International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Special Issue 2, April 2014)
National Conference on Computing and Communication-2014 (NCCC'14)

Enhancing Point Coverage in Mobile Wireless Sensor Network using Computational Geometric Approach

Poornima S[1], Roselin J[2], Dr. Latha P[3]

[1,2]Department of Computer Science and Engineering, Regional Office of Anna University, Tirunelveli Region, Tirunelveli
[3]Department of Computer Science and Engineering, Government College of Engineering, Tirunelveli

[1]spoorni2003@gmail.com, [2]roselin.research@gmail.com, [3]plathamuthuraj@gmail.com

***Abstract*— Coverage is an important issue which is considered in the design of Wireless Sensor Network. In real time environment, certain points in the sensor network have to be monitored closely and those points are called High Priority Points (HPP).Under the proposed method, the randomly deployed mobile sensors are relocated based on the Euclidean distance between the sensors and HPPs and NPRatio such that the HPPs are covered as much as possible. Simulation results ensure that all the High Priority Points are monitored closely thereby providing high coverage.**

***Keywords*— Coverage, Wireless Sensor Network, High Priority Points, Mobile sensors, NPRatio**

I. Introduction

A Wireless Sensor Network (WSN) consists of sensor nodes which are randomly deployed over a target area to monitor the physical and environmental conditions. Various applications of sensor networks include military applications, surveillance, border intrusion detection,, health monitoring and so on. The sensor nodes of the wireless sensor network have limited communication and processing power. One of the major requirements of the network is coverage and connectivity which determines the Quality of the network. The coverage of the network is based on the how the sensors are placed in target area [1]. In order to improve the network quality, coverage and the lifetime of the sensor network have to be maximized. The sensor nodes must be properly deployed in the target area so that the overall efficiency of the network can be improved.

Various deployment strategies exist. The two types of deployment are static deployment and dynamic deployment. Static deployment of sensors occurs when all the sensor nodes deployed in the target area are static. If the wireless sensor network has at least one mobile node, then it is termed as dynamic deployment. Static deployment can be either random or deterministic. In deterministic static deployment, the position of sensors in WSN is known in advance [2].

In most of the applications the sensor nodes are deployed in unattended or hostile environment. So the deterministic static deployment cannot be used for node deployment. Here the sensor nodes should be randomly deployed. This type of deployment is called dynamic deployment. Dynamic deployment can be again classified into centralized and distributed methods. In the centralized method, one of the sensor nodes is classified as the base station or the cluster head. It positions itself in the network. Other nodes are deployed by cluster heads or base stations. In distributed methodology, base station or the cluster head does not exist. Each node is capable of localizing itself in the network.

Coverage of the network can be mainly classified into two types. They are area coverage and point coverage. The area coverage specifies that the entire target area should be monitored by the sensors. The point coverage ensures that the specific points in the target area are monitored by the sensors [2].

The deployment of sensors can be either dense or sparse. A dense deployment has high number of sensor nodes in the given target area while sparse deployment have fewer nodes. The dense deployment of sensors is used when every event in the target area is to be monitored accurately. Sparse deployments are used in cases where less number of sensors should be used or when maximum coverage is achieved using limited number of sensors.

The sensing range of the sensors is restricted to certain radius which leads to the coverage problem. This problem can be solved by using sensor with greater sensing radius, but this type of sensor is more expensive [2].

One of the important aspects of WSN is its ability to be randomly deployed in the target area without the manual intervention. The random deployment can be done by air dropping the sensors. However random deployment may cause some of the sensors being deployed very closer to one another while others are deployed far away from each other. In dense deployment, the sensing capabilities of the sensors are wasted and the coverage is minimized, while in sparse deployment, certain points in the target area will be left uncovered.

The static nodes once deployed can't be redeployed as they are immobile. So to enhance the coverage, the mobile nodes should be moved to the optimal position so that certain points in the target are are covered and monitored closely.

