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COVERAGE HOLE DETECTION AND HEALING IN WSN - A SURVEY

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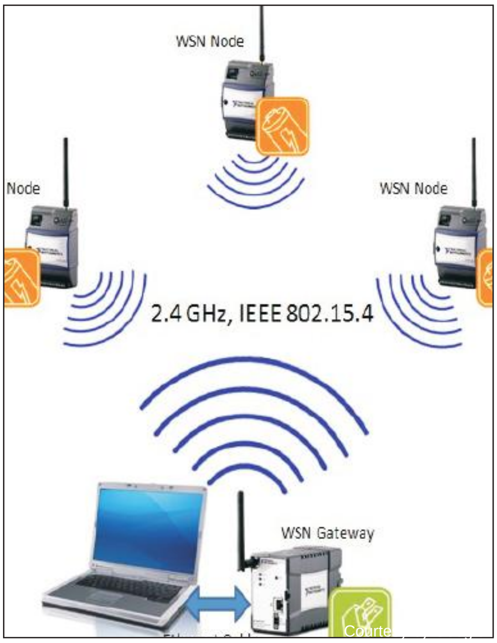
ABSTRACT:

A Wireless Sensor Network contains a network of wireless sensor nodes working in a hostile environment. The lifetime of the WSN depends on number of nodes, sensing range and transmission range of sensor node, connectitvity of the nodes and fault tolerance. The paper reviews on the different types of sensor node deployment ,hole occurrence in network due to improper deployment of sensor nodes, types of holes ,coverage hole detection mechanisms , coverage hole healing and coverage enhancement techniques.

KEYWORDS:

Deployment, Coverage, Coverage hole, Wireless Sensor Network.



1. INTRODUCTION

The Wireless Sensor Networks (WSN) consists of clusters of sensor nodes forming a network. The sensor nodes are deployed at one location and base station is at some remote location, transferring the data to base station via gateway through relay nodes. Monitoring the region of interest (ROI) is the service provided by the wireless sensor network (WSN). The main role of this service is sensing the environment condition for the ROI and sending the sensed information to the destination node.

Most of these nodes are deployed in hostile environment, where there is no human intervention. These sensor nodes have low battery power consumption, which will result in nodes to die [1]. Also, the deployed nodes may get destroyed, due to the natural disasters like floods, earthquakes, stroms, and tsunamis, physical destruction caused due to the damage by animals or enemies outside the territories, which affects the communication between the nodes ,and results in communication voids or holes in the network. Hence, it is necessary to detect and heal the holes in the network for an effective communication to take place.

The paper reviews on the different types of deployment, hole occurrence in network due to improper deployment of sensor nodes, types of holes , coverage hole detection mechanisms , coverage hole healing and coverage enhancement techniques.

2. DIFFERENT TYPES OF SENSOR NODES DEPLOYMENT

Node deployment is a fundamental issue to be solved in wireless sensor network. A proper node deployment can reduce the complexity of problems in WSN such as routing, data fusion, communication and enhances the network coverage, connectivity, cost and lifetime.

Anu Rathee[2], investigated on random and deterministic deployments. Three alternative deployment schemes have been proposed based on the requirements- application specific deterministic deployment, random deployment and grid based deployment. P.Saritha Hepshiba[3] analysed about deterministic deployment suitable for small-scale

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applications, where the sensors are placed directly in the required region. For large-scale applications, random deployment is suitable, where sensors are thrown randomly from helicopter or aeroplane onto the ground to form a network. Grid-based deployment is suitable for moderate to large scale applications, where individual sensors are placed exactly at grid points as in figure 1.

