IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Volume-4, Issue-10 E-ISSN: 2347-2693

Sweep Coverage for Boundary of Rectangular Region Using Geometric Approach

Ritesh Sharma[1*], Gurbax Kaur[2]

[1,2]*Department of Computer Science and Engineering, Indus International University Una, India*

Available online at: www.ijcseonline.org

Received: 16/Sep/2016 Revised: 28/Sep/2016 Accepted: 16/Oct/2016 Published: 31/Oct/2016

Abstract— There are typical applications where only periodic patrol inspections are sufficient instead of continuous monitoring like in traditional coverage. This periodic monitoring is termed as sweep coverage. In the sweep coverage scenario deployment of static sensor nodes may partially solve the purpose but it suffers from poor efficiency and unnecessary extra overhead. Moreover static sensor network suffers from static sink neighborhood problem as in static sensor network all sensing data from the sensors are relayed to the sink node (base station) through multi hop. As a result, the sensors near to the sink node become the bottleneck since they have to relay the data of other nodes. Once they die, the sink disconnects from the rest of the network while the rest of sensors are still fully operational with sufficient residual energy. To overcome this problem in our work, we proposed Mobile Sink Wireless Sensor Network (MSWSN). We assume that the given region is Rectangular and our aim is to do Sweep Coverage for Boundary of the Region. In Wireless sensor network Sensor node has fixed communication range (let D be the communication range then Sensor node will cover all the points which lie within D distance from it in all directions) and therefore to guarantee the coverage of Boundary Mobile sink will not traverse whole of the boundary but visit certain points in the Boundary known as points to Visit (P1, P2, ----- Pn). Points to Visit (P1, P2, ----- Pn) are to be chosen in such a way that every boundary point lie within the communication range of Mobile sink from at least one points to Visit (P1, P2, ----- Pn) and Mobile Sink must visit every edge of the boundary during traversal. Keeping above coverage conditions in mind our main objective is to choose points to Visit (P1, P2, ----- Pn) in such a way that the overall length of closed path travelled by the Mobile sink to collect the data is minimum.

Keywords— Sweep coverage problem; Area sweep coverage; Point sweep coverage; convex hull algorithm; Tessellation.

I. INTRODUCTION

Coverage in wireless sensor networks (WSNs) have been widely studied for different monitoring applications. It has been an active and important research topic, evidenced by many research contributions to this field in recent years. On the basis of monitoring Coverage problems are broadly categorized in two types. First one is continuous coverage and other is sweep coverage. In continuous coverage continuous monitoring with static sensor nodes is required. There are typical applications where only periodic patrol inspections are sufficient instead of continuous monitoring like in traditional coverage. This type of coverage problem is called sweep coverage in which periodic monitoring is done .In the sweep coverage scenario deployment of static sensor nodes may partially solve the purpose but it suffers from poor efficiency and unnecessary extra overhead. Moreover static sensor network suffers from static sink neighborhood problem as in static sensor network all sensing data from the sensors are relayed to the sink node (base station) through multi hop. As a result, the sensors near to the sink node become the bottleneck since they have to relay the data of other nodes. Once they die, the sink disconnects from the rest of the network while the rest of sensors are still fully operational with sufficient residual energy.

Depending upon the type of coverage sweep coverage can be categorized in three types.

