Maximum Coverage in WSN using Optimal Deployment Technique

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ABSTRACT
Present sensors are inbuilt with sensing capabilities, battery, mobilization and storage capability, for better monitoring of targets and storage of information regarding targets. The sensors can be static or dynamic, depending upon their application. Since the dynamic sensors are costlier, hence are used for supreme purpose. Here we suggest an algorithm for distributed sensor network consisting of homogeneous static nodes. The nodes are deployed as per the graphical illustration regarding the area. This approach is carried out to solve the hole problem and to perform efficient monitoring with minimum number of nodes. Here nodes are deployed statically, one by one, sensing each target in a given field, and thus completing the entire field. This algorithm produces cover set, consisting of sensor nodes, which would monitor the field consisting of targets, completely. A number of cover sets can be generated using the same technique to improve the life period.

General terms
Coverage algorithm

Keywords
Coverage, node deployment, cover sets, target sensing.

1. INTRODUCTION
Now a day's sensor networks have found its application in nearly every field. For instance we can consider tracking objects for military purpose, infrastructure security, environmental and habitat monitoring, industrial sensing, traffic control etc. [1]. Though the above fields are different, but they share a common technical issue. A sensor network consists of sensor nodes which are comprised of a sensing module and a communicating module. These modules are responsible for monitoring, gathering data and transmission of data from base station to all sensor nodes. This facilitates communication and formation of a coverage area. Moreover additional features like computing, sensing advance communication bring about development in sensor network. Such development can be brought about by deploying hardware and software algorithms. A sensor is very small in size, can be active or passive. An active sensor probes the environment on actual manipulation whereas passive sensor senses the data without actual manipulation. A sensor network, may be large or small, consists of such sensors which may be homogeneous or heterogeneous in nature. The network architecture may be centralized, distributed or hybrid and communication between the sensors may be wired or wireless. These sensors are capable of collecting information regarding subject of interest and its entity. Once a set of sensors are deployed in an area, they are capable of forming links to each other and start working as a network. Depending upon the type of environment and preferred applications the deployment of sensors can vary from predefined way to random way; where the density of sensor cannot be guaranteed [2]. The sensor network of 21st century are much more advanced and have better communication and computation skills which have made it easier to achieve our goal of high and better coverage . Such advancement is brought about by advance networking and better information processing techniques, which makes it reliable, useful and time efficient.

The advancement is sensor's communication and life is brought about by scheduling the different mode of the sensor nodes in a network. WSN (wireless sensor network) operates under three modes and they are:

Active mode: When a node can sense the environment and communicate with other sensor nodes.

Sleep mode: When a sensor is incapable for both monitoring the environment and transmitting the data, but becomes active when it receives the signal. This mode it consumes much lesser energy [2].

Off mode: When a node is completely turned off and it becomes dead and never come back to active mode. Each sensor has a battery and hence do have limited life-time or battery life.

Though a sensor have a fix life time, hence it need to be scheduled so as to monitor target efficiently. Moreover the holes too exist in sensor network, which degrades its performance. Hence to overcome all these problems we need such an algorithm which would minimize the problem and would provide an energy efficient coverage network with minimum number of nodes. In this context we deal with such problems and discuss about the various approaches to minimize them, choosing the most efficient one out of those approaches.

The paper is organized as follows. Section 2 gives the overview of sensor node and its components. In section 3 we briefly discuss about application of sensor network. In Section 4 we discuss about the technical problems and challenges regarding WSN. In Section 5 we focus on the resent work. In Section 6 we discuss the connectivity within the sensor network. In Section 7 we addressed the coverage problem in WSN and in Section 8 we proposed an approach to deal with the problem and implementation through MAT lab. Finally, the section 9 gives conclusions.

2. SENSOR NODE & SENSOR NETWORK

Sensors are hardware electronic devices that response to the change in a physical condition like temperature and pressure, it sense physical data to be monitored and equipped with limited power supply. It consists of an analog to digital converter and is characterized by small size, consumes very low energy, and operates in high volumetric density, autonomous and adaptive to environment. It can be passive (Omni-directional or narrow beam) or active. Omni directional sensors have no idea regarding the direction and measurement, where as narrow beam sensors are boosted with such properties.

