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A Study on Efficient Methods Used to Enhance Coverage in Wireless Sensor Networks

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Abstract: **Wireless sensor networks are a rapidly growing area for research and commercial development. The sensor coverage problem is prime factor being considered in recent advances. The coverage concept is subject to a wide range of interpretations due to a variety of sensors and their applications. Different coverage formulations have been proposed in this paper. The Voronoi diagram for a sensor network is a diagram of boundaries around each sensor such that every point within a sensor's boundary is closer to that sensor than any other sensor in the network. The complete co operative (CC) algorithm is distributed in the sense that each sensor computes its own Voronoi cell. The task of computing a Voronoi cell can be split into two main parts: finding the Voronoi neighbors of the sensor and solving the geometric intersections of bisectors .The above two methods are focused on networks with identical nodes. In this paper, we also focus on sensor networks with the effects of heterogeneity of sensing and transmission ranges on the network coverage and broadcast reach ability. The heterogeneous nodes coverage problem is efficiently minimize by using is by using SEP (Stable Election Protocol). In this paper, we propose representative survey to improve coverage in homogeneous and heterogeneous nodes.**

Keywords**: — sensor coverage, Voronoi diagram (VD), complete co operative (CC) algorithm, Heterogeneity, SEP (Stable Election Protocol**).

I. INTRODUCTION

Recent advances in hardware miniaturization, communication technologies, and low-cost mass production have facilitated the emergence of wireless sensor networks (WSNs) that consist of small, inexpensive, battery-powered, and wirelessly connected sensors. The WSNs have brought up various new applications, including surveillance, home security, and environmental monitoring [1,2,3,4]. WSN sensors are deployed randomly or systematically to collect information about their surroundings within their sensing range. They can transmit the collected information via wireless communication; some can even process the data before transmission. Despite their widely varying characteristics, all sensors essentially collect, transmit, and relay information randomly or systematically to collect information about their surroundings within their sensing range randomly or systematically to collect information about their surroundings within their sensing range. They can transmit the collected information via wireless communication; some can even process the data before transmission. Despite their widely varying characteristics, all sensors essentially collect, transmit, and relay information randomly or systematically to collect information about their surroundings within their sensing range. A promising WSN application is long-term surveillance in hostile or distant environments. Using WSNs for military surveillance, for example, involves deploying numerous sensors throughout the region of interest by aircraft to detect enemy activity or equipment. However, a key consideration in the design of WSNs is the power supply since replacing batteries in sensors is often impractical. Although a considerable number of studies have addressed energy efficiency issues in generic wireless ad hoc networks, distributed sensing applications impose new constraints on sensor network coverage [5].Although a considerable number of studies have addressed energy efficiency issues in generic wireless ad hoc networks, distributed sensing applications impose new constraints on sensor network coverage [5]. For instance, surveillance applications may require at least one sensor in each location in a geographic region of interest [6], while object tracking applications may require at least three sensors [7]. Data sampling of a given percentage of monitored regions. In addition to sensing coverage, network connectivity is another important property of WSNs. Connectivity enables sensor nodes to relay collected information back to data sinks. Zhang and Hou [8] proved that if the communication range is at least twice the sensing range, then full coverage of a convex area implies connectivity of the WSN. Hence, the constraints of full coverage and connectivity can be reduced to the full coverage constraint alone. This study adopts this result and therefore considers the full coverage constraint..

The objective of this paper is:

- Survey different Methods for increasing the coverage and connectivity of wireless sensor networks.
- Survey different methods for increasing the coverage and connectivity of the wireless sensor networks with non identical nodes (heterogeneous node)

II. Issues in Wireless Sensor Network Coverage.

There are several factors that must be considered when developing a plan for coverage in a sensor networks. Many of these will be dependent upon the particular application that is being addressed. The capabilities of the sensor nodes that are being used must also be considered. Most researchers focus on a single deployment model but there are papers that attempt to

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develop a more general algorithm that can be used in many types of deployment.

