Local Maximum Lifetime Algorithms for Strong Barrier using Coordinated Sensors

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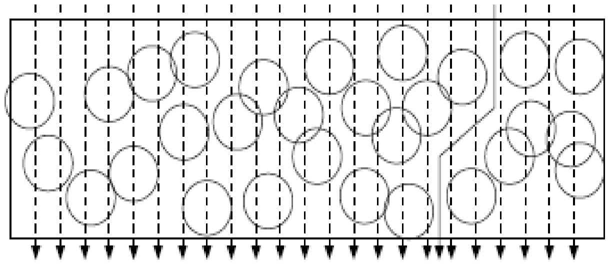
Abstract*— *Barrier coverage is known to be an appropriate model of coverage for movement detection and boundary guard, which is achieved by barriers of coordinated sensors. A Border Security System watches intruders by using sensor nodes with communication function. The detection of some intruders and the use of a long-term operation system are required in this system. This paper proposes network construction methods of sensor nodes for Border Security Systems that uses a Divide-and-Conquer scheme. The design is based on new local maximal lifetime algorithm and following protocol for strong k-barrier with coordinated sensors. The proposed barrier coverage network construction methods are suitable for Border Security Systems and reduce the power consumption of the whole network system by effective control of sensor nodes.

Keywords*- *wireless sensor network, barrier coverage, local algorithm, data fusion.

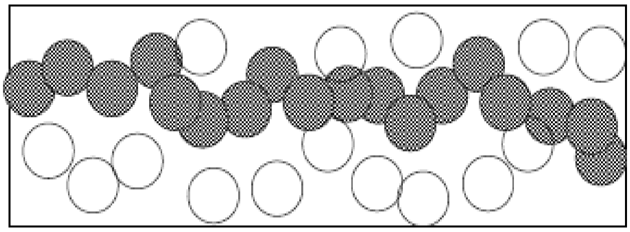
I. INTRODUCTION

Several important applications of wireless sensors involve movement detection, such as when deploying sensors along international borders to detect illegal intrusion, around a chemical factory to detect the spread of lethal chemicals, on both sides of a gas pipeline to detect potential sabotage, etc. barrier coverage, which guarantees that every movement crossing a barrier of sensors will be detected, is known to be an appropriate model of coverage for such applications [1]. Chen et al. [2] devised a centralized algorithm to determine whether a region is k-barrier covered, and derived the critical conditions for weak barrier coverage in a randomly deployment sensor network. But the centralized algorithm could incur high communication overhead and computation cost on large sensor networks, and conditions for strong barrier coverage remain an open problem. Liu et al[3]. First discussed the strong barrier coverage problem. They map the strong barrier coverage as a discrete bond percolation model and derive the conditions of having multiple disjoint sensor barriers.

Figure 1[3] illustrates the difference between strong barrier coverage and weak barrier coverage. In the top figure, the network has weak barrier coverage for all orthogonal crossing paths (dashed paths). However, there is an uncovered path (solid path) through the region. The bottom figure shows an example of strong barrier coverage where no intruders can cross the region undetected, no matter how they choose their crossing paths. The barrier is highlighted using shaded sensing areas.



Weak coverage



Strong coverage

Presented [3] a critical condition for weak barrier coverage. But conditions for strong barrier coverage remain an open problem. In [5-8], detection coverage models have been proposed, based on different event scenarios and detection techniques. In [8], Yang and Qiao first induced the detection coverage model into barrier coverage and theoretically analyzed the constraints between data fusion algorithm and coverage regions.

This paper, discusses on the problem of constructing strong *k*-barrier based on detection coverage model, considering the neighboring sensors which can cooperate in surveillance by data fusion.

Specifically, the paper proposes a new technique which as follows: first work that motivates the problem of constructing strong *k*- barrier based on detection coverage model and data fusion. Second formalize a coordinated detection coverage model, where the data fusion rule is described by a general function f(x). Third analyze the influencing factors of barrier coverage lifetime, and transfer it to a multi objective optimization problem. Fourth it proposes a new Divide-and-Conquer scheme and the design is based on a new local maximal lifetime algorithm and following protocol for strong *k*- barrier with coordinated sensors.

II.EXISTING METHOD

The local barrier coverage algorithms have been introduced in [1, 2, 3, 4]. And [5, 6, 8] have introduced the centralized algorithms. One of algorithms for local barrier coverage, called RIS(Random independent sleeping algorithm). This algorithm is based on a power saving method, in which the sensor nodes are scheduled and switch between two modes, Active and Sleep.

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RIS provides a weak barrier coverage with the high probability of intrusion detection, in such a way that each sensor, in certain periods, selects Active or Sleep mode, with a predetermined probability rate, P. As mentioned earlier, the presented method will be based on the power saving method, used by RIS. However, the modes considered in sensor nodes have been changed to Active and Passive modes. It must be noticed that RIS does not guarantee the barrier coverage, deterministically. First, global active scheduling algorithms are not achievable in a large scale sensor network. Second, [1] proved that one sensor cannot locally determines whether the surveillance field is k-barrier covered or not.

