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Adaptive Energy Efficient Scheduling (AEES) for Fault Tolerant Coverage in Sensor Networks

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Abstract:- For many sensor network applications it is necessary to provide full sensing coverage to a security-sensitive area. To actively monitor the set of target the subset of sensors are redundantly deployed. One of the major challenges in devising such network lies in the constrained energy and to tolerate unexpected failure to prolong the life span of the network. In this we rapidly restore the field monitoring, by periodically refreshing and switching the cover to tackle unanticipated failure in an energy efficient manner, because energy is the most critical resource considering the irreplaceable of batteries of the sensor nodes. In the same time it should amenably support more than one sensor at a time with different degree in distributed approach that periodically selects the covers and switch between them to extend coverage time and tolerate unexpected failures at runtime. In this scheme the sensor is an autonomous system that has the authority to decide how to cover its sensing range. It also incorporates a novel technique for offline cover update (OCU) to facilitate asynchronous transition between covers. This approach is robust to failure pattern is no uniform.

Keywords: *Coverage, distributed approach, offline cover update.*

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1. Introduction

Recent advances in wireless communications and electronics have enabled the development of low-power, low-cost sensor nodes. These sensor nodes are multifunctional and small in size to communicate with each other in short distances.. Wireless sensor network are battery powered therefore prolonging the network life time through a power aware node organization is highly desirable. Since energy is the most critical resource considering the irreplacement batteries of the sensor nodes, an efficient method for energy saving is to be scheduled. Since the sensors are deployed in the important areas like military surveillance it should provide improved quality of field coverage and it should tolerate unexpected failures. The project aims to rapidly restore the field monitoring in an energy efficient way and to tolerate unexpected failures. It should also flexibly maintain diverse degree of redundancy in the field without needing the centralized control. Each node in the wireless sensor network should have the ability to recover quickly from illness. It also aims to extend the life span of the network and provide maximum coverage of the sensing region in an efficient approach.

In the last years, wireless sensor networks have gained increasing attention from both research community and actual users. In [9], the author focused on distributed deterministic cover selection technique to select a set of backup covers. Energy is optimized by putting sensors to sleep as possible. It provides full coverage to the monitoring area without the prior knowledge of neighboring nodes. But the unexpected node failure may reduce the quality of coverage until a new cover is selected. The flexible energy-efficient sensing coverage protocol is that each node can energetically decide a schedule to provide coverage with optimized energy [17]. MAC-based approach [5], in which sleep and wakeup periods of nodes is scheduled by duty cycle thus by idle listening the energy is consumed. In changing network conditions, such as unstable load or unexpected node failures this approach does not adapt. In [12], centralized deterministic cover selection approach is focused to increase the energy efficiency and to extend the network life span by schedule the sensors to participate alternatively both in sleep and active state. The multiple sets of sensors that works in equal interval allows redundant node to come in sleep state. Each point in the sensor network is covered by as a minimum of some pre-defined value of sensors thus the target area is sufficiently covered [2]. Here one type of resources is substituted with another using multimodal sensor fusion. In [6] probing environment and adaptive sleeping (PEAS) protocol which turnoff the nodes and tries to achieving good coverage and connectivity. PEAS consist of two simple algorithms they are Probing environment, which determines which node should work and Adaptive sleeping, which determines how to adjust dynamically the sensors sleep times in order to keep a constant wake-up rate. Optimal geographical density control (OGDC) protocol [9], which mainly focuses on maintaining coverage and connectivity using small number of nodes in the one of the following states UNDECIDED, ON or OFF. In [3], the author focuses on power conservation and quality of surveillance in target tracking sensor network where the nodes sleep for long interval of inactive time. In [15], author proposes a new model of coverage called trap coverage that scales well with large deployment regions. In [18], author propose the power efficient heuristic scheme for scheduling which makes the disjoint sets that determine the active time to maximize the life time of the network.

