STUDY OF MOBILE NODE BASED COVERAGE RECOVERY PROCESS FOR WSN DEPLOYED IN LARGE FOOD GRAIN WAREHOUSE

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ABSTRACT

As the demand for food quality, health benefits, and safety increases, more stringent scrutiny on the inspection of agro-food products have become mandatory. Also being increasingly demanded is "traceability", which requires not only rigorous inspections, but also systematic detection, and recording of quality and safety parameters. Wireless sensors allow otherwise impossible sensor applications, such as monitoring dangerous, hazardous, unwired or remote areas and locations. This technology provides nearly unlimited installation flexibility for sensors and increased network robustness. Furthermore, wireless technology reduces maintenance complexity and costs. This promising technology of wireless sensor network (WSN) is anticipated to offer an extensive range of applications, such as environmental monitoring, smart buildings, military applications and so on. The coverage problem is a elementary issue in WSN, which primarily alarms with a basic question: How well the area under consideration is covered by the deployed sensors? To achieve optimum network coverage, the traditional approach is to deploy a large amount of stationary sensor nodes and then to schedule their sensing activities in an efficient manner. Recently mobile nodes have proved to be very useful as large coverage can be achieved using a few mobile nodes. One can also use them for flexible extension of the network. When we consider large number of sensors distributed in a food grain warehouse, there may be a problem of power distribution and maintenance of these sensors. In this case we can use mobile wireless sensor nodes. These sensors can be placed in transporting vehicles to monitor the environment. If the base station is placed at center or in some corner, there may be loss of signal due to presence of grain and environmental factors. The network may lose connectivity and hence there may be reduction in coverage due to battery life, broken links or excessive attenuation. A network with provision of a set of standby mobile nodes that will reach the location wherein connectivity is affected and will take over the job of the static nodes, is proposed in this paper. This team of mobile node scan gives some time to the network controller to repair the network problems without loss of data.

KEYWORDS: *WSN, Mobile sensor node, Food Grain Warehouse, coverage recovery, holes, voronoi cells*

I. INTRODUCTION

As the demand for food quality, health benefits, and safety increases, more stringent scrutiny on the inspection of agri-food Godowns that enable scientific storage of food grain. This can be done by maintaining these parameters at predefined level and monitoring of the storage space. In this paper we present the concept of food grain warehouses monitored by hybrid wireless sensor networks with emphasis on optimization and redundancy.[1,2,3,4] The large food grain warehouses are distributed over the area of few acres. The activity inside each godown is monitored by a set of ad hoc wireless sensor network that reads the temperature, humidity and carbon dioxide levels after fixed time intervals. It is also products have become mandatory. Also being increasingly demanded are rigorous inspections, and systematic detection and recording of quality and safety parameters. After producing huge quantities of food grains, as is the case with Indian Agriculture, the next challenge is to provide an effective, safe and viable storage method. We need to protect these food grains from problems such as unpredictable weather conditions, high humidity and weeds growth. [5] The mobile node will also work in the situation where in any one of the fixed nodes is not working; may be due to low battery, excessive attenuation etc. The battery operated nodes are connected as multihop ad hoc networks. This network may suffer loss of connectivity due to several reasons such as battery life, broken linkages, attenuation due to obstacles .There may be some acute places where it is not possible to achieve connectivity and hence coverage[4]. In this paper we propose use of mobile wireless sensor nodes that will reach such locations where static nodes are not sufficient to provide coverage due to one or the other reason. The mobile node will reach the location and continue data transfer to the base station and meanwhile, the network problem can be repaired. The mobile sensor node will be a stop-gap arrangement.

The rest of the paper is organized as follows: section II takes in to account the related work done so far. Section III explains the need of this work. The reasons and mathematical modeling is covered in section IV. Proposed model with a fleet of mobile nodes is discussed in section V. Section VI concludes the paper with a statement of scope for future work. The references are given at the end of the paper.

