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Faulty node detection in Wireless Sensor Networks

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ABSTRACT : *Wireless sensor networks (WSN) with large numbers of portable sensor nodes has potential applications in a various fields, like battle field surveillance, home security, military purposes, medical, environmental and industrial monitoring. As the number of nodes in the network increases the probability of node failure also increases. Faulty sensor node may reduce the Quality of Service (QoS) of entire network. Identifying and detaching such faults are essential in order to maintain a better QoS under failure conditions. In the proposed method, faulty sensor node is detected by measuring the round trip delay (RTD) time of discrete round trip paths (RTP) and comparing these delays with a threshold value. By taking discrete round trip paths, the analysis time to find faulty can be greatly reduced.*

Keywords : *sensor node, round trip delay, round trip paths, WSNs.*

I. INTRODUCTION

Sensor networks are highly distributed networks of small light weight wireless nodes which are deployed in large numbers to monitor any physical or environmental parameters such as temperature, pressure, or humidity. Sensor networks are used in variety of applications that require constant monitoring and detection of certain events. One of the major reasons behind the growing popularity of wireless sensors is that they can work in remote areas without any human intervention. Data which are accessed by the sensor nodes are gathered by the users and meaningful information from them are extracted. Usually sensor applications require many sensors to be deployed together. These sensors form a network and cooperate with each other to collect the data and send it to the base station. The base station will acts as the control centre where the data from the sensors are collected for further analysis and processing. In a nutshell, a Wireless Sensor Network (WSN) can be defined as a network which consists of spatially distributed nodes called sensor nodes to monitor physical or environmental conditions [1][2]. These nodes are combined with routers and gateways to create a WSN system. As the number of nodes in a wireless sensor network increases, the node failure ratio also increases Node faults of WSNs can be divided into two broad categories: hard and soft. The “hard fault” is said to be occurred when a sensor node cannot communicate with other nodes in the network due to the failure of certain module [3]. A “soft fault” is said to be occurred when the failed nodes are ready to work and communicate with other nodes in the network, but the data sensed or transmitted may not be correct. These faulty nodes can produce erroneous data [4][5] and may collapse the entire network. Manual checking of the network to find such failed sensor nodes is troublesome. So to achieve the good quality of WSN through accuracy, reliability, effective methods should be adopted for the detection of sensor node failure or malfunctioning. The proposed method of fault detection is based on RTD time measurement of RTPs. RTD times [6][7] of discrete RTPs are compared with threshold time to determine failed or malfunctioning sensor node. Round Trip Paths (RTP) which are having a Round Trip Delay (RTD) time greater than the threshold value are considered to be faulty paths and nodes in the corresponding paths are analysed.

II. RELATED WORKS

In most of applications, the sensor nodes are deployed in harsh environments where the nodes are susceptible to damage. Also nodes may fail due to energy depletion [8] or some software or hardware malfunctioning. The failure of nodes degrades the QoS of the network by leaving some areas uncovered and may sometimes disconnect the network [9]. Losing network connectivity will impose adverse effects on the applications since it prevents data exchange and coordination among some. nodes. Effective methods should be adopted to detect such faults at the earliest. Some of the existing methods to detect the faulty nodes are :

DFD node fault detection scheme proposed by P Chen [10] determines the status of node by testing among neighbour nodes mutually. It compares the difference of data of two neighbour nodes at different time intervals. If the difference between them is greater than a particular threshold value then one among the node is considered as faulty and further analysis is performed to detect which node is faulty.

M. Asim, H. Mokhtar, and M. Merabti [11] proposed a Fault Management Architecture in which the network is partitioned into a virtual grid of cells .Each of the cell will be having a cell manager as well as a gateway node which are selected on the basis of available energy. This method works by the use of update messages. Each node will send their update message and further analysis will be performed when any node fails to send this message.

S. Guo, Z. Zhong, and T. He proposed [12] Find: faulty node detection for wireless sensor networks in which the whole area is divided into different sub areas and the faulty node is detected in three stages. Here a detected sequence and distance sequence are mapped to obtain an estimated sequence. Faulty nodes can be obtained by analysing the inconsistencies in detected and estimated sequences.

