Automatic sensor node failure detection in WSNs for Patient monitoring system

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***Abstract-*Rapid growth of wireless infrastructure in following years will allow a range of new medical applications that will significantly improve the quality of health care. WSNs playing a vital role in various fields such as surveillance, Home security and safety system. In our paper we are using WSNs in the field of medicine for effective monitoring of patient round the clock. There is a possibility if a node gets failed, which will degrade the lifetime and QOS of the node. In our proposed method we encounter the detection of faulty node by means of comparing RTD with predefined threshold value. In our paper, the detection of faulty node in patient monitoring is done with zigbee technology and PIC microcontroller. For the better scalability, our proposal is stimulated by using NS2 software. The similarity between the hardware and stimulation proves that our proposal is quite applicable for patient monitoring.**

Keywords: Faulty sensor nodes, Quality of Service (QOS), Round Trip Delay (RTP), WSNs, Zigbee.

I.INTRODUCTION

The increasing size of the aging population, nursing staff shortages, and decreasing hospital capacities suggest that the current level of patient care may decrease in the future [1]. Furthermore, lack of resources and communication infrastructure can also prevent care givers from saving lives in disaster response scenarios in which hospitals, emergency departments are overloaded with critical patient. In response to these challenges, we have assembled an interdisciplinary team of researchers and practitioners to develop a Wireless Sensor Network (WSN) with the goal of automating the patient monitoring process

patients physiological parameters is measured in hospitals using Wireless sensor networks[11],[12].Now in patient monitoring system Bluetooth is used with less number of nodes to monitor the patients in hospitals[2].In our proposed method the patient monitoring system with Bluetooth is replaced with zigbee for long distance coverage.

Even though these techniques are possible for patient monitoring, it will be hazardous if a node gets failed[8]. The sensor node in the WSNs can become faulty due to various reasons such as battery failure, environmental effects, hardware or software malfunctions[3],[4]. In existing methods the faulty sensor node is identified by comparing between the neighboring nodes using cluster head failure recovery algorithm which has data loss problem[7]. To overcome the Data loss problem, path redundancy technique was suggested but the energy consumption is more and also it reduces the speed of the process. [5]

The proposed method of fault detection is based on RTD time measurement of RTPs. RTD times of discrete RTPs are compared with threshold time to determine failed or malfunctioning sensor node

II.LITERATURE SURVEY

The patient monitoring system described in[2] monitors the physiological signals using Bluetooth and the sensed output is displayed at the receiver in WSNs. The approach presented in[5]describes identification of Faulty sensor node using RTP in circular topology.

III-ROUND TRIP PATH AND DELAY ANALYSIS:

For the detection of the faulty sensor node in the automatic patient monitoring the estimation of the round trip paths and round trip delays are very important.

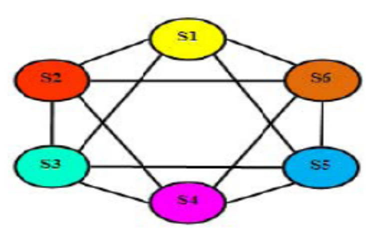


Fig.1 Mesh topology WSN with six sensor nodes.

The RTD is estimated for every different RTP in the WSNs network .by comparing the time taken for the RTD in RTP with the threshold value. The node gets failure when the RTD is higher or infinity than threshold value.

A.ESTIMATION OF RTD TIME

RTD time mainly depends upon the numbers of sensor node present in the round trip path and the distance between them. Proposed fault detection technique accuracy can be increased by reducing the RTD time of RTP[9]. It can be decreased only by reducing the sensor nodes in RTP because the distance between sensor nodes in WSNs is determined by particular applications and can't be decided. Selecting minimum numbers of sensor nodes in the RTP will reduce the RTD time. The round trip path (RTP) in WSNs is formed by grouping minimum three sensor nodes Hence the minimum round trip delay time (τ_{RTD}) of RTP with three sensor node is given by

$$\tau_{RTD} = \tau_1 + \tau_2 + \tau_3 ----------(1)$$

Where τ_1, τ_2 and τ_3 are the delays for sensor node pairs (1, 2), (2, 3) and (3, 1) respectively [14]. Circular topology with six sensor nodes is shown in Fig. 1. Three consecutive sensor nodes in each RTP are almost at equidistance because of circular topology. As a result sensor node pair delays τ_1, τ_2 and τ_3 will be equal. Let 'τ ' be the uniform time delay for all sensor node pairs in RTPs i.e. $\tau_1 = \tau_2 = \tau_3$, Round trip delay time for RTP with uniform sensor node pair delay is obtained by referring equation (1) as

$$\tau_{RTD} = 3\tau ---------(2)$$

This is the minimum RTD time of an RTP in WSNs. It is determined by the sensor node pair delay(τ), which is decided by particular application of WSNs, as it depends upon the Distance between the sensor nodes. Hence the efficiency of proposed method can be improved only by reducing the RTPs in WSNs.

