COVERAGE HOLE DETECTION IN WIRELESS SENSOR NETWORKS

Rakesh Kumar
Department of Computer Science
Guru Jambheshwar University of Science & Technology, Hisar, Haryana, India.

Sakshi Dhingra
Department of Computer Science

Guru Jambheshwar University of Science & Technology, Hisar, Haryana, India.

Abstract

Wireless sensor network is the area where many researchers are focusing. The emerging technology of WSN is expected to provide a broad range of applications, such as battlefield surveillance, environmental monitoring and smart space and so on. Coverage is the important quality of service which is provided by the wireless sensor network. The coverage hole problem is a fundamental issue in WSN. This problem occurs when sensor nodes are arranged randomly in the area, poor installment or nodes whose power weeks and when the design of the network fails. By knowing the above issue, a modified hole detection and healing method is proposed that could remove the redundant nodes and moving the nodes that removes holes by using distributed virtual force based approach in WSNs. An efficient geometric analytical method of theoretical basis is used to detect the coverage hole of the wireless sensor network when the communication range and sensing range of the nodes are identical. In this paper geometrical approach are used to detect and remove coverage hole.

Keywords - Wireless sensor network, Coverage hole, Hole healing.

1. INTRODUCTION

A wireless sensor network is a collection of small randomly dispersed autonomous sensors that are able to monitor physical and environmental conditions, in real time, such as temperature, pressure, light and humidity and to provide efficient, stable communications with the help of a wireless network. They cooperatively pass their data through the wireless network to a main location.

Wireless sensor network made of the small low-cost sensing nodes which collect and disseminate environment data. Many problem are occurs in wireless sensor network. They may be form of various types of coverage hole detection problem [1]. The total coverage of the complete network is defined as the common coverage of all nodes sensing gradients. It shows that how properly each point in the sensing area is covered. A coverage hole refers to in a volume in 3-dimensional space or in a continuous space in the sensing area which is not covered by the any sensing nodes [2].

WSN are highly dynamic and susceptible to network failures, mainly because of the physically harsh environment. The WSN has reduced the installation cost.The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors.WSNs are naturally self-organizing and self-healing.

CHARACTERISTIC OF A WSN

- Power utilization constrains for nodes using batteries or energy harvesting.
- Ability to cope with node failures.
- Mobility of nodes.
- Dynamic network topology
- Communication failures.
- Heterogeneity of nodes.

- Scalability to large scale of deployment.
- Ability to withstand incompatible environmental condition.
- Easy to use.
- More energy efficient routing.

COVERAGE HOLE DETECTION

In an area when a group of sensing nodes does not work properly and not sensing the data and communication then it is a problem of hole in the network. The performance of the network are affected or degraded by the holes in the network [3]. So, the point of area coverage place an important role in sensor networks and there connectivity.

Coverage is one of the important part or concern in WSN. It is used to evaluating or calculating the quality of service (QoS) in WSN [4]. So coverage can be explained or classified into three categories:

- ✓ Area Coverage
- ✓ Point Coverage
- ✓ Barrier Coverage

The main aim of the area coverage is to maximize the coverage for a region of interest; point coverage covers a set of points and barrier coverage minimize the probability of an undetected penetration through a sensor network.

The dynamic solutions to find out and optimize the coverage in sensor networks are [5]:

- Exposure Based
- Mobility Based

Exposure Based: It check out the unauthorized intrusion in the networks. It is a completely measure of how well the sensor network observe "an object which is moving on a different path over a period of time".

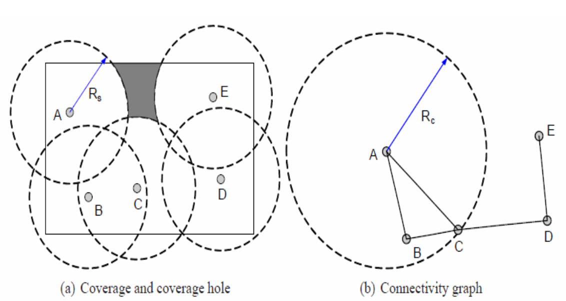

Figure 1 Coverage and Connectivity [2].

