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Design and Implementation of detecting the failure of sensor node based on RTT time and RTPs in WSNs

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Abstract

Wireless Sensor Networks (WSNs) are widely used in various applications. The efficient and accurate design of WSNs to increase the quality of service (QoS) has become an important area of research. Implementing such networks requires deployment of the large numbers of portable sensor nodes in the field. The QoS of such network is affected by lifetime and failure of sensor node. The main function of wireless sensor networks is to gather data from the monitoring area. The collected data might be wrong due to fault nodes hence detecting failure nodes are important to improve the QoS. The objective is to reduce detection time by considering less number of nodes in round trip paths construction because the number of nodes (N) in WSN increases detection time increases exponentially and the maximum numbers of round trip paths produced are not adequate method to speed up detection time. The round trip transmission (RTT) time of discrete round trip paths (RTPs) are compared with threshold value and result shown by simulating the circular topology of WSNs.

Keywords: *Wireless Sensor Networks, Round Trip Transmission time, Round Trip Paths.*

1. Introduction

Wireless sensor network (WSN) consists of low-cost, low-power, and energy-constrained sensors. These are deployed randomly in the field based on the requirement of specific applications. The purpose is to sense, collect and process information from all nodes then sending this information for analysis. If the deployed node or nodes in the field becomes faulty then the processed value is not appropriate for analysis and this may degrade the quality of service (QoS) of the entire WSN. Manually checking of fault nodes is also difficult, hence detecting the fault node becomes an important issue in WSNs. In the WSNs the node or nodes can become faulty because of various reasons such as environmental effects, battery failure, hardware failure or software failure. By discarding the data from such faulty node or nodes in the analysis the good QoS is achieved [3], [4]. WSNs are gaining more popularity by providing potentially low cost solutions to various real world challenges [5].

Detection of faults in WSNs is important because node failures degrade performance of WSNs. There are two types of node faults first one is function faults, function faults are crash of nodes, packet loss, routing failure or network partition are falls in to this category and second is data faults, data faults are those behaves normally except for sensing results.

The different detecting node failure approaches in WSNs are centralized, distributed, and clustering [6].The discrete clustering approach is used to detect the faulty node. Detection of fault is based on observing the discrete RTPs for their RTD time. Few RTPs are analyzed during fault detection therefore involvement of sensor node finding the fault is rare. This will improve the lifetime and QoS of WSNs.

The proposed method of detecting fault node is based on RTT time measurement of RTPs. RTT times of discrete RTPs are compared with threshold value to determine failed node behavior by simulating circular topology WSNs with RTT protocol in open source software NS2.

The paper is organized as follows. In Section 2, literature survey is explained. In Section 3, round trip transmission time and round trip paths concepts are described. In Section 4, proposed method and its realization is explained. In Section 5, design methodology is described. In Section 6, simulation results are presented. Conclusion and future work is stated in section 7.

2. Literature Survey

Nodes in the WSN are prone to failure; these failure nodes will degrade the QoS of the entire network. To improve the QoS, need to have complete knowledge about detecting the node fault methods due to the following reasons [7], [8]. More importance should be given to some high security application like identifying fault node, monitoring of nuclear reactor. The sensor node fails because of deployment of low-cost sensors in uncontrollable environment so failure of nodes occurs more frequently. Energy depletion is another major problem faced in sensor nodes since they are battery-powered with limited energy that causes failure. Due to dynamic changes of networks failure of links will cause sensor node to fail permanently or temporarily. Congestion occurs in sensor network due to overload and traffic that results in packet loss and node failure. Due to hardware failure during fabrication process sensor node becomes faulty. Failure of nodes cannot be examined manually to determine the proper functioning of nodes. Ref. [7] detects the faulty node by using neighbor-data analysis method. In which node trust's degree is calculated. But the algorithm proposed is weak and not accurate. Ref. [8] uses time delay based direction of arrival (DOA) estimation and confidence factor to detect faulty sensor node.

The sensor node failure or malfunctioning detection in [9] is achieved with the help of confidence factors of round trip paths in WSN. The confidence factor of round trip path is computed with the help of threshold and instantaneous round trip delay time. Confidence factors of all round trip paths are stored in lookup table. Then by analyzing the status of confidence factor of all paths in the look-up table, failed or malfunctioning sensor node is detected easily.