R. N. Duche and N. P. Sarwade [13] introduce a method to detect faulty node by using confidence factor and a look up table. Round Trip Delay time of paths are computed and confidence factor is set. Lookup table includes the round trip paths and the confidence factor for each path. Faulty nodes can be identified by analysing the lookup table.

The accuracy of existing method may vary with the number of nodes in the network and the analysis time can be high as the number of nodes increases.

III. PROPOSED METHOD

CF In this method the entire Wireless Sensor Network (WSN) is considered as different Round Trip Paths (RTP).Each of the paths will be having a number of sensor nodes. For any path our aim is to minimize the Round Trip Delay (RTD) time .To minimize the RTD of any path either the number of nodes in the network have to be minimized or the distance between nodes in the path should be minimized. Since nodes in a sensor network are randomly deployed distance between nodes cannot be predicted. So we are reducing the number of nodes in a network. Hence we are considering only three nodes in a network.

A. ROUND TRIP DELAY TIME

Round Trip Delay time can be defined as the time required for a signal to travel from a source node to a destination through a sequence of nodes and back again. Round Trip Delay may vary based on the nodes in the path [14] [15]. If RTD of a path is greater than a particular threshold then one among the nodes in the path is assumed to be faulty. This path can be examined further and the faulty node can be identified. For any Round Trip Path with three sensor nodes the maximum round Trip Delay time can be given as :

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

where τ_1, τ_2, τ_3 are the delays of sensor node pairs (1,2),(2,3),(3,1).Assuming uniform delay for all pairs the equation can be written as

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

This is the minimum delay time of any path in the network.

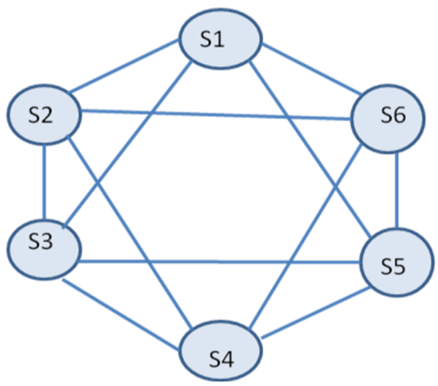

Fig 1: Topology with 6 sensor nodes

B. Evaluation Of Round Trip Paths

The total number of Round Trip Paths that can be formed with 'm' sensor nodes in a path is given by

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

where P is the total number of RTPs and N is the total number of nodes in the network. The total analysis time for a network with N sensor nodes and P number of RTPs is given by

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

$$\tau_{ANL} = \sum_i^P \tau_{RTD-i} \quad (5)$$

Considering uniform RTD for all paths, analysis time will become

$$\tau_{ANL} = P * \tau_{RTD} \quad (6)$$

Combining both equations (2) and (6) we can obtain

$$\tau_{ANL} = p * 3\tau \quad (7)$$

Maximum possible round trip paths that can be obtained by considering three sensor nodes per round trip path can be obtained by substituting m=3

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

Combining equations (7) and (8) we can obtain the analysis time to detect faulty sensor node as

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

The fault detection analysis time will vary depending on the number of RTPs that are to be analysed. Hence optimisation of the number of RTPs is essential to minimize the analysis time.

C. Round Trip Path Optimization

Analysis time can be greatly reduced if the number of round trip paths that are to be analyzed is small. Hence optimization is required to reduce the fault node detection time.

1) Linear RTP

Here the number of RTPs selected is equal to the number of nodes in the network. As it provides linear relation between number of RTP and nodes, it is called linear RTP. Figure 2 shows a linear RTPs of a network with six sensor nodes.Linear RTPs with N sensor nodes in a network can be written as

$$P = N \quad (10)$$

where P is the number of RTPs. Referring equations (7) and (10) the analysis time τ_{ANL} for linear RTPs is given by

