointments can be effectively identified through minimal effort software detectors.

- **Neighbour Coordination**

Neighbour coordination method is used mainly to detect the hard permanent fault and soft permanent fault. Failure detection through this neighbour coordination is an example of fault management distribution. In this method, Nodes coordinate with their neighbours to detect and identify the network faults before consulting with the central node. In [9] Authors used the neighbouring coordination approach, it uses the Neyman-Pearson method to detect the faulty sensor nodes. The Byzantine fault is detected by using this neighbour coordination approach. In [10] the Hard Permanent and Soft Permanent faults are detected by using the neighbouring coordination method. The neighbouring coordination method used the modified three-sigma edit test. i.e., Mean replaced by Median and Standard deviation replaced by Normalize absolute deviation to detect the fault. In [14] Faulty sensor nodes can be diagnosed using the Neighbor-Coordination method. The hard permanent and soft permanent fault can be detected easily using this method. The main contributions of this paper include mainly three points: First, we advocate a brand new set of rules known as Neighborhood Hidden Conditional Random area that is derived for coping with fault diagnosis is such as finding defective nodes in a WSN. Second, in assessment to other traditional strategies that particularly comes across faulty sensor nodes, the proposed Neighborhood Hidden Conditional Random Field (NHCRF) algorithm and its secure feature allows hidden states of a WSN be decided. For this reason, the dependencies among sensors and transmission paths are found. And as an end result, faulty scenes due to defective transmission route but not sensor nodes can also be detected. Third, best community dependencies as opposed to international dependencies are used for detecting states of hidden variables. This removes the impact resulting from distant pals, and for that reason complements the robustness of prognosis notably. Distinctive from the previous fault diagnosis methods employing many metrics gathered by more devices tracking the sensors in a WSN, the proposed diagnosis technique is based only on the amassed signal put off data. Therefore, it could be used in lots of excessive environments. The drawback of this approach is due to its complicated states of relationships between sensors and transmission paths faulty nodes cannot be detected easily. The advantage of this approach is it presents thorough results on different types of WSN traffic, the free-traffic, light-traffic and heavy-traffic. And also using this method, data can be delivered with superior sorting concert with other methods.

- **Clustering Approach**

This approach is energy efficient and responsive due to its property of consuming fewer powers than break down faults is identified. The cluster based algorithm lends fine to the uninterrupted function and safeguarding of vigorous sensor networks. Clustering has become a promising technique for building scalable and energy balanced applications for WSNs. In [7] authors derived a solution that efficiently detects the failures by means of a cluster-based communication chain of order to achieve scalability, comprehensiveness, and correctness concurrently. In this first, they divide the whole network into diverse clusters and then consequently dispense defect management into each individual section. The authors proposed the Fuzzy MLP Approach to recognize the defect in Wireless Sensor Networks. It is utilized to recognize the flaws like Hard Permanent, Soft Permanent, Intermittent and Transient defect. The hard lasting defective nodes are not proficient to collective with other sensor nodes. In the event of soft permanent defective nodes are imparting among other sensor nodes with perpetually broken behaviour. The discontinuous broken nodes are given sporadic conduct for some subjective measure of time and afterward undergo great behaviour. The transient broken nodes are given unpredictable conduct for minute and continue well in the rest of the time. The connections are under dealt with the MAC layer convention. The proposed fault determination convention comprises of three stages: (i) clustering stage, (ii) fault recognition and characterization stage, and (iii) fault separation stage. The proposed calculations identify the flawed nodes as well as classify the faulty sorts and isolate the broken nodes in the system. In [7] Authors proposed the Fuzzy Machine Learning Percepteron (MLP) approach for fault diagnosis in Wireless Sensor Networks. This protocol is based on the neural network concept. Using this protocol Hard Permanent, Soft Permanent, Intermittent and Transient Faults can be detected easily. The authors used the Fuzzy MLP based methods, it consists of three phases (i) Clustering phase, (ii) Fault Detection and (iii) Classification phase and Fault Isolation phase to detect faulty nodes and to classify the faulty types and isolate the faulty nodes in the network. This Fuzzy MLP protocol can be used in variety of applications like Military, Industrial, and Environmental applications. The main advantage of this protocol is it detects all types of faults occurring in wireless sensor networks. In [10] and [7] both hard permanent and soft permanent fault can be detected. But, Fuzzy MLP approach can easily detect the fault than used in [10] because; the neural network concept is widely used to detect the fault effectively and also used extensively in many research applications.

- **Hierarchical Approach:**

In hierarchical approach, a traversing tree fixed at the sink with all the fault-free nodes in the network is constructed first. Then, fault detection is carried out at each level of the tree. Detection latency will increase with increase in number of nodes in this approach. In [8] Authors proposed the Data- Driven Multi-Unit Monitoring scheme with Hierarchical fault detection and diagnosis method. The main aim of this approach is to present a data-driven multi-unit monitoring scheme function of hierarchical fault detection and diagnosis. This proposed plot is subsequently encouraging to decrease the endeavours in building up a checking framework for various comparable units. It merits specifying that despite the fact that the plot is delineated for disconnected blame recognition and analysis, with a couple of adjustments it might well be connected to online fault discovery and diagnosis. Once a MPCA demonstrate is assembled based on a recorded dataset of a specific length in time, vital parts are characterized. By using this method, faults can be successfully detected and diagnosed. In [6] Hybrid fault diagnosis architecture for WSNs is proposed. This protocol takes into account inter-process dependencies and intra-process communication. This hybrid method shows a reliable transmission and distributed processing of diagnostic information along alternative paths.

