Sensor Node Failure Detection using Multiway Tree based Round Trip Path in Wireless Sensor Networks

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Abstract

To upgrade the Quality of Services among the sensor node correspondence in WSN, the recognizing confirmation of sensor node range, ID of reduced sensor nodes, amounts of sensor nodes included, recognizable proof of issue nodes are the over the top testing civil argument. The main objective of this work is to identify the faulty node, its readings, detection of the malfunctioning nodes. Round Trip Path is used to evaluate the Round Trip Delay time with which the information about the sensor nodes is accomplished. In perspective of the round trek deferral time esteem, the deficiency node is diagnosed. The detection of the faulty node is determined by the previous work but the obtained path for the detection is more. In the proposed Multi way Tree based Round Trip Path (MTrTP) system, the faulty node is identified with less number of paths when compared to the existing work. In this method, the shortcoming sensor node is recognized, by measuring the RTD time of every single possible way and the results are appeared differently in relation to edge esteem. MTrTP system is had a go at using six at mega sensor nodes with Xbee Series2 ZigBee modules. By taking a gander at the distinctive results got using the RTD examination, MTrTP strategy exhibits that, it will give raised results in regards to number of RTP and investigation time. In this work, diverse gained results are plotted and the relating examinations are inspected. The plotted result of the existing work and the current work is compared. The proposed work has much more advantages when compared to existing because the number of path obtained and the analysis time for the fault node detection is less. Thus, the detection of the fault node is determined by the MTrTP algorithm. Therefore, the lifetime of the wireless sensor network, the degree of coverage and connectivity among the sensor network are increased. This work can be used for industrial automation and all WSN applications.

Keywords: Multi way Tree based Round Trip Path, Round Trip Delay Time, Round Trip Path

1. Introduction

Identification of failure of sensor nodes in the network is critical, on the grounds that blame nodes may make erroneous results and can prompt complex faults, which influences the network performance. Physical checking of sensor nodes, before the network arrangement is insufficient, additionally troublesome in light of the fact that, nodes have specific attributes, practices which influence the node rapidly amid the continuous assessment. The battery failure, programming and equipment failure, device failure can be the imperative reasons of faulty node. Consequently, location of fault gets to be basic and an extensive procedure. Foundation of an element fault recognition network is a troublesome undertaking for the network creator, as they need to consider the fault discovery time and in addition absolute vitality devoted by the node to distinguish the device fault.

In WSN, QoS components of the whole network will be extremely influenced by faulty sensor nodes. Subsequently organize life time, exactness of information transformed; unwavering quality of the network gets influenced. The distinguishing proof of the defective sensor nodes are exhibited in M. Lee et al.1 in view
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of neighbour node data and the current state of every node. Node failure and Cluster Heed failure rectification calculation A. Akbari et al.\textsuperscript{7}, utilizing path redundancy technique C–C. Song et al. and A. Mojoodi et al.\textsuperscript{3,4}, are discussed. Link failure recognition utilizing checking methodology is examined as a part of S. S. Ahuja et al. and Ravindra N. Duche et al.\textsuperscript{5,6}. Identification of fault in WSN are discussed in Myeong-Hyeon Lee et al.\textsuperscript{7}, C. Jaikeo et al.\textsuperscript{8} examined fault analysis method, in F. Koushanfar et al.\textsuperscript{9} online fault identification procedure are proposed. In L.B Ruiz et al.\textsuperscript{10} event driven based shortcoming analysis networks are exhibited. In C. Jaikeo et al.\textsuperscript{8}, utilizing its own particular sensed information; the limited shortcoming location calculation is exhibited. X. Luo et al.\textsuperscript{11} have examined event recognition with more vitality productivity for WSN. M. Yu et al.\textsuperscript{12} made a nitty gritty study about fault administration handle in WSN. In \textsuperscript{4} in light of RTD of RTP, the fault sensor node is identified. Round trip delay time of distinctive RTP are measured and contrasted with the threshold value. The limit worth is resolved and settled by the network designer in view of the aggregate time needed to structure the RTP. The essential fault of this work is to identify the quantity of fault node. The designer needs to confirm all Round Trip paths. Before distinguishing and proclaiming the faulty nodes the co-ordinator must visit all the round trip paths.

In Linear RTP, the aggregate number of path acquired is high when contrasted with the Discrete RTP network. Thus the analysis time is high for Linear RTP when contrasted and Discrete RTP.