$$\tau_{ANL}(L) = N * 3\tau \quad (11)$$

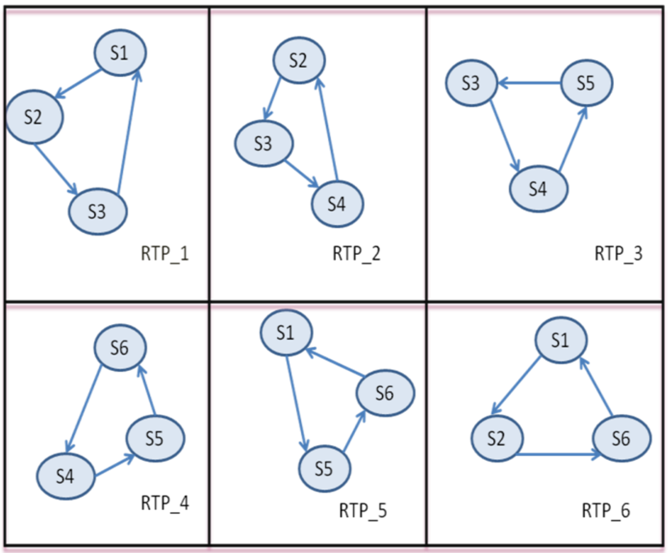

Fig 2: Linear selection of RTP

2) Discrete Selection of RTPs

No of RTPs that are to be analysed in case of Linear RTP is still large when the number of nodes in the network are very large. Hence an optimisation is required for linear RTP. In discrete selection of RTP, discrete paths are selected from sequential RTPs by eliminating two consecutive paths from linear RTP. Figure 3 explains Discrete RTPs. ie if RTP_1 is selected both RTP_2 and RTP_3 are eliminated. The discrete RTPs in WSNs can be obtained by

PD= Q + C (12)

where Q and C in above equation are expressed as below

$$Q=\lfloor N/m \rfloor \tag{13}$$

$$C=\begin{cases} 0 & if \quad R=0 \\ 1 & otherwise \end{cases} \tag{14}$$

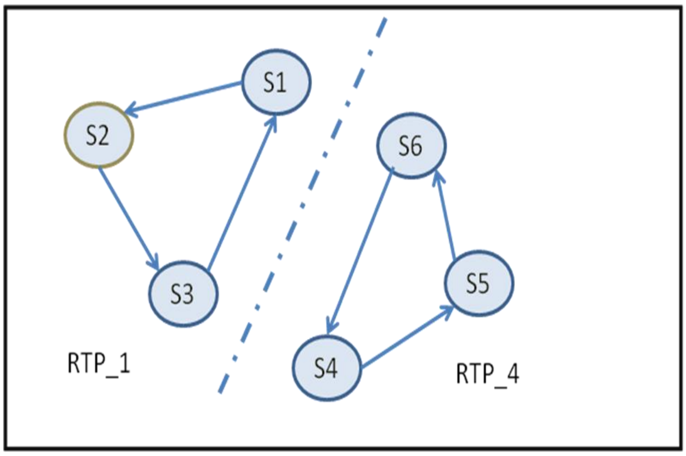

Fig 3: Discrete selection of RTP

where Q is the quotient , m is the number of nodes in the path, R is remainder, N is the number of nodes in the network. Referring equations (7) and (12) analysis time can be obtained as

$$\tau_{ANL}(D) = (Q + c) * 3\tau \tag{15}$$

With three sensor nodes in a path, analysis time can be obtained as

$$\tau_{ANL}(D) = (\lfloor N/3 \rfloor + c) * 3\tau \tag{16}$$

Selection of discrete RTPs will save the analysis time to a great extend.

D. Faulty Sensor Node Detection

The faulty node detection algorithm is executed 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 first phase execution is taken as the threshold value of RTD time for all discrete RTP's in the WSN[16][17]. Discrete RTP's are selected by incrementing the source node value by three. Flow chart of the entire method is given in figure 4.

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. The path with greater threshold is examined in three stages to locate the exact faulty node. Consider an RTP path with nodes Sx, Sx+1, Sx+2 whose RTD time is greater than the threshold value[18][19]. To detect which among the three nodes are faulty in the RTP path , consider RTP paths with nodes Sx+1,Sx+2,Sx+3 and Sx+2,Sx+3,Sx+4.The RTD time of these discrete RTP's are compared to detect the faulty node. LetRTDx,RTDx+1,RTDx+2 be the round trip delay time of discrete RTP's Sx-Sx+1-Sx+2, Sx+1-Sx+2-Sx+3 and Sx+2-Sx+3-Sx+4 respectively.

