Sensor Node Failure Detection

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***Abstract*—Wireless sensor networks are used to monitor physical or environmental conditions such as temperature, pressure, sound etc. The quality of service of wireless sensor networks (WSN) can be improved by increasing the number of wireless sensors. Failure of sensor node degrades the quality of service of WSN. Failure detection of sensor nodes is important for the effective operation of WSN. Faulty node is detected by comparing the round trip delay time of discrete round trip path's with its threshold value. After the detection of faulty node further analysis is done to check whether fault has occurred in sensor .Nodes with fault in the sensor can be reused for routing purpose as traffic node which in turn helps in reducing the cost of wireless sensor circuit. Proposed method can be implemented in NS2.**

Keywords— Faulty sensor node, round trip delay, round trip paths, WSN

I. INTRODUCTION

Wireless sensor networks (WSNs) are ad hoc networks that encompass small inexpensive low power devices , distributed in large number at a remote geographical region, in office buildings or in industrial plants . A WSN is used widely in such environments for monitoring the environment, which includes air, soil and water, habitat monitoring, military surveillance inventory tracking, condition base maintenance and in many more cases. The main components of a sensor node are a microcontroller, transceiver circuits, memory, power source and one or more sensors. The microcontroller is mainly responsible for data processing and managements of other components of sensor nodes . Transmitter and receiver are combined in a single device known as transceiver. Transceiver is responsible for data receiving and data transmission. The most relevant kind of memory is on-chip memory of a microcontroller. Low capacity memory chip is used for data buffering. The power is stored in batteries, both rechargeable and non-rechargeable and these are the main sources of power supply for sensor nodes.

The node failure detection approaches are classified into two primary types: centralized and distributed approach. In centralized fault management systems, usually a geographical or logical centralized sensor node identifies failed or misbehaving nodes in the whole network. This centralized node can be a base station, a central controller or a manager. This central node usually has unlimited resources and performs wide range of fault management tasks .A common centralized fault management approach Sympathy is a debugging system and is used to identify and localize the cause of the failures in sensor network application. Sympathy algorithm does not provide automatic bug detection. It depends on historical data and metrics analysis in order to isolate the cause of the failure. Sympathy may require nodes to exchange neighbourhood list, which is expensive in terms of energy. Also, Sympathy flooding approach means imprecise knowledge of global network states and may cause incorrect analysis. Centralized approach is suitable for certain application. However, it is composed of various limitations. It is not scalable and cannot be used for large networks. Also, due to centralized mechanism all the traffic is directed to and from the central point. This creates communication overhead and quick energy depletions. Moreover, central point is a single point of data traffic concentration and potential failure. Lastly, if a network is portioned, then nodes that are unable to reach the central server are left without any management functionality.

Distributed approach is an efficient way of deploying fault management. Each manager controls a sub network and may communicate directly with other managers to perform management functions. Distributed management provides better reliability and energy efficiency and has lower communication cost than centralized management systems.

The algorithm proposed for faulty sensor identification in is purely localized. Nodes in the network coordinate with their neighbouring nodes to detect faulty nodes before contacting the central point. In this the reading of a sensor is compared with its neighbouring median reading, if the resulting difference is large or large but negative then the sensor is very likely to be faulty. This algorithm can easily be scaled for large network. However, the probability of sensor faults need to be small as this approach works for large networks. This paper is organized as follows. SectionI is the introduction part. Section II is a literature survey. Proposed method is mentioned in section III. Section IV describes about the sensor node fault detection. Paper is concluded in section V

II. LITERATURE SURVEY

Sensor nodes find application in surveillance, vehicle tracking, climate and habitat monitoring, intelligence, medical, and acoustic data gathering. The accuracy of data is important to the whole system's performance, detecting nodes with faulty readings is an important issue in network management. The approach presented in [1] compares detected and estimated sequence to find out the faulty node. For two sensor nodes 1 and 2, the perpendicular bisector Div (1,2) divides the area into two subareas. For any position point below Div (1,2), node 1 is closer than node 2, so the distance sequence is 1-2. For any position point above Div (1,2), node 2 is closer than node 1, so the distance sequence is 2-1.In detection sequence mapping, a number of events appear in the monitored region and are detected by the sensor nodes. For a single event, the sensing result of each node (e.g., the received signal strength or time-of-arrival) varies depending on how far the node is away from the event. A detected sequence is then obtained by ordering the sensing results of all the sensor nodes. The distance sequences corresponding to the face in which the event most likely takes place, yielding an estimated sequence. Based on the comparison between the estimated and detected sequence ranking difference is found. Node with larger ranking difference is detected as faulty.