Wireless sensor network (WSN) represents a significant improvement over traditional sensors. A sensor network in practice can be composed of tens to thousands of sensor nodes, which are distributed in a wide area [12, 13]. Or we can say a sensor network is cluster of a group of sensor nodes. Sensor nodes can be deployed in random fashion dynamically or can be planted manually for sensing the environment. The dynamic sensors are inbuilt with artificial intelligence for tedious job of tracking.

Here we described briefly some of the components of sensor node used in our experimental study.

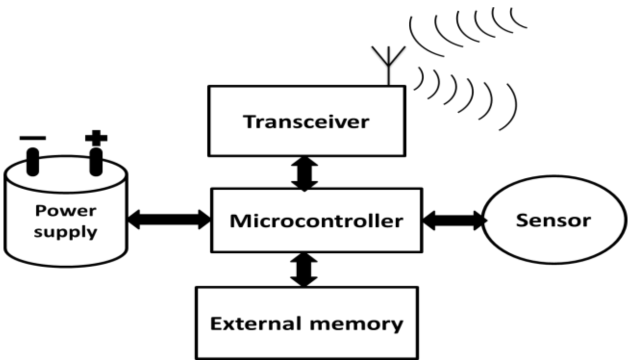


Fig 1: Architecture of a sensor node and a sensor

Microcontroller: Performs tasks, process data, controls the functioning of other components in the sensor node and provides flexibility to connect to other devices, ease of programming and low power consumption. Power consumption is done by switching into various steps (sleep, active, etc.), which consumes negligible powers.

Transceiver: It works on combined principle of transmitter and a receiver, which often lacks unique identifiers. Current generation transceiver are embed with artificial intelligence, i.e. they are capable of switching between states (transmit, receive, idle and sleep) automatically.

External memory: For storage capacity, on-clip memory of a micro-controller and flash memory are used, which have following two objectives:

1) Storing application related or personal, data.
2) Used for programming the device.

Power source: Power consumption is required for sensing, communication and data processing. Especially data communication consumes more power. Power can be stored in battery or capacitors. We can have variety of batteries depending upon nature (rechargeable and non-rechargeable). Present sensors can renew energy from solar, temperature and vibration [3]. Two policies are associated with it:

Dynamic power management: shutting down parts of nodes which are currently not in used.

Dynamic voltage scaling: varying the power level, determining the power lode [4].

This architecture is shown in Figure 1.

3. APPLICATION OF SENSOR NETWORK

As sensors are capable of processing and communicating data, so when they form network, they becomes capable to solve many problems, in many different fields. Hence such sensors can find there application in the following fields:

3.1 Infrastructure Security: It helps counter terrorism application, protecting the facilities, e.g. communication center, power plant etc., detecting possible threats like biological, chemical, nuclear attack and also provides additional coverage. It also helps detecting terrorist camp activities and movements.

3.2 Environmental and Habitat Monitoring: Sensors helps monitoring the variable parameters which are distributed over a large region. The parameters like temperature, pressure, humidity, composition in air, etc.. To enable such application radars are connected to satellites by high speed network however ground based sensors are connected by low speed network.

3.3 Industrial Sensing: Sensors helps in lowering costs, improving performance and maintaining machinery by determining its health for lubrication and variation of wear and tear. Special sensors are capable of replacing existing instrument; perform material property and composition measurements. A sensor enables multipoint or matrix sensing. Inputs from many sensors are feed into the database that can be discussed and interpreted in any number of ways to show real time information on a large and small scale.

3.4 Traffic Control: Sensor are either buried or over headed to detect vehicles and control traffic light and video camera are used to sense heavy sensors embedded to improvise the networking capabilities which can be deployed at road intersection to detect traffic and speed vehicles. These sensors would communicate with nearest sensor to represent a global traffic picture. Traffic jam can be avoided by passing the information from vehicle to vehicle to inform about the current traffic density, so they could choose alternate path [1].

4. TECHNICAL PROBLEM AND CHALLENGES

Sensor network possess some technical problems in the field of communication, data processing and sensor management, hence there are some challenges in network discovery, network control and routing collaborating information processing, querying and tasking, and these challenges are described below.

4.1. Ad-Hoc Network Formation: As network topology is always involved mechanism, so it must be provided to sensor node to discover each other which, is required for collaboration, data communication, supporting network and processing.