Information exchange rate of every sensor node in the network, path of the transmission medium utilized for the correspondence, physical separation among the sensor nodes put, number of nodes included in the round trip path, aggregate number of different appeals took care of by other middle of the road nodes, vicinity of obstruction in the circuit are the regular components to influence the round trip delay time of the WSN. Consequently all the variables must be considered to assess the delay time and from the delay time value, the fault node must be recognized. In the proposed work, for fault recognition investigation, rather than all the RTP, just the distinguished paths in WSN are considered. It will build the framework proficiency of the proposed work. The proposed work, utilizing the Multi way Tree based Round Trip path (MTyTP), the aggregate number of RTDs in the fault location investigation are minimized. Thus the aggregate shortcoming analysis time is lessened and the likelihood of fault location investigation has been progressed. When the fault node has been recognized, the portable hand-off node physically replaces the defective node and the information to be sensed are prepared and conveyed by MRN to different nodes and base stations rather than the faulty node.

The principle target of the proposed work is to recognize the faulty sensor node\textsuperscript{11} and breaking down node by the estimation of round trip delay value worth. The round trip delay value is measured by computing aggregate time needed for a signal (packet) to go from a source node to other correspondence nodes and will reach back to the same source node. The aggregate round trip delay time can be figured by considering least three sensor nodes n1, n2 and n3 and communicated as TRTD = T(n1, n2) + T(n2, n3) + T(n3, n1). Pace, separation, correspondence medium, clamour level, number of nodes in the round trip path are the outside elements which influences the aggregate round trip delay time of the network.

In linear technique\textsuperscript{13}, the quantity of round trip delay time is measured in view of the quantity of sensor node in the network. PL = N. The aggregate round trip delay path in most extreme is registered utilizing the accompanying relationship RTD path = (N-m). Where, N- Total number of sensor nodes, m – Number of sensors to structure the individual RTD path. In Discrete path\textsuperscript{15}, fault identification techniques consider minimal number of RTP’s. The discrete RTP is figured utilizing the accompanying relationship PD = Q + C, where, Q = N/3, C = 0 if R = 0, 1 otherwise, Where Q – Quotient, R – Remainder, N – Number of sensor nodes, C – Correction element. Both Linear and Discrete techniques are utilized to secure the round trip path to distinguish the defective nodes among the network. Contrasted with linear RTP, discrete RTP is best in which the recognition of defective nodes are assessed with least number of RTD path. In light of the threshold value, the RTD time of discrete RTP is contrasted to identify the faulty node, if RTD time is more noteworthy than the threshold value, the RTD of specific RTP is considered.

**Linear RTP\textsuperscript{13}**: In Linear RTP, number of path acquired is same as that of the quantity of sensors conveyed. It is utilized to minimize the fault discovery determination process, instead of considering maximal numbers of sensors, just less number of nodes are sufficient. The faulty node is recognized by corresponding the three distinctive RTP. At the point when the quantity of nodes expands the relating path additionally increments. The determination
of faulty node is not ideal when the network is tremendous. The path obtained is significantly diminished. To get the ideal path discrete RTP is proposed and it’s additionally used to distinguish the defective node. **Discrete RTP** 15: In Discrete RTP, the quantity of nodes expands the path acquired declines. The path framed just from back to back linear RTPs. The path is chosen by disregarding the two consecutive paths. Indeed by utilizing this strategy the path acquired to discover the faulty node is not ideal. The network configuration is symmetric, the sensors are set at uniform separation, and limit quality is computed is accepted as equivalent. At the point when the network is asymmetric the estimation of the faulty node is not viable. To beat the deficiencies of the above methods, the network can be considered as a cluster based network. In 16 **CLUE-HOPE** method is used which isolates the system into virtual lattices in an appropriated way. To diminish the inconsistency in bunch head situations, CLUE-HOPE permits the group to modify its size by taking care of the sensors from and to the neighbour lattices. Besides, it turns the part of group head among the bunch individuals in a conveyed way, and in this way it accomplishes uniformly appropriated vitality load among sensors. This work is sorted out into 4 segments. In segment 2, the framework model of the proposed MTrTP is examined. In area 3, equipment usage of MTrTP and the got investigation results to recognize the faulty nodes are examined. This work is finished up in area 4.

