

A Sensor Utilization Scheme for the Coverage Guarantee Criteria in a Wireless Sensor Network

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Abstract— This paper considers a cluster-based wireless sensor network (WSN) where each sensor node takes turn to be cluster head. The main function of the cluster head is to oversee the communication within and between clusters while the remaining sensor nodes are involved in sensing of the surrounding environment. We address the sensor utilization problem where non-cluster head nodes in a cluster make decision to whether to be active and join the sensing process. The decision is based on the remaining energy of a sensor, and a performance criterion. Here, we use the probability that given point in the cluster is covered by at least N sensors. By using a probabilistic model, it can be analytically calculated. Since only the high energy and necessary sensors are used, the energy consumption can be greatly decreased. To evaluate the performance of our algorithm, the simulation results are shown that our proposed schemes are efficient in terms of lifetime and energy consumption. The experiment results show that our algorithm achieve a good performance in term of lifetime.

Keywords— Network lifetime, Coverage guarantee, Sensor deployment, Wireless sensor networks, energy efficient

I. INTRODUCTION

Due to the advance developments in embedded micro-electro-mechanical systems and low power consumption wireless technologies in recent years, the development of the small size sensors capable of sensing in inhospitable terrains, processing the various types of data and communicating with each other become available in reasonable price. These sensors are an essential part for the development of a wireless sensor network, composed of a large number of sensor nodes. One of the main purposes of a typical WSN is to monitor the surrounding environment and communicate among sensor where data are sensed and collected to the sink node or base station through the cooperation between sensor nodes. Due to the reduction of cost and size of the integrated circuits as mentioned earlier, wireless sensor networks have been received the increasing attention in wide range of applications such as military surveillance and security applications, medical monitoring, disaster prediction, environment monitoring, agriculture and other commercial applications. As wireless sensor nodes are used in wide range of applications, the energy consumption becomes an important issue because, in some applications, Wireless sensor networks are deployed in a harsh terrain or difficult to access area. In many situations,

the system performance of a WSN is measured in terms of network or system *lifetime*, the maximum period that the system performs its assigned tasks successfully.

A typical wireless sensor network relies on batteries on an individual node to supply the energy for both sensing and communication. The lifetime of a WSN is constrained. As a result, the energy-efficient utilization algorithms of sensor nodes is a key factor is the successful implementation of Wireless sensor network. Many researchers have addressed various methods of minimizing energy consumption and prolonging network lifetime while maintaining coverage in wireless sensor networks.

Most of researchers attended to prolong the network lifetime by guarantee percentage of coverage, one of the parameter to ensure that any particular points in the sensing area are being properly monitored. For easy management of the system energy, the hierarchical routing protocols especially clustering algorithms seems to be a preferable choice since they distribute the energy consumption of all sensor nodes in the system while performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink as in [1]. Thus clustering algorithms can reduce the communication load. Cluster heads can do some aggregation and reduction of data in order to save the energy. An Energy-Aware Routing Protocol (EAP) as in [2] purposed a clustering algorithm which selects cluster heads by the ratio of residual energy to the average residual energy of all neighbour nodes in its cluster range. This can better handle heterogeneous energy circumstances than existing clustering algorithms which elect the cluster head only based on a node's own residual energy. Because the cluster heads always keep rotation in whole life of network, EAP can maintain uniform energy consumption among all nodes. Hence minimizing energy consumption in each round can prolong the network lifetime.

Network lifetime is the key characteristic to evaluate the performance of sensor networks. Several researchers (e.g. [1], [3]-[5]) defined network lifetime as the time that the region of interest is covered by sensor nodes seems to be a natural way as in [6]. Several papers base their definitions of network lifetime on a coverage variant. Model k -coverage is an appealing solution demanding that each point in a field is sensed by at least k sensors. To guarantee coverage several

studies propose their probabilistic models for sensor deployment (e.g. [2]-[5]).

Resulting in EAP clustering algorithms and probabilistic models which guarantee coverage of sensors, the energy consumption are maintain uniform and the connectivity can be guarantee in terms of coverage respectively. To prolong network lifetime sensors in each cluster need to be selected as active sensors to balance load within each cluster. In this paper, we consider the sensors utilization algorithm which aims to prolong the network lifetime by balancing energy consumption among sensor nodes within the clusters. The existing works (e.g. [1]-[2]) proposed methods to form cluster and guarantee the coverage to achieve a good performance in terms of lifetime and energy cost consumption. Our work is an extending of the existing methods which do not consider to identify active sensors deployment after forming clusters as in [2]. We propose a probabilistic model to guarantee coverage within each cluster and an algorithm to select active sensor deployment algorithm which can be balance the load among sensors in clusters. These lead the network to be uniform energy consumption and good performance in terms of lifetime. The selective algorithm is base on the residual energy of sensor nodes, density, distribution and coverage characterization.