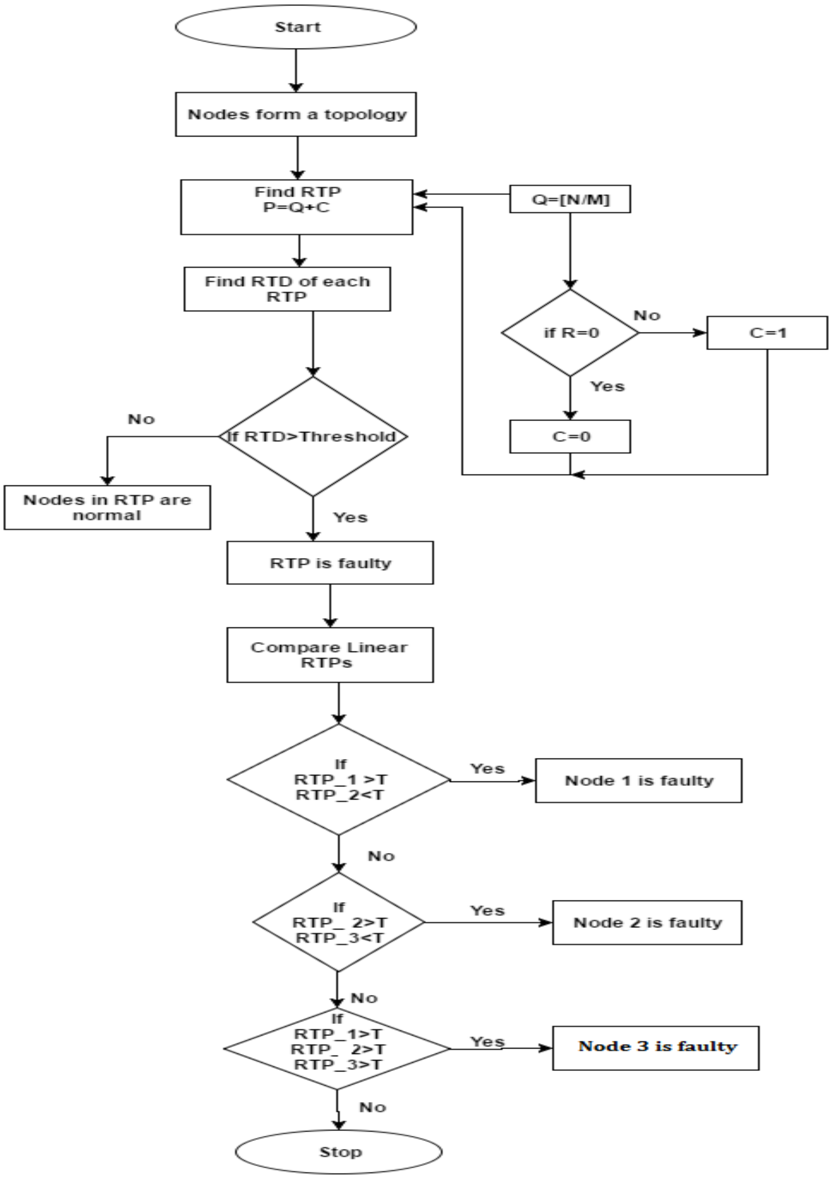

Fig 4: Flow chart for fault node Detection

If RTDx value is greater than threshold and RTDx+1 is equal to threshold then node Sx is declared as faulty. If the value of RTDx is infinity then node is declared as failed otherwise malfunctioning.
In the second stage RTDx+1 and RTDx+2 are compared provided RTDx value is greater than the threshold, if RTDx+1 is greater than threshold while that of RTDx+2 is equal to threshold value determines node Sx+1 as faulty.
In the third stage RTDx, RTDx+1,RTDx+2 are compared and if their RTD values are higher than the threshold then node Sx+2 is declared as faulty. After that Sx+2 sensor node value is compared with the value of last node SN in the WSN and if found less than SN 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.

IV. SIMULATION RESULTS

Simulation of the proposed algorithm will be performed with the help of NS-2 and the simulation results will show how the faulty sensor nodes are identified using with minimum analysis time by using Discrete Round Trip Paths (RTP) and by Round Trip Delays(RTD). These simulations will explore the accuracy of the methodology.

