Fault Prediction and Relay Node Placement in Wireless Sensor Network - A Survey

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Abstract: *A collection of a sensor nodes which co-ordinate with each other in a sensor network.. The WSN have become popular due to their various varieties of real world applications. Failures are occurring in WSN due to many reasons such as communication link failures, battery exhaustion, environmental hazards, hardware failures or malfunctioning, this may reduce the reliability of WSN network to act as monitoring systems for networks. In WSN networks detection of an event by nodes is one of the most important application of wireless sensor network, because of impact of environmental factor or faults. In this paper we concentrate on the prediction models in WSN to be useful for predict the faulty nodes in WSN and repair the faulty nodes by using Relay Node Placement.*

Keywords: Wireless Sensor Network, Fault Prediction, Fault Recovery, Relay Node Placement.

1. Introduction

Wireless Sensor Network (WSN) has been widely employed for enabling various monitoring and control applications, such as environmental surveillance, industrial sensing, traffic monitoring, health care, and military, etc. Wireless Sensor Network consists of various types of sensor nodes. The nodes communicate with each other wirelessly and often self organize in an ad-hoc fashion. These nodes can be placed in various places likes underwater, on human bodies, in the air, on the ground and within the buildings, etc. which sense the environmental conditions such as temperature, pressure, humidity, etc. each sensor node capture events of interest and transfer that captured event to the base station called sink node. Due to small irreplaceable and non rechargeable batteries, sensor nodes have limited power. [11]
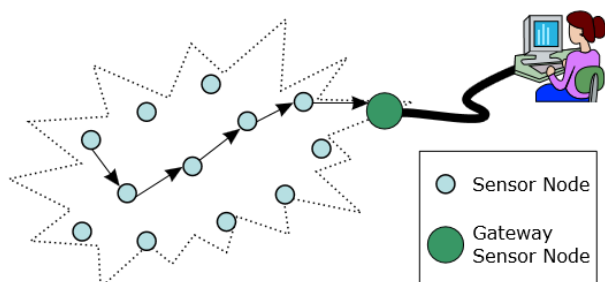
Figure 1: Architecture of WSN

In figure sensor nodes send the sensed data to the main location or sink by using gateway sensor node.

The failure is occurs in WSN in many reasons such as environmental hazards, hardware failure, or malfunctioning, communication link failure, battery exhaustion, etc. Faults in sensor nodes may act on network to produce in incorrect data provided by sensor nodes or the network may make a misjudgment on events. The faults may reduce the quality of services (QoS) and reliability of the network. [7]

There are three types of failures in WSN [13]

- **Fault**: Fault means an abnormal condition or defect to lead to failure.
- **Error**: It is a state to lead to failure in undefined way.
- **A Failure**: It is a state or condition to not meet at desirable objective.

To recover from these faults, we first detect the fault in the network for the purpose of repair the network and continue working of this network. To identify the faulty nodes in WSN, is not a trivial task, the nodes in WSN are powered by limited power sources, such as irreplaceable batteries, so it is expensive and power hungry technique for the sink (base station) to collect status information from every sensor node in the WSN to identify faulty nodes in the centralized manner. Many applications require the faulty node detection with low latency in real time. The time needed for detection of faulty node jeopardize the reliability of WSN networks during that period of time. [12]

To recover from faults in nodes of WSN the commonly used solution is to use redundant nodes in the network. In particular nodes in WSN periodically forward sensed data to the sink. If some nodes fail to provide sensed data, the sink still receives the information from redundant nodes. Multipath routing can also be used to send sensed information from the nodes to the sink. The sink discards duplicate information. [1][14]

To place the additional relay nodes in WSN to improve network connectivity, in this two ways to place relay nodes in WSN. [16]

- **Homogeneous** wireless sensor nodes are to be placed a relay nodes having the same transmission radius
- **Heterogeneous** wireless sensor nodes are to be placed a relay nodes having the different transmission radii.

2. Prediction Models

Prediction Models In paper [1] they propose a statistical modeling by using the data of real WSN application i.e. ARIMA (p, d, q). The Auto Regressive Integrated Moving Average is useful for forecasting a time series .The properties are statistical like mean, variance are constant. The advantages of ARIMA model is to use for the particular node we want and also in fault tolerant purpose. The ARIMA model is construct the prediction model for sampled data. The ARIMA model makes more computational overhead than simple prediction methods.

