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COVERAGE ASSESSMENT IN RANDOMLY DEPLOYED WIRELESS SENSOR NETWORKS VIA HETEROGENEOUS NODES

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Abstract. Coverage as a performance metric, quantifies the quality of network connectivity in a wireless sensor network (WSN). The fundamental idea of this paper is to maximize the coverage in randomly deployed WSN. This paper proposes the usage of some smart nodes which will provide the link establishment between unconnected nodes to the base station. Smart nodes are deployed according to the distance information to increase the coverage and the network connectivity. By the simulated experimental results in ImageJ tool and Matlab, it is proved that the coverage will increase with the help of optimum number of heterogeneous smart nodes.
Keywords: Wireless Sensor Network, Coverage, Connectivity, ImageJ, Smart node, Heterogeneous, Matlab.

I. INTRODUCTION

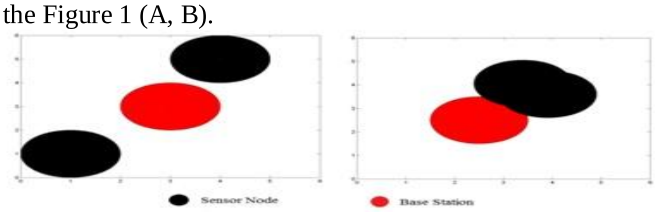
Thus sensing coverage is one of the most important service factors in Wireless sensor networks. Coverage reliability of any sensor network is given by coverage rate that is the area covered by sensor nodes in the region of interest [1]. WSN consists of number of small, low-power nodes in which each equipped with sensing devices and wireless transceiver and often works in unknown environment. Spatially distributed self configurable sensors are employed in WSN to monitor environmental or physical conditions. WSN is normally being applied in many areas such as military, civilian, medical, industrial application. The cost and size constraints of a sensing node are a trade off for resources such as energy, computational speed and memory [2]. Due to these limitations of sensor nodes many problems such as routing, scheduling and coverage are to be dealt with in WSN. In customary WSN sensor nodes are stationary, the sensing area of most nodes is overlapped and the sensing coverage fraction cannot be repaired automatically. A large numbers of sensor nodes should be employed in stationary sensor network to provide proper sensing coverage according to the proportion of the sensing range of nodes to the area of the target region. This paper mainly focusses on increasing the coverage by using anchor nodes. These anchor nodes can repair the connectivity based on the precise distance information of the sensing fraction which is deduced from the relative position of each node to the other nodes in WSN. The rest of the paper is organized as follows: Section 2 briefly summarizes the related work and also details the coverage problems in WSN. Section 3 gives the proposed work. Section 4 details the results and observations. Finally, Section 5 concludes the paper with some future prospects.

II. RELATED WORK

One of the primary tasks of a WSN is the collective monitoring of a field of interest. In order to monitor the entire field of interest, one needs to make sure that every point of the field is covered by at least one sensing node. The coverage problem is to quantify how well is the field of interest sensed by the deployment of the sensor network [3]. Coverage problem is defined as a minimization problem, in which the total area of coverage holes and uncovered region in a network need to be minimized [4]. In the research paper [5], sensing coverage area is calculated by theoretically assuming a uniform deployment of sensors in a field. We know the deployment of sensors in a field may not be uniform in real world. A lot of research has been done to solve coverage problem in WSN [6-7]. The main focus is on the type of coverage strategies; Voronoi and Delaunay triangulation, force based and grid based. Wang [8] used voronoi diagram as the coverage strategy that helped sensors to decide whether to stay or to reposition. Combination of voronoi diagrams and PSO algorithm is explained clearly in [9]. The authors [10] also stated that PSO application in voronoi diagram approach can give better coverage result. The research paper [11] uses Voronoi diagram to estimate the number of additional nodes needed to be deployed and relocated to optimal positions to maximize the coverage.
According to the subject to be covered, coverage in sensor networks can be classified into three types namely, point coverage, area coverage, and barrier coverage [12]. This paper discusses more on area coverage where the main idea is to maximize the coverage percentage. The root causes of coverage problem in WSN are:

- Random Deployment,
- Limited Communication Range of each sensor node
- Overlapped Area and limited power

Random deployment becomes a problem when some of the sensors are deployed quite far or too close to each other causing a coverage problem, which is called connectivity. There is also a possibility that only a few number of nodes connect directly to the sink (Base station). So in this case, only some nodes are participating in coverage as shown in the Figure 1 (A, B).



(A) (B)

Figure-1: Base Station Connectivity (A) No Connectivity (B) Full Connectivity

In Figure-1(A) none of the sensor nodes are connected to the base station (BS) and hence no inforrmation can be extracted from the network. While in (B) both the sensors are connected to the BS so the sensed information can be communicated to BS and hence the coverage and connectivity is increase. Limited sensing range can be resolved by choosing a sensor with higher sensing range, but it will be more costly and there will be more energy consumption. The limited power supply affects the sensors' operation as some of them might die out. It will result in inadequat sensors to cover the whole region and will reduce the coverage rate [1]. Another factor for coverage problem is a Hole. Hole is the uncovered area in between the covered area. Therefore, to tackle the coverage problem, it needs to be addressed during the deployment phase itself.