In Maxmin-curve, Minmax-curve and Curtex [2] algorithms, a proper destination point is obtained for each sensor. Then, the new local coverage area of each sensor (in the previously constructed MW-Voronoi region) is compared to its preceding local coverage area. If the new local coverage area is larger than the preceding one, the sensor moves to the new destination; otherwise, it remains in its current position. If, on the other hand, the local coverage area of every sensor in an iteration is not increased by a certain threshold level, the algorithm is terminated (to ensure a finite number of iterations). But this algorithm is computationally complex [2].

Causataxis protocol[3] is used to maximize the sensing coverage in an unknown, noisy, and dynamic sensing environment while minimizing energy consumption.

SMART [4](Scan-based Movement-Assisted Sensor Deployment) is the optimization technique used to eliminate the communication hole problem.

This method reduces the total moving distance and reduces the communication cost. It can be extended even to disconnected sensors but the Hungarian algorithm used here is centralized and thus the solution doesn't suit for practical purposes.

A distributed bidding protocol [5] is proposed for the deployment of sensors that are a mixture of mobile sensors and static sensors in which the mobile sensors can move from dense areas to sparse areas to improve the overall coverage. But this proposed method does not deal with non-uniform sensing range.

A Flip-based mobility method [6] is used for optimal deployment of sensor node based on connectivity and load balancing. It determines a movement plan for the sensors in order to maximize the sensor network coverage, and minimize the number of flips. Its advantages are minimum cost and maximum mobility. But it has its limitations such as erroneous movement of sensors to uninterested regions and it does not assist continuous sensor movement.

Three distributed self-deployment protocols-VEC(VECtor-based), VOR (VORonoi-based), and Minimax[7] are proposed for maximizing the network coverage. But this does not deal with non-uniform sensing range.A virtual force component [8] provides one time repositioning of sensor nodes. But it doesn't provide a theoretical bound on the number of sensors needed to provide the coverage threshold and also it can't be extended to point coverage.

A sensor placement algorithm based on art gallery problem is proposed to optimize coverage under constraints of imprecise detections and terrain properties of grid points [9].An Incremental Self-Deployment Algorithm [10] aims to maximize the network coverage. It provides perfect deployment of nodes at the beginning stage itself. But it relies on the global localization method.

The rest of the paper is compiled as follows: Section 2 presents the necessary background that is required for the work. Section 3 formulates the problem. In Section 4 the distributed deployment method for increased Point Coverage is proposed. Section 5 evaluates the performance of the proposed methodology. Section 6 deals with the conclusion of the proposed work based on the simulation results obtained.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Special Issue 2, April 2014)
National Conference on Computing and Communication-2014 (NCCC'14)

II. TECHNICAL BACKGROUND

The most commonly used Computational Geometry approach is Voronoi Diagram. Voronoi diagram is partition of sites in such a way that points inside a polygon are closer to the site inside the polygon than any other sites, thus one of the vertices of the polygon is the farthest point of the polygon to the site inside it [12][13]. The Diagram that is obtained after the partitioning is called the Voronoi Diagram [16]. Voronoi Diagram is used as a partitioning technique when all the sensors that are deployed have similar sensing capability. To construct the Voronoi polygon, the perpendicular bisector of line segment that connects the sensor node to its neighbors is drawn [11].

When the sensors have non identical sensing ranges, conventional Voronoi diagram cannot be used for partitioning the target area. Instead, Multiplicatively Weighted Voronoi Diagram (MW-Voronoi Diagram) [12][14][16] is used with sensing range of each sensor as weighting factor that is associated with it.

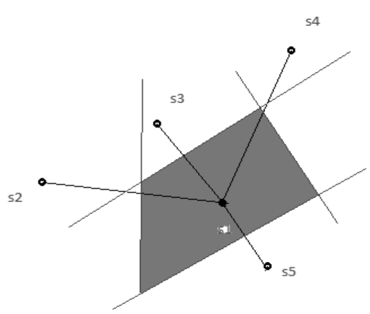


Fig 1. Voronoi Region for sensor node S_1 with S_2, S_3, S_4, S_5 as neighbors

The Mathematical Representation of Voronoi Region is,

$$R=\{S_i \in TA \mid w_k d(S_i,S_j) \le w_j d(S_i,S_k)\} \quad (1)$$

Where the sensor S_i is in the Target Area TA and w_i and w_k are the weights associated with each Sensor (Here the weights of the sensor is its the sensing range).