A. Traditional Activity Scheduling Strategy

One traditional method is to activate the nodes with highest left energy[1-4], which can avoid the nodes with less left energy died prematurely and prolong the barrier coverage lifetime. However there usually exists the situation that the horizontal projection of above-mentioned nodes is relative small, i.e. the count of active nodes is not optimal. The other method is to activate the least nodes by greedy algorithms [8][9]. The nodes in suitable location can been activated frequently, and died untimely, which affect the sensor network connectivity, and further shorten barrier coverage lifetime.

III. PROPOSED METHOD

As mentioned earlier, the main problem to be solved includes providing a k-barrier graph which creates and describes a k-barrier coverage in a barrier area. As a result, all paths crossing through the barrier area are covered k-times, by the network sensors. The proposed method consists of three minimizing objectives and one maximizing objective.

A. Modeling Maximum Barrier Coverage Lifetime

An effective sensor activity scheduling should tradeoff the count of nodes in a cover set, their left energy and consumed energy in one cycle. As a result, maximum o of barrier coverage lifetime essentially is a multi-objective optimization problem. The problem can be considered as three minimizing objectives and one maximization objective, i.e. minimizing the count of active nodes, minimizing the total energy used in one cycle, minimizing the ratio of an active node's consumed energy in one cycle and its left energy, the maximizing minimum ratio of an active node's left energy and its initialized energy. The n nodes only can switch between active state and sleep state, and the active nodes whose count is less than n can make up not less than k disjoint barrier, n and k are constraints.

B. k-CLBCS Algorithm

This paper proposes a global *k*-CLBCS algorithm (Constructing Local *k*-Barrier with Coordinated Sensors), the main idea of *k*-CLBCS algorithm is described as follows:

Algorithm name: *k*-CLBCS
Protocol Description: **step1:**calculate every edge's capacity, and construct the coverage graph *G(N)*; **step2:** search *k* disjoint paths from *s* to *t* in the *G(N)*; **step3:** if the *k* disjoint paths are found, return the nodes' *ID* that should be activated to form *k*-barrier, otherwise, return constructing failure.

C. k-SBCCS Protocol

Based on the overlapped divide-and-conquer scheme and *k*-CLBCS algorithm, this paper proposes a practical protocol. A sink and n-sensors are assumed in the rectangle belt, at the beginning, all sensors are active. The main idea of *k*-SBCCS Protocol (Protocol of Strong *k*-Barrier Coverage with Coordinated Sensors) is described as follows:

Protocol name: *k*-SBCCS
step1: sink divide the belt region into v equal-width sub regions, and broadcast the value of Ws (width of each sub region),Wo (width of overlapped strip)and v(equal width sub regions). **step2:** every node calculates which sub region it belongs to, judge if it is located in the overlapped strip, and reports its information to the sensor who have highest energy. **step3:**In each sub region, the sensor who has the highest energy runs k- CLBCS algorithm .If k disjoint barriers are found, it activates these sensors, otherwise, it reports the failure information to sink. **step4:** the activated sensor who has the highest energy in every overlapped strip checks if the overlapped strip is strong k-barrier covered or not. If it found the overlapped strip not strong k-barrier covered, some other nodes will be activated to form strong k-barrier coverage in the overlapped strips. If all live sensors in the overlapped strip can't form strong k-barrier, the above sensor reports the failure information to sink. **step5:** repeat step3 and step4 until all sensors die.

Compared to the centralized approach that computes barrier for the whole strip, the above divide-and-conquer approach has the following advantages:

- *Lower communication overhead and computation costs* .By dividing the large network area into small segments, the message delay, communication overhead, and computation cost can be significantly reduced. The location and sensing area information of a sensor node only need to be broadcast within the strip segment (or within the thin vertical strip) where the node is located, resulting in a smaller delay and communication overhead compared to the whole network broadcasting.
- *Improved robustness of the barrier coverage*. In a centralized approach which constructs global horizontal barriers for the whole strip, a horizontal sensor barrier could be broken if some nodes on the barrier fail, or become compromised or displaced by adversaries. In a new divide-and-conquer approach, the original strip is divided into segments by interleaving vertical barriers. In case of node failure, these vertical barriers act as firewalls" that prevent intruders from moving from its current segment to adjacent segments. This limits the barrier damages within the local segment and hence improving the robustness of the barrier coverage improving the robustness of the barrier coverage.

• *Strengthened local barrier coverage*. By dividing the original strip into small segments and computing barriers in each segment, a larger number of local horizontal barriers will be found in each segment than
for the whole strip.

These local barriers are not necessarily part of the global barriers for the whole strip, whose number remains unchanged. Since adjacent segments are blocked by interleaving vertical barriers, a large number of local barriers results in a strengthened local barrier coverage for each segment.

IV. CONCLUSION

This paper proposes a k-barrier coverage protocol, called *k*-SBCCS, for prolonging the network lifetime.. The proposed protocol maximum lifetime scheduling for strong *k*-barrier coverage based on detection coverage model and by establishing a balance in using nodes energies, which is more appropriate for intrusion detection scenarios. Transfer maximal barrier coverage lifetime to a multi objective optimization problem, and model the evaluation function as the capacity of coverage graph. Moreover, based on the enhanced coverage graph, a *k*- CLBCS algorithm has been proposed which is of maximum network lifetime. Theoretical proof shows that the activated nodes by in every overlapped strip can form k-barrier. At last, by using the new Divide-and-Conquer scheme and *k*- SBCCS protocol a strong *k*- barrier with coordinated sensors has been designed and experimented.

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