III. ARCHITECTURE OF THE PROPOSED SYSTEM

There are number of ways to organize the communication architecture of a sensor network. One way for making sensor network architecture is a hierarchical structure which is also known as cluster based method. In this each sensor communicates with a local cluster head and finally the cluster head communicates directly with the sink node. Another way is flat communication structure, where each sensor has essentially the same role and relies on other sensors to relay its messages to the sink node via multi hop radio communication. For the sake of simplicity here in this paper we assume the flat communication architecture. We considered sensor networks in a two-dimensional field and assume that sensor nodes are randomly and independently deployed in a field and after deployment all the nodes are stationary and only some redeployed anchor nodes are mobile. Random deployment strategy is much easier and cheaper than manual deployment in predefine positions [13].

Proposed work:

In monitoring area if we deploy the nodes randomly then there is possibility that most of the sensors are not connected to the base station. If the number of deployed nodes is very large i.e. when sensor nodes are densely deployed in the field then there will be absolute connectivity between these nodes and it will help in coverage whereas with minimum number of nodes there will be less connectivity between these nodes and in such a case coverage is very less. This paper proposed a minimum distance connectivity algorithm (MDCA) wherein by making connectivity between each set of sensor nodes the coverage in the target region can be enhanced by redeploying the anchor nodes again and again. To obtain the distance information a great deal of work is being done to compute the relative distance of each node to its neighbour. If the distance between two nodes is less than twice of their sensing range then two nodes will definitely overlap with each other and will transmit data with each other. With increasing connectivity, the area of uncovered region will be decreased.

The proposed algorithm has following steps:

Step 1- Firstly on considering 200*200 area, the nodes is deployed randomly. Here 20 nodes are being considered from $N = \{n_1 \ldots\ldots n_{20}\}$ and for optimum results, we assume base station is at center of the sensing field denoted by n_0.

Step 2- Sensors which are directly connected to the base station i.e. with $n_0$contributes in the coverage so these nodes are denoted by set-1 with

$S = \{n_1, n_2, n_3, n_4, n_5\}$ (figure 2).

Sets (S): Sets is a group of nodes which are connected to the base station directly or with some links.

Unconnected Sets (US): An unconnected set is a group of nodes which are not connected to the base station either directly or indirectly.

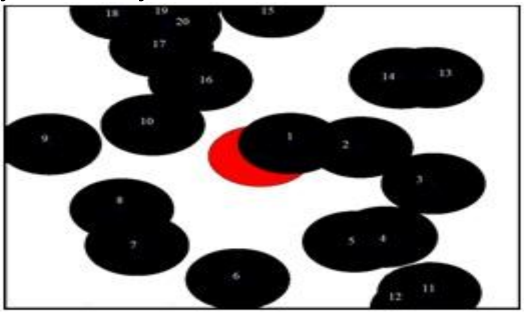


Figure-2: Randomly Deployed Network

Step 3- Sets which are not connected to the base station set are denoted by unconnected sets US1, US2and so on. Sets are arranged according to the number of sensors in that unconnected set.

US1 = {n10, n16, n17, n18, n19, n20, n15}

US2 = {n7, n8}, US3 = {n11, n12}, US4 = {n13, n14}, US5 = {n6} and US6 = {n9}

Initially,

Number of nodes connected to the base station in set, S Count = {5}

Number of nodes not connected to the base station in each unconnected set,

US Count = {7, 2, 2, 2, 1, 1}

Step-4 Calculates distance between all unconnected sets to the base station set and whenever minimum distance is found then add that unconnected set with base station set.

$$D = \sqrt{(xi - xj)\ 2 + (yi - yj)\ 2}$$

Step-5 For making connection between unconnected sets anchor node (AN) is put along

with the Radius of half of the distance between the base station and unconnected set.

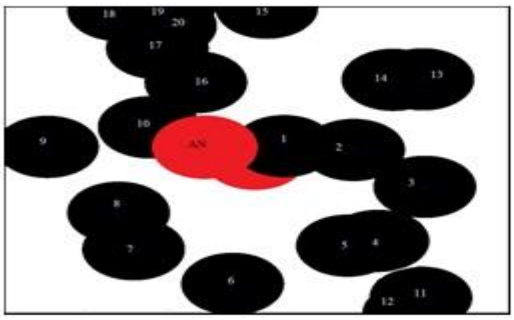


Figure-3: Connection between base station set S and unconnected set US_1

Suppose unconnected set US_1 is having minimum distance then it will connect with set S (Figure-3). Now, $S = S \cup US_1$ and count becomes,

$$S\ Count = \{12\}$$
$$US\ Count = \{2, 2, 2, 1, 1\}$$

Step-6 If the set of unconnected node consists of less than two nodes; then it will not be considered for main connected set of nodes S, because the cost of anchoring nodes is high as compared to the normal node so anchor node is not used to connect the single unconnected node. Also these cases do not increase the coverage of network efficiently. This process is repeated until all sets are joined with set S and at last we found (Figure-5).

