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# Coverage In Presence Of Obstacles:A Survey

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**Abstract**
Wireless sensor networks have sparked immense research interest since the mid 1990's. Ongoing improvements in affordable and efficient integrated electronic devices have put a great impact in the advancement of wireless sensor networks, which has enabled this field for a broad range of applications in battlefield surveillance, environment monitoring, industrial diagnostics, healthcare etc. Coverage which is one of the most important performance metrics for sensor networks resonates how accurately a sensor field is monitored. The coverage concept for a sensor field is accountable to a wide range of apprehensions due to a diversity of sensors and applications. Due to constrained resources for a sensor node it is valuable to construct a fully covered and energy efficient sensor network for real world applications. There are different conceptions that have been proposed based on the coverage type, deployment mechanism as well as network properties. This paper surveys research progress made to address various coverage problems in sensor networks. I present various coverage formulations and their assumptions as well as an overview of the solutions proposed.

**Keywords:** wireless sensor networks, coverage problem, sensor, Network connectivity, Computational *geometry, Network topology.*

## I. Introduction

We can define sensor as a device which sense the physical environment properties such as thermodynamics disturbances, sound waves generated in the environment, pressure generated over a place, magnetic force, a movement of object etc. and convert the parameter associated with the physical stimulus into signals that could be recorded, stored and processed. The form of signals could be electrical signals, mechanical signals etc. These signals are then converted into binary data which is referred as sensing data.

Therefore the fundamental functional units associated with the sensor nodes are Power supply unit, which supplies power since sensor nodes are generally deployed at remote locations and are wireless in nature, Data storage unit to store the sensing data which is generated by sensing unit, Data processing unit to process the data generated by sensing unit to make it effective sensing data with minimum overheads and a Data transmission unit to transmit data to the peer nodes or sink.

A Sensor network is the collection of different atomic nodes interacting together deployed over different geographical location. A sensor network also includes an interfacing unit called sink which receives the data collected by individual sensor nodes and transmit it to the master operating the sensor network. WSN is mainly distinguished from the conventional wireless ad hoc network by their unique and dynamic network topology.

Sensor network has enumerable applications in the real world which includes Environmental monitoring under which habitat monitoring, integrated biology and structural monitoring are the prominent domains, Interactive and control under which pursuer-evader, Intrusion detection and automation are primary one. WSN is a great enabling technology that can revolutionize information and communication technology. Coverage is one of the performance metric of sensor network. It is one of the fundamental issues that arise in the sensor networks, in addition to localization, tracking and deployment. Coverage can be considered as the measure of quality of service of a sensor network. The goal is to have each location in the physical space of interest with the sensing range of at least one sensor. In many cases, we may interpret the coverage concept as a non negative mapping between the space points of a sensor field and the sensor nodes of a sensor network. Coverage problems could arise in different network stages. It is also formulated in various ways with different scenarios, assumptions and objectives.

Researchers so far have worked significantly to do a more realistic theoretic background for coverage estimation. Several approaches with mathematical and simulation based proofs have been presented. All these approaches lead to a more efficient coverage over a sensing field. The most recent work that is gaining interest is the coverage in presence of obstacles .Determining coverage in presence of obstacles is an interesting task. In this paper I would like to dig about the approaches of determining coverage in presence of obstacles, the limitations of the approaches with future scope. The paper is organized as in the first section basic concept and terminology regarding coverage and obstacles then the current approaches that have considered obstacles into consideration and then conclusion with future scope.

## II. Basic Concepts and Terminologies.

Coverage for wireless Sensor Network is described as a measure which tells whether a target or a location is sensed or not irrespective of the way sensing is performed. Researchers so far have proposed various techniques to determine coverage and parameters associated with it. Various formulations and definitions are there to describe the type of coverage and environmental factors while determining the coverage. Coverage over a sensing area not only depends on the sensing ability of sensing device but also on the nature of field on which sensors are deployed. There are several concepts and terminologies present in the literature for providing theoretical Interpretations of wireless sensor coverage.

## 2.1 Coverage Problem Type

Coverage problem could be categorized into three categories based on coverage type. Each coverage type has different objectives.