II. RELATED WORK

It is observed that the widely used sensor coverage model is the circle model where a sensor can cover a circle centred at itself with a radius equal to a fixed sensing range. In many cases, we may interpret the coverage concept as a positive mapping between the space points and the sensor nodes the deployed network. For example, given the sensing circular model, the area covered by a set of sensor nodes is the complete set of their sensing circles. According to the subject to be covered, three coverage types can be identified, namely, area coverage, target coverage and barrier coverage.[6] Area coverage addresses the problem of how the whole sensor field is covered. Target coverage, on the other hand, mainly deals with how to cover a set of discrete targets with known locations. Barrier coverage concerns with finding a penetration path across the sensor field with some desired property. All the three coverage types are important to the success of running a WSN and they have been intensively researched in the literature. Huang and Tseng [7] present a brief review on some barrier cover- age problems and area coverage problems. Cardei and Wu [8] survey some energy-efficient algorithms for improving area and target coverage. Both of them only address the coverage problems in the context of stationary WSN where all nodes are considered stationary once deployed. Wireless sensors can be either deterministic placed or randomly deployed in a sensor field. Deterministic sensor placement can be applied to a small to medium sensor network in the field. When the network size is large or the sensor field is remote and hostile, random sensor deployment might be the only choice, e.g., scattered from an aircraft. It has been shown that a critical sensor density exists beyond which a sensor field can be completely covered almost surely in every random deployment [9,10]. To guarantee complete coverage in one random deployment, it is often assumed that the numbers of scattered sensors are more than that required by the critical sensor density. However, this normally requires a great number of sensor nodes to be deployed. Another way to improve network coverage is to leverage mobile sensor nodes. Mobile sensor nodes are equipped with locomotive platforms and can move around after initial deployment, for example, the mobile sensor nodes Robomote [11] and iMouse [12]. Force based, grid based and computational geometry based coverage solutions are discussed in [13].

Although in general a mobile sensor node is more expensive than its stationary compeer, it can serve many functionalities such as a data relay or collector, and can greatly improve many network performances such as enhancing timeliness of data report. In this paper the effort is to provide the standby arrangement of the mobile node is case of failure and avoid loss of data during the repair work of the network. A discussion on how the mobility has been used to get better area coverage is given in the next section. Also target coverage is discussed in the following sections. In different network scenarios, the objectives of node mobility are different. In a hybrid network consisting of both stationary and mobile sensor nodes, the goal is mainly to provide stop gap arrangement with mobile nodes to recover the coverage holes caused due to battery failure, broken linkages or obstacles. In a mobile network consisting of only mobile nodes, the objective is to maximize or to optimize the coverage of these mobile nodes. And in event monitoring application where some short-lived events may appear in different locations, the objective is to dispatch mo bile nodes to monitor the event sources for better event coverage. We have discussed the latest trends on how the mobility can be used to recover the broken networks.

III. NEED ANALYSIS

Over the years India with constant efforts of scientists could produce sufficient food grains to feed the people in the country. India with its present agricultural produce of thousands of tonnes of food grains stands self sufficient in the world. In India, food grain warehouses would mainly belong to Food Corporation of India, Warehouse Corporation of India, Public Distribution System, Agriculture Markets, Railway, Sea Port, Traders. These warehouses (Normal + temperature Controlled) can be used for storage of Food grains, Perishable Fruits, Perishable Vegetables, Perishable Flowers, Fish, Meat Products, Dairy Products, Processed Food. But in India the temperature and humidity levels are varying with seasons. The food grain storages can range from a small room to a very huge warehouse. We need to protect these food grains from problems such as unpredictable weather conditions, high humidity and weeds growth.[4] This can be done by maintaining these parameters at predefined level. Wireless sensor networks are application-specific, and therefore they have to involve both software and hardware. They also use protocols that relate to both the application and to the wireless network. The proprietary networks operate in the ISM (Industrial, Scientific and Medical) bands. Applications such as remote temperature monitoring, pressure and actuation are many times best handled via ISM band. Users are demanding devices, appliances, and systems with better capabilities and higher levels of functionality. Sensors in these devices and systems are used to provide information about the measured parameters or to identify control states, and these sensors are candidates for increased built-in intelligence.

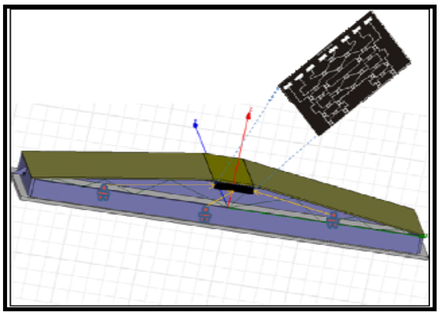


Fig. 1: Wireless monitoring of food grain warehouse.

