A Review on Fault Detection in Wireless Sensor Networks

Sathiyavathi.R and B.Bharathi

.

***Abstract*—In these days, Wireless sensor network becomes integral part of the computer and communication technology. A huge number of sensor nodes can be deployed in the field of interest to monitor, detect the time critical events by which an emergency of the situation can be evaluated. All the sensor nodes in the network, may not perform well always and it may fail due to several reasons. Fault detection is considered as a vital factor in order to achieve the quality of service, to increase the bandwidth and the lifetime of the network. In this paper, we have classified various fault detection approaches used in wireless sensor networks.**

***Index Terms*—Fault detection, fault diagnosis approaches, wireless sensor networks.**

I. INTRODUCTION

Wireless sensor networks are emerging technology as computing platforms for monitoring and controlling different environments including remote geographical regions, and modern plants .The topology of the network may starts with star topology into distributed multi hop wireless mesh topology, which contains large amount of tiny sensor nodes built with limited computing capabilities. Low-cost sensor nodes can be deployed over uncontrolled environment or probably unattended environment, in order to monitor, detect various events occurred in the environment. Each node in the network is connected with the sink node in order to check the behavior of the network and to monitor data being collected. The sensor nodes being deployed might fail to do its process which leads to faulty sensor nodes. The damage or an error in the node or network can be referred as fault in the network. The faulty sensor nodes cannot produce the correct data or information, which misleads the sink node while taking decisions. Sometimes faulty node may not respond to the instruction given by the sink node. So it is necessary to detect the faulty sensor nodes, and ignore them from the network during normal operation of the network. An invalid state of the program or hardware can be defined as fault, which can starts from simple fault where nodes are get into inactive state to abnormal fault where faulty nodes start behaving maliciously. Since we have a constant change in the network everyday , monitoring the network is not sufficient to control the network, failure of the network or node occurs in fault prevention too. So fault detection should be used in the first place to detect the exact fault in the system.

Sathiyavathi.R and B.Bharathi are with the School of Computing, Sathyabama University, Chennai, India

Fault detection can increase the QoS(Quality of Service) in the sensor networks. Since sensor network can be used in the various environment , if fault occurs in the network, the result can be serious in human life and economic loss. With the wrong output of faulty sensor nodes results in life threatening event to occur in the real time. The sensor node architecture is given in the Fig. 1.

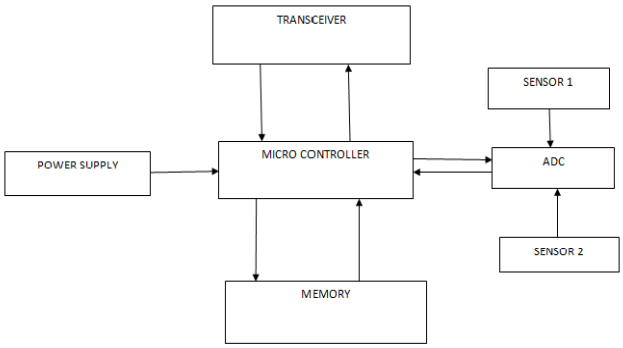

Fig. 1. Sensor node architecture

A. Applications

Wireless sensor networks is used in all the fields in these days.

- Environmental monitoring:

WSN is used monitor the quality of the water, pollution in the air, forest fire detection, and also monitors the natural disaster occurrences which includes the applications of sensing the quality of the air, light, temperature and humidity. A huge number of sensors can be deployed in the hostile or unattended environment to sense and detect the environment change , it also detects forecast disaster before they occur.

- Healthcare center :

Sensors can be placed in the different places in the body of the patient, to monitor the well being of patients in which a patient can stay at home, a doctor can monitor the health condition of the patient in the remote system.

- Agricultural monitoring:

Due to low power consumption of sensor nodes, highly it can be deployed in the agricultural land to monitor the growth of the crops, by sensing the soil moisture and humidity in the air.

- Smart home environment:

Smart home environment can be created using using wsn to have a comfort , secure and automated house . Sensor nodes are deployed to read the measurements of electricity,water and gas. These values can be transmitted to the data centers, where necessary action is taken.

978-1-5090-3800-8/17/$31.00 ©2017 IEEE

B. Terminologies Used In Fault Detection:

- Completeness: It refers to identifying all the faulty sensor nodes present in the network .
- Consistency:In every diagnostic round, the number of faulty sensors should be same.
- Communication complexity: Total number of diagnosis messages exchanged in wsn to ensure the correctness and completeness
- Detection accuracy: It is a ratio between number of faulty node detected in the network and number of faulty node present in the network.

