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DISTRIBUTED FAULT DETECTION MECHANISM IN WIRELESS SENSOR NETWORKS

Urmila
M. Tech Scholar-CSE,
BRCM CET, Bahal

Sunil Kumar
Asst. Professor-CSE
BRCM CET, Bahal

Dr. Sajjan Singh
Associate Professor-ECE
LPU, Jalandhar

Abstract: **Wireless sensor networks have seen fabulous advances and use in the past two decades. Wireless sensor network that consists of a large number of low-cost and low powered sensor devices is a self-organized network, called sensor nodes. These systems are often deployed in remote or hard-to reach areas. Hence, it is critical that such networks operate unattended for long durations. Unlike the cellular networks and ad hoc networks where energy has no limits in base stations or batteries can be replaced as needed, nodes in sensor networks have very limited energy and their batteries cannot usually be recharged or replaced due to hostile environments. Therefore, the efficient use of energy has been a key issue in the development of wireless sensor networks have extending network lifetime. In distributed fault detection (DFD) mechanism for wireless sensor networks the status of each sensor node to be either good or faulty is based on the neighbouring nodes, but in the DFD algorithm, when the sensor fault probability increases the fault detection accuracy decreases or the false alarm rate increases rapidly. In this paper an improved DFD scheme is proposed to detect intermittently faulty sensor nodes and to rigorous power budget during fault analysis process on sensor nodes in wireless sensor network.**

Keywords: **Wireless Sensor Network (WSN), Distributed fault Detection (DFD), Fault Analysis, Self Management Mechanism**

I. INTRODUCTION

The WSN is made of nodes from a few to several hundred, where each node is connected to one or several sensors [1, 3].

- Sensor and actuator - an interface to the physical world designed to sense the environmental parameters like temperature and pressure.
- Controller - is to control different modes of function for processing of data
- Memory - luggage compartment for programming data.
- Communication - a device like antenna for receiving and sending data in excess of a wireless channel.
- Power Supply- supply of energy for smooth operation.

The topology of the WSNs can diverge from a simple star network to an advanced wireless mesh network. The propagation technique among the nodes of the network could be routing. Wireless sensor networks the power lies in the capability to deploy large numbers of small nodes that assemble and construct themselves. In addition to radically decreasing the installation costs, WSN have the potential to dynamically adapt to changing environments. Adaptation mechanisms can lead to changes in network topologies.

- Resource Constraint
- Unknown topology before deployment
- Unattended and unprotected once deployed

Due to the above characteristics, WSN are easily susceptible to attacks. Providing security solutions to these networks is difficult due to its characteristics such as tiny nature and constraints in resources.

II. A SELF MANAGEMENT MECHANISM FOR WSN

In this advance a new fault management mechanism was projected to deal with fault detection and recovery. It proposes a heavily introducing more self-managing functions hierarchical structure to properly distribute fault management household tasks among sensor nodes. The proposed failure detection and recovery algorithms have been compared with some existing related algorithm and proven to be more energy capable [2]. The proposed fault management mechanism can be divided into two phases:

- Fault detection and diagnosis
- Fault recovery

2.1 FAULT DETECTION AND DIAGNOSIS

Detection of faulty sensor nodes can be achieved by two mechanisms i.e. self-detection (or passive-detection) and active-detection. In self-detection, sensor nodes are required to regularly monitor their residual energy, and identify the probable failure. In this scheme, we consider the battery depletion as a main cause of node rapid death. A node is termed as failing when its energy drops below the threshold value. When a common node is failing due to energy depletion, it sends a message to its cell manager that it is going to sleep mode due to energy below the threshold value. This requires no recovery steps. Self-detection requires less in-network communication to conserve the node energy and is considered as a local computational process of sensor nodes [3].

