# Implementation of Wireless Nodes for Energy Efficient Coverage and Connectivity In Wireless Sensor Network

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***Abstract***— In the previous work, system has been developed for improving the coverage via energy efficient techniques. But these techniques do not take into consideration the movement of the node required foe energy efficient coverage improvement. Thus the major energy of the node is spend on moving from location to location for coverage improvement. So each node had the responsibility to contribute for coverage efficiency of the entire network, which made the node to move from network to network in the entire area for coverage improvement which causes a huge energy consumption. Thereby reducing the overall energy of the network.

To overcome this problem we will use the concept of Voronoi diagrams to divide the entire network into regions of varying nodes. So a node will only have the responsibility to improve the coverage of the area in which Voronoi diagram has placed it. Thus the node movement is restricted. So the energy needed for movement will be reduced and the coverage area will be improved. This will allow the network to retain energy for a longer time duration.

***Keywords***-*Wireless sensor network, Voronoi Diagram, Coverage Connectivity, Coverage Hole, Sensing range*

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## I. INTRODUCTION

Wireless sensor network is a wide area of research in the field of wireless communication. A WSN consists of several electronic devices, referred to as a node that communicates through wireless transmission. Each node is equipped with a sensor to collect data from the environment. Wireless sensor networks have attracted tremendous research attention because of its number of applications like security surveillance, environmental monitoring, etc. All applications required a reliable detection, which can only be achieved if there is no coverage holes in the target field which is monitored by the WSN. For instance a sensor network can be deployed in a remote island for monitoring wildlife habitat or near the crater of volcano to measure the temperature and pressure, in such cases the environmental conditions is not suitable for human intervention. Thus the sensor nodes will be deployed randomly or sprinkled from air and will remain unattended for a long time without any battery replacement. So energy consumption is also of a great importance here .So it is essential to detect the coverage holes and to improve the coverage area and connectivity of wireless sensor networks to ensure the full operability of the WSN.

Each sensor node is facilitated with the multiple power levels to transmit the data in the wireless channel. Each sensor node runs by the battery power and has sensing capability so it can sense the data within the limited area called sensing radius .Coverage is usually interpreted as how well the nodes in the wireless sensor network monitor the specified environment. Along with the coverage, connectivity is equally important in wireless sensor networks. Connectivity is defined as the ability of any sensor node to send the collected information to the sink. If no route is available for the sensor node to send the data to the sink then there will be no connectivity and hence the collected data is useless. Communication range of the node is defined as the area in which another node can be located in order to receive the data. The sensing range is different which is defined as the area where a node can observe an event.

Obstacles and environmental factors affect the network coverage and may result hole in the sensing area. Efficient sensor deployment strategies are developed to increase the coverage in wireless sensor networks. The sensors find coverage holes within their Voronoi polygon and then move in an appropriate directions to minimize them. The movement strategies are based on the distances of each sensor and the points inside its Voronoi polygon from the edges and vertices of the polygon. The distances of each sensor from the vertices of its Voronoi polygon is obtained and the desired location for the sensor is calculated. Some approaches use Voronoi diagram and Delaunay triangulation to identify sensing holes in the network and create an optimal arrangement of the sensors to eliminate the holes [10].

In order to achieve both coverage and connectivity in WSN, sensor deployment also plays an important role .Sensor deployment can be basically categorized into two types, i.e. dense deployment and sparse deployment. Dense deployment is usually helpful in situations where every event needs to be detected or multiple sensors need to cover a desired area. Sparse deployment basically helps in achieving maximum coverage using minimum number of sensor nodes.

Low-cost sensor devices are failure-prone. In typical sensor networks, these devices are deployed in higher than necessary densities to meet various design specifications. In order to conserve energy and prolong network lifetime, at any time instant, only a portion of these sensors are required to be active while others operate in “sleep” or inactive mode. However, if too many nodes are turned off, coverage holes can be formed and the network can be disconnected. In this chapter, the problem of node scheduling for energy saving and meanwhile the network coverage is still preserved is investigated. A Configurable Coverage Protocol (CCP) is proposed. CCP makes uses of the distance between two nodes rather than their actual locations. Distance information among nodes is easier to obtain than accurate global location information. In addition, CCP allows the trade-off between coverage and node usage (i.e., the number of active nodes). It can be configured to cover at least a portion of the area with high probability. For complete coverage (a = 1), CCP is comparable to OGDC [7] in terms of coverage and number of active nodes required. Simulation shows that for 90% coverage, 22% node savings can be achieved. E.g., for the node density of 10, about 400 active nodes can support 90% coverage while about 530 active nodes are required to support full coverage.