2. Related Work

In the last years, wireless sensor networks have gained increasing attention from both research community and actual users. In [9], the author focused on distributed deterministic cover selection technique to select a set of backup covers. Energy is optimized by putting sensors to sleep as possible. It provides full coverage to the monitoring area without the prior knowledge of neighboring nodes. But the unexpected node failure may reduce the quality of coverage until a new cover is selected. The flexible energy-efficient sensing coverage protocol is that each node can energetically decide a schedule to provide coverage with optimized energy [17]. MAC-based approach [5], in which sleep and wakeup periods of nodes is scheduled by duty cycle thus by idle listening the energy is consumed. In changing network conditions, such as unstable load or unexpected node failures this approach does not adapt. In [12], centralized deterministic cover selection approach is focused to increase the energy efficiency and to extend the network life span by schedule the sensors to participate alternatively both in sleep and active state. The multiple sets of sensors that works in equal interval allows redundant node to come in sleep state. Each point in the sensor network is covered by as a minimum of some pre-defined value of sensors thus the target area is sufficiently covered [2]. Here one type of resources is substituted with another using multimodal sensor fusion. In [6] probing environment and adaptive sleeping (PEAS) protocol which turnoff the nodes and tries to achieving good coverage and connectivity. PEAS consist of two simple algorithms they are Probing environment, which determines which node should work and Adaptive sleeping, which determines how to adjust dynamically the sensors sleep times in order to keep a constant wake-up rate. Optimal geographical density control (OGDC) protocol [9], which mainly focuses on maintaining coverage and connectivity using small number of nodes in the one of the following states UNDECIDED, ON or OFF. In [3], the author focuses on power conservation and quality of surveillance in target tracking sensor network where the nodes sleep for long interval of inactive time. In [15], author proposes a new model of coverage called trap coverage that scales well with large deployment regions. In [18], author propose the power efficient heuristic scheme for scheduling which makes the disjoint sets that determine the active time to maximize the life time of the network.

3. System Model

In WSN the sensor nodes are deployed in the area to be monitored. These sensors should have certain parameters. The nodes in the target region are assigned to active state that is V_A and the remaining nodes in the network are in sleep state.

3.1. Selecting One Hop Neighbor

The one hop neighbor is selected for the nodes in V_A for continuous surveillance. The distance between each node in V_A and the other nodes in the network is calculated using the distance formula,

$$d(a,s) = \sqrt{(a_2 - a_1)^2 + (s_2 - s_1)^2} \quad (1)$$

Where,

(a_1,a_2) is the x and y coordinates of V_A

(s_1,s_2) is the x and y coordinates of remaining nodes except V_A

The neighbor set of each active node in V_A is defined as

$$N_b = \{n \in N_s | d(a,s) \leq r, a \notin V_A\} \quad (2)$$

Where,

n is the neighbor node

N_s is the set of nodes in the deployed region

Equation (2) explains that the neighbor node should be an element of the nodes in the deployed region and the distance should be less than or equal to some constant.

3.2. Backup cover selection

The backup cover is selected such that the set of neighbor node should cover the whole sensing region of the active node v in the set V_A. The nodes in the backup cover S is disjoint. The backup cover S is constructed by sorting the neighboring node in the set N_b. The sorting of the nodes is based on the following optimization parameter.

- The neighbor nodes should have largest percentage of area in common.
- Nodes should not be the member of the backup cover set of other active node.
- Prefer the nodes which have least frequency.

The top listed node is added to the backup cover set S. Similarly more than one backup cover set is computed.

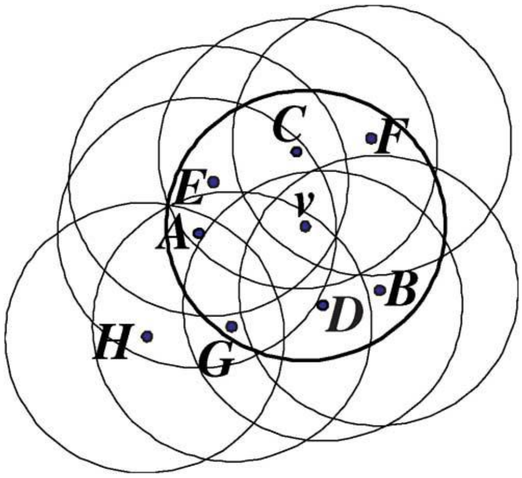


Figure 1. Configuration containing node v and its neighbors

Table 1:- Selecting three backup cover for a node v that shown in Figure 1.

