AN ALGORITHM FOR SENSOR NODE FAILURE DETECTION IN WSNs

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Abstract— **In recent years Wireless Sensor Networks (WSNs) are the most widely used networks and got attractive applications in various fields such as medical, military, safety agriculture and environmental monitorings etc. People are attracted to the networks which provide good services with less cost and judges the network based on their experience of network performance. The network performance seen by the customers is called as network Quality of Service (QOS). Hence to increase this QOS huge numbers of nodes are positioned. But due this increment in number of sensor nodes possibility of node failure also increases, this imposes to find an accurate faulty node detection algorithm so as to maintain network QOS. This paper presents an algorithm to detect faulty node present in WSNs. The algorithm is based on Round Trip Delays (RTDs) and Round Trip Paths (RTPs). First the proposed algorithm is experimented by taking six sensor nodes; later on the scalability of this proposed detection algorithm is demonstrated by simulating wireless sensor network with large number of nodes.**

Keywords— Faulty node; RTD; RTP; WSNs.

I. INTRODUCTION

Wireless sensor networks containing large numbers of convenient sensor nodes have probable applications in a miscellany of fields, such as military operations, surveillance, medical, home security, industrial monitoring and environmental monitoring. With speedy development of electronic production technology, it is possible to produce convenient sensor nodes at small cost with improved accuracy and sensitivity. Hence more number of convenient nodes may be placed in application field to boost quality of service (QOS).The application of greater number of nodes will increases the possibility of node failures in WSNs. Data analysis on the basis of such faulty sensor node will be inaccurate or departs from the actual data. This will ultimately corrupt the QOS of networks. The wireless sensor nodes of WSNs may become faulty because of various reasons like failure of battery, software or hardware malfunctions and ecological effects. Superior QOS is achieved by means of clearance of the data from such defective sensor nodes in the analysis [1], [2]. Therefore, it becomes essential to find the efficient and accurate detection of failed nodes in WSNs. The proposed technique of fault detection is based on Round Trip Delay (RTD) time measurement of Round Trip Paths (RTPs). RTD times of separate RTPs are compared with predefined threshold time to conclude failed wireless sensor nodes that are present in the WSNs. In paper [3], I. Chen, discussed the query based WSNs. In these networks client can put query and be expecting a response to comeback in a specific time frame. But because of such queries energy of the system rapidly depletes. Therefore, there will be intrinsic swapping among energy consumption versus query reliability. In his research the author developed adaptive fault tolerant QOS control algorithm. This is based on hop by hop packet delivery using "source" and "path" redundancies. Author worked an arithmetical model for the life span of sensors system. The author concluded that existence of finest "source" and "path" redundancies beneath which the life span of system maximizes and satisfies QOS of application necessities. The paper [4], by M Lee, describes distributed fault discovery method for WSNs. Failed nodes are recognized by comparing neighbor nodes and disseminations of decision made at every node. In order to tolerate transitory faults of sensing and communications time redundancies are used. To get rid of delay that is implicated in time redundancy method here sliding window protocol is used. In paper [5], P.Jiang, proposed improved distributed fault detection (DFD) scheme. The proposal checks faulty nodes by data exchange and mutually testing among neighbors nodes in this network. The chief drawback in existing DFD system is that fault detection correctness could reduces speedily if the number of nodes that has to be diagnosed is low but the failure ratios are extremely more. In paper [6], A. Akbari, constructed techniques for maintaining the cluster structures in the event of faults. Initially, node that has highest energy becomes the cluster's head and sensor node with the second highest energy will be the secondary cluster's head. And later selection of cluster head as well as secondary cluster head will be on the basis of available residual energy. In paper [7], Wang P, proposed an agreement based fault detection method. The scheme is designed for UWSNs (Underwater Sensor Networks). Each cluster member in a network is permissible for detecting the failed status of cluster head discretely. A distributed agreement protocol is used for achieving an agreement on failed position of the cluster head. The method is based on

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TDMA MAC protocol. Distributed detection process at every cluster member is performed periodically. It uses data sent by the cluster head for faults detections. A pair of backward and forward time TDM frames is specifically prepared for each time detection process. Moreover a scheme of schedule generation is also proposed. That generates the transmission schedules of the backward, forward frames.