Setting the value allows the network administrator to flexibly control the number of active nodes in the network and the coverage level. The main aim of CCP is to schedule the “on” and “off” of the sensor nodes and preserve the microscale network coverage. The overall network coverage requirement can also be achieved if local coverage is preserved. CCP also implicitly maintains the network connectivity. Therefore, the work presented in this chapter serves the purpose of microscale coverage and (implicit) connectivity control. At last, one shall notice that the vacancy estimation scheme proposed in CCP also provides a way to compute the microscale vacancy of the given network, and thus can also serve as a management function for microscale coverage monitoring.

e addition step. The main aim of this paper is comparison of area, speed and other parameters of Conventional MAC unit with the Vedic MAC design.

## II. COVERAGE AND CONNECTIVITY IN WSNS

Coverage is a measure of the quality of service provided by a sensor network. Due to the attenuation of energy propagation, each sensor node has a sensing gradient, in which the accuracy and probability of sensing and detection attenuate as the distance to the node increases. The total coverage of the whole network can therefore be defined as the union (including possible cooperative signal processing) of all nodes’ sensing gradients. It represents how well each point in the sensing field is covered [12]. A coverage hole refers to a continuous area (or volume in 3-dimensional space) in the sensing field that is not covered by any sensor node, i.e., the events that occurred within a coverage hole cannot be sensed nor detected.

## III. COVERAGE AND CONNECTIVITY MANAGEMENT

Due to the large variety of application requirements and physical parameters of sensor nodes, the problems involving coverage and connectivity are highly diverse. Taking coverage as an example, according to the different application objectives, coverage can be classified into point coverage, barrier coverage, and area coverage [15]. Each of the classification can be further sub classified. Furthermore, each of the problem can be tackled from different angles according to assumptions like whether a centralized or distributed algorithm is required, the sensing and communication model used, and the availability and accuracy of localization. It is generally difficult, if not impossible, to construct a single framework that solves all problems. This thesis focuses on the problem of area coverage and connectivity management, which is defined as the activities, methods and procedures to monitor and control the network sensing coverage (area coverage) and connectivity. It involves the functions of coverage and connectivity planning, monitoring and maintenance according to user needs. Network management is by itself a broad topic. The network management functions are traditionally categorized into the well-known FCAPS (fault, configuration, accounting, performance and security) in ISO Tele communications Management Network model. However, this categorization is defined for broad-sense network management and does not directly apply when the focus is narrowed down to coverage and connectivity management.

In this work, the coverage and connectivity management functions are categorized into *microscale* management and *macroscale* management according to the geographical scale upon which the collaboration between sensor nodes takes place. The categorization of microscale and macroscale management is justified by the fact that coverage and connectivity problems can be investigated at both microscale level, where the focus is on the coverage and connectivity of individual components, and macro scale level, where the focus is on the coverage and connectivity over a large geographical scale.

For example, collecting each sensor node’s connectivity (neighbor table) information at the central controller belongs to the problem of microscale connectivity monitoring. While monitoring a large-scale topological hole belongs to the problem of macro scale connectivity monitoring.

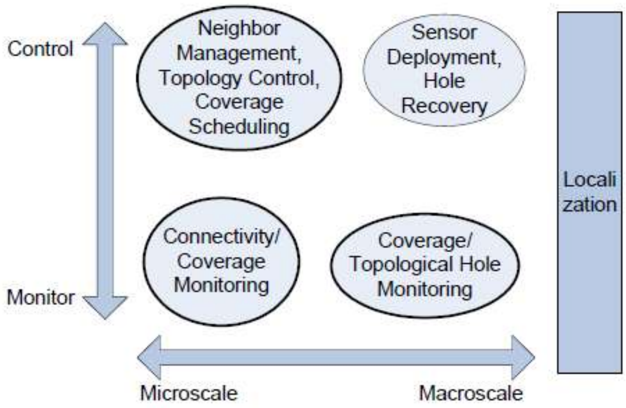

Fig 1. Coverage and connectivity management system.