A. Coverage Types

The first step in deploying a wireless sensor network is determining what it is exactly that you are attempting to monitor. Typically you would monitor an entire area, watch a set of targets, or look for a breach among a barrier. Coverage of an entire area otherwise known as full or blanket coverage means that every single point within the field of interest is within the sensing range of at least one sensor node. Ideally you would like to deploy the minimum number of sensor nodes within a field in order to achieve blanket coverage. This problem was addressed in [9] where the author proposes placing the nodes in a construct called an r-strip such that each sensor is located distance away from the neighboring sensor where r is the radius of the sensing area. The strips can be then placed in an overlapping formation such that blanket coverage is achieved. The biggest problem with this solution is that it is impractical to try to deploy sensors in such a formation. Target coverage refers to observing a fixed number of targets. This type of coverage has obvious military applications such as those covered in [10]. The authors in this paper did extensive tests to not only detect targets, but to classify and track them. The authors in [11], [12], [13], [14], and [15] attempt to maintain target coverage while conserving energy. The authors in discuss both Blanket and target coverage in terms of energy efficiency. Barrier coverage refers to the detection of movement across a barrier of sensors. This problem was defined as the maximal breach path in [16]. The authors in this study quantify the improvement in coverage when additional sensors are added to a network. A variation of barrier coverage known as sweep coverage is also discussed in [16] .Sweep coverage can be thought of as a moving barrier problem

A. Node Types

The set of nodes that are selected for a sensor network can be either a homogeneous or Heterogeneous group of nodes. A homogeneous group is a group in which all of the nodes have the same capabilities. A heterogeneous group is one in which some nodes are more powerful than other nodes. Usually you would have a smaller group of more powerful nodes known as cluster heads which would gather data from the less powerful nodes. Examples of homogeneous and heterogeneous nodes are given in figures 1 and 2. A homogeneous set of nodes is required for the algorithms in [9] and [22]. Each of these solutions requires the nodes to be placed at a precise distance in relation to each other that is dependent on the sensing ranges of every node being identical. The authors in [21] assume homogeneous sensors but repeat their experiments with different uniform sensing ranges in order to prove the efficacy of their algorithm. Any algorithm that will work for a heterogeneous network will also work with a homogeneous network. Several papers attempt to prove their theories first with a homogeneous deployment then show that the findings will hold up for a heterogeneous deployment. In [23] the authors design a rectangular based coverage model using homogeneous sensors to monitor a barrier. The authors do this by assuming a maximum and minimum sensing range and substituting these values into the theorem that was previously proven for homogeneous networks. The authors in [24] build an energy efficient network by using homogeneous sensors. This is then extended for heterogeneous networks. They do this by using a weighted Voronoi diagram.

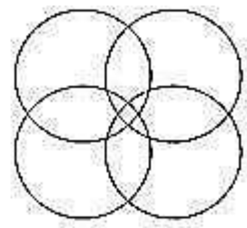


Fig1: homogeneous sensors

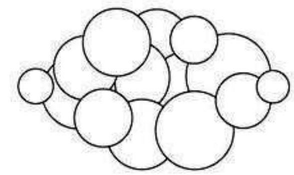


Fig2: heterogeneous sensors

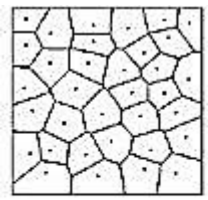
III. Methods to improve coverage for identical nodes

A. voronoi diagram and Delaunay triangulation

The Voronoi diagram has been used a model in several coverage algorithms. The Voronoi diagram for a sensor network is a diagram of boundaries around each sensor such that every point within a sensor's boundary is closer to that sensor than any other sensor in the network. A formal definition of the Voronoi diagram is given in [25]:

Let P = {p1, p2,...,pn } be a set of points in a plane A Voronoi region V (pi) is the set of points that are as close to pi as any other point:$V(pi) = \{x: |pi - x| \leq |pj - x| \text{ for all } j \neq i\}$