To efficiently detect the node rapid death, our fault management systems work with an active detection mode. In this approach, the message of updating the node residual battery is applied to track the existence of sensor nodes. In active detection, cell manager asks its cell members on regular basis to send their updates. Such as the cell manager sends "get" messages to the associated common nodes on regular basis and in return nodes send their updates. This is called in-cell update cycle. The update_msg consists of node ID, energy and location information. As shown in figure 2.1, exchange of update messages takes place between cell manager and its cell members. If the cell manager does not receive an update from any node then it sends an instant message to the node acquiring about its status. If cell manager does not receive the acknowledgement in a given time, it then declares the node faulty and passes this information to the left over nodes in the cell [3].

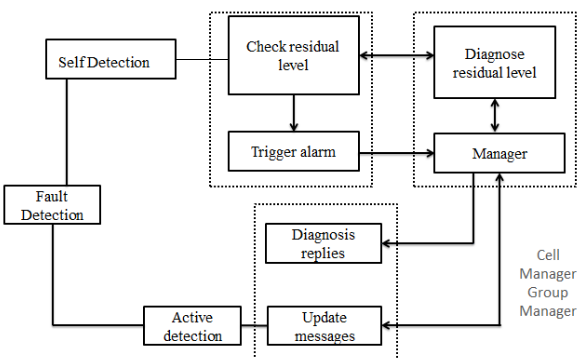

Fig: 2.1 Fault Detection and Diagnosis

Cell managers only focus on its cell members and only inform the group manager for further assistant if the network performance of its small region has been in a critical level. A cell manager also employs the self-detection approach and regularly monitors its residual energy status. All sensor nodes start with the same residual energy. After going through various transmissions, the node energy decreases. If the node energy becomes less than or equal to 20% of battery life, the node is ranked as low energy node and becomes liable to put to sleep. If the node energy is greater or equal to 50% of the battery life, it is ranked as high and becomes the promising candidate for the cell manager. Thus, if a cell manager residual energy becomes less than or equal to 20% of battery life, it then triggers the alarm and notifies its cell members and the group manager of its low energy status and appoints a new cell manager to replace it.

Health status information every cell manager sends to its group manager. This is called out-cell update cycle and are less frequent than in-cell update cycle. If a group manager does not hear from a particular cell manager during out-cell update cycle, it then sends a fast reminder to the cell manager and enquires regarding its status. If the group manager does not hear from the same cell manager again during second update cycle, it then declares the cell manager faulty and informs its cell members [2]. This approach is used to detect the sudden death of a cell manager. Group manager also monitor its health status frequently and respond when its residual energy drops below the threshold value. It notifies its cell members and neighboring group managers of its low energy status and an indication to appoint a new group manager. Rapid death of a group manager can be detected by the base station. If the bases station does not receive any traffic from a particular group manager, it then consults the group manager and asks for its current status. If the base station does not receive any acknowledgement, it then considers the group manager faulty (rapid death) and propagates this information to its cell managers [4]. The base station primarily focuses on the existence of the group managers from their sudden death. Meanwhile, the group managers and cell managers take most parts in passive and active detection in the network.

2.2 FAULT RECOVERY

After nodes failure detection sleeping nodes can be awaked to cover up the required cell density or mobile nodes can be moved to fill the coverage hole. A cell manager also appoints a secondary cell manager within its cell to acts as a backup cell manager. Cell manager and secondary cell manager are known to their cell members. If the cell manager energy drops below the threshold value (i.e. less than or equal to 20% of battery life), it then sends a message to its cell members including secondary cell manager. It also informs its group manager of its residual energy status and about the candidate secondary cell manager. This is an indication for secondary cell manager to stand up as a new cell manager and the existing cell manager becomes common node and goes to a low computational mode. Common nodes will automatically start treating the secondary cell manager as their new cell manager and the new cell manager upon receiving updates from its cell members; choose a new secondary cell manager [3].

