Directional Wireless Sensor Networks with Guaranteed Connectivity and Coverage

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Problem Formulation

Motivation:

In deployments, sensors may only possess limited sensing coverage, such as sector (or directional) sensing coverage, due to equipment constraints or environmental impairments.

Assumption:

❋Stationary wireless sensors whose sensing coverage is a sector centered at each sensor with a sensing radius *rs* and a sensing angle α ($0 \leq \alpha \leq \pi$).

❋ Each sensor has an omni-directional communication range, which is a circle centered at each sensor with a communication radius *rc*.

❋ For simplicity, we assume $rs \leq rc$.

The Problems We Study:

❋ **Connected Point-Coverage:** Deploy a minimum number of directional sensors to form a connected network that covers a given set of point-locations scattered in a 2D plane.

❋ **Connected Region-Coverage:** Find an efficient pattern to deploy directional sensors to form a connected network to cover an infinite 2D plane.

Connected Point-Coverage

Complexity : NP-hard problem. We focus on finding approximation algorithm and its approximation ratio.

Algorithm for Geometric Sector Cover :

❋ In order to solve the *connected point-coverage* problem, we need to first solve another NP-hard problem, namely geometric sector cover, which seeks to use a minimum number of sectors to cover a given set of points.

❋ We give an O(logN)-approximation algorithm for sectors with arbitrary α.

❋ We given a constant approximation algorithm for fat sectors where $\sin(\alpha) \geq c$ *(c is a constant).*

Algorithm for Connected Point-Coverage :

Algorithm:

Step 1: Run Geometric Sector Cover algorithm on the give set of points and get a set of sensors *S.*
Step 2: Compute a geometric MST *T* over *S*.
Step 3: For each edge *ab* in *T*, starting from *a*, add one sensor for every distance of *rc* along the edge *ab* until *a* and *b* are connected.

Approximation Raito :
(2X + 10) where X is the approximation ratio of the algorithm for Geometric Sector Cover.

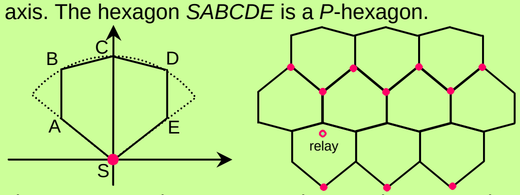
Connected Region-Coverage

Complexity : Finding the optimal solution is an open problem. We focus on finding an efficient pattern to form a connected sensor network.

Definition: A *P-hexagon*[1] is a hexagon with a pair of parallel opposite sides of equal length.

Find *P*-hexagon in sector to cover the plane:

For a sector, *S* and C denote the center of the sector and the middle point of the arc, respectively. We put this sector on an xy-coordinate system where *S* coincides with the origin, and *C* is on the y-axis. We find two points *A* and *E* on the two edges of the sector with equal distance to *S*. Then we find two more points *B* and *D* on the arc such that *AB*, *DE* are vertical to the x-axis. The hexagon *SABCDE* is a *P*-hexagon.



Theorem: Each sector contains a P-hexagon whose area is no less than $\frac{3\sqrt{3}}{2\pi}$ (≈ 82.7%) of the area of the sector.

Remark: Additional relay nodes need to be added to guarantee connectivity. However. Since the number of relay nodes is vanishingly small, the overlap area can be omitted.

[1] W. Kuperberg "Covering the plane with congruent copies of a convex body", Bulletin of London Mathematical Society. Vol.21, PP.82-86, 1989.

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