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Link Failure Detection and Classification in Wireless Sensor Networks using Classification Method

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Abstract—This paper develops a method to detect the failures of wireless links between one sensor nodes to another sensor node in WSN environment. Every node in WSN has certain properties which may vary time to time based on its ability to transfer or receive the packets on it. This property or features are obtained from every node and they are classified using Neural Networks (NN) classifier with predetermined feature set which are belonging to both weak link and good link between nodes in wireless networks. The proposed system performance is analyzed by computing Packet Delivery Ratio (PDR), Link Failure Detection Rate (LFDR) and latency report.

Keywords: Wireless links, sensor nodes, link failure, neural networks, performance;

I. INTRODUCTION

Wireless Sensor Network (WSN) consists number of sensor nodes which can be connected through the wireless networks [11]. The sensor node responsibility is to deliver the packets from source node to distant sensor node through certain number of intermediate sensor nodes [12]. The sensor nodes are grouped into one cluster and each cluster may have single cluster head, which is the responsible node for accumulating all the packets from all the sensor nodes with in this cluster region. Fig.1 shows the architecture of WSN. Each sensor node in wireless sensor networks transmits and receives the packets from one sensor node to another sensor node through the shortest wireless link or path [13]. This path between two sensor nodes can be categorized into weak and strong. The path or link between two nodes will be strong if both nodes are having enough number of energy and they must not be malicious or residual sensor nodes [14,15]. If any one of the node between two nodes is having lack of energy in network environment, then there will be the formation of link failure between two nodes. This is the main reason for developing and originating the link failures in wireless sensor networks [16]. The present link failure detection method detects the faults between two nodes after forming the link failures in between them.

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This will cause the lost of packets over the network environment. Hence, the detection of link failures or faults before it is occurring in wireless sensor networks is important in order to lose the packets while transmission or reception over the network [17]. This paper proposes a method for identifying the faults which causes the link failures on the sensor nodes in wireless sensor networks, using soft computing approaches.

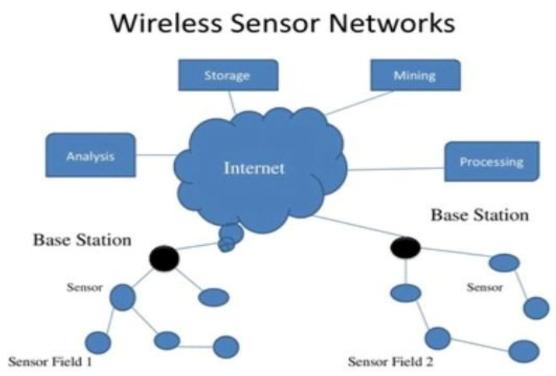

Figure 1 WSN architecture

This paper is structured as, section 2 states various conventional techniques for fault detection between two sensor nodes, section 3 proposes a novel method for detecting and classifying the link failures between sensor nodes, section 4 states the network simulator simulation results. Section 5 concludes this paper.

II. LITERATURE SURVEY

ZainibNoshad et al. (2019) used random forest classification technique to detect the failure of wireless link between two adjacent sensor nodes in WSN environment. The detection rate was not optimum using this unsupervised classification technique and the authors obtained 90.1% of LFDR, 81.6% of PDR and 35.3 ms of latency. Yuan et al. (2018) detected linear faults in wireless sensor network using Support Vector Machine (SVM) classifier. The faults were detected between any two distinct sensor nodes in WSN environment. The authors tested this fault detection method using regression test scheme and this method for fault detection obtained 88.7% of LFDR, 80.4% of PDR and 52.2 ms of latency. Gao et al. (2018) developed a method for detecting the distributed faults in sensor nodes of WSN environment. Fuzzy logic based Stochastic matrix was developed by considering the internal weights of each sensor nodes in wireless sensor networks.

The authors obtained 82.1% of recognition rate by implementing their proposed work on large number of sensor nodes deploying environmental simulation area.