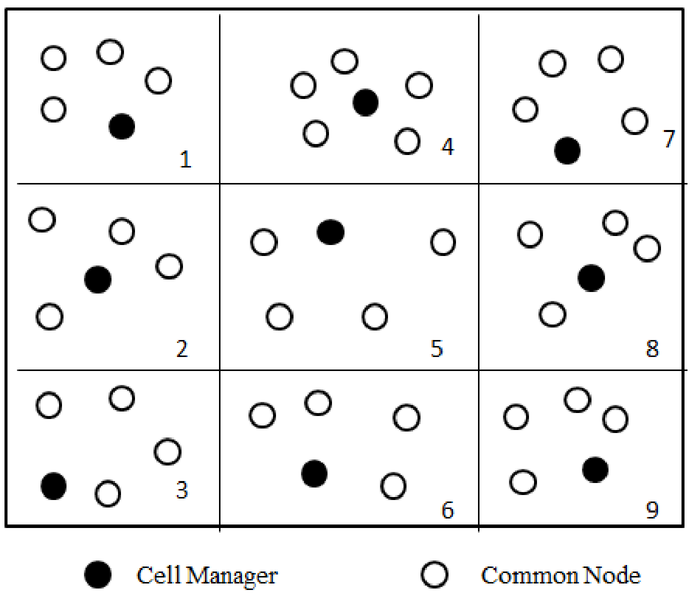

Fig: 2.2. Virtual Grid of Nodes

The failure recovery mechanisms are performed locally by each cell. In Figure 2.2, let us assume that cell 1 cell manager is failing due to energy depletion and node 3 is chosen as secondary cell manager. Cell manager will send a message to node 1, 2, 3 and 4 and this will initiate the recovery mechanism by invoking node 3 to stand up as a new cell manager. In a scenario, where the residual battery energy of a particular cell manager is not sufficient enough to support its management role, and the secondary cell manager also does not have sufficient energy to replace its cell manager. Thus, common nodes exchange energy messages. within the cell to appoint a new cell manager with residual energy greater or equal to 50% of battery life. In addition, if there is no candidate node within the cell that has sufficient energy to replace the cell manager. The event cell manager sends a request to its group manager to merge the remaining nodes with the neighboring cells.

When a group manager detects the sudden death of a cell manager, it then informs the cell members of that faulty cell manager (including the secondary cell manager). This is an indication for the secondary cell manager to start acting as a new cell manager. A group manager also maintains a backup node within the group to replace it when required. If the group manager residual energy drops below the threshold value (i.e. greater or equal to 50% of battery life), it may downgrade itself to a common node or enter into a sleep mode, and notify its backup node to replace it. The information of this change is propagated to neighboring group managers and cell managers within the group. As a result of group manager sudden death, the backup node will receive a message from the base station to start acting as the new group manager. If the backup node does not have enough energy to replace the group manager, cell managers within a group co-ordinate to appoint a new group manager for themselves based on residual energy.

Each cell maintains its health status in terms of energy. It can be High, Medium or Low. These health statuses are then sent out to their associate group managers periodically during out- cell update cycle. Upon receiving these health statuses, group manager predict and avoid future faults. For example; if a cell has health status high then group manager always recommends that cell for any operation or routing but if the health status is medium then group manager will occasionally recommend it for any operation [5]. Health status Low means that the cell has insufficient energy and should be avoided for any operation. Therefore, a group manager can easily avoid using cells with low health status or alternatively, instruct the low health status cell to join the neighboring cell.

Algorithm for DFD Exciting Scheme [2]

p : probability of failure of a sensor;

k : number of neighbor sensors;

S : set of all the sensors;

$N(S_i)$: set of the neighbors of S_i;

x_i : measurement of S_i;

d_{ij}^{t} : measurement difference between S_i and S_j at time t,

$d_{ij}^{t} = x_i^t - x_j^t$;

$\Delta t_l = t_{l+1} - t_l$;

$\Delta d_{ij}^{\Delta t_l}$: measurement difference between S_i and S_j from time t_l to t_{l+1}, $\Delta d_{ij}^{\Delta t_l} = d_{ij}^{t_{l+1}} - d_{ij}^{t_l} = (x_i^{t_{l+1}} - x_j^{t_{l+1}}) - (x_i^{t_l} - x_j^{t_l})$;

c_{ij} : test between S_i and S_j, $c_{ij} \in \{0,1\}$, $c_{ij} = c_{ji}$;

$\theta 1$ and $\theta 2$: two predefined threshold values;