Mobility Based: To get the better coverage condition it accomplishment moving properties of nodes and for the maximum coverage it tries to relocate sensor nodes to optimal locations.

There are four key elements that are critical for ensuring effective coverage in mobile WSNs:

i. Determining the boundary of the RoI.
ii. Detecting Coverage Holes.
iii. Determining the best target location to relocate mobile nodes to repair holes.
iv. Minimizing the moving cost when dispatches mobile nodes to the target locations [6].

Coverage problem is a fundamental issue in WSN. This paper aims to address the work of hole detection and healing in WSNs.

2. RELATED WORK

Wireless sensor network have become large area of research. There have been a large number of researches on detection of coverage and remove redundancy in WSNs over the last few years.

In this section some of the hole detection algorithms is analyzed and summarized. The substantial nodes are deployed randomly over the entire area; therefore, the sensing region of different nodes may be partially overlapped and this problem is known as the sensing coverage problem. So to remove this problem [7] defines a maximum sensing coverage region problem (MSCR) in WSN and used the algorithm to improve LEACH, a hierarchical protocol for WSN. They developed a simulation program to evaluate the performance of LEACH protocol using an algorithm. The experimental result shows that this method reduced total energy consumption in the whole system and increased significantly network lifetime.

There is a problem of hole detection and healing in mobile WSNs. The main problems are determining the boundary of the ROI (Region of Interest), detecting coverage hole and estimating their characteristics, determining best target locations and dispatching mobile nodes to the target locations. So to addresses these all problem [8] propose a solution called the holes detection and healing (HEAL). It is distributed and localized algorithm that operate in two phases, first one is identifies the boundary nodes and discover holes and second one is treats the hole healing. The first phase is done by using a lightweight localized protocol over the Gabriel graph of the network and second phase is done with hole haling area. HEALS deals with holes of various forms and sizes, and facilitate a cost-effective and an accurate solution for hole detection and healing.

Vinay Rana, Rani, Ravi [9] proposed a method to find the hole. They using the information generated about the network topology during route discovery and route maintenance. For detection of hole in network path, they used three algorithms, namely routing protocol, hole detection protocol and optimal hop count. They used the swarm intelligence based technique to remove excess burden on the network or for hole detection by using these algorithms between source node to base station.

In WSN coverage problem is a major problem. In hybrid sensor networks, to enhance the area coverage mobility is exploited. The main objective for using mobile sensor nodes is to heal coverage holes when designing a hole healing algorithm. There are two issues related with this, first is to decide the existence and size of a coverage hole and second is to find the best location to relocate mobile nodes to repair coverage holes. So to remove this problem they use the triangular oriented diagram (HSTT). In this diagram they used circum circle and in circle to achieve this. This diagram is simple for construction and has less calculation than Voronoi Diagram [10].

On the other hand Hwa-Chun Ma, Prasan Kumar Sahoo, Yen-Wen Chen [11] designed a computational geometry approach based distributed hole detection protocol to find out the coverage holes in area or dense forests. An efficient geometry method is used to detect the coverage holes where communication and sensing range of the nodes are same. They consider the two criteria to evaluate the performance of algorithms, first criteria is average hole detection time and second is average power consumption.

The quality of service i.e. provided by a sensor network depends on its coverage area. Yang-Tsung Hou, Chia-Mei Chen, Bing chiang Jeng [12] used the placement algorithm for improving barrier coverage. They deploy new sensors in order to improve the coverage of an existing network. Best and worst case coverage problem are observability of a path. The algorithm adds new nodes to the shortest path, so that the support of the sensor network is reduced the most.

Chi Zhang, Yanchao Zhang and Yuguang Fang [13] develop a deterministic method for boundary node detection. It is based on localized Voroni polygons, which originated from the computational geometry. It can be applied to any random deployed sensor network and require one hope neighbors information. It increased the scalability and energy efficiency of the detection algorithm. It provides a distributed protocol that allows each sensor node to identify them which is located on the coverage boundary.