C. Types Of Fault:

The faults in the wireless sensor network can be classified as follows.

- Node fault: Node failure can be created by malfunctioning of hardware or software component. If the energy falls below the threshold, then the sensing unit may provide incorrect readings. The depletion of energy in the node is considered as a common failure in the sensor network
- Network failure: Wsn has a concept of collecting the information from the nodes and sending it to the sink node. During this communication, a link or path may fail due to many reasons like interference between nodes or collision of packets may cause loss of packets.
- Sink failure: Sink node is considered as an essential component in wireless sensor network. The failure of the sink leads to failure of the whole sensor network. The sink node does not have any energy constraint.

The rest of the paper is organized as below. Section II describes the related work. Section III describes the approaches of fault detection. At last, section IV concludes the paper.

II. RELATED WORK

In[2], proposed mobile sink based diagnosis algorithm for wireless sensor networks, where the hardware and software status of the sensor nodes can be diagnosed by the mobile fault detector which is mobile transceiver does a job of mobile base station. The mobile fault detector moves around the network to detect the hardware and software status of static nodes in the network. It also introduced tour planning algorithm ,by which functionality and accuracy of the network is increased. The faulty nodes are excluded in the next diagnosis tour.

In [3], have proposed Cluster Heed Failure recovery Algorithm, if the cluster head is failed, then the secondary cluster head will take over the role of cluster head which is failed. The cluster head and secondary cluster head information will be known to all cluster members, once the cluster head energy drops down below the threshold value, then it sends the message to all its members including secondary cluster head regarding their energy level, then the secondary cluster head becomes the cluster head then all other nodes in the cluster starts communicating with secondary cluster head.

In [4], have presented ,Cluster based fault detection algorithm is proposed, in which initially the cluster is based on Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, and then the reliability of cluster members are verified. The cluster head takes the responsibility of fault detection with its member Cluster based fault detection algorithm provides better network performance and detection accuracy.

In [5], have proposed a fault tolerance method based on mobile agent federation which is used for diagnostic and repair system based on consumption of less energy. It provides the fault tolerance at the node and network level, which had a hierarchical arrangement of nodes, where the nodes are grouped as cluster ,in each cluster will be having a cluster head which in turns reporting to the sink node. In each node in the cluster , fault tolerance mechanism is implemented. Statistics of the network element can be captured for fault detection , it also proposed communication protocol to initiate the fault repair system.

In [6],have suggested, distributed fault detection algorithm in which sensor nodes detects its own fault depends on the information from its neighboring nodes. It also minimize the computational complexity and improve the accuracy, it uses the Neyman-Pearson test method to predict the fault status in every sensor nodes and neighboring sensor nodes. Voting scheme in applied on all sensor nodes to detect the final fault status of each sensor nodes.

In [7], has presented a Fault Detection and Recovery technique for Cluster heads (FDRC) in mobile wireless sensor networks . it chooses the monitoring node which in turn detects the faulty node in the network, It also finds the cluster head failure, then it is the responsibility of monitor node to determine the alternate cluster head.

In [8], have proposed a novel centralized Naïve Bayes Detector (CNBD) fault detection method , where the end to end transmission time is calculated at the sink node using the communication protocols to determine the network status. If the network is faulty ,then suspicious faulty sensor nodes can be listed where the Sensor nodes does not perform any of the computation as its own.

In [9], have proposed a modified three sigma edit test based self fault diagnosis algorithm to detect the faulty sensor nodes in the network where each node diagnosis itself with high detection accuracy, low false alarm rate. The traditional method of finding faults like using mean, median and majority voting approaches does not suit for large size wireless sensor networks.

In [10], have designed a distributed fault detection algorithm based on the temporal and spatial correlation of the sensor data. Resource consumption and processing burden of the node is minimized by detecting the faulty data is detected and discarded locally. This algorithm performs well in terms of detection accuracy and false alarm ratio when the network is sparse.

In [11], have given a multi objective particle swarm optimization (2LB-MOPSO) algorithm to detect the e intermittent faults in the network which is formulated as a optimization problem. It also provides a generic parameterize diagnosis scheme which detects permanent and intermittent faults with less energy overhead and high accuracy. A fuzzy mechanism can also be applied to produce the best compromised solution.

III. FAULT DETECTION APPROACHES

Many fault detection techniques have been used for WSN which is shown in the Fig. 2.