$d(S_i,S_j)$ and $d(S_i,S_k)$ are the Euclidean distances between the Sensors S_i and S_j and Sensors S_i and S_k.

The sensors S_i and S_j are called neighbors [15][16] if they satisfy the following properties

i) The nodes S_i and S_j are called the neighbors if $R_i \cap R_j \neq \emptyset$ where R_i and R_j are the Voronoi Regions of Sensors S_i and S_j

ii) The set of all neighbors of S_i is a subset of Sensor set S and is given as,

$$N_i = \{S_j \in S \mid R_i \cap R_j \neq \emptyset\} \quad (2)$$

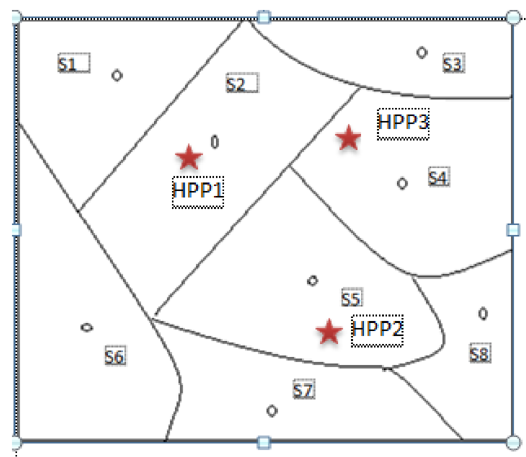


Fig 2. MW-Voronoi Regions with 8 sensors and 3 HPP

III. PROBLEM FORMULATION

A group of n mobile sensors with non-identical sensing ranges are randomly deployed in the target area around the HPP. A computational geometric approach called MW-Voronoi Diagram is used to partition the target area such that each partition contains one sensor node. The sensors should be relocated towards certain points in the target area called High Priority Points (HPPs) such that the HPPs are monitored closely.

IV. DISTRIBUTED DEPLOYMENT PROTOCOL

In this section, distributed methodology is introduced for mobile sensor network. This method works iteratively until all the High Priority Points are covered. Initially, HPPs are present in $(x_1,y_1),(x_2,y_2),\ldots(x_n,y_n)$ and the sensors are randomly deployed around those HPP .The Multiplicatively Weighted Voronoi (MW-Voronoi) region is constructed for each sensor. The Euclidean distance between the randomly deployed sensors and the HPP is calculated using the distance metric.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Special Issue 2, April 2014)
National Conference on Computing and Communication-2014 (NCCC'14)

$$d\,(s,p) = \sqrt{(x_s - x_p)^2 + (y_s - y_p)^2} \qquad (3)$$

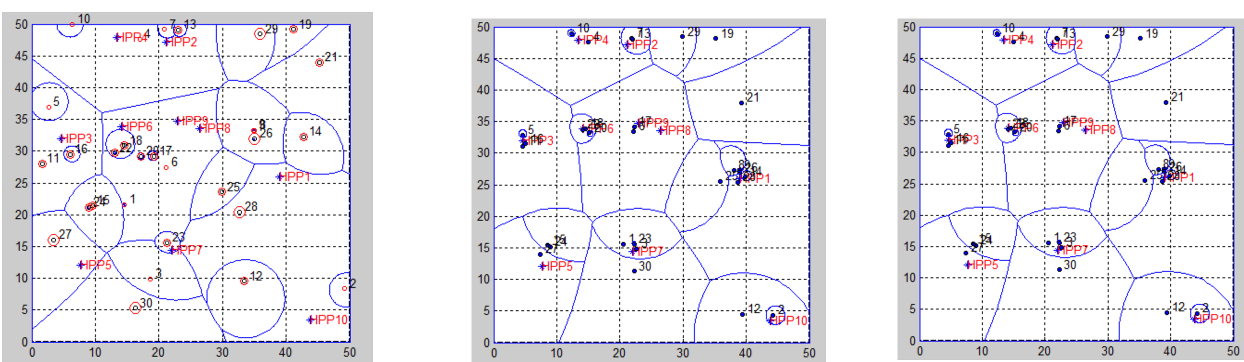
(x_s, y_s) is the location of the sensor
(x_p, y_p) is the location of the HPP

Based on the Euclidean distance, the sensors which are at a minimum distance from the HPP are repositioned towards the HPP so that those HPPs are covered in order to ensure the Point Coverage.

