Localization of Sensors

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Problem Statement

Given a sensor network of N sensors at locations S = {S1, S2,.......,SN}. So, mathematically the localization problem can be formulated as follows: given a multihop network, represented by a graph G = (V, E),and a set of beacon nodes B, their positions {xb, yb} for all b ε B, we want to find the position {xu, yu} for all unknown nodes u ε U.

Radio Propagation Model

- ITU Terrain Model.

- Applicable for all terrains.

- Valid for all distances and frequency.

- Handles diffraction due to obstacles.

- Developed on the basis of diffraction theory and first fresnel zone.

Radio Propagation Model
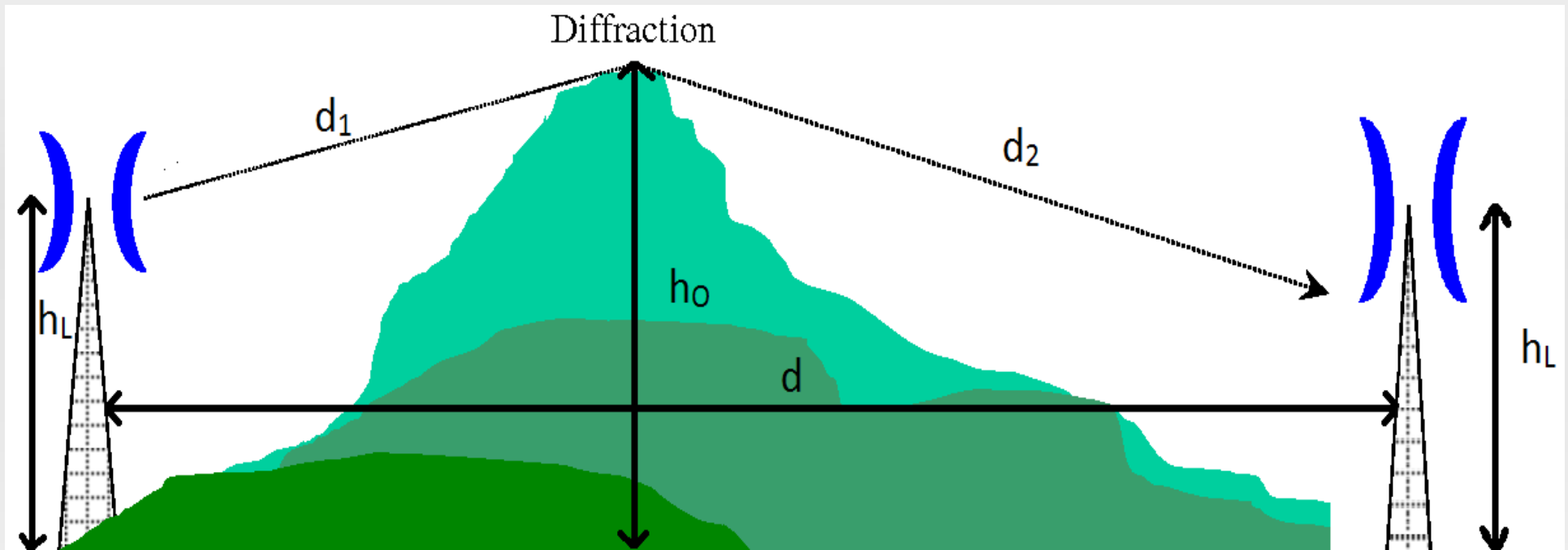
Formula: $A = 10 - 20C_N$ $C_N = h/F_1$ $h = h_L - h_O$

$F_1 = 17.3 \sqrt{d_1 d_2 / fd}$ where, f is frequency and A is additional loss due to diffraction.

These losses are summed with Friis transmission equation loss to get overall signal strength.

Implemented Algorithms

- APIT
- Diffusion
- Moving Sensor
- Gradient
- Centroid

APIT

- Node are assumed to be listening to beacons, and storing distances from each one.

- Based on the signal strength, it determines the triangles in which the node lies.

- Centroid of the intersection area of all such triangles is estimated to be the localized coordinates.