4.2. Network Control and Routing: Capability to accommodate the dynamically changing of resources like energy bandwidth and processing power lacks in ad hoc network and hence it depends on algorithms and software for this purpose. To face such problem, either network must consist of more number of nodes to provide redundancy, or mobile IP. As under such condition node does not possess IP address a number of network devices can be deployed to optimize path which could be answer to connection demand for data specific and application specific purpose. Problem regarding this is that it requires routing table which incurs high overhead for maintenance. Diffusion routing may prove helpful in such case as it relay on the information of the neighboring node[1].

4.3. Collaborative Signal and Data Processing: Nodes are required for essential data collection and information processing throughout the network. Vital technical issues are degree of information sharing and information fusion between nodes. Processing data from more sensors would enhance the performance but would require more energy resource. On the other hand using less sensors, less information are lost but requires more bandwidth. Hence these multiple trade-off between performance and resource must be considered under collaborative information processing. The information fussed with local information create a trade-off between performance and robustness. This process of fusion is robust but sub-optimal, however using high performance and more sophisticated fusion rules may be sensitive to the underlying model. Fusion algorithm helps finding dependencies in information to be fused and avoid double counting. Data association is an important problem when multiple target exist in a small region. Under such condition association of measurement of environment with individual target is done by each node along with the association of target decided by each node with the other node in order to avoid duplicity and enable fusion. Again it's a trade-off between performance and resource utilization requiring data association algorithm[1].

5.4. Coverage and Connectivity: From the coverage point of view there are different algorithms, like centralized and distributed, which are responsible for easy data transfer and less power consumption. The connectivity between the sensors are similarly covered by different approaches, such as cover set, which all will be viewed briefly later on, in this context .

4.5. Tasking and Querying: The sensor field is like a database with many features and is accessible by environment to acquire data and information. The data is distributed across nodes geographically, nodes being connected by links. Database of such features appears more challenging in military field where low latency, real-time and high reliability is required. It's important to have a simple interface for interaction during task and query processing, for which simple language and efficient distributed mechanism is need to be developed. User should have command to access to the information. Hence there is a need of a data base which would support all above challenges for query and task compilation, placement organization and caching.

4.6. Security: Sensor networks plays a very vital role in security field, hence it's very important to discuss about its usage. As sensor network may operate in a hostile environment, security is of high concern, hence it is designed to protect against intrusion and spooling. For such, network networks techniques are need to be provided with low latency, survivable and secure network.

5. RESENT WORK AND SUGGESTION ON CHALLENGES

Some works and researches are being done towards the improvement of sensor networks; to enhance it's working, which are discussed below:

5.1. Localized Algorithm and Direct Diffusion:

Centralized algorithms are not desirable for data collection from multiple sensors nodes because of high communication cost and lack of robustness and reliability. On the other hand localized (distributed) algorithm full-fills all the above requirements and are robust to network changes and node failures, as sensor nodes communicates with their neighborhood. The cost even scales well with increasing networks however because of their potentially complicated relationship between local and global behavior, it's difficult to implement. Diffusion algorithm in case of centralized is a type of broadcast routing that doesn't specify the destination. The data is transferred in the direction of target, by passing from one node to other and in such case intermediate nodes may transfer or cache the data locally. Such type of transfer is called data forwarding and increases efficiency, robustness, stability, avoid delicacy and saves energy. The data forwarding follows a gradient which can be based on geographic information, attributes and other resources available in the network nodes, to control the broadcast.

5.2. Distributed Tracking in Wireless Ad-Hoc Network:

Tracking in Ad-Hoc networks, which is important from security point of view, possess different challenges due to communication, processing and energy constraint. Collaboration is required for data fusion which incurs high overloading networks and energy supply. An alternative approach is, to know what to sense and whom to communicate. Each sensor computes the predicted information about a piece of data about a nonlocal sensor and uses this to determine which sensor to request data. Data association is needed in tracking multiple targets that are close to each other. Such distributed networks fit better for large numbers of nodes.

5.3. Distributed Classification in Sensor Network using Mobile Agent:

Data is collected by individual nodes and is transmitted to fusion node for processing in a sensor network. Since the bandwidth is typically lower than wired network, the communication requirement may exceed their capacities. Hence mobile agent can be a solution as data get stored in each sensor in a DNS, until the conversion of fusion code to data takes place. Sensor network is not affected by increase in the number of sensors, as the communication bandwidth requirement may be reduced if the agent is smaller in size than the data [1].