Wei Li [14] provide a novel graphic approach to describe coverage hole in WSN. It divided into two phases, namely, coverage hole detecting and coverage hole describing. This method indicates the location and configuration of coverage hole. It also indicates the vulnerable parts in holes. The graphical description of this method can serve as a useful tool for healing coverage hole. The simulation result this method predict the coverage holes, and graphic holes can be exploited to heal actual holes. The computational complexity of proposed method is, O(bn) where b indicates the nearby sensor in each node and n is the amount of sensor nodes in network.

To detect and localize coverage holes in sensor networks they used the algebraic topological methods to define coverage hole, and develop provably correct algorithm to detect a hole and partition the network into smaller subnetworks and checking for holes in each. By repeating this process leads to localize the coverage holes. In simulation observed that all the nodes in these subnetworks are always at most one hope away from the shortest cycles bounding a coverage hole [15].

The presence of coverage holes in WSN is a major issue. Yao Sun, Cheng dong Wu, Yunzhou Zhang, Nan Hu [16] present an algorithm based on centroid calculation to locate the position of the coverage holes and uses a graphical method to detect coverage holes, and discusses the research on route planning for Unmanned Aerial Vehicle (UAV). UAV is used to place the redeployment nodes.

Chia-Pang Chen, Cheng-Long Chaung, Tzu-Shiang Lin, Chia-Yen Lee, Joe-Air Jiang et al. [17] proposed a novel hybrid genetic algorithm (HGADSC). It comprise of genetic operations and fitness-improving local search strategy. Both these strategy divide all wireless sensor node into a number of disjoint set covers (DSCs). The HGADSC is used to solve the NP-complete problem. It guaranteed the longer network lifetime by switching disjoint set covers. The result shows that the network lifetime can be effectively improve by the proposed method. The network lifetime ranging from 0.54% to 36.1% under different simulation scenarios by using this method.

Move on wireless communication and Micro Electro Mechanical Systems (MEMS) have enabled the growth of low-cost, low-power, multi-functional, tiny sensor nodes which can sense the environment, perform data processing and communicate with each other untethered over short distances. Amitabha Ghosh, Sajal K. Das [18] used the one of the important criteria for being able to deploy an efficient sensor network is to find optimal node deployment strategies and efficient topology control techniques. Nodes can either be placed manually at predetermined locations or dropped from an aircraft. However, since the nodes are randomly scattered in most practical situation it is difficult to find a random deployment strategy that minimizes all the desirable metrics simultaneously, such as, sufficient coverage and connectivity, low-computation and communication overhead.

WSN is the collection of the independent and distributed sensor. It has an additional functionality or capacity of mobility. Mobility adds additional functionality to the wireless sensor network by providing self-deployment and relocation of sensors. Many approaches have been used for this by considering different issues. Main issue of deployment is Coverage and Connectivity. When deploy mobile sensor other issues are also come like sensor relocation, energy efficient movements of sensors, obstacle adaptability, lifetime of network, fault tolerance etc. So, Mayur C. Akewar, Nilesh singh V. Thakur [19] defined the different types of deployment techniques and algorithms with different ways of deployment. The approaches are virtual force based, movement assisted, computational geometry and pattern based approach.

The given approach should self-deploy the sensor into a connected ad-hoc network that has the maximum coverage. Non-uniform random distribution and exhausted energy of sensor nodes may lead to coverage holes problem in wireless sensor networks. So, to solve this problem of coverage holes in wireless sensor networks Wang Qing-Sheng, Gaohao [20] a geometry-based distributed coverage holes discovery algorithm. This algorithm is forming a triangle by sensor node and its two neighbor nodes, calculating circumradius and circumcenter of the triangle. This two neighbor nodes also judging existence of coverage holes under the guidance of relevant knowledge of geometric graphics. For the experimental or practical purpose MATLAB platform is used. The result shows that this algorithm is better than others algorithms and give better or high accuracy than the others algorithms.