T_i : tendency value of a sensor, $T_i \in \{LG, LF, GD, FT\}$;

Sensors are considered as neighboring sensors if they are within the transmission range of each other. Each node regularly sends its measured value to all its neighbors. We are interested in the history data if more than half of the sensor's neighbors have a significantly different value from it. We can find the current measurement is different from previous measurement. If the measurements change over the time significantly, it is more likely the sensor is faulty [3]. A test result C_{ij} is generated by sensor S_{ij} based on its neighbour S_j 's measurements using two variables and two predefined threshold value. If a sensor is faulty, it can generate arbitrary measurements. If C_{ij} is 0, most likely either both S_i and S_j are good or both are faulty. Otherwise, if C_{ij} is 1, S_i and S_j are most likely in different status.

STEP-1

Each sensor S_i, set $c_{ij} = 0$ and compute d_{ij}^{t};

IF $|d_{ij}^{t}| > \theta 1$ THEN

Calculate $\Delta d_{ij}^{\Delta tl}$;

IF $|\Delta d_{ij}^{\Delta tl}| > \theta 2$ THEN $c_{ji} = 1$;

STEP-2

IF $\sum_{S_j \in N(S_i)} c_{ij} \le \lceil |N(S_i)|/2 \rceil$, where $|N(S_i)|$ is the number of the S_i's neighboring nodes THEN

$T_i = \text{LG}$;

ELSE $T_i = \text{LF}$;

Communicate T_i to neighbors;

STEP-3

IF $\sum_{S_j \in N(S_i) \text{ and } T_j = \text{LG}} (1 - 2c_{ij}) \ge \lceil |N(S_i)|/2 \rceil$

THEN

$T_i = \text{GD}$;

Communicate T_i to neighbors;

STEP-4

IF $T_i = \text{LG}$ or $T_i = \text{LF}$ THEN

IF $T_j = \text{GD}$ $\forall S_j \in N(S_i)$ THEN

IF $c_{ij} = 0$ THEN

$T_i = \text{GD}$;

ELSE $T_i = \text{FT}$;

ELSE repeat

Communicate T_i to neighbors;

STEP-5

FOR each S_i, IF $T_j = T_h = \text{GD}$ $\forall S_j, S_h \in N(S_i)$, where $j \ne h$, and IF $c_{ji} \ne c_{hi}$ THEN

IF $T_i = \text{LG}$ (or LF) THEN

$T_i = \text{GD}$ (or FT)

III. ISSUE IN THE EXISTING ALGORITHM

From the realization of DFD node fault detection scheme, for a normal node *Snormal*, if the number of its neighbor nodes having initial detection status of LG is less than [| *N* (*Snormal*) | / 2], then *Snormal* is misdiagnosed as faulty, thus reducing the fault detection accuracy

The conditions of detecting the normal node as "normal" are too harsh in DFD node fault detection scheme.

The improved DFD node fault detection scheme proposed in this project changes the detection criterion of DFD scheme as follows:

- For any node *Si* and the nodes in *N* (*Si*) whose initial detection status is LG, if the nodes whose test result with *Si* is 0 are not less than the nodes whose test result is 1, then the status of *Si* is normal (GD), otherwise, the status of *Si* is faulty (FT).

STEP-1

Each sensor S_i and any sensor $S_j \in N(S_i)$ set $c_{ij} = 0$ and compute d_{ij}^{t};

IF $|d_{ij}^{t}| > \theta 1$ THEN ($C_{ij} = 1$) and turn to next node in $N(S_i)$;

IF $|d_{ij}^{t}| < \theta 1$

Calculate $\Delta d_{ij}^{\Delta tl}$;

IF $|\Delta d_{ij}^{\Delta tl}| > \theta 2$ THEN $c_{ji} = 1$; and turn to next node in $N(S_i)$;

Repeat above steps until the test results of each node in $N(S_i)$ with S_i are all obtained

STEP-2

IF $\sum_{S_j \in N(S_i)} c_{ij} \le \lceil |N(S_i)|/2 \rceil$, where $|N(S_i)|$ is the number of the S_i's neighboring nodes THEN

