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Design and Simulation of Fault Detection in Wireless Sensor Networks

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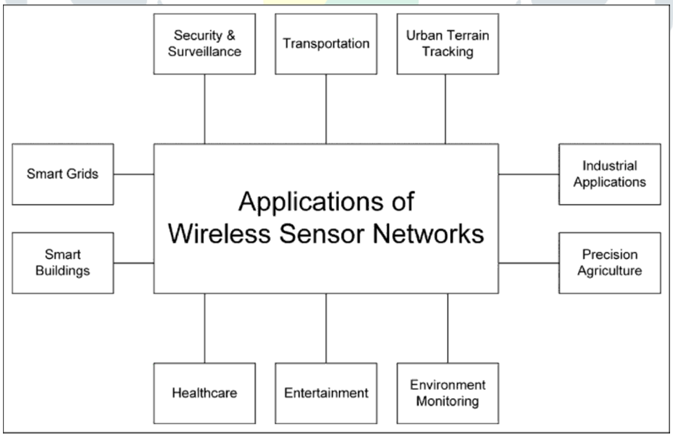
***Abstract*: Advancement in technology has led to the invention of low-cost and multifunctional devices. These devices consist of numerous sensors which are accountable for physical environment sensed data, processing sensed data, and sharing or transmitting the data to other devices or nodes. The presence of fault nodes in the network leads to performance degradation and delay in data communication. It is essential to detect and remove such fault nodes since this data's accuracy is crucial. This paper proposes a system that detects the faulty nodes, removes them, and transmits data which leads to improved data quality, on-time data transmission, and greater efficiency of the system.**

I. INTRODUCTION

Wireless Sensor Networks consist of numerous sensors, sink nodes, and a base station. The users are connected to the network through the base station. The communication among sensor nodes is done using radio signals. They comprise sensing units, processing units, memory, microcontroller, transceiver, and power source.

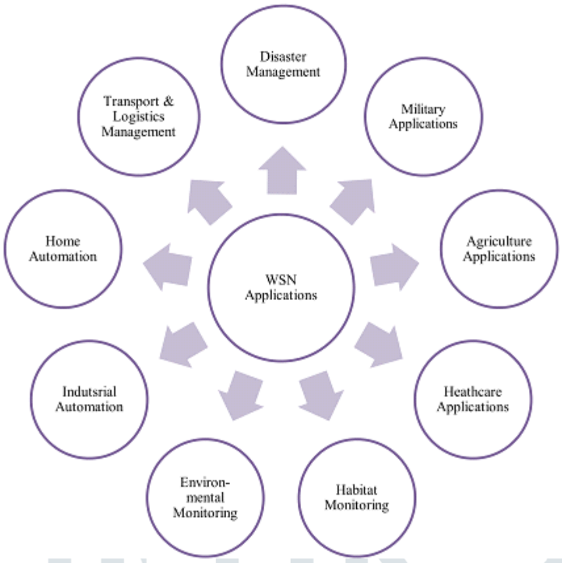


WSN has greater flexibility, distribution, and many vital characteristics encompassing an enormous selection of applications like Warfield, emergency area, investigation, threats related to the environment, etc. However, the sensor nodes face several attacks and other damage because these nodes are employed in drastic environments. In addition, sensor nodes have a low cost for manufacture and restricted resources and radio range. Several factors can cause a fault in the sensor node failure and hence it will reduce the efficiency of sensed or monitoring data. The fault detection in the network node is more important for assuring the precision of observing results.