An example Voronoi diagram is shown in figure 3. So and ye present algorithms using generalized Voronoi diagrams to solve two coverage problems in [30]. The first problem is to determine whether a specified level of k-coverage exists in the field of interest. The second problem is to determine the highest level of k-coverage provided by the sensor nodes. They produce an algorithm for the first problem that is proven to run in O (n log n + nk2) time. They then extend the solution to work with heterogeneous nodes for an area requiring coverage of k = 1. Finally the authors provide a solution for the second problem that will run in O (n3) time for two dimensional spaces and O (n4) time for three dimensional spaces. The only drawback to the authors' solutions is that they are centralized so they may not scale well for larger networks. In [26] the authors utilize Voronoi diagrams as part of a fuzzy logic systems used to control the movement of sensors from a random deployment. A fuzzy logic system is one which is designed to take continuous or analog input values and output a discrete or digital value. The input value is analyzed against a set of rules by an inference engine. The engine uses these rules to compute the output. The Voronoi diagram is used to help calculate an ST-FACTOR for the node. The ST FACTOR is used by the inference engine to determine if the node should move itself. The authors experiments show that the algorithm will provide coverage of 93% or greater after three iterations. One shortcoming of this algorithm is that a node must be able to communicate with other nodes in order to be able to move. If a node on the outer edge of the coverage area had only one neighbor and that neighbor died then the network would not move another node to re-establish communication with the outlying node. Another problem with the algorithm is that it does not provide k-coverage for k > 1. The lack of redundancy of the deployed network limits its usefulness in areas that are not easily redeployed. The movement of sensor nodes in random deployments is a problem that is also addressed by Wang, Cao, and La Porta in [20]. The authors use Voronoi diagrams to find gaps in coverage and propose three separate deployment protocols to control the sensor movement. The Vector-based algorithm (VEC) compels two sensors that are too close to each other to move away if there is a coverage hole in either one of their Voronoi polygons. The Voronoi-based algorithm (VOR) will pull a sensor towards a coverage gap. The movement is limited to one half of the communication range in order to avoid communication problems with the neighboring nodes. Finally the Minim ax algorithm works similar to VOR except that it further limits the maximum movement of a node. The idea behind this algorithm is to create a move even Voronoi diagram so that the area covered by each sensor is more uniform. The experiments show that Minim ax provides the best coverage with the fewest sensors while VEC performs the worst. Minimax does require the most sensor movement while VEC requires the least. The protocols all perform acceptably for the problem for which they were designed. However, these protocols suffer from the same shortcomings as the fuzzy logic system described previously.Carbunar, Grama, and Vitek utilize Voronoi diagrams as a means of detecting and eliminating redundancy while preserving coverage in [24]. The authors also tackle the problem of detecting the boundaries of coverage in a sensor network. The authors use what they call a Multiplicative.Weighted Voronoi Diagram (MWVD) in which the sites are assigned weights which are used instead of the Euclidean distance in determining how the closest site to a point. The addition of weights allows the Voronoi diagram to be used with heterogeneous sensor nodes. They define the redundant sensor elimination (RSE) solution which selects sensors to deactivate. The simulations run by the authors show that RSE detects all redundant sensors. To find the boundaries of coverage in a sensor network, the sensors whose Voronoi cell is not covered by its sensing range must be found. If there are points in the Voronoi cell not covered by the sensing range of a node that implies there are no other sensors that cover those points. Those points exist in a coverage hole and the sensors that border that coverage hole are boundary sensors. The results of the simulations show that RSE is able to detect all of the sensor boundary nodes in the network. The RSE protocol shows very promising results in the simulations but a true test would be having it implemented in an actual deployment. The Delaunay triangulation is closely related to the Voronoi diagram. A Delaunay triangulation is defined as a triangulation of an area such no points in any triangle are located within the circumscribed circle of any other triangle in the area. A Delaunay triangulation can be built from a Voronoi diagram simply by drawing edges that connect the sensors which border one another. An example of a Delaunay triangulation is given in Figure 4. The Delaunay triangulation can be used to determine which two sites are closest to each other by finding the shortest edge in the triangle. The Delaunay triangulation is used by the authors in [16] in order to find the maximal support path. Neither the Voronoi diagram nor the Delaunay triangulation can be constructed with localized algorithms. Distributed algorithms for their construction have been found to be inefficient.



