Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 2 (2024)

An Area Coverage Improvement Using Voronoi Diagram

[1]Sindhuja R.,[2] Suvetha S., [3]Vijaya Harshitha S., [4]Subramanian K.

[1]Department Of Electronics & Communication Engineering

National Engineering College

Tamilnadu-628503,India

[2]Department Of Electronics & Communication Engineering

National Engineering College

Tamilnadu-628503,India

[3]Department Of Electronics & Communication Engineering

National Engineering College

Tamilnadu-628503,India

[4]Department Of Electronics & Communication Engineering

National Engineering College

Tamilnadu-628503,India

Abstract

Sensor Deployment And Area Coverage Plays An Important Part In The Wireless Sensor Network (Wsn). This Research Paper Explains About The Issue Of The Network Coverage And Sensor Node Deployments. The Majority Of The Ecological Environment, Vast Areas, Remote Areas Etc.., Are Uncovered And Lack Of Network Connectivity. Moreover, These Issues Makes A Major Impact On The Data Collection And Time Consumption. Voronoi Diagram Splits The Areas Into Regions And It Partition The Areas. It Is Useful To Calculate The Area Coverage. Area Coverage Also Be Monitored By Plotting The Circles In The Voronoi Cells. The Coverage Improvement Performance Can Be Implemented By The Robust Algorithms. The Voronoi Vertex Algorithm (Vvaa) Is To Improving The Coverage In Wsn And It Helps To Reduce The Sensor Displacement And Time. Matlab Tool Evaluate The Sensor Deployment, Area Coverage. Area Coverage Also Be Monitored By Plotting The Circles In The Voronoi Cells. The Coverage Improvement Performance Can Be Implemented By The Robust Algorithms. The Voronoi Vertex Algorithm (Vvaa) Is To Improving The Coverage In Wsn And It Helps To Reduce The Sensor Displacement And Time. We Use Matlab Tool To Evaluate The Sensor Deployment, Area Coverage. This Algorithm Approaches Moving Sensors Away From High Density Areas And Towards Low Density Areas. Improving The Coverage Is The Main Objective, Which Is Critical In The Wsn. This Algorithm Makes Sensor Deployment Randomly And Covering The Areas.

Keywords: Voronoi Diagram, Wireless Sensor Network, Area Coverage

1.Introduction

The Wireless Sensors Are Widely Used In Various Applications To Sense And Detect The Conditions Of Certain Geographical Locations. In The Wireless Sensor Node Deployment, Various Methods Like Artificial Intelligence, Machine Learning Are Used To Effectively Utilize The Coverage Area Of Individual Sensor Node And To Make Greater Use Of Available Resources.

To Make Effective Use Of The Sensor Node, Voronoi Diagram A Mathematical Concept Can Be Used In The Region Of Geographical Location, Which Is Needed To Be Studied. The Concept Of Voronoi Diagram Is Integrated To Optimize The Sensor Node. The Computational Techniques And Adaptability Of Voronoi Diagrams Are Extremely Capable Of Solving Real World Problems.

The Voronoi Vertex Averaging Algorithm (Vvaa) Is Used Here For Maximizing Network Coverage. The Issue Of Inadequate Network Coverage In Wireless Sensor Network Due To The Random Placement Of Static Sensor Nodes. This Problem Can Be Solved By Using Movable Sensor Nodes. Various Problems In Sensor Node Deployment Including Coverage, Holes, Coverage Improvement Of Nodes, Redeployment Of Nodes Can Be Improved By Using Vvaa.

Instead Of Deploying Large Number Of Sensors Randomly To Cover An Area, We Can Cluster Out The Areas Into Small Sub Regions And Then Assign The Sensor Nodes Carefully Which Will Then Reduce The Resources Spent On The Sensor Deployment. Here The Sensors Are Deployed Randomly And The Nodes Of Each Sensor Is Taken Into Account And Each Node Uses The Neighbouring Points Using Which The Voronoi Polygon Is Constructed.

The Vertices Of Each Voronoi Polygon Is Averaged Using The Voronoi Vertex Averaging Algorithm. Each Sensor Node Averages Its Vertices And The Average Is Taken As The Centroid Of Polygon. Hence After Averaging, If The Average Point Is Within The Polygon The Node Will Move Towards The Average Point To Make Efficient Coverage. This Process Is Done At All The Nodes At The Same Time. To Achieve The Improvement Of Sensor Coverage Several Iterations Are Done In Which The Program Deploys Random Sensors, Calculates Total Network Coverage, Identifies Neighbours, Builds Voronoi Polygons, Averages Vertices, And Moves Nodes To Ideal Places. This Iterative Approach Makes Vvaa More Efficient And More Optimizing.

2. Literature Survey

The Findings Of The Paper [1] The Work "Voronoi-Obstacle Group Reverse K Farthest Neighbor Query Method" Focuses On The Creation Of A New Algorithm For Handling Complicated Spatial Data Queries In The Context Of Geographic Information Systems. The Fundamental Goal Of The Study Is To Handle The Problem Of Efficiently Discovering The Farthest Closest Information From A Collection Of Query Points Regardless Of The Presence Of Spatial Impediments. This Issue Has Major Ramifications In A Variety Of Practical Applications, Such As Facility Location, Quake Comfort Marketing, And Others. The Current Approaches For Reverse Farthest Neighbor Queries, However, Have Drawbacks. They Are Typically Concerned With Single-Query Points And Do Not Take Into Account Circumstances In Which The Number Of Query Points Changes From One To A Group.