Li et al. (2015) developed the constrained mapping method for detecting the non-static faults in between two sensor nodes in WSN environment. This mapping architecture was constructed based on the number of packets correctly transmitted and received between two set of sensor nodes over a specific time period. The authors obtained 86.5% of LFDR, 79.9% of PDR and 79.9 ms of latency. Duche et al. (2012) identified the misbehavior nodes due to faults between two sensor nodes in wireless networks using machine learning algorithm. The authors constructed feature matrix from each sensor node and this feature matrix was classified using linear protocol method. The authors obtained 81.1% of fault detection rate by implementing their proposed method. Jiang (2009) developed fault free wireless sensor network with large number of sensors. The authors used propagation linear and regression algorithm for detecting the faults between two sensor nodes in wireless networks.

III. PROPOSED METHODOLOGY

This paper develops a method to detect the failures of wireless links between one sensor nodes to another sensor node in WSN environment. Every node in WSN has certain properties which may vary time to time based on its ability to transfer or receive the packets on it. This property or features are obtained from every node and they are classified using Neural Networks (NN) classifier with predetermined feature set which are belonging to both weak link and good link between nodes in wireless networks. Fig.1 shows the classification procedure of each link between sensor nodes in WSN.

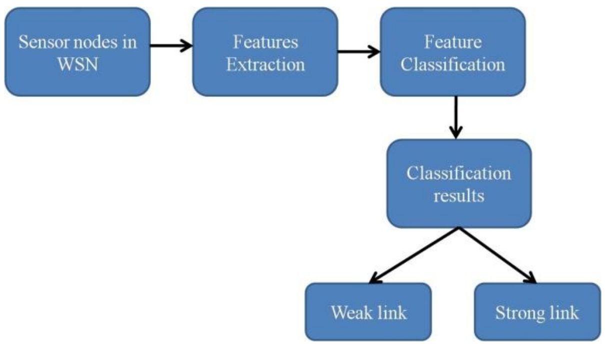

Figure 1 Classifications of links between sensor nodes

Feature Extraction

Peak time features

The nodes in sensor networks are differentiated as static and dynamic nodes. Each dynamic node follows certain peak time to keep the same place and the time taken by the dynamic node is given as,

$$tn = \frac{\alpha}{\omega * \tau * \sqrt{1-\rho^2}}$$

Whereas, α is the number of packets transmitted at time 't', ω is the bandwidth of the sensor node, τ is the mobility period of the sensor node and ρ is the velocity of sensor node.

The velocity of sensor node is determined using the following equation,

$$\rho = \frac{P}{c}$$

Whereas, P is the total number of cumulative packets at time 't' and c is the speed of the light particle.

Heuristic features

The heuristic features describe the packets transmission and reception flow on each node in WSN environment. The heuristic feature of each node depends on the weight function of the node in network. Fig.3 shows the nodes deployment in WSN environment which consists of five numbers of sensor nodes N1, N2, N3, N4 and N5. Each node has its own weighting function W1, W2, W3, W4 and W5.

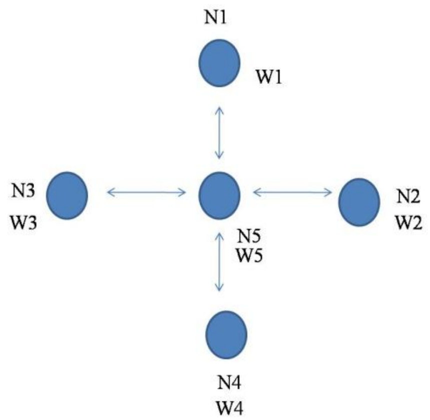

Figure 3 Heuristic features computations

The weighting function of each sensor node in wireless network is given in the following equation.

$$W_i = \frac{\alpha * (1-\beta)}{\alpha + \beta}$$

Whereas, α is the total number of packets transmitted by a node in network over the time period 't' and β is the total number of packets received by a node in network over the time period 't'.

The heuristic feature of each node in sensor network is computed as,

$$h_i = \frac{\alpha * \beta - \gamma}{W_i}$$

Whereas, γ is the total number of packets lost over the time period on node.