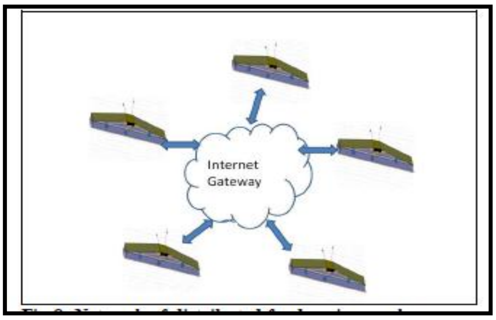


Fig. 2: Network of distributed warehouses

A wide range of electronic sensor based gadgets have been developed, which are effectively used for periodic recording of environmental parameters. The technologies mentioned should be made available to the Indian farmers in a form which suits their economic and environmental conditions. This would give better control over parameters responsible for food grain damage and would maintain the storages in low cost in terms of energy and man power requirement. Measurements of temperature and humidity at various locations, to ensure that they fall within a prescribed range, are performed either visually by inspectors or automatically at warehouses storing food. In order to implement a system to automatically verify the temperature and humidity with wired links within a warehouse, where inspectors visually read measurements, construction work needs to be performed for the power supply and communication facilities. Also, measurement points become fixed and the system will not be able to respond to changes of measurement points required by the replacement of items stored in the warehouse or changes with the layout. Human errors and delays are also possible in such manual systems. If wireless sensor terminals are used in such a case, a system can be built by simply placing wireless sensor terminals at measurement points. Furthermore, it is possible to respond flexibly to the replacement of items stored in the warehouse or changes to the layout as shown in the figures 1 and 2.

IV. HOLES IN COVERAGE

Voronoi diagram can be used to detect a coverage hole and calculate the size of a coverage hole [14,15]. A Voronoi diagram for N sensors s1; s2; .... ; sN in a plane is defined as the subdivision of the plane into N cells each for one sensor, such that the distance between any point in a cell and the sensor of the cell is closer than that distance between this point and any other sensors. Two Voronoi cells meet along a Voronoi edge and a sensor is a Voronoi neighbour of another sensor if they share Voronoi edge. For more discussions on Voronoi diagram and its applications, please refer [16].

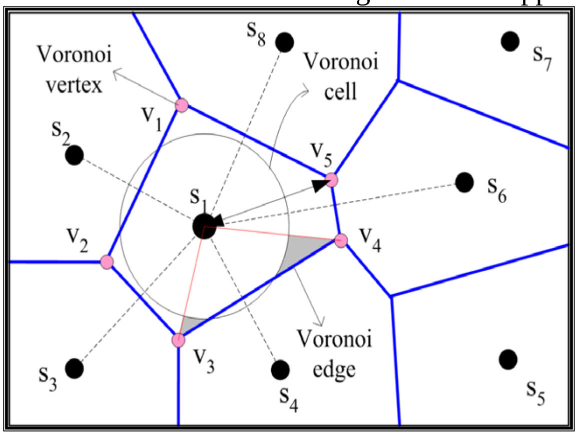


Fig 3: Illustration of using Voronoi diagram to detect a coverage hole and decide the hole size.

A Voronoi diagram is initially constructed for all stationary sensor nodes, assuming that each node knows its own and its neighbours' coordinates. Wang et al. [15] proposes a localized construction to construct a local Voronoi diagram: Each node constructs its own Voronoi cell by only considering its 1-hop neighbours. After the local Voronoi diagram construction, the sensor field is divided into sub regions of Voronoi cells and each stationary node is within a Voronoi cell. A node is a Voronoi neighbour of another one if they share a Voronoi edge. Figure 3 illustrates a Voronoi diagram in a bounded sensor field, where the boundaries of the sensor field also contribute to a Voronoi cell. According to the property of a Voronoi diagram, all the points within a Voronoi cell are closest to only one node that lies within this cell. Therefore, if some points of a Voronoi cell are not covered by its generating node, these points will not be covered by any other sensor and contribute to coverage holes. If a sensor covers all of its Voronoi cell's vertices, then there are no uncovered points within its Voronoi cell; otherwise, uncovered points exist within its Voronoi cell. Ghosh [14] describes how to compute the uncovered area within a Voronoi cell. They call a triangle consisting of a node and its two adjacent Voronoi vertices a Voronoi triangle. For example, the Voronoi triangle $\Delta s_1 v_3 v_4$ in Figure 3. The line $\overline{(v3\ v4)}$ is the perpendicular bisector of the line $\overline{(s1s2)}$ and the area of $\Delta s_1 v_3 v_4$ can be computed as $\frac{1}{4} d(s1, s4) d(v3, v4)$. The area of the Voronoi cell for a node is the sum of the area of such Voronoi triangles contained within the Voronoi cell. However, the exact area of the uncovered portion of a Voronoi cell is not equal to the area of this Voronoi cell minus the area of the sensing circle. This is because the sensing circle of a sensor node may protrude its Voronoi cell. For example, in Fig. 3 some of the s1's sensing circle is also located at the s4's Voronoi cell. The protrusion depends on the relations between the sensing range and the distance between two Voronoi neighbours and the lengths of the Voronoi triangle sides. The above calculation for the exact area of uncovered portion within a Voronoi cell is complicated. Wang et al. [13] propose to use the distance between itself and its furthest Voronoi vertex to decide a coverage hole and the size of the coverage hole. If such a distance is larger than its sensing range, then there exists a coverage hole and the size of the hole is considered as proportional to the distance.