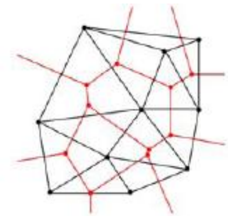


Fig3: voronoi diagram Fig 4: Delaunary triangulation

The authors employ the Voronoi diagram to determine the worst case or maximal breach path. Since the Voronoi diagram maximizes the distance between the sensors the maximal breach path must lie upon its segments.

B. The complete Voronoi diagram.

Waleed Alsalih,et,al[27] focus on the complete voronoi diagram to overcome the drawbacks of voronoi diagram.In practice, the ratio between the transmission and sensing ranges may not apply. Thus, algorithms that compute the complete VD in a more general scenario are needed. We propose a new algorithm for distributed computing the VD, namely the completely cooperative (CC) algorithm. The CC algorithm is distributed in the sense that each sensor computes its own Voronoi cell. The task of computing a Voronoi cell can be split into two main parts: finding the Voronoi neighbors of the sensor, and solving the geometric intersections of bisectors (between the sensor and its neighbors). Even when these two parts are handled simultaneously, we will focus on the discovery of the neighbors since the intersection of geometric primitives do not impose any new challenge. The basic idea behind the CC algorithm is that sensors do not need to send out queries to the network in order to discover their Voronoi neighbors; instead, sensors are informed about possible Voronoi neighbours by other neighbours. In order to explain the details of the algorithm, we adopt the following terminology. Let S be a set of sensors embedded in the plane and let G = (S, L) be the connected unit graph induced by S, where L _ S×S contains pairs of sensors that can directly communicate with each other. Let also V D(G) be the VD of G. We refer to elements of L as a link, saving the term edge for the corresponding element in the VD. Similarly, we refer to sensors that share a link as adjacent and to sensors that share a Voronoi edge as neighbours. We informally describe how the CC algorithm works before giving a more formal description.Let s be a sensor that receives a message about a new candidate for (Voronoi) neighbor (t) at some point during the computation. Then s proceeds to compute the intersection of the corresponding half plane, as defined by the bisector between itself and t, with its current cell C. We call this step the refinement of a cell. If the new cell C0 resulting from the intersection is equal to C, t is discarded. Two adjacent vertices that fall outside of C0, define a piece of bisector for a sensor t2 that is then discarded. A new vertex v on C0 is created by the intersection of the bisector between s and t, and the bisector between a certain sensor t1 and s. Therefore, t and t1 may be neighbors of each other since they have a common Voronoi vertex according to s cell. Consequently, s proceeds to inform both t and t1 about each other. This way, the information about possible neighbours flows towards the corresponding sensors until every pair of neighbours finds each other. See Theorem 3.2 for the correctness of this approach. A pseudo code description of the CC algorithm is given below

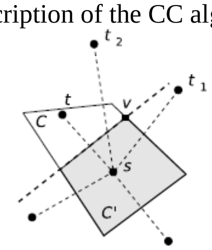


Fig-5 : Successive approximations (C and C0) to the Voronoi cell of s. Thin dashed lines represent links. The bisector b(s, t) between nodes s and t is represented with a thick dashed line. Vertex v appears on C0 and indicates that s and t are neighbours and also that s should notify t and t1 about each other. t2 is no longer a neighbour of s.