The basic problem in Wireless Sensor Networks (WSNs) is the coverage problem. The coverage problem in WSNs causes the security environments is supervised by the existing sensors in the networks suitably. The coverage in WSNs is so important that it is one of the quality of service (QoS) parameters. If the sensors do not suitably cover the physical environments they will not be enough efficient n supervision and controlling. The other reasons which had increased the importance of the coverage problem are the topologic changes of the network. The changes are done by the damage or deletion of some of the sensors and in some cases the network must not lose its coverage. SO, Isa Maleki, Seyyed Reza Khaze, Marjan Mahmoodi Tabrizi, Ali Bagherinia [21] used the hybrid Particle Swarm Optimization (PSO) and Differential Evolution (DE) algorithms. These are the Meta-Heuristic algorithms and have analyzed the area coverage problem in WSNs. Also a PSO algorithm is implemented to compare the efficiency of the hybrid model in the same situation. The results of the experiments show that the hybrid algorithm has made more increase in the lifetime of the network and more optimized use of the energy of the sensors by optimizing the coverage of the sensors in comparison to PSO.

Coverage is a major problem for wireless sensor networks (WSN) to examine a region of interest (ROI) and to provide a good quality of service. In many applications, full coverage is required, which means every point inside the region must be covered by at least one sensor node. The occurrence of hole is unavoidable in ROI due to the inner nature of WSN, random deployment, environmental factors, and external attacks. For ensuring successful coverage in WSNs the following key elements are critical: 1) Determining the boundary of the RoI, 2) Detecting Coverage holes, and 3) Determining the best target locations to relocate nodes to repair the holes. For maintaining the coverage quality of the given WSN, K. Kavitha, T. Thamarai Manalan, M. Suresh Kumar [22] proposed a low complexity distributed and localized algorithm (HEAL) to detect and heal the holes. This algorithm allows a local healing where only the nodes located at a proper distance from the hole will be involved in the healing process. For practical work NS2 tool is used. Performance results through ns 2 simulator shows that HEAL can handle holes of various forms and sizes and provides a cost-effective and an accurate solution for hole detection and healing. They also improve the Distributed Virtual Forces Algorithm (DVFA) to deal with obstacles. Performance results show that DVFA provides an efficient deployment even if obstacles present in the monitoring area.

MOTIVATION

In the wireless sensor network any coverage hole present in the network. It is important to find the coverage hole at time to time as sensor may fail due to technical problems many works proposed the coverage and connectivity maintenance protocols. Some of the algorithm proposed to detect the coverage hole. I proposed a geometrical approach to detect and remove coverage hole. In this sensing range and communication range are equal.

3. PROBLEM FORMULATION

In a wireless sensor network some part of the network has enough coverage due to the presence of many redundant nodes, where other parts have coverage holes due to absence of any sensor. Every node knows its location information and collects its one hope and two-hop neighbors. Sensing range is equal to communication range and every node knows its location information by GPS.

TERMS

Sensing Range: Sensing range of a node is the radius (R_s) of a circular disk; it is centered to its location

Communication Range: Communication range of a node is the radius (R_c) of the circular disk.

Reference Node: A source node that initiates to execute the hole detection algorithms called reference node (RN).it collect its neighbors information located within $2r_c$ and execute the hole detection algorithm.

Neighbor: If a and b are two nodes, distance between them is $d_{ab} \leq r_c$then a and b are one hop neighbor to each other, if $r_c < d_{ab} \leq 2r_c$,a and b are two neighbor to each other.

Circum radius(R): Radius of circum circle formed by location of any three sensors as the vertices of a triangle is called circum radius.

Circum centre (z): Centre of the circum circle formed by any three vertices of a triangle is called circum center.