The Research [2] One Of The Research Hotspots In The Field Of Wireless Sensor Network Coverage Control Is Barrier Coverage. The Voronoi Diagram Is Used To Split The Complete Deployment Region In Order To Correct The Issues And Shortcomings Of The Network, Which Comprises Of All Identical Cells In The Barrier Coverage. A Mixed Network Deployment Technique Consisting Of Both Static And Dynamic Nodes Is Formed Using The Least Square Method, With Static Nodes Serving As The Reference Boundary Line. By Assessing If Dynamic Nodes Require Little Movement To Redeploy The Monitored Area, The Monitoring Area Can Be Successfully Covered Through Determining If There Is A Barrier Covering The Blind Spot In The Deploying Region. And Proposes The Combined Node Barrier Covered By This Algorithm.

This Paper [3] The Achievement Of Comprehensive Coverage Of The Region Of Interest (Roi) In Wireless Sensor Networks (Wsns) Is Critical, Especially In Areas Such As National Security, Surveillance, Military Operations, Healthcare, And Environmental Monitoring. Reduced Reliance On Initial Node Deployment Is A Significant Difficulty In Providing Optimal Coverage. The Voronoi-Based Cooperative Node Deployment (Vcond) Algorithm Has Been Proposed To Overcome This Issue. Vcond Distinguishes Itself By Optimizing Coverage Efficiency Regardless Of Initial Sensor Node Positions.

This Paper [4] Solving Geometrical Issues On A Set Of 3d Balls Is A Difficult Task In Computerized Geometry. When The Voronoi Structure For The Set Is Given, They Can Be Solved Effectively. Edge Tracing Or Related Methods Focused On Identifying Voronoi Vertices Along Edges Are Commonly Used To Create The Diagram. However, Due To The Projected Quadratic Time Complexity, It Is Unfeasible. Our Novel Technique Has The Potential To Greatly Enhance This. Whenever A Vertex Is Required, A Delaunay Triangulation Of Ball Centers Is Carried Out Across To Locate One Specific Ball. The Search Is Contained Within A Geographic Filter, Which Can Be Shrunk During The Search. Because This Is Our Intended Use, We Show The Improvement On Enzyme Data (A Set Of Balls Represents Atoms In A Molecule).

In This Paper [5] Wsns Are Made Up Of Sensor Nodes That Have Energy Constraints And Complex Network Configurations, And Their Major Job Is To Gather And Communicate Perception Data To Displays For A Variety Of Applications Such As Security, Monitoring, And Environmental Monitoring. It Is Critical For These Applications To Achieve Good Coverage In Wsns. The Suggested Method Tries To Enhance Coverage While Consuming Less Energy And Maintaining Network Connectivity. It Begins By Solving The Issue Of Separated Nodes, Which Can Impair Network Connectivity. By Altering Sensor Placements, The Connectivity Enhancement Phase Minimizes These Isolated Nodes.

This Paper [6] The Voronoi Diagram (Vd) Is A Basic Technique For Overcoming Mobile Sensor Network Coverage Difficulties. Most Vd-Based Coverage Methods Use A Centralized Construction Mechanism To Aggregate Global Location Information And Generate A Vd. However, Gathering Global Location Information Is Costly And Cannot Be Assured In All Cases. This Work Offers An Area Coverage Method And A Completely Sponsored Coverage Method Using A Localized Vd Creation Algorithm That Removes The Gps Requirement For Global Location Awareness. The Level Of Difficulty And Message Cost Of Such Algorithms Are Used To Evaluate Their Performance In A Series Of Simulation Trials. When Compared To Concentrated Area Coverage Methods And Central Angle Algorithms, The Results Reveal That Our Algorithms Are Superior In Both Respects.

This Paper [7] Wireless Sensor Network (Wsn) Is Primarily Formed Of A Number Of Sensor Nodes, The Primary Responsibility Of Which Is To Perceive Various Events In The Surrounding Environment, Perform Processing On Top Of It, And Eventually Propagate Relevant Information To The Observer Via Several Intermediate Nodes. One Of The Difficulties In Wsn Is Area Coverage, Which Ensures That The Selected Active Nodes Among All Deployed Nodes Reach Each Point Of The Deployed Area. The Goal Of Total Area Coverage Is To Identify And Deactivate Redundant Nodes So That The Balance Of Nodes That Are Active Are Capable Of Covering The Deployed Area. Among The Several Existing Ways For Wsn Area Coverage, A Grid-Based Strategy Has Been Developed That Gives An Improved Means To Select Nodes That Are Active Or Deactivate The Inactive Nodes.

This Paper [8] A General Structure For 3d Surface Remeshing In This Study. The Result We Produce Is An Effective 3d Triangular Mesh That Has A User-Defined Vertex Budget, Created Using A Metric-Driven Discrete Voronoi Diagram Construction. Our Method Can Handle An Extensive Variety Of Applications, Including High-Quality Mesh Production And Shape Approximation. The Application Of Proper Metric Constraints Allows Thee Approach Produces Isotropic In Nature Or Anisotropic Elements. Our Technique, Which Is Based On Point Sampling, Combines Robustness And Theoretical. The Robustness Of The Delaunay Criterion Is Combined With The Productivity Of Fully Discrete Geometry Computation.