The remainder of this paper is organized as follows: Section II defines the problem statement and describes the system. Section III presents the detailed of our algorithm. The various simulation results are shown in section IV. Section V is describes the conclusion of the paper and also describes the work in future.

II. PROBLEM STATEMENT

In this paper, we consider the problem where wireless sensor nodes are randomly deployed in the area of interest A . The location of each sensor is assumed unknown but a sensor node find its neighbours by listening to the broadcast radio messages emitted by each sensors at the initialization step. Here, a communication radius, denoted by r_c , are assumed to be the same for all sensors whereas the notation r_s denotes the sensing radius of all sensors. To equally distribute energy usage among all sensors, the cluster based routing protocol is employed in this paper. Let us emphasize here again that the goal of this paper is to find the efficient energy usage through the sensing. In other words, this paper aims to reduce number of active node N in the clusters while guarantee a desired percentage of coverage denoted by $P(cov)$.

As mentioned in previous paragraph, the energy aware routing protocol (EAP) in [2] is used as the clustering algorithm. After selecting cluster heads and forming clusters, the remaining nodes make decisions whether to be active and join sensing process. The decision criterion is based on the number of necessary active sensors in each cluster in order to achieve a desired percentage of coverage $P(cov)$. Sensors decide to active if and only if the number of active sensors is less than the minimum number of sensors that yields the target coverage probability. As the number of active sensors is

reduced compared to the all node active situations, the energy consumption in the network is decreased.

III.A SENSOR DEPLOYMENT COVERAGE ALGORITHM

A. Clustering Algorithm in the EAP Protocol

Since cluster heads consume more energy than cluster members in receiving sensed data from their member nodes. Therefore the role of the cluster head must be rotated among all sensor nodes. The operation of the EAP is divided into rounds. Each node needs to maintain a neighbourhood table to store the information about its neighbours for cluster head selection algorithm as in [2]. In the EAP, the cluster head selection algorithm depends on the factor between the average energy of its neighbours and the residual energy of nodes. In term of energy usage, the EAP can handle the heterogeneous energy circumstance as in [2] better than other cluster head selection algorithms depending only on the residual energy of nodes. Let E_a denotes the average residual energy of the cluster range of node and be defined as

$$E_a = \frac{\sum_{j=1}^m V_j E_{residual}}{m} \quad (1)$$

where V_i represents a neighbour node in cluster range of V_i and m is the number of nodes within the cluster range. After computing E_a each node computes the broadcasting delay time t for competing cluster head, i.e.,

$$t = kT \frac{E_a}{E_{residual}} \quad (2)$$

where k is a real value uniformly distributed between 0 and 1 and T is the time duration for cluster heads election. At the time t , a node broadcasts the Compete for competing cluster head message. Clearly the time at which is a node compete to be a cluster head is related to $E_a/E_{residual}$. This means that the lifetime of the nodes with low residual energy within the cluster range will increase as in [2].

B. Probabilistic Model for Coverage Guarantee

The idea to achieve a sensing coverage probability is to use a good sensor utilization scheme to which each points in the area of interest is being monitor with a probability $P(cov)$. We consider method to identify the appropriate number of sensors that are essential to be active (denoted by N) to guarantee a desired percentage of coverage $P(cov)$. Our algorithm considers the intersection of sensing range r_s to guarantee sensor coverage as in Figure1. Thus, we derive a probabilistic model as a function of the intersection area of the each sensor sensing radius r_s .

Consider Figure 1, sensors denote as S_1 and S_2 decide whether to be active. The position sensor S_1 gives the worst case of member intersection where member is placed at the edge of communication radius r_c with the relation $r_s = 0.5r_c$. Sensor decides to active and join the sensing activity if and only if there is no intersension of coverage. As a consequence, the sensor at the edge of cluster range is consider to evaluate the guarantee probability model.