Distance metric features

The distance metric features are computed between center node to all of its surrounding nodes using Euclidean method in WSN environment. The distance metric between two adjacent sensor nodes is computed using the following equation.

$$T_1(ED) = \sqrt{(x_c - x_1)^2 + (y_c - y_1)^2}$$

Whereas, (x_c, y_c) are the position coordinates of the center sensor node and (x_1, y_1) are the position coordinates of the surrounding sensor node.

Classifications

The computed features from each sensor node in WSN environment is classified using NN classifier in this paper. This NN classifier are categorized into Radial NN and Feed forward back propagation NN. The training time period is high in case of radial NN and hence this paper uses Feed forward back propagation NN for the classification nodes computed features. Fig.4 shows the architecture of NN classifier used in this paper. This architecture consists of input layer and output layer with hidden layers. The input layer is fed with the extracted set of features and the hidden layer is designed with weight basis of the nodes. The neurons in output layer are unique and hence it produces unique response. Initially, this architecture is trained by the features from weak link and strong link and the trained pattern is stored for classifications. Then, this trained pattern is classified with the features which are obtained from the nodes to be checked.

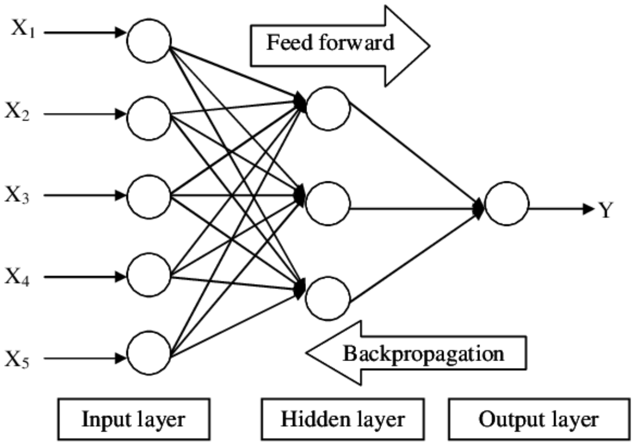

Figure 4 Feed forward back propagation NN architecture

This multi layer neural network architecture produces binary output. The strength of the link between nodes in network is classified with respect to the following equation.

$$Stenght\ of\ node = \begin{cases} Strong; if\ y = 1; \\ Weak; if\ y = 0; \end{cases}$$

IV. RESULTS AND DISCUSSIONS

In this paper, Network Simulator 2 (NS2) is used to simulate the proposed link failure detection and classification system. The simulation environment consists of 100 number of sensor nodes and the distance between each node is assumed to be 100 m with total environment width and height is 1000 m and 1000m, respectively. The nodes initial bandwidth is fixed as 100 MHz and its baud rate of each node is 150 bytes per second. During simulation time period, 15 number of link failures are generated in simulation environment. The performance of the link failure classification system is analyzed using the following equation.

$$Link\ Failure\ Detection\ Rate(LFDR) = \frac{Number\ of\ link\ failures\ detected}{Total\ number\ of\ link\ failures} * 100$$

This proposed system detects 14 number of link failures over 15 number of link failures in the network environment. Hence, the methodology to detect the link failures in WSN environment achieved 93.3% of LFDR.

The packets transmission and reception on each sensor node is affected by the link failures. Hence, the analysis of Packet Delivery Ratio (PDR) is important for the proposed system. The PDR values are analyzed with respect to the number of link failures in this paper. The value of PDR decreases when there are number of link failures in the network. In this paper, the number of link failures is increased exponentially in the simulation environment and then PDR is computed and stated in Table 1.

If there is a link failure between two node, then the packets should be transmitted to the destination node by selecting alternate path and computing its strength of the path also. This will increase the packet delivery time period. This period which takes time between two nodes such as source node and destination node. Table 2 shows the latency analysis of the proposed system.