The paper is organized in six sections. Section II gives basics of round trip path and round trip delay. In section III RTD time estimation and selection of RTPs is discussed. The proposed algorithm is formulated in section IV. Section V gives the simulation results. Finally the paper is concluded in section VI.

II. Round Trip Path And Round Trip Delay

A. *Round Trip Path (RTP)*

The name itself defines the round trip path (RTP) in WSNs. RTP is formed by grouping minimum three or more number of nodes. Selecting a node as initial point i.e. source node and coming back to the same initial node through two or multiple nodes is said to be a RTP.

The above concept can be easily understood by the topology as shown in figure 1 consisting of nine sensor nodes.

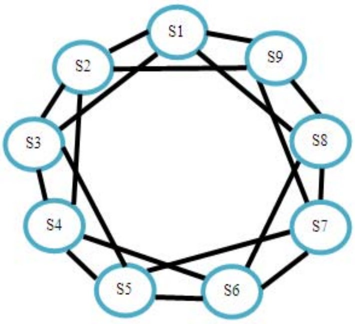

Fig. 1. Circular topology

Following figure 2 shows some examples of RTPs formed by selecting three sensor nodes.

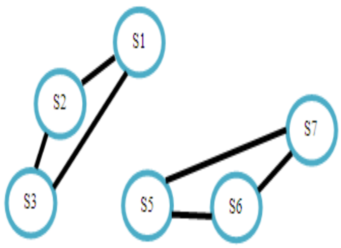

Fig. 2. Examples of RTP

Travelling from s1 though s2 to s3 and coming back to the node s1will make one RTP that belongs to sensor nodes s1, s2 and s3. Similarly another RTP formed by sensor node s5, s6 and s7 is also shown.

B. *Round Trip Delay (RTD)*

Round Trip Delay (RTD) is the time requisite by the message to travel from source to destination and coming back to same source node. Say the delay starting from some source node via pathway of one or more nodes and coming back again to same source node is said to be round trip delay. The round trip delay time can be few milliseconds to several seconds.

For example consider the figure 3, which is a round trip path involving four sensor nodes.

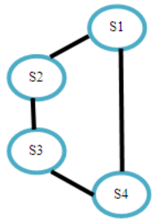

Fig. 3. RTP involving four sensor nodes

The delay for the above RTP shown in figure 3 will be sum of delay taken by the message to travel from s1 (source node) to s2, s2 to s3, s3 to s4 and from s4 to s1. Let these be T1, T2, T3, and T4 respectively then T1+T2+T3+T4 will be the round trip delay for the above shown RTP.

C. *Why to consider three nodes in a RTP*

If we form RTP by taking four nodes that is more than three nodes then during faulty node detection method, we have to analyze and compare four RTPs which will take more time and energy. Hence to improve speed of fault detection method and to find faulty node correctly three sensor nodes in a RTP are sufficient.

III. RTD Time Estimation And Selection Of RTP

A. *RTD time estimation*

RTD time primarily depends on number of wireless nodes present in the round trip path and distance between them. Proposed fault detection method accurateness can only be increased by means of reducing the RTD time of RTP. And this delay can be decreased simply by reducing the wireless sensor nodes in a RTP as because of the distance between sensor nodes in WSNs is determined by respective applications and cannot be decided. Selection of minimum number of wireless sensor nodes in a RTP helps to reduce RTD time. The figure 4 shows the circular topology of six sensor nodes.

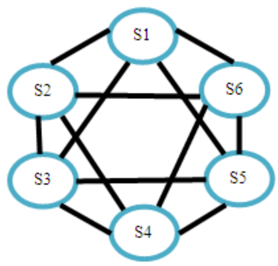

Fig. 4. Network with six sensor nodes

The round trip path in wireless sensor networks can be formed by assembling minimum three wireless sensor nodes.

