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Determination and Patching of Coverage Holes in Hybrid WSN with Energy Aware Routing

Chettiyanthodi Ameera, Sreeram S
Computer Science and Engineering, MEA Engineering College, Perinthalmanna, Kerala, India

ABSTRACT
In the recent days, wireless sensor network that consists of several tiny sensors has been extensively used. One of the predominant demanding situations in such networks is a way to cover the sensing region effectively and maintain longer network lifetime with restricted power simultaneously. In this system, a hybrid sensor network, which contains both static and mobile sensors under random distribution, is being observed. Here the monitoring plane is divided into triangles using Delaunay Triangulation algorithm, in order to estimate coverage holes produced by static sensors. Mobile nodes are deployed to provide assistance in case of hole formation. Subsequently, nearest mobile sensors will move to heal the coverage holes.[8]In comparison with the similar strategies, the system proposed here is less complicated, and the major highlights of the system are that it facilitates a relatively simple effort to estimate the coverage holes, deployment of assisted mobile sensors to provide a better communication experience, connectivity to sink made in energy efficient manner to provide prolonged network lifetime thereby maintaining the overall quality of the network.
Keywords : Hybrid Sensor Network, Delaunay Triangulation, Coverage Holes

I. INTRODUCTION

WSN consists of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. It is a unique category of ad hoc network.WSN employs data-centric approach. Mobility can be there but not a mandatory. Size of the network is larger than typical ad hoc network.WSN is employed in the areas with difficult accessibility. They are used in disaster prone areas where wired networks are difficult to be deployed. Since Sensors are tiny portable battery-powered devices, energy management is major issue in QoS Provisioning.

With the improvement of the cutting-edge era and the extending of carried out variety of wireless sensor networks(WSNs), wireless sensor networks have won widely attention for applying in natural disasters and some risky environment , consisting of earthquake stricken vicinity and old-growth forest fire. Risky environment exits large safety hazard for the rescuers if they need enter the first scene. Fortunately, casting a mount of sensors to the tracking vicinity can not only clear up the safety risk hassle but additionally make up WSNs networks to gain the immediately message of catastrophe place. However, the random deployment sensors may additionally lead to the coverage holes and WSNs are the data-centric network. As a consequence, it's miles a worth research to attain efficient coverage[8].

Presently, several researches are available on the coverage problem and the mechanisms to heal them. The main strategies of increasing coverage include identifying the coverage holes, healing the holes, and using distinct methods to patch them up. Most of them discusses methods of detecting coverage hole and mechanisms to recover the holes are not described. [1-7] At the same time, the expense of enhancing the coverage is steeply-priced, some of them requires sensors to have locomotion abilities have distinct energy levels.

In this system, the region coverage of hybrid sensor networks is being observed [8]. At the start, static sensors are used to estimate the position of coverage holes. The sensing radii of assisted mobile sensors are adjusted in such a way that it covers the hole with a minimum of one mobile node inside the random distribution sensor network. Then deploying the assisted mobile nodes to heal the coverage holes.

It is expected that a sensor network is deployed with a positive number of static nodes within the sensing region stochastic ally. The static nodes construct DT, then estimating the coverage holes in every triangle, and locating out the apt positions of assisted nodes to be moved in every triangle. At last, the static sensors conduct the mobile sensors move to the optimal location to heal the coverage holes. In comparison with the present methods, this approach specially suggests several highlights as follows.

1. The calculation approach of coverage is less difficult than different works performed regarding the coverage issue.
2. Provides mobile nodes deployment method to heal the coverage holes.
3. Facilitates energy efficient communication to the sink.[20]

II. METHODS AND MATERIAL

The proposed system aims to rectify issues related to effectively covering the sensing region, healing of coverage holes by mobile sensors, facilitates energy efficient communication to sink and helps to maintain a longer network lifetime.

Methodology

1. Sensor nodes are randomly distributed in a 2D plane which includes both static and mobile nodes
2. Division of plane done by Delaunay Triangulation
3. Defining sensing radius for static and mobile nodes. Mobile nodes are provided with large radius to enhance coverage
4. Region not falling in the sensing range of any sensors identified and corresponding triangle is expected to contain a coverage hole
5. Nearest mobile node moves to hole region to provide assistance to heal the hole detected
6. Dijkstra algorithm enables shortest path communication to sink. Mobile nodes used to cover the holes take part in communication if they come along the shortest path.