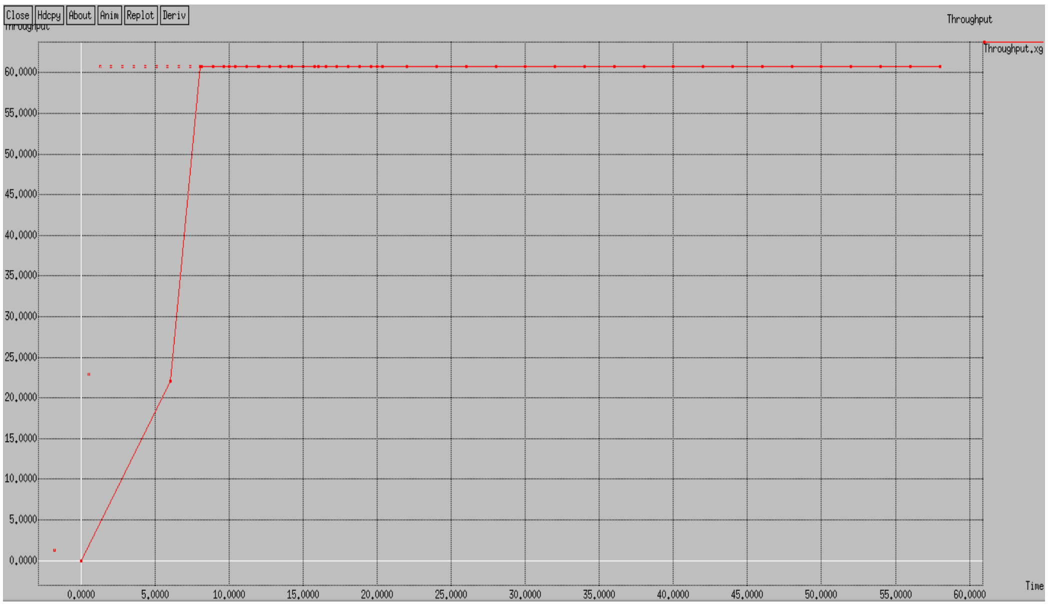

Fig 5: Throughput

Throughput can be defined as the number of packets that are delivered per unit of time to the sensor nodes ie the rate of successful message delivery over a communication channel. Figure 5 shows the throughput graph. From the graph we can analyse that the throughput of the method increases as the time goes on .Also the analysis time can be greatly reduced to a great extend since the number of paths that are to be analysed is small.

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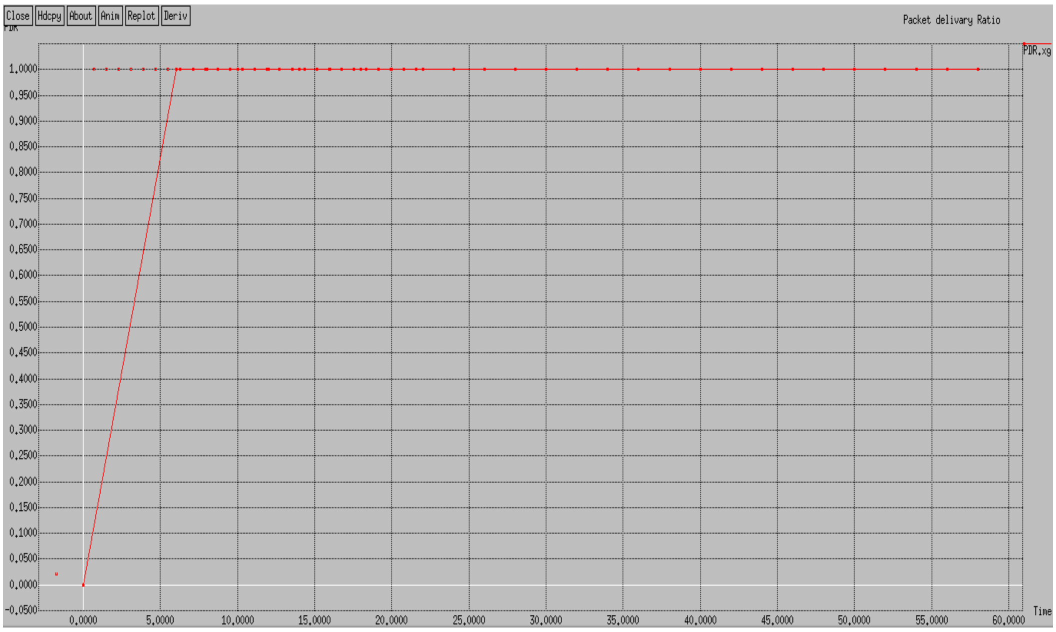