## IV. METHODOLOGY

### *A. Implemented Architecture :*

we cover some background information and the technical preliminaries relevant to our subsequent discussions of sensor network coverage and optimization. We focus our discussions on location discovery algorithms and techniques, basic computational geometry constructs, distributed implementations and motivations behind them, the Set Cover Problem, and Integer Linear Programming optimization techniques.

### 4.1 Location Discovery Techniques and Algorithms

Geographical information is an integral attribute of any physical observation. Thus, the knowledge of node locations is fundamental in proper operations of a sensor network. The ad hoc nature of such networks necessitates that the nodes determine their locations through a location discovery process. The Global Positioning System (GPS) is one method that was designed and is controlled by the United States Department of Defense for this purpose that works well. The GPS system consists of at least 24 satellites in orbit around the earth, with at least 4 satellites viewable from any point, at a given time, on Earth. They each broadcast time-stamped messages at periodic intervals. Any device that can hear the messages from 4 or more satellites can estimate its distance from each satellite and thus perform trilateration to compute its position. Although GPS is an elegant solution to the location discovery process, it has several limitations that hinder its use in wireless sensor network applications. First, GPS is costly both in terms of hardware and power requirements. Second, GPS requires line-of-sight between the receiver and the satellites and thus does not work well when obstructions such as buildings, trees, and mountains block the direct “view” to the satellites. To address this, other techniques have been proposed to dynamically compute the locations of the nodes in a particular deployment. In several location discovery schemes, the received signal strength indicator (RSSI) of RF communication is used as a measure of distance between nodes. In other schemes, the time difference in arrival of RF and acoustic (ultrasound) signals are used to approximate node distances. Once nodes in a deployment have the ability to estimate distances between each other (ranging), they can then compute their locations using iterative multilateration methods [11]. In order for a multilateration to be successful, a node must have at least three neighbors who already know their locations. This requires that at least a subset of nodes determine their locations through other means such as by using GPS, manual programming, or deterministic deployment (manually placing nodes at specified coordinates). In [12] RSSI measurements are not used due to their imprecision.

There, when a reference node sends a message, a receiving node only concludes that the distance between the two nodes is shorter than the transmission range of the sender. The reference nodes are positioned in predefined locations. Under this framework, the position of a node is estimated as the centroid of all reference nodes that the node can hear from. Similarly, a number of recent papers in academia have considered the connectivity based location discovery problem that can be used in cases where GPS and iterative multilateration-based schemes fail. An alternative approach to distance estimation presented [11] is measuring the time difference of arrival (TDoA) between radio and ultrasound signals. Currently, this technique is limited by the short range of ultrasound (up to 3m as reported, and by the weaker capabilities of ultrasound in penetrating obstacles in the signal path. As in previous cases, reference nodes have their locations predefined or estimated using other methods. Using a multidimensional scaling technique to compute relative positions of sensors in a wireless sensor network, [13] proposes a distributed sensor positioning method to get the accurate position estimation and reduce error cumulation. The scheme is more suited to dealing with anisotropic topologies and complex terrains, as well as eliminating measurement error cumulation.

### 4.2 Computational Geometry: Voronoi Diagram and Delaunay Triangulation

Triangulation the Voronoi diagram has been reinvented, used, and studied in many domains. According to [14] it is believed that the Voronoi diagram is a fundamental construct defined by a discrete set of points. In 2D, the Voronoi diagram of a set of discrete sites (points) partitions the plane into a set of convex polygons such that all points inside a polygon are closest to only one site. This construction effectively produces polygons with edges that are equidistant from neighboring sites. Figure 3.1 shows an example of a Voronoi diagram for a set of randomly placed sites. Reference [14] presents a detailed survey of Voronoi diagrams and their applications