In ARIMA model given n moving window at Pt, the prediction is:

$$\acute{P}_t = c + \varphi_1\,\acute{P}_{t-1} + \dots + \varphi_r\,\acute{P}_{t-r} + \theta_1\,e_{t-1} + \dots + \theta_q\,e_{t-q} + e_t,$$

Where, Pt is different series, r and q are the order of the autoregressive and the moving average part; d is degree of differencing involved φ and θ are parameters of the AR and MA terms respectively. [8]

In paper [3] discuss about the different data prediction methods for WSN. The data prediction techniques contain two prediction models, one at sink side and other at the sensor side. It avoid the rapid fall in the predicted values, Therefore these approaches want to timely validated and update their models. Data prediction models for WSN are based on time series forecasting.

In paper [10] discuss about the grey model and kalman filter model for prediction based data aggregation in wireless sensor networks.

- **Grey Model:**

If all information about the system is known as white system and the no information about the system is known as black system. The intermediate between white system and black system is known as grey model. For the purpose of powerful tool for modeling discrete series with a few data items and for forecasting based on determination of an exponential pattern the grey model is used. The sensor nodes can be behave as a uncertain grey system in the data aggregation process, therefore only a small sample and poor information is stored provided.

- **Kalman Filter Model:**

Kalman Filter estimates the state of a linear dynamic system. Also it is an efficient recursive filter. It shows small quantity of information on high prediction accuracy. Kalman Filter used local aggregation of the sensor data. The Kalman Filter is used to estimate the data sequence for each sensor node than to choose sensor nodes.

In paper discuss [9] about the cluster based fault identification and detections.

Two ways predicted the faulty nodes in WSN.

- **Monitoring node status**

- **Monitoring link status**

Sensory nodes can be observe periodically using predefined time to predict link failure and TDMA time slot to predict the range and link failure, also event driven techniques to predict energy depletion.

Monitoring link quality is useful for predefined time schedule to detect the link failure. Monitoring link quality using TDMA time slot to detect link and range failure.

3. Relay Node Placement

In paper [16] two ways we can place the relay nodes in wireless sensor network

✓ **Steinerization of Edges:**

Suppose u and v be two target nodes, we want to place the minimum relay nodes in between u and v then two steps we follow:

- **One way Steinerization**

In one way stenerization the directed edge uv is considered and create one way path from u to v and place a minimum number of relay nodes from u to v when necessary.

In two way stenerization the undirected edge uv is considered and create a two way path from u to v and place the minimum number of relay nodes from u to v when necessary.
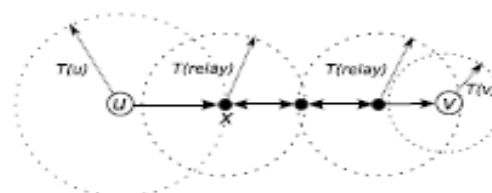

Figure 2 (a): One way Steinerization of directed edge uv

In Figure 2 (a) One way Steinerization is shown ,In this T(u) and T(v)are the range of target nodes u and v. T(relay) is the range of relay nodes and they are placed in one way in minimum number.
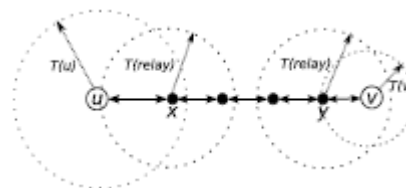
- **Two way steinerization**

Figure 2 (b): Two way Steinerization of undirected edge uv

In Figure 2 (b) Two way Steinerization is shown, In this relay nodes are placed in two ways like left to right or right to left.

✓ **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, split the neighbors of x with the pair of positive values (r1, r2). First we create a circle with radius r1 at node x and also create a square just large to recover the circle. Then segment this square from left to right and top to bottom into small cells with length is diagonally equal to r2. This is shown in figure 3.
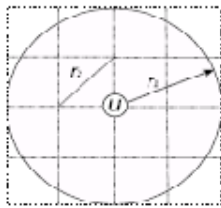
Figure 3: Segmentation of neighborhood of nodes u with (r1, r2).

In paper [4] two iterative algorithms are discussed.

- **Steinier MPC:**
The Steineir MPC algorithm is to deploy minimum number of relay nodes to create number of k-vertex disjoint path from any sensor node to any other sensor node or relay nodes.

- **Steineir PSO MPC:**
The PSO algorithm is a population based iterative parallel search algorithm that takes social behavior and moment dynamics of swarm. The PSO execute each degree deficient node in the list to relay nodes with the objective of particle swarm population to minimize sum of weights all nodes in the list with relay and for increase connectivity of maximum nodes in the list.

4. Conclusion

In this paper, we discuss about the various Fault Prediction methods and ways of minimum number of Relay Node Placement in Wireless Sensor Network.

In future we propose a new prediction model to predict the Faulty nodes in the Wireless Sensor Network and place a minimum number of Relay nodes heterogeneously to repair the fault in Wireless Sensor Network.

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