2. **System Model**

The faulty node in the network is recognized in existing strategy is by utilizing Round Trip Path (RTP). The improvement of the RTP can be separated into two courses of action: 1) Linear RTP 13 and 2) Discrete RTP 15. In these two methods threshold value and the RTD time are computed and contrasted with the RTP shaped. On the off chance that the threshold value is more prominent than the RTD time the sensor node is a defective node. On the off chance that the RTD time is interminability then the node is fizzled. On the off chance that the RTD time is same as the threshold value then the node is working legitimately. The path got by gathering least of three sensor nodes, at exactly that point it structures a loop. The methodology utilized for distinguishing the faulty node in this work is cluster based network structure to be specific called as Multi way Tree Based Round Trip Path (MTrTP). In this strategy, the source nodes (Two Hop) are assembled as first group. Next interchange nodes are gathered as second group. Remaining nodes are gathered as third group. The quantity of RTP got can be figured by utilizing P (MTrTP) = m (log m N-1), Where m is the base number of sensors in RTP and N is the number sensors in the Network. In the point when the quantity of nodes builds, the path acquired is less. The location of the faulty node 14 is distinguished in less number of paths contrasted with alternate networks. The MTrTP is framed for a mesh network. In this network any node is associated with any node with direct correspondence. The specimen network embodies 10 separate nodes and comparing conceivable RTP developments utilizing MTRTP methodology are indicated as a part of Figure 1.

2.1 **M-path Tree based Round Trip Path (MTrTP)**

1. All nodes are interconnected with one another.
2. In request to discover the incorrect node in the group of nodes, this calculation clears an effective path. The idea driving this calculation has the premise of Linear RTP calculation. Considering all the nodes set of three nodes (Linear RTP) assumes an indispensable part here.

   i. Firstly, select all the first nodes from all the Linear RTP sets and perform RTP
   ii. If the computed RTP is not as much as threshold, select the second arrangement of nodes and repeat i, ii.
   iii. If not then apply direct RTP and get the linear RTP triplets
   iv. Repeat step i, ii, iii till the aggregate number of nodes in the set is three
   v. Then assess the three nodes independently for slips.

The comparative method of RTP calculations of Linear, Discrete, MTrTP is tabulated in Table 1

The quantity of path got for Linear 13, Discrete 15 and MTRTP is analysed and organized. At the point when the quantity of nodes expands the quantity of path gained in linear is equivalent to the quantity of nodes in the network. In Discrete RTP the path obtained is diminished contrasted with linear RTP. In the proposed network, the quantity of path framed is less contrasted with the other two networks. The identification of faulty node is related to minimum number of path.
2.2 Pseudo Code: MTRTP – RTP Calculations

main subroutine
- Let node be the set of address of all the nodes in the network
- Call function func (1,m,1, node)
- print the error node address
end main

function func (start_index, hop_count, previous_hop, node [])
    count = 0;
    while (count <= m-1)
        1. current = start_index + count* previous_hop;
        2. list sensors[ ];
        3. while current <= node length do
            3.1 sensor.push_back (current);
            3.2 current = current + hop;
        end loop
        4. end loop
    5. if sensor.length == 1 then
        5.1 if node [sensor[1]] is error then
            5.1.1 return node [sensor[1]]
        6. else
            6.1 measure RTD of the list sensor
            6.2 if T_{RTD} > T_THRESHOLD then
                6.2.1 return call func (current, hop*m, hop, node)
            end func

2.3 M-way based Round Trip Path

The ideal fault discovery is viably done utilizing MTrTP strategy, utilizing round trip path analysis. Contrasted with linear and discrete, MTrTP strategy gives enhanced results as far as number of RTP and aggregate analysis time needed. The aggregate number of RTP used to gauge the fault utilizing discrete RTP examination are given by \((N/m) + L\), Where, \(N\) – Total number of nodes in the network, \(m\) – Various number of sensor nodes chose every RTP in WSN, \(L\) – Number of sensor nodes barring source node. In proposed work MTrTP techniques, the quantity of RTP used to quantify the fault in the given network are given by \((m \log (m N-1)) + L\). The analysis time of discrete RTP is given by \(T_{ANL} = \frac{(N/m)}{1 - \frac{1}{m}}\times m\), But in the proposed MTrTP method the analysis time for fault detection node in the network are

\[
T_{ANL} = \frac{N\left(1 - \left(\frac{1}{m}\right)^h\right)}{1 - \left(\frac{1}{m}\right)}
\]

Where ‘\(h\)’ height of the tree is given by \(\log_m N\).
Table 2. Measured RTP of Linear, Discrete, MTrTP

| Number of node | m  | Maximum RTP | Linear RTP | Discrete RTP | MTrTP RTP |
|---------------|----|-------------|------------|--------------|-----------|
| 10            | 3  | 70          | 10         | 4            | 4         |
| 40            | 5  | 1400        | 40         | 8            | 7         |
| 60            | 6  | 3240        | 60         | 10           | 8         |
| 80            | 7  | 5840        | 80         | 12           | 9         |
| 90            | 8  | 7380        | 90         | 12           | 10        |
| 100           | 9  | 9100        | 100        | 12           | 10        |
| 200           | 10 | 38000       | 200        | 20           | 14        |