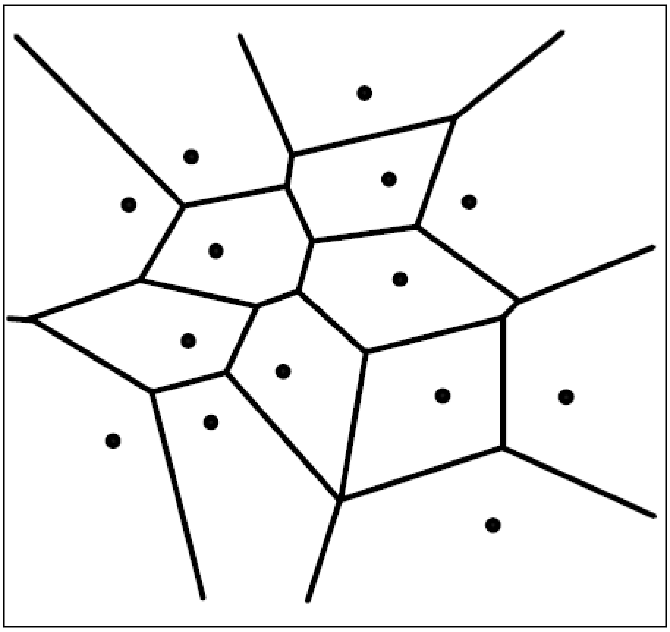

Fig 2. Voronoi diagram example.

Another structure that is directly related to Voronoi diagrams is the Delaunay triangulation [15]. The Delaunay triangulation can be obtained by connecting the sites in the Voronoi diagram whose polygons share a common edge. It has been shown that among all possible triangulations, the Delaunay triangulation maximizes the smallest angle in each triangle. In addition, a Delaunay triangulation must satisfy the empty circle property, which states that there is a circle containing the end points of a Delaunay edge and no other points (edges). Neighborhood information can be extracted from the Delaunay triangulation since sites that are close together are connected. In fact the Delaunay triangulation can be used to find the two closest sites by considering the shortest edge in the triangulation.

We use the properties of the Voronoi diagram and Delaunay triangulation to solve for best- and worst-case coverage. In chapter 4, we will show how the Voronoi diagram and the Delaunay triangulation serve as the underlying structures to limit our search space for agent "paths" in a sensor field. The lines at the boundaries of the Voronoi diagram extend to infinity. However, since here we are dealing with a finite area, we must clip the Voronoi diagram to the boundaries of the field. Since traveling along the bounds of the sensor field also constitutes a valid path, we introduce extra edges in the Voronoi diagram corresponding to the bounds. In subsequent discussions, when we refer to the Voronoi diagram, we are actually referring to the bounded diagram.

### 4.3 The Set Cover Problem

There are three popular classes of combinatorial optimization problems that are known as set-covering, set-packing, and set-partitioning. Suppose $M = \{1, 2, ..., m\}$ is a finite set and $\{Mj\}$, where $j \in \{1, .., n\}$, is a given collection of subsets of $M$. We say that set of subsets $F$ covers $M$ if $\cup_j Mj \in F = M$. The other relevant combinatorial problem is the packing problem, where the $Mj \cup Mk = \emptyset$f or all $j$ and $k$ ($j \neq k$).If $F$ is both covering and packing, then $F$ is said to be a partition of $M$. In the set covering problem, $cj$ is the cost of $Mj$ and we seek a minimum cost cover. In the set packing problem however, $cj$ is the weight or value of $Mj$ and we seek a maximum weight packing. An excellent reference on the set cover problems and their numerous applications is [17]. For more details on the set covering problem, please refer to [18].

### 4.4 Integer Linear Programming

Linear programming is an efficient method for minimizing a linear form under linear inequality constraints [17]. Since its invention [19], it has found a large number of applications in many areas [20]. Integer linear programming (ILP) is linear programming where additional constraints are imposed on the objective function that all solution variables be integers. While any linear programming instance can be solved in polynomial time, solving ILP is NP-hard. Nevertheless, numerous effective techniques have been developed that solve fairly large instances in reasonably short run times. In particular, when problems have special structures such as set cover problems, the run-times can be drastically shortened. Unless otherwise specified, we use the public domain LP SOLVE solver for our experimentations.

### 4.5 Coverage-Preserving Node Scheduling

Low-cost sensor devices are failure-prone. In typical sensor networks, these devices are deployed in higher than necessary densities to meet various design specifications. In order to conserve energy and prolong network lifetime, at any time instant, only a portion of these sensors are required to be active while others operate in "sleep" or inactive mode. However, if too many nodes are turned off, coverage holes can be formed and the network can be disconnected. In this chapter, the problem of node scheduling for energy saving and meanwhile the network coverage is still preserved is investigated. A Configurable Coverage Protocol (CCP) is proposed. CCP makes uses of the distance between two nodes rather than their actual locations. Distance information among nodes is easier to obtain than accurate global location information. In addition, CCP allows the trade-off between coverage and node usage (i.e., the number of active nodes). It can be configured to cover at least a portion of the area with high probability. For complete coverage ($a = 1$), CCP is comparable to OGDC [10] in terms of coverage and number of active nodes required. Simulation shows that for 90% coverage, 22% node savings can be achieved. E.g., for the node density of 10, about 400 active nodes can support 90% coverage while about 530 active nodes are required to