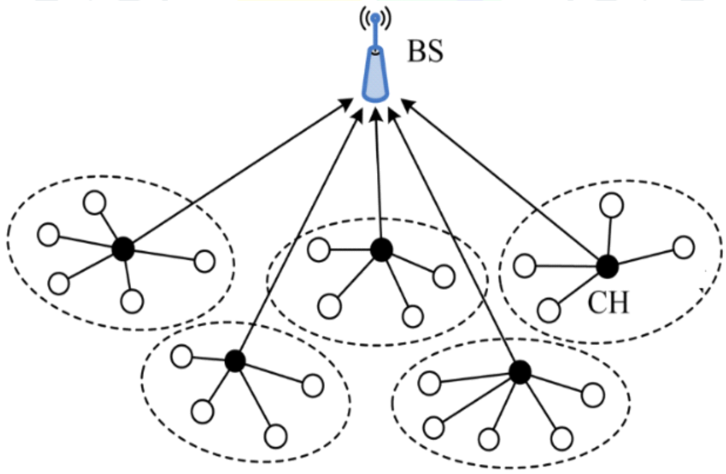
Fault detection algorithms are majorly divided into two algorithms namely distributed (DFD) and centralized (CFD) detection. The CFD algorithms normally require every node-specific information so that it can know about the state of the other nodes presented in the same station. These algorithms may cause many problems easily like single node fault, loss of information, and high consumption of energy. The DFD algorithms require knowing the ability of each node to find the faults and have to go through the collected data which was collected by the same node or the neighboring nodes to get a solution for the faults. Still, some problems have been existing in these types of fault detection algorithms are as follows:

(1) For high detecting precision requires high energy consumption. As of now with the current detection algorithms, the sensor nodes have to interact with the neighboring nodes while detecting the faults, So it leads to energy consumption high.

(2) There are only limited styles of the detection algorithm, Hence the performance of detection declines fast when faults increase in the nodes.
(3) The energy of the sensor is not properly utilized because only partial power is used to achieve the correlation of the nodes.
WSN is used widely in applications as follows:
a) Tracking environmental data such as temperature, pressure, animal positions, etc.
b) Tracking enemies and their vehicles for military applications.
c) Tracking patients and their health statistics
d) Tracking and monitoring traffic



Apart from the various applications, WSN has some restrictions like limited power supply, limited bandwidth for communication, etc. The sensors are attached with a small battery to provide low cost and size. Hence, they cannot communicate over long-range distances. In order to transmit data to the nodes out of the range, the sensors perform multi-hop communication. Energy efficiency is the most important constraint as there is a limited power supply. To achieve higher energy efficiency, the clustering method is used for communication. This method reduces the energy consumed by reducing the hops count required in the transmitting range. In clustering, sensor nodes are distributed into groups. A cluster head is elected in each cluster and all the other nodes are known as the cluster nodes. These cluster nodes will communicate with the cluster head which in turn helps to transmit and further to base station.



Some of the issues which are need to be resolved for efficient clustering of the sensor nodes are
a) The number of clusters to be formed so that data transmission is faster and better.
b) Number of nodes to be included in a cluster.
c) Procedure to be followed for selection of head of clusters.
d) Cluster head reselection in case of addition or removal of sensor nodes.

Fault is defined as an undesired behavior or malfunctioning of nodes in a network which leads to the failure if the entire system. Faults can be of two types: Soft faults and Hard faults.
In hard faults, sensors loose capacity to communicate with other nodes. Hard faults are permanent which are caused due to failure of hardware parts such as the transceiver, battery, etc.
In soft faults, sensors can communicate efficiently but start behaving abnormally. Data transmitted is faulty. Soft faults are temporary and difficult to detect.

There are 3 types of approaches which can be used for faulty nodes recognition:

- Centralized approach : A node is elected as the central or main node which has higher responsibilities.

- Distributed approach: Every node is equally responsible and allowed to take decisions. Here each sensor node makes a decision based on comparison between its own reading and readings of its one-hop neighbors.
- Hybrid approach:Both the central node and member node can make decisions.

II. Methodology

LEACH-algorithm protocol was used for clustering. It is Time Division Multiple Access (TDMA) based protocol that helps to increase the lifespan of the network by reducing the consumption of energy.
The protocol is divided into two phases: The set-up phase and the steady phase. These phases are repeated in every round.