intially, the cell of any sensor s is equal to the entire plane. Then all sensors broadcast their locations triggering the entire computation as explained above. The following describes the most important terminology used in Algorithm 2. Let s be a sensor with location s.loc, a field s.cell that stores the description of its Voronoi cell, and a message queues.q used for the computation. Let also s be equipped with methods s.refine(t.loc) that carries out the refinements and s.send message(t1.loc, t2.loc) that sends a message to sensor t1 containing the location of t2. This results in t2.loc being added to the message queue of t1 (i.e. t1.q). Notice that a cell may be bounded or unbounded and may or may not contain vertices. If s.cell contains vertices these can be accessed through s.cell.verts. A vertex v of a Voronoi cell is defined as a point in the plane equipped with a method v.third(s.loc, t.loc) that returns the location of the third sensor associated to v that is neither s nor t.

Algorithm: Completely Cooperative (CC): Computes the Voronoi cell of each sensor.

```
// Initialize the cell
s.cell = ENTIRE_SPACE
// Broadcast the sensor location to all adjacent sensors
s.send_message (BROADCAST, s.loc)
// Process each (sensor) message in the queue
While (t.loc = s.q.get_message)
old_Cell = s.cell
s.cell = s.cell.refine (t.loc)
For each (v in s.cell.verts and not in old_Cell.verts)
// Notify each pair of possible neighbours about each other
s.send_message (t.loc, v.third_sensor ( s.loc, t.loc ) )
s.send_message ( v.third_sensor ( s.loc, t.loc ), t.loc )
End
End
```

The CC algorithm has been described in its simplest form. Some optimizations like, before the initial refinements, every sensor s broadcasts (to all adjacent sensors) its adjacency list (only the list of locations or identifiers of adjacent sensors is needed)and in not sending two messages simultaneously to possible neighbours s and t while trying to inform them about each other. Instead, a message is first sent to s and then it is s that informs t, if required. This also reduces the number of messages since s and t may already be neighbors by the time s receives the notification and, consequently, there is no need to inform t at this point. The above optimizations can be introduced to make cc algorithm more efficient.

TABLE.1. Comparison of Vernon diagram to cc algorithm

Sl no	Description	Vernoi diagram	complete vernoi algorithms (cc algoritms)
1	Working principle	Voronoi diagram of a set of sensors is a meaningful way of partitioning the plane such that each sensor is assigned the set of points that are closer to itself than to any other sensor	The CC algorithm is distributed in the sense that each sensor computes its own Voronoi cell. The task of computing a Voronoi cell can be split into two main parts: finding the Voronoi neighbours of the sensor, and solving the geometric intersections of bisectors (between the sensor and its Neighbours). Even when these two parts are handled simultaneously.
2	Discovering the neighbours	In vernoi diagram sensors are need to send queries to the network in order to discover their Voronoi neighbours	In CC algorithm sensors do not need to send out queries to the network in order to discover their Voronoi neighbours;instead,sensors are informed about possible Voronoi neighbours by other neighbours
3	Placing of sensors	A Voronoi diagram divides a plane that includes a number of sensors into polygons such that each polygon contains exactly one sensor and every point inside the polygon is closer to the contained sensor than to any other sensor.	In CC algorithm computes the VD of a set of sensors in a distributed way, in the sense that each sensor computes its own Voronoi cell.
4	Computation process	The computation of the complete VD provides other useful structures such as the Delaunay triangulation and the convex hull.	The CC algorithm off ers the computation of the VD for the entire plane, a smaller number of message transmissions, and independence from the underlying routing mechanisms. CC algorithms' are more efficient
5	Reducing the message Transmission	Sending the message to neighbours sequentially. This wiil increases transmission time of messages	sending two messages simultaneously to possible Neighbours, while t to inform them about each other. This will reduces the number of messages and also transmission time of messages

IV. Methods to improve coverage for non identical nodes

A. Heterogeneous Networks

Yun Wang, et.al [28]focuses on heterogeneous nodes. The most existing research efforts in the area of wireless sensor networks have focused on networks with identical nodes, deploying sensors with different capabilities has become a feasible choice. In this paper, we focus on sensor networks with two types of nodes that differ in their capabilities, and discuss the effects of heterogeneity of sensing and transmission ranges on the network coverage and broadcast reach ability. Our work characterizes how the introduction of a few sensor nodes with better capabilities can reduce the number of total required sensors without sacrificing the coverage and the broadcast reach ability.