### 4.5 System model

The sensor nodes are assumed to be deployed in high density over the whole area of interest, such that the network is completely connected and the area is fully covered. The sensing model is the binary disk model, i.e., each node has a sensing radius *Rs* and all points located within *Rs* of a sensor node are considered to be covered by the node. Each node maintains the distance information to its direct neighbors, it will also work with any other distance estimation schemes or absolute co-ordinate localization schemes as long as the error is constrained to be within a small portion of the sensing radius *Rs*. We do not assume any communication pattern in the chapter

### 4.6 Effects of Localization Errors on Covera

In most WSN coverage protocols, knowing the exact location of each sensor node is essential to determine how well the whole network is covered. However, accurate and low cost localization is still a big research challenge as discussed in Section 1. In fact, the accuracy of the localization scheme used is often determined by application requirements. Accurate location information normally requires extra computation, storage, communication and even hardware cost. In this section, we study the impact of localization errors on optimal coverage protocols, taking OGDC [107] as an example. The model of localization error may vary depending on different localization algorithms and sensor operating environments. To keep the study simple, we define a simple circular uncertainty model: the location obtained by a localization algorithm is uniformly distributed in a circular region centered around the actual location of the node. The radius of the circular region is *R*max, which is also the maximum possible localization error. Most coverage algorithms try to build a coverage set distributively such that minimum number of sensors are used to cover the entire region of interest.

### 4.7 Overview of Configurable Coverage Protocol (CCP)

we present the configurable coverage protocol (CCP), which only makes use of the distance information among the neighboring nodes. CCP allows the users to specify the coverage objective a, in which at least a portion of the network is covered. In order to ensure that the coverage objective will be met, a way to compute or estimate the vacancy of the network in a distributed manner (with only distance information) is needed. The approach used in CCP is shown in Figure 3.7. Given a set of active nodes, the area is divided into non-overlapping triangles (without considering boundary effects), and the vertices of these triangles are the active nodes. The vacancy is estimated within each of the triangle. For a large WSN, by ensuring that coverage objective is met locally (in each triangle), the global coverage which is computed as 1−å*Vj*/å*Tj* will be satisfied too, where *Vj* is the vacancy in triangle *j* and *Tj* is the area of the triangle.

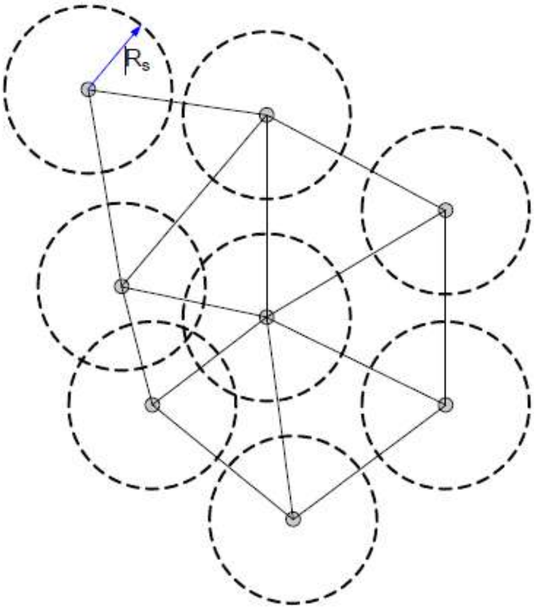

Figure 3: Illustration of coverage and vacancy estimation.

The basic idea of CCP is to sequentially select an additional node to be active such that the ratio of the size of the vacancy (*Vj*) inside the newly formed triangle to the area of the triangle (*Tj*) should be less than or equal to 1−a. In CCP, each node distributively elects itself based on the existing edges/triangles that have already been formed and the vacancy values of possible new triangles if it is active. Each node will start a timer based on the vacancy value of the new triangle formed by itself and existing edges, and once a node decides to be active, it will broadcast power on information first and other nodes will implicitly cancel their timers.