4. PROPOSED MODEL

In our system model, it is expected that there are multiple coverage holes in the monitoring region and the network is connected. Therefore, the one-hop and two-hop neighbors of a node must be connected with it through one and multi hops, respectively. For example, as shown in Fig. 2, if A is considered as a referencenode, it is connected with other nodes of the network with help of its one and two hop neighbors though a coverage hole exists in the network. In fact, B and D are one-hop neighbors of A. Hence, A is connected to C and E through its

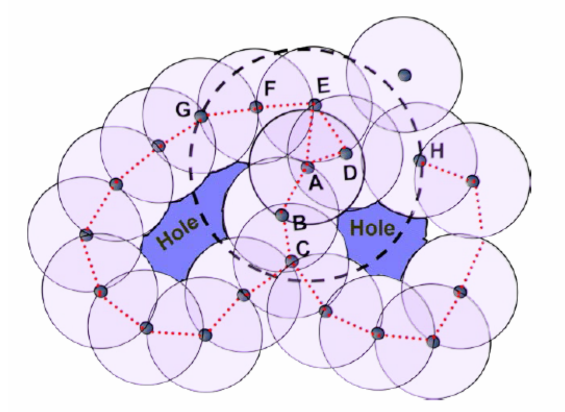

Figure 2 Example of network connectivity with presence of holes [23]

One-hop neighbors B and D, respectively. Besides, C, E, F and G are two-hop neighbors of A as they are within its 2Rc. Though, A is not connected with G and, F through It is one-hop neighbors B and D, it is connected with them through its two-hop neighbor E, which is connected to D. Hence, the whole network is connected though there are coverage holes in it. Fig.2 example of network connectivity with presence of holes.

REMOVE REDUNDANT NODE

Redundant Rule: Consider sensor node ν and aset of its overlapped neighbors $C_{overlap}$. Given a natural number*k*, node ν is redundant node if two conditions aresatisfied.

1) The union of boundary arcs created by the set of overlapped neighbor nodes $C_{overlap}$ covers completely *k* times the entire boundary sensing region of node ν.

$\square arc_i \geq 2k\pi, I \in C_{overlap}$

2) The Euclidian distance from ν to each node in the set $C_{overlap}$ is less than or equal to the sensing range R_s.

$D(\nu\ i) \leq R_s \forall I \varepsilon C$

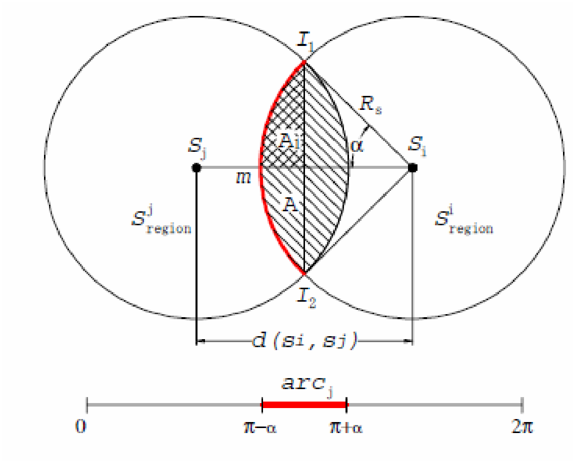

Figure3 the boundary arc created by two overlapped sensor nodes [7] and its transformation to the angle of [0,2π]

HOLE DETECTION ALGORITHM

1) Select any node as the start node from which holes detection is to be carried out.
2) The start node checks whether any overlapping of its own sensing region is present with any other sensing region of the sensor.
3) If overlapping is present, then it calculates the distance from that sensor node.
4) If the distance is less than 2Rs then it sets the node as its one-hop neighbor and the two-hop neighbor of the start node accordingly.
5) Now we connect the centers of the sensors such that a triangle is formed with the start node and its neighbors.
6) Now if a triangle is formed with the neighbors of the start node such that Rc< 2Rs and if the point of intersection of the 2 node lies within the coverage range of any sensors, then we can say that there exists no holes, else there exists a hole round the start node.

