

The Geographic Event-Driven Dispatch Algorithm for a Hybrid Sensor Network

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Abstract-Sensor deployment is an important issue in wireless sensor networks. In this paper, we propose the geographic event-driven dispatch algorithm in a sensor network with a mix of mobile and static sensors. The key feature is that the deployment process is triggered by an event-driven request and tries to solve the sensor dispatch problem. The mobile sensor will be selected to heal coverage hole, according to the position and the approximate contribution estimation of each mobile sensor. The efficiency estimation of each mobile sensor is related to the geographic information and distance between two sensors. Experiments demonstrate the superiority of our algorithm for average energy consumption and network lifetime by using geographic event-driven sensor dispatch algorithm in a hybrid sensor network.

Keywords: Geographic, Coverage, Mobile Sensor, Sensor Deployment, Wireless Sensor Networks.

1. Introduction

A sensor network is composed of a large number of sensor nodes that are densely deployed. Unlike traditional mobile ad-hoc networks [1], wireless sensor networks [2] consist of the sensor nodes which are made up of four basic components: a sensing unit, a processing unit, a transceiver unit and a power unit [3]. These nodes can self-organize and adapt to support the specific applications such as environment monitoring, pollution detection, and target tracking. Therefore, more and more researchers pay their attention to the sensor networks, and one of the most important issues focused in previous works is sensor deployment. By employing different deployment strategies sensor deployment may be optimized for commutation/computation cost, coverage rate, and power efficiency.

Since the problems of sensor coverage and deployment are fundamentally inter-related [4] in a sensor network, many deployment algorithms were proposed for increasing the coverage of the sensor field. Some of these related works assume all of the sensors are static [5, 6]. Since randomly deploying sensors usually obtains an undesired coverage ratio, the static sensor networks must be deployed according to a predefined shape decided by the different optimal algorithms. More recent works on sensor deployment assume all sensors are mobile [7, 8, 9]. The key advantage of employing mobile sensors is that sensors can dynamically move to monitor uncovered areas for increasing coverage ratio. The sensors may move from a densely deployed area toward a sparse area from a k-covered area to a coverage hole.

Recently, only few studies [10, 11] have so far been made at deploying a mixture of mobile and static sensors to construct sensor network for balancing sensor cost and coverage. A bidding protocol was proposed in [10]. Static sensors estimate coverage holes which are areas not covered by any node, and bid mobile sensors to heal the holes. Mobile sensors choose highest bid and move to the corresponding target location for covering holes. These processes may go into iterations until stable status is achieved. No more sensors will move and desired sensing coverage is achieved in this stable status. In paper [11], a novel approach for relocating mobile sensors in a hybrid sensor network was presented. It utilized flip-based mobile sensors [12], and the optimal decision of the mobile sensor node moving direction is made based on Analytical Hierarchy Process (AHP) [13] according to four factors: coverage hole, obstacle avoidance, hot spot, and the boundary effect. Each factor consists of eight direction alternatives. Mobile sensors will flip to the decided direction according to calculated

global weights. The processes also iterates until the network stable state is achieved. These recent two papers deal with the coverage problem, but there may be a lot of movements during the process.

Based on this observation, we propose a geographic event-driven dispatch algorithm in a hybrid or called a mixed wireless sensor network consisting of both static and mobile sensor nodes. By choosing to move the mobile sensor with lowest cost which means the best, it will make improvements of decreasing total cost of coverage and power consumption in a different applied consideration.

The rest of this paper is organized as follows. In Section 2, we introduce some preliminaries on our assumption, system scenario, and problem definition. Section 3 presents the geographic event-driven dispatch algorithm. Experiment results are given in Section 4. Finally, concluding remarks are made in Section 5.

2. Preliminaries

2.1. Assumptions

In this paper, we discuss the related deployment problem, which is “mobile sensor dispatch problem.” The object of our algorithm is to select a set of adaptable mobile sensor to be move with more efficiency. There are some assumptions.