3.Proposed Work

3.1 Problem Statement

The Paper Presents About The Deterministic Sensor Deployment In Wireless Sensor Network Makes A Serious Problem Which Leaving The Certain Regions Uncovered. The Major Issues Were:

• Coverage

• Coverage Holes

• Sensor Deployment Displacement

•Redeployment Time

Real-Time Applications Makes A Great Impact For Monitoring The Environment, Disaster Management. To Tackle These Issues It Is Necessary To Provide The Efficiency Coverage By Sensor Placement. Sometimes In Unexpected Environments Many Sensor Nodes May Malfunction. It Is Critical To Provide Solution To The Constant Coverage For The Mobile Sensors. Determining And Optimizing The Sensor Node May Be Challenging Particularly In Irregular Shape Spaces. Poor Data Collectiveness From The Coverage Holes.

3.2 Approached Theory

The Voronoi Vertex Averaging Approach (Vvaa) Approaches The Movement Of Sensors Deployment Relocation. The Sensors Are Reallocated From Sparsely Deployed Locations To Heavily Deployed Regions. Initially The Sensors Are Deployed Randomly In The Regions. The Average Value For Each Vertex In The Node's Own Voronoi Polygon Is Then Calculated. The Ideal Placement Is Thought To Be The Average Point. The Sensors Are Thus Free To Move In The Direction Of The Freshly Determined Ideal Positions. Matlab Tool Is Used To Implement The Method. The Average Value Points Out The New Location Of The Each Polygon.

The Steps For The Algorithms Includes, Random Sensor Deployment: In The Beginning, Sensor Nodes Are Dispersed In A Sensor Field At Random. In Other Words, There Is No Particular Order Or Pattern In Which The Sensor Nodes Are Distributed. Calculating Total Network Covering: The Algorithm Determines The Total Network Coverage After The Random Deployment. By Adding Together The Coverage Regions Of All Sensor Nodes, This Is Accomplished.

Each Node Has A Coverage Area (R2) That Is Specified By Its Sensing Range (R), Which Is Thought To Be A Circular Circle With A Radius Of R. Neighbour And Voronoi Polygon Identification: Each Sensor Node Recognizes Its Neighbours. After That, Voronoi Polygons Are Built For Every Sensor Node. These Polygons' Vertices Stand In For Crucial Locations In The Sensor Field. Vertex Average Calculation: The Procedure Determines The Average Coordinates (X, Y) Of The Vertices Of Each Sensor Node's Associated Voronoi Polygon

The Sensor Node Should Be Placed At These Average Coordinates To Enhance Network Coverage. The Sensor Nodes Are Then Shifted Toward The Average Points Of Their Voronoi Polygons, Which Have Been Estimated To Be Their Newly Optimum Placements. Redistributing Sensors From Heavily Populated Areas To Less Populated Areas Is The Goal Of This Initiative. Iterative Process: Steps 2 Through 5 Are Performed As Many Times As Necessary (N) To Complete The Process. These Polygons' Vertices Stand In For Crucial Locations In The Sensor Field.

Vertex Average Calculation: The Procedure Determines The Average Coordinates (X, Y) Of The Vertices Of Each Sensor Node's Associated Voronoi Polygon. The Sensor Node Should Be Placed At These Average Coordinates To Enhance Network Coverage. The Sensor Nodes Are Then Shifted Toward The Average Points Of Their Voronoi Polygons, Which Have Been Estimated To Be Their Newly Optimum Placements. Redistributing Sensors From Heavily Populated Areas To Less Populated Areas Is The Goal Of This Initiative. Iterative Process: Steps 2 Through 5 Are Performed As Many Times As Necessary (N) To Complete The Process.

Using The Voronoi Vertex Averaging Technique, Network Coverage Is Progressively Enhanced. The Fundamental Idea Behind Vvaa Is To Use Voronoi Diagrams To Pinpoint The Best Locations For Sensor Nodes For Increased Network Coverage. Each Sensor Node's Zones Of Effect May Be Determined Using A Voronoi Diagram, Which Also Directs Nodes To Places With Less Coverage.

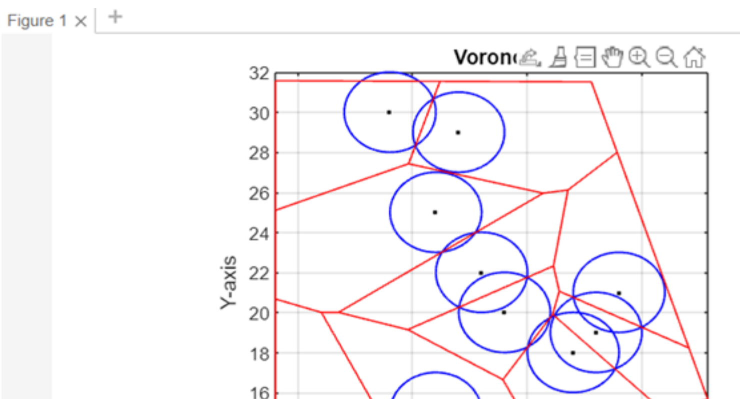


Fig 1. Voronoi Vertices Single Polygon

(I). Area Coverage: In The Context Of Wireless Sensor Networks, Area Coverage Refers To How Well The Network Can Track Or Detect The Actual Space It Is Installed In. It Is A Crucial Parameter Since It Has A Direct Impact On The Accuracy And Dependability Of The Sensor Nodes' Data. There Are Several Forms Of Area Coverage, Including:

Full Coverage: This Is Attained When There Is At Least One Sensor Node Covering Each Location In The Monitored Region. No Events Or Environmental Changes Can Go Unreported Thanks To Full Coverage. Partial Coverage: Depending On The Circumstances, Obtaining Complete Coverage Might Not Be Possible Because Of Resource Limitations Or The Size Of The Deployment Region.

Targeted Coverage: In Targeted Coverage, Sensor Nodes Are Placed Strategically To Ensure Coverage In Specific Areas Of Interest; This Approach Is Often Used In Applications Like Surveillance Or Environmental Monitoring. Random Coverage: Randomly Deploying Sensor Nodes Can Lead To Non-Uniform Coverage, Where Some Areas Have More Sensors Than Needed, While Others Have Fewer. This Can Result In Coverage Gaps Or Overlaps.

Node Connection: Node Connection Focuses On A Sensor Node's Capacity To Keep In Touch With Its Surrounding Nodes. Node Connection May Be Impacted By Node Failures Or Movement. Energy-Efficient Connectivity: In Sensor Networks With Limited Energy Resources, It's Crucial To Retain Connectivity While Minimizing Energy Use. Protocols And Algorithms Are Created To Maximize Connection While Reducing Energy Use.

(Ii). The Vvaa (Voronoi Vertex Averaging Algorithm): Vvaa Is A Technique That Enhances Sensor Connection And Coverage In Wireless Sensor Networks. To Accomplish These Goals, It Makes Use Of The Voronoi Diagram Notion And Vertex Averaging. Voronoi Polygons Are These Regions, And They Reflect The Spheres Of Influence Or Accountability For Certain Sensor Nodes.

Vertex Averaging: For Each Sensor Node, Vvaa Determines The Typical Coordinates (X, Y) Of The Vertices (Corners) Of The Voronoi Polygons. To Maximize Network Coverage And Connection, The Sensor Nodes Should Be Placed At These Average Coordinates. The Sensor Nodes Are Then Shifted From Their Initially Random Sites To The Recently Determined Ideal Locations.

The Goal Of This Movement Is To Shift The Sensor Nodes Such That Sparsely Deployed Areas Get More Coverage While Heavily Deployed Areas Become Less Congested. Iterative Process: For A Predetermined Number Of Iterations (N), The Algorithm Repeatedly Executes The Vertex Averaging And Node Moving Processes. The Coverage And Connectivity Of The Network Are Improved With Each Iteration.

Optimization Of Area Coverage Is Crucial For Wireless Sensor Networks. With The Help Of Sensor Relocation And The Power Of Voronoi Diagrams, Vvaa Dynamically Improves Coverage, Making It Easier And More Dependable To Keep An Eye On The Actual World. The Difficulties Brought On By Haphazard Deployment, Erratic Sensing Ranges, And Energy Constraints Are Successfully Addressed By Vvaa By Shifting Sensors To Their Average Voronoi Positions, Which Ultimately Improves Network Performance And Data Quality

(Iii). By Iteratively Expanding The Coverage Area Of Voronoi Regions And Enhancing The Precision Of The Voronoi Diagram, The Voronoi Vertex Averaging Algorithm (Vvaa) Makes Advantage Of The Idea Of Averaging Points. A More Thorough Explanation Of How The Algorithm Accomplishes This Is Provided Below:

A. Initialization: The Process Begins With An Initial Set Of Seed Points, Which Are The Centers Of Voronoi Areas And Are Frequently Dispersed Randomly.

B. Allocate Points To Regions: The Algorithm Calculates Which Seed Point Is Closest To Each Point In The Plane For Each Point. With Each Zone Being Connected To A Distinct Seed Point, This Assignment Divides The Plane Into Regions.

C. Create The Voronoi Vertices As Follows: The Procedure Calculates The Centroid (Average) Of All The Points That Were Allocated To Each Voronoi Area. The "Average" Position In That Area Is Represented By The Centroid.

D. Changing The Seed Points: The New Centroids (Average Points) Are Used As The New Seed Points For The Subsequent Iteration. This Is An Essential Step In Expanding The Reach Of Voronoi Regions. The Centroids Are Chosen As The New Seed Sites Because Of Their Propensity To Move Toward The Region's Center Of Mass. As A Result, They Approach The Regions That The Seed Points Had Initially Underrepresented.

E. Applications: Numerous Fields, Including Computer Graphics, Computational Geometry, Geographic Information Systems (Gis), And Others, Use Voronoi Diagrams Produced By Vvaa. They Are Utilized For Many Things, Including Terrain Modelling, Nearest Neighbour Searches, And Proximity Analysis.

