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Fault Prediction and Relay Node Placement in Wireless Sensor Network

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ABSTRACT: In Wireless Sensor Network (WSN), collected data will be faulty due to internal and external influences, such as environmental conditions, communication link failure, battery drain, etc. These are reduces the reliability of the WSN network. Faults may affect on quality of services (QoS), in WSN networks faults may produce incorrect data provided by sensor nodes or the network may make a misjudgment on nodes or the network and placing relay nodes to tolerate these faults, to improve Qos and reliability of the network.

In this work, we propose the prediction model Support Vector Machine (SVM) to predict faulty nodes in wireless sensor network and add minimum number of relay nodes as compared to existing system to recover the network proactively from the faults and to continue working successfully.

KEYWORDS: Wireless Sensor Network (WSN), Support Vector machine (SVM), Fault Prediction, Fault Recovery, Relay Node Placement.

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a collection of many various types of wireless sensor nodes for the purpose of data communication. These sensor nodes pass their information through the network cooperatively to the sink node. The sensor nodes sense various conditions such as temperature, humidity, pressure, etc. The different wireless sensor networks have been developed for different applications like military, healthcare, civil, bridge monitoring, home automation, traffic monitoring, etc.[4][6]

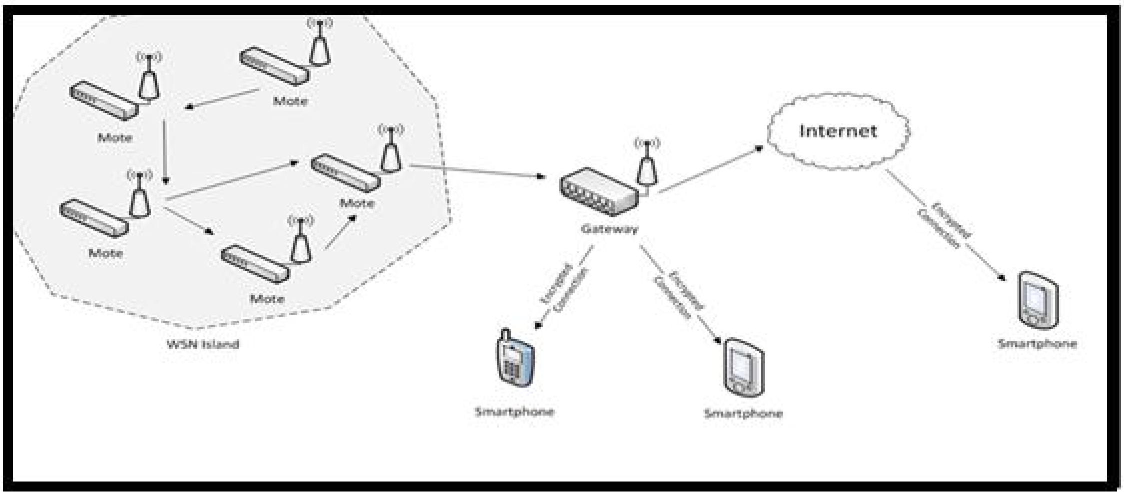

Figure 1 Wireless Sensor Network Architecure

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Figure 1 shows the architecture of wireless sensor networks. It contains various sensor nodes, the nodes are transmits their data to the main location cooperatively.

The sensors in WSN are inexpensive, low power devices and which have limited resources. In most wireless sensor network, battery is the only source of energy. The faults in WSN are occurs due to various reasons like hardware failure, communication link failure, malfunctioning, environmental hazards, battery exhaustion, etc. May lead to produce incorrect data and reduce reliability and quality of services (QoS) and make misjudgement on events. [5][7][15].

