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Research Article

COVERAGE IMPROVEMENT AND PATH SELECTION IN WSN

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ABSTRACT

In the heterogeneous network, energy exhausted sensor nodes may uncover some parts of the sensing field, resulting in the coverage hole. The substitution of energy exhausted sensors is complex and has a greater effect on coverage and path from source to sink node. Therefore, in order to provide the required coverage and path, Candidate Generation Algorithm is proposed using mobility management of sensors. A sensor with low energy sends a message requesting other sensors in the network to replace it before it gets energy exhausted entirely. The sensor of Null polygon goes to energy exhausted node in order to heal coverage hole. This is based on VorLag algorithm and considers Null Polygon sensors, along with sensors of Empty Polygon, to ensure maximum coverage over the network. Candidate Generation algorithm detects and repairs the coverage hole quickly and ensures continuous monitoring. Path is selected based on hop count and path length. Simulated results show that the work proposed gives greater coverage profit with minimum sensor's movement.

INTRODUCTION

Technological advancements in the recent days' open new opportunities for wireless sensor networks. A study of WSN technology, its challenges and applications are discussed in [1]. Sensors in the mobile WSN move after the initial random deployment to increase coverage in an energy efficient way [2]. A coverage hole is the area that is not covered by existing nodes in the given sensing region. Mobile sensors are capable to re-organize themselves to heal the coverage holes. The detailed descriptions of coverage problem and sensor deployment are discussed in [3].

Failure of sensors is a common problem which has a major significance on coverage [4]. Overlapped coverage leading to the sensor failure problem is discussed in [5]. A faulty sensor node replacement framework is designed with energy efficiency in [6].

The existing works on coverage use Voronoi diagram. This approach increases the energy by improving the performance of the network. A novel perception of Voronoi diagram is energy aware. The virtual position of neighbours is used by each sensor to calculate coverage locally [7].

In the sensor network, the coverage gap refers to the uncovered regions of the sensors in the monitoring field. In WSN, the unattended coverage gap results in missing of prominent features of the mobile target. The coverage gap in the sensor network may arise due to several reasons such as initial random deployment, energy depletion, damages or displacement caused by animals or any natural event. Developing a generalized approach that detects all kinds of node failures caused by coverage loss is still a challenging task. The number of sensors required to repair the coverage gap concerns the energy consumption that implicitly affects the overall network lifetime. A forced movement of mobile sensor towards the coverage gap is an energy-susceptible operation. Therefore, it is a serious issue to select the minimum number of coverage-hole repairing sensors to repair the coverage gap. Detection of the coverage gap in the centralized manner lacks scalability and also drains the energy of the centralized sensor sooner. There are many solutions for coverage control in the high density networks. Those solutions provide better coverage with considerable moving distance by the sensors. There is no appropriate solution to solve the problem of the coverage gap due to energy depleted sensors. The proposed work mainly focuses on the repairing of the coverage gap due to energy depleted sensors in the Target area. The proposed work attempts to provide better coverage with the minimum movement cost.

This paper presents Candidate Generation algorithm that maximizes network coverage. This algorithm repairs the coverage hole caused because of a node failure because of

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energy loss. This is derived from the existing VorLag approach. In VorLag approach, sensors move to ensure coverage in the target field. The introduction of Laguerre distance instead of the traditional Voronoi concept of the heterogeneous sensor network improves coverage. VorLag algorithm exploits the mobility of the sensors to provide coverage and solves sensor deployment issues effectively. The traditional Voronoi algorithm discusses the mobility of the sensors of Empty polygon. Voronoi algorithm does not allow Null polygon sensors to move. Candidate generation algorithm attempts to move the sensors in the Null Polygon along with the Empty polygon to heal the hole and ensure maximum coverage in the network. From the results, the suggested CGA improves the overall coverage and network lifetime.

The next section presents literature on coverage in WSN. Section 3 gives Voronoi algorithm which maximizes the coverage in the network region using less moving distance. The simulated results of the CGA algorithm are given in section 4. Work done in this paper is concluded in section 5.