F. Visualization: The Boundaries Of The Voronoi Cells Can Be Formed By Joining The Voronoi Vertices (Centroids) After The Voronoi Diagram Has Been Created. The Areas Of Effect In These Cells Are Those That Surround Each Input Point.

G. Extensions: There Are Expansions And Modifications Of The Algorithm For Higher-Dimensional Voronoi Diagrams (3d And Beyond), Even Though Vvaa Is Generally Used For 2d Voronoi Diagrams. Different Methods For Determining Centroids And Boundaries In Higher-Dimensional Spaces Are Used In These Modifications.

The Use Of Average Points (Centroids) In The Vvaa Plays A Vital Role In Increasing The Coverage Area Of Voronoi Regions And Improving The Overall Quality Of The Voronoi Diagram.

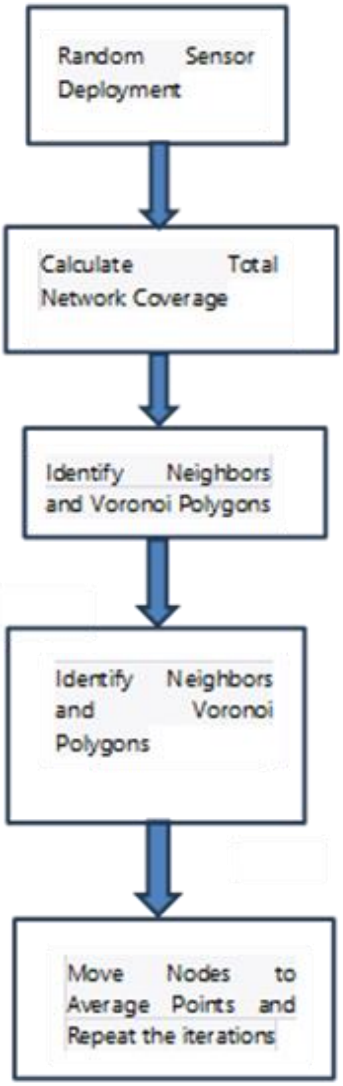


Fig 2. General Flow Diagram Of Coverage Of Area

The Deployment Of Sensor Nodes At Random Within A Certain Sensor Field Is The First Step In This Procedure. The Algorithm Then Determines The Coverage Area For Each Sensor Node Based On Its Sensing Range And Adds These Individual Coverage Areas To Get The Total Covered Area In Order To Calculate The Overall Network Coverage. The System Then Locates Nearby Nodes And Creates Voronoi Diagrams For Each Sensor Node. These Voronoi Polygons' Vertices Are Placed To Enable The Best Network Coverage. Then, Sensor Nodes Are Moved To The Average Positions Of Each Voronoi Polygon's Vertices. Before Completing The Procedure, The Full Set Of Stages Is Repeated A Predetermined Number Of Times To Fine-Tune The Deployment Of The Sensor Network.

4. Methodology

The Vvaa Based Sensor Deployment Was Carried Out Using Matlab And The Area Coverage Performance. Initially The Sensor Nodes Are Deployed In The Sensor Field Of Size 50 X 50. Fig 3 Shows The Randomly Deployed Sensors.

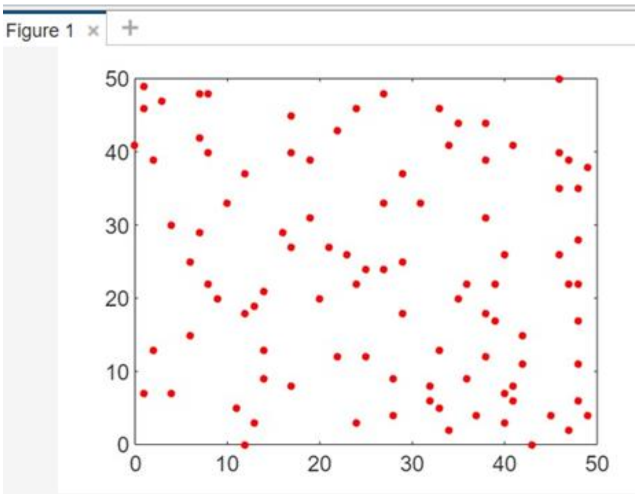


Fig 3. Random Sensor Deployment

The Dropped Sensors Are Represented In Red Colours. The Sensors Are Deployed Randomly And Some Sensors Are Covered The Most Regions And Other Remaining Sensors Are Covered Least Density The Approach Was Taken Into A Construction Of Voronoi Diagram For Identifying The Neighbour Sensors And Constructing The Voronoi Polygon. Fig 4 Shows The Construction Of Voronoi Diagram.