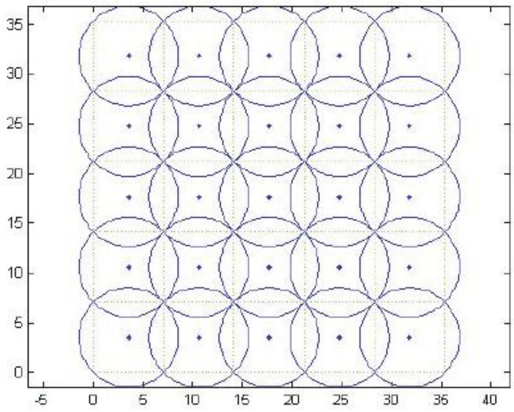

Figure 1: Sensor node grid deployment

The network coverage for various grid-based node deployment strategies namely, square-grid, rectangular-grid, triangular-grid, and hexagonal-grid are done. It has been analyzed that the hexagonal grid deployment provides better area coverage than other schemes.

UNIFORM RANDOM DEPLOYMENT

In the uniform random deployment, each of the 'n' sensors has equal probability of being placed at any point inside a given field i.e., the nodes are scattered on locations which are not known with certainity. Such a deployment can result from throwing sensor nodes from an airplane. A uniform random deployment is assumed to be easy as well as cost-effective.

SQUARE GRID DEPLOYMENT

There are popular grid layouts like unit square, an equilateral triangle, a hexagon, etc. Among them the square grid is the most feasible one because of its natural placement strategy over a unit square.

TRI-HEXAGON-TILING (THT)

It uses the concept of tiling. A tiling is the covering of the entire plane with figures which do not overlap nor leave any gaps. Tilings are also sometimes called tesselations. Among many tilings used, a semi-regular tiling (which has exactly eight different tilings) is used, where every vertex uses the same set of regular polygons. A regular polygon has the same side lengths and interior angles.

3. HOLE OCCURRENCE IN NETWORK DUE TO IMPROPER DEPLOYMENT OF SENSOR NODES

Since the nodes are deployed in hostile environment, by randomly throwing from airplane, without human intervention, hence these sensor nodes are subjected to get destroyed from the deployed locations, due to the natural disasters like floods, earthquakes, storms, tsunamis, physical destruction by animals or enemies outside the territories .This affects the communication between the nodes and results in communication voids or holes in the network.

COVERAGE

Coverage ensures that every point in sensor field must be covered by at least one sensor node, and Connectivity ensures that all the sensor nodes present in the network must be in the transmission range of the neighbors and connected with neighboring nodes.

A unit square is said to be covered if every point in the square is within detection (sensing) range of an active node. Coverage will ensure that the intrusion is detected and connectivity will ensure that messages are propagated to the appropriate authority (transmission or communication).

Network Coverage can be dealt as full coverage and partial coverage. G.Rao et al [3] studied about the comparison of three node deployment models like the uniform random, square grid and THT(Tri-Hexagon tiling) deployment models in terms of coverage , energy consumption and worst case delay. The worst case delay is performed by calculating the maximum allowable message transfer delay between the nodes, which must be bounded for enabling time-sensitive applications of WSNs. The sensor network calculus is used to calculate the worst-case end-to-end delays for each flow and find the maximum worst-case delay in the sensor field.

The full coverage can sometimes be used for partial coverage since, in some cases of temperature and pressure measurements the readings at one point is sufficient to be the same in the surrounding regions. A point is said to be covered if it belongs to the sensing range of at least one sensor. The area 'A' is said to be covered if every point is covered. 'A' is said to be k-covered if each point belongs to the intersection of sensing ranges of at least sensors. A wireless sensor network that provides full k-coverage of a field is called k-covered wireless sensor network, where a maximum value of is called degree of coverage of the network.

In a WSN, every sensor has a limited sensing range and a limited communication range. The union of the sensing ranges of all sensors is defined as the network sensing coverage. Coverage defines how well the area of sensor field is monitored.

CONNECTIVITY

A WSN is said to be connected if, for any two sensors, there is a single-hop or multi-hop communication path between them consisting of consecutive wireless communication links. The WSN connectivity is primarily determined by the sensors' deployment locations and the communication ranges. Connectivity eliminates the isolation of sensors and enables each sensor to report its sensing data to its fusion center.

Mohamed Younis and Kemal Akkaya[5] proposed two different node placement strategies in WSN namely static and dynamic optimized node placement .The placement strategies depend on optimized placement of nodes done at the time of deployment or while the network is operational.