6. CONNECTIVITY WITHIN A WSN

A WSN consist of spatially distributed autonomous devices known as routers and end nodes, which uses sensor to monitor the physical properties (temperature, pressure etc.) of the environment. Such routers and end nodes are connected to a gateway, to complete the WSN system. The central gateway act as network coordinator, which manages authentication, message buffering and helps collect, process, analyze and present data. According to Jennifer Lick [3] , WSN can be categorized into three groups :

System: Each sensor node is an individual system, which is capable of supporting various application software and manipulating data.

Communication protocols: It enables communication between, with in the sensors and application.

Service: Services are developed to enhance the application, system performance and network efficiency.

7. COVERAGE PROBLEM

Distance is an important factor for sensing. With the increase in the distance between nodes and targets, sensing power deceases. Sensors get charged up by batteries; hence they can be used for a limited period of time. Hence to make the battery work longer, energy conservation and coverage preserving protocols are required.

In order to achieve the efficient monitoring of targets by sensor network efficient algorithms are proposed, which are capable of producing cover sets (both disjoint and non-disjoint), each capable for monitoring of targets. Here battery life is taken into concern, so that availability of cover set would increase, offering short time execution and make it desirable for a wide range of node deployment environment. If all the sensors are made to work at the same time , then the whole network will soon become dead, hence cover set technique is need to be implemented. Hence now we emphasis on network coverage and coverage related problems.

For implementation of such concept, first the network needs to be divided into a number of subset of nodes, called cover set. Such cover set must be capable of monitoring all targets. Hence when one cover set is active, other may sleep. If the cover sets are disjoint in nature i.e. one sensor node can be present in only one cover set, then the life of WSN can be increased to that number of cover set. For example if there are 'n' number of disjoint cover set , having 'h' life time of each set , then the life of the WSN can be increased to ' n . h' . Now if we consider the cover sets to be non-disjoint, in that case, any given sensor can participate in more than one cover sets [2]. Under such condition each cover set is allowed to participate in multiple sets. In real time it is observed that, the disjoint sets provide a better life to the WSN.

Coverage problems are of two types, point coverage and area coverage. In point coverage, a set of points is governed by a cover set, where each point is monitored by a sensor. On the other hand, in area coverage, an area is divided into fields and each is uniquely identified by a cover set. Thus a set of cover sets completely covers the entire area. Here, our objective is to propose an optimal (sub-optimal) disjoint cover sets by generic methodology. In this algorithm we take into account the monitoring capabilities of a sensor, it's association with poorly monitored targets and sensor remaining battery life. Thus our algorithm life of a sensor network is dependent on two aspects: firstly by extending the number of cover set, it increases the actual coverage time [2], secondly ,by producing multiple cover sets it provides high redundancy in terms of target coverage.

We must emphasis towards development of a WSN, which would involve less sensor nodes with efficient coverage and life time, energy efficiency and connectivity. The node can be homogeneous or heterogeneous, being deployed random or deterministic with centralized or distributed algorithm, Classification of coverage problem is based on the following algorithms.

7.1. Centralized Coverage Algorithm

Here the central host controller carries out all the computation process and send data to the nodes for execution, which requires less energy . Under this we can have two more concepts:

7.1.1. Disjoint centralized algorithms:

Slijiepcevice and Potkonjak [7] proposed this algorithm for solving area coverage problem. Two targets belongs two the same field , if and only if , they are governed by same set of sensors . A sensor may cover more than one field, but a field is covered by at least one sensor. Once a node has been selected for the critical field, remaining nodes to the same fields are discarded, and hence, every field is covered by a node in a given area.

- Here we consider a undirected graph , G=(V,E) ;where V is set of sensors and E is the set of edges ,such that (u , v) Є E, if and only if 'u' and 'v ' are in each other sensing range . This maximizes the number of dominating sets by graph coloring technique [9].
- Cardei and Du proposed an algorithm [6] to solves the random target coverage problem by heuristic method and compute the disjoint set. It is a type of maximum flow problem, which aims to maximize the number of covers and is solved by mixed integer programming to produce final number of cover set .
- Abrams et al [10], proposed a centralized algorithm which implements randomization to solve the coverage problem. Each generated cover sets does not provide complete coverage of target and then they should be scheduled to produce 80% coverage.