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Therefore the minimum RTD time (T_{RTD}) of RTP involving three sensor nodes is given by

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

Where T_1, T_2 and T_3 are the delays of wireless sensor nodes pairs (s1, s2), (s2, s3) and (s3, s1) respectively. In circular topology of six wireless sensor nodes as shown in figure 4 making an assumption here that three consecutive wireless sensor node in each RTP are approximately at equidistance as because of the circular topology. As a result we have wireless sensor node pairs delays T_1, T_2 and T_3 equal. Assuming 'T' be uniform time delay of all wireless sensor nodes pairs in round trip paths i.e. $T = T_1 = T_2 = T_3$. Then RTD time of RTP with uniform wireless sensor nodes pairs delay can be obtained using equation (1) as

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

This is minimum round trip delay time of round trip path in wireless senor networks. It can be determined on the basis of sensor nodes pair delay (T) which is found by required application of wireless sensor networks.

B. *Linear selection of RTPs*

With the intention of reducing number of RTPs in fault detection method only few paths equivalent to number of nodes in networks are considered. Instead of taking maximum number of RTPs, we can select the RTPs equal to the numbers of nodes in WSNs for reducing the analysis instance. RTPs chosen in this manner is referred to as linear RTPs because of linear relationship of N (number of nodes in network) and P (number of linear paths).

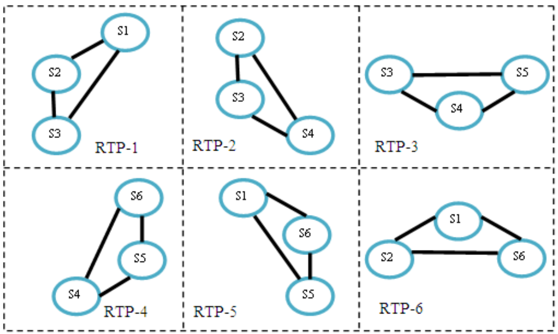

Fig. 5. Illustration of six linear RTPs

For the network shown in figure 4, six linear round trip paths are created and are as shown in figure 5. Each and every sensor node is involved in three linear RTPs. Therefore comparisons of three linear RTPs are enough to detect faulty sensor nodes. The linear round trip paths in networks with N number of nodes can be given by equation 3 below

$$P_L = N \quad (3)$$

Where

P_L is number of linear round trip paths.

C. *Discrete selection of RTPs*

Fault detection time will be considerably high for networks with higher number of nodes. Thus there is a need of minimizing the round trip paths in wireless sensor networks. Here we can reduce numbers of RTPs by selecting discrete paths in wireless sensor networks. Discrete RTPs can be selected among the sequential linear round trip paths only. They are selected by ignoring two consecutive paths, after each selected linear path. To calculate discrete round trip paths following equation 4 is used.

$$P_D = Q + C \quad (4)$$

Where

$$Q = N/m \quad (5)$$

Where

N = number of nodes in network

m = number of nodes in RTP

C is zero if remainder of equation 5 is zero and for remainder other than zero C is equal to one.

For N=6, P_D=2

The figure 6 illustrates the discrete RTPs.

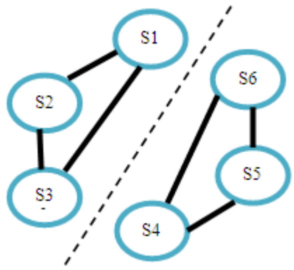

Fig. 6. Illustration of discrete RTPs

The table 1, below shows linear and discrete RTPs for different N values

TABLE 1: Linear and discrete RTPs for different N values

N	Q= N/3	C	P_L	P_D=Q+C
6	2	0	6	2
10	3	1	10	4
20	6	1	20	7
30	10	0	30	10
40	13	1	40	14
50	16	1	50	17
100	33	1	100	34

The figure 7 shows the comparison graph of linear and discrete RTPs.