B. Evaluation of Round Trip Paths

Faulty sensor node is detected by comparing the specific RTPs to which it belongs. More numbers of sensor nodes in the round path will reduce the RTPs created. But due to this individual sensor node will be present in more RTPs. While detecting faults, comparisons of all such RTPs become necessary. This will delay the fault detection process[15]. The numbers of RTPs formed with 'm' sensor nodes is given by

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

Where P is the numbers of RTPs. Analysis time of fault detection method is the time required to measure the RTD times of all RTPs in the WSNs. It is the addition of all RTD times. The equation for analysis time with P numbers of RTPs is given by

$$\tau_{ANL} = \tau_{RTD-1} + \tau_{RTD-2} + ... + \tau_{RTD-p} -----(4)$$

$$\tau_{ANL} = \sum_{i}^{p} \tau_{RTD-i} ---------(5)$$

RTD time of RTP will increase for additional numbers of sensor nodes. Referring (2), optimum value of RTD time of RTP is obtained by considering only three sensor nodes. All the RTPs in WSNs are formed by selecting only three sensor nodes (m = 3). Then the round trip delay for all RTPs is approximately same.

$$\tau_{RTD} = \tau_{RTD-1} = \tau_{RTD-2} = ... = \tau_{RTD-p} ---(6)$$

Equation (5) can be written with the equal RTD time as

$$\tau_{ANL} = P * \tau_{RTD} ----------(7)$$

Referring (2), analysis time can be written in terms of sensor node pair delay is as

$$\tau_{ANL} = P * 3\tau ----------(8)$$

Minimum numbers of sensor nodes used to form RTP will create substantial numbers of RTPs. The maximum possible round trip paths P*M,* created by three sensor nodes per RTP are obtained by substituting m = 3 in (3) and is given by

$$P_M = N(N-3) -----------(9)$$

Analysis time $\tau_{ANL}(M)$, to detect the faulty sensor node using maximum RTPs is obtained by referring (8) and (9) as follows

$$\tau_{ANL} = N(N-3) * 3\tau --------(10)$$

The fault detection analysis time will increase exponentially with increase in numbers of sensor nodes N in WSNs. Also the maximum numbers of RTPs produced are not required for comparison to detect the fault[13]. Such selection of RTPs is not an adequate solution to speed up fault detection. Hence optimization of RTPs in WSNs is essential to speed up the fault detection.

IV-ALGORITHM TO DETECT THE FAULTY SENSOR NODE:

This algorithm which is used to detect the working and non working sensor node in the patient monitoring system .this algorithm which consists of two phase. The first phase which is used to detect the threshold value of the RTD and the detection of the faulty node is the second phase.

In the first phase the all the node which is considered as the working node in the WSNs .in this the discrete RTPs are selected by increasing the source node value by three for this selected nodes the respective RTD time is calculated .the higher value of the RTD of the RTP is considered as the threshold value for all discrete RTPs in WSNs.

In the second phase is to determine the faulty node. The RTD time of the discrete RTP is compared with the threshold when the RTD is found to be greater than the threshold the RTP is said to be the faulty nodes path.

The particular RTP is analyzed in the three stages to locate the exact position of the faulty node. Let considered the source node S_X of the particular RTP with the sequence of the sensor node as S_X-S_{X+1}-S_{X+2}.the faulty node which is located in S_X or S_{X+1} or S_{X+3} in the RTP, from this faulty node as to be detected.

When the second node and third node have to be examine to locate the faulty node sequence as S_{X+1}-S_{X+2}-S_{X+3} and as S_{X+2}-S_{X+3}-S_{X+4} respectively the faulty node is determined from this sequence this RTPs are compared to detect the faulty sensor node. This is either failed or malfunction with the corresponding threshold value of that RTPs respectively.

ALGORITHM Discrete RTPs Analysis for detecting Fault in WSNs

1. Select any sensor node S_X from WSN with N Sensor node

   The values of X=1, 2, 3….N ($S_1 \le S_X \le S_N$).