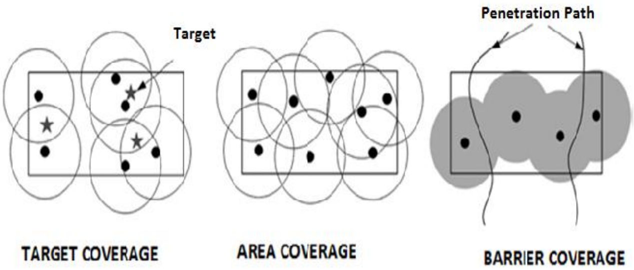



**Fig 1:** Types of Coverage problems

### 2.1.1 Point Coverage Problem

In point coverage problems, the subject to be covered is a set of discrete space points. These points can be some particular space points to represent the sensor field (e.g., the vertices of a grid) or are used to model some physical targets in the sensor field (e.g. the missile launchers in a battlefield). In order to cover these points, sensor nodes can be deterministically placed or randomly deployed in the sensor field.

A scenario for optimal node placement could be made to optimize sensing results. Placement of node could be done in such a way that each sensor node can cover at least one target. Deterministic node placement could be done at a place where physical intervenes is possible and network size is not too large.

So placement could be modeled as the need occurs. It could be modeled through indicator function; it could also be done through Integer Linear Programming. Generalization of ILP gives more flexibility to the network. There could also be a scenario such that few locations could be left unnoticed to decrease the cost of deployment. For small problem cases, exhaustive search can be used to find the global optimum by trying every possible placement. The problem of placing the least number of sensors to cover all discrete targets can be equated to the canonic set-covering problem.

Besides the greedy algorithms, some other well known approximation algorithms have been applied to find approximate solution such as simulated annealing which is a generic probabilistic heuristic for locating a good approximation to the global extremum of a given function.

Genetic algorithms are inspired by biological evolutionary process, model and apply biological inheritance, mutation, selection and crossover in the search of global optimal solution.

### 2.1.2 Area Coverage Problem

In area coverage the main objective is to cover entire area. All the points on the sensing field are considered as target. To know about the number of sensors required so as to cover the sensing field, Sensor density is defined which is given as number of nodes per unit area. Critical Sensor Density for a homogeneous sensor network is defined as the minimum number of nodes required for complete area coverage. In deterministic deployment a pattern based approach could be followed to put sensor over entire field. For Random deployment mathematical analysis could be done to provide a lower bound of CSD for a sensor field with finite area.

In deterministic node placements when complete K coverage is required, simple approaches like to put k sensors at same location or to put k layers of tessellation where each layer of tessellation provide complete 1-coverage. Putting sensors in a tessellation provides complete 1-coverage and not let all sensors to fail at same time. It is also desirable to place sensors not too close to each other i.e., minimum separation required for higher degree of Coverage.

In random deployment it is desirable to know an average vacancy parameter. One of the major issues that occur in this type of deployment is Redundancy. There are several redundancy check methods. The grid approach can be used in sensor activity scheduling to achieve differentiated coverage, where each grid point may be required to be covered by different number of sensors. Four redundancy check approach, extended perimeter coverage approach, extended crossing approach and extended Voronoi approaches are used to check redundancy.

### 2.1.3 Barrier Coverage Problem

In barrier coverage problems, desired coverage characteristic is the main objective. Existence of such coverage characteristic is a constraint. The two major issues in barrier coverage are to build intrusion barrier and find penetration path.

Intrusion barrier is a typical application of wireless sensor network. The main purpose of building an intrusion barrier with the help of sensor network is to detect a mobile object entering into the boundary of sensor field or moving across the sensor field. Detection of the moving object at any instance is sufficient for such type of application. A moving object has to be get detected by at least k distinct Sensors before it penetrates through the sensor field.
Finding Penetration Path is also one of the Barrier Coverage Problem which is related to building intrusion barrier problem. A penetration path is a crossing path which starts from one end of the sensing field and finish from other end. On this path all points should follow a certain defined coverage criteria. This problem is different from finding intrusion barrier which mainly guarantee that some points of every crossing path should meet certain coverage requirements.

### 2.2 Deployment Strategies

Deployment strategies are the way in which sensors are put up over a sensor field. They may be put in a certain sequence or randomly so as to create sensor network.

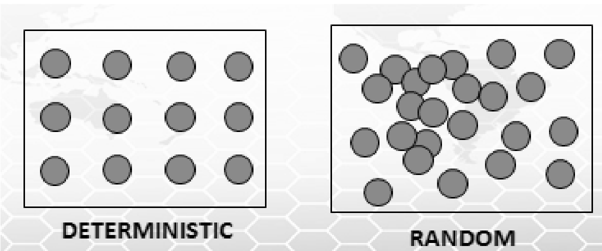



**Fig 2:** Deployment Strategies

Deterministic deployment is planned deployment. In such type of deployment the location of sensors are predetermined. Sensors are kept on known location so as to optimally cover the entire sensor field. The properties on which the deployment depends are the type of application, connectivity and coverage. If a location is inaccessible then random deployment is adopted. Coverage and connectivity are the related aspect of wireless sensor network. So based on the type of coverage required and connectivity constrained deployment is done.