The WSN networks recover from faults proactively is the solution of this problem. When predict the faulty nodes before they actually faulty and repaired this faulty nodes at that time, save the time and continue working of wireless sensor network without disturbing for this purpose proposed the new prediction model to predict faulty nodes in WSN proactively, which results more reliability, availability, and QoS, etc. and placing minimum number relay nodes to recover the faulty nodes in WSN. [18]

II. RELATED WORK

In paper [1] author discuss about the prediction of the patients disease by using naïve Bayesian classification. The naïve bayes contained in the data sample by observing them individually, independent of each other. It based on bayes rule of conditional probability. It uses all attributes contained in data and analyses them individually as though they are equality important and independent of each other

In paper [2] author discuss about the J48 classifier used for the purpose of quality prediction in software. A decision tree is a predictive machine training model that decides the target values (dependent variables) of a new sample based on various attributes of the available data. The J48 decision tree classifier follows the simple algorithm in order to classify the new items it first needs to create a decision tree based on the attribute values of the available training data.

In paper [3] author presents a forecasting model i.e. ARIMA (p,d,q) using the data of real WSN applications. They propose an algorithm to find suitable ARIMA model and forecast, which corrects the anomalous data at sink for each sensor node with ARIMA, forecast values at any point of time. The methods uses ARIMA model to construct a prediction model for sampled data. In this method the model is being run on both sensor nodes and at the base station. If the difference between values sampled at sensor node model is smaller than a predefined tolerance, the value is not transmitted over network to the base station.

In paper [18] author discuss about how to place the relay nodes in WSN. There are two ways to place relay nodes in WSN.

- Stenerization of Edges:- Suppose u and v be two target nodes, we want to place minimum number of relay nodes in between u and v then follow two steps.
  - One way steinerization: In one way steinerization the directed edge uv is considered and create a one way path from u to v and place a minimum number of relay nodes from u to v when necessary.
  - Two way steinerization: In two way steinerization the undirected edge uv is considered and create a two way path from u to v and place a minimum number of relay nodes from u to v when necessary.
- Segmentation of neighborhood: Segment or divide the neighboring area of a particular node into small region such that the nodes within the same region. Suppose u be the one node then split the neighbor of u with the pair of positive values (r1,r2). First we create a circle with radius r1 at node u and also create a square just large to recover the circle. The n segment this square from left to right and top to bottom into small cells with length is diagonally equal to r2.

In paper [6] author deploys the additional relay nodes by using iterative algorithms to achieve desired connectivity. steiner MPC algorithm is to deploy minimum number of relay nodes in which the algorithm create a path between two nodes like u and v and placing the relay nodes when necessary.

In paper [19] the author deploying relay nodes for fault tolerant in the heterogeneous wireless sensor networks, which having different transmission radius. There are two categories for deploying relay nodes.

- Partial Fault Tolerant Relay Node Placement (PFRP): In PFRP placing the minimum number of relay nodes between every pair of sensor node.
- Fully Fault Tolerant Relay Node Placement (FFRP): In FFRP placing the minimum number of relay nodes between every pair of sensor and / or relay node.

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III. PROPOSED ALGORITHM

A. *Description of the Proposed Algorithm:*

Aim of the proposed algorithm is to predict the faulty nodes before they actually faulty and to place minimum number of relay nodes as compared to existing system to recover the network from faults.

- Support Vector Machine (SVM) Algorithm for fault prediction:

Step 1: Let PT_{is} = path that connect node i to sink s, then obtain the value for every node n_i in path PT_{is}.

Like,

$D^{i,i-1}$ = delay bound between node ni & ni-1

$Jit^{i,i-1}$ = jitter between node ni & ni-1

$SNR^{i,i-1}$ =signal to noise ratio between node ni & ni-1

Thrput i,i-1 = throughput between node ni & ni-1

Step 2: Build a data set of failed nodes for variables mentioned in step 1 for these nodes for time Δt.

Step 3: Use SVM function for extracting features from the dataset in step 2.

$$\max \sum_{v=1}^{n} \phi_j - \frac{1}{2} \sum_{j,k=1}^{n} \phi_j \phi_k y_j y_k k(x_j x_k) \qquad (3)$$

Subject to the condition

$$\sum_{j=1}^{R} \phi_j y_j = 00 \leq \phi_j \leq C \qquad (4)$$

For j = 1,2,…,n

Step 4: Collect the four parameters for all nodes after time Δt and using extracted features in Step2 and using SVM function in Step3 to predict whether node will fail or not.