There are chances for certain HPPs to be left uncovered. As the deployment of the sensors is random, certain HPPs may not have sensors that are closer to them. Hence, another factor called NPRatio can be considered in addition to the Euclidean distance to reposition the sensors. The NPRatio can be defined as the ratio between the total number of sensor nodes and total number of HPPs. It can be represented as ,

$$NPRatio = \frac{Total\ Number\ of\ Sensor\ Nodes}{Total\ Number\ of\ HPPs} \qquad (4)$$

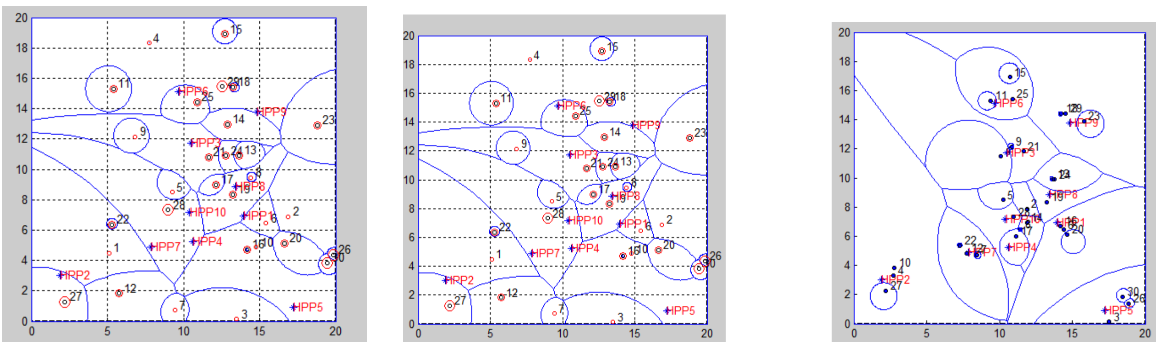
Let us consider 30 sensors with three different sensing radii deployed in the 20×20 target area. 10 sensors with the sensing range of 10m, 10 sensors with sensing range of 20m and 10 sensors with sensing range of 30m are randomly deployed. The number of High Priority Points considered for this scenario is 6. They are assumed to be fixed at locations $(x_1, y_1), (x_2, y_2), \dots (x_6, y_6)$. The initial location of the randomly deployed sensors is found. The location of the HPP is also known. Based on the distance metric, the sensors are repositioned towards the HPPs. Fig 3 shows the MW-Voronoi region of each sensor after its initial random deployment with intermediate snapshots. The HPPs are shown in red color. In the final round it can be clearly seen that the sensors are concentrated towards the HPPs. The MW-Voronoi Region R is reconstructed after the repositioning of the sensor nodes and iteration continues till the nodes are relocated towards the HPPs.



(a) (b) (c)

Fig 3 Snapshots of (a) Initial Coverage (b) Intermediate Coverage and (c) Final Coverage of 30 sensors deployed in the target area where Euclidean distance alone is considered

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Special Issue 2, April 2014)
National Conference on Computing and Communication-2014 (NCCC'14)



(a) **(b)** **(c)**

Fig 4 Snapshots of (a) Initial Coverage (b) Intermediate Coverage and (c) Final Coverage of 30 sensors deployed in the target area where NPRatio is also considered

Fig 3 shows 30 sensors deployed in the target area with 6 HPPs. The MW-Voronoi region for each sensor is constructed. (a) depicts the initial coverage of sensors. (b) depicts the intermediate coverage of sensors. It can be seen that the sensors mover towards the HPP based on the Euclidean distance. The sensors that are closer to the HPPs move towards the corresponding HPP. (c) depicts the final coverage of sensors. The sensors converge at the HPP and hence the HPPs are monitored closely ensuring distributed priority coverage.It is also evident that certain HPPs are left uncovered. As the sensors are randomly deployed, some HPPs may not have sensors closer to them. When the Euclidean distance between the sensors and HPP is considered as the only factor, those HPPs may be left uncovered.