1. Point coverage : Set of discrete points as shown in Fig.1 are to be covered

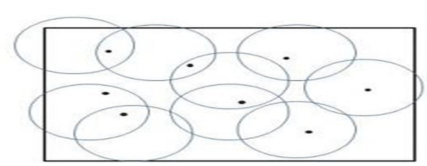

Fig.1: Point sweep coverage

2. Area coverage: Whole of the given region as shown in Fig.2 is to be covered

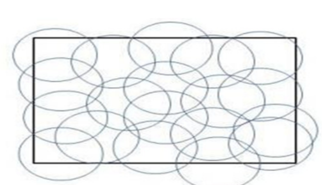

Fig.2: Area sweep coverage

3. Boundary coverage: Boundary of the given region as shown in Fig.3 is to be covered

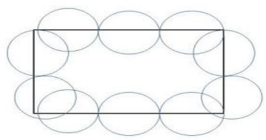

Fig.3: Boundary sweep coverage

To overcome this problem in our work, we proposed Mobile Sink Wireless Sensor Network (MSWSN). We assume that the given region is Rectangular and our aim is to do Sweep Coverage for Boundary of the Region. In Wireless sensor network Sensor node (Mobile Sink) has fixed communication range(let D be the communication range then Sensor node will cover all the points which lie within D distance from it in all directions) and therefore to guarantee the coverage of Boundary Mobile sink will not traverse whole of the boundary but visit certain points in the Boundary known as points to Visit (P1, P2, ----- Pn). Points to Visit (P1, P2, ----- Pn) are to be chosen in such a way that every boundary point lie within the communication range of Mobile sink from at least one points to Visit (P1, P2, ----- Pn) and Mobile Sink must visit every edge of the boundary during traversal. Keeping above coverage conditions in mind our main objective is to choose points to Visit (P1, P2, ----- Pn) in such a way that the overall length of closed path travelled by the Mobile sink to collect the data is minimum.
Rest of the paper is structured as follows: In section II, algorithm of Sweep Coverage for Boundary of Rectangular Region Using Geometric Approach is presented. The conclusion and Future work are presented in section III.

II. PROPOSED APPROACH

A. ASSUMPTIONS

We assume that the given region is Rectangular as shown in **Fig 4** and Mobile Sink must visit every edge of the boundary during traversal

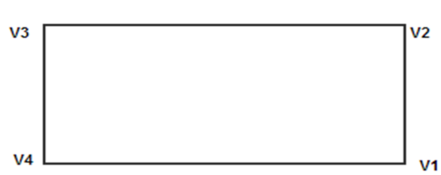

Fig.4: Rectangular region

Keeping above coverage conditions in mind our main objective is to choose points to Visit (P1, P2, ----- Pn) in such a way that the overall length of closed path travelled by the Mobile sink to collect the data is minimum .

Algorithm 1: Algorithm For Selection of Points to Visit

Symbol	Description
$V1, V2, V3, V4$	Corner vertices of rectangular region
$\lvert V_i V_j \rvert$	Length Of edge between vertices $\mathbf{V_i}$, $\mathbf{V_j}$
D	communication range of mobile sink

If $(|V1V2|$ && $|V2V3| > 2D)$ // **Lemma2**

In every edge points to visit is **D** distance far from its end vertices.

Else If $\left(|V1V2| \le 2D \text{ \&\& } |V2V3| > 2\left(D + \sqrt{D^2 - \frac{|V1V2|^2}{4}}\right)\right)$ // Lemma3

{

In edge V1V2 point to visit is mid point of V1V2

In edge V3V4 point to visit is mid point of V3V4

In edge V2V3 distance of point to visit from end vertices is $D+\sqrt{D^2 - \frac{|V1V2|^2}{4}}$

In edge V4V1 distance of point to visit from end vertices is $D+\sqrt{D^2 - \frac{|V1V2|^2}{4}}$

}

Else If $\left(|V2V3| \le 2D \text{ \&\& } |V1V2| > 2\left(D + \sqrt{D^2 - \frac{|V2V3|^2}{4}}\right)\right)$ // Lemma3

{

In edge V2V3 point to visit is mid point of V2V3

In edge V4V1 point to visit is mid point of V4V1

In edge V1V2 distance of point to visit from end vertices is $D+\sqrt{D^2 - \frac{|V2V3|^2}{4}}$

In edge V3V4 distance of point to visit from end vertices is $D+\sqrt{D^2 - \frac{|V2V3|^2}{4}}$

}

Else // **Lemma4**

In every edge point to visit is mid point of edge .