$T_i = \text{LG}$;

ELSE $T_i = \text{LF}$;

Communicate T_i to neighbors;

STEP-3

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IF $\sum_{S_j \in N(S_i) \text{ and } T_j = \text{LG}} (1 - 2c_{ij}) \geq \lceil |N(S_i)| / 2 \rceil$

THEN

$T_i = \text{GD};$

ELSE

THEN

$T_i = \text{FT};$

Communicate T_i to neighbors;

STEP-4

- If there are no neighbor nodes of Si
- Whose initial detection status is LG, and if the initial detection status Ti of Si is LG, then set the status of Si as normal (GD), otherwise as fault(FT);

STEP 5

- Check whether detection of the status of all nodes in network is completed or not. If it has been completed, then exit. Otherwise, repeat steps of (1), (2), (3) and (4).

IV. RESULTS AND ANALYSIS

In this approach a total of 3 scenarios will be implemented the one with no faulty nodes (ideal situation). Second one where information will stop when faulty nodes occur (faulty situation). Third one where faults will be detected and accordingly shortest path will be made (Proposed work).

The evaluation results should demonstrate the ability of the mechanism to identify faulty nodes anciently and with limited overheads an example simulation scenario composed of total 90 sensor nodes which are randomly deployed

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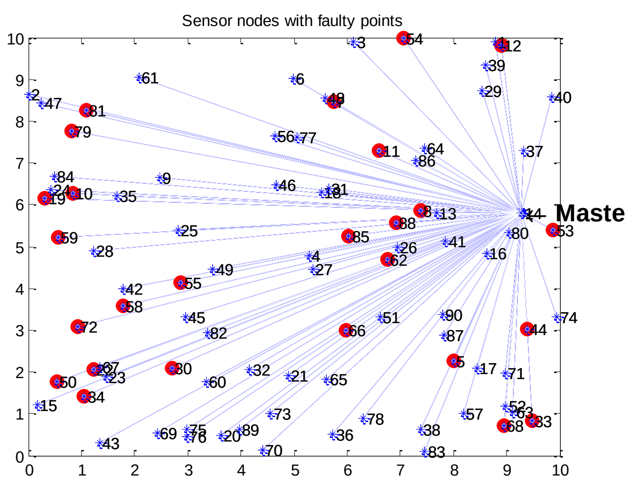

Fig. 3: Sensor node with faulty points

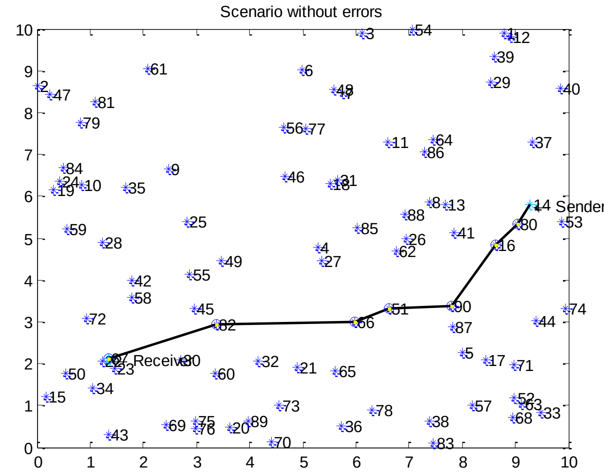

Fig. 4: Scenario 1: No Errors

This is the ideal scenario. Here, Fig 4, we assume that there are no faulty nodes. All the nodes are authentic and fault free. Information is securely transferred from sender to the receiver. We have selected the shortest path from sender to receiver.