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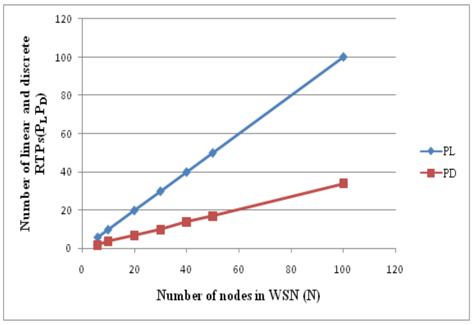

Fig. 7. Comparison graph of linear and discrete RTPs

IV. Fault Detection Algorithm

The algorithm is executed in two phases in first phase all the sensor nodes are assumed to be working correctly and RTD of all RTPs is measured and highest value is set as threshold value. In second phase comparison of RTD of each node with threshold is done.

Following are the steps involved in faulty node detection process.

Step1: Initially all the sensor nodes are at the initial position.

Step2: Sensor nodes will then move to their particular position to form a circular topology.

Step3: RTPs are formed.

Step4: Transmission starts between three sensor nodes of RTP.

Step5: Step4 is repeated until all the sensor nodes should involved in the transmission. Then go to next step.

Step6: Find RTD of all the sensor nodes.

Step7: Set threshold Value.

Step8: Compare each sensor node RTD with Threshold value, if any node having RTD time greater than threshold value means that node is considered as faulty sensor node.

V. Simulation Results

First the detection method is simulated for wireless sensor network consisting of six wireless sensor nodes, and on the basis of RTD measurement of RTPs and comparing mechanism sensor node '1' is found faulty and is indicated by red color in the simulation result as shown in figure 9. Scalability of the algorithm is tested by taking one more network of thirty sensor nodes, where sensor node '22' and sensor node '29' are detected as faulty and these are indicated by red color in the simulation result, as shown in figure 11. Performance graphs of throughput and packet delivery ratio are plotted for both six sensor nodes network and thirty sensor nodes network.

TABLE 2: Simulation parameters

Parameter	**Description**
Channel type	Wireless channel
Propagation model	Radio propagation model
Packet size	20 bytes
Antenna model	Omni directional
Maximum queue length	50 bytes
Number of nodes in network	6, 30
Traffic type	CBR
Bandwidth	11MHz

A. Simulation results of six sensor nodes network

Fig. 8. Illustration of packet transmission in a RTP

The figure 8 shows the transmission between sensor nodes of a round trip path. This round trip path is formed by taking node 3, 4 and 5. The sensor nodes involved in transmission are indicated by orange color. The black colored circles in the figure indicates the wireless communication. This is done to measure round trip delay associated with particular round trip path.

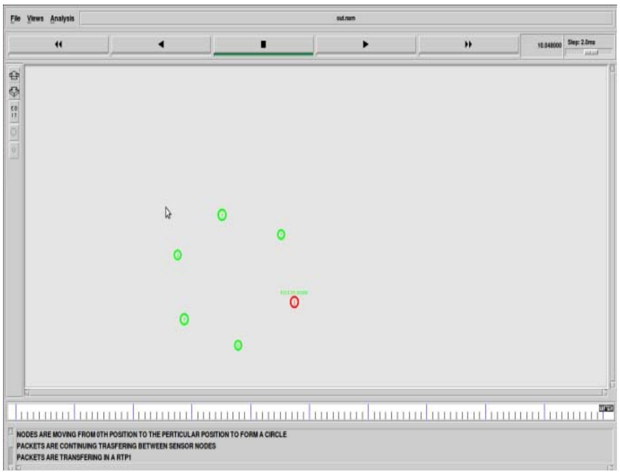

Fig. 9. Detection result of six sensor nodes

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The figure 9 shows the circular topology formed with six sensor nodes. Here after the execution of detection method, sensor node number 1 is found as faulty and it is indicated by red color.

B. Simulation results of thirty sensor nodes network

The figure 10 shows the transmission between sensor nodes of a round trip path. This round trip path here is formed by taking node 22, 23 and 29. The sensor nodes involved in transmission are indicated by orange color. This is done to measure round trip delay associated with particular round trip path.