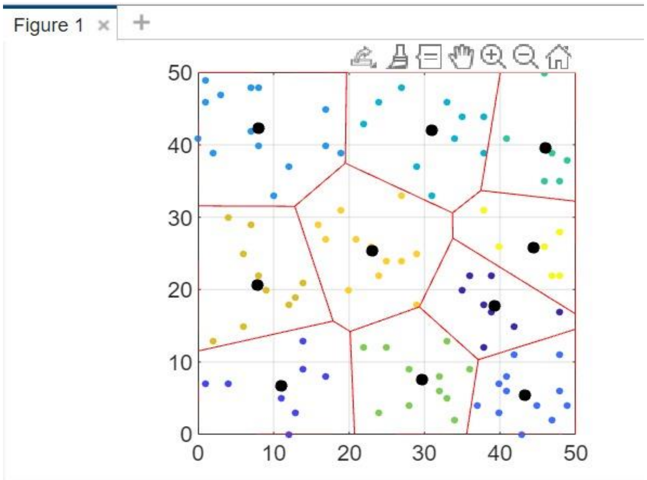


Fig 4. Voronoi Diagram Polygon

Fig 5. Depicts Initial Deployment And Voronoi Diagram Of The Network In Which Each Sensor Nodes Are Given A Sensing Range, This Sensing Range Is Represented By The Blue Circles

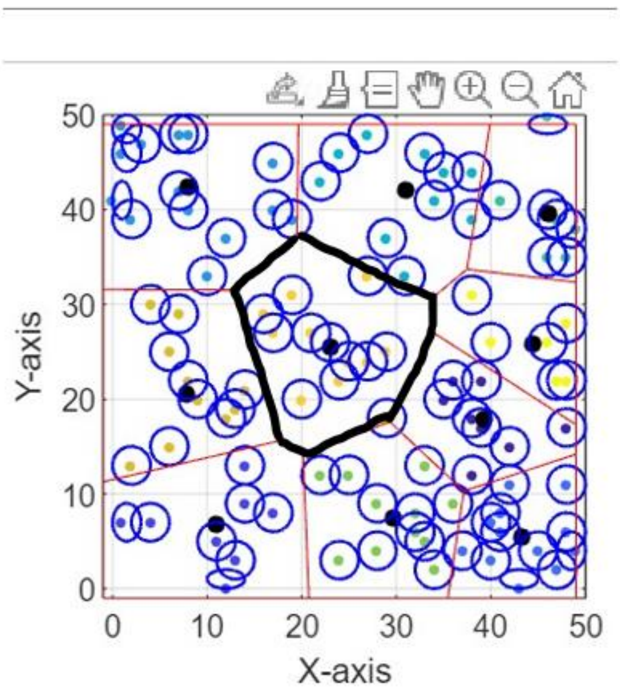


Fig 5. Sensing Range Deployment

For A Better Deployment Of Sensors The Internal Voronoi Diagram Is Drawn For Every Voronoi Cell As Shown In Fig 6 And The Total Area Covered By The Voronoi Cells Are Calculated

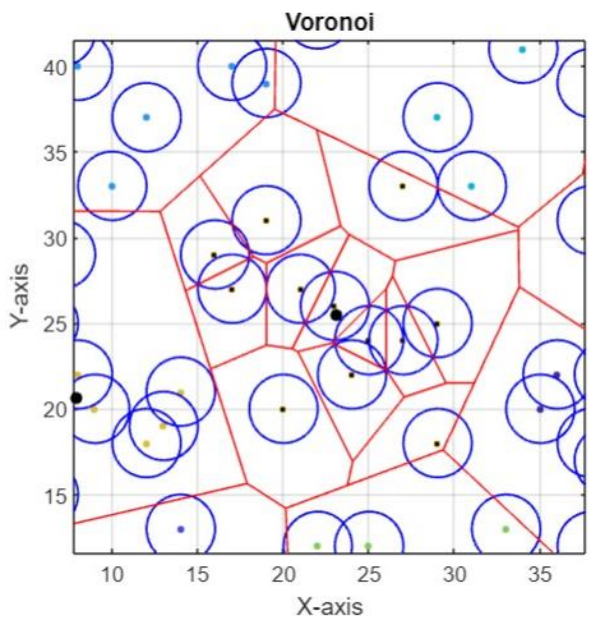


Fig 6. Internal Voronoi Diagram

The Total Area Covered By Each Voronoi Cell Is Calculated And The Area Covered And Un-Covered By The Sensors Inside The Particular Cell Is Calculated.