### 2.3 Coverage Degree

Coverage degree is the number of sensors required to cover a single target location or the number of sensors involved to sense a single point on a sensing area. Researchers have so far mentioned about different coverage degrees over a sensing area. In different researches the degree is classified as 1-degree and more than 1-degree i.e. k-coverage where k is the positive integer greater than 1.

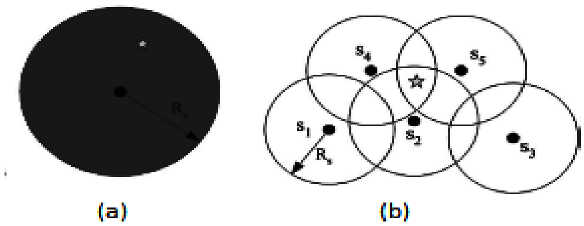



**Fig 3:** Coverage Degree 1-coverage (b) 3-coverage

In fig 3 there is an illustration of different coverage degree. In fig 3(a) there is an omnidirectional coverage model covering a single space point. In fig 3(b) a space point is being 3-covered by 3 sensors.

### 2.4 Sensing coverage models

Sensor coverage model is a measure of sensing ability of a sensing device and quality of sensing by capturing the geometric relation between a space point and sensors. In almost all cases, a sensor coverage model can be formulated as a function of Euclidean distance (and the angles) between a space point and sensors. The inputs of such a coverage function are the distance (and angle) between a particular space point and sensors location and the output is called the coverage measure of this space point, which is non negative number.

Concept of coverage function is introduced in the context of a two dimensional plane. Considering a space point T and a set of sensors $S= \{S_1, S_2,\ldots\ldots, S_n\}$. d(S,T) (d(S,T) >= 0) is used to denote Euclidean distance between sensor S and a space point and in the two dimensional space.

$$d(S,T) = [( S_x - T_x)^2 + ( S_y - T_y)^2)]^{1/2}$$

where $(S_x, S_y)$ and $(T_x, T_y)$ are the Cartesian co-ordinate of sensor S and the space point T, respectively.

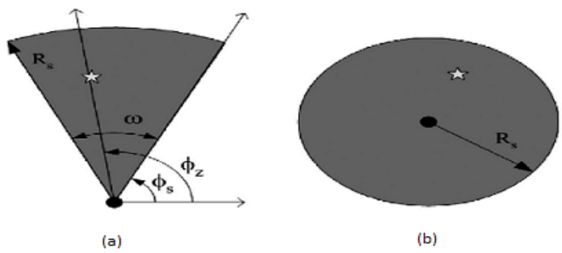



**Fig 4:** Illustration of (a) Directional Coverage model (b) Omnidirectional coverage model where $R_s$ is sensing radius.

A number of sensing coverage models are proposed in literature. The input of coverage function could be the distance and angle between the space point and one sensor. The input can vary as input could be the distances and angles between the space point and more than one sensor.

Coverage models could be classified into two type's Boolean coverage model and General coverage model. In Boolean coverage model coverage measure is either 0 or 1for one space point and for general coverage model coverage measure can take various non negative values. The angle argument could be included or discarded from the coverage function. If angle is included then it is directional coverage model and if it is excluded then it is omnidirectional coverage model. In fig 4(a) $\square_s$ and $\square_Z$ are the orientational angle and model is directional coverage model where fig 4(b) is an example of omnidirectional coverage model also called disk coverage model with $R_s$ as sensing Radius and shaded region is its vicinity. A target denoted by a star is being sensed as its presence is within the vicinity of disk coverage model.

### 2.5 Communication and Sensing Ranges

A sensors sensing range is the range up to which a sensor is able to sense a particular object and sensors communication range is the range up to which a sensor can communicate with other sensing device. Both these ranges are inversely proportional to the distance from the sensing device. Sensing range is generally half of communication range

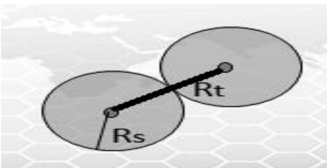



**Fig 5:** sensing range($R_s$) and communication range($R_t$) .

### 2.6 Obstacles

Obstacles with respect to sensor networks is defined as the unwanted objects causing hindrances on the sensor field their presence effect the sensors sensing ability and can also destroy some features of sensor network. Obstacles are prominent in physical Scenario and are mostly remain unnoticed in several research works. Few researchers have done magnificent work by involving obstacles and have shown their effect in various sensing applications.