Table 1 Analysis of proposed system with respect to PDR and latency

Number of link failures	PDR (%)	Latency (ms)
1	98.9	12.7
2	97.6	16.9
3	96.5	21.5
4	96.1	23.8
5	94.1	28.1
6	93.8	32.9
7	92.1	34.7
8	91.6	37.8
9	90.5	39.1
10	89.7	41.8
11	88.3	42.2
12	87.6	45.8
13	86.5	48.1
14	72.9	51.9
15	70.1	53.2

The proposed link failure detection method stated in this paper achieved 93.3% of LFDR, 89.7% of PDR and consumed 35.3 ms of latency. Fig.5 shows that the analysis of proposed system with respect to PDR and latency.

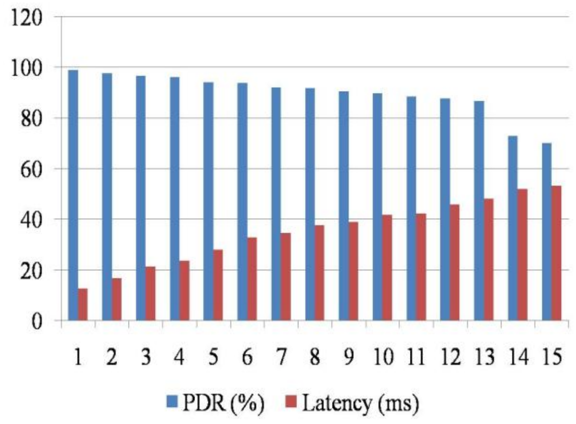

Figure 5 Analysis of proposed system with respect to PDR and latency

Table 2 shows the comparisons of the proposed link failure detection methodology with conventional link failure detection methodologies in terms of LFDR, PDR and latency.

ZainibNoshad et al. (2019) obtained 90.1% of LFDR, 81.6% of PDR and 35.3 ms of latency. Yuan et al. (2018) obtained 88.7% of LFDR, 80.4% of PDR and 52.2 ms of latency. Li et al. (2015) obtained 86.5% of LFDR, 79.9% of PDR and 79.9 ms of latency.

Table 2 Comparisons of the link failure detection methodologies

Methodologies	LFDR (%)	PDR (%)	Latency (ms)
Proposed work	93.3	89.7	35.3
ZainibNoshad et al. (2019)	90.1	81.6	45.9
Yuan et al. (2018)	88.7	80.4	52.2
Li et al. (2015)	86.5	79.9	79.9

Fig. 6 shows the comparisons of proposed method with other state of art methods.

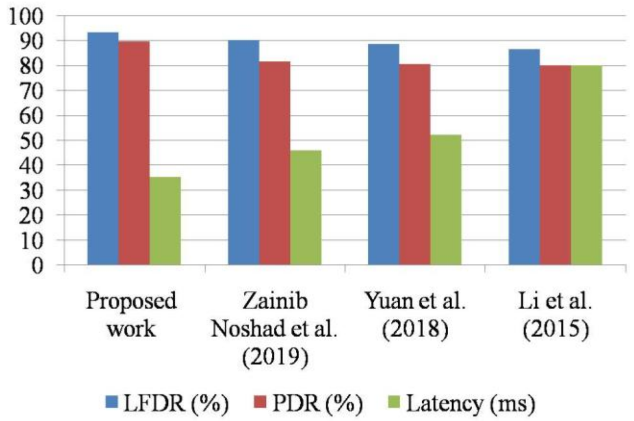

Figure 6 Comparisons of proposed method with other state of art methods

V. CONCLUSIONS

In this paper, NN classification approach based link failure detection method is developed and proposed. Every node in WSN has certain properties which may vary time to time based on its ability to transfer or receive the packets on it. This property or features are obtained from every node and they are classified using Neural Networks (NN) classifier with predetermined feature set which are belonging to both weak link and good link between nodes in wireless networks. The proposed link failure detection method stated in this paper achieved 93.3% of LFDR, 89.7% of PDR and consumed 35.3 ms of latency.

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