4. TYPES OF HOLES

Occurrence of fault in a single node is called as cut. The fault occurred in multiple nodes in a particular region are called as hole. Holes have sometimes been referred to as 'communication voids' as they act as an obstacle for communication. The detection of holes inside the wireless sensor network is one of the major problems that need the attention of researchers.

There are various types of holes that hamper the efficient performance of the network. They are classified as Routing holes, Network holes and Coverage Holes.

Coverage holes depend on various factors such as buildins, mountain, technologies and radio frequency. The coverage holes affect communication in network.

Routing holes occurs due to failure of sensor node .It results in dead node affecting routing in the network.

Jamming holes occurs due to disturbance caused by radio frequency in the communication way among the sensors. Sensor node failure does not happen here.

Black/sink hole occurs when incoming or outgoing or both traffic is discarded ,without informing the sender, then the data cannot reach to its intended receiver. Sensor node failure does not happen here.

Worm hole occurs due to Denial of Service attack. Malicious nodes create a tunnel among themselves. They start forwarding packets and receive from one part of the network to the other end of the tunnel using separate radio channel .It makes the nodes located in different parts of networks to believe that they are neighbors, resulting in incorrect routing convergence.

COVERAGE HOLES

Coverage holes exist if the target point (area) is not covered by at least required degree of coverage as shown in Figure 2.

Coverage holes are formed due to the following reasons: if the design of the sensor node fails, unsystematical arrangement of sensor nodes in the area, poor installment, power depletion, topology failure, presence of obstacles.

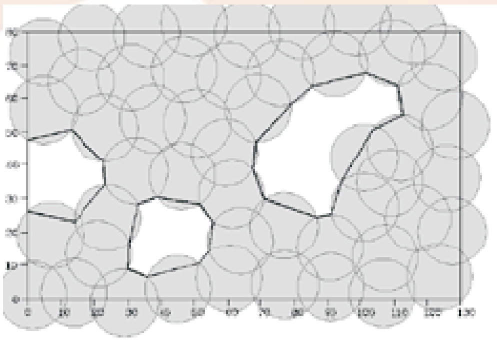

Figure 2: Coverage Hole in WSN.

The figure 3. below shows intersection of 3 sensor nodes, which leaves no coverage hole(i.e. full coverage).

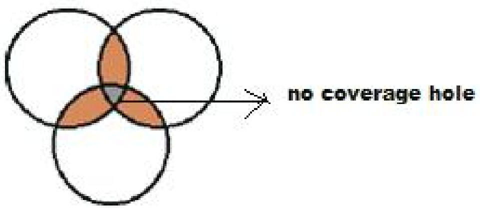

Figure 3: no coverage hole between three nodes

Coverage holes detection mainly depends on number of nodes that detect holes, total time required to detect holes and average power consumption by sensors depending on hole detection algorithm.

5. COVERAGE HOLES DETECTION AND HEALING MECHANISMS

B. Kun, T. Kun, G. Naijie, L.D.Wan and L. Xiaohu [4] presented a distributed scheme based on communication topology graph. The paper proposes the problem of detecting topological holes in sensor networks with no localization information in any node. To detect the holes in the network, each node has to exchange information with its 1-hop and 2-hop neighbors. In this the node decides if it is on the boundary of a hole. This is done by comparing its degree with the average degree of its 2-hop neighbor. Shahram Babaie, Seyed Sajad Pirahesh [6] used triangular oriented diagram, which is simple ,low construction diagram to detect hole and calculate the size of hole exactly. A sensing disk model is used as sensor coverage model, where the sensor can cover a disk centered at itself with radius equal to fixed sensing range. The structure is formed using 3 different sensors forming homogeneous sensors. After calculating the size of coverage hole, area of hole is calculated , by deciding if the circle is in-circle or circum-circle.

Funke[7] proposed a heuristic based technique for detecting the coverage holes based on communication topology graph. The hole detection algorithm is based on the topology of the communication graph. The information is communicated between the neighbor nodes, nodes which are close to each other.

This approach is not localized as it requires the computation of distance of all nodes over the whole network.