- In a sensing field A , we distributed a lot of static sensors, and a few mobile sensors around the sink initially.
- Each sensor has the same communication distance R_c and sensing distance R_s . Sensor node’s communication range R_c is larger than the sensing range R_s . Here, we assume the communication range R_c is twice the sensing range R_s .
- Every sensor node can receive another sensor node’s message within its communication range. The sink knows the position and distance between them.
- Every sensor node can detect if there are obstacles in its sensing range and knows these obstacles’ position. Also assume that the size and shape of obstacles are known beforehand and loaded into sink before deployment.

2.2. System Scenario

In this paper, the proposed method to rearrange mobile sensor nodes in the rescue scene uses the efficiency estimation to decide the candidate which should be moved by the sink. The goal of this method is to heal coverage hole efficiently in order to get acceptable coverage and low power

saving while keeping network connectivity.

Initially the static sensors are randomly deployed in the monitoring area, and Voronoi diagram [14, 15] is employed to detect and estimate the coverage holes. The sink (a base station or control center) collect information and determine the target location of the mobile sensors. The event-driven request means the sink observes the collected data represents an abnormal phenomenon. To meet sensing coverage requirements once the sink detect event driven request, it will allocate or relocate mobile sensors which satisfy certain of criteria to move to the target location. Both holes and mobile sensors are labeled with geographic location to be the basis of the strategy of selection mobile sensors.

Sensor nodes don’t send data until a certain event occurs in event-driven wireless sensor network [16]. In our opinion, while an event occurs around a hole, the mobile sensors are dispatched to heal the hole, and this is the reason why our methods are called event-driven algorithms. Unlike some other previous works, our algorithm is event-driven sensor management which is closer to some specific real application. It decreases the average total moving distance and reduces the power consumption to achieve both deployment efficiency and extend the sensor network lifetime.

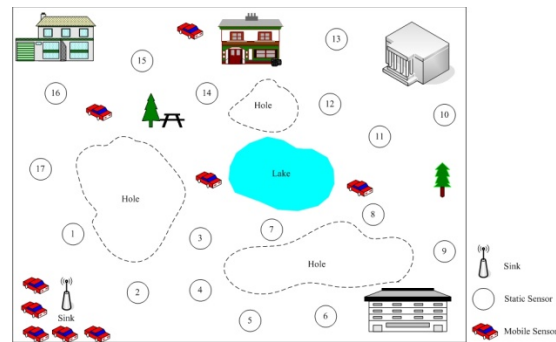


Figure 1. The Scenario of This Paper.

An example is shown in Fig. 1. The quadrangle indicates the interested sensing field A . There are more static sensor nodes (circular shape with an ID) and a few mobile sensors which are some in the sensing field A and some around the sink. All buildings, trees, and lake are considered as obstacles. Each sensor node knows its own geographic location by using localization algorithm [17, 18, 19], and then appraises to sink. Thus, the sink can construct a Voronoi cell after receiving the local information from all of sensors. As shown in Fig. 2, the sink can evaluate the bisector lines between sensors. After all bisector

lines have been evaluated, these lines can construct Voronoi cells. In a given cell, the sensor in the cell is closer to the every point in the cell than any other sensors. Therefore, the sink can obtain all the hole information by using the Voronoi diagram. In this paper, while a certain event occurs around a hole H or the total hole size HS is larger than threshold ε , the mobile sensors will be dispatched to heal the hole H .