### 4.8 Vacancy inside Triangle

While the vacancy may be easily identified graphically or visually, computing the exact values of *Vj* using only distance information among nodes is more complicated. Before we formally describe CCP, it is essential to have a look at how the vacancies inside the triangles can be calculated. Given the distances between each pair of the sensor nodes are *d*1, *d*2 and *d*3, the area of the triangle is,

$$T(d1, d2, d3) = \frac{\sqrt{s(s-d1)(s-d2)(s-d3), c}}{1}$$

where $s = 1/2(d1 + d2 + d3)$. The common coverage between any pair of the nodes with distance *d*, where $d < 2Rs$, is given by

$$f(d) = 2R_s^2 \arccos\left(\frac{d}{2R_s}\right) - \frac{d}{2}\sqrt{4R_s^2 - d^2}.$$

The vacancy *V* of the several cases shown in Figure 3.3 can be calculated easily. The circle in the figures represent the sensing radius. The percentage of vacancy inside the triangle can then be evaluated by *V*/*T*.

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### 4.9 Selection of Starting Node

At the initial selection phase, all nodes are in the “UNDECIDED” state. A node should volunteer to be the starting node with probability *p*. The value of *p* should be a small value such that it is not likely to have many volunteer starting nodes in each round of selection. When a node decides to be a starting node, it first waits for a random time *ts* uniformly distributed within [0, *tsmax*]. *tsmax* can be any reasonably large values, for example, 20 times the maximum transmission time. This waiting time is used to reduce the probability of having multiple starting nodes but is not crucial for the correctness of CCP. If the node does not hear any messages from neighboring nodes within *ts*, it will change its state to “ON” and broadcast the power on message. If it receives any power on messages from neighbor nodes, it will simply cancel the timer.

### 4.10 First Edge and First Triangle Formation

After the first starting node broadcasts the power on message, all neighbors around the starting node will set a timer *t*1. If the timer fires, the node will change its state to ”ON”. The value of *t*1 is based on the distance to the starting node *d*. When a node turns ”ON”, it broadcasts power on message together with the edge information. The edge information includes the local unique id of the two end nodes a well as the length of the edge. Upon receiving the edge information, the neighboring nodes will set a timer *t*2. If the timer fires, the node turns ”ON” and form the first triangle. The value of *t*2 depends on the vacancy as well as the angles inside the triangle it forms. The node will broadcast the power on message together with the triangle information. The information includes the id of the three vertices and the length of the three edges. This message also has information about the new edges generated by this triangle (there are normally two new edges). All nodes will save the triangles formed associated with itself (i.e. if a node is a vertex of the triangle, it will save this triangle information). All nodes that hear the triangle information and locate at the same side with the broadcasting node will cancel their timers.

### 4.11 Node Selection Process

Upon receiving the triangle and new edge message, only those nodes that are located at different sides of the new edge with the triangle will perform actions. Each node will first examine whether it has any triangle associated with itself and share a common vertex with the new edge. If there is, it will then look at the edge connecting itself and the common vertex, to see whether the edge has two triangles associated with it. The node will take no action if there are already two triangles associated with this edge. If there is only one triangle associated with the edge, and it satisfies the vacancy requirement, it will announce the creation of a new triangle with only one new edge immediately. This approach always tries to close the region around the common node first. Otherwise, all other nodes set timer *t*2 based on the vacancy and angles to the new edges. The node that fires first turns itself ”ON” and announce the existence of a new triangle with two new edges. All nodes that hear the new triangle information will cancel their timer *t*2. Based on the triangle information broadcast neighbors, when a node notices that it is within one of the triangles formed, it turns itself ”OFF”. The protocol terminates when all nodes are either in the ”ON” or ”OFF” states

## V.RESULAT ANALYSIS

| Area ($m^2$) | Nodes | Points | Sensing Radius (m) | Coverage & Connectivity (%) | | Energy left (J) | |
|---|---|---|---|---|---|---|---|
| | | | | Without Algorithm | With Algorithm | Without Algorithm | With Algorithm |
| 300 | 30 | 1 | 1 | 93 | 98 | 15366 | 16192 |
| 300 | 30 | 2 | 2 | 96 | 98 | 11813 | 12060 |
| 500 | 30 | 3 | 5 | 93 | 97 | 14664 | 15295 |
| 500 | 30 | 4 | 3 | 93 | 98 | 13780 | 14521 |