RELATED WORKS

Sensor Coverage is the essential factor in wireless sensor applications. Sensors should ensure complete coverage in the network region. The coverage of the sensor depends mainly on sensor node failures and deployment pattern. Expected coverage may not be achieved with random deployment.

Coverage using Virtual Forces

Many works were done on self-organization of sensors to achieve either coverage or connectivity. The most preferred solutions are potential field [8-10] and virtual force algorithm (VFA) [11] concepts. This applies electro-magnetic forces among any sensor pairs. When the sensors are too close, a repulsive force is exerted among them and moved to farther distance. In the same way, when the sensors are distant, an attractive force is exerted among them and moves the sensors closer. Repulsive forces bring sensors from a dense to a sparse network, increasing the coverage and decreasing the sensing overlap. Enhanced VFA improves the coverage and minimizes consumption of energy [12]. CPVF (Connectivity Preserved Virtual Force) is a technique which maximizes the coverage and provides improved network lifetime [13].

Coverage using Voronoi Diagram

Voronoi diagram partitions the given region into various sub groups where sensors move for coverage maximization [14]. This partitions the region into polygons, where one sensor stays only in one polygon. Voronoi diagrams are efficient in certain scenarios only and practically Voronoi construction has several problems.

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In order to optimize drawbacks of solutions based on Voronoi diagram, bidding protocol has been recommended in [15] which balance cost and coverage. The required coverage is not guaranteed by moving the sensors. This is the other drawback of the existing system. In order to overcome this drawback, Voronoi diagram with a Laguerre distance parameter is used. This is called VorLag algorithm which locates sensors efficiently [16-17]. This enhancement of the Voronoi approach ensures the correct execution of algorithm and improves convergence time.

CANDIDATE GENERATION ALGORITHM

Network Model

The heterogeneous wireless sensor network contains sensors with the equal communication range and varied sensing range, given as CR and SRi respectively, with i=1,2,…..,n. Initially, the sensors are distributed randomly at interval, Ti = 0, in an area, A= S*S. Every sensor broadcasts its locations, identities, communication ranges and also its direct neighbours. The network is constructed with the assumption that, there exists a topology control protocol, resulting in a connected network and the connectivity degree of each node is not less than two. This paper considers the sensors with four different sensing ranges (heterogeneous). With these scenarios, sensor locations can be predicted by Poisson point techniques. Sensors are deployed in the open medium move passively with respect to the external forces.

Basic VorLag

The proposed VorLag approach is the extended work of Voronoi approach. Finding a coverage hole with the Voronoi approach is applied only on network with homogenous sensors. The Voronoi approach in the heterogeneous network gives an improper Voronoi polygon construction producing barrier effect [15]. The VorLag approach avoids drawbacks of the Voronoi approach in the heterogeneous WSN which uses the parameter called Laguerre geometry.

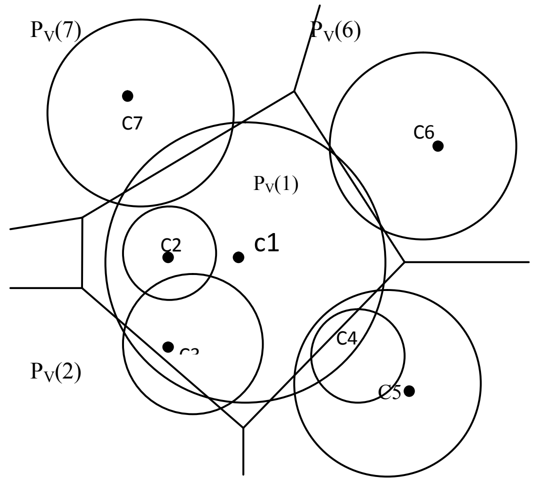

Figure 1 VorLag Diagram

Laguerre geometry constructs the polygons using radical axis. This partitions the target region properly into two planes using sensing radius and location of the sensors. Every sensor repeatedly constructs its VorLag diagram with the axis of its neighbours. VorLag polygon consists of the region that is almost fully covered with its sensor node than any other sensor. Every sensor compares its sensing region with its polygon region. The uncovered region is described as “coverage hole”. The additional distinguished characteristic of VorLag when compared with Voronoi is a creation of Empty Polygon and

Null polygon. Null polygon will not contain any point in its polygonal area and this arises when there exists more number of sensors in the area. Null polygon overlaps with the other sensors' area. Empty polygon consists of sensors placed in other polygons, and is not centered in its own polygon. A sensor belonging to the Empty Polygon moves to its own polygon to provide more coverage. On the contrary, sensor related to Null Polygon does not move to any location as its sensing area does not contain any point in the network area.

