Detection of Coverage Hole Nodes in Wireless Sensor Network using Artificial Intelligence

Mainka, Khushal Thakur, Kiran Jot Singh

Abstract: Adequate coverage of the sensing field in Wireless sensor networks (WSNs) is critical to many applications. However, when one or more sensor nodes stop working due to energy exhaustion or physical damage, the network may experience overlay vulnerability. This can disrupt network connectivity and hinder performance. Therefore, it must be fixed automatically. To resolve this problem, swarm inspired Artificial Bee Colony (ABC) scheme in addition to the Artificial Neural Network (ANN) approach is used. The aim of ABC is to optimize the shortest path by selecting an appropriate fitness function and then identify holes using ANN. Before the detection of holes, ANN is trained as per the optimized properties of nodes that are as per the genuine nodes and coverage hole repair properties. Therefore during the testing process, ANN compares these properties with the stored properties and then identify the hole repair node. From the experiment, it has been analyzed that the energy consumption up to 23.88% is saved.

Index Terms: WSN, coverage holes, mobility, ABC, ANN

I. INTRODUCTION

A WSN consists of tiny sensor nodes, each of which is used to sense certain physical properties, performing some task on the collected data and communicate with each other [1]. The sensor nodes are installed in a remote area with multiple numbers and interconnected to create a network known as WSN as shown in figure 1. All the sensor nodes are self-organized, each of which is responsible for the data collection and transformation using the sensor node named as a source node and destination node respectively [2]. These networks find application in various fields such as in civil and military application. In civil applications such as used for environmental monitoring, traffic control whereas in military WSN can be used to identify attacker, to track objects and disaster recovery [3].

To collect data from the sensor nodes deployed in these applications needs adequate coverage of the sensing area so that the sensed data can be transmitted to the receiver node [4]. The observation of sensing area helps to measure the region, which is being monitored by the deployed nodes [5]. Therefore, nodes must be deployed either randomly or in a planned way lies in a region of interest (ROI). The network faces the problem of coverage holes, in case, when the nodes lose their energy or any hardware failure. After the appearance of coverage holes the network stop functioning or that area cannot be monitored by the sensor nodes.

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In addition, the formation of coverage holes is a predictable phenomenon in WSN, and if it remains unattended, the number and size will gradually increase [6]. Covering the existence of vulnerability reduces and destroys the functionality as well as the throughput of the complete network.

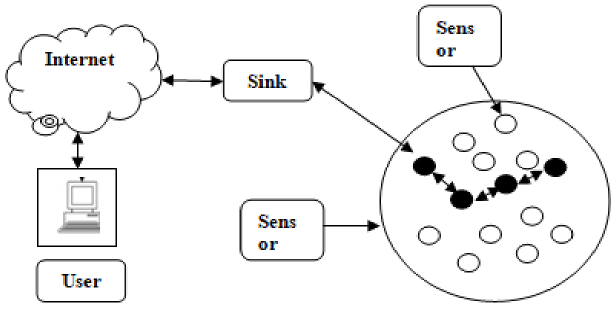

Figure 1 WSN architecture

The coverage holes can damage data transfers, disconnect the network connections, and leave certain areas of the network unmonitored. Therefore, one may not be able to observe critical events or may compile inaccurate data [7]. As the continuous monitoring of the network is very important, which again depends upon the sensing of field therefore, it is necessary to make sure that the sensing area must be covered continuously. Since, the network is designed to a remote area where the human approach is unfeasible. Therefore the management of WSN connectivity becomes a serious problem. Therefore, we must design a network that can detect and repairs these holes with high efficiency and at the accurate time [8]. In this research, to resolve this problem, optimization technique along with artificial intelligence has been used.

II. RELATED WORK

Sahoo et al. (9, 2015) presented an effective hole repair algorithm by using the concept of reducing the coverage area of overlapping nodes. This helps to keep nodes connected with the limited movement of the nodes. The nodes are selected as per the rate of overlapping coverage area. The mobility of the nodes has been limited by one hop and hence save the amount of energy. Zhao et al. (10, 2016) have focused on detecting boundary holes as well as coverage holes.

Two algorithms named as Distributed Sector Cover Scanning (DSCS) and Directional Walk (DW) have been used to detect the nodes on the ROI of the network as well as to allocate these identified holes respectively. From the experiment, it has been observed that the proposed DSCS algorithm works efficiently to detect holes as well as the boundary nodes respectively. Cheng et al. (11, 2011) presented a delay aware data gathering network for WSN and helps to reduce the delay exists during the data collection process. The mainly centralized and decentralized approach has been used to design a network and concluded that these approaches help to minimize data during the data gathering process. He, Y and Q. (12, 2017) presented a sensor development density structure to detect and repair signal hole pair in WSN. Using this scheme the problem of coverage route as well as the hidden route can be resolved by utilizing the concept of multi-direction connected graph. Fan et al. (13, 2014) proposed an intent strategy known as 'Improved Hybrid Particle Swarm Optimization' (IHPSA) for the fixing of coverage holes. In a hybrid sensor network, the solution combines the displacement, energy consumption and energy balance of the mobile sensor nodes, effectively scheduling those nodes, repairing coverage holes by moving to the suitable location, and then increasing the event detection rate. The simulation results show that the mobile algorithm has better coverage with better event detection capability.