Obstacles study has mainly involved two aspects. The obstacle property and obstacles shape. Based on the property of obstacles they may be classified as Transparent Obstacles and Opaque Obstacles. Transparent Obstacles by their presence on sensing field can obstruct the path and Opaque obstacles obstruct the line of sight as well as the path. The shape of the obstacles could be classified as line segment, Circular, Ring, Crescent, Rectangular. These primitive shapes could be combined to form a complex shape.

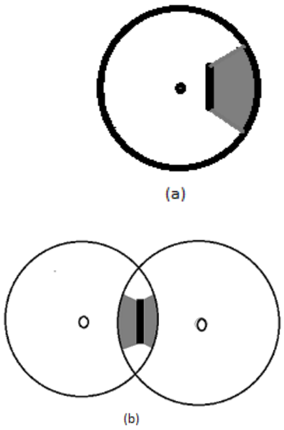



**Fig 6:** Illustration of line segment obstacle over (a) Single sensor (b) Two sensors

In fig 6 obstacles presence in a simple scenario could be understood. In fig 6(a) line segment obstacle within the sensor sensing range can obstruct sensing power and can create a region left unmonitored. In fig 6(b) Obstacles can obstruct the sensing range as shown in figure. Here obstacle instead of two sensors creates a 1 coverage region.

## III. Current Approaches for Obstacles Presence over Sensing Region

Obstacles presence on the sensing field is a novel problem. Researchers have not involved themselves a lot by considering presence of obstacles in their proposed solutions of various coverage problems. The environment of their problem consideration has therefore remained too idealistic. Obstacles have a noticeable impact on the wireless sensor networks. The study about the obstacles was started in year 2005 when an attempt was made to develop an obstacle model for sensing field. The researchers have worked brilliantly to find out the impact of obstacles on various data transmission protocols of wireless sensor networks. They has also used different shapes to illustrate obstacles and then simulated them to analyze their effect. Then two years later an effort was made to compute the best coverage path in presence of obstacles. Polynomial time algorithms were designed to compute the path in presence of obstacles. In this approach the researcher has defined properties of obstacles as Opaque and Transparent.

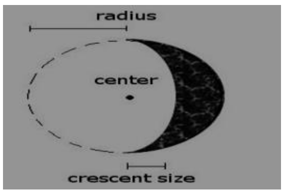
Recently researchers have brilliantly used the concepts of computational Geometry to handle the presence of obstacles for determining coverage. In one of the current approach DCEL is used to store the information regarding obstacle and then a sweep line algorithm is used to identify obstacles and their presence on the field. The other approach also uses computational geometry technique to determine redundancies and coverage detection in presence obstacles. In this section an attempt has been made to discuss prime approaches of obstacles considerations.

**3.1 Effect of Obstacles on performance of Wireless Sensor Networks**

The main objective of this paper is to design an obstacle model to be used while simulating Wireless Sensor Networks (WSN). Obstacles are introduced and categorized based on their nature, their shape as well as their nature to change over time. Nature of obstacle could be Physical and Communication Obstacles. With the help of simulation it is shown that obstacles effect on the performance of representative data propagation protocols for wireless sensor networks. Author has shown that obstacles presence has a significant impact on protocols performance and a conclusion has also been drawn over which protocol is best in obstacles environment.

A systematic and generic obstacle model is proposed to be used in simulations of wireless sensor network. Author has provided a category of Obstacles based on variety of criteria. The author believe that inclusion of Obstacles in WSN simulations will lead to interesting and important findings and the categorizations of obstacles is necessary in order to study the effect of various types of obstacles in the behaviour of data dissemination protocols for wireless sensor network. The author has included obstacles of various shapes that are expected to appear in real deployment scenarios. Also obstacles of various shapes in the model are combined to produce more complex shape.

The author has implemented model of obstacles in the Simdust simulator in order to incorporate the proposed obstacle model in the simulator. A simulation environment is created that integrates a variety of network topologies, Protocols and Obstacles. Experimental results were provided by comparing the performance of several representative protocols for data propagation in WSN in various settings of obstacles in protocol performance in general as well as the particular effect of certain obstacles to each protocol.