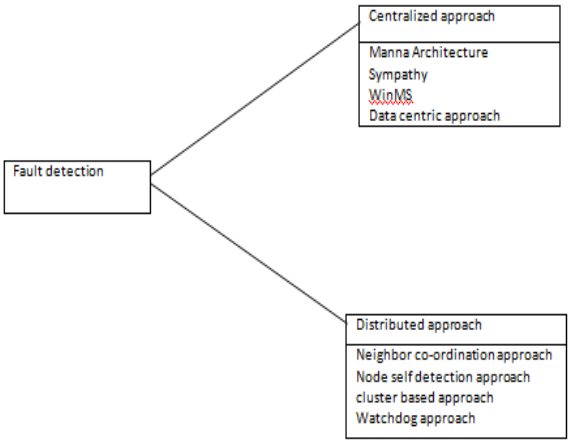

Fig. 2. Fault detection approaches used in Wsn

A. Centralized Method:

A central node can also be called as sink node provided with the unlimited resources, which is also referred as base station, takes responsibility of detecting the faulty nodes in the network. With the regular interval sink node sends the query to the network and gets the response from the every nodes in the network , by analyzing the state information of every node, a central node decides whether it is a failed node or suspicious sensor node. MANNA architecture is an approach, which has an external manager located outside the wireless sensor networks, whenever there is a state change, a node can send the signal to the manager. A manager can send a GET operation signal to the node to get the state information of the node. The manager also maintains the energy map to check the residual energy. Sympathy is an approach uses the message flooding to detect the node failure. It uses the sensor nodes neighbors and next hops as a parameters to detect the sensor nodes which are not delivered sufficient data to the base station. Wireless information network management system (WinMS) uses residual energy and topology map of the node organization to detect the faulty node in the network. Data centric approach can also be used where the source sensor node sends the two copies of the data to the sink node via different paths in the network. If these two contents are not identical then the source sends the same packet in another path to the sink node. Using this information sink node identifies the faulty sensor nodes and the faulty path.

1)Issues in Centralized method :

Centralized approach is inefficient when it is used with the large scale network, because it is very expensive to have a base station which accommodate the all the information from every sensor node in the network. It also has hot spot problem where the sensor nodes which are placed in the closer region of base station leads to rapid energy depletion leads to network partition, It also places bottleneck on performance of the network.

B. Distributed Method:

The state of the network can be decided by the individual nodes in the wireless sensor network. Here an individual node capable of taking their own decision before communicating with the base station. Network is divided into number of portion and fault management is equally distributed in the network. In each portion of the network, one node takes the responsibility of detecting the fault in the network. Even though the sensor nodes take the more decision only less information is delivered to the base station, by which it saves the node energy and prolongs the network lifetime. The management node just monitors the network, by which it saves the communication overhead.

1) *Neighbor Co- Ordination Approach*:Sensor node co-ordinates with the neighbor nodes to find the faulty node.DFD algorithm has been used, which compares the sensor readings. Sensor reading of individual node is compared with the sensor reading of one hop neighbor before communicating with the central node.
2) *Node Self Detection Approach:*Each sensor node in the network is capable of detecting its own status from the network. An additional hardware can be added to the architecture of sensor node, which allows sensor nodes to detect their own their condition.
3) *Cluster Based Approach*: Sensor nodes are grouped into different size to form the cluster which splits the entire network into different groups. Every group is having the cluster head or leader node executes fault detection in their group using centralized or distributed manner.
4) *Watch Dog Approach*: It is the simplest mechanism to monitor the fault in the network. The working principle of the watchdog is that a node checks whether its one-hop neighbor forwards the packets to its next node or not. If the one-hop neighbor fails to forward the packet within given time, the neighbor is considered as misbehaving node. When the misbehaving value exceeds a predefined threshold, the source gets notification and the following packets are forwarded along another route.

The various methodologies used for fault detection are listed in the table 1.