The work mentioned in [2] is applicable to small and medium scale wireless sensor networks. The sensor fault detection method is based on Principal component analysis and wavelet decomposition. PCA has the ability to extract system correlations, decrease data dimension and conduct sensor node fault diagnosis by extracting the correlations between sensor variables. Data matrix is formed with n samples and p sensors, it is then standardized. After the principal component analysis is completed the data matrix consist of two matrices, one is the principal component subspace and the other is the residual subspace. Once a sensor fails the data of residual subspace increase significantly and thus sensor failure can be detected due to the variation in the residual subspace. In [3] two methods are used for faulty sensor node detection namely self detection and active detection. In self detection nodes periodically monitor their residual energy and identify the potential failure. When the energy of a node falls below the threshold value it sends a message to the cell manager that its going to sleep mode due to energy below the threshold value. This requires no recovery steps. Self detection is considered as a local computational process. In active detection cell manager asks its cell members on regular basis to send their updates. The update message consist of node ID, energy and location information. If the cell manager does not receive an update from a node it sends an instant message to that enquiring about its status ,if it does not receive any acknowledgement in a given time it declares that node as faulty.

In [4] faulty nodes are detected by neighbour nodes temporal and spatial correlation of sensing information and heart beat message passed by the cluster head. Vector fault detection method is used to check sensor circuit fault detection. In a sensor network neighbor nodes are deployed closely in the sensing region. So the information sensed by a node differs slightly from its neighbouring node. If the information sensed by a node is y(t) and by its neighbour is x(t),the component of x(t) along y(t) is cy(t).Consider a time interval between t_1 and t_2,thrn the difference vector is given by

$e(t)=x(t)-cy(t)\ ,t_1<t<t_2$.

The difference vector value is greater than threshold value if the neighbour node is orthogonal and node's sensor circuit is declared as faulty. Node can check its battery or power failure by periodical checking of its battery level and if its power level falls below the threshold value it is declared as faulty node by sending message to its neighbour. Each node periodically sends a heartbeat message to its cluster head and if the cluster head does not receive this message for a certain period of time ,then cluster head declares that there is a fault either in its microcontroller or transmitter circuit. In [5] distance based fault detection method is mentioned. It uses a distance based algorithm for detecting faulty sensor nodes in wireless sensor networks using the average value of confidence level and sensed data. A sensor network with n number of deployed sensor can be defined as a communication graph G(V,E).Here V represents the set of all sensor nodes in the network and E represents the set of edges connecting the sensors nodes. Two nodes are said to have an edge in the graph if the distance between them is less than the transmission range. According to the measurement data(i) of the sensor node node(i) and the weighted average av(i) of its neighbor's sensor measurements, the decision function f(data(i), av(i)) is 0 if the magnitude of the difference between data(i) and av(i) is less than or equal to a threshold value where δ is a predefined threshold and 1 otherwise. If deviation of measure value from the true value is less than δ, the node(i) is considered as fault-free.

III. PROPOSED METHOD

After finding the faulty sensor node it is further analyzed to check whether fault has occurred in the sensor. Nodes with faulty sensors can be reused as traffic node. Detection of faulty sensor node is done by comparing the round trip delay time of round trip path's with the threshold value. The sensor node is detected as failed if the round trip delay time is infinity and as malfunctioning if the round trip delay time is higher than the threshold value. Number of sensor nodes present in the round trip path and the distance between them are the two main factors on which the RTD time depends. The accuracy of fault detection technique can be improved by decreasing the RTD time of round trip path. It can be decreased by reducing the number of senor nodes in round trip path. Round trip path is formed by grouping minimum three sensor nodes. The minimum round trip delay time of round trip path is given as

$$T_{RTD=}T_1+T_2+T_3 \qquad (1)$$

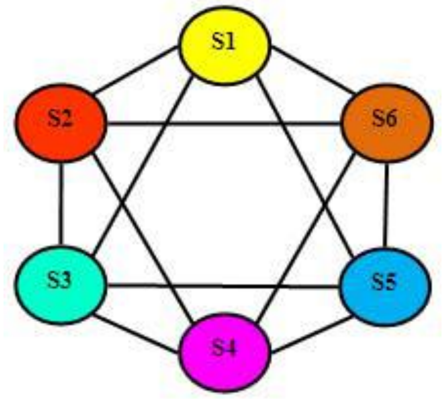

Fig. 1. Circular topology with six sensor nodes

Here T_1 is the time delay between nodes 1 and 2, T_2 is the time delay between nodes 2 and 3 ,T_3 is the time delay between nodes 3 and 1.Sensor nodes are arranged in circular topology. So three consecutive sensor nodes in an RTP will be almost at equal distances from each other. Hence T_1=T_2=T_3=T. Therefore the minimum round trip delay time is

$$T_{RTD}=3T \quad (2)$$

which depends on the distance between the node pairs. The distance between the node pairs varies based on the application for which wireless sensor network is used. Efficiency of the proposed method can be increased by reducing the round trip paths in WSN.