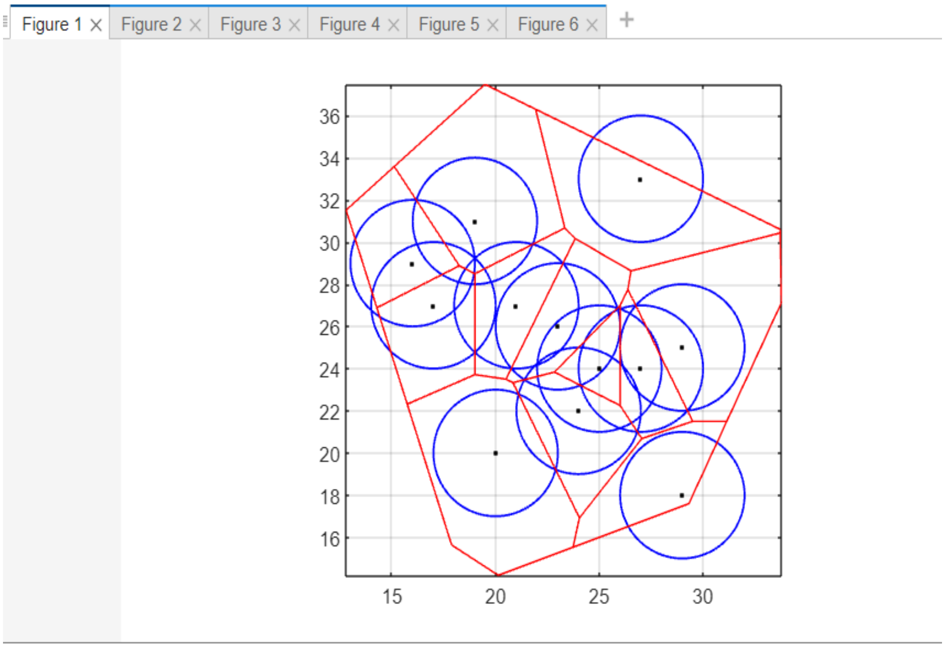
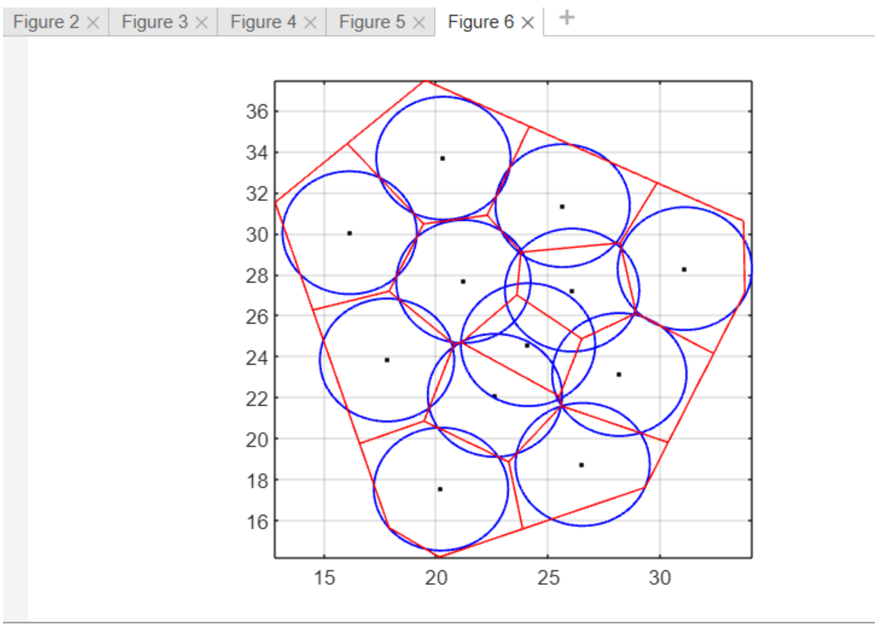


Fig 7 Coverage Of Sensors In Particular Cell

Using The Voronoi Vertex Averaging Algorithm The Sensors Are Moved To Better Positions For Improved



Coverage Area

Fig 8. Improved Coverage Of Sensors In Particular Cell

5.Results & Conclusion

In Conclusion, The Area Coverage Improvement Was Done By Random Placement Of Sensors And Constructing Of Voronoi Polygons Helps To Identify The Neighbouring Sensors With The Construction Of Voronoi Polygons. The Sensing Range And The Coverage Of Sensors Are Represented By The Circles. Each

Sensor Node Averages Its Vertices And The Average Is Taken As The Centroid Of Polygon. Hence After Averaging, If The Average Point Is Within The Polygon The Node Will Move Towards The Average Point To Make Efficient Coverage. This Averaging Process Is Done Repeatedly With The Help Of Voronoi Vertex Averaging Algorithm Until The Improvement Is No Longer Possible. In This Study We Have Improved The Coverage Of Area By Simulating With The Help Of Matlab. Hence The Area Coverage Is Improved With The Help Of Vvaa.

Table 1. Area Of Voronoi Cell And Its Coverage At Round 10

Voronoi Cell Number	**Voronoi Cell Area (Sq. Km)**	**Covered Area**	**Coverage Percentage**
1	338.78	332.34	98.1
2	313.57	302.34	96.42
3	300.81	279.81	93.02
4	317.70	302.03	95.07
5	293.98	264.72	90.05
6	165.55	162.27	98.02
7	161.60	154.89	95.85
8	183.63	177.05	96.42
9	166.54	158.74	95.32
10	257.85	235.00	91.14
Average Coverage Percentage			94.94 %

Table 1. Shows The Total Area Covered By Each Voronoi Cells, The Coverage Of Area By The Sensors After The Application Of Vvaa And Its Calculated Coverage Percentage.

References:

[1] Yongshan Liu, Xiang Gong, Dehan Kong, Tianbao Hao And Xiaoqi Yan, "A Voronoi-Based Group Reverse K Farthest Neighbor Query Method In The Obstacle Space", In Ieee Access, Vol. 8, Pp. 50659 - 50673,10 March 2020 , Doi: 10.1109/Access.2020.2979739

[2] Xuqi Wang, Zijian Tian, Wenqing Wang, Fangyuan He And Liyong Zhao, " A Novel Algorithm For Barrier Coverage Based On Hybrid Wireless Sensor Nodes", In Ieee Access, Vol. 7, Pp. 118866 - 118875, 21 August 2019 , Doi: 10.1109/Access.2019.2936640.