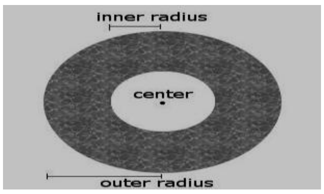


Fig 7(a) Crescent Obstacle (b) Ring Obstacle

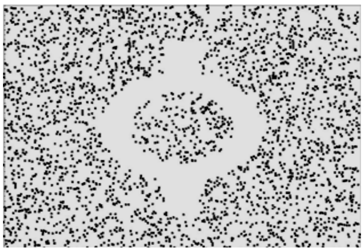


Fig 7(c) Combination Of Shapes

**Keynotes:-**

- Fig 7(a) (b) shows the shapes of few obstacles. Obstacles could also be rectangular, Circular and stripe shape.
- Obstacles can be combined together as shown in figure 7(c).
- Energy consumption model has been used. Generally each node has three modes (a) Transmission of message (b) Reception of a message (c) Sensing of event.

$E_T(k,r) = E_{elec} *k + emp * k* r^2$.
$E_{elec}$ is radio energy dissipates to run transmitter and receiver.
emp is radio energy to achieve acceptable signal to noise ratio.
$r^2$ is energy consumption if message is transmitted to a range r.
k is number of bits in the message.

- The success rate has been plotted. Success rate is defined as fraction of number of events successfully propagated to the control centre over the total number of events.
- Physical Obstacles $O^{Phy}$ prevents the physical presence of sensor device.
- Communication Obstacles $O^{Com}$ causes disruption to the wireless communication medium.
- Protocols on which performance is analyzed are PFR, LTP and VTRP.
- PFR is probabilistic forwarding based on probability of nodes capable of forwarding a signal based on threshold angle.
- LTP is a protocol which is simple based on Boolean decision making. It has least success rate.
- VTRP is a transmission range adjusting protocol in which transmission range is varied for forwarding a packet.

**3.2 Best Coverage Path in presence of Obstacles**

Paper is about computing BCP(s, t), a Best Coverage Path between two points s and t in the presence of m line segment obstacles in a 2D field under surveillance by n sensors. Based on the nature of obstacles two variants of problem has been studied.

Opaque obstacles obstruct paths and block sensing capabilities of sensors. Transparent obstacles only obstruct paths but allow sensing. For opaque obstacles there is an algorithm ExOpaque for computation of BCP(s, t) that takes $O((m^2n^2 + n^4) \log(mn + n^2))$ time and $O(m^2n^2 + n^4)$ space. For Transparent opstacles an exact as well as an approximation algorithm, where the exact algorithm ExTransparent takes $O(n(m+n)^2(\log n+\log(m+n)))$ time and $O(n(m+n)^2)$ space. On the other hand, the approximation algorithm ApproxTransparent takes $O(n(m +n)(\log n +\log(m +n)))$ time and $O(n(m +n))$ space with an approximation factor of $O(k)$, using k-spanners of visibility graph.

Given a 2D field with obstacles under surveillance by a set of sensors, it is required to compute a Best Coverage Path (BCP) between two given points that avoids the obstacles. Informally, such a path should stay as close as possible to the sensors, so that an agent following that path would be most “protected” by the sensors. This problem is also related to the classical art gallery type of problems. It is one of the first efforts to study the presence of obstacles in coverage problems in sensor networks.

More specifically, It is studied that how the presence of obstacles significantly impacts the computation of best coverage paths. Obstacles are objects that obstruct paths and/or block the line of sight of sensors. Obstacles are common in a sensor deployment, particularly in unmanned terrains. They include buildings and trees, uneven surfaces and elevations in hilly terrains, and so on. In this paper, the study is restricted to obstacles that are line segments. This is because line segments are fundamental building blocks for obstacles, and more complex obstacles (e.g., polygonal obstacles) can be modeled as compositions of line segments.

More formally, let S = {S1, . . . , Sn} be a set of n homogeneous point sensors deployed in a 2D sensor field Ω. Each sensor node (point) has the capability to sense data (such as temperature, light, pressure and so on) in its vicinity defined by its sensing radius. An assumption is made that these sensors are guards that can protect any object within their sensing radius, except that the level of protection decreases as the distance between the sensor and the object increases. Let P(s, t) be a path between a given source point s and a destination point t. The least protected point p along P(s, t) is one such that the Euclidean distance between p and its closest sensor Si is greatest. This distance between p and Si is known as the cover value of the path P(s, t). BCP(s, t), the Best Coverage Path between s and t, is that path with the minimum cover value. A BCP is also known as a maximal support path (MSP).