GEOMETRIC ANALYSIS

Inthe geometric analysis, we used the distributed virtual attractive and repulsive force. In this we find the attractive and repulsive force for node mobility, when the nodes are homogenous initially. We calculate a seam angle for the mobility of node outside or inside.

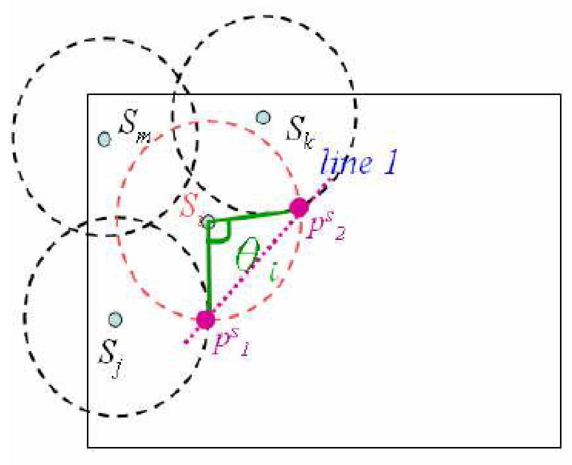

Figure 4

When s_i is the reference node, it connected to its neighbor node. When θ is the seam angle, it defines the node mobility condition:

If 0^0□θ_i□ 180^0, s_i locates on the left side of line1.

If $\theta_i = 0^0$ or 180^0, s_i locates on the line1.

If 180^0 □ θ_i □ 360^0, si locates on the right side of line 1.

Total attractive force(F^{ij}_a)

$$
\begin{cases} F_A^i = 0, & m = 0 \\ F_A^i \ltimes \sum_{j=1}^{m} (d_{ij} - r_s), & m \neq 0 \end{cases}
$$

Total repulsive force (F^{ij}_r)

$$
\begin{cases} F_A^i = 0, & m = 0 \\ F_A^i \ltimes \sum_{j=1}^{m} (r_s), & m \neq 0 \end{cases}
$$

5. Performance evaluation

In this section performed the hole detection algorithm for different number of nodes.

SIMULATION SETUP

It is simulated using MATLAB for different number of nodes that are performed randomly over an area of 500m*500m.The number of nodes varies from100 to 1000. For each sensor node has fixed amount of 90 j reserved energy,thesensing range varies from 15m to 30m with communication range equal to sensing range and a homogenous environment is setup.When the holes are generated among the multi-hop and fully connected nodes. First of all nodes discover its neighbor, all nodes give its location information to reference node and calculate distance between the nodes, control packets are sent in every 2s to detect its neighbor, which is continued to get list of all neighbor of each node. When the power (Imax) also increases.

Simulation result

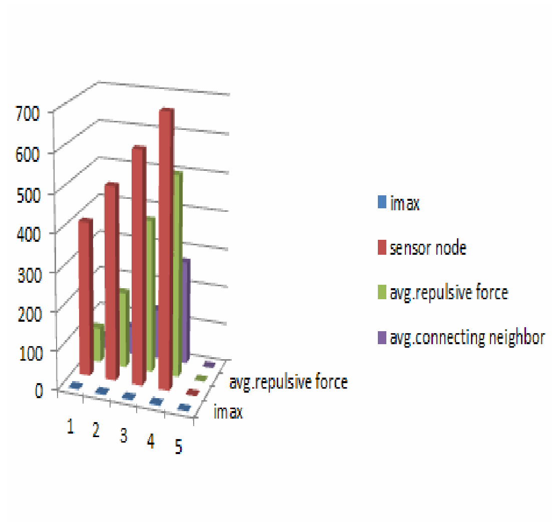

Figure 5

We simulated in fig.5 when Imax = 1.1,2 also increases with the sensor node and the repulsive force increases, avg. connecting neighbors also increases. The sensing range of each node is fixed, r_s = 15 and fixed size of monitoring area.

```
total_force_num =

     0

total_force_num =

   955

num_boundary =

    98

avg_total_att_force =

  22.114991804315803

avg_total_rep_force =

  44.387755102040842

average_connecting_neighbor =

   9.755102040816327
```

Figure 6

```
total_force_num =

     0

total_force_num =

   403

num_boundary =

   188

avg_total_att_force =

   5.698560325168634

avg_total_rep_force =

  11.170212765957437

average_connecting_neighbor =

   2.148936170212766
```

Figure = 7

In above fig. 6, 7, 8 we simulated the avg. total forces and number boundary and avg. connecting neighbors.