- **Setup-phase**: The important aspect of this setup of this phase is to form a cluster and select a cluster head. This phase is segregated into three steps:
  - Advertisement phase
  - Cluster formation
  - Scheduling transmission

  During the advertisement phase, the cluster head sends the advertisement packet to cluster nodes. This is done to inform every node about the cluster head.
  And in the cluster formation phases the nodes join the cluster head which is closest to them. The procedure is repeated till all the nodes are clustered.
  During the last phase, the cluster head schedules the time of transmission for every node belonging to its cluster. The nodes communicate with the cluster head in its allotted time only.
  The Cluster Head capability is to be given to capable nodes in each slot.
  The ratio of nodes that are capable of the role of Cluster Head is C These nodes choose a random value 'R' ranges 0,1. In case the number is within the threshold value that is T then that node becomes the cluster head.
  The Threshold value is calculated as:
  T = C if n ∈S
  1-C(R*modulus(1/C)
  Where,
  S: Number of sensor nodes that have not been cluster head in 1/C round
  T: Threshold value
  C: Number of nodes capable of being Cluster Head
  R: Number of rounds

- **Steady Phase**: Every node will transmit the observed data to the head of a cluster during this phase. The cluster head collects all the data and sends it further to sink node. After successful transmission, set-up phase is executed once again.

This procedure is followed by fault node recognition. While transmitting data, if a node has the following limitations, it is considered to be malicious.

- Low energy
- Smaller lifetime
- More delay
- More power consumption
- High data loss

When such a faulty node is detected, it is neglected and an alternate path is chosen for data transmission.