System Design

This section describe the events carried out in each phases of Project. Here initially the nodes are randomly deployed in a 100x100 2D plane. The nodes are randomly distributed in the monitoring region. The network under consideration is a hybrid wireless sensor network. The deployed nodes include both static and mobile nodes. The division of the plane is done by constructing Delaunay Triangles. The sensing regions for all the static nodes are determined. Coverage holes appear in the area where the sensing regions do not overlap. Nearest mobile nodes are moved to position where holes are present to patch them. Dijkstra algorithm is being used to facilitate shortest path communication to sink in order to minimize the energy consumption, which in turn improve the surveillance time of the network

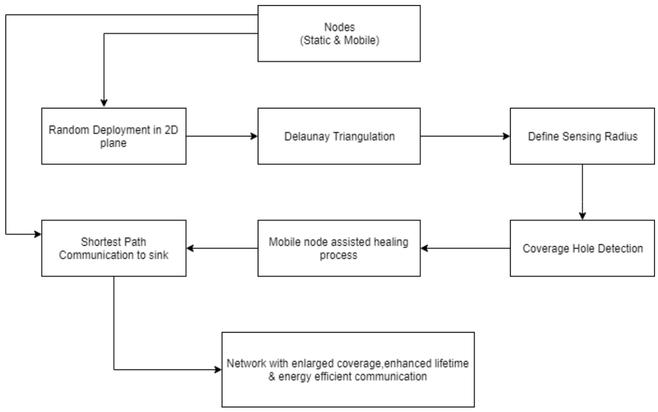

Figure 1. System Design

Algorithm 1 Coverage Hole Detection and patching

1. Construct a 100x100 area and generate random static nodes of N numbers.
2. Generate M mobile nodes and static nodes are fixed at each corner of the area.
3. Construct a Delaunay triangle using the above static nodes using sweep-line strategy.
4. Fix a coverage range for each node at the vertex of the triangles. Draw a circle to show the coverage of nodes.
5. Find coverage holes. If the half length of any side of the triangle is greater than coverage range of the nodes there exist a coverage hole.
6. Fix the coverage hole by moving the mobile node to the current location.
7. Set the node at the position (X,Y)-(0,0) as the sink node.
8. Find the minimum path distance to the sink node from any of the triangles using Dijkstra's Algorithm.
9. Show the minimum path distance using static as well as mobile nodes.
10. Search for further coverage holes once all triangles are considered

While deploying sensor nodes at random or due imbalance of energy among the nodes, some regions in the network would not fall in the sensing ranges of any sensor nodes. As a result of which there can be gaps or communication voids in the network which categorized as coverage holes. There are different methods and techniques used to tackle this problem.

Once the deployment of static and mobile nodes is completed, next step is to divide the plane using a computational geometry approach called Delaunay Triangulation. Unique properties like empty circle property are being exploited here to detect coverage holes. The locomotive properties of the mobile nodes are utilized to patch the already determined holes. Energy aware routing is provided for communication to the sink.

The coming sections introduce a few preparatory know-how of techniques and methods used inside the project for the following evaluation.

A. Sensing Radius and Communication Radius

Every sensor has communication ability and sensing capability, Rc is described as communication radius and Rs is described as sensing radius, Figure 2. indicates the communication and sensing models. If and only if the distance between two sensors is inside Rc , they could communicate with one another, in any other case the node is isolated.[10]

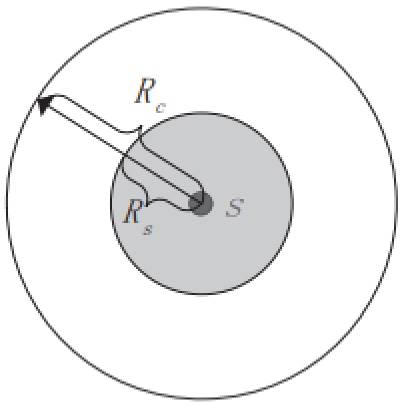

Figure 2. Sensing radius and communication radius

- S indicates the sensor node
- Rs represents the sensing range of the nodes
- Rc represents the communication ranges of nodes

Definition 1

Sensing range: Sensing range of a node is the circular disk of radius Rs, which is centred at its location .As shown in Fig 2, the circumference of the circle centred at S, represents sensing range of node S. Any object present within the sensing range is perfectly detected by the sensor.