7.1.2. Non-disjoint centralized algorithms:

Such algorithm complexity is though more, but it may extend the life time of the network as compare to disjoint .

- Cardei et al [5] , proposed a greedy strategy with lower complexity O(dk2n) , where 'd' is the number of sensors that cover targets that are associated with a minimum number of sensors and 'k' as number of targets .

- Berman et al proposed a LP technique to compute a series of cover sets with each cover set having a optimal life.

7.2. Distributed Algorithm: Such algorithm cooperatively and disseminate the information to the sensor . Though it incur more processing power but well suitable for large network . Switching between states is proposed by several distributed algorithms for less power consumption and rapid dissemination.

There is a trade off between life time and efficiency. To cover a given number of targets we would have to deploy as many sensors so as to cover all targets. If holes exist then that part would remain uncovered and hence target cannot be sensed at that hole area. Hence more number of sensors are required to cover the targets and fill the holes. This creates overlapping area which increases the life time of the network to some extent. As when target is sensed by two sensors, then in case if one sensor goes off, the other is still there to sense it. Hence we required such an approach so as to cover all targets with minimum number of sensors and provide better life time. In other words we would have to find the answer for the following questions:

- How the life time of the sensor can be enhanced?
- What strategies to follow?
- What type of coverage we prefer?
- What type of sensor to consider?
- What technique is to be implemented to solve the problem of coverage?
- How far the implemented algorithm successful?

8. OUR PROPOSAL FOR OPTIMAL NODE DEPLOYMENT TECHNIQUE

To resolve the above problems lets plot a graph over the given area as shown in Figure 2. We can have area of any size, i.e. area is undetermined. Let us consider the radius of the coverage circle of the sensor is 250m. Hence the diameter becomes 500m. It is very important to decide the unit block length of the graph, as this would help in easy estimation of the number of sensors we would require.

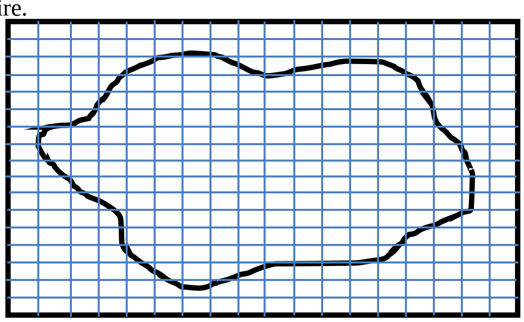


Fig 2 : Graph plotted over the giver area.

So let us assume the circular area of the sensor to be a square. Now this square will be the unit block of the graph. The diameter of the circle now becomes the diagonal of the square. This is depicted in the Figure 3.

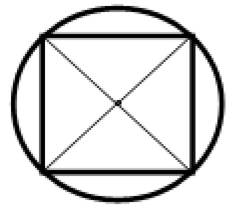


Fig 3: Circular area in terms of square

Now mathematically we can calculate the sides of the square as follows:

2 × radius = diameter

The diagonal divides the square into two isosceles triangle, each having two equal sides (which we need to calculate), two equal angle of 45˚, one right angle and the hypotenuses (diagonal).

As per trigonometric ratio:
Sin θ= perpendicular / hypotenuses
We have θ=45˚ and hypotenuse= 500m
Putting in the above formula, we get perpendicular (side of the square):
Perpendicular= hypotenuses × Sin θ
= 500 × 0.707 = 354m (approx.)

Hence each unit of the graph is 354m approx. hence the desired graph looks like:

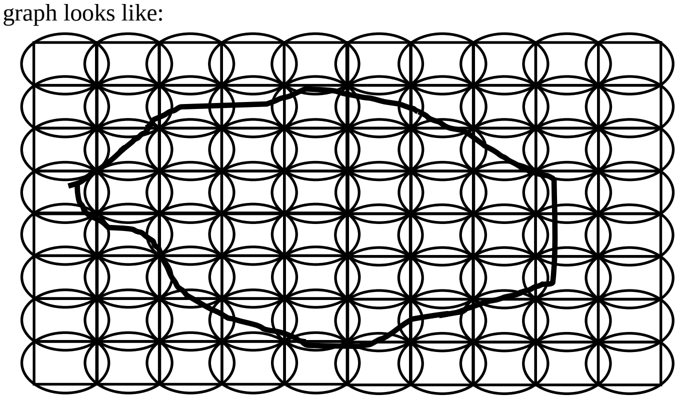


Fig 4 : Graph scenario

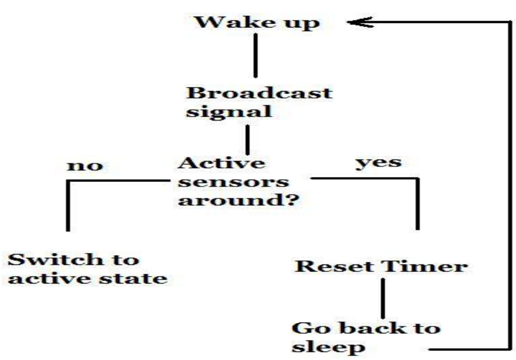
Now each block on the graph consisting the real area, with more than half of the real area will be considered, and hence that much number of blocks or sensors is required to cover the whole area.

Let's start with the first question, to manage the life time of the sensor node. Now as being already discussed, we have two policies to deal with power supply[8], namely: Dynamic power management and dynamic voltage scaling. Besides this we can also switch between the various states of the sensor so as to save the power supply, which would in turn increase the life time of the sensor. For example if both the sensor are sensing the same area, then in that case one can be switched off till the other is working; else if a sensor have nothing to sense, it can be switched to sleep mode etc., such techniques are governed by set of protocols and algorithms. One of such strategy is discussed below[14].

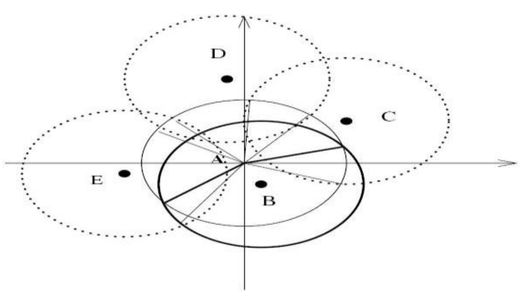
The steps are depicted as follows:

```
FOR (each node) {
   Check Radius of coverage area
  Check all intersection points of area
```

if diameter is inside other coverage areas of sensors
Sensor go to Sleep
}//end of loop
The complexity of the above code is:
IPM: O (k*m*n*m) log (n*m))
ASM: O (n*m^2+n)
Probing: O (n)
Where:
"n" is average number of neighbors of a node
"m" is number of nodes
"k" average edges involved in the node
Intersection point method (IPM)
Association Sensors Method (ASM)



(a)



(b)

Fig 5: (a) The flow chart of the strategy being followed; (b) The technique in-build in the strategy

In the first diagram of Figure 5, it shows that the sensor senses, only when it has something to sense, else it goes to sleep mode and get activated after a random interval of time. The second figure shows how a sensor can be switched to sleep mode, if its target is being sensed by other nodes or comes under the same coverage. Here the optimization protocols play a very important role in making sure that the network is not dropped.

Now we proceed to our third question about what type of coverage we prefer. Here we prefer area coverage to point coverage. Hence we need to form the cover set containing a set of sensors, covering each target within the field. A set of such cover set will cover the entire area. Under area coverage, the sensors can be deployed in two ways: Dynamic deployment and Static deployment.

Dynamic deployment: Here the nodes are deployed and they automatically search for the target to sense.

Since we are concerned with area coverage, we will deploy the homogeneous sensor (having same area of coverage) statically. Here we approach with a concept of producing non-disjoint cover set. Non-disjoint cover sets are appropriate for area coverage than disjoint cover set. In disjoint case only one target is covered by one node where as in non-disjoint case a node can sense more than one target.