TABLE I
SUMMARY OF THE CONTRIBUTION

REF	Methodology Used	TYPES OF FAULT
[2]	Fault diagnosis tour planning scheme	Hardware and software fault
[3]	Cluster Heed Failure recovery Algorithm	Link failure
[4]	Low Energy Adaptive Clustering Hierarchy (LEACH) protocol	Link failure
[5]	Honey bee dance classification	Communication link failure
[6]	Neyman-pearson test method	Software fault
[7]	Random sample method/used for cluster head selection	
[8]	Centralized naive bayes detection(CNBD)	Hardware fault
[9]	A modified sigma edit test	Hardware and software fault
[10]	Self detection and weighted-median detection	Data fault
[11]	Multiobjectives particle swarm optimization algorithm	Permanent and intermittent fault

VI. CONCLUSION

This survey presents different types of faults and various approaches used for fault detection in the wireless sensor network. In the summary of contribution dealt with what are the fault detection methodologies used in the existing system and what are type of fault handled by them were discussed, which is used to derive a strong and weak points among different fault detection technique available in the network. A detection framework and the classification can be extended as a future work of this study.

REFERENCES

.

[1] Arunanshu Mahapatro and Pabitra Mohan Khilar," Fault Diagnosis in Wireless Sensor Networks:A Survey",in IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 15, NO. 4, FOURTH QUARTER 2013Development (INDIACom), New Delhi, 2016, pp. 2008-2010.

[2] Prasenjit Chanaka, Indrajit Banerjeea , R. Simon Sherratt," Mobile sink based fault diagnosis scheme for wireless sensor networks" in The Journal of Systems and Software ,Volume 119, Pages 45–57, 2016

[3] Abolfazl Akbari , Arash Dana , Ahmad Khademzadeh and Neda Beikmahdavi," Fault Detection and Recovery in Wireless Sensor Network Using Clustering" in International Journal of Wireless & Mobile Networks (IJWMN) Vol. 3, No. 1, February 2011

[4] Wenbo Zhang, Guangjie Han, Yongxin Feng, Long Cheng, Deyu Zhang, Xiaobo Tan, and Lidong Fu," A Novel Method for Node Fault Detection Based on Clustering in Industrial Wireless Sensor Networks" in International Journal of Distributed Sensor Networks , Hindawi Publishing Corporation ,Volume 2015, Article ID 230521, 9 pages http://dx.doi.org/10.1155/2015/23052

[5] Sarah Salim, Mohsin Javed and Ali Hammad Akbar," A Mobile Agent-based Architecture for Fault Tolerance inWireless Sensor Networks" in the proceedings of "8th Annual Communication Networks and Services Research Conference" 978-0-7695-4041-2/10 $26.00 © 2010 IEEE

[6] Meenakshi Panda and P.M. Khilar ," Distributed Byzantine fault detection technique in wireless sensor networks based on hypothesis testing" in Computers & Electrical Engineering, Volume 48, Pages 270–285, , November 2015.

[7] Sachin Paranjapei, Dr. Mukul Sutaone Dr. Prachi Mukherjii," Fault Detection and Recovery of Cluster heads in Mobile Wireless Sensor Networks" in the proceedings of TENCON 2015, year 2015, Pages: 1 - 5, DOI: 10.1109/TENCON.2015.7373124.

[8] Bill C.P. Lau a , Eden W.M. Ma a , Tommy W.S. Chow, "Probabilistic fault detector for Wireless Sensor Network", in Probabilistic fault detector for Wireless Sensor Network, Volume 41, Issue 8, 15 June 2014, Pages 3703–3711.

[9] Meenakshi Panda , P.M. Khilar,"Distributed self fault diagnosis algorithm for large scale wirelesssensor networks using modified three sigma edit test" in Meenakshi Panda , P.M. Khilar, Volume 25, Part A, February 2015, Pages 170–184.

[10] Tianqi Yu, Auon Muhammad Akhtar, Xianbin Wang, Abdallah Shami ,"Temporal and Spatial Correlation based Distributed Fault Detection in Wireless Sensor Networks" in the Proceeding of the IEEE 28th Canadian Conference on Electrical and Computer Engineering Halifax, Canada, May 3-6, 2015.

[11] M.Jayekumar & V.Nagarajan, "A Novel Energy-Link Failure Recovery Routing (E-Lfrr) Algorithm for Qos Optimization in Wireless Sensor Network" in *5TH International Conference on Science, Management, Engineering and Technology 2016 (ICSMET 2016)*, 11th and 12th December 2016 at Hyatt Place Hotel, Dubai

[12] R.Rathna. (2016). Simple Clustering for Wireless Sensor Networks. Cybernetics and Information Technologies, Bulgarian Academy of Sciences, Vol.16. No.1, pp. 57-72. ISSN: 1314-4081

[13] Sandeep Saurav Singh,Y.Bevish Jinila," Sensor Node Failure Detection using Check Point Recovery Algorithm", Fifth International conference on recent trends in Information Technology (ICRTIT 2016).