Worst and Best-Case Coverage in Sensor Networks
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Definition of Sensor coverage

Sensor coverage is the quality of service (surveillance) that can be provided by a particular sensor network.
Example

Millions of acres that are lost around the world, due to forest fires every year. In all fires, early warnings are critical in preventing small harmless brush fires from becoming monstrous infernos.

Q: how well the network can observe a given area and what the chances are that a fire starting in a specific location will be detected in a given time frame?
Network Topology & Sensor Model

Topology and Network model are affected due to the extremes targeted at:

• Miniaturization
• Availability
• Accuracy
• Reliability,
• Power savings
• Small physical nodes
• Low power consumption
• Low cost \(\rightarrow\) limited communications
In most models one aspect is in common → sensing ability is directly dependent on **Distance**

**Location Discovery Techniques**

- GPS → Expensive
- Received Signal Strength Indicator (RSSI) of RF communication → distance of nodes
- Time difference in arrival of RF and acoustic (ultra-sound) signals
- Trilateration → know location of three nodes
In our Discussion

• **worst-case coverage problem**
we want to find the closest distance to sensors that an agent traveling on any path in the sensor field must encounter at least once. The main idea here is that the closest distance to sensors is one metric by which sensor coverage of the field can be characterized.

• **Best-case coverage problem**
we want to find the farthest distance to sensors that an agent traveling on any path in the sensor field must have from sensors, even if it tries to stay as close to sensors as possible.
Knowledge-base

• Computational geometry

• Graph theoretic techniques
  • Voronoi diagram
  • Graph search algorithms
Voronoi diagram

- All points inside a polygon are closest to only one point
- Edges are equidistant from neighboring points
Worst-Case Coverage & Maximal Breach Path

- $S =$ Sensors in area.
- $P =$ Path connecting areas I and F.
- Breach = Minimum Euclidean distance from $P$ to any sensor in $S$.
- Problem: Maximal Breach Path. Identify a Maximal Breach Path $P$ in $A$, connecting the areas I and F.
Worst-Case Coverage: Theorem & Proof

**Theorem**: At least one Maximal Breach Path must lie on the line segments of the bounded Voronoi diagram formed by the locations of the sensors in S.

**Proof**: Since by construction, the line segments of the Voronoi diagram maximize distance from the closest sites, a Maximal Breach Path must lie on the line segments of the Voronoi diagram corresponding to the sensors in S.

If any point p on the Maximal Breach Path deviates from Voronoi line segments, by definition, it must be closer to at least one sensor in S.
Algorithm for Finding a Maximal Breach Path

1. Generates the Voronoi diagram corresponding to the sensors in S.
2. The weighted, undirected graph G is constructed by creating a node for each vertex and an edge corresponding to each line segment in the Voronoi diagram. Each edge in graph G is assigned a weight equal to its minimum distance from the closest sensor in S.
3. Performs a binary search between the smallest and largest edge weights in G.
4. In each step, breadth-first-search (BFS) is used to check the existence of a path from I to F using only edges with weights that are larger than the search criteria called breach_weight.
5. If a path exists, breach_weight is increased to further restrict the edges considered in the next search iteration.
6. If a path is not found, breach_weight is lowered to relax the constraint on the search.
7. The algorithm has found a Maximal Breach Path, which is a path from I to F with its smallest weighted edge being as large as possible.
Breach = 40
- All edges with weights less than 40 are ignored
- The optimal breach_weight has been found to be 57.
Best-Case Coverage and Maximal Support Path

- **S** = Sensors in area.
- **P** = Path connecting areas I and F.

**Support** = Maximum Euclidean distance from the path P to the closest sensor in S.

**Problem**: Identify the Maximal Support Path in S, starting in I and ending in F.
Best-Case Coverage: Theorem & Proof

**Theorem**: At least one Maximal Support Path must lie on the edges of the Delaunay triangulation (with the exceptions of the start and end points connecting Maximal Support Path to I and F).
• After deploying 100 sensors, breach coverage can be improved by about 10 percent by deploying just one more sensor.
Stochastic Deployment—Asymptotic Behavior

Given the unit square field and using the distance-based sensor model, after deploying about 100 sensors, additional random sensors do not improve coverage very significantly. This asymptotic nature of breach and support coverage suggests that by analyzing a given field and selecting the proper number of sensor nodes, certain levels of coverage can be expected even if sensor deployment cannot be performed according to an exact plan.
Thank You.

Questions?