- **Test-based Approach:**

In test-based approach, firstly jobs exist allocated to a set of sensor nodes and their experiment outcomes are taken as foundation for classifying faulty sensor nodes [4]. Though this approach provides high detection accuracy but the results obtained by tests may not be reliable if the testing processing element itself is faulty. Also, communication overhead and detection latency increases with increase in number of nodes.

C. Distributed Detection

The main aim of this approach is to make each node to make a conclusion on faults. This method is mainly used to detect the data fault in Wireless Sensor Networks. This approach is particularly vitality proficient and perfect for information driven sensor uses. However, there keep on different research challenges so as to accomplish a superior harmony between fault discovery exactness and the liveliness use of the system. As a rule, the efficiency of such failure detection schemes is checked as far as node correspondence costs, exactness, recognition precision and the quantity of defective sensor nodes middle of the road in the system. In [3] authors proposed a algorithm called Distributed Bayesian Algorithm by presenting the edge nodes. In this strategy, every node calculates its possibility of fault as indicated by its neighbours' readings and the likelihood is balanced by its border nodes. A misdiagnosis rate of DBA is extraordinarily diminished when contrasted with the customary DFD technique because of the alteration of border nodes. In this [10] paper, A disseminated self fault diagnosis using modified three sigma edit test protocol for WSNs is used to detect the fault. A neighbouring coordination method using modified three sigma edit test technique is used to detect the fault. In neighbouring coordination method, the nodes can synchronise with the neighbouring nodes to find the network faults. The main concept of this method includes two techniques they are, Mean is replaced by median and Standard deviation is replaced by normalize absolute deviation. Using this methods and protocol a hard permanent and soft permanent faults are detected. In [2] Authors proposed Check Point Recovery Algorithm to identify defects in sensor nodes. Utilizing this convention data fault can be distinguished. They utilized three strategies to identify the fault they are, AODV directing convention, Check Point Recovery Algorithm and Network topology management. Utilizing these techniques data fault can be effortlessly identified in a quick and exact way. The principle disadvantage of this is, it utilizes Round Trip Delay (RTD) time for choosing the disappointment node. RTD is characterized as the time taken to get the bundle at recipients end and after that getting back the affirmation to the sender. On the off chance that RTD esteem surpasses the general esteem, at that point it is affirm that the node is failed. Be that as it may, this strategy does not prompt the disappointment identification at fitting time. Henceforth, it can establish data loss in the system. To overcome from this confinement, the Check Point Recovery Algorithm (CPRA) is utilized for fault discovery in the sensor nodes.

D. Online Fault Detection

A fault tolerant Wireless Sensor Network is considered to afford continuous and accurate delivery of information to the sink node. The ability to detect and diagnose a correct set of faulty nodes in an online manner establishes an significant part of error acceptance. The objective of this fault diagnosis is to constantly recognize a defective node so as to confine its consequence on wireless sensor network actions. The flawed data generated by faulty sensor nodes can be protected from entering the network for effective and efficient bandwidth utilization. If diagnosis is performed as an online process, the results provide an effective means to manage network resources. The drawback of this approach is endeavour constrained only to faults in sensors relatively taking other message and reckoning elements of a node into consideration. The main advantage of online fault detection is Accuracy in presence of Gaussian noise even for relatively sparse networks. In [12] authors Proposes a generic parameterized diagnosis scheme that identifies permanent and intermittent faults with high accuracy by maintaining low time, message and energy overhead and analysed the effect of transient faults in communication channel and intermittent faults in sensing on the performance of the diagnosis algorithm. In [5] authors used Recursive Principal Component analysis (RPCA) model to detect the fault in sensor nodes. The RPCA method is proposed to overcome from the limitations of conventional PCA method. This RPCA algorithm is applied in order to update the model representing the normal behaviour of the sensed data adaptively and realize the online-fault detection. Using this method, the temporary fault and permanent failure of WSNs can be detected. The Principal Component Analysis (PCA) is an effective tool used for WSN fault detection. The RPCA framework consists of two main things: one is to build an initial normal model using PCA method to detect the upcoming data and second one can be done based on the detection result. The RPCA algorithm has the following properties :(i) to build an initial data, it requires very less sample data, (ii) it suits streaming, alternately rapidly updated data. The RPCA method involves mainly three parts: (i) a recursive pre-processing of sensed data, (ii) a recursive calculation of the PCA model with the help of the first-order perturbation (FOP) analysis theory and (iii) a recursive determination of the monitoring statistics and their confidence limits for fault detection purposes. By comparing this RPCA method with generic parameterized diagnosis scheme, the RPCA method is more powerful for detection of any type of fault in WSNs. Because, of its less usage of data samples for detection initially and then it detects the permanent failures easily. The fault detection mechanisms discussed above can be used for detection of faults in a sensor node with different ways. By our comparison, the centralized approach is having more complexity than other approaches. In hierarchical method the detection can be done in a very structured way but that does not accurately provide the fault tolerance results. The distributed approach is having the least complexity among all the approaches, but that cannot always provide an exact solution. However, none of the approaches provide the accurate fault tolerance that supports all types of faults that a WSN node is exposed to. So, in future work, we will try to propose an effective and efficient fault tolerance mechanism that covers all types of faults that sensor nodes are exposed to that faults.

V. CONCLUSION

In this paper we surveyed many existing techniques that deal with the faults in Wireless Sensor Network. Different types of protocols and methods are used to detect the faults like data fault, hard permanent fault, soft permanent fault, and all other types of faults. Many statistical approaches to detect faults in WSNs are presented and comparison is made and used that approaches to identify and classify the data and system faults. We reviewed the problem of fault detection and prevention by surveying different mechanisms that are presently applied in WSN research. In the future work, we will try to intend an efficient fault tolerance mechanisms for WSN, this fault tolerant mechanisms can cover all types of faults that a node is exposed to those faults.

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