V. PROPOSED NETWORK WITH MOBILE NODES

In this section, we discuss how mobility is used to improve area coverage in a kind of combination networks. In a combination network consisting of both stationary and mobile sensor nodes, coverage holes may exit if the number of the deployed stationary nodes are not large enough in one random deployment. The main objective for using mobile sensor nodes is to recover coverage holes after the initial network deployment, such that the area coverage can be maximized .The mobile node team can reach such hole locations and provide coverage support to recover the network. The concept is illustrated in figure 6.

The main challenges to the connected coverage after deployment arise due to limited battery life of nodes, attenuation caused by various obstacles in the signal path, broken linkages, acute places where nodes cannot be placed. The situations are shown in figure 3.

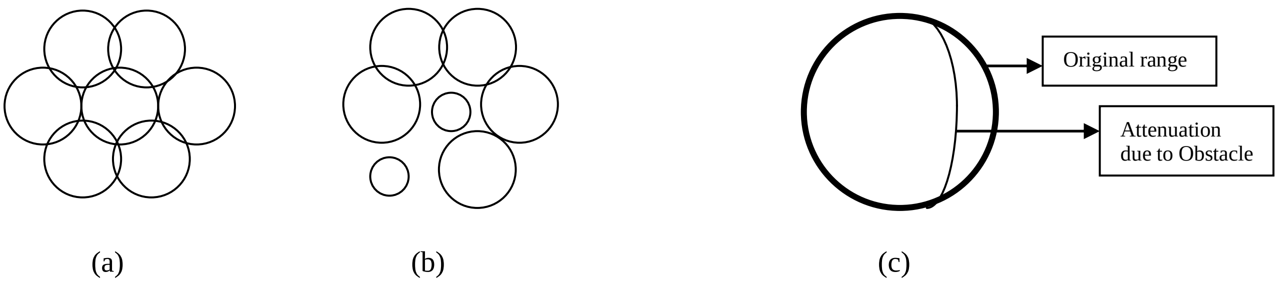


Figure 4: a) connected network with full coverage b) reduction in range of some nodes due to low battery c) Excessive attenuation in single node range due to obstacle.

As shown in figure 4(a), the network is fully connected and there are no 'holes'. Over the time the battery of each node will be utilized and some nodes may end up with very low power resulting in broken links. This can affect total connectivity and coverage. This is demonstrated in figure 4(b).

Figure 4(c) shows a situation where the range is attenuated because of obstacle in the path of the network. The network will try to overcome these problems by using routing techniques and establishing network with alternate paths. But a stage will reach when these solutions will not work as the links will be totally broken and connectivity cannot be established. These challenges can be handled with the help of a team of mobile nodes that will reach the problem location one by one till connectivity is established and complete coverage is achieved. The coverage degradation is observed due to two reasons: a) Holes generated due to node failure as shown in figure 3b. And b) Holes are generated due to deployment issues as discussed in section IV .

The graph in figure 5 shows the effect of holes generated due to node failure on the coverage area.

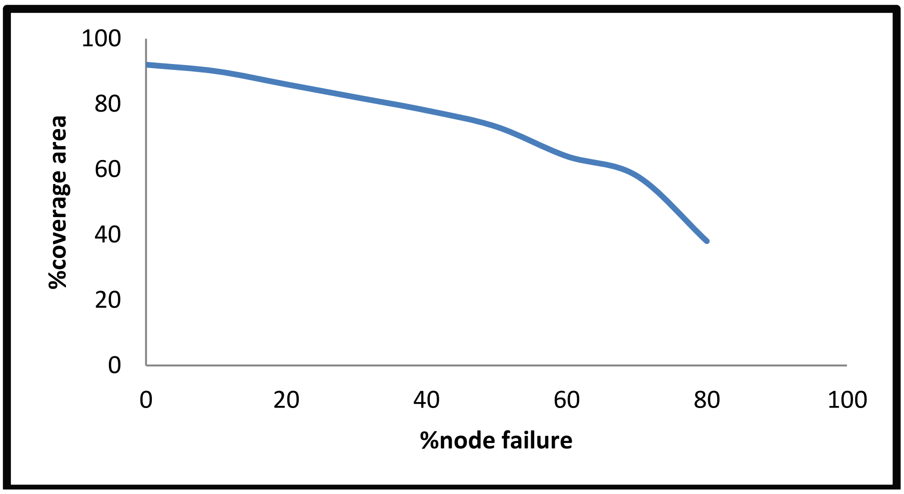


Figure 5: Graph of % node failure Vs % coverage area

As the % number of nodes goes on increasing one can clearly observe that there is not much change in the covered area but as the number increases, there is significant reduction in the coverage area.