Lemma1: If we are given two points (let P1 and P2) on the same side of a line(say L) and we are asked to find third point (let P3) on a line such that |P1P3| +|P3P2| is minimum than we can use the Fermat's principle which says that Light always follow the path of least time and when we apply Fermat's Principle we get Law of Reflection of Light which says that Angle of Incidence = Angle of Reflection as shown in **Fig 5**

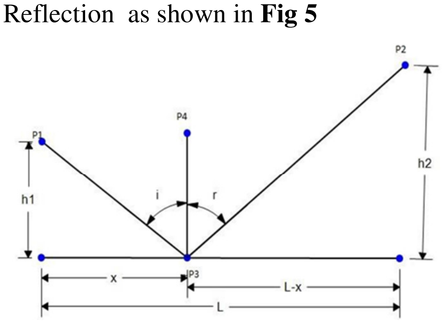

Fig 5 : Angle of Incidence = Angle of Reflection

Symbol	Description
|P1P3|	Distance between points P1 and P3
|P3P2|	Distance between points P3 and P2
L	Length of given line
h1,h2	Perpendicular distance between line 'L' and points P1 and P2 resp.
t	Time taken for the ray to travel the distance |P1P3| +|P3P2|
c	Velocity of light, which is a constant
P3P4	Normal to the given line 'L'
i , r	Angle of Incidence , Angle of Reflection resp.

Proof :

$$t = \frac{|P1P3|}{c} + \frac{|P3P2|}{c}$$

$$t = \frac{\sqrt{x^2 + h1^2}}{c} + \frac{\sqrt{(L-x)^2 + h2^2}}{c}$$

As per Fermat's principle light takes the path of least time.

Therefore, the derivative $\frac{dt}{dx} = 0$ gives

$$\frac{x}{\sqrt{x^2 + h1^2}} = \frac{L-x}{\sqrt{(L-x)^2 + h2^2}} \quad \text{i.e} \quad \sin(i) = \sin(r)$$

Means Angle of Incidence = Angle of Reflection
Taking tan on both sides

$\tan(i) = \tan(r)$ gives $\frac{x}{h1} = \frac{L-x}{h2}$

From here we get value of **x** as $x = \frac{L \times h1}{h1 + h2}$

Lemma2: When | V1 V2 | && |V2 V3| > 2D length of closed path is minimum under the condition that every boundary point must be present within communication range of Mobile sink from at least one points to Visit (P1, P2, --- Pn) and Mobile Sink must visit every edge of the boundary during traversal iff in every edge points to visit is D distance far from its end vertices as shown in **Fig 6**

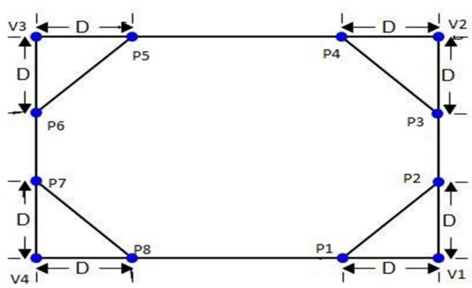

Fig 6

Proof :

Consider edge **V1V2** of given rectangle, as the sensing range of Sensor is **D** therefore in edge **V1V2** to cover extreme point of edge i.e. V1 we can visit any point between V1 and P2 (which is D distance far from V1) but for minimum length we have to visit P2 and to cover other extreme point of edge i.e. V2 we can visit any point between V2 and P3 (which is D distance far from V2) but for minimum length we have to visit P3 .

As the given figure is rectangle , given that **| V1 V2 | && |V2 V3| > 2D** which means length of all the four sides is greater than 2D and hence the similar procedure can be applied for remaining edges . Therefore length of closed will be minimum iff in every edge points to visit is **D** distance far from its end vertices .