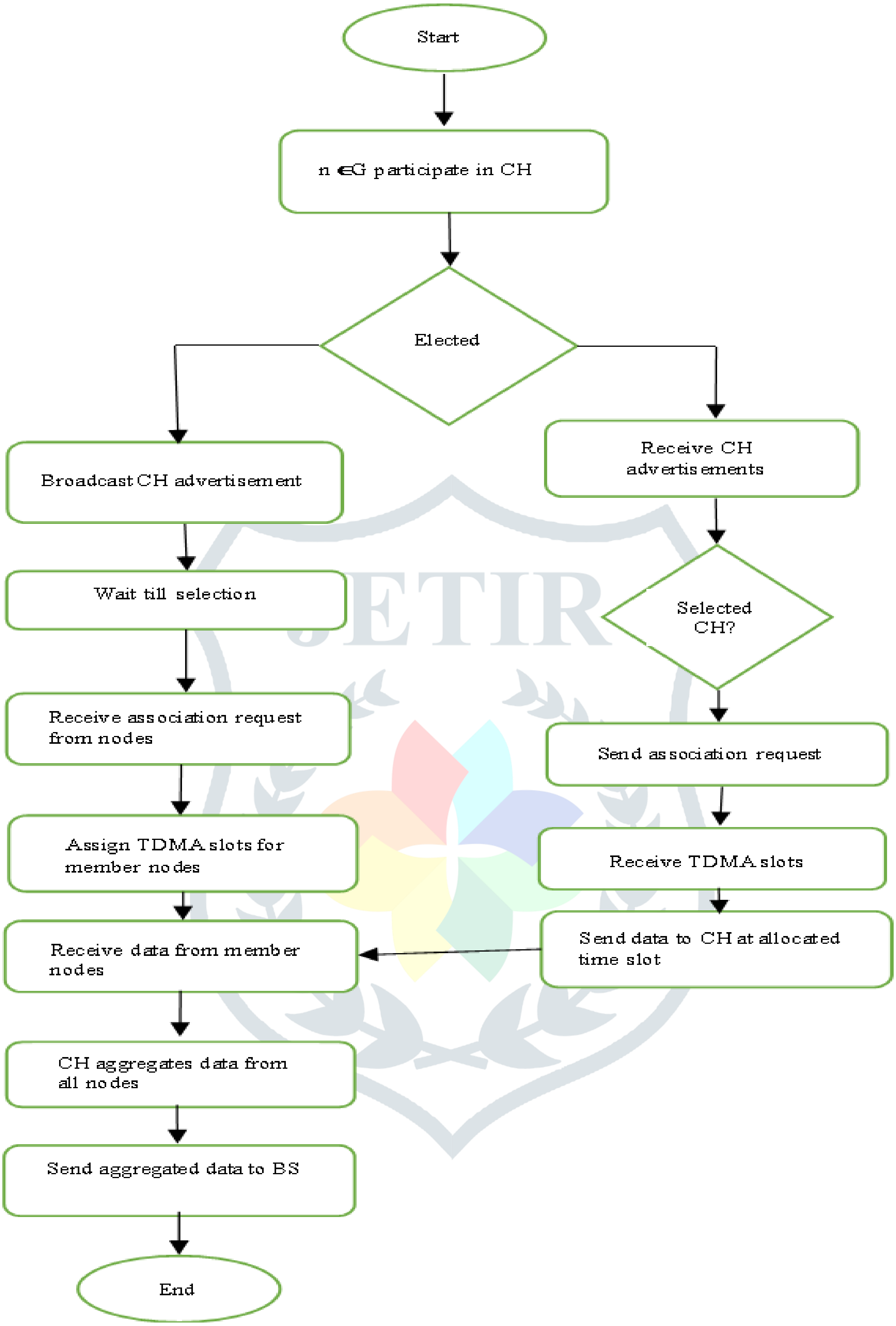


Fig 3 Flow diagram of proposed system

III. Results

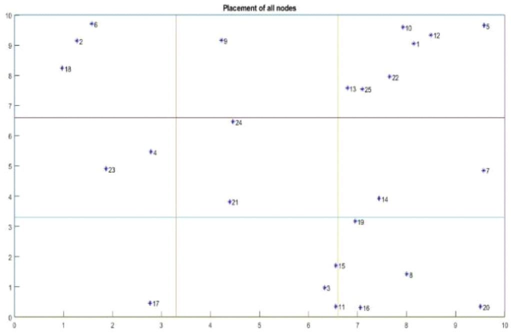


Fig 1: Clustering of nodes in WSN

In the beginning, the system asks for the number of nodes to be deployed in the area. Once entered, the nodes will be distributed randomly. Then, clusters will be formed dividing the nodes into groups.

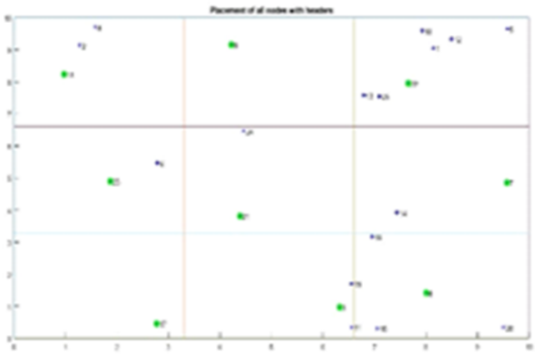


Fig 2: Selection of Cluster Head

Once the nodes are clustered, cluster head is elected for every cluster. Selection of the cluster head depends on the energy and distance from the other nodes. The node with high energy and which is close to the member nodes as well as the cluster head of the other cluster is selected as the cluster head.

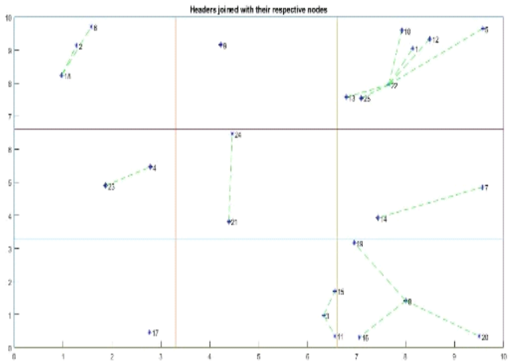


Fig 3: All member nodes are connected to the cluster

After the selection of cluster head, it is connected to the member nodes with a duplex link where all the data would be transferred. If any member node needs to transfer data to another node of same or another cluster, it cannot do the transfer directly. It first sends the data to the cluster head which would further take care of the successful transmission of data.

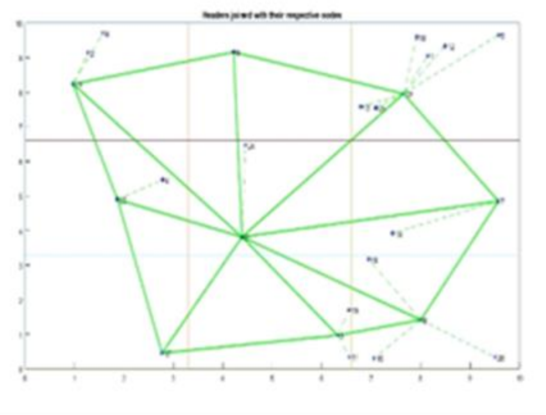


Fig 4: Cluster heads are inter-connected

The cluster heads are connected with all the other cluster heads. When a member node sends some data for transmission to the cluster head, it takes the data and sends the data to the cluster head of the destination node either directly or through an intermediate cluster head.