To ensure that all the HPPs are covered, an additional factor called NPRatio is considered along with the Euclidean distance between the sensors and HPP.

Fig 4 shows 30 sensors deployed in the target area with 6 HPPs. (a) depicts the initial coverage of sensors. (b) depicts the intermediate coverage of sensors. It can be seen that the sensors mover towards the HPP based on the Euclidean distance and NPRatio. The sensors that are closer to the HPPs move towards the corresponding HPP. (c) depicts the final coverage of sensors. The sensors converge at the HPP. If some HPPs do not have sensors closer to them, the sensors are repositioned based on NPRatio. Hence all the HPPs are monitored closely ensuring distributed priority coverage.

V. Simulation Results And Discussion

The simulation results serve to verify the effectiveness of the proposed system. The effectiveness of coverage is analyzed and compared with the existing systems.

A. Simulation Results

The relocation of sensors towards the HPP is done based on two factors

i) On the basis of Euclidean distance between the Sensors and HPP
ii) On the basis of NPRatio and Euclidean distance between the sensors and HPP

The following analysis of relocation of sensors is done on the basis

a) Convergence Factor: The number of iterations taken before the sensors converge towards the HPP
b) Coverage Factor: The number of HPPs that are covered.

The Performance Evaluation is done by varying the number of sensor nodes and the number of High Priority Points. Here the system is evaluated for both Euclidean Distance and NPRatio method

No.of HPP	Convergence Factor	
	Euclidean Distance	NPRatio
1	20	18
2	20	19
3	20	19
4	21	21
5	20	20
6	21	21
7	20	20
8	22	21
9	20	18
10	21	20

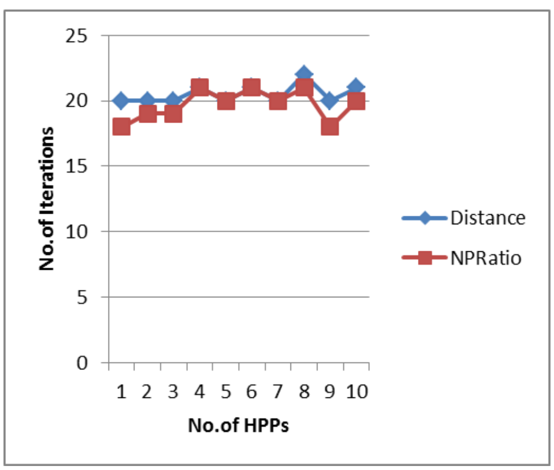


Fig 5 Simulation Results based on the convergence factor

From Fig 5, it is observed that in NPRatio strategy, the number of iterations taken to reach the HPPs is less than or equal to the number of iterations considered in Euclidean Distance Method.

No.of HPP	Convergence Factor	
	Euclidean Distance	NPRatio
1	1	1
2	2	2
3	3	3
4	4	4
5	3	5
6	5	6
7	6	7
8	6	8
9	6	9
10	7	10

From Fig 6, it is observed that in NPRatio strategy, the all the HPPs are covered whereas in Euclidean Distance strategy ceratain HPPs are left uncovered.