A. Evaluation of round trip paths

Consider a wireless sensor network with N sensor nodes and let m be the number of sensor nodes in a round trip path. Then the total number of round trip paths in a WSN is given by

$$P=N(N-m) \quad (3)$$

The total time required for the fault detection method depends on the time taken to measure the round trip delay time of all the round trip paths. The optimum value of number of nodes in a round trip path is 3.Total time for analysis is given by

$$T_{anly=}T_{RTD-1}+T_{RTD-2}+\ldots\ldots..T_{RTD-P} \quad (4)$$

All RTP's has only 3 sensor nodes, so RTD time of each RTP will be the same. Therefore equation 4can be written as

$$T_{anly=}P*T_{RTD} \quad (5)$$

Substituting equations 2 and 3 in 5

$$T_{anly}=N(N-3)*3T \quad (6)$$

Thus fault detection time depends mainly on the number of sensor nodes in the wireless sensor network. To speed up fault detection process optimization of round trip path is essential.

B. Optimization of Round Trip Paths

Fault detection time varies exponentially with the number of sensor nodes in wireless sensor network.So optimization of round trip path is essential. The number of RTP's can be reduced by selecting only discrete paths in wireless sensor networks. The equation to select the discrete RTP is given by

$$P_D=Q+C \quad (7)$$

$$\text{where } Q=N/m \quad (8)$$

C=0 if remainder is 0 and 1 otherwise, here N is the number of nodes in the wireless sensor network. The time taken for the fault detection is given by

$$T_{anly}=(Q+C)*3T \quad (9)$$

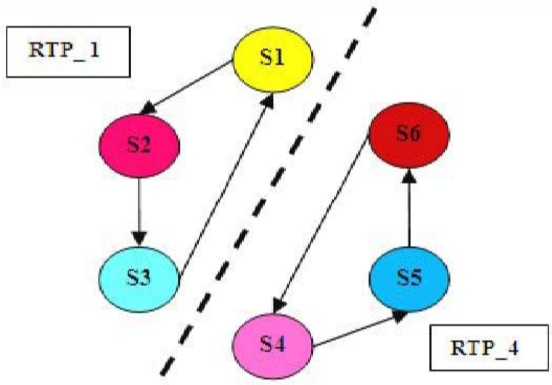

Fig. 2. Illustration of two discrete RTP's

Additional two RTP's are needed along with the discrete RTP's in WSN to locate the fault present at second and third levels .Therefore the total number of RTP's required to find out the fault is given by

$$P_{T=}P_D+L \quad (10)$$

Here L is the number of sensor nodes in each RTP excluding the source node ie L=m-1.

Analysis time is lowest when number of sensor nodes in an RTP path is 3 ie m=3.

IV. FAULTY SENSOR NODE DETECTION

The execution of the algorithm is carried out in two phases. First phase is used to determine the threshold value of round trip delay time and fault detection is done in the second phase. All the sensor nodes are considered as working properly in the first phase and the highest value of RTD time measured during the execution of first phase is taken as the threshold value of RTD time for all discrete RTP's in the WSN. Discrete RTP's are selected by incrementing the source node value by three. In the second phase the instantaneous RTD time of discrete RTP's is compared with the threshold value. The RTP's whose RTD time is greater than the threshold value is analyzed further. Consider an RTP path with nodes S_x,S_{x+1},S_{x+2} whose RTD time is greater than the threshold value. To detect which among the three nodes are faulty in the RTP path ,consider RTP paths with nodes S_{x+1},S_{x+2},S_{x+3} and S_{x+2},S_{x+3},S_{x+4}.The RTD time of these discrete RTP's are compared to detect the faulty node. Let RTD_x,RTD_{x+1},RTD_{x+2} be the round trip delay time of discrete RTP's S_x-S_{x+1}-S_{x+2}, S_{x+1}-S_{x+2}-S_{x+3} and S_{x+2}-S_{x+3}-S_{x+4} respectively. If RTD_x value is greater than threshold and RTD_{x+1} is equal to threshold then node S_x is declared as faulty. If the value of RTD_x is infinity then node is declared as failed otherwise malfunctioning. In the second stage RTD_{x+1} and RTD_{x+2} are compared provided RTD_x value is greater than the threshold, if RTD_{x+1} is greater than threshold while that of RTD_{x+2} is equal to threshold value determines node S_{x+1} as faulty. In the third stage RTD_x,RTD_{x+1},RTD_{x+2} are compared and if their RTD values are higher than the threshold then node S_{x+2} is declared as faulty. After that S_{x+2}

sensor node value is compared with the value of last node S_N in the WSN and if found less than S_N the algorithm is repeated for next discrete RTP. This process is repeated till the last discrete RTP's are found in the wireless sensor network.