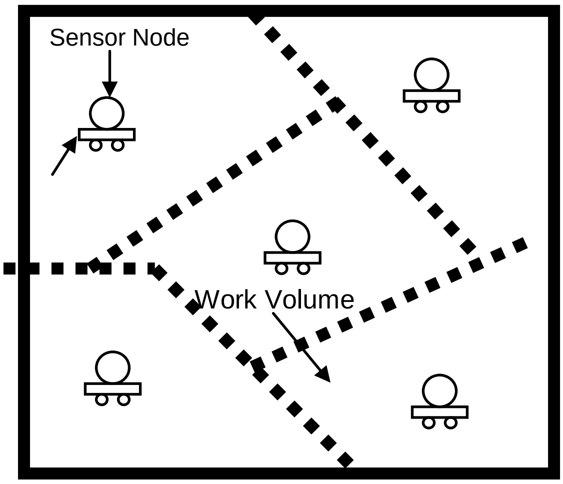
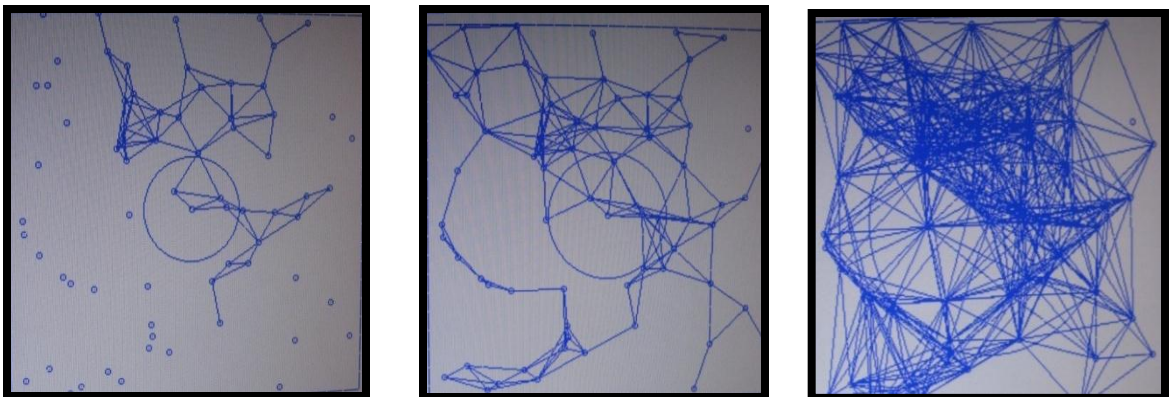


Fig 6: Proposed Mobile sensor Nodes

In order to improve coverage area, a fleet of mobile nodes is proposed to be used. Figure 6 shows a large region divided into sections and mobile nodes are deployed in each section. They will be activated when a hole is developed and network may start losing data. This stop gap arrangement of mobile nodes will give some time to repair the network and avoid loss of data during this period.



(a) (b) (c)

Fig.7: (a) Network failed due to 2 node failures (b) recovery with one mobile node (c) Recovery with two mobile nodes.

Role of mobile nodes in network recovery is illustrated in figure 7. Initially the network is disconnected in a major region due to failure of two nodes as shown in figure 7(a). Now first mobile node enters the scenario and takes over the job of one node and network is recovered to some extent as shown in figure 7(b). Still more recovery is observed when the second node comes into picture and as shown in figure 7(c) network is recovered enough. The graph in figure 5 shows the degradation of network. Which can be recovered with mobile nodes and complete coverage can be obtained. This will provide some breathing time for the network control team and the failed nodes can be repaired or replaced without losing data during repair work.

VI. CONCLUSION AND FUTURE WORK

The team of mobile sensor nodes works as a reserve force in the wireless sensor network deployed in large food grain warehouse. When the battery operated nodes fail over the time, it may create broken links in spite of routing. This will affect coverage loss. The mobile node will reach at this position and take over the job and establish connectivity. If required, more mobile nodes can reach the location and

continue till complete coverage is achieved. This will provide a mobile standby arrangement for coverage recovery of the wireless sensor network.
Future work is planned for the determination of the movement plan of the mobile nodes. It is necessary to decide where and how the mobile nodes should be moved. Design of the movement strategies of the mobile nodes towards the holes in the network will be the next step.

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