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TARGET COVERAGE MANAGEMENT PROTOCOL FOR WIRELESS SENSOR NETWORK

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ABSTRACT

One of the major challenges of Wireless Sensor Network is Target Coverage Problem which is concerned with random deployment of sensor nodes for monitoring the specific targets for maximum duration. These small sized sensor nodes have limited resources in terms of energy, memory, computational speed and bandwidth; and can't withstand extreme environmental conditions. Therefore, more number of sensor nodes are deployed than the specific requirements in order to improve fault tolerance of the sensor network. However, this high redundancy of sensor nodes can lead to excessive energy wastage. Since the nodes have limited energy resources and each sensor node requires a specific amount of energy to monitor a target, judicious energy management becomes an important concern of the Target Coverage Problem. In this paper we propose a protocol for Target Coverage Management with the aim to minimize consumption of energy.

Keywords: *Wireless Sensor Network, Target Coverage, Energy Conservation*

1. INTRODUCTION

Recent advances in technologies made it technically and economically feasible to combine sensing, processing and communicating capabilities into small low cost sensor devices. Once these nodes get deployed, they self organize to form Wireless Sensor Network (WSN) and communicate via wireless links to perform a specific task of real world. Availability of different sensor nodes with varieties of sensing capabilities results in hundreds of applications including National Security [8], Habitat Monitoring [17,18], Environment observation and forecasting [19], Health Applications [8,20], Home and Office Applications [21].Therefore WSNs are becoming an active research field with numerous research activities carried out every year to explore and solve different constraints.

The Wireless Sensor Network may be defined as being composed of large number of spatially distributed autonomous wireless sensor nodes that co-operatively monitor the physical conditions of the environment such as temperature, pressure, humidity, wind speed, sound, etc. and forward the sensed information to the special node called base station which acts an interface between these sensor nodes and the real world[9].

Typically a Wireless Sensor Node consists of a sensing unit, a processing unit, a communication unit and a power unit [22,23], that is used for sensing the relevant data, processing of the collected data and communicating with other connected nodes in the WSN. These nodes after deployment form the network to monitor the specific region of interest.

1.1. Characteristics

Some of the unique characteristics and constraints of WSN includes:

- The sensor nodes are densely deployed in the specific region of interest.
- These nodes after deployment can automatically self-configure into a network
- The sensor network topology changes frequently.
- The nodes are usually battery powered.
- They are equipped with limited resources.
- They are prone to failures.
- They are application specific.

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Therefore most sensor network design objectives include scalability, self-configurability, low power consumption, flexibility, low node cost, smaller node size, fault tolerance, security, and support for QoS requirements.

1.2. Coverage Problem

An important problem addressed in Wireless Sensor Network is Coverage Problem [1,2]. It is basically concerned with a question: How efficiently the specific region of interest is being covered by the sensor nodes? The objective is to have the region monitored by at least one sensor node. It may be broadly classified into three main categories:

- Area Coverage Problem [4,5,25,13,15] where the goal is to monitor a specific region or area.
- Target Coverage Problem [1,6,7,16,24]where the goal is to monitor a specific set of targets or points.
- Coverage dealing with the determination of the maximum support /breach path [10,14]

In this paper we will be dealing only with the Target Coverage Problem which is concerned with the coverage of specific targets by the sensor nodes. These nodes require energy for performing the coverage task. Since, the sensor nodes are usually battery powered, therefore judicious management of energy is an important concern so that coverage task can be performed for a maximum duration. In this paper, we propose an algorithm to perform the coverage task with minimum participation of sensor nodes to cover the targets, thereby consuming minimum energy.

This paper is organized as follows: In section 2, the Target Coverage Problem and the related works are discussed. In section 3 we present a Target Coverage Management Protocol for WSN. Finally, in section 4 we conclude our work.

2. TARGET COVERAGE PROBLEM AND RELATED WORK

Target Coverage Problem is one of the challenges of Wireless Sensor Network. It is concerned with the maximization of sensor network lifetime while performing the task of monitoring the specific targets by a set of randomly dispersed sensor nodes (as shown in Figure 1). Considering a number of targets (say $r_1,r_2,r_3.....r_m$) whose locations are already pre-determined, a set of sensor nodes (say $s_1,s_2.........s_n$) are redundantly deployed with the help of an aircraft to keep track of these specific targets, assuming that a sensor node covers the target if the Euclidean distance between the sensor node and the target is smaller or equal to the sensing range of the node [1]. Each of these nodes requires energy to monitor the targets. Since the nodes have limited battery life, efficient utilization of the available energy resources becomes important for performing the coverage task for a maximum period of time. Therefore the energy conservation becomes a critical issue while tracking the targets.