- Algorithm for Relay Node Placement

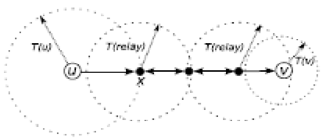
  Relay Node Placement Techniques:

  1. One way Steinerization

     Where, $\overrightarrow{uv}$ - Directed edge from 'u' and 'v'

     $|uv|$ - Euclidian distance from 'u' and 'v'

$$weight(\overrightarrow{uv}) = \begin{cases} 0 & \text{if } T(u) \geq |uv| \\ \left\lceil \frac{|uv| - T(u)}{T(relay)} \right\rceil & \text{if } T(u) < |uv| \end{cases} \qquad (1)$$



  2. Two way Steinerization

     Where, $\overset{\frown}{uv}$ - Undirected edge from 'u' to 'v'

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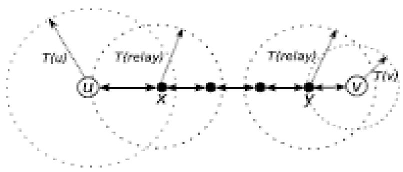
$|uv|$ - Euclidian distance.

$\delta = min\{T(u), T(v)\}$, $\lambda = min\{T(u), T(relay)\}$ and $\omega = min\{T(v), T(relay)\}$.

$$weight(\widehat{uv}) = \begin{cases} 0 & \text{if } |uv| \le \delta \\ \left\lceil \frac{|uv| - \lambda - \omega}{T(relay)} \right\rceil + 1 & \text{if } |uv| > \delta \end{cases} \qquad (2)$$



Algorithm for **One way** Partial Fault-tolerant Relay Node Placement (PFRP)

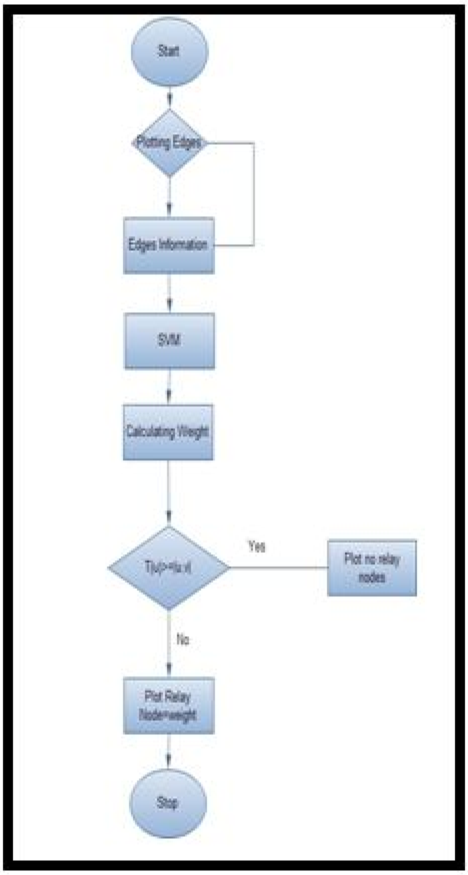


Figure 2 Flow Chart of Algorithm of **One Way** Partial Fault-tolerant Relay Node Placement (PFRP)

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Algorithm for **Two Way** Partial Fault-tolerant Relay Node Placement (PFRP)