III. MATERIALS AND METHODS

The algorithm mainly goes through three different phases namely; distance calculation, node optimization and classification.

A. Distance calculation

To retrieve coverage holes, the replacement node must require determining the best distance and target position. Therefore, it becomes necessary for each sensor nodes to be determined distance so that the nodes can take a decision regarding the way where to move the node.

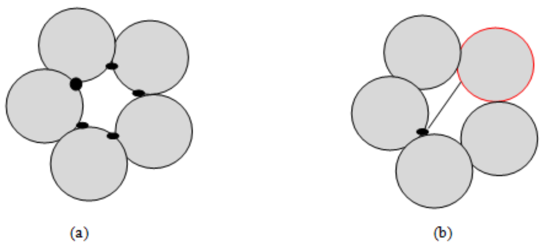

Figure 2 Intersection Point and the moving distance

These distance calculations will be used to select the most qualified replacement node. Particularly, each node calculates coordinates of the pair of intersections with each neighboring node. Using this formula, the points that are nearer to the coverage hole are considered whereas the remaining points are discarded [14].

The intersection of hole pair determined at the ROI of the network is shown in figure 2. The distance can be calculated by using the formula written below:

$$d = \sqrt{(x_i{}^2 - x_j^2) + (y_i{}^2 - y_j^2)} - r \ldots.. (i)$$

In equation (i), the moving distance of sensor points is determined by distance d, it is basically the distance between the ROI of the existing node and the point of intersection of the distant node as shown in figure 2(b) The distance of these points can be optimized by using the ABC algorithm the detail description is provided in the subsequent section.

B. ABC

It is a swarm inspired optimization scheme used to find the best points in the network. The fitness function is decided on the basis of which, it becomes able to find the best route. In 2005, Derbis Karaboga has defined the new ABC algorithm determined by the smart behavior of bees. Artificial bee colony algorithm is as simple as PSO (Particle Swarm Optimization). In ABC algorithm, the location of food is customized by the artificial bees according to the time and the bee's goal is to find out the places of food sources with high nectar amount and at last the one with the maximum nectar [15]. The algorithm of ABC is defined below:

ABC algorithm

Load properties of nodes
Evaluate the fitness function of the nodes
Initiate the network size
Fitness function

$$ABC_{fit\_fn} = \begin{cases} Bee_{cur} & if \quad Bee_{cur} > Bee_{on} \\ Bee_{on} & else \end{cases}$$

Where ABC_{fit_fn} the output of fitness is function and Bee_{cur} is the total bee which is called properties of nodes and Bee_{on} is the threshold value of nodes
Set iteration to 1
Define the- Employed bee
-Onlookers bee and
-Scouts bee
Repetition
For each employed bee
Construct a new solution using fitness function condition
Calculate the best fit value according to the fitness function
Calculate the probability of optimal value for the solution
End
For each onlooker bee
Select a solution depending on the fitness value
Produce a new solution
Calculate the best fit value
End
If there is a redundant solution
Then replace it with a new solution
Update the best solution and store
End
Iteration=Iteration + 1
Until iteration = Maximum Iteration

C. ANN

The optimized features of the sensor nodes are provided as an input to the input layer of the ANN structure. The ANN comprises of mainly three layers: input, output and the middle layer also known as a hidden layer. This algorithm works in the same fashion as that of the human brain. The input properties such as energy consumption of node, delay, a distance of nodes are provided as an input to the input layer. In the hidden layer, the neurons are applied in such a way so that the nodes can be adjusted in such a way so that the exact solution can be determined [16]. The algorithm of ANN is defined below:

ANN Algorithm:

Input: Network properties as a Training Data (T), Target (G) and Neurons (N)
Output: detect hole repairs
Initialize ANN with parameters – Epochs (E)
– Neurons (N)
– Performance
parameters: MSE, Gradient, Mutation & Validation
– Training
Techniques: Levenberg Marquardt (Trainlm)
For each set of T
$Group = Categories\ of\ nodes$
End
Initialized the ANN using Training data and Group
Net = Newff (T, G, N)
Set the training parameters as per the requirements and train the WSN
Net = Train $(Net, Training\ data\ , Group)$
Classify = simulate (Net, Single node properties)
If Classify = True
Genuine Node = Simulated Node
Else
Affected hole repair node = Simulated Node

IV. EXPERIMENTAL RESULTS

The experiment has been performed in MATLAB simulator. The nodes range from 50 to 100 are deployed randomly in the designed network area of dimension (1000×1000) square meter as shown in figure 3.

The performance of the network is measured in terms of different QoS parameters such as throughput, PDR, energy consumption, and battery usage. The throughput of the proposed network with respect to a number of iterations is shown in figure 4. The Average throughput determined for the designed network while applying ABC with ANN approach or after the detection of coverage hole is about 90.7%. From the figure5 it is clear that as the number of iterations increases throughput decreases.