Here we propose an algorithm for producing a non-disjoint cover set to sense a field containing a certain number of targets. This algorithm would help to deploy sensor in random fashion, one by one manner, completing each target in the field. Such algorithm is depicted below:

Algorithm

```
Set num_cover_set=0
Initialize Nodes_avail and set Target_uncovered=n
While (Target_uncovered!=0)
    Deploy the node to target
    Update Nodes_avail= Nodes_avail-1
    Update Target_uncovered= Target_uncovered-1
    For (i=0; i<n; i++)
            Set position of the node deployed
            Set position of the uncovered targets
            Distance=sqrt((xt - xs)2 + (yt - ys)2)
             If (distance < radius)
                     Uncovered target can be sensed
                     Target_uncovered= Target_uncovered-1
      End of for loop
      num_cover_set= num_cover_set + 1
End of while loop
Return num_cover_set
Exit
```

Where:
num_cover_set: Number of nodes required to form a cover set to sense a particular field
Target_uncovered: Number of targets in a field to be covered
Nodes_avail: Number of nodes available
Distance: Distance between the nodes to the uncovered target
Radius: Radius of the coverage area of the node
'xt' and 'yt' are the coordinates of the target and, 'xs' and 'ys' are the coordinates of the sensor.

Explanation: First we deploy a node in a field. Then we search expect the particular target for which the node is deployed, what other targets are covered by the same node. This is done by comparing the length of the radius and the distance between the node and the other uncovered targets. As we use homogeneous nodes of almost same coverage area, so a fixed radius is considered. As many targets are covered, the number of uncovered targets decreases and the node is added to the cover set. By this procedure we can produce cover set and the steps can be repeated to find out the number of cover sets required to cover the whole area.

From the center of the node deployed, every uncovered target is compared, then which ever target comes under its coverage is considered as covered. This is done by comparing the radius of the sensor coverage area and the distance from the other target. The diagram in Figure 7, shows the process. The sensor is deployed for the target T1, but it also senses the T2, but not T3. This is done by comparing radius and the distance between the targets say d1 and d2, which ever distance is less than radius is considered as covered.

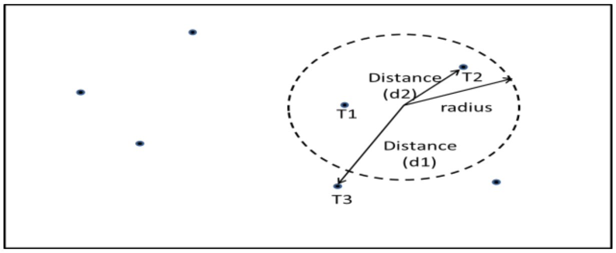
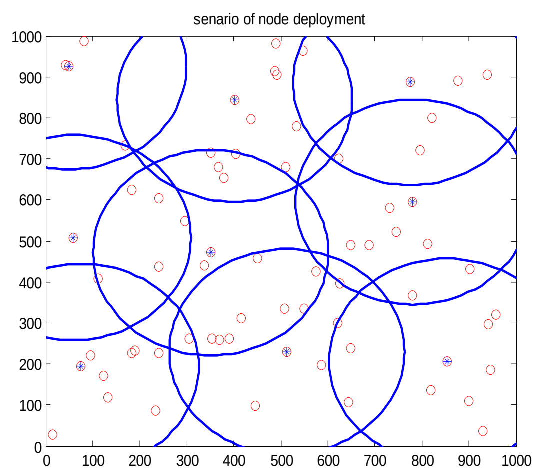


Fig 6: Figure showing the technique how nodes are covered

As the nodes are being deployed at random, hence each time the result varies, To visualize the scenario, that how the sensors are deployed is simulated in MAT lab. Similar to the number of nodes, the scenario also changes each time we execute the same program. The scenario is depicted in the figure below.



Here we have taken available sensors to be 50, random targets to be 70 and radius to be 250. In the graph the area is taken as 1000 square unit, the blue color ring shows the coverage area of the sensor i.e. 100 square unit, the red small rings are the targets and the blue star represents the sensor nodes, being deployed for the particular sensor(red color small rings with blue color star in it).

9. CONCLUSIONS AND FUTURE WORK

We have tried to suggest a better coverage for wireless sensor network, with better life. Our present work is concerned about the graphical representation of nodes, which helps in easy estimation of number of nodes to be required to cover a particular area. Moreover the algorithm also deals with the sensing strategies that we follow to sense our targets, providing answer to the hole problem. Our future work will concern to reduce the complexity of the algorithms. Though a lot of researches are being carried out in this field, but it suffers from 99% complete syndrome. Hence advancement of such algorithm is must. Though several algorithms exist, based on this concept, but reduction in complexity or improving the existing one or designing a new algorithm is possible. Our proposed model is just a first step toward this approach. In our future work we will try to test it in test bed and a comparative study is required to analyze the efficiency of the proposed algorithm.

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