Definition 2

Communication range: Communication range of a node is the circular disk of radius Rc, which is centred at its location .In Fig. 2, communication range of node S is represented by the circumference of the circle centred at S.

B. Random Deployment of Sensor Node in a 2D Plane

Here the nodes are randomly deployed in a 2-dimensional plane. The distribution consists of both static and mobile nodes. Static nodes are used for division of the plane. Mobile nodes help to patch the holes. The mobile nodes have sensing ranges higher than that of the static nodes.

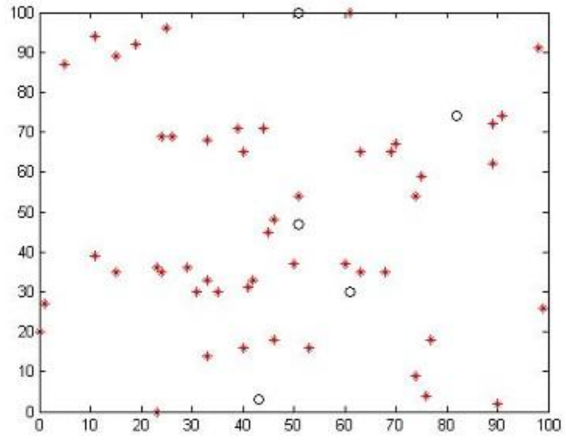

Figure 3. Random Deployment of Nodes in 100X100 plane

* Static nodes
° Mobile nodes

The static nodes basically serves the purpose of plane division and communication. Due to variations in the density of nodes some areas in the network would be dense where others would be sparse. Since the deployment is done randomly, probability to have coverage holes is high. As a result of which detecting and covering the holes is of great significance. This function is done by the mobile sensors. Nearest mobile sensors move to the region of hole to patch them up, thereby preventing data loss and network breakage.

C. Division of plane by Delaunay Triangulation

Delaunay Triangulation[17] is position-based algorithm in computational geometry. They are obtained by drawing perpendicular bisectors to the voronoi edges. The uniqueness of DT is that they satisfy empty circle property.

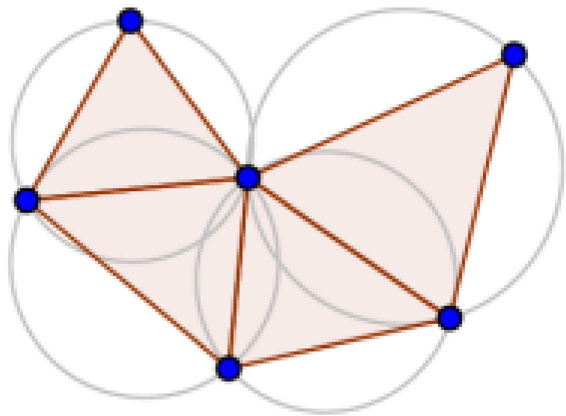

Figure 4. Empty circle property

As the Delaunay triangle satisfies the empty circle property there would no nodes in the circumcircle of the triangle other than its vertices. There would no nodes in the interior of circle passing through the vertices of the triangle. Another property of DT is that they try to maximize the minimum angle so as to avoid long thin triangles.

The algorithm for implementing Delaunay triangulation using sweep-line strategy is follows

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Algorithm 2 Delaunay Triangulation

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1. Sort all point by their x-coordinate first and by the y-coordinate if the x-coordinate of two points is identical.
2. Take the three first points of the sorted list to form the first triangle. You will need another data structure to remember the convex hull of the points you already have connected. At first, it is all the three line of the first triangle.
3. Now iterate over your sorted list of points. For each point check if you need to connect with the two points of the line segments of the convex hull. This can form a new triangle. If it does, you need to check as well if you have to flip the edge of the newly formed triangle and the existing neighbouring one. Do not forget to update the convex hull.