In recent years there have been several efforts to design efficient algorithms to compute various kinds of coverage paths. However, one notable limitation of these works is that they have not considered the presence of obstacles in the sensor field, i.e., objects that obstruct paths and/or block the line of sight of sensors. To compute BCP(s, t) without obstacles, existing approaches leverage the fact that the Delaunay triangulation of the set of sensors – i.e., the dual of the Voronoi diagram – contains BCP(s, t).
Furthermore, it is shown that sparse sub graphs of the Delaunay triangulation, such as Gabriel graphs and even Relative Neighborhood graphs, contain BCP(s, t). However, such methods do not easily extend to the case of obstacles.

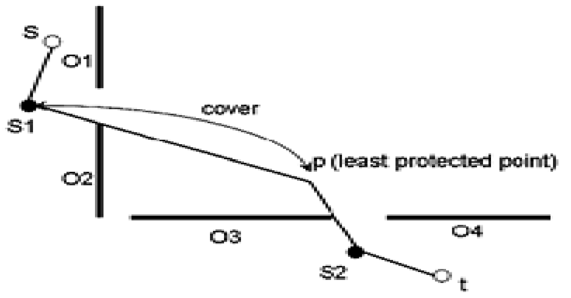



Fig 8(a) BCP(s,t) for Opaque Obstacle

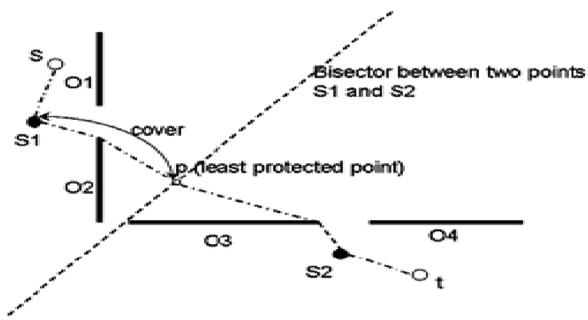



Fig 8(b) BCP(s,t) for Transparent Obstacles

It should additionally be clear from Fig. 8(a) that the visibility graph is also not applicable to the BCP(s, t) problem for opaque obstacles, as the best coverage paths in this case need not follow edges of the visibility graph. In fact, to solve the BCP(s, t) problem for opaque obstacles, an algorithm is developed that takes quartic-time, based on constructing a specialized dual of the Constrained and Weighted Voronoi diagram (henceforth known as the CW-Voronoi diagram) of a set of point sites in the presence of obstacles. This type of Voronoi diagram is a generalization of Peeper’s Voronoi diagram that involves only two obstacles.

Fig 8(b) shows BCP(s,t) for transparent obstacles. Best coverage path is contained in a graph which can be obtained by stitching together n standard visibility graphs, each local to a sensor’s Voronoi region, which enables author to develop a more efficient algorithm. An approximation algorithm is also developed for computing BCP(s, t) for transparent obstacles using k-spanner of the visibility graph and its approximation factor is proved.

**Keynotes:-**

- The main difference between the art gallery problems and the BCP problems is that the former attempt to determine paths that optimize total Euclidean distances under certain constraints.
- Whereas the metric (i.e. best cover) to optimize in the Best Coverage Path problems is sufficiently different from Euclidean distance, thus requiring different approaches.
- Let BC(x, y) be the cover value of the path BCP(x, y). BC(x, y) is the Euclidean distance between the least protected point in the path to its closest sensor.
- Best Cover (BC) holds all properties of a metric space.

(i) Non-negativity property: BC(x, y) > 0, ∀x = y.

(ii) Symmetric property: BC(x, y) = BC(y, x),∀x = y.

(iii) Triangle inequality property:
BC(x, y) <= BC(x, z) +BC(z, y).

### 3.3 COVERAGE IN PRESENCE OF TRANSPARENT OBSTACLE

In this paper the author has considered the presence of transparent obstacles with arbitrary shape in the region and present algorithm based on computational geometry techniques to measure coverage percentage of a region by sensors arbitrarily distribution in that region. It is not necessary that all sensors have same sensing range. The algorithm works in the heterogeneous environment of sensors sensing ranges.

A situation is considered as n sensors are distributed in a region containing some obstacles. Obstacles have arbitrary polygonal shapes and are present in arbitrary location. In this paper it is also considered that obstacles are having Opaque and Transparent property and author deals with transparent obstacles problem. The author a Doubly Connected Edge List (DCEL) for representing subdivisions to compute area covered by sensors, or by obstacles.