Fig 6: Packet Delivery Ratio

Packet Delivery ratio can be defined as the ratio of the number of delivered data packet to the destination ie the level of delivered data to the destination. Greater the value of packet delivery ratio means better performance of the protocol. Any faulty node in the network may results in packet loss and delay. The delay of a packet is the time it takes the packet to reach the destination after it leaves the source. This delay may results in the reduction of packet delivery ratio. From the figure it can be observed that by observing faulty node at the earliest packet delivery ratio can be increased.

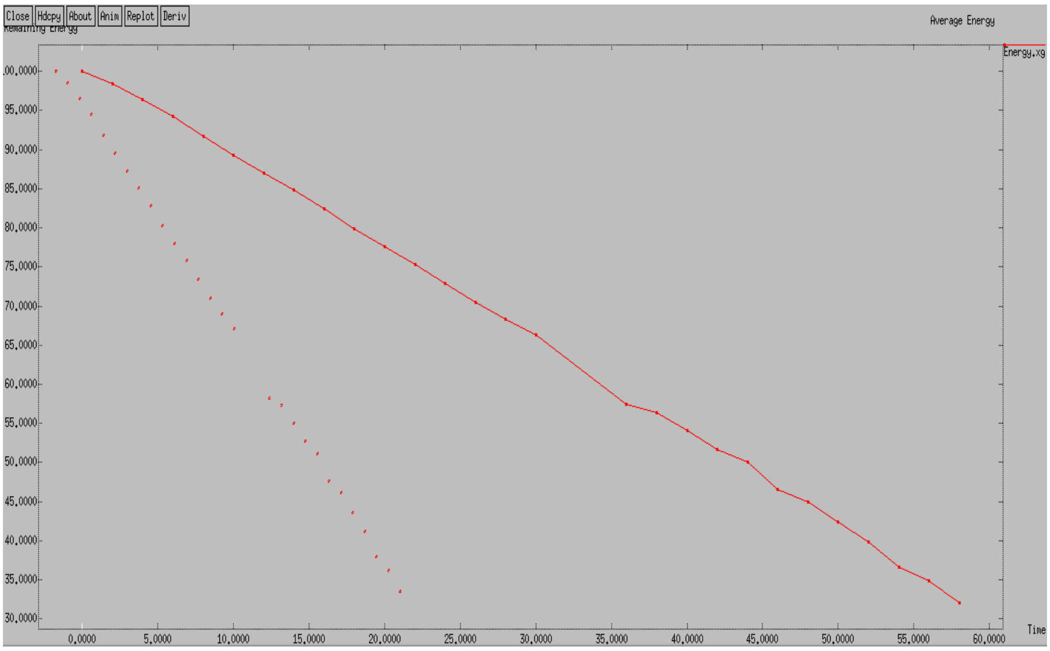

Fig 7: Energy

Faulty nodes in the network may results in packet loss or delay which may reduce the available energy. Nodes in the network are randomly deployed and usually battery powered ,so effective methods should be adopted to maintain the available energy.. In the proposed method available energy is retained maximum.

V. Conclusion

In a wireless sensor network random occurrences of faulty nodes may happen and these faults may reduce the Quality of Service of the entire network. Effective methods should be adopted to detect the faulty node at the earliest. Discrete selection of Round Trip Paths reduces the analysis time to find the faulty node to a greater extend. Round trip delay time of all RTPs is obtained and the path which is having a delay greater than the threshold is further analysed to find the faulty node. Faulty node can be then eliminated from the network which may increase the efficiency of the network.

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