Actually, the convex hull is not necessary for the algorithm to work. But, it will speed things up significantly and is not very hard to implement. We need data structures that work both ways: A triangle needs to know all its edges and vertices. And the edges need to know the corresponding triangles and its vertices. We should store all this information explicitly.

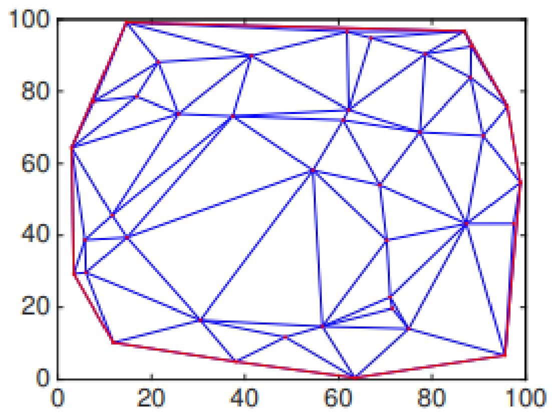

Figure 5. Delaunay Triangulation

Once the random deployment of nodes are completed, next step is to divide the sensing region. This is done by using a geometrical approach called Delaunay Triangulation. The DT divides the monitoring regions into small triangles. The triangles satisfy the empty circle property where the circumcircle containing the triangle remains empty. It also restricts the formation of long thin triangles.

Delaunay Triangulation Corrected

In Fig 6, some nodes are fixed to the boundary regions in order to ensure the boundary coverage. A new Triangulation is done including the fixed nodes.

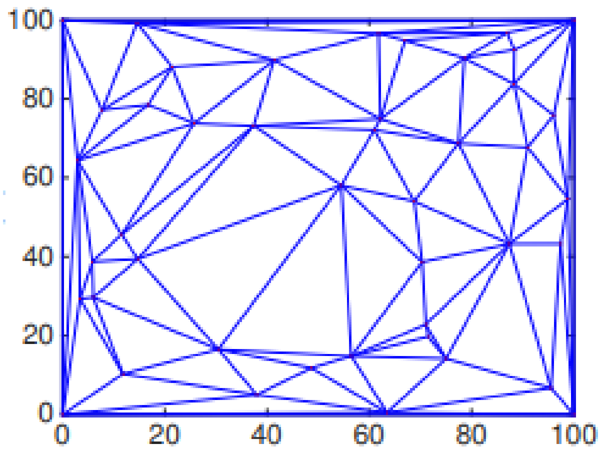

Figure 6. Delaunay Triangulation Corrected

D. Sensing Radius Definition and Coverage Hole Prediction

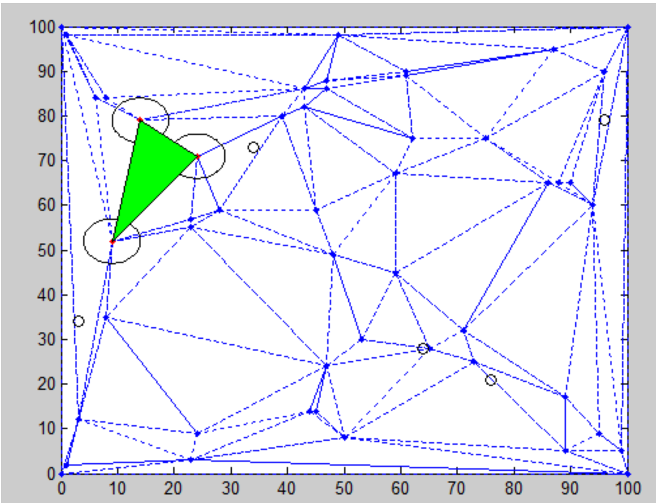

Figure 7. Coverage hole prediction in single triangle

The Wireless sensor network considered here has both mobile and static nodes. Sensing range of a node is the circular disk of radius, which is centred at its location. The sensing radius of the static nodes are smaller when compared to that of the mobile sensors. The idea behind larger radius provision for mobile is to patch the coverage holes.