The author has intelligently extended DCEL to store extra records. Since each sensor senses the environment in a circular manner therefore author extends DCEL to store both line segments and arcs. The new DCEL consist of three collections of records, one for vertices, one for faces and one for the half edges. The records for vertices and the faces is similar to the conventional DCEL. Half edges have some extra fields. The exceptions of isolated sensors are handled by defining virtual vertex v in the rightmost point of the circles. The author then obtains two subdivisions representing polygon obstacles and sensors. The author defines a modified sweep line algorithm to compute overlays of these two subdivisions.

**Keynotes:-**

- A new algorithm to compute the area covered by a set of sensors distributed in a region containing transparent obstacles with arbitrary shapes.
- Computational Geometry Technique used to design an algorithm for heterogeneous sensors.
- Transparent Obstacles hinders the path but allow line of sight.
- A DCEL was maintained to store the overlays formed by sensors and obstacles.
- The area covered is calculated using sweep line algorithm.

### 3.4 Redundancy and Coverage Detection in Wireless Sensor Networks in the Presence of Obstacles.

The area covered by wireless sensor network and the energy consumed by the sensor are two main problems of WSN. Several efforts have been made to find coverage percentage of sensors and to eliminate redundant sensors. All these approaches haven't considered obstacles on the deployment area. In this paper author proposes a new efficient algorithm to compute the area covered by the sensors in a region containing transparent and opaque obstacles and studied the problem of detecting and eliminating redundant sensors in order to improve energy efficiency, while preserving network coverage. The proposed algorithm has used Computational Geometry technique and is applicable to both homogeneous and heterogeneous WSNs'. This technique has considered arbitrary polygonal shapes and their location is also not known.

In order to measure the coverage percentage of a region by the sensors and detect the redundant sensors the author has used some computational geometry techniques such as Sweep Line Algorithm, Doubly Connected Edge List and Visibility. Then author has designed two algorithms to deal separately with Opaque and transparent obstacles. In both the algorithm firstly the coverage detection is done in presence of obstacles using suitable Computational geometry tool and then Detect Redundancy algorithm has been designed to find out the extra sensors present and schedule the sensors to make system energy efficient.

The input of the algorithm for transparent obstacles is two subdivisions; one of them represents the structure of sensors and the other represents the structure of obstacles.
The information of subdivisions is stored in separate DCEL. Each face in the DCEL is labeled properly.

More specifically the input of the algorithm is the collection of subdivisions forming a DCEL. The output of the algorithm is a collection of cover sets which can be active to preserve coverage, while other sensors are switched into sleep mode. The author has shown that using algorithm the network lifetime will increase from 1 unit to I units where I is calculated in the algorithm.

| AUTHOR | COVERAGE PROBLEM TYPE | NATURE OF NODES | TYPES OF OBSTACLES | OUTCOME |
|---|---|---|---|---|
| IOANNIS (GREECE) | Protocols Based | Homogeneous | Disk, Ring, Crescent, Stripe and mixed. | Effect Of Obstacles on protocol Performance |
| AZADE FOTOUHI (IRAN) | Area Coverage | Heterogeneous | Polygon Shape | Area Covered & Redundant Sensor Node |
| MOHAMAD REZZAZI (IRAN) | Area Coverage | Heterogeneous | Any Shape (Transparent Opaque) | Precise Area Coverage |
| S.BASU ROY (U.S.A) | Barrier Coverage | Homogeneous | Line Segment | Best Coverage Path In Presence Of Obstacles |

## Keynotes:-

- A new efficient algorithm to compute the area covered by the sensors in a region containing transparent and opaque obstacles.
- Study the problem of detecting and eliminating redundant sensors in order to improve energy efficiency, while preserving the network's coverage.
- Obstacles are polygon shaped and present in arbitrary location.
- In this method an idea is picked up to recognize whether a sensor sees an obstacle endpoint or not by the help of visibility graphs.
- A rotational sweep line sweeps the plane and does proper action at each event point.
- Event points are the endpoints of obstacles, and the status of the sweep line is obstacle edges which it intersects.
- By using the information stored in the overlay DCEL the following values can be computed:

(i) Coverage percentage: The union of all faces labeled with the name of circles gives the area covered by the sensors.

(ii) Blocked area: The union of all faces labeled with intersection of one subdivision and other circle will give total area that the presence of obstacles causes to not cover by the sensors. These areas are called blocked areas.