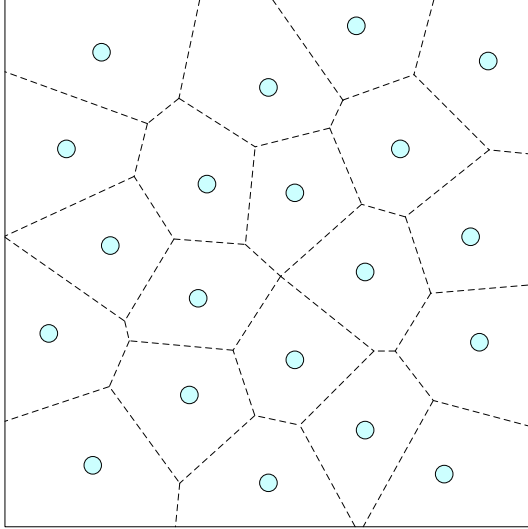
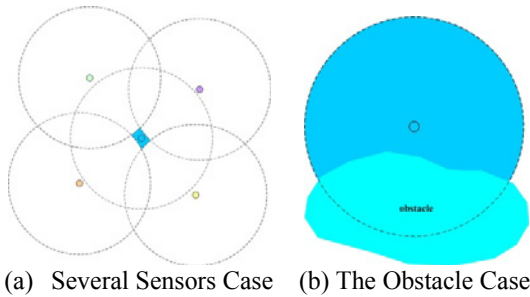


Figure 2. The Voronoi Diagram.

2.3. Problem Definition

By using sensor efficiency estimation the sink can decide the mobile sensor which must to be moved, so the mobile sensor with high efficiency and lowest moving distance move to provide the require coverage. Thus, there are some characterizations must be consideration.



(a) Several Sensors Case (b) The Obstacle Case

Figure 3. Two Cases of Characterizations around the Mobile Sensor.

In this paper, we define two sensors s_i and s_j is connected if the distance between sensors s_i and s_j is less than R_c and the line segment between sensors s_i and s_j does not intersect any obstacle or

boundary of sensing field A ; otherwise, they are disconnected. If there are several sensors are inside communication distance R_c of sensors s_i , these sensors may reduce the efficiency of the sensor. Otherwise, we assume that a point can be monitored by a sensor if it is within a distance of R_s and line of sight exists with the existence of obstacles. In other words, the obstacles may also reduce the efficiency of the sensor. Fig. 3(a) and (b) show the examples which may reduce the efficiency of sensor. Therefore, we discuss the mobile sensor dispatch problem, it means given a set of mobile sensors S already deployed in A and an area of hole H that has to be monitored. There is a problem asks how to find a subset of mobile sensors $ms \in S$ to be moved to H with lower cost.

3. The Geographic Event-Driven Dispatch Algorithm

3.1. Basic Structures

In the section, we design a sensor dispatch algorithm which is a centralized algorithm. The sink owns the information of the holes and the mobile sensors, and decides to location the mobile sensors with minimum cost. If the environment is known in advance, then a map can be stored into the memory of each sensor node and the movement of all the nodes can be well planned so that each of them can move to its target directly without any extra delay and energy consumption.

The static sensors should explore and be deployed randomly to cover the area A . If a sensor node becomes dysfunctional due to energy depletion or, there is a space that can no longer be monitored. The hole in the area is defined as a region that is uncovered by any sensors S and needs the mobile sensors to move to. Each $h \in H$ owns the following fields:

- *Hole Size*
- *Position*

Hole Size denotes the size of the hole, and *Position* field indicate the center coordinate of the hole. This information about the holes can be obtained through Voronoi diagram.

As for mobile sensors, there are the following fields to indicate the situation for each mobile sensor.

- *Position*
- *Monitor Area*

For each mobile sensor, the initial *Position* field is set to $(0, 0)$. It means the mobile sensor is located at origin. The *Monitor Area* field describes the efficiency of mobile sensor.