Here the coordinates obtained after Delaunay Triangulation is exploited for the calculation of coverage holes. Here, the edges of each triangles are calculated using the distance formula. The mid-point of each edge is determined next. Sensing radius of the static nodes are then compared to the obtained value. If the sensing radius is smaller than the mid-point value of edge, there is coverage hole in that triangle. Otherwise, the triangle is considered to be fully covered.

As shown in Fig 7 the circles at the vertex of the triangle indicates the sensing region of the static nodes contained in that triangle and the portion shaded in green represents the triangle containing a coverage hole.

E. Mobile Node Assistance to Patch the Coverage Holes

On detecting the coverage holes by using Delaunay triangulation, the nearest mobile node would move to the position of the hole to patch them. Here the sensing radius of the mobile sensor is twice as that the static node to cover the hole with minimum of one node.[16]

F. Energy Efficient Communication to sink

The proposed system also provides shortest path communication to the sink. The sink is deployed at the origin. It is accomplished by utilizing Dijkstra algorithm. A source node is selected at the start and it senses ten nearest neighbours and marks the most nearest one as visited and all the others as unvisited. The procedure continues until the shortest path is discovered from source to the destination.

Below are the detailed steps used in Dijkstra's algorithm[15] to find the shortest path from a single source vertex to all other vertices in the given graph.

Algorithm 3 Dijkstra Algorithm

1. Create a set *spt*Set (shortest path tree set) that keeps track of vertices included in shortest path tree, i.e., whose minimum distance from source is calculated and finalized. Initially, this set is empty.
2. Assign a distance value to all vertices in the input graph. Initialize all distance values as INFINITE. Assign distance value as 0 for the source vertex so that it is picked first.
3. While *spt*Set doesn't include all vertices

a. Pick a vertex u which is not there in *spt*Set and has minimum distance value.

b. Include u to *spt*Set.

c. Update distance value of all adjacent vertices of u. To update the distance values, iterate through all adjacent vertices. For every adjacent vertex v, if sum of distance value of u (from source) and weight of edge u-v, is less than the distance value of v, then update the distance value of v.

III. RESULTS AND DISCUSSION

In this section results of the proposed system based on coverage hole detection and patching with energy aware routing is presented. Static and mobile sensors are deployed in a 100x100 2-dimensional monitoring region. The sink station is fixed at (0,0) position of an x y coordinate system and all routing activities are forwarded to the sink.

Each node is provided with its own sensing radius and communication regions. Here the sensing radius of mobile node is twice as that of the static nodes.

This is done to provide assistance when coverage hole occurs. The mobile move to the hole region in order to reduce the communication voids in the network. Dijkstra algorithm is employed in order to impart an energy efficient communication to the sink.

A. Analysis of Results

The simulation results obtained using Matlab are described here.

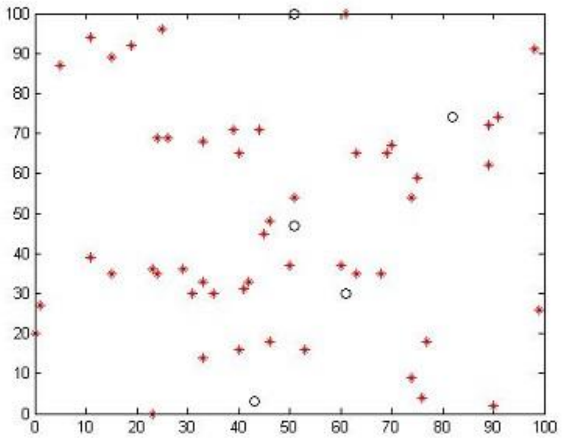

Figure 8. Random distribution of nodes

As shown fig 8, represents random distribution of nodes in 2D plane. The red stars indicates the static nodes while the small circles denote mobile sensors.