The Distributed Fault detection algorithm [10] is used to detect the failure nodes by comparing the result of the sensing information with the neighboring nodes to enhance the accuracy of diagnosis. It works well for the identification permanent of node faults. Some faults in communication and sensor reading may happen which can be tolerated to some extend by using time redundancy. To reduce the delay in time redundancy the interval in the sliding window is increased. Sensor nodes that are permanently failed in the network are identified with high accuracy. This algorithm works well for permanent failure of nodes.

3. RTT time and RTPs

3.1 RTT time

Round trip transmission (RTT) is the time required for a signal to travel from a specific source node through a path consisting series of other nodes and back again. The RTT time for the path consisting of three sensor nodes i.e. sensor node1, sensor node 2 and sensor node 3 in the fig.1 is expressed as

$$\tau_{RTT} = \tau(1, 2) + \tau(2, 3) + \tau(3, 1)$$

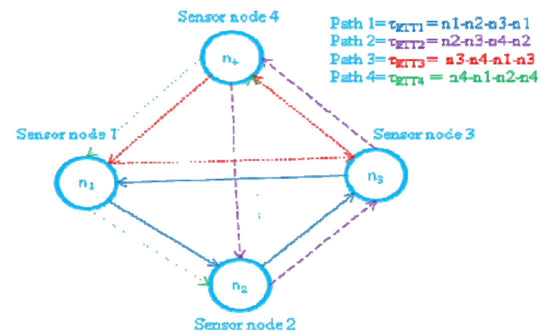

Fig.1. WSN with four nodes.

3.2 RTPs

Round trip path (RTP) in WSN will be formed with at least three sensor nodes including the source node. The number of sensor nodes in the path can be increased to maximum as N-1.The range of sensor nodes in round trip path can be [9] expressed as

$$3 \leq m \leq (N-1)$$

N' is the total number of sensor nodes present in WSN and 'm' is the number of sensor nodes present in the round trip path.

The maximum number of RTPs (P_M) in WSN having N nodes can be calculated by using the equation

$$P_M = N\ (N - m)$$

The number of possible round trip paths for the network with four nodes is shown in Fig.1.

4. Proposed Method

4.1 Existing System

In the existing method detecting sensor node failure by comparing the RTT time of RTPs with threshold value.
(a) If the RTT time of RTP is infinity then sensor node failure is detected
(b) If the RTT time of RTP is greater than the threshold value then the sensor node malfunctioning is detected

Disadvantages:
(1) Redundancy increases the energy consumption and

reduces the number of correct responses
(2) Excessive redundant paths will slow down the fault detection process

4.2 Proposed System

The proposed method is the "Detecting the failure of sensor node based on RTT time of discrete Paths in WSNs". Selecting the minimum number of nodes in formation of RTPs will reduce RTT time and Select discrete RTPs and compare them for quick fault detection.

Advantages:
(1) To maintain the better QoS under failure conditions, identifying and detaching such faults are essential
(2) Necessity of received signal strength measurement in cluster head variation and assigning separate wavelength for each link in other fault detection techniques are overcome here

For the proposed system WSN with six nodes (N=6) and RTPs are shown in Fig.2. Also the linear RTPs and discrete RTPs are shown in Fig.3.

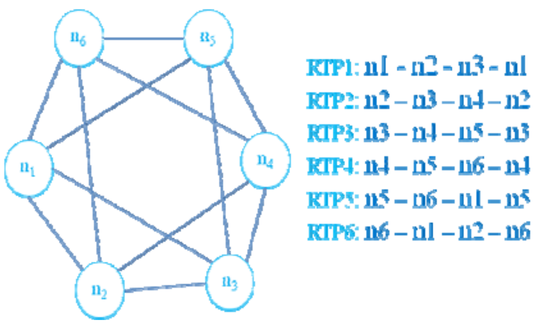

Fig.2. WSN with six nodes and its RTPs.

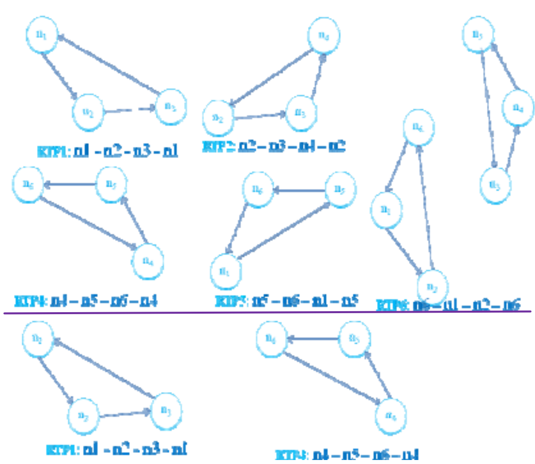

Fig.3. Linear and Discrete RTPs.