S.Mini, Siba K.Udgata and Samrat L Sabat[8] used artificial bee colony algorithm and particle swarm optimization for sensor deployment followed by heuristic for sensor scheduling. The scheduling of sensors is done by finding the priority of sensor nodes.

Funke and Klein[9] proposed linear-time algorithm for hole detection. The method required communication graph that follows the unit disk graph model. The authors had proved that, using a very simple linear-time algorithm helps to find the boundary of the holes in the sensor network. Also, the paper has proved that, there is enough geometry information hidden in the connectivity structure to identify topological features.

Fekete et al.[10] described the co-ordinate free technique to detect the boundary of the hole in WSNs. The assumption made here is that the nodes are uniformly distributed in non-hole areas. The technique makes use of a combination of stochastic, topology, and geometry.

Fang et al. presented bound hole algorithm [11] using right-hand rule to identify nodes on the boundary of geometric holes.

Shirsat and Bhargava[12] proposed the bounded hole algorithm assuming the relative geographic information of 2-hop neighbors. The hole boundary detection algorithm takes best approach in detection process.

Zhiping Kang, Honglin Yu and Qingyu Xiong[13] proposed a method to find boundary critical points and coverage holes .Hole detection based on calculating boundary critical points and hole patching based on finding the boundary critical points provide best coverage possible.

Wang et al. proposed boundary algorithm to find the information of the connectives[14]. For the hole detection process, the author had used special structure of the shortest path tree. This algorithm relies on repetitive network flooding.

A. Kroller, P.Fekete, D. Pfisterer, and S.Fischer[15] used deterministic method for boundary recognition and also used topology extraction technique for larger network of sensors. The authors had dealt with the self-organization considering its topology and also geometric packing arguments to find the boundary nodes and also the structure of the sensor network.

6. COVERAGE ENHANCEMENT AND HOLE HEALING

The several movement strategies for improving network coverage are discussed in this section

G. Wang, G. Cao and T.F.L. La Porta described the three different types of deployment protocols [14]. These protocols use Voronoi diagrams to relocate the nodes, once the holes are being detected.

The technique cannot be used for large holes. And also this method requires global computation.

C.Y. Chang et al[16] proposed three algorithms for maintaining temporary coverage in WSNs. Authors proposed strategies for hole movement for the large hole. This is done in such a way that either the power consumption of the sensor or the energy consumption of the node is balanced or reduced respectively.

The algorithm requires synchronization among the nodes in the network.

C.Y. Lin et al proposed tracking mechanism and robot repair algorithm. By using this technique [17] the coverage problem is solved using a moving robot. The robot's footmark is left behind on the sensors during the tracking mechanisms. This helps the sensors to find better routes for sending repairing requests to the robot. The healing algorithm helps to develop an efficient path for communication.

The authors make an assumption that the WSN has been deployed using robot deployment mechanisms.

A. Nadeem, S.K. Salil and J.Sanjay proposed a pragmatic approach[18] to area coverage in hybrid wireless sensor networks. The MAPC- Mobile-Assisted Probabilistic coverage maintained the coverage by moving the sensor nodes to strategic positions in the uncovered area.

In this technique only the sink involves in the triggering of the hole detection and healing and the source does not involve in triggering process for hole detection and healing.

X. Li et al. proposed a randomized carrier based sensor relocation[19] where the robots picks up passive sensors and replaces them in the holes. This is done in random manner and hence called as randomized relocation.

This relocation technique assumes that the boundary of the wireless sensor network is known already, which is the main drawback of this paper.

X. Li et al.[19] proposed two strictly localized solution algorithms, Greedy Advance (GA), and Greedy-Rotation-Greedy (GRG) for sensor deployment problem . These two algorithms drive sensors to move along the TT (triangle tressellation) graph to surround POI (point of interest).

The paper considers only point coverage problem and not the region of interest.

Z. Yong et al. proposed a virtual force algorithm (VFA)[20] as a sensor deployment strategy to improve the coverage after an initial random placement of sensors.