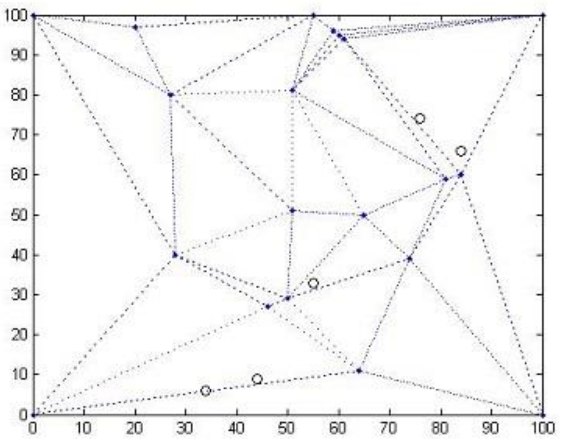

Figure 9. Delaunay Triangulation for 50 static sensors

Plane division by Deluanay Triangulation for 50 sensors are shown in figure 9.The plane is divided in such a way that it always tries to avoid formation of long thin triangles.

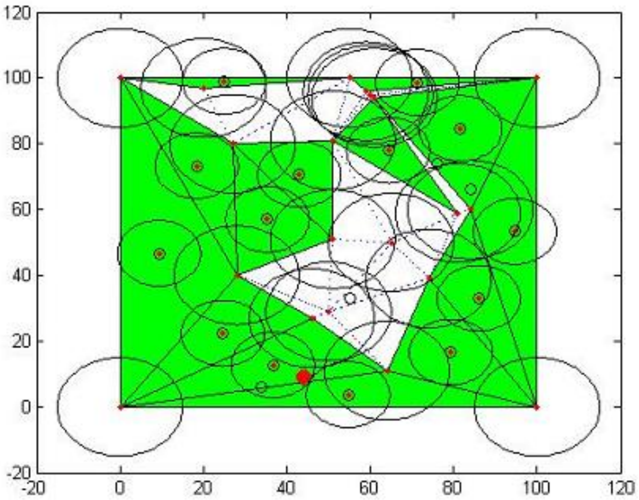

Figure 10. Coverage hole detection and healing for 50 sensors

Experimentation by varying the number of sensors

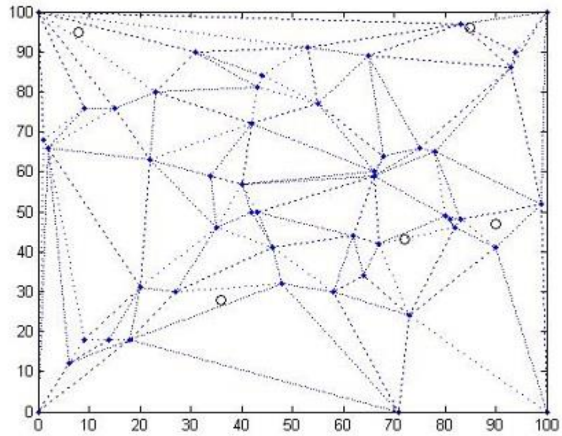

Figure 11. Delaunay Triangulation for 100 sensors

Fig 11 shows division of plane done using Delaunay Triangulation which is a geometrical approach. The triangles satisfy the empty circle property where the circumcircle containing the triangle remains empty. It also restricts the formation of long thin triangles where it tries to maximize the minimum angle.

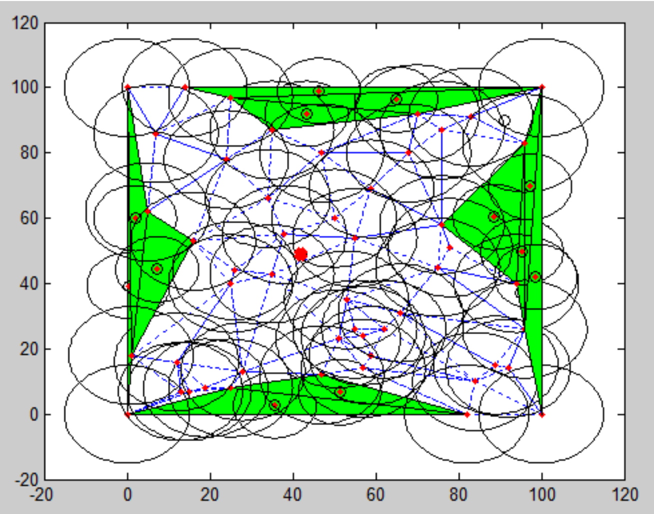

Figure 12. Hole detection and patching for 100 sensors

Coverage hole detection and healing of hole by mobile sensors is depicted in Fig.12 .The triangles shaded green contain coverage holes. The mobile nodes are moved to the hole region to cover the holes.