2.1. Challenges:

Wireless Sensor Nodes while covering the specific targets may suffer from some challenges [22] like:

- The Sensor nodes are prone to failure due to extreme environmental conditions.
- The topology of a sensor network changes very frequently.
- Sensor nodes are limited in power, computational capacities, and memory.
- Wireless Sensor Networks processing sensitive data are facing the risks of data manipulation, data fraud and sensor destruction or replacement.
- WSN deals with real world problems where the sensed data must be delivered within fixed time limits. However most protocols fail to meet the deadlines.

Therefore more number of sensor nodes than the specific requirements are deployed to improve the fault tolerance. However, this high redundancy of sensor nodes can lead to excessive energy wastage and also the maintenance of batteries of the sensor nodes is not a simple task. So while covering the targets, minimum consumption of energy must be taken into consideration in order to achieve coverage for a maximum duration. An energy saving technique is to alter the sensor nodes between high energy consumption active mode and low energy consumption sleeping mode [1,11]. The nodes that are actually performing the coverage task are in active mode that consumes a considerable amount of energy while the rest nodes may enter into sleep mode which consumes negligible amount of energy. The latter nodes can be re-entered into active mode when needed and the former may go into sleep mode. This scheduling of nodes may result in efficient energy conservation.

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In the Figure 1, four sensor nodes represented by small filled circles are in active mode covering the targets represented by small squares. Rest sensor nodes represented by small circles are in sleep mode.

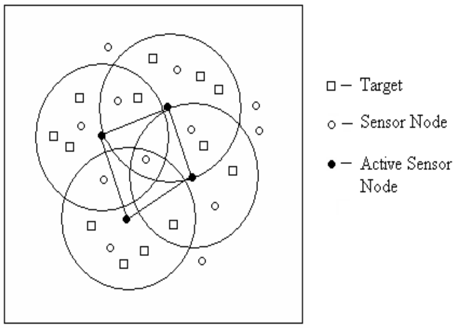

Figure 1.A Scenario of Target Coverage Problem

Numerous research works [1,3,6,7,12,16] have been conducted to cover the required targets by the randomly dispersed sensor nodes: Simplest method was to have all the redundant nodes deployed to get activated but at the cost of unnecessary wastage of energy resulting in coverage of the targets for a minimum duration. Later several energy efficient approaches were proposed in which the nodes alter between the active and sleep modes. Set covers of sensor nodes are formed with each set cover having sensor nodes covering all the targets. According to the work in [16] several dis-joint set covers of active sensor nodes are successively activated until all the nodes get exhausted of their energy. Work in [1] came with a much more energy aware approach in which non-disjoint set covers were formed with a sensor node being part of more than one set cover which resulted in coverage of the targets for longer period of time. Many coverage approaches also dealt with partial coverage where information is collected only about a sub-set of targets [12].

3. OUR PROPOSED WORK

We propose that in the formation of non-disjoint set covers of sensor nodes to cover the specific targets, if a target is within the sensing range of two or more sensor nodes, then only one of the sensor nodes may be initiated to monitor the specific target while the other sensor nodes of that sensing range may not be required to participate, as shown in Figure 2. This prevents unnecessary wastage of the energy as each sensor node consumes a specific amount of energy to continuously sense a target.

In Figure 2, target r_k is within sensing range of sensor nodes s_i and s_j (denoted by W_i and W_j respectively). It may be possible to assign one of these nodes to cover the target based upon the shortest Euclidean distance between the sensor node and the target, i.e. if ($d_{ik} <= d_{kj}$),then $s_i = \{r_k\}$ else $s_j = \{r_k\}$ as shown in Table 1.

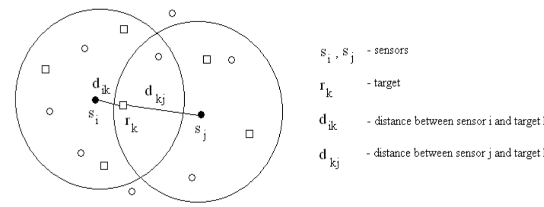

Figure 2.Coverage of a target by sensor nodes based on shortest Euclidean distance between them.

```
for i ← 1 to n
    do for j ← 1 to n
          do for k ← 1 to m
               do if ( d_ik <= W_i ) && ( d_kj <= W_j )
                    find t ← min(d_ik, d_kj)
                    s_t = s_t ∪ r_k
                    if (t = = i)
                      s_j = s_j - r_k
                    else if (t = = j)
                      s_i = s_i - r_k
```

Table 1.Algorithm for Coverage of targets by sensor nodes based on shortest Euclidean distance between the sensor nodes and the targets

Consider a scenario in which there are five number of targets (r_1,r_2,r_3,r_4,r_5) which are being covered by a set of six sensor nodes (s_1,s_2,s_3,s_4,s_5,s_6) with the sensor-target coverage relationship known as:
$s_1=\{r_1,r_5\}$, $s_2=\{r_1,r_2\}$, $s_3=\{r_2,r_3\}$, $s_4=\{r_3,r_4\}$, $s_5=\{r_4,r_5\}$, $s_6=\{r_1,r_2,r_3,r_4,r_5\}$ and the Euclidean distance assumed as shown in Table 2. Here each sensor node's sensing range is assumed to be 41 unit of distance.