Table1: Area v/s Coverage & Connectivity Table

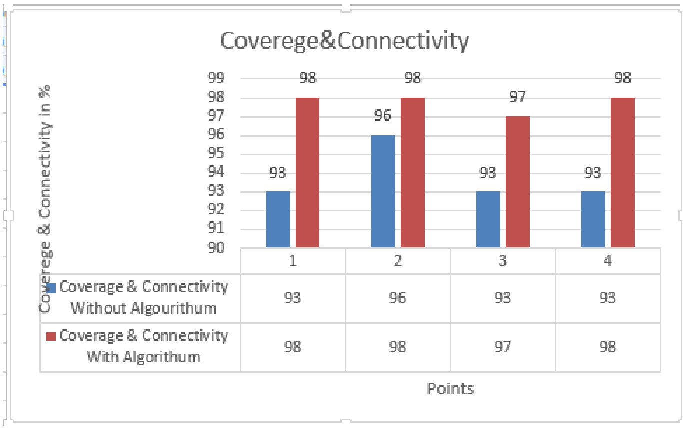

Figure 5.1 Graph of Coverage and Connectivity

Figure 5.1 represent graph of coverage and connectivity of nodes. From figure it is concluded that coverage of nodes is improved by applying proposed algorithm. Results show that connectivity between nodes is much better after applying algorithm as compared to method without algorithm.

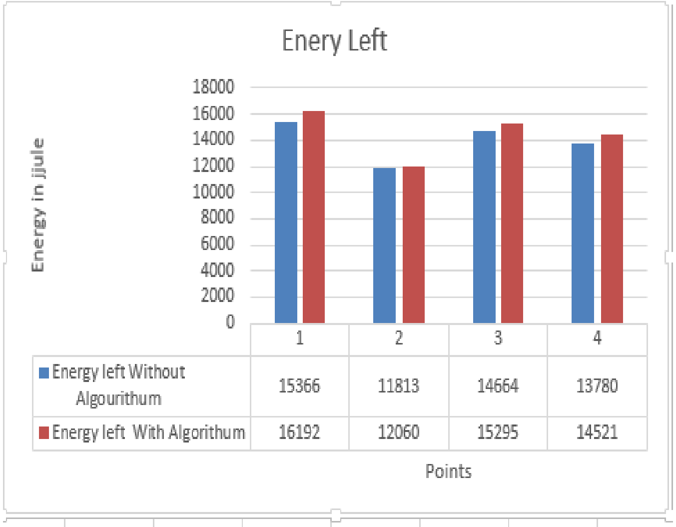

Figure 5.2 Graph of Energy Left

Figure 5.2 represent graph of Energy Left of nodes. From figure it is concluded that Energy of nodes is improved by applying proposed algorithm. Results show that Energy Left of nodes is much better after applying algorithm as compared to method without algorithm.

## VI. CONCLUSIONS

This paper addresses the issues of coverage, connectivity and energy-efficiency in wireless sensor networks. An efficient method to prolong the network lifetime is to devise appropriate activation schedules for the sensor nodes in the network. One of the approaches is to decompose the complete set of sensors into mutually exclusive sets such that each set can independently ensure coverage and connectivity in the network. Each of these sets can be activated in succession or rounds. Only one set of sensors is active during a particular round while the other sensors are put to sleep state to conserve battery energy. The coverage modeling that have either extended the techniques discussed here, or focused on other aspects of the problem when integrated in the sensing system. Among these approaches, we note the treatment of sensor coverage and connectivity as a natural candidate for joint optimization since the two are tightly coupled as system design constraints. While minimizing active sensors subject to coverage constraints can drastically reduce energy consumption, it can adversely impact communication and connectivity in the network. Current trends and technologies however indicate that communication ranges are much greater than sensing “ranges” even for very low power technologies. At the same time, sensor data prediction and approximate query processing have been shown to hold tremendous potentials in extending the resource savings of such systems, by providing a means of more judiciously allocating resources to sensing, storage, processing, and communication. This in turn has opened up the door for a wide array of future research efforts in investigating superior prediction models, better understanding the relative costs of sensing, processing, and communication with respect to the accuracy and confidence levels of reported results, as well as the impacts on system lifetime.

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