3.2. The Efficiency Estimation of Mobile Sensor

Given a set of mobile sensors S already deployed in A and an area of the hole H that has to be monitored. There is the problem asks how to find a subset of mobile sensors $ms \in S$ to move to H . Here, we consider a movement solution to relocate mobile sensors in an efficient way. Initially all the mobile sensors with the same capability is located around the sink. The mobile sensor dispatch algorithm use the efficiency calculated by each mobile node to decide which mobile sensors should be moved. In this paper, if the mobile sensor is used and deployed in A , we calculate the monitor area M_s of the mobile sensors S to estimate the individual contribution, that is,

$$M_s = 1 - \frac{\sum_{i=1}^m \theta_i + \sum_{o=1}^n \theta_o}{2\pi} \quad (1)$$

where θ_i is the overlapping angle of the neighbours sensor and θ_o is overlapping angle of the obstacles. Besides if the mobile sensor is unused and deployed in A , the monitor area M_s of the mobile sensor is equal to zero.

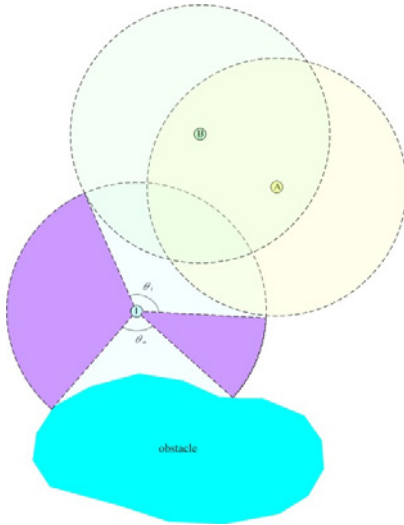


Figure 4. A Sample of Contribution Estimation of Mobile Sensor.

Fig. 4 indicates an example. We estimate the contribution of the mobile node S by using equation (1). The dotted line denotes the sensing area of sensor. It must be noted that the sensing area of sensor A and B is overlapping with each other, and they also overlapping with the sensing area of mobile sensor S . Thus, the sensing area of sensor A and B can be noted as a group. Therefore, we can obtain the overlapping angle of the neighbour sensors θ_i and the obstacle θ_o . Finally,

we can obtain the monitor area M_s of the mobile sensor.

3.3. The Mobile Sensor Dispatch

Initially, the sink receives the hole H information from the sensors. Generally speaking, the sink obtains the data from all the sensors and confirms whether an event happened. In other words, if the collected data represents an abnormal phenomenon, thus the event happens and the sink must decide which mobile sensors will move to the target hole by the minimum monitor area. In other case, if the sensor is decentralize or some of the sensors have non-energy, it may cause the decrease in coverage area. Therefore, the sink may decide some mobile sensor move to.

Notations:

e_i : a event occurs in the i -th hole $h_i \in H$, where $i = 1, 2, \dots, n$; n is the total number of holes.

HS : the total hole size.

Sensor Dispatch Algorithm:

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if  $e_i = true$ 
  for each  $ms$ 
    find the set of mobile sensor with the
    minimum monitor area  $M_i$ 
    select one mobile sensors  $ms_i$  from the above
    set, in which the sensor is the closest to  $h_i$ 
    move  $ms_i$  to the  $h_i$ 
  end if  $HS > \epsilon$ 
  find the maximum size of hole  $h$ 
  find the set of mobile sensor with the minimum
  monitor area  $M_i$ 
  select one mobile sensors  $ms_i$  from the above
  set, in which the sensor is the closest to  $h_i$ 
end

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Figure 5. The Geographic Event-Driven Dispatch Algorithm.

Fig. 5 shows the geographic event-driven dispatch algorithm. When the event happens around the H_i , the mobile sensor which is chosen by the sink will be moved to. If a mobile sensor ms_i satisfies the following constrains, it is a candidate which will move to h_i .

- The *monitor area* is low.
- The distance between ms_i and h_i is short.

4. Experiments

In this section, we present some simulation results to verify the effectiveness of the proposed algorithm. We compare our proposed with bidding protocol, in-order scheme, and random scheme. The in-order scheme and random scheme mean the

sink decide which sensor should be moved by in-order and random, respectively. Table 1 presents the environment parameters of the simulation, and the energy consumption parameters are the same as in [20].

Table 1. Simulation Parameters.