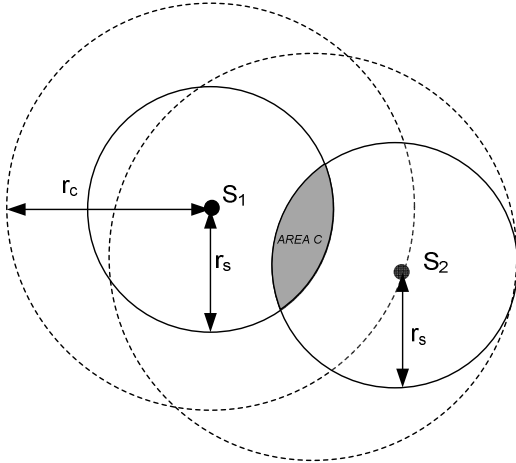


Figure 1. Coverage area in cluster

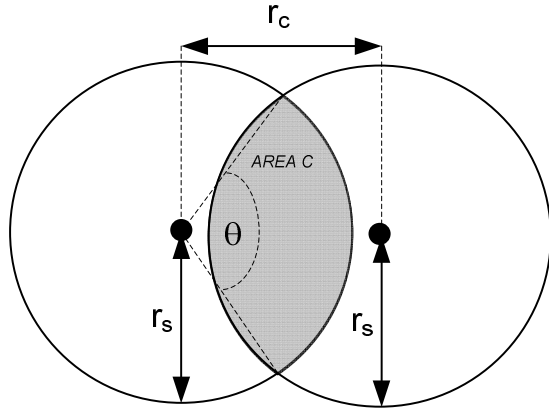


Figure 2. Area of the coverage intersection

The probability that worst case sensor is coverage of interest *Area C* denoted as $P(\text{cov} \in \text{Area C})$ is a function communication radius r_c and r_s . Considering Figure2, we can derived the probability model to determine a number of active sensors N that essential for ensure the desired percentage of coverage $P(\text{cov})$ as follow.

$$P(\text{cov}) = 1 - (P(\text{cov} \notin \text{Area C}))^N \quad (3)$$

$$N = \frac{\log(1 - P(\text{cov}))}{\log(1 - P(\text{cov} \in \text{Area C}))} \quad (4)$$

From Figure 2, the probability that worst case sensor is coverage of interest *Area C* $P(\text{cov} \in \text{Area C})$ can be defined as

$$P(\text{cov} \in \text{Area C}) = \frac{(r_s^2(\theta - \sin \theta))}{\pi r_c^2} \quad (5)$$

where

$$\theta = 2 \cos^{-1} \frac{r_c}{2r_s} \quad (6)$$

As a result, the cluster head selection depends on the factor between the average energy of its all neighbor and residual energy of each node. The number of essential active sensors N in the cluster is derived from our purposed a probability model as in equation (4). At least N sensors in each cluster need to be active to achieve the desirable percentage of coverage. Sensors decide to active if and only if the number of active sensors is less than N . As the number of active sensors is reduced compared to the all node active situations, the energy consumption in the network is decreased. As a result, the network achieves a good performance in terms of energy consumption and lifetime. In our derived probability model the communication and sensing radius are main factor that affects the number of essential active sensors N in clusters.

IV. EXPERIMENTAL RESULTS

In this section, we illustrate the experimental results of our purpose our algorithm. A Sensor Utilization Scheme for Coverage Guarantee Criteria in a Wireless Sensor network achieves a good performance in terms of the wireless sensor network lifetime. We illustrate the experimental results that show the relationship between the lifetime and network density. We also show that sensing and communication ratio can affect the lifetime.

In the experimental, we randomly placed sensor nodes in the field (100x100) and formed the clusters. The communication radius r_c and sensing radius r_s are equal. The desired percentage of coverage is 80 and 90 percent. The experiments compare the different among the number of sensors as 100, 200, 300, 400 and 500 nodes. The simulation results show that the proposed algorithm can prolong the network lifetime while guarantee the desired percentage of coverage. The simulation results are the average of 100 experiments where each experiment uses a different randomly generated uniform topology of sensor nodes compare to the network that all member in the clusters need to be active all the time. The increasing of number of node is mentioned as high density network. The network lifetime increases as the higher node density.

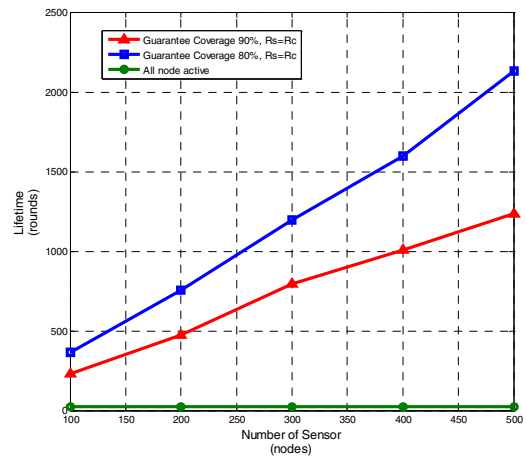


Figure 3. Comparison between network lifetime and the number of sensors among different guarantee percentage of coverage and all node active scheme while sensing range is equal to the communication range.