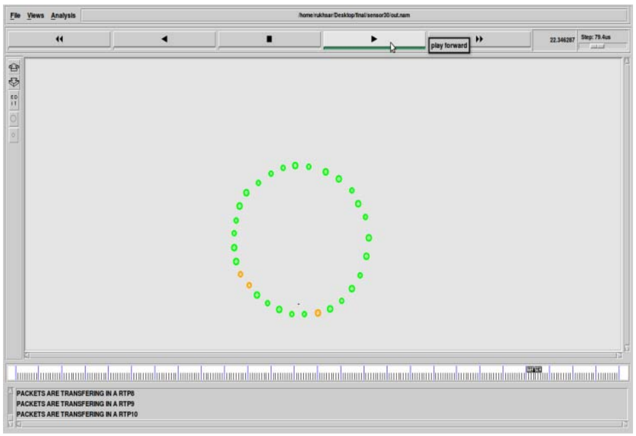

Fig.10. Illustration of packet transmission in a RTP

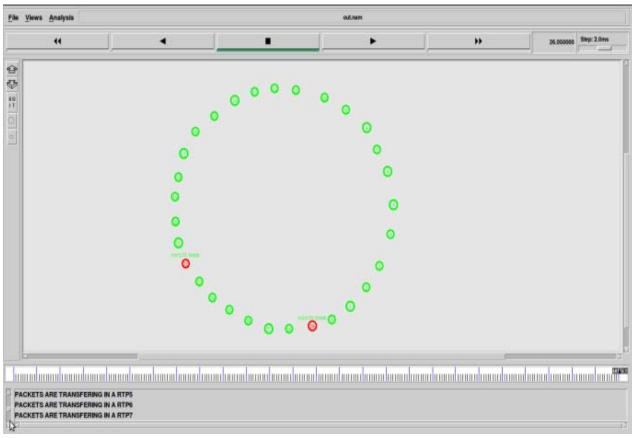

Fig. 11. Detection result of thirty sensor nodes

The figure 11 shows the circular topology formed with thirty sensor nodes. After the execution of detection method, sensor node number 22 and 29 are found as faulty and they are indicated.

C. Performance graphs of six sensor nodes network

There is no data transmission from time 0 to some time units therefore throughput for this time duration is zero. As the transmision starts the throughput is increasing linearly with time as shown in above figure 12.

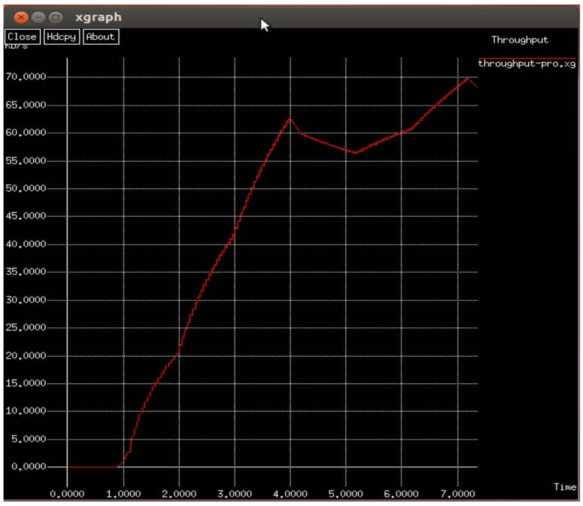

Fig. 12. Throughput graph of network with six sensor node

The figure 13 shows the plot of time versus packet delivery ratio.