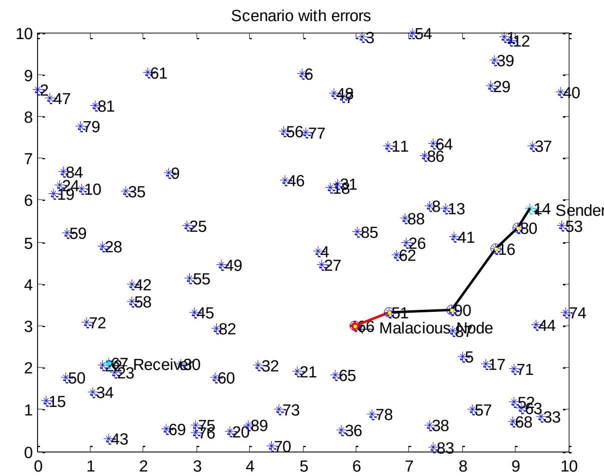

Fig. 5: Scenario 2: With Errors

In Fig. 5 is scenario in which errors are also considered.

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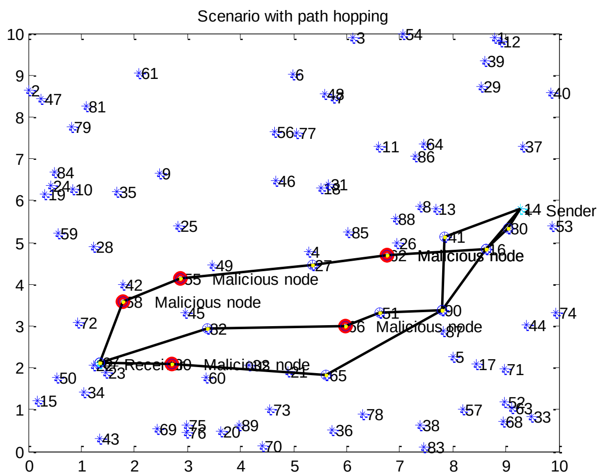

Fig. 6: Scenario 3: Path Hopping

In Fig. 6 the scenario when the sender assume 14 node send the information to assume receiver node 67 than finds more than 1 route to the receiver. And even after occurrence of a faulty node, the information loss does not intervene in the route formation. The route is still completed even after a faulty node occurs. This scenario is meant to show the path hopping between sender and receiver. Information can be transferred from more than 1 route also.

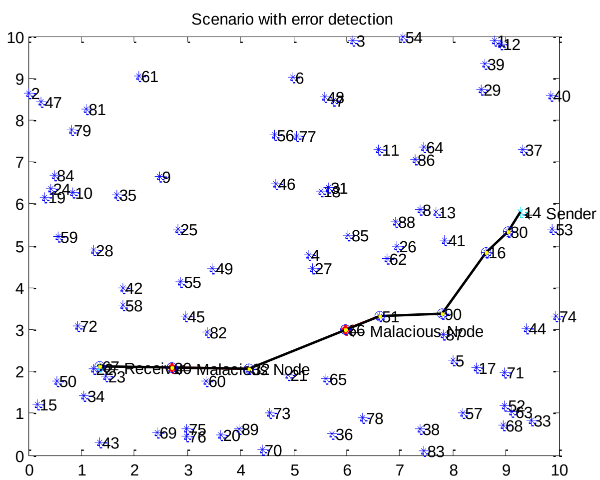

Fig. 7: Retraced Path after Fault Detection

In Fig. 7 this is the final scenario. Here, the faults are detected and the route will change accordingly. The system will find the shortest path between sender and receiver despite of fault occurrence.

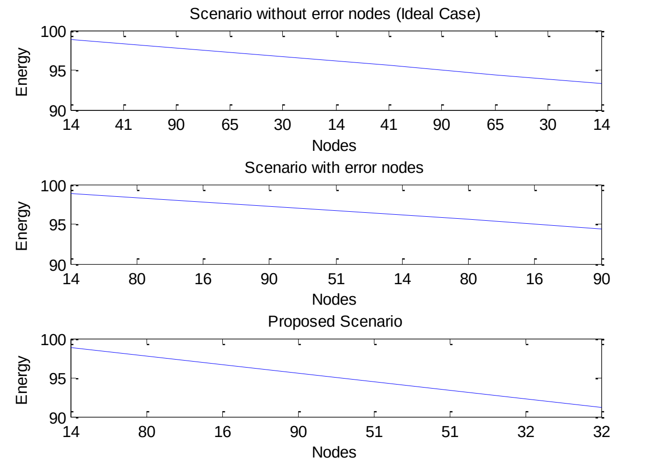

Fig. 8: Comparison b/w No. of Nodes and Energy Distribution

In Fig. 8 this nodes showing various energy distributions are shown. In path hopping there are multiple path involved, the paths having different nodes energy distribution.