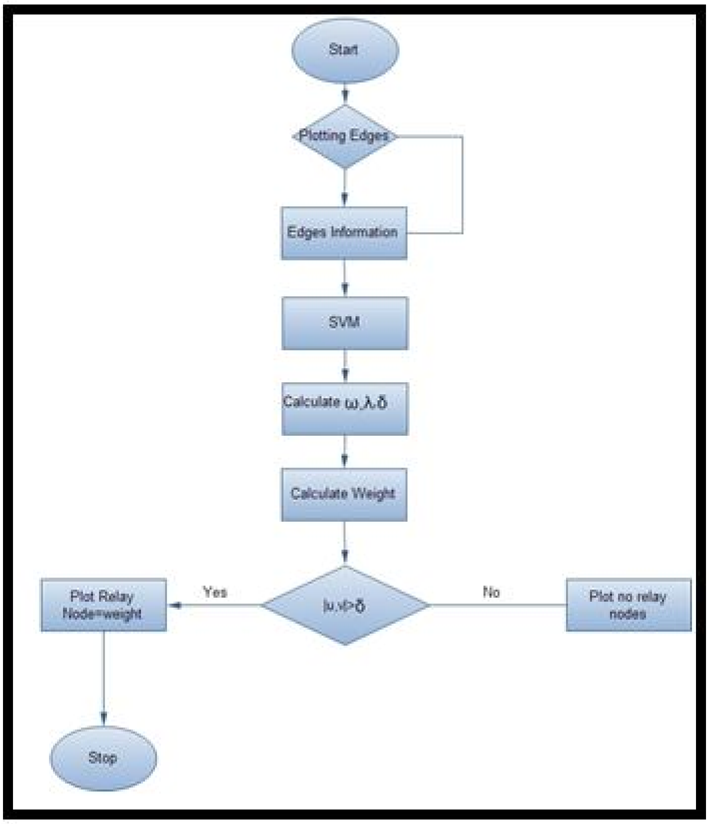

Figure 3 Flow chart of Algorithm of **Two Way** Partial Fault-tolerant Relay Node Placement

IV. SIMULATION RESULTS

There will be two parts for getting results.

1. For Fault Prediction:

   The Support Vector Machine (SVM) is compared to J48 and naïve bayes classifier. In this six parameters are considered true positive, false positive, precision, recall, F-measure and ROC. The performance of the SVM is better than j48 and naïve bayes. These six parameters are calculated by following formulas.

- True positive:-Faulty nodes correctly predict as faulty
- False positive:-Non faulty nodes are incorrectly identified as faulty
- True negative:-Non faulty nodes correctly identified as non faulty
- False negative:-Faulty nodes incorrectly identified as non faulty
- Precision= No. of true positives/No. of true positive + false positive
- Recall=No. of true positives/No. of true positives + No. of false negatives
- F-Measure=2.Prcision.Recall/Precision + Recall
- ROC (Receiving Operating Characteristics):- It is a curve plotting true positive rate against the false positive rate at various threshold settings.

In JAVA the jar files are used for calculating these values in my project these values are calculated which are shown in figure 4.

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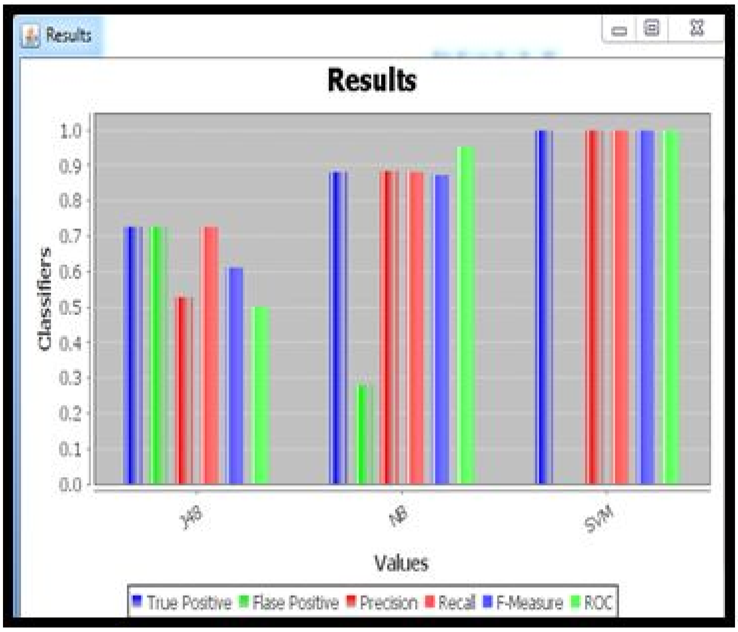