5. Design Methodology

The Design for the proposed method consists of two parts, first part is the measurement of RTT time and second part is the analysis of RTPs, to test the faulty node behavior [1].

5.1 Measurement of RTT time of RTPs

RTT in WSN with four nodes is calculated as

$$\tau_{RTT} = \tau(1, 2) + \tau(2, 3) + \tau(3, 1)$$

The RTP in WSN is formed by grouping minimum three nodes hence minimum RTT time (τ_{RTT}) of RTP with three nodes is given by

$$\tau_{RTT} = \tau_1 + \tau_2 + \tau_3 \quad (1)$$

Where τ_1, τ_2, τ_3 are the delays of sensor node pairs (1, 2), (2, 3) and (3, 1).

$$\tau_{RTT} = 3\tau \quad (2)$$

Nodes in RTP of circular topology are almost at equidistance so delays are equal, $\tau = \tau_1 = \tau_2 = \tau_3$, hence efficiency improved only by reducing the RTPs by considering m=3 in construction of RTPs in WSN. While construction of RTPs, if consideration of m value more than three then RTPs will reduce but chance of participation of one node in more than one RTP is more. It takes more time to analyze all nodes of RTP and takes more time to identify fault node. Because of this need to choose m value minimum for obtaining optimum value of RTT time [2]. The algorithm used for measurement of RTT time of RTPs is shown in Fig.4.

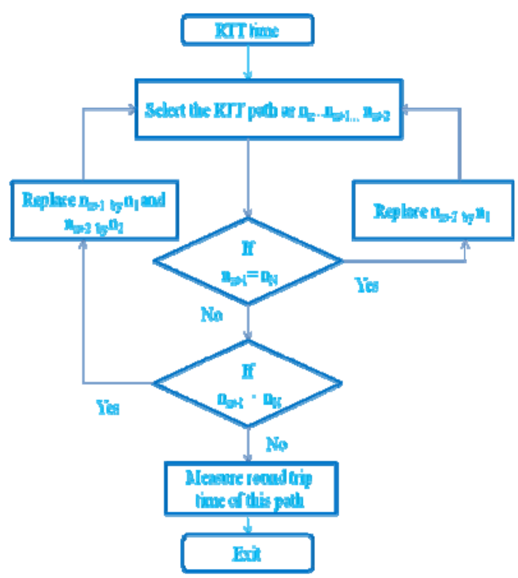

Fig.4. Algorithm for measurement of RTT time of RTPs

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5.2 Analysis of RTPs

The number of RTPs (P) formed with m nodes given by the equation

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

Analysis time is the measurement of RTT time of all RTPs i.e. addition of all RTT times, the equation with P is given by

$$\tau_{Analysis}(M) = \tau_{RTT-1} + \tau_{RTT-2} + \dots\dots\dots\dots + \tau_{RTT-P} \quad (4)$$

$$\tau_{Analysis} = \sum_{i}^{P} \tau_{RTT-i} \quad (5)$$

Referring to (2)(i.e.$\tau_{RTT} = \tau_{RTT-1} = \tau_{RTT-2} = \dots\dots\dots\dots = \tau_{RTT-P}$) Equation (5) can be written with equal RTT time as

$$\tau_{Analysis} = P * \tau_{RTT} \quad (6)$$

Referring to (2) $\tau_{Analysis}$ written in terms of sensor node pairs delay as

$$\tau_{Analysis} = P * 3\tau \quad (7)$$

The maximum number of possible RTPs (P_M) created by three nodes per RTP, are obtained by substituting m=3 in (3) given by the equation

$$P_M = N(N - 3) \quad (8)$$

Analysis time $\tau_{Analysis}$ (M), to detect fault node using RTPs is obtained by referring (7) and (8) as

$$\tau_{Analysis}(M) = N(N - 3) * 3\tau \quad (9)$$

Analysis time $\tau_{Analysis}$ (M), increases exponentially with increase of N in WSN and RTPs produced are not required for comparison to detect faults. Hence need to select discrete RTPs for comparison. The discrete RTPs are calculated for the WSN with variable number of sensor nodes (N) and shown in the Table 1.