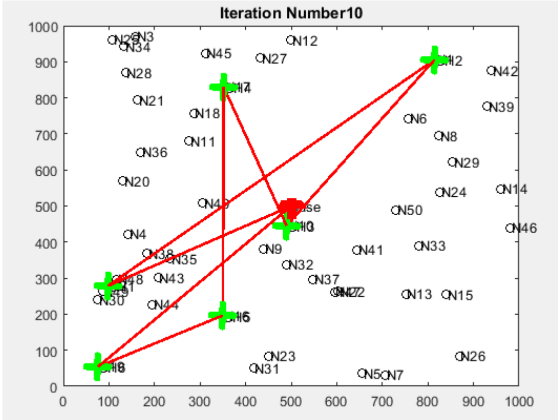

Figure3 50 nodes are deployed to monitor 1000 square meter network area.

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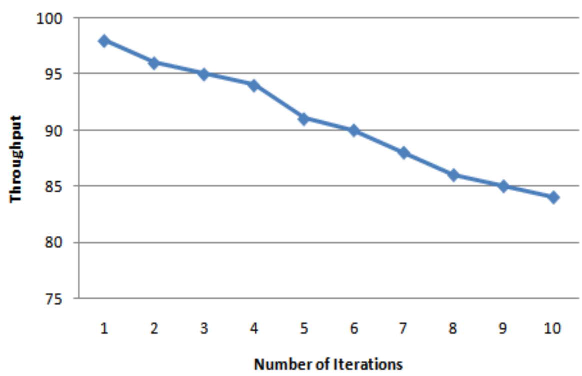

Figure4 Throughput

Packet delivery ratio represents the rate of transmitting a number data packet to the receiver with respect to the total number of data transmitted from the source node. In this research after the detection of coverage hole, the PDR of about 0.525 has been achieved.

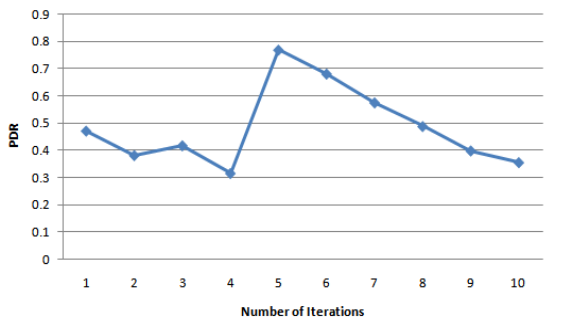

Figure5 Packet Delivery Ratio

The main focus of this research is to minimize energy consumption. Therefore, using ABC with ANN approach the energy consumed by the nodes while detecting and preventing the network from the coverage hole repair is shown in figure 6.

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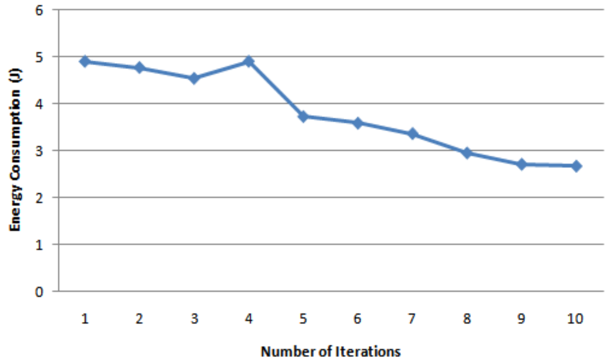

Figure6 Energy consumption (j)

The average energy consumed by the nodes of about 3.806 J has been obtained. To show the efficiency and the enhanced of our work, a comparison between proposed and existing work is provided as shown in figure7.

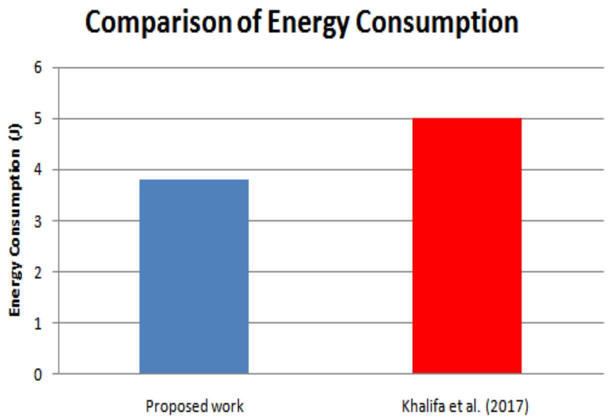

Figure 7 Comparison of energy consumption with existing work.

V. CONCLUSION

Depending upon the minimization concept of the coverage overlap area the network area can be maximized. Therefore by proper utilizing the concept of swarm intelligence inspired ABC algorithm along with machine learning technique (ANN), the connectivity among the nodes retains. The coverage hole repair algorithm is designed to maintain network coverage and connectivity through the limited mobility of nodes. The shortest distance identified by using the distance formula has been optimized using an appropriate fitness function of the ABC algorithm. The detection of holes has been performed using the ANN technique. Using this process, the energy up to 23.88 % has been saved compared to the existing approach.

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