$$S = S \cup US_1 \cup US_2 \cup US_3 \cup US_4$$

For calculating the area using image j tool. [13]

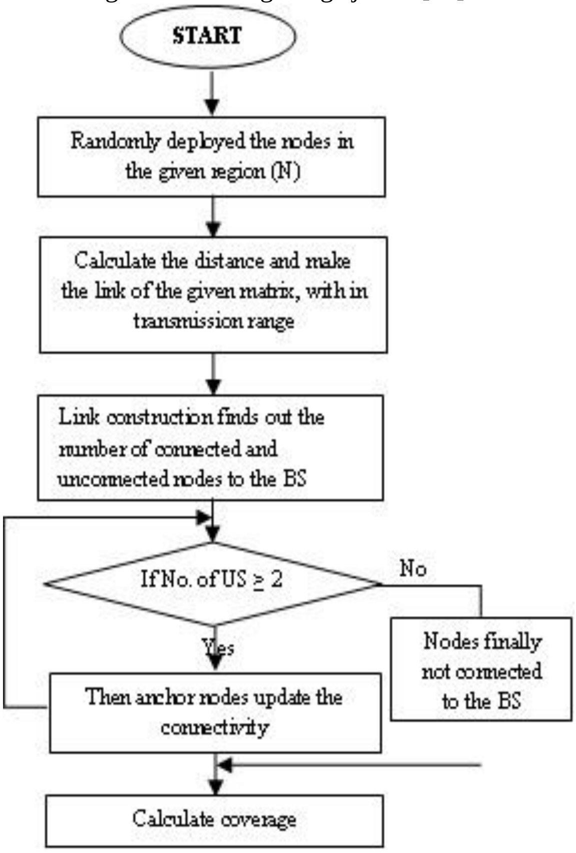


Figure-4: Flow chart of algorithm

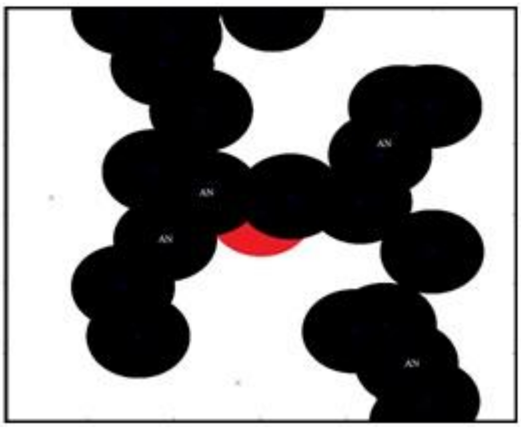


Figure-5: Connectivity Between nodes

IV. RESULTS AND OBSERVATIONS

The graph shows the comparison between results in basic case i.e. when no connectivity algorithm is applied between sensors and proposed algorithm. In basic case there is a possibility that some nodes are directly connected to the base station and help to find the coverage. It is clear from the graph that when only 25 nodes are deployed in the concerned region then the connectivity between these nodes is very less and they give minimum coverage but when connectivity algorithm is applied along with some anchor nodes then coverage increases rapidly. As and when the number of nodes increases in the region then connectivity between these nodes increases along with the coverage. After deploying 75 nodes the connectivity increases exponentially but it will not make much difference since it will work same as the existing algorithm and due to anchor node it will show the problem of energy consumption whereas when considering minimum number of nodes then proposed algorithm shows better result i.e. more than twice of the existing algorithm.

Area size	200m × 200m	Anchor node transmission range	Max((1+√2) * r)
Base station	150m × 150m	Minimum power	1 Joule
Sensing range	30m	Transmission range	60m

Table 1: Simulation Perameters

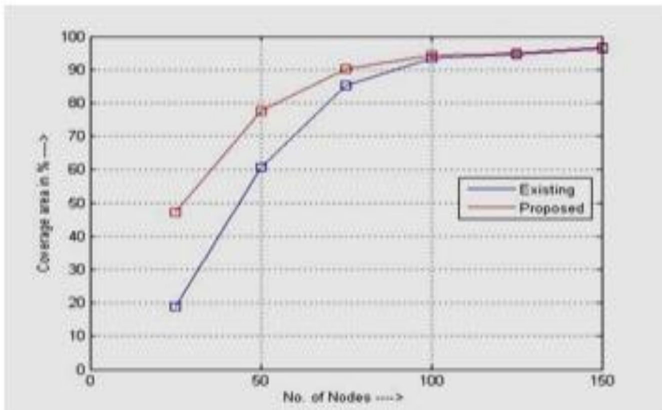


Figure-6: Comparisons between existing and proposed algorithm

V. CONCLUSION & FUTURE WORK

This algorithm is used to enhance the coverage in the network when minimum numbers of nodes are used in the monitoring region. Main aim of this algorithm is to make better connectivity between nodes. This algorithm is highly efficient only when numbers of nodes are limited. With increasing number of nodes the connectivity between nodes increases and it affects the desired output. And also in such cases hole is the main problem that may occur. To find the location of that hole and to cover it is the main future aspect that will help to increase the coverage in sensor networks.

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