Candidate Genration Algorithm

The Candidate generation algorithm resolves the problem of the coverage hole caused by the energy exhausted sensors. Complete energy depletion of a sensor makes the node failure which leads to the coverage hole in the corresponding sensing field of the sensor. This algorithm calls VorLag diagram for detecting the coverage hole. Candidate generation algorithm exploits the unique feature of the VorLag diagram called a Null Polygon. Null Polygon plays a crucial role in healing the coverage hole formed because of energy depletion. Fig. 2 shows the notations used in implementing the algorithm.

//*Notations Used*//

SL(id$_i$, (x$_i$, y$_i$)) : ith Sensor Location
SR$_i$: i$_{th}$ Sensor Sensing Radius
CLF$_i$: ith Sensor Coverage Lost Factor
ELF$_i$: i$_{th}$ Sensor Energy Lost factor
Ocost(i) : ith Sensor Offer cost
E_res$_i$: ith Sensor Residual energy
ϕi(A) : ith Sensor Exclusive Coverage Area
δ : Energy level threshold for sensing operation
ψ$_i$: ith Sensor Movement cost
ε_A_Req :'Ehole_Assist_Request' message
ε_A_Rep : 'Ehole_Assist_Reply' message
Pv(i) : VorLag Polygon
Dcost(i) : ith Sensor Demand cost
I(p) : Intersection points
Sπr2(i) : ith Sensor Sensing circle
Dist (i,j) : Distance between two sensors i, j
Π$_i$: ith Sensor Neighbors

Figure.2 Notations Used

Proposed algorithm works in the following five phases.

1. VorLag Construction Phase
2. Exclusive Coverage Area Estimation Phase
3. Coverage Ehole_Assist _Request Phase
4. Coverage Ehole_Assist_Reply Phase
5. Coverage Ehole_Repair Phase
6. Path Selection Phase

VorLag Construction Phase: Sensors using the GPS system will have the information about their location and also the XY-coordinates of the target region. The sensor network consists of four different types of sensors having the radius of S_1, S_2, S_3 and S_4 where $S_1 > S_2 > S_3 > S_4$. Initially, each sensor broadcasts the data packet containing its location to all its neighbours. Based on the received information sensor identifies its neighbours, and constructs radical axis based on the sensing radius and the distance between them. Every sensor builds its polygon by repeating the radical axis construction process using all of its neighbours. Every sensor identifies the coverage hole by comparing its polygon to its own sensing area. If its sensing area is less than the area covered by its polygon area, the coverage hole is detected. For the coverage improvement, sensors iteratively perform the polygon construction process.