Lemma3: When | V1 V2 | ≤ 2D && |V2 V3| > $2\left(D + \sqrt{D^2 - \left(\frac{|V_1V_2|}{2}\right)^2}\right)$ length of closed path is minimum under the condition that every boundary point must be present within communication range of Mobile sink from at least one points to Visit (P1, P2, --- Pn) and Mobile Sink must visit every edge of the boundary during traversal iff In edges **V1 V2 ,V3V4** point to visit is midpoint of **V1 V2 , V3V4** resp. and In edges **V2V3 , V4V1** points to visit is $D + \sqrt{D^2 - \left(\frac{|V_1V_2|}{2}\right)^2}$ distance far from end vertices of **V2V3 , V4V1** resp. as shown in **Fig7** below

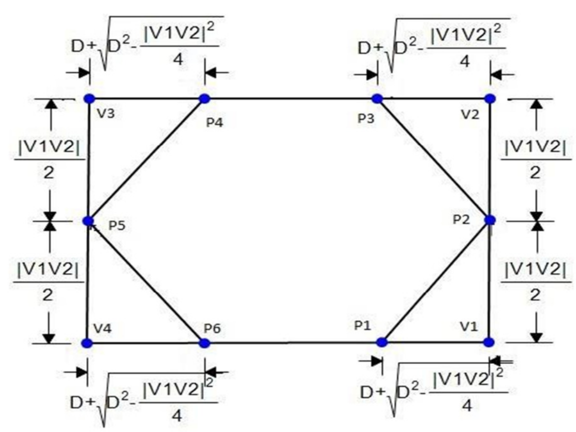

Fig 7

Proof :

Consider edge **V2V3** of given rectangle, as the sensing range of Sensor is **D** therefore in edge **V2V3** to cover extreme point of edge i.e. V2 we can visit any point between V2 and P3 (which is D distance far from V2) but for minimum length we have to visit P3 and to cover other extreme point of edge i.e. V3 we can visit any point between V3 and P4 (which is D distance far from V3) but for minimum length we have to visit P4

As the given figure is rectangle, therefore we can apply the same procedure for selection of Point to visit in edge **V4V1**

As the length of | V1 V2 | ≤ 2D therefore a single Point of visit is required in this edge for coverage. Therefore we have to select position of that point(let P2) on the edge V1V2 such that such that |P1P2| + |P2P3| is minimum . For this we can use result of **Lemma 1**.

According to Lemma1 the point to visit on the edge V1V2 such that such that |P1P2| + |P2P3| is minimum is given by

$$x = \frac{L \times h1}{h1 + h2}$$

where

h1 = distance between P1 and V1

h2 = distance between P3 and V2

L = distance between V1 and V2

From the above Fig: 7 h1=h2 and L= |V1V2| therefore we get

x = $\frac{|V1V2|}{2}$ **i.e** mid point of edge V1V2

In the similar manner we can find the point to visit for edge V3V4 which is given by

x= $\frac{|V3V4|}{2} = \frac{|V1V2|}{2}$ **i.e** mid point of edge V3V4

Now when the sensor node visits P2 i.e the mid point of edge V1V2 it will cover some boundary of adjacent edges i.e V2V3 , V4V1 as shown in **Fig 8**

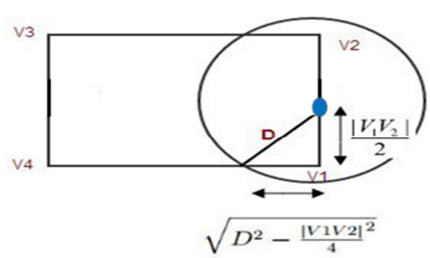

Fig 8

Therefore point to visit in both the edges V2V3 , V4V1 will be $D + \sqrt{D^2 - \left(\frac{|V_1V_2|}{2}\right)^2}$ distance far from V2 and V1 resp.

Similarly when the mobile sensor visits P5 (mid point) in edge V3V4 it will cover boundary of length $\sqrt{D^2 - \left(\frac{|V_3V_4|}{2}\right)^2}$ in adjacent edges i.e V2V3 , V4V1 . Therefore point to visit in both the edges V2V3 , V4V1 will be $D + \sqrt{D^2 - \left(\frac{|V_3V_4|}{2}\right)^2}$ distance far from V3 and V4 resp.

This proves Lemma 3

Lemma 4 When only one point to visit in each edge is sufficient for coverage then length of closed path is minimum iff point to visit lie in the mid point of every edge .