APIT



Centroid of intersection
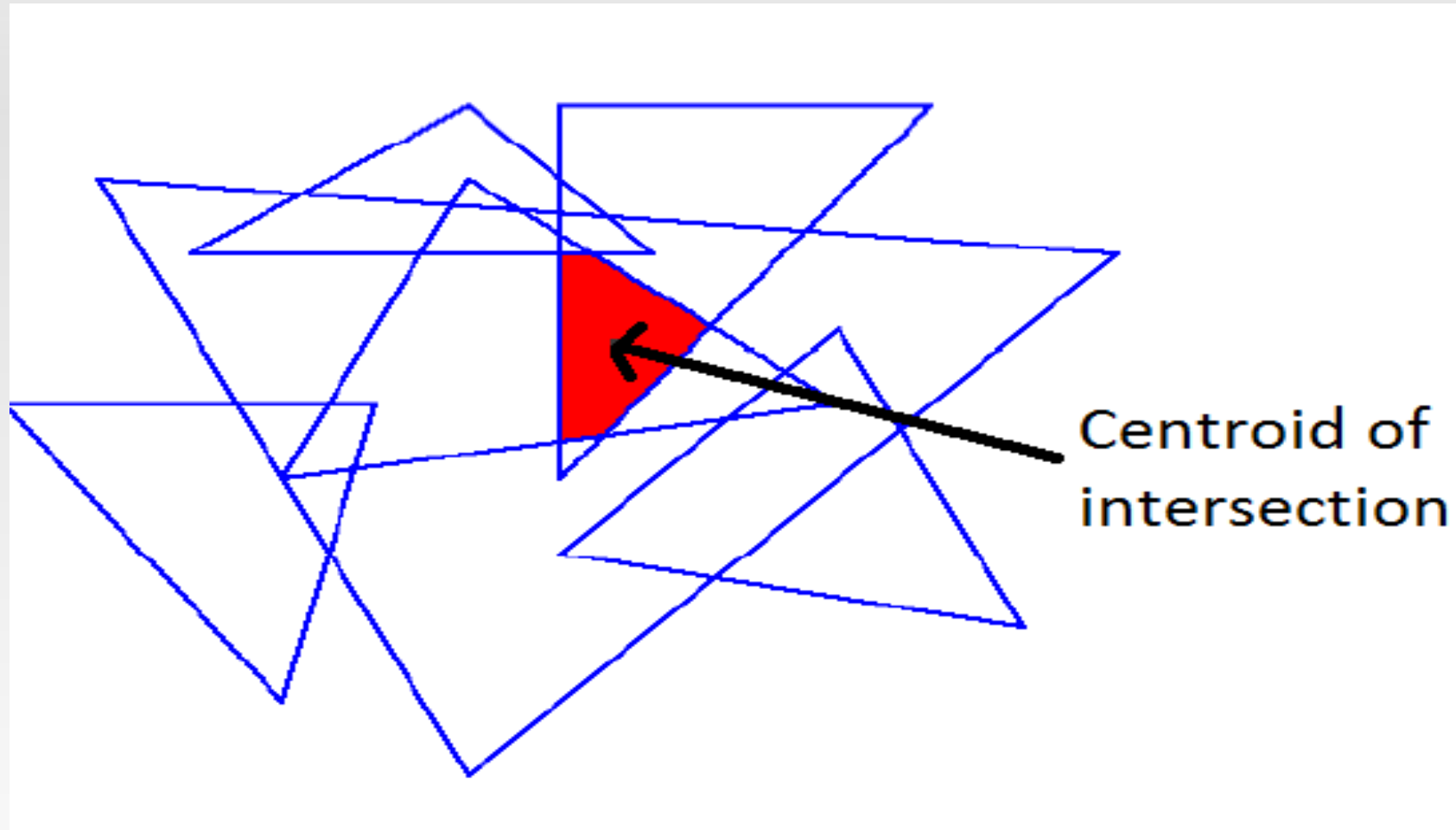
Diffusion

- Location of a node is centroid of its one hop neighbors.

- Iteratively allocate location of a node to be average of it's neighbors.

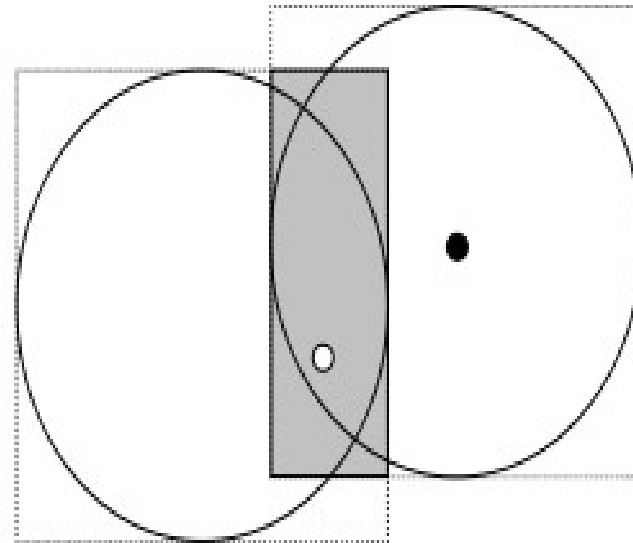- Terminate when steady state is reached, or after a fixed number of loops.

Moving Sensor

- A beacon is randomly moved in the grid and it broadcasts its coordinates to the neighbors at all time.

- Every time a node senses the beacon, it generates a new quadratic constraint that it uses to further reduce the uncertainty in its position.

Moving Sensor