The fig. 9 shows the delivery of packets at nodes. There are different packet delivery ratios.

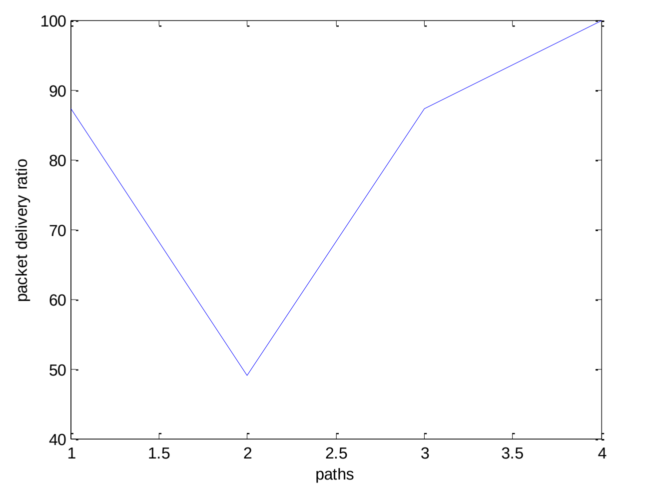

Fig. 9: Packet delivery ratio

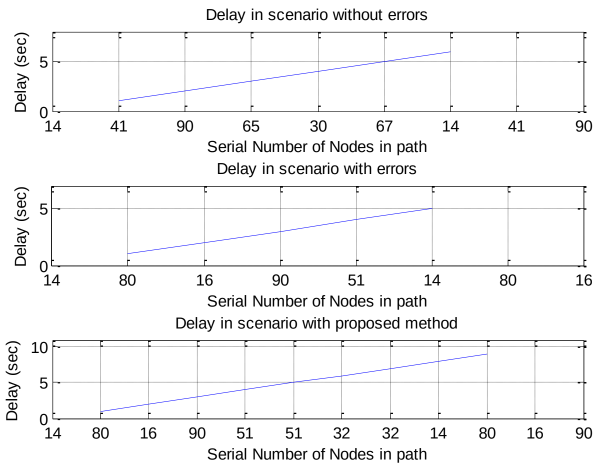

Fig. 10: Comparison b/w No. Of Nodes And Delay

In Fig. 10 this various delay are considered at various nodes. These are three scenarios.

Table 1: Comparison table for Delay and Packet Delivery

Parameter used	Value
Delay in ideal case	0 s
Delay with errors	1.5 s
Delay with improved DFD method	0.5 s
Packet delivery in ideal case	100%
Packet delivery with errors	60%
Packet delivery with improved DFD	99%

In Table 1 show the overall comparison results delay with error 1.5 s and delay with improved DFD method 0.5 s. The packet delivery with errors is 60% and packet delivery with improved DFD scheme is 99%.

V. CONCLUSION

In this paper proposed a distributed localized faulty sensor detection algorithm where each sensor identifies its own status to be either ”good” or ”faulty” and the claim is then supported or reverted by its neighbors as they also evaluate the node behavior.. This paper has presented a new strategy for power control in WSNs where operational longevity is an issue. As the deployment of thousand numbers of sensor Nodes in area needs energy performance and better packet delivery from the sender to the receiver The new approach provides a methodology for the retracing of path having good packets with an energy efficiency and accuracy. This assessment becomes the power performance booster among the previous workout as it automatically determines the shortest path after path hopping is traced. A self management approach links the sensor nodes from the source to the destination with in a shortest path and shows distributed accuracy. It improves the fault detection accuracy of the gathering area. We conclude that the time consumed by our approach to find out the faulty node is relatively less than the time consumed by the existing scheme.

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