d_{11} = 32	d_{12} = 63	d_{13} = 75	d_{14} = 61	d_{15} = 40
d_{21} = 38	d_{22} = 22	d_{23} = 67	d_{24} = 91	d_{25} = 88
d_{31} = 71	d_{32} = 37	d_{33} = 24	d_{34} = 64	d_{35} = 79
d_{41} = 93	d_{42} = 80	d_{43} = 36	d_{44} = 30	d_{45} = 56
d_{51} = 98	d_{52} = 105	d_{53} = 76	d_{54} = 36	d_{55} = 37
d_{61} = 37	d_{62} = 37	d_{63} = 37	d_{64} = 37	d_{65} = 37

Table 2.Assumed Euclidean distance between the sensor nodes and the targets

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According to the work in [1] ,these sensor nodes get organized to six non-disjoint set covers to monitor the targets for a maximum duration (assuming that a sensor node covers the target if the Euclidean distance between the sensor node and the target is smaller or equal to the sensing range of the node) : $SC_1 = \{s_6\}$, $SC_2 = \{s_2,s_3,s_5\}$, $SC_3 = \{s_2,s_4,s_5\}$, $SC_4 = \{s_1,s_3,s_4\}$, $SC_5 = \{s_1,s_2,s_4\}$, $SC_6 = \{s_1,s_3,s_5\}$.Energy consumed by a sensor node to cover a particular target in each set cover is represented by a unique rectangular box as shown in the Figure 3. Here, if each sensor node consumes x unit of energy to keep track of a target, the total energy consumed by all the sensor nodes is 35x units of energy.

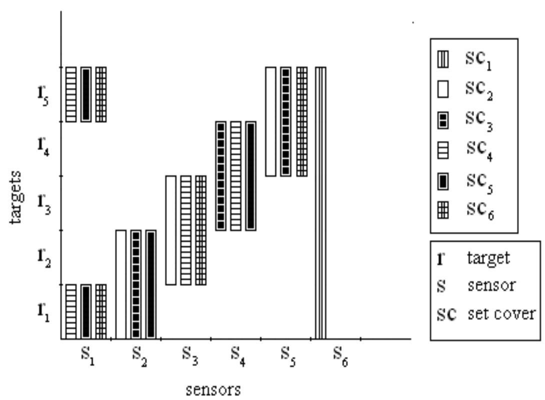

Figure 3.Coverage of targets by sensor nodes in different set covers according to work in [1].

However we propose that the targets, which are within the sensing range of more than one sensor nodes, may be covered by only one of these nodes having the minimum distance to the target. For instance in set cover SC_2 , r_2 is covered by s_2 and s_3. So here r_2 now would be covered only by s_2 due to shortest distance between them. Rest calculation is done similarly as shown in Figure 4. Here, the total energy consumed by all the sensor nodes is 30x units of energy, thus a saving of 5x units of energy can obtained as compared to the previous work. This method in certain situations may result in load balancing between the sensor nodes. We have proposed the protocol for smooth management of the Target Coverage Scenario where the energy consumption is lower as compared to the existing protocol.

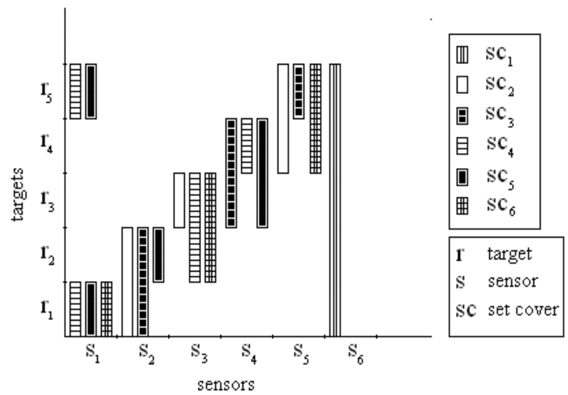

Figure 4 .Coverage of targets by sensor nodes in different set covers according to our proposed work.

4. CONCLUSION

Coverage of the specific targets is an important concern in Wireless Sensor Network. In this paper we discussed the basic Target Coverage Problem and some strategies to achieve energy efficient coverage of the specified targets taking into consideration maximization of network lifetime and minimum participation of the sensor nodes while performing the coverage task. Energy is the scarcest resource of the sensor nodes. So, taking into consideration the judicious management of the energy resources of the sensor nodes, that results in saving of a considerable amount of the energy of the nodes by eliminating the simultaneous activation of redundant sensor nodes while observing a specific target.

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