The Virtual forces algorithm (VF) involves the forces of attraction and repulsion between the sensors nodes .This is similar to van Der Waals forces , involved between two atoms as seen in Chemical reactions.

It depends on threshold distance between two atoms .If the distance between two atoms is greater than threshold distance then , there exists a force of attraction between the sensor nodes. If the distance between two atoms is lesser than threshold distance then , there exists a force of repulsion between the sensor nodes

S.Yangy et al. proposed scan-based movement-assisted sensor deployment technique for wireless sensor networks[21]. In this paper the region of interest is divided into many small grid cells. And the number of nodes in the grid cell is the load of the grid cell.

The technique generates enormous message overhead in a denser network since the number of rounds of scan is being increased. And at the final stage of clustering process, if two nearby clusters are empty the scanning process will be incorrect.

G. Wang, G. Cao, P. Berman and T. La Porta[22] proposed two bidding protocols for sensor deployment in wireless sensor network. Here, static sensors detect coverage holes locally by using Voronoi diagrams and bid mobile sensors to move. And these mobile sensors accept highest bids and help to heal the bigger holes.

This method requires global computation which means that all the nodes in the network needs to run the algorithm.

Massimo Vecchio, Roberto Lopez-Valcarce [23] used scan based algorithm in a random grid deployment for detection of coverage hole. A bidding strategy is used between the static sensor nodes and mobile sensor nodes for patching of hole.

The main contribution is distributed path planning and co-ordination technique for the mobile nodes of a mixed WSN. The trajectories of the mobile nodes are controlled by a number of techniques, based on distance to target and repulsion from static nodes.

The work is based on the previous research of the authors. Each mobile node autonomously navigate through the field and sample the areas least covered by the stationary sensor nodes, thus improving area coverage. The mobile node is a robot carrying a sensor node towards the target.

Sensing coverage is a fundamental design problem in a WSN. Davood[24] has proposed a fuzzy logic based self healing coverage scheme for randomly deployed mobile sensor nodes.

The proper placement of sensor nodes is required for efficient area coverage using different deployment techniques. Swati Singh, Puneet Sandhu in[25] tried out for optimized deployment using k-means clustering technique. The fuzzy based approach is used to determine the uncovered sensing areas and select best mobile nodes to move towards the uncovered areas called as holes.

A dead sensor is considered as hole , noisy sensors add more bits to original data during transmission , affects BER(Bit Error Rate) and impacts SNR (Signal to Noise Ratio).Coverage problem can be solved by finding proper neighbor node. To find the sensor nodes within same Euclidean distance, thereby enhancing coverage ratio.

Two centralized algorithms are used here , for efficient deployment of sensor nodes. The authors have proposed the algorithms based on (OR) Operations Research concept. An isotropic sensing model is used for the algorithms , which employ sensing area of each sensor node ,represented by circle with same radius .

Zi-Qi Hao et al.[26] analyzed Voronoi diagrams are used to detect the coverage hole and heal the coverage hole. The Voronoi diagram consists of set of points , forming a Voronoi polygon .All points inside the polygon are closest to only one point .If all points lie within the range of Voronoi polygon ,then there is coverage ,else there is no coverage of points .The Hungarian algorithm dispatches the mobile nodes to heal the coverage holes. The shortest distance required to dispatch the mobile nodes to coverage holes is decided by threshold based assignment algorithm.

M.P.Singh , M.M.Gore[27] presented a solution to deploy the nodes in the specified area such that area will be fully covered and QoS and fault tolerance of sensor network will increase. The paper is dealt for sensor nodes with similar architecture (homo geneous) and sensor nodes with dissimilar architecture (heterogeneous).

7. CONCLUSION

Proper network node deployment can not only reduces the node redundancy and the network costs, but also can prolong the service life of the network. For example, in the building of traffic warning system, the collection of all kinds of transportation information which affects the traffic control is the foundation of getting good control effect.

Therefore, in order to achieve the collection of traffic information using wireless sensor network, the coverage of sensor nodes deployment becomes one key work that is how to make use of effective node deployment to achieve maximum coverage, provide good connectivity and energy saving performance.

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