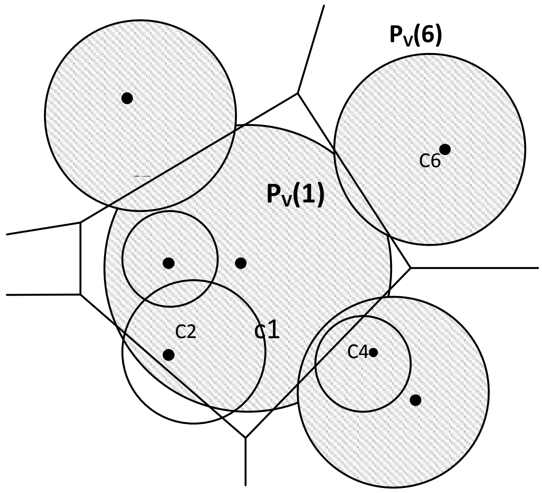

Figure 3 VorLag Diagram

Fig.3 shows the VorLag diagram with VorLag polygons and sensing a circle of each of the four different types of sensors over the target field. VorLag polygon contains both null and non-null polygons. Pv(i) and Ci denote the VorLag polygon and center of ith sensor respectively. Sensor 2 and sensor 3 create Empty Polygon since they do not place their center in their own polygon. Sensor 4 creates Null Polygon. Sensor 1, 5, 6 and sensor 7 create Non-Null and Non-Empty Polygons. With the movement adjustment algorithm, sensor 2 and sensor 3 move to its polygon with more coverage. Sensor 4 will not change the location initially as its polygon don't have any point in the area and its region stays on the union of the sensing region of sensor1 and sensor5.

Exclusive Coverage Area Estimation Phase: The exclusive coverage is the area covered by unique sensors without overlapping with other sensors in the covered region. Every sensor has the information of its sensing radius and neighbour's location. It traces the meeting points of neighbours using its sensing radius and location. Using these, it calculates the overlapping area. Elimination of the overlapping area from the sensing area generates an exclusive coverage region of that particular sensor.

Coverage Ehole_Assist_Request Phase: This phase uses the residual energy of the sensors. Sensors with low energy announce its energy losing state to its neighbours. Subsequently, neighbours disseminate this information to the entire network. The Null polygon sensors are moved to restore the coverage hole. When the sensor of Null polygon does not exist in a short distance, other sensor in the target area with adequate energy is used as a healing sensor which heals the coverage hole in the target field. When a sensor lacks with energy, it sends the 'Ehole_Assist_Request' (ε_A_Req) message to all the sensors in the network. 'Ehole_Assist_ Request' contains demand cost and location. Demand cost of a sensor represents the energy losing state with an exclusive coverage area. Demand cost of the sensor is a binary value i.e. either 0 or 1. The initial value of demand cost of each sensor is 0 that indicates sufficient energy. The cost of the healing node to restore the hole is described as "offer cost" (Ocost). Sensors that belong to Null Polygon have the high probability to possess the demand cost of 0, since their exclusive coverage area is null, results in 0 CLF.

Coverage Ehole_Assist_Reply Phase: On receiving the 'ε_A_Req' messages, sensors execute the steps given in the candidate generation algorithm. Initially, it calculates the movement cost that refers to the energy required to move and replace the low energy sensor. It calculates the offer cost using the Coverage Lost Factor (CLF) and Energy Lost Factor (ELF). Both the ELF and CLF have the numeric value of a binary digit (either 0 or 1). Therefore, resultant O_{cost} is also a binary digit. O_{cost} of 0 denotes the low cost and the sensor are a suitable candidate for the movement. If it is 1, a sensor is not suitable for the movement due to the high cost. Sensors having the zero O_{cost}, send the 'Ehole_Assist_reply' (ε_A_Rep) message.

Coverage Ehole_Repair Phase: The nodes having Ocost value zero are called candidates. Candidates send "ε_A_Rep" message to a low energy sensor during the previous phase. The low energy sensor selects one sensor as a repairing sensor among the candidates. Sensor calculates the distance from itself to candidates using the location information available in the 'ε_A_Rep' message. It selects the coverage hole repairing the sensor among the candidates that have a minimum distance between them to reduce the movement cost. After choosing, it sends message to the repairing sensor. When receiving the message, the healing sensor moves to the low energy sensor. Algorithm stops its execution when the coverage of the network area is increased. The approach given in this paper is different from that given in [18] which employ beacon messages to support self-deployment.

Path Selection Phase: Optimal path is selected based on the hop count and path length from source to sink based on energy constraint.

SIMULATION RESULTS AND ANALYSIS

This presents the execution and the analysis of the obtained results.

Experimental Setup

Proposed Candidate generation algorithm is evaluated with a simulator using the Network Simulator (NS-2). The performance of this work is compared with the existing VorLag approach. Initial deployment is made in the target region of 100m X 100m. The communication range of the sensor is made to 150m where the sensor travels with 1ms-1 speed. The below table.1 give the parameters used in simulation.