PDR=∑ number of packet received /∑ number of packets sent

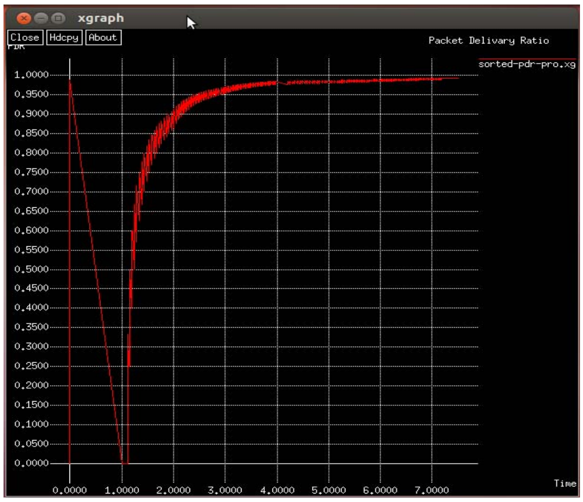

Fig. 13. PDR graph of network of with six sensor node

The packet delivery ratio is measured before the sensor nodes get failed, therefore after initiation of transimssion of packets the packet delivery ratio is increased linearly with time and becomes constant.

D. Performance graphs of thirty sensor nodes network

There is no data transmission from time 0 to some time units, therefore throughput for this time duration is zero. As the transmision starts the throughput is increasing linearly with time as shown in figure 14.

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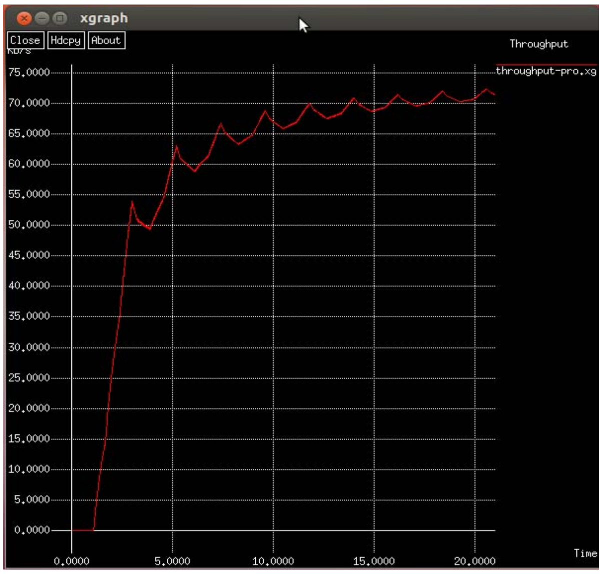

Fig. 14. Throughput graph of network with thirty sensor node

The figure 15 shows the plot of time versus packet delivery ratio.

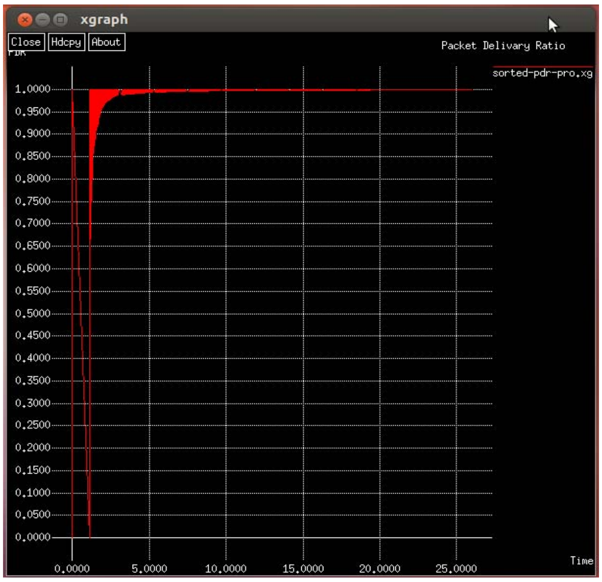

Fig. 15. PDR graph of network with thirty sensor node

The packet delivery ratio is measured before the sensor nodes get failed, therefore after initiation of transimssin of packets the packet delivery ratio is incresed linearly with time and becomes constant.

VI. Conclusion

In this paper, round trip delay, round trip path based failure detection algorithm is proposed. The proposed detection algorithm is successfully implemented and tested in NS2 software. To detect faulty sensor node only the comparison of RTD time of discrete RTPs is sufficient. Scalability of the detection method is verified by implementing it to various wireless environments with different number of sensor nodes.

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