Table 3. Discrete (m – different)

| N  | m | N/m   | (N/m) + L | Analysis Time | (N/m) + L × m |
|----|---|-------|-----------|---------------|---------------|
| 10 | 3 | 3.333333 | 2         | 5.333333      | 16            |
| 40 | 5 | 8      | 4         | 12            | 60            |
| 60 | 6 | 10     | 5         | 15            | 90            |
| 80 | 7 | 11.42857 | 6         | 17.42857      | 122           |
| 90 | 8 | 11.25  | 7         | 18.25         | 146           |
| 100| 9 | 11.11111 | 8         | 19.11111      | 172           |
| 200| 10| 20     | 9         | 29            | 290           |
| 400| 15| 26.66667 | 14        | 40.66667      | 610           |

For different m estimation of distinctive sensor node, the deliberate aftereffects of discrete RTP are demonstrated in Table 2. Relating analysis time likewise recorded in Table 3 individually. The Table 4 is utilized to depict the aftereffects of the proposed MTrTP network. The quantity of RTP value and comparing analysis time are recorded. From the deliberate results, it plainly expresses that, the proposed MTRTP network gives better results regarding number of RTP obliged and absolute analysis time. From the after effect of Table 4, choice of sensor nodes every RTP in every cluster is equivalent to three and it will be ideal to enhance the fault identification of the proposed work.

3. Hardware Implementation and Analysis

Utilizing Atmega8L microcontroller and Xbee Series2 wireless interface card the remote sensor nodes are created and the network is surrounded utilizing six sensor nodes. Typical experimental set up includes six sensor
nodes with sensing units and Xbee wireless module is shown in Figure 2. The RTD estimation of the proposed framework is measured. For each Round Trip Path, the source location and destination addresses for every node in the network are relegated. From the trial examination, MTrTP analysis gives preferable results over other existing techniques. The variety of RTP in linear RTP, discrete RTP and proposed MTrTP examination for different estimations of sensor nodes N is described in Figure 3. The quantity of RTP in discrete network, MTrTP strategy for consistent m and distinctive m worth is depicted in Figure 4. In Figure 5, the quantity of RTP of the proposed MTrTP network for consistent m worth and the distinctive m quality are portrayed. The aggregate analysis time for of the proposed work of MTrTP and Discrete strategy are depicted in Figure 6.
Table 4. MTRTP (m – different)

| N  | m | Log$_m$N | h | 1 - (1/m)$^h$ | N (1 - (1/m)$^h$) | N (1 - (1/m)$^h$)/1-(1/m) |
|----|---|---------|---|-------------|----------------|---------------------------|
| 10 | 3 | 2.095903| 2 | 0.888889    | 8.888889        | 14                        |
| 20 | 4 | 2.160964| 2 | 0.9375     | 18.75           | 25                        |
| 40 | 5 | 2.29203 | 2 | 0.96       | 38.4            | 48                        |
| 60 | 6 | 2.285097| 2 | 0.972222   | 58.33333        | 70                        |
| 80 | 7 | 2.251916| 2 | 0.979592   | 78.36735        | 92                        |
| 90 | 8 | 2.163951| 2 | 0.984375   | 88.59375        | 102                       |
| 100| 9 | 2.095903| 2 | 0.987654   | 98.76543        | 112                       |
| 200| 10| 2.30103 | 2 | 0.99       | 198             | 220                       |
| 400| 15| 2.212464| 2 | 0.995556   | 398.2222        | 427                       |

Figure 5. MTrTP: RTP in WSN (Constant m and Different m Value).

4. Conclusion

In this work, Multi way Tree based Round Trip Path (MTrTP) is proposed as fault detection mechanism for remote sensor network. Every sensor node recognizes its status taking into account the RTD time and threshold value. This proposed calculation is easy to actualize and successfully distinguishes the faulty sensor nodes with most extreme unwavering quality with minimal effort.

This proposed work is effectively broke down and tried on low power equipment stage. Contrasted to Maximum, Linear and Discrete RTP examination the proposed MTrTP analysis gives less number of RTP for fault node identification and expends less time for data analysis. Subsequently, the proposed MTrTP technique enhances the nature of administration as far as information exactness and network lifetime.
5. Acknowledgement

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