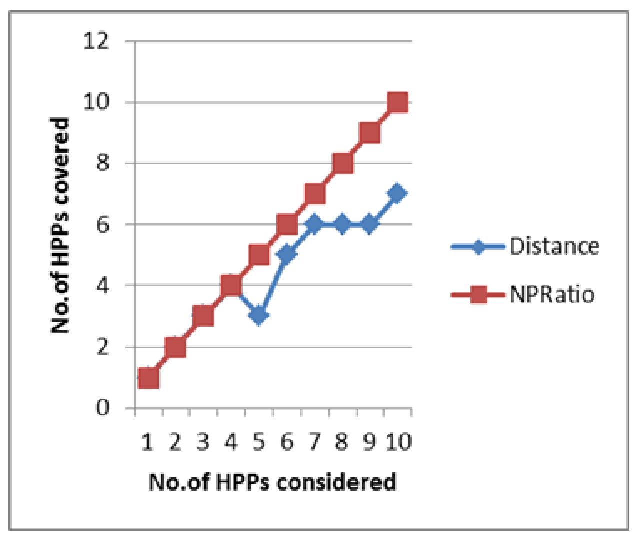


Fig 6 Simulation Results based on the Coverage factor

VI. Conclusion

Distributed Deployment Protocol is proposed to enhance the point coverage in a mobile sensor network. Here the sensors are repositioned so that they are concentrated towards the HPP which demands close monitoring. If the Euclidean distance between the sensors and the HPPs is considered as the only metric to reposition the sensors towards the HPP, certain HPPs in the target area are left uncovered. In addiXtion the NPRatio factor is also considered for sensor repositioning. This ensures that all the HPPs are covered with equal number of sensors and that no HPP is left uncovered. Simulation results that compare the performances of the deployment methods prove that the Distributed Deployment Protocol outperforms the other methods.

REFERENCES

[1] Pallavi Sahu, Sunil R.Gupta, "Deployment Techniques in Wireless Sensor Networks",International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-3, July 2012

[2] H.Mahboubi, K.Moezzi,A.G.Aghdam, and K. Sayrafian-Pour, "Selfdeployment algorithms for field coverage in a network of nonidentical mobile sensors," in Proc. IEEE Int. Conf. Commun., 2011, pp. 1–6.

[3] S. Yoon, O. Soysal, M. Demirbas, and C. Qiao, "Coordinated locomotion and monitoring using autonomous mobile sensor nodes," IEEE Trans. Parallel and Distrib. Syst., vol. 22, no. 10, pp. 1742–1756, 2011.

[4] S.Yang, M.Li, and J. Wu, "Scan-Based Movement-Assisted Sensor Deployment Methods in Wireless Sensor Networks", IEEE Transaction on Parallel and Distributed Systems,2007

[5] G.Wang, G. Cao, P. Berman, and T. F. L. Porta, "A bidding protocol for deploying mobile sensors," IEEE Trans. Mobile Comput., vol. 6, no. 5, pp. 563–576, 2007.

[6] S.Chellappan, X. Bai, B. Ma, D. Xuan, and C. Xu, "Mobility Limited Flip-based Sensor Networks Deployment", IEEE Transaction on Parallel and Distributed Systems 2007

[7] G. Wang, G. Cao, and T. F. L. Porta, "Movement-assisted sensor deployment," IEEE Trans. Mobile Comput., vol. 5, no. 6, pp. 640–652,2006.

[8] Y. Zou, K. Chakrabarty, "Sensor Deployment and Target Localization Based on Virtual Forces", Proceedings of IEEE INFOCOM, 2003.

[9] S.S. Dhillon, K. Chakrabarty, and S.S. Iyengar, "Sensor Placement for Grid Coverage under Imprecise Detections", Proceedings of Fifth International Conference in Information Fusion, 2002

[10] A. Howard, M.J. Mataric, and G.S. Sukhatme, "An Incremental Self-Deployment Algorithm for Mobile Sensor Networks", Autonomous Robots, 2002

[11] R. Reitsma, S. Trubin, and E. Mortensen, Weight-proportional space partitioning using adaptive voronoi diagrams, Geoinformatica, vol. 11, pp. 383–405, (2007)

[12] Nor Azlina Ab. Aziz, Kamarulzaman Ab. Aziz, and Wan Zakiah Wan Ismail, Coverage Strategies for Wireless SensorsNetworks, World Academy of Science, Engineering and Technology (2009)

[13] R. Klein, Concrete and Abstract Voronoi Diagrams(New York:Springer, 1989)

[14] A. Okabe, B. Boots, K. Sugihara, and S. N. Chiu, Spatial Tessellations:Concepts and Applications of Voronoi Diagrams (New York: Wiley,2000)

[15] D. E. Koditschek, Robot Planning and Control via Potential Functions (Cambridge, MA: MIT Press, 1989)

[16] Q. Li, M. D. Rosa, and D. Rus, Distributed algorithms for guiding navigation across a sensorsnetwork, in Proc. 9th Annu. Int. Conf. Mobile Comput. Networking, 2003, pp. 313–325.