2. RTP_X formed has sensor sequence as

   $S_X - S_{X+1} - S_{X+2}$

3. Call subroutine "RTD Time".

   RTD Time Subroutine

   3(a). If S_{X+1}=S_N then replace S_{X+2} by S_1
   Else if S_{X+1}>S_N then replace S_{X+1} by S_1 and S_{X+2} by S_2 respectively.

   3(b). Measure the round trip delay time of Corresponding RTP. Initially it is RTP_X.

   3(c). Return to main program.

4. If $\tau_{RTD\_X} = \tau_{THR}$ then increment S_X by 3

   ($S_X = S_{X+3}$)

   If $S_{X+3} > S_N$ then reset S_{X+3} to S_N and Go to step 2

   Else go to step 2

   Else call subroutine "RTD Time". Measure RTD time Of RTP_(X+1) having sequence as

   $S_{X+1} - S_{X+2} - S_{X+3.}$

5. If $\tau_{RTD\_(X+1)} = \tau_{THR}$ then go to step 7

   Else if $\tau_{RTD\_X} = \infty$ then S_X node is failed (dead)

   Otherwise S_X node is malfunctioning.

6. Go to step 4.

7. Call subroutine "RTD Time". Measure RTD time Of RTD_(X+2) having sequence as

   $S_{X+2} - S_{X+3} - S_{X+4.}$

8. If $\tau_{RTD\_(X+2)} = \tau_{THR}$ then go to step 10

   Else if $\tau_{RTD\_(X+1)} = \infty$ then S_{X+1} node is Failed (dead)

   Otherwise S_{X+1} node is malfunctioning

9. Go to step 4.

10. If $\tau_{RTD\_(X+2)} = \infty$ then S_{X+2} node is Failed (dead)

    Otherwise S_{X+2} node is malfunctioning

11. If $S_{X+2} > S_N$ then go to step 4.

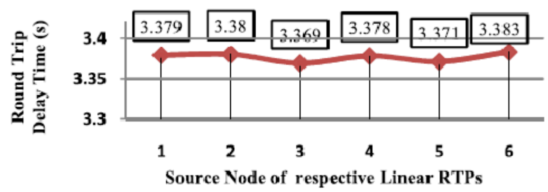
12. Stop.

V- EXPERIMENTAL ANALYSIS

1. Hardware implementation.

The wireless sensor nodes are designed by using the PIC16F877A microcontroller and the Zigbee wireless module is used. the implementation of the hardware is done with the six sensor nodes are shown in Fig 2 .NS2 is the software is used for stimulation .the round trip path is assigned for source and the destination addresses. The sensor node such as the heat sensor, pulse sensor, ECG sensor is placed in 1 foot distance in WSNs in a circular topology.

Fig.2 WSNs implemented in hardware with six sensor nodes.



FFig. 3 RTD time of Linear RTPs in WSNs.

NS2 is used to stimulate the whole network in the patient monitoring system. The baud rate of the zigbee is set as the 9600bps and 12 MHz crystal is used for PIC16F877A.

2. Detection Of RTD Threshold :

Initially all sensor nodes in WSNs are assumed as non faulty (working). WSNs are simulated in real time to determine the RTD time of all linear RTP. Referring the numbers of linear RTPs for WSNs with six sensor nodes are equal to six.

The RTD time simulation results for six linear RTPs are shpwn in Fig 3. RTD time depends upon various factors of WSNs, sometime due to improper selection of threshold value normal working sensor node can be detected as faulty. Appropriate selection of threshold RTD time is essential to detect the correct faulty sensor node in WSNs. For this reason the highest value of RTD time is selected as threshold value.

The highest RTD time is almost 3.4s. Threshold RTD time value of linear RTPs is 3.4s. It is used to detect the failed or malfunctioning faulty sensor node. The threshold time detection can be done by using only discrete RTPs in the network. Numbers of discrete RTPs obtained.

For WSNs with six sensor nodes are two. Simulation results of RTD time for two discrete RTPs are shown in Fig 4. Highest RTD time is almost equal to 3.4s. The threshold RTD time can be determined by using discrete RTPs. In this method few RTPs are sufficient to obtain the required result, thereby reducing the overall analysis time.