Step	A	B	C	D	E	F	G	H	Cover set
0	0	0	0	0	0	0	0	0	
1	1	1	1	0	0	0	0	0	s_1={A,B,C}
2	1	1	1	1	1	1	0	0	s_2={D,E,F}
3	1	2	1	1	2	2	1	0	s_3={G,B,E,F}

In the Table 1 the numbers under each neighbor denote the frequency of occurrence of that neighbor in the S covers. Node H was not selected in s_3 because it became redundant after was added. Note that our approach ensures that no partial covers of v are selected unless all full covers are.

3.3. Scheduling Backup Node

This system employs that opportunistic sleep/wakeup schedule and optimization scheduling scheme. Number of slots in which lost monitoring is tolerated is M. This method reduces the ideal listening of the node while sensing the important region. The duty cycle for each node is assigned. In single wake up schedule the length of the schedule is k slots and each sensor assigned one of the k slots during which it activates its radio for reception known as the active slot. Otherwise the sensor nodes are in sleep state to prolong the life time of the sensor. Since there is no synchronization between nodes, a backup node u follows the schedule that is defined by the master node v and based on v's current clock without having to update u's clock.

1. Let Si be the i^{th} backup cover of v , $1 \le i \le S$.
2. The opportunistic approach activates the nodes in S_1 within M slots, the nodes in S_2 within 2M slots, and so on.
3. Let V_J be the neighbor of V.
   - Initial wakeup time for the node V_J is max{ iM-nci+j , 0}
   - V_J can sleeps for min {iM ,T^1} cycles.

3.4. Backup node probing

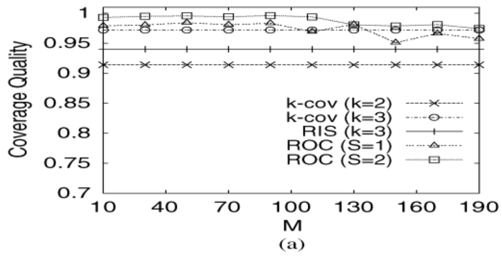
The activated node sends message to neighbor node which belongs to active node set (V_A). If the current node region is already monitored by any other active sensor node then the node goes back to sleep mode.

3.5. Offline Cover Update

To select covers without the need for synchronized nodes, we develop a novel technique for offline cover update (OCU). OCU selects a new cover based on any cover-selection algorithm. It lets the nodes in the current V_A compute the next network cover that should take charge after V_A 's operation interval is over. The nodes V_A in participate in the selection of a new cover by exchanging information about their one-hop neighborhoods and simulating the roles of their sleeping neighbors (proxying).

4. Performance Evaluation

To evaluate and analyze the performance of the proposed schemes, we simulate in a stationary WSNs with N sensors and M targets deployed randomly in 50m x 50m area. In the simulation, it is assumed that all sensors have the same initial energy. Each sensor can be activated for a unit time of 1. In the simulation, the performance of the OCU is compared.



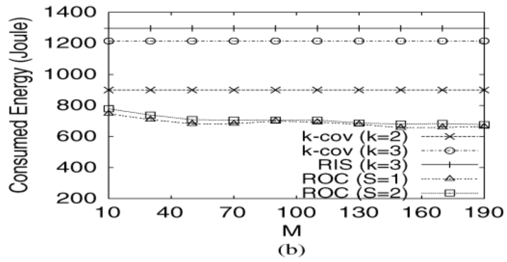


Figure 2. Performance analysis a. Coverage quality b. Energy Consumption

Figure 2 shows the network lifetime as a as a coverage quality and energy efficiency. When the number of targets M is vary. It is shown that the network lifetime is increased by 75% in case of applying OCU scheme. As the number of sensors increases, each target is covered by a larger number of sensors. Therefore, the life span of is increased and it is fault tolerant and energy efficient.

5. Conclusion

In this work, the resilient online coverage is presented with opportunistic scheduling approach, to achieve adaptability, fault tolerance, and energy efficiency. This scheme can employ to both area coverage and barrier coverage techniques. It allows different degrees of redundancy across the field, in addition to controlled speed of recovery of failures. Simulation experiments show that OCU scheme is more energy efficient and fault tolerant than the opportunistic scheduling. So the lifespan of the network gets extend.

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