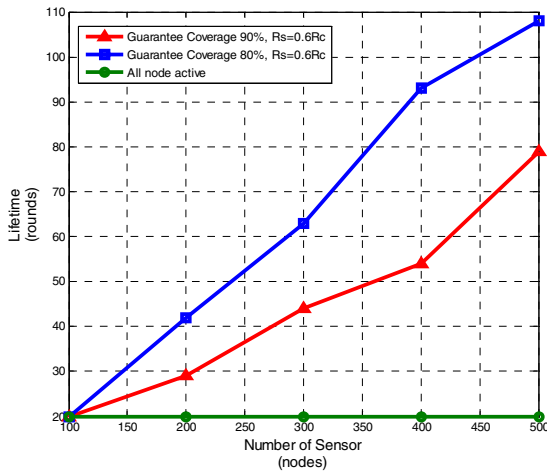


Figure 4. Comparison between network lifetime and the number of sensors among different guarantee percentage of coverage and all node active scheme while $r_s = 0.6r_c$.

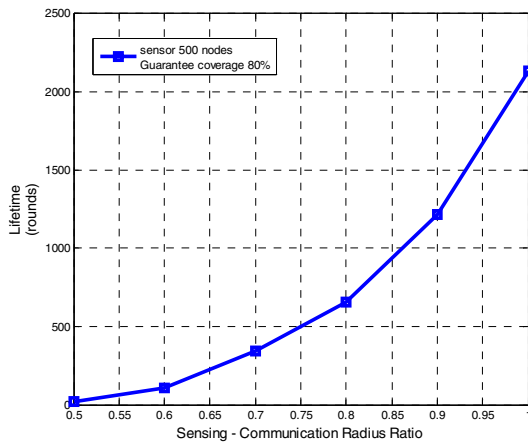


Figure 5. Comparison between network lifetime and different sensing-communication radius ratio

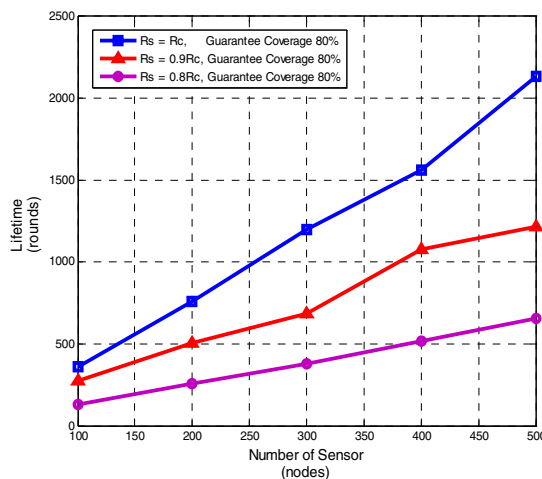


Figure 6. Comparison between network lifetime and different sensing-communication radius ratio while guarantee coverage 80 percent

In the simulation results shown in Figure 3 and 4 illustrate that network lifetime is increasing as higher sensor density. The result in Figure 3 is a comparison between the guarantee percentage of coverage 80 and 90 percent with all active sensor nodes scenario as equal sensing and communication ratio. The result in Figure 4 is a comparison between the guarantee percentage of coverage 80 and 90 percent with all active sensor nodes scenario as $r_s = 0.6r_c$. The results as illustrated in Figure 3 and 4 show that as the higher sensor node density, the network lifetime is extended. The simulation result in figure 5 illustrates the relationship between network lifetime and the ratio of sensing and communication radius. We simulated 500 number of sensor nodes with guarantee percentage of coverage 80 percent. The result shows that the network lifetime is increase as higher sensing radius. The simulation result in Figure 6 is a comparison among different sensing and communication radius ratio as guarantee percentage of coverage 80 percent. From the result, the network performance interm of lifetime is better as high sensing radius and node density.

V. CONCLUSIONS AND FUTURE WORKS

In this paper, we present a sensor deployment coverage guarantee algorithm for wireless sensor network. The simulation results show that our algorithm achieves a good performance in terms of energy consumption and lifetime while retaining the desirable coverage probability. The performance is better as the increasing of network density. Furthermore, we illustrate the relationship between sensing and communication radius ratio and network lifetime. In future work we focus on the evaluation of the performance of our algorithms by comparing the simulation result to other existing algorithms. Moreover, we aim to identify the most proper sensing range for extending network lifetime.

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