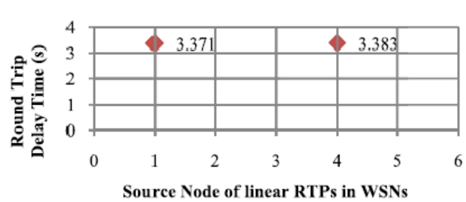


Fig 4.RTD time of discrete RTPs in WSNs

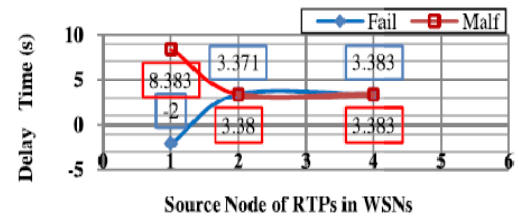


Fig.5 RTD time results of discrete RTPs for faulty sensor node S1

3. Results of Faulty Sensor Node

To test and verify the suggested method, one sensor nod in the implemented WSNs is made faulty. Experiments are performed for three cases of faulty sensor node at different locations in RTP. The complete network is then simulated in real time to measure the RTD time of RTPs. Real time simulation results for failed as well as malfunctioning sensor nodes of three cases are illustrated simultaneously in the following figures. Hence the RTD time results in case of failed and malfunctioning sensor nodes are shown by blue and red line respectively. The fault detection procedure described in algorithm is used to locate the faulty sensor node. While performing the experiment for failed (dead) state detection, one sensor node is made faulty by switching off its power supply. Infinity (∞) value of RTD time in simulation is indicated by '–2' value in all cases. For detecting malfunctioning state, a delay of 5s is added to the RTP of particular sensor node in WSNs.

1) Experiment (1): The Sensor Node S1 is Made Faulty:

S_1 is the source node of first discrete RTP i.e. RTP_1. Real time simulation results in this case are shown in Fig 5.RTD time for RTP_4 less than threshold value confirms that sensor nodes S_4, S_5 and S_6 are working properly. RTD time of RTP_1 indicates that S_6 is faulty. Infinity value of this result concludes that S_1 is failed, while higher value confirms the malfunctioning of S_1. Thus fault present at source node is detected by discrete plus one RTPs analysis.

2) Experiment (2): The Sensor Node S2 is Made Faulty:

The position of S_2 in RTP_1 is equivalent to S_{X+1} as explained in the algorithm. The total numbers of RTPs required to detect the fault at location other than source node in RTP are four. Real time simulation results of discrete plus two additional RTPs are presented in Fig 6. Less RTD time of RTP-4 confirms that S_4, S_5 and S_6 sensor nodes are working properly. Higher RTD time results of RTPs_1, 2 and less RTD time of RTP_3 indicates that S1 is faulty. Infinity time of RTPs_1 and 2 validate S_2 as failed and higher value confirms thermal functioning respectively.

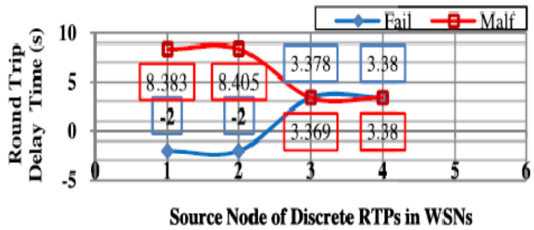


Fig. 6 RTD time results of discrete RTPs for faulty sensor node S2.

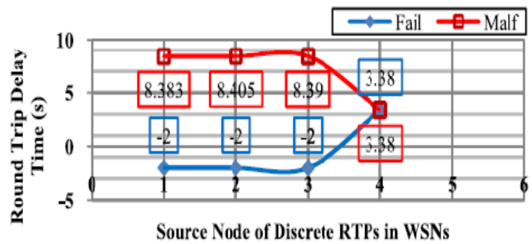


Fig.7 RTD time results of discrete RTPs for faulty sensor node S3.

3) Experiment (3): The Sensor Node S3 is Made Faulty:

The position of S_3 in RTP_1 is equivalent to S_{X+2}. In this case the numbers of RTPs required for fault detection are four obtained. Real Time stimulation results are presented in Fig 7.Less RTD time of RTP-4 confirms that S_4, S_5 and S_6 sensor nodes are working properly. RTD time results of RTPs_1, 2 and 3 are higher than threshold value. By comparing these RTPs we have found that S3 is common to them indicating that S3 is faulty. Infinity time of RTPs_1, 2 and 3 validate S_3 as failed and higher value confirms the malfunctioning respectively.

VI.CONCLUSION AND FUTURE WORKS :

Detection of the faulty sensor in the node placed in the WSNs has been encountered using the discrete RTD method by comparing with the threshold value. As the detection of the faulty sensor leads to the standardized increase in the quality of service and simultaneously the scalability is also increased .as the result by implementing of this system in real time can give a helping hand to monitor the patient round the clock.The proposed system can be enhanced better by replacing the zigbee module to the GSM so the chief can continuously monitor the patient globally so the rural people can also benefited with best quality of medical service.

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