Fig.13 describes shortest path communication to the sink .It is employed by using Dijkstra algorithm. Initially it starts with a node and senses its ten nearest neighbors and selects the most nearest among that and marks it as visited. The procedure continues until the shortest path is discovered from source to destination.

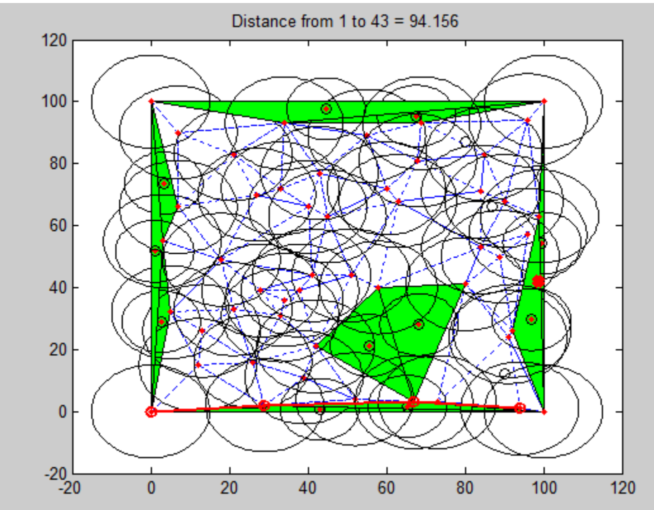

Figure 13. Shortest path communication to the sink

B. Performance Analysis

Among the various algorithms studied, Distance Vector Hole Determination algorithm requires frequent flooding of distance information in order to impart energy efficient communication. While considering the energy requirement as key perspective, probability for hole formation increased to a greater extend as the packets may route through the hole region. As a result of which large amount of energy is wasted.[16] Distributed coverage hole detection algorithm requires CIP and CP calculation to estimate the coverage holes which in turn increases the average hole determination time as well. Complex calculations are also involved in this algorithm.[9] COVEN algorithm requires division of polygon into triangles to get precise location of hole prone area which makes the algorithm much more complex. Major part of the energy is being spend on plane division itself rather than for hole determination and to rectify them.[5] The proposed system aims to rectify issues related to effectively covering the sensing region, healing of coverage holes by mobile sensors, facilitate energy efficient communication to sink and helps to maintain a longer network lifetime.

IV. CONCLUSION

In this paper, the coverage hole detection and healing in a hybrid WSNs is being studied. The project uses computational geometry based approach for hole detection. Division of the plane is accomplished by constructing Delaunay Triangulation which is one of the unique methods. A few nodes are fixed to boundaries to ensure boundary coverage. The communication range of the sensor nodes is twice as that of the sensing radius. Accurate detection of holes and efforts to patch them is a basic necessity for surveillance of the wireless sensor network. Delaunay Triangulation algorithm makes the position of nodes available which are constructively used for hole determination and for providing mobile node assistance to patch them. The sensing radius of the mobile nodes are adjusted in such a way that the holes can be covered with a minimum of one mobile sensor node.

Since the sensors are battery powered devices energy is also a vital concern. To facilitate this, Dijikstra algorithm, one among the Shortest Path algorithms is being used for facilitating communication to sink. The mobile nodes used for healing may also take part in communication if they come along the shortest path thereby preventing the breakage or data loss. Thus, the output obtained is a hybrid sensor network with enlarged coverage, extended lifetime and energy efficient communication to sink. As a future scope energy of the nodes can also be considered while discovering the shortest path. Also strategies to implement the network in an irregular region can also be studied.

V. REFERENCES

[1] Abdellatief, W., Abdelkader, H., and Hadhoud, M. (2016). An energy-efficient coverage hole detection technique for randomly deployed wireless senor networks. In 2016 11th International Conference on Computer Engineering & Systems (ICCES), pages 340–347. IEEE.