Table 1: comparison of maximum and discrete RTPs

RTPs	Number of sensor nodes (N) in WSNs						
	4	6	10	20	30	40	50
P_M=N(N-3)	4	18	70	340	810	1480	2350
P_D=P_i+3	1	2	4	7	10	14	17

The discrete RTPs shown in Fig.3 are selected from sequential linear RTPs using algorithm is shown in Fig.5 and the RTT time of these selected RTPs are compared with threshold value to detect fault node is shown in Fig.6.

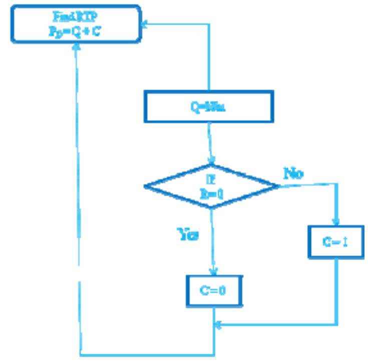

Fig.5. Algorithm for calculating discrete RTPs.

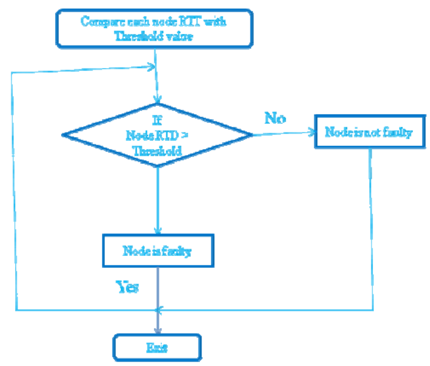

Fig.6. Algorithm for comparing discrete RTPs with threshold value.

6. Simulation Result

The tcl file named sensor.tcl is simulated for measurement of RTT time and evaluation of RTPs to test the faulty sensor node behavior. The algorithm is used to measure the RTT time of RTPs and detect faulty nodes using discrete RTPs. Faulty sensor node can be either failed or malfunctioning hence two cases evaluated separately. In case of failed node detection is done by declaring particular node as dead in tcl file and in case of malfunctioning node, the node is detected by adding certain delay in the RTPs of particular sensor node.

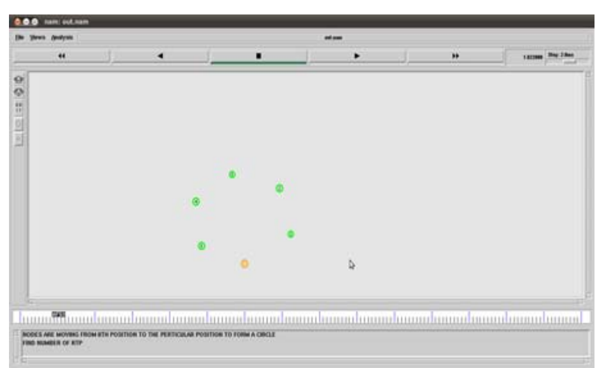

Fig.7. Simulated circular topology WSN in NS2 with six nodes.

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Table 2: RTT time of RTPs

Sl No	RTPs	Node sequence in RTP	RTT Time
1	RTP_1	n1 – n2 – n3 – n1	0.000987854
2	RTP_2	n2 – n3 – n4 – n2	0.116327
3	RTP_3	n3 – n4 – n5 – n3	0.000803481
4	RTP_4	n4 – n5 – n6 – n4	0.000507795
5	RTP_5	n5 – n6 – n1 – n5	0.00134349
6	RTP_6	n6 – n1 – n2 – n6	0.00116345

The RTT time of maximum RTPs are shown in the Table2. The round trip paths RTP1 and RTP4 are selected as discrete RTPs using the algorithm then RTT time of RTP1and RTP2 are compared with threshold value. The RTT time of RTP1 is greater than threshold value, hence sensor node one is detected as fault node. The same result is shown in Fig.7.

Fig.7. Simulated result showing faulty sensor node.

7. Conclusions

In the proposed faulty node detection method in wireless sensor networks, discrete round trip paths are selected and compared with threshold value to identify sensor node behavior. The simple algorithm is used to detect effectively and it enhances fault detection efficiency by selecting the discrete RTPs. Each sensor node in WSNs is rarely utilized in fault detection due to discrete selection of paths, this improves lifetime due to less energy consumption. Therefore, this method improves lifetime and quality of service of WSNs. This method is scalable to wireless sensor networks with large numbers of sensor nodes.

The proposed method is successfully implemented on circular topology WSNs with variable sensor nodes (N). Our future work includes verifying the performance of this method on other topologies in WSNs.

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