Proof

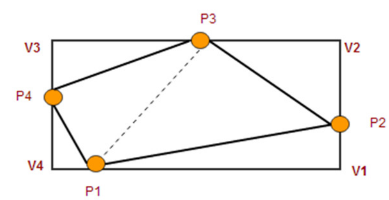

Fig 9

Let P1 ,P2,P3,P4 be the point to visit in edges V4V1 ,V1V2,V2V3,V3V4 resp as shown in Figure 3.6 and therefore P1P2P3P4P1 forms the closed path , Length of closed path is |P1P2| + |P2P3| + |P3P4| + |P4P1|. Join P1 and P3 , this forms two triangles P1P3P4 and P1P2P3

From triangle P1P3P4

|P3P4| + |P4P1| ≥ |P1P3| ----------------eq 1

From triangle P1P2P3

|P1P2| + |P2P3| ≥ |P1P3| -----------eq 2

Eq 1 + Eq2 implies

|P1P2| + |P2P3| + |P3P4| + |P4P1| ≥ 2 |P1P3 |-----eq 3

From **Fig:9** minimum value of |P1P3| is |V1V2| and when |P1P3| = |V1V2| from **Fig:9** we get equations

|V3P3|= |V4P1|--------- eq4

|V2P3|= |V1P1| -------- eq5

From **eq4 , eq5 and Lemma1** we can conclude that for minimum length of |P1P4P3|and |P1P2P3| P4,P2 lies is the mid point of edges V3V4 and V1V2 resp.

And if P4,P2 lies is the mid point of edges V3V4 and V1V2 resp , from **Lemma1** we can conclude that P1,P3 also lies is the mid point of edges V4V1 and V2V3 resp

This proves Lemma 4

III. CONCLUSION AND FUTURE WORK

The point sweep coverage problem is to find optimal (minimum) number of mobile sensor nodes moving with uniform speed required to guarantee sweep coverage of all given points as per given sweep period 't'. As per Jun Zhao Du et al. [17] minimum number of mobile sensors required for point sweep coverage is given by $\left\lceil \frac{L}{vt} \right\rceil$ where

L= length of closed path formed by joining points of visit

v=velocity of mobile sensor node which is constant

t=sweep period which is also constant

Therefore, In order to minimize the number of mobile sensor nodes we can minimize the value of L by choosing point to visit wisely. We have presented algorithm in section II for selection of points to visit which will minimize the length of closed path formed by joining the points to visit during Sweep Coverage for boundary of rectangular region.

Sweep coverage is a purely new concept for sensor network monitoring. There are still many interesting problems not discussed.

One significant extension of this problem is that the given region is any general Polygon and we need to do the Sweep Coverage for boundary of the region.

One other variation is that the given region is any general Polygon and we need to do the Sweep Coverage for Area of the region .

In my future work, I plan to study these problems in Sweep Coverage and obtain useful results ..

References

[1] Gurbax kaur, Ritesh Sharma, "Point Sweep Coverage in Wireless Sensor Networks Using Convex Hull Algorithm", International Journal of Computer Sciences and Engineering, Volume-04, Issue-08, Page No (23-27), Aug -2016

[2] Gurbax Kaur, Ritesh Sharma, "A Review on Sweep Coverage in Wireless Sensor Networks", International Journal of Computer Sciences and Engineering, Volume-4, Issue-6, Page No (113-117), June 2016

[3] Barun Gorian , Partha Sarthi Mandal,"Approximation algorithm for sweep coverage in wireless sensor networks " ,Journal of Parallel and Distributed Computing , Volume-74, Issue-8, Page No(2699-2707), Aug 2014.

[4] Mo Li, Wei-Fang Cheng, Kebin Liu, Yunhao Liu,Xiang-Yang Li, Xiangke Liao, "Sweep coverage with mobile sensors", Transaction on Mobile Computing , Volume-01, Issue-11, Page No (1534–1545), Nov 2011.

[5] Barun Gorian ,Partha Sarthi Mandal, "Point and area sweep coverage in wireless sensor networks",11th International Symposium and Workshops on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt), Tsukuba Science City, pp (140-145) ,May 13th-17th ,2013,ISBN : 978-1-61284-824-2.