## IV. Analyses of Current Approaches

All the current approaches that have been discussed in section 3 are applicable to different WSN applications and in each presented approach the main problem was the presence of obstacles on the sensing field. The authors in their work have firstly done some assumptions regarding obstacles to make the solution possible and then have tried to develop a solution for handling these obstacles.

The approach discussed in section 3.1 shows that the obstacles have a great impact over WSN performance and a complete obstacle model has been created. The simulation results that have been discussed in this paper show that obstacles on the sensor field have a great impact.

The approach in section 3.2 shows that the best coverage path that has been calculated in the absence of obstacles differs a lot than the path that has been calculated in the presence of obstacles. In this approach the shape and properties were fixed still the impact of obstacles was prominent. In section 3.3 keeping the obstacles of same properties as it was defined in section 3.2 the other tried to estimate the coverage over entire area in which sensors are deployed. Here author uses an innovative approach for handling heterogeneous environment. Finally in section 3.4 it has been shown that redundancy check and activity scheduling problems could be solved in presence of obstacles too and thus power saving could be done to prolong the network lifetime.

In this section an analysis is done in the tabular form to see the various aspects of problems that has been dealt so far. It has also been tried to analyze the shapes and properties of obstacles. A listing of outcome and nature of outcome has been done to see end products. In the following analysis tables all the papers are considered that have been discussed in section 3. Since obstacles study is a

**Table 1**

| AUTHOR | OBSTACLES PROPERTIES | TECHNIQUE INVOLVED | OUTCOME NATURE |
|---|---|---|---|
| IOANNIS (GREECE) | $O^{comm.}$ $O^{phy}$ | Simulation of Obstacle model | A Model to simulate Protocols in Obstacles Presence |
| AZADE FOTOUHI (IRAN) | Opaque & Transparent | Computational Geometry | Pseudo Code to detect Redundancy |
| MOHAMAD REZZAZI (IRAN) | Transparent | Computational Geometry | Algorithm to detect Obstacles |
| S.BASU ROY (U.S.A) | Opaque & Transparent | Computational Geometry. | Polynomial time BCP |

**Table 2**

Novel approach therefore it is hard to find a number of approached in the existing researches. The approaches that have been discussed are also of recent years and much work is still left. In the tables given above the rows shows the contents that have been covered in each paper and the column shows the categories of various types of analysis that have been done.

In table 1 there are four rows each for the separate paper. In column 1 there is a category of author name and place from where they belong. In the second column there is a category of the type of coverage problem that is being taken up by the researchers. In the third column the type of nodes that has been assumed in each paper has been categorized. In the fourth column there is the category of types of obstacles definition given by the author in the paper. In the fourth column there is a category of results that author has reached up to in each paper.

In table 2 there is again the analysis of the same papers. Column 1 is same as column 1 of table 1.In column 2there is a category of properties of obstacles that have been assumed by the author to make maximum resemblance to real world obstacles. In column 3 there is a category of technique involved in the paper to solve the problem. Mostly computational geometry technique is used to develop an efficient solution. In column 4 there is a category of type of outcome in each paper. This could be understood as the form of result that has been presented by each author. The outcome could be of various types but mostly pseudo codes are generated by authors. In this section through tables it has been tried to present an efficient analysis of the papers.

## V. Conclusion

In this survey we have presented some fundamental concepts behind the study of obstacles on wireless sensor field. Then it is being tried to cover a variety of work accomplished for obstacles in wireless sensor networks. Then an attempt is made to analyze the approaches and present it in a tabular form.

The obstacles work as described in the paper was started with simulation based approach in which integrated and systematic obstacles model was used. With the help of simulations the effect of obstacles on protocol performance was shown. The model was efficient but with some abstractions regarding flow of signals. There could also be other protocols that could be implemented. In another paper it was shown that obstacles make the problem significantly difficult. It was suggested that more practical solution could be investigated with available heuristics. The paper also motivates to investigate other types of coverage problems. In another approach presence of arbitrary obstacles was considered and a precise area coverage computation pseudo code was generated. Author has considered both homogeneous and heterogeneous sensing nodes. In the last paper discussed new efficient algorithm has been developed to compute the area covered by the sensors and detect all redundant sensors to improve energy consumptions in presence of obstacles.

All the techniques discussed have shown that obstacles affect the results a lot. There are enumerable problems that could be analyzed while considering obstacles. Obstacles are prominent in in physical scenarios and it's an immense need to research a lot for obstacles on sensor field.

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