Area Coverage with Heterogeneous Sensors in the presence of Jammers in a Wireless Sensor Network environment

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Purview

- Introduction
- Applications
- Motivation
- Broad Objective
- Certain Definitions
- Problem Statement
- Approach to Solve the problem
- Experimental Setup
- Results obtained
- Future aim
- References

Introduction

- What are Wireless Sensor Networks (WSN)
- Deployment options
- Applications
  - ❖ Agriculture
  - ❖ Environmental Monitoring
  - ❖ Military Applications
- Threat by Jammers
  - ❖ Attacks on the network
  - ❖ Attacks on the sensor

Coverage in WSNs

- Point Coverage
- Sweep Coverage
- Path Coverage
- Breach Coverage
- Barrier Coverage
- Area Coverage

Motivation

- Reconnaissance & Surveillance
- Long border with enemy
  - Large patches inhospitable
  - Can't cover every inch of land manually
- Increase in cross-border activity
- Easier to transport troops to affected areas than placing them there ab-initio
- Enemy will interfere with our WSN
  - Jam the network
  - Jam the sensor
  - Inject false information
  - Deceive the sensor

Broad Objective

- Create a Surveillance Grid using WSN
  - Use of heterogeneous sensors like Radar, Camera, Audio sensors, etc.
  - All sensors types might have different ranges
  - Obviate the effect of enemy jammers
  - Minimize the number of sensors used

Definitions

- Area of Interest
  - The area under surveillance
  - Depicted by $A = \{(x_0^A, y_0^A), (x_0^A, y_1^A), (x_1^A, y_1^A), (x_1^A, y_0^A)\}$

- Set of heterogeneous sensors
  - $S = \{S_0, S_1, S_2, \dots, S_n\} \quad n \geq 1$
  - Info with each sensor type $S_i \in S$
    - Range of operation R_i^S which determines the Area of Influence A_i^S of the sensor
    - Set of feasible locations $L_i^S = \{(x, y) \mid x_0^A \leq x \leq x_1^A,\ y_0^A \leq y \leq y_1^A\}$
    - Cost C_i^S

- $\forall s \in S_i$ following tuple is associated
  - $(s.type, s.range, s.location, s.cost)$

    where, $s.type \in S$

    $s.range = R^S_{s.type}$

    $s.location \in L^S_{s.type}$ (the current location of the sensor)

    $s.cost = C^S_{s.type}$

- Set of jammers $J = \{J_0, J_1, \dots, J_m\}$ $m \geq 1$
  - $\forall J_i \in J$ following holds:
    - have a circular area of influence
    - Range of operation R^J_i which determines the area of influence of the jammer A^J_i
    - Fixed location $L^J_i = (x_i, y_i)$
    - Cost of operation C^J_k

- $\forall S_j \in S$ in presence of a jammer J_k has a probability of sensing P_{jk} defines as follows:

$$P_{jk} = \begin{cases} 0 & if\ S_j\ can\ be\ jammed\ by\ J_k \\ 1 & if\ S_j\ cannot\ be\ jammed\ by\ J_k \end{cases} \quad 0 \le i \le m, \qquad 0 \le j \le n$$

Assumptions

- Position of the enemy Jammers remain static.
- Area of Interest A is a rectangle.
- Infinite number of sensors of each type are available
- Feasible locations for the sensors is within the Area of Interest.

Goal

- Find a minimum cardinality set $R = \{r_i\}\ 1 \leq i \leq q$ where,
  - ❖ r_i is a sensor such that $r_i.type \in S$
  - ❖ $r_i.location \in L^S_{r_i.type}$ is the location of the sensor fixed by the algorithm.
  - ❖ For every point $p \in A$ following should hold:
    - ➢ If p is in the Area of Influence of a jammer $J_k \in J$ then p is in the Area of Influence of some sensor r_i with $t = r_i.type$ such that P_{tk}=1
    - ➢ If p is out of the Area of Influence of all jammers then p is in the Area of Influence of some sensor r_i

Literature Survey

Development Approach

- Related computational geometry problems
  - Art gallery problem
  - Circle packing problem

- Problems in direct application
  - Art gallery problem
    - Assumes the cameras have ∞ range
    - Heterogeneous sensors not considered
  - Circle packing problem
    - Assumes all circles have the same radius when covering a rectangle
    - Variation with different radii circles leaves gaps between circles

Development Approach

- Phase 1
  - Ignore the use of jammers
  - Assume all sensors have same cost
  - ∞ sensors of each type are available
  - Find the minimum cardinality set of sensors which covers the rectangular region

- Phase 2
  - Jammers to be considered
  - Sensors types will incur different costs
  - Fixed number of each type of sensors are available
  - Find the minimum cardinality set of sensors which covers the rectangular region

Problem Subdivision

- Problem can be subdivided into:
  - ❖ Identify if a rectangular region is covered by a set of heterogeneous sensors
  - ❖ Find subsets of sensors which cover the region
  - ❖ Find the minimum cardinality subset

Definitions

- Perimeter-covered
  - Consider any two sensors s_i and s_j. A point on the perimeter of s_i is perimeter-covered by s_j if this point is within the sensing range of s_j.
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- k-Perimeter covered
  - Consider any sensor s_i. We say that s_i is k-perimeter covered if all points on the perimeter of s_i are perimeter covered by at least k sensors other than s_i itself. Similarly, a segment of $s_i's$ perimeter is k-perimeter covered if all points on the segment are perimeter covered by at least k sensors other than s_i itself.

Definitions

- Perimeter Coverage Level (PCL)
  - PCL of a sensor A is the number of the sensors in the same set that cover any point on A's perimeter of the sensing area.

Region Coverage

- Huang and Tseng in their paper titled "The Coverage Problem in a Wireless Sensor Network" prove the following:

  - *Suppose that no two sensors are located in the same location. The whole network area A is k-covered iff each sensor in the network is k-perimeter-covered*

- Above result used in determining if a rectangular region is covered or not

Boundary Conditions