B. Method to Improve coverage in Heterogeneous Nodes.

Georgios Smaragdakis et.al,[29] focuses on improve coverage in Heterogeneous Nodes by using SEP(Stable Election Protocol)which improves the stable region of the clustering hierarchy process using the characteristic parameters of heterogeneity, namely the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (α).In order to prolong the stable region, SEP attempts to maintain the constraint of well balanced energy consumption. Intuitively, advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption. Let us assume the case where a percentage of the population of sensor nodes is equipped with more energy resources than the rest of the nodes. Let m be the fraction of the total number of nodes n, which are equipped with α times more energy than the others. We refer to these powerful nodes as advanced nodes, and the rest (1−m)× n as normal nodes. We assume that all nodes are distributed uniformly over the sensor field.

C. SEP Deployment

The heterogeneity in the energy of nodes could result from normal network operation. For Example, nodes could, over time, expend different amounts of energy due to the radio communication characteristics, random events such as short-term link failures or morphological characteristics of the field (e.g. uneven terrain).To deal with such heterogeneity, our SEP protocol could be riggered when ever a certain energy threshold is exceeded at one or more nodes. Non-cluster heads could periodically attach their remaining energy to the messages they send during the handshaking process with their cluster heads, and the cluster heads could send this information to the sink. The sink can check the heterogeneity in the field by examining whether one or a certain number of nodes reach this energy threshold. Our approach is to assign a weight to the optimal probability kopt. This weight must be equal to the initial energy of each node divided by the initial energy of the normal node. Let us define as knrm the weighted election probability for normal nodes as in equation 1, and kadv the weighted election probability for the advanced nodes as in equation 2. Virtually there are n× (1+α ·m) nodes with energy equal to the initial energy of a normal node. In order to maintain the minimum energy consumption in each round within an epoch, the average number of cluster heads per round per epoch must be constant and equal to n×kopt. In the heterogeneous scenario the average number of cluster heads per round per epoch is equal to n·(1+α·m)× kpnrm (because each virtual node has the initial energy of a normal node). The weighted probabilities for normal and advanced nodes are, respectively:

$$knrm = \frac{kopt}{1+\alpha.m} \quad - (1)$$

$$kadv = \frac{kopt}{1+\alpha.m} X (1+\alpha) \quad - (2)$$

The sink could broadcast to cluster heads in that round the values for Pnrm and P adv, in turn cluster heads uni-cast these values to nodes in their clusters according to the energy each one has attached earlier during the handshaking process .If some of the nodes already in use have not been programmed with this capability, a reliable transport protocol, such as the one proposed in [30], could be used to program such sensors. Evaluating the overhead of such SEP deployment is a subject of our ongoing work

V. CONCLUSION

This paper focuses on different methods used to overcome the problem of coverage in homogenous and heterogeneous nodes in wireless sensor networks. We believe that the analytical characterization of WSN is important since it provides real insights on the design of WSN. Probabilistic analysis on the effects of heterogeneity on coverage and reach ability has been presented in this paper. It substantiates our intuition that the introduction of nodes with better capability, namely longer sensing range and transmission range, can dramatically increase the network coverage and broadcast reach ability, though the effects on connectivity are only modest. This work can also provide useful guide on choosing the optimal number of different types of nodes, as well as sensing and transmission ranges of large-scale heterogeneous WSN design. We proposed SEP (Stable Election Protocol) so every sensor node in a heterogeneous two-level hierarchical network independently elects itself as a cluster head based on its initial energy relative to that of other nodes. Finally SEP is scalable as it does not require any knowledge of the exact position of each node in the field. We propose efficient methods to enhance the coverage in homogeneous and heterogeneous nodes used in wireless sensor networks.

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