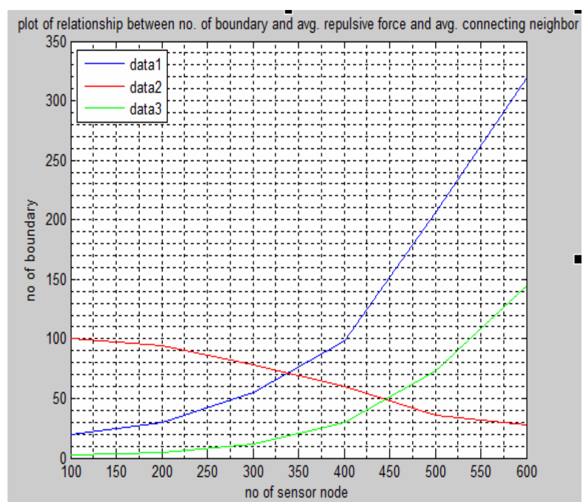

Figure8

In fig.8 numbers of nodes increases, avg. repulsive force increases and the number of boundary decreases. Data 1 indicate the avg. repulsive force and data 2 indicate the no. of boundary and data 3 indicate the avg. connecting neighbor.

The attractive force is less than the repulsive force, when $r_s = 2r_c$, the no. of sensor node increases, coverage hole also decreases. When the power increases, percentage of hole recovery also increased.

6. CONCLUSION AND FUTURE WORK

In this paper we define the coverage problem and redundancy in WSN. Distributed virtual force based approach solves this problem. Simulation result shows power increased to decrease the coverage hole. In future work, we will study to reduce power consumption.

REFERENCES

[1] Zhiping Kang, Honglin Yu, Qingyu Xiong, "Detection and Recovery of Coverage Holes in Wireless Sensor Network," *Journals of Networks,* Vol. 8, No. 4, pp. 822-828, April 2013.

[2] Zhang Mingze, "Coverage and Connectivity Management in Wireless Sensor Network," pp. 1-162, 2009.

[3] Samidha N. Kalwaghe and Atul V. Dusane, "Literature Review on Hole Detection and Healing in Wireless Sensor Network," *International Journal of Current Engineering and Technology,* Vol. 4, No. 6, pp. 4184-4188, Dec 2014.

[4] Nor Azlina Ab. Aziz, Kamarulzaman Ab. Aziz, Wan Zakiah Wan Ismail,"Coverage Strategies for Wireless Sensor Networks," *World Academy of Science, Engg. And Technology 50*, pp. 145-150, 2009.

[5] Meysam Argany, Mir Abolfazl Mostafavi, Farid Karimipour and Christin Gagne, "A GIS based Wireless Sensor Network Coverage Estimation and Optimization: A Voronoi approach," *Springer Science*, pp. 151-172, 2011.

[6] Vaishnavi Sukumaran, T.P Saravanabava, "Modified Sensor Deployment Algorithm for Hole Detection and Healing using NS2, *International Journal of Engineering Research and Applications,* ISSN: 2248-9622, Vol. 4, Issue 4, pp. 43-50, April 2014.

[7] Vinh Tran Quang, Takumi Miyoshi, "An Algorithm for Sensing Coverage Problem in wireless sensor networks".

[8] Mustapha Reda Senouci, Abdelhamid Mellouk and Khalid Assnoune, "Localized Movement-Assisted Sensor Deployment Algorithm for Hole Detection And Healing," *IEEE Transactions on Parallel and Distributed System,* Vol. 25, No. 5, pp. 1267-1277, May 2014.