[3] Mahsa Sadeghi Ghahroudi, Alireza Shahrabi And Tuleen Boutaleb, "Voronoi-Based Cooperative Node Deployment Algorithm In Mobile Sensor Networks", 2020 Ieee 91st Vehicular Technology Conference (Vtc2020-Spring), 30 June 2020, Doi: 10.1109/Vtc2020-Spring48590.2020.9129431.

[4] Martin Manák And Ivana Kolingerová, "Fast Discovery Of Voronoi Vertices In The Construction Of Voronoi Diagram Of 3d Balls", 2010 International Symposium On Voronoi Diagrams In Science And Engineering, 26 July 2010, Doi: 10.1109/Isvd.2010.22.

[5] H. Zhang, J. C. S. Lui, And D. Towsley, "Voronoi-Based Deployment Algorithms For Wireless Sensor Networks: A Comprehensive Survey", 2015 34th Chinese Control Conference (Ccc), Pp. 1934-1768, 14 September 2015, Doi: 10.1109/Chicc.2015.7260884..

[6] Azzedine Boukerche And Xin Fei, "A Voronoi Approach For Coverage Protocols In Wireless Sensor Networks", Ieee Global Telecommunications Conference, Pp. 1930-529x,26 December 2007, Doi: 10.1109/Glocom.2007.984

[7] Sasmita Dash, Biraja Prasad Nayak, Bhabani Shankar Prasad Mishra And Amulya Ratna Swain, "Randomized Grid-Based Approach For Complete Area Coverage In Wsn", 2017 Ieee 7th International Advance Computing Conference (Iacc),13 July 2017, Doi: 10.1109/Iacc.2017.0073.

[8] Sebastien Valette, Jean Marc Chassery And Remy Prost, " Generic Remeshing Of 3d Triangular Meshes With Metric-Dependent Discrete Voronoi Diagrams", Ieee Transactions On Visualization And Computer Graphics , Volume: 14, Issue: 2, March-April 2008, Doi: 10.1109/Tvcg.2007.70430

[9] Pradipta Ghosh, Jonathan Bunton, Dimitrios Pylorof, Marcos A. M. Vieira, Kevin Chan, Ramesh Govindan, Gaurav S. Sukhatme, Paulo Tabuada And Gunjan Verma, "Synthesis Of Large-Scale Instant Iot Networks", Ieee Transactions On Mobile Computing, Vol.22, No.3, Pp.1810-1824, 2023, 18 October 2021 , Doi: 10.1109/Jiot.2021.3120744.

[10] Dongming Yan, Guanbo Bao, Xiaopeng Zhang And Peter Wonka, "Low-Resolution Remeshing Using The Localized Restricted Voronoi Diagram", Ieee Transactions On Visualization And Computer Graphics,Vol.20, Pp. 1418 – 1427, 12 June 2014, Doi: 10.1109/Tvcg.2014.2330574.

[11] Qiang Du, Vance Faber And Max Gunzburger, "Centroidal Voronoi Tessellations: Applications And Algorithms", Siam Rev., Vol. 41, Pp. 637-676, 1999 , Doi: Https://Doi.Org/10.1137/S0036144599352836

[12] Ruiyun Yu, Xingwei Wang And Sajal K. Das, "A Voronoi Diagram Approach For Mobile Element Scheduling In Sparse Sensor Networks", 2008 Second International Conference On Future Generation Communication And Networking, 30 December 2008, Doi: 10.1109/Fgcn.2008.159.

[13] Dash, S Mishra And B S P, "Grid Based Methods For Complete Area Coverage In Wsn Using Voronoi Approach", 2021, Doi: Http://Hdl.Handle.Net/10603/364711.

[14] Ali M.M. Mady And Khairuddin Omar, "A Comparative Study Of Voronoi Algorithm Construction In Thinning", Proceedings Of The 2011 International Conference On Electrical Engineering And Informatics, **19** September 2011, Doi: 10.1109/Iceei.2011.6021658.

[15] Qiang Du And Deshang Wang, "Anisotropic Centroidal Voronoi Tessellations And Their Applications", Siam J. Scientific Computing, Vol. 26, Pp. 737-761, 2005, Doi: Https://Doi.Org/10.1137/S1064827503428527.

[16] Go Hasegawa, Shoichi Takemori, Yoshiaki Taniguchi And Hirotaka Nakano, "Determining Coverage Area Using Voronoi Diagram Based On Local Information For Wireless Mesh Networks", 2012 Ninth International Conference On Information Technology - New Generations(Ieee), 31 May 2012, Doi: 10.1109/Itng.2012.19.

[17] Aparajita Chowdhury , Debashis De , "Energy-Efficient Coverage Optimization In Wireless Sensor Networks Based On Voronoi-Glowworm Swarm Optimization-K-Means Algorithm", Volume 122, 1 November 2021, Pp.102660, Doi: Https://Doi.Org/10.1016/J.Adhoc.2021.102660.

[18] Franz Aurenhammer, "Voronoi Diagrams - A Survey Of A Fundamental Geometric Data Structure," Acm Computing Surveys, Vol. 23, Pp. 345-405, Sep. 1991, Doi: Https://Doi.Org/10.1145/116873.116880.