Sensor node with failure in the sensor can be used for routing purposes as a traffic node. So after finding out the faulty node node it can be analysed further to check whether there is fault in the sensor. Sensor nodes are deployed closely in a region. So by comparing sensed information of a node with its neighbour nodes sensed value sensor circuit fault can be detected. If the difference between these sensed value is greater than a threshold value it is detected as node with faulty sensor. .If the information sensed by a node is y(t) and by its neighbour is x(t),the component of x(t) along y(t) is cy(t).Consider a time interval between t_1 and t_2,then the difference vector is given by $e(t)=x(t)-cy(t)$,$t_1<t<t_2$

The difference vector value is greater than threshold value if the neighbour node is orthogonal and node's sensor circuit is declared as faulty. Node can check its battery or power failure by periodical checking of its battery level and if its power level falls below the threshold value it is declared as faulty node by sending message to its neighbour node.

V. CONCLUSION

In a wireless sensor network random occurrences of faulty nodes degrade the quality of service of the network. The use of discrete round trip path has enhanced the efficiency of fault detection. Round trip delay time mainly depends upon the number of sensor nodes present in the round trip path and the distance between them. Further analysis on faulty sensor node helps in determining whether fault is present in the sensor or battery. This analysis helps in reusing the other parts of the sensor node including microcontroller and transceiver. Nodes with faulty sensors can be reused as traffic node for routing purposes. This in turn helps in reducing the cost of wireless sensor networks.

REFERENCES

[1] Srikanta Kumar Saho,"Faulty node detection in wireless Sensor networks using cluster",International Journal of Scientific and engineering research,vol.4,april 2013
[2] Muhammad Asim,Hala Mokhtar,"A self managing fault Management mechanism for wireless sensor networks", International journal of wireless and mobile networks,vol.3 Nov 2010
[3] Ayasha siddiqua,Sandip mandal,"Distance base fault Detection in wireless sensor networks",InternationalJournal on computer science and engineering,vol.5,May 2013
[4] I.Chen,A.P.Speer,and M.Eltoweissy,"Adaptive fault tolerant QoS control Algorithms for maximizing system lifetime of query based wireless sensor networks",IEEE Trans. Dependable Secure Comput. ,vol.8 ,no.2 ,pp.1-35,2011.
[5] R.N Duche and N.P.Sarwade,"Sensor node failure or mal-Functioning detection in wireless sensor networks", ACEEE Int .J . Communication ,vol.3 ,no.1,pp.57-61,2012.
[6] Akbari, Dana, A. Khademzadeh, and N. Beikmahdavi,"Fault detection and recovery in wireless networks usi ng clustering",IJWMN,vol. 3,no .1,pp.130-138,February 2011
[7] Ian F Akyidiz,Weilian Su,Yogesh Sankarasubramaniam, Erdal Cayirci,"A survey on sensor networks",IEEE Communications,102-113August 2002.
[8] Xi Liang,Feng Zhang,"Sensor fault diagnosis and location For small and medium scale sensor networks",Conference Paper,2010
[9] Indrajit Banerjee,Chanek,"Effective fault detection and Routing scheme for wireless sensor networks",Elsevier April 2013
[10]]K. Sha, J. Gehlot, and R. Greve, "Multipath routing Techniques in wirelesssensor networks: A survey," Wireless Personal Communication vol 70,no.2,pp 807-829,2013
[11] T.W.Pirinen,J.Yli-Hietanen,P.Pertil, and A.Visa,"Detection and compensation of sensor malfunction in time delay based direction of arrival estimation,"IEEE Circuits Systems ,vol. 4,no.1,pp.872-875,2004
[12] S Ahuja ,R.Srinivasan,M.Krunz,"Single link failure detection in all optical networks using monitoring cycles and paths",IEEE Transactionss ,vol.17,no 4,pp.1080 -1093,August 2009.
[13] Mengjie yu, Hala Mokhtar, and Madjid Marabti,"Fault Management in wireless sensor networks",IEEE Wireless Communications, vol.4, december 2007.