[2] Beghdad, R. and Lamraoui, A. (2016). Boundary and holes recognition in wireless sensor networks. Journal of Innovation in Digital Ecosystems, 3(1):1–14.

[3] Dai, G., Lv, H., Chen, L., Zhou, B., and Xu, P. (2016). A novel coverage holes discovery algorithm based on voronoi diagram in wireless sensor networks. International Journal of Hybrid Information Technology, 9(3):273–282.

[4] Fortune, S. (1995). Voronoi diagrams and delaunay triangulations. In Computing in Euclidean geometry, pages 225–265. World Scientific.

[5] Ghosh, A. (2004). Estimating coverage holes and enhancing coverage in mixed sensor networks. In 29th annual IEEE international conference on local computer networks, pages 68–76. IEEE.

[6] Ghosh, P., Gao, J., Gasparri, A., and Krishnamachari, B. (2014). Distributed hole detection algorithms for wireless sensor networks. In 2014 IEEE 11th International Conference on Mobile Ad Hoc and Sensor Systems, pages 257–261. IEEE.

[7] Jewel, D., Brundha, P., Wise, D., and Swaminathan, G. A. (2016). Improved hole detection healing and replacing algorithm for optimal coverage in wireless sensor networks. Int. J. Sci. Res. Sci. Eng. Tech, 2:724–731.

[8] Koriem, S. and Bayoumi, M. (2018). Detecting and measuring holes in wireless sensor network. Journal of King Saud University-Computer and Information Sciences.

[9] Kumar Sahoo, P., Chiang, M.-J., and Wu, S.-L. (2016). An efficient distributed coverage hole detection protocol for wireless sensor networks. Sensors, 16(3):386.

[10] Li, X., Hunter, D. K., and Yang, K. (2006). Wlc12-1: Distributed coordinate-free hole detection and recovery. In IEEE Globecom 2006, pages 1–5. IEEE. 11. Liang, J., Liu, M., and Kui, X. (2014). A survey of coverage problems in wireless sensor networks. Sensors & Transducers, 163(1):240.

[11] Liang, J., Liu, M., and Kui, X. (2014). A survey of coverage problems in wireless sensor networks. Sensors & Transducers, 163(1):240.

[12] Ma, H.-C., Sahoo, P. K., and Chen, Y.-W. (2011). Computational geometry based distributed coverage hole detection protocol for the wireless sensor networks. Journal of network and computer applications, 34(5):1743–1756.

[13] Mohamadi, H., Salleh, S., Razali, M. N., and Marouf, S. (2015). A new learning automata-based approach for maximizing network lifetime in wireless sensor networks with adjustable sensing ranges. Neurocomputing, 153:11–19.
[14] Soundarya, A. and Santhi, V. (2017). An efficient algorithm for coverage hole detection and healing in wireless sensor networks. In 2017 1st International Conference on Electronics, Materials Engineering and Nano-Technology (IEMENTech), pages 1–5. IEEE.
[15] Umale, M. and Markande, S. (2015). Energy efficient routing algorithm on the target tracking in wireless sensor network. In 2015 International Conference on Information Processing (ICIP), pages 176–181. IEEE.
[16] Wang, G., Cao, G., Berman, P., and La Porta, T. F. (2007). Bidding protocols for deploying mobile sensors. IEEE Transactions on Mobile Computing, 6(5):563–576.
[17] Wu, C.-H., Lee, K.-C., and Chung, Y.-C. (2007). A delaunay triangulation based method for wireless sensor network deployment. Computer Communications, 30(14-15):2744–2752.
[18] Zhang, G., Qi, C., Zhang, W., Ren, J., and Wang, L. (2017). Estimation and healing of coverage hole in hybrid sensor networks: A simulation approach. Sustainability, 9(10):1733.
[19] Zhang, G., You, S., Ren, J., Li, D., and Wang, L. (2016). Local coverage optimization strategy based on voronoi for directional sensor networks. Sensors, 16(12):2183.
[20] Zhang, L., Yang, W., Rao, Q., Nai, W., and Dong, D. (2013). An energy saving routing algorithm based on dijkstra in wireless sensor networks. JOURNAL OF INFORMATION &COMPUTATIONAL SCIENCE, 10(7):2087–2096.

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