Parameter	Values
Monitor Area	100m x100m
Communication Radius	20 m
Sensing Radius	6 m
Moving Speed	5 m/sec
Energy Consumption (Action State)	11.2 J/m
Energy Consumption (Idle State)	0.727 J/s
Energy Consumption (Transmission)	0.986 J/s
Energy Consumption (Reception)	0.751 J/s
Threshold	95%
Number of Static Sensors	100

In the first experiment, as shown in Fig. 5, investigates the changes of average coverage ratio with the increase of the number of mobile sensors. The average coverage ratio of our proposed which satisfies the coverage request is similar to the bidding protocol. Therefore, our proposed is feasible.

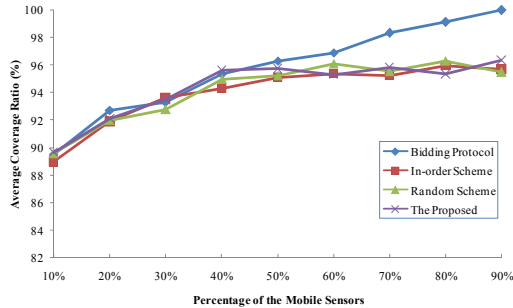


Figure 5. Average Coverage Ratio.

Assume each sensor node equips with three basic energy consumption types: sensing, transmitting and receiving. We simulate the changes of the system lifetime in the second experiment. The simulation results are shown in Fig. 6. As expected, the system lifetime in our proposed algorithm is longer than that in compared bidding protocol. Fig. 7 depicts the average depleting energy between these algorithms. Our algorithm starts the deploying process by an event-driven request. Thus, the event-driven deployment can effectively reduce the unnecessary movements and the energy consumption of the mobile sensors. Moreover, our proposed decide

which mobile sensor should be move by using efficiency estimation. Thus, the sink can solve the sensor dispatch problem with low cost. Therefore, our proposed have the better performance.

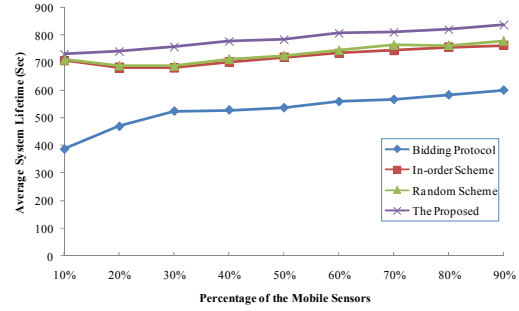


Figure 6. Average System Lifetime.

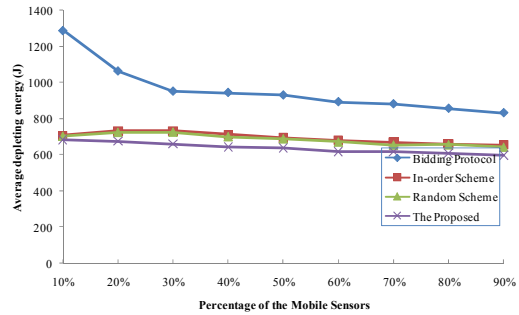


Figure 7. Average Depleting Energy.

5. Conclusions

In this paper, we propose the geographic sensor dispatch algorithm in a hybrid sensor network consisting of static and mobile sensors. The objective is to utilize an event-driven request instead of the overall coverage approach to reduce unnecessary sensor movements. Besides, this paper tries to solve the sensor dispatch problem. The mobile sensor should be selected to heal coverage hole, according to the position and the approximate efficiency estimation of each mobile sensor. Our proposed algorithm can decide the adaptable mobile sensor to be moved with lowest cost. Simulation results showed that our proposed algorithm can achieve the purposes of solving sensor dispatch problem and improving network lifetime. Since our approach is a centralized deployment algorithm, we will improve it with distributed deployment scheme based on this work in the future. Conducting the algorithm to a real specific sensor network application is also an important future work and great contribution.

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