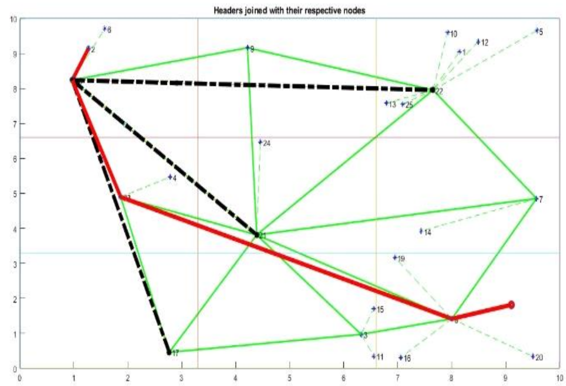


Fig 5: Re-transmission by alternate paths due to faulty nodes

The above figure 5 shows an example of a multi-hop data transmission where the intermediate clusters are detected to be faulty and hence the algorithm redirects the data through other path where there are no faulty nodes, the distance is comparatively less and there are lesser number of hops required for the transmission of data. The algorithm remembers the faulty nodes and does not consider it for transmission of data from next time.

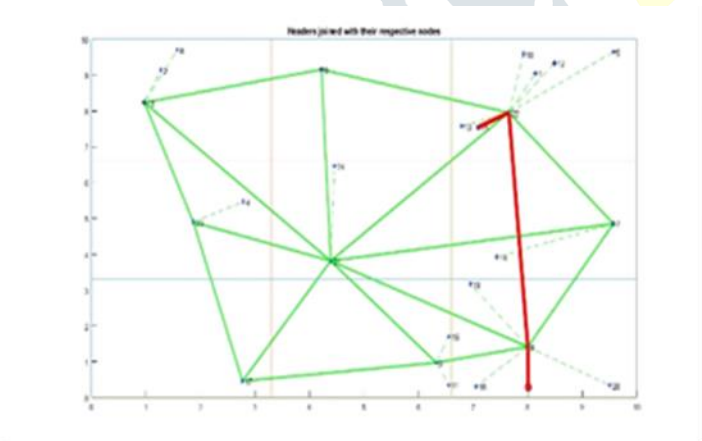


Fig 6: Transmission of data

The figure 6 shows an example of successful transmission of data where the fault node is not considered for transmission. Hence, the process becomes faster.

The two performance indicators used to evaluate the faulty node identification are detection accuracy and false-positive ratio.

- Detection Accuracy (DA) is the ratio of the number of the faulty nodes detected to the actual number of faulty nodes. The number of faulty nodes was nearly equal to 0.75 in our proposed system.

- False-Positive Ratio (FPR) is the ratio of the nodes wrongly detected as faulty to the total number of non-faulty nodes. The FPR gained in our proposed system was equal to 0.25.

IV. Conclusion

In the proposed method, a reliable communication was produced by overcoming the challenges such as delay, data loss, power loss, etc. Providing tolerance to the Wireless Sensor Network has been accomplished by using the clustering method which also improves the network lifetime.

The routing algorithm has been shown to run in $O(m)$ time without any fault and $O(m^2)$ time with occurrence of faults in the worst case. It has been shown that the proposed algorithm outperforms the existing algorithms, namely FTCA, MHRM and DEBR in terms of number of dead CHs, energy consumption, number of data packets received by the base station. The algorithm has also been shown to be more efficient than the algorithms FTCA and LBCA in terms of number of inactive sensor nodes.

In the future, further detecting precision of every node can be calculated in the WSN where the ratio can be defined by the number of the fault nodes to number of total nodes in that network. Still in this project approach that consumes very less time to detect fault nodes. So it needs to be verify for the large number of the nodes.

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