Figure 4 Comparison of SVM, J48 and naïve bayes classifiers

2. For Relay Node Placement:
   The number of relay nodes which are placed in proposed system is less than 3 to existing system. Therefore the performance of the proposed system is better than existing system, because the minimum number of relay nodes required send the packet from sensor to sink as compared to existing system, so the time required to sending packet and cost of relay nodes reduces.
   The formulas of calculating relay nodes in proposed system, which are as follows:

- One Way Stenerization:-

$$weight(\overrightarrow{uv}) = \begin{cases} 0 & \text{if } T(u) \geq |uv| \\ \left\lceil \frac{|uv| - T(u)}{T(relay)} \right\rceil -3 & \text{if } T(u) < |uv| \end{cases}$$

- Two Way Stenerization:-

$$\delta = min\{T(u), T(v)\}, \quad \lambda = min\{T(u), T(relay)\} \text{ and } \omega = min\{T(v), T(relay)\}.$$

$$weight(\widehat{uv}) = \begin{cases} 0 & \text{if } |uv| \leq \delta \\ \left\lceil \frac{|uv| - \lambda - \omega}{T(relay)} \right\rceil -3 & \text{if } |uv| > \delta \end{cases}$$

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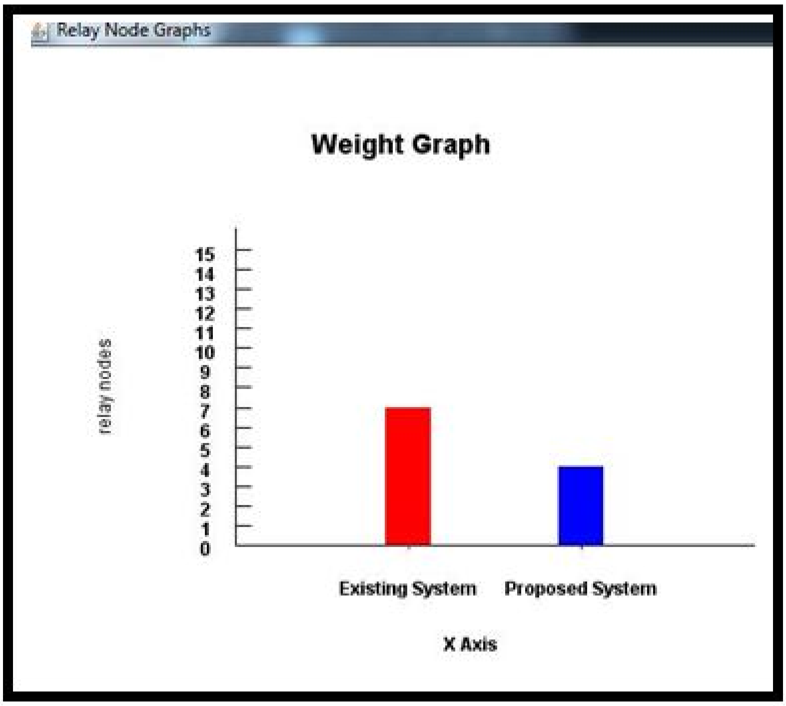

Figure 5 Comparison of Existing System and Proposed System for Relay Node Placement

V. CONCLUSION AND FUTURE WORK

Faults occurring in WSNs are common due to various reasons such as battery exhaustion, malfunctioning, etc. This may jeopardize the reliability of WSN network. Existing solutions use reactive approaches for relay node placement in WSN to tolerate the faults. In proposed system a proactive technique is used to predict nodes that are likely to become faulty in WSN and then they will be tolerate proactively to placing minimum number of relay nodes to continue network communication.

In future the distributed wireless sensor network is developed for the purpose of fault prediction and fault tolerant. The distributed wireless sensor network contain the more than one sink node, so the load of on one sink node is decrease and time is reduces for complete the all process.

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BIOGRAPHY

Smita Kharade and Prof. Simran Khiani are a research in the computer department, college of G.H.Raisoni college of Engg and Mgmt, Savitribai Phule Pune University. Smita Kharade is the student of ME(Computer Network) in computer department, Assistant Professor is BTech, MTech, PHD (Pursuing), her research interests are Computer Networks, Image Processing.