[9] Vinay Rana, Rani, Ravi, "Coverage Hole Reduction in Wireless Sensor Networks using Swarm Technique," *International Journal of Science and Research (IJSR),* Vol. 3, Issue 6, pp. 1492-1499, June 2014.

[10] Shahram Babaie and Seyed Sajad Pirahesh, "Hole Detection for Increasing Coverage in Wireless Sensor Network using Triangular Structure," *International Journal of Computer Science Issue (IJCSI),* Vol. 9, Issue 1, No 2, pp. 213-218, January 2012.

[11] Hwa-Chun Ma, Prasan Kumar Sahoo, Yen-Wen Chen, "Computational Geometry Based Distributed Coverage Hole Detection Protocol For The Wireless Sensor Networks," *Science Direct Journals of Network and Computer Application 34* pp. 1743-1756, 2011.

[12] Yang-Tsung Hou, Chia-Mei Chen, Bing chiang Jeng, "An optimal new-node placement to enhance the coverage of wireless sensor networks," *Springer Science LLC,* pp. 1033-1043, May 2009.

[13] Chi Zhang, Yanchao Zhang and Yuguang Fang, "Detecting Coverage Boundary Nodes in Wireless Sensor Networks," *IEEE,* pp. 868-873, 2006.

[14] Wei Li, "A Novel Graphic Coverage Hole Description in Wireless Sensor Networks," *IEEE Communication Letter*, Vol. 18, No. 12, pp. 2205-2208, December 2014.

[15] Harish Chintakunta, Hamid Krim, "Distributed Localization of Coverage Holes using Topological Persistence," *IEEE Transactions on Signal Processing,* Vol. 62. No. 10, pp. 2531- 2540, May 15, 2014.

[16] Yao Sun, Chengdong Wu, Yunzhou Zhang, Nan Hu, "Holes Detection in Wireless Sensor Networks and Redeploy Route Planning Based on Unmanned Aerial Vehicle," *Journals of Information and Computational Science 9:13*, pp. 3665-3672, 2012.

[17] Chia-Pang Chen, Cheng-Long Chaung, Tzu-Shiang Lin, Chia-Yen Lee, Joe-Air Jiang, "A Coverage guaranteed Algorithm to Improve Network lifetime of Wireless Sensor Networks," *Science Direct Procedia Engg. 5,* pp. 192-195, 2010.

[18] Amitabha Ghosh, Sajal K. Das, "Coverage and connectivity issues in wireless sensor networks:

A survey," *Science Direct, Pervasive and Mobile Computing 4*, pp. 303-334, February 2008.

[19] Mayur C. Akewar, Nileshsingh V.Thakur, "A Study of Wireless Mobile Sensor Network Deployment," *IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC),* Vol.2, No 4, pp. 533-541, August 2012.

[20] Wang Qing-Sheng, Gaohao, "Coverage Holes Discovery Algorithm for Wireless Sensor Network," *Journal of Theoretical and Applied Information Technology,* Vol. 48, No.2, pp. 1121-1125, February 2013.

[21] Isa Maleki, Seyyed Reza Khaze, Marjan Mahmoodi Tabrizi, Ali Bagherinia, "A New Approach for Area Coverage Problem in Wireless Sensor Networks with Hybrid Particle Swarm Optimization and Differential Evolution Algorithms," *International Journal of Mobile Network Communications & Telematics (IJMNCT)* Vol. 3, No.6, pp. 61-75, December 2013.

[22] K. Kavitha, T. Thamarai Manalan, M. Suresh Kumar, "An Optimized Heal Algorithm for Hole Detection and Healing in Wireless Sensor Networks," *International Journal of Advanced Engineering Research and Technology (IJAERT)* Volume 2 Issue 7, pp. 243-249, October 2014.

[23] Hwa-Chun Ma, Prasan Kumar Sahoo, Yen-Wen Chen, "Study of Coverage Hole Detection Schemes for Wireless Sensor Networks," pp. 1-81, Nov 1994.