Table 1 Simulation Parameters

Parameters	Values
Sensing range	10m,20m,50m
Communication range	100m
Number of sensors	200-1000
Movement cost	8.3J/m
Simulation time	10800 sec
Initial Energy of a Sensor	500 Joules
Simulated Area	1000m X 1000m
MAC layer	802.11
Target Field Area	100m X 100m
Data Reception Power	10mA
Data Transmission Power	25mA

Result Analysis

This discusses the results with respect to parameter metrics. The metrics taken are moving distance and coverage profit.

Coverage Profit: It is the ratio of the total region enclosed after the implementation of coverage causing algorithms i.e., CGA and VorLag, with the initial area. Fig.5 shows a coverage profit percentage with respect to the known sensors. Coverage profit enhances as the sensors' increases. CGA provides improved possible coverage with the existing sensors. VorLag achieves comparatively lower coverage due to the large overlaps of the sensing circles. CGA attempts to provide maximum coverage in the target region based on available sensors in the network having medium density.

Moving Distance: Fig. 6 demonstrates the moving distance of the sensors to fill the hole during the execution of CGA algorithm. CGA ensures maximum coverage with minimum moving distance. CGA algorithm calls the sensor having less energy consumption to travel a distance of ψj in energy hole repairing phase. Thus, CGA algorithm selects the sensor having less moving distance as a repairing sensor.

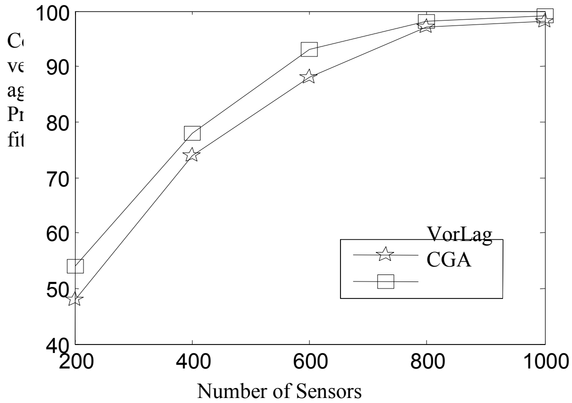

Figure 5 Coverage Profit

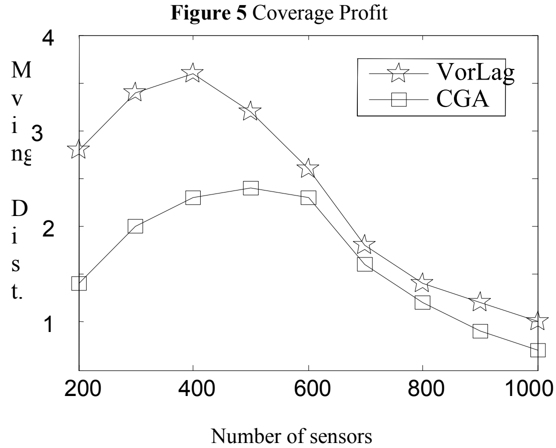

Figure 6 Moving Distance

CONCLUSION

Proposed approach solves the Coverage hole caused by the energy exhausted sensors in the target region using the mobility feature of sensors. The VorLag approach works well for finding the hole created because of random deployment. An efficient Candidate Generation algorithm is presented to solve the coverage hole problem. CGA is an extended algorithm based on VorLag using Laguerre geometry. However, the existing VorLag algorithm does not handle the coverage hole because of the energy hole. CGA algorithm repairs the coverage hole in five phases. It invokes the VorLag diagram construction as a first phase of the initial local adjustment. After a certain period of sensing operation, the remaining phases predicts the coverage hole due to the reduced energy level in the sensor, and executes a series of steps as a preventive measure to avoid the Coverage hole. In CGA, the best matching sensors are selected among the candidates for repairing the coverage hole, thereby utilizing the sensor capability efficiently. CGA strives to provide maximum coverage and optimal path over the Target Field even in the presence of low density sensors. On the whole, proposed CGA is a fine-tuning mechanism to heal the coverage hole. Experimental results demonstrate that CGA provides increased uninterrupted coverage compared to existing approaches.

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