[6] Nasimkhazan,Ali Braumandinia and Nima Ghazanfari Motlagh,"Node Placement and coverage in Asymmetric area", International Journal of Advanced Research in Computer Science and Software Engineering, Volume-2, Issue-11, Page No (278-282), Nov 2012.

[7] R.A. Jarvis, "on the identification of the convex hull of a finite set of points in the plane", Information Processing Letters, Volume-2, Issue-1, Page No (18-21), Dec 1973.

[8] Novella Bartolini, Tiziana Calamoneri, Emanuele G. Fusco, Annalisa Massini, Simone Silvestri , " Push & pull: autonomous deployment of mobile sensors for a complete coverage", Wireless Netw. , Volume-16, Issue-3, Page No (607–625), Jan 2009.

[9] Adrian Dumitrescu, MinghuiJiang, "Sweeping an oval to a vanishing point", Elsevier: Discrete applied mathematics, Volume-159, Issue-14, Page No (1436-1442), Aug 2011.

[10] Edoardo S. Biagioni, Galen Sasaki,"Wireless sensor placement for Reliable and Efiicient data collection",IEEE 36th Annual Hawaii International Conference on System Sciences, 2003. Proceedings of the - Big Island, HI, USA, January 6th-9th, 2003, ISBN: 0-7695-1874-5.

[11] Santosh kumar, Ten H .Lai, Anish Arora,"Barrrier coverage with wireless sensors",Mobicom'05 Proceedings of the 11th annual international conference on Mobile computing and networking,Org by-ACM, NY, USA, pp(284-298) , August 28 , 2006 ,ISBN: 1-59593-020-5.

[12] Xiaojiang Du,Fengjing Lin, "Improving sensor network performance by deploying mobile sensors",IEEE international performance, computing, and communications conference , Phoenix, AZ, USA ,pp(67-71),April 7th – 9th ,2005, ISBN: 0-7803-8991-3.

[13] Hung-Chi Chu, Wei-Kai Wang, Yong-Hsun Lai, "Sweep coverage mechanism for wireless sensor networks with approximate patrol times", Ubiquitous Intelligence & Computing and 7th International Conference on Autonomic & Trusted Computing (UIC/ATC), Xian, Shaanxi, pp(82–87) ,October 26th-29th,2010,ISBN: 978-0-7695-4272-0.

[14] Yi Ning Chen, Ko-Jui Lin ; Chang Wu Yu,"Dynamis coverage techniques in mobile wireless sensor networks" ,Fifth International Conference on Ubiquitous and Future Networks (ICUFN), Da Nang, pp(12-17), July 2nd -5th ,2013, ISSN:2165-8528.

[15] Min Xi, Kui Wu, Yong Qi, Jizhong Zhao, Yunhao Liu, Mo Li, "Run to potential:sweep coverage in wireless sensor networks" ,IEEE: International Conference on Parallel Processing (ICPP-2009),Sponsored by-IACC, Vienna ,

Austria , pp (50–57) ,September 22nd-25th , 2009 ,ISBN: 978-0-7695-3802-0.

[16] Gautam K. Das, Sandip Das, Subhas C. Nandy, Bhabani P. Sinha, "Efficient algorithm for placing a given number of base stations to cover a convex region", Journal of. Parallel Distributed Computing,Volume- 66,Issue-11,Page No (1353 – 1358),July 2006.

[17] Junzhao Du,Yawei Li,Hui Liu and Kewai Sha, " On sweep coverage with minimum mobile sensors", 16th international conference on Parallel and Distributed System, Shanghai, pp(283-290). December 8th-10th, 2010, ISBN: 978-1-4244-9727-0.

[18] A. Bykat, "Convex Hull Of A Finite Set Of Points In Two Dimensions", Information Processing Letter, Volume-7, Issue-6, Page No (296-298), Oct 1978.

Authors Profile

Ritesh Sharma, Assistant Professor in Department of Computer Science and Engineering,Indus International University Una, India

Gurbax Kaur, M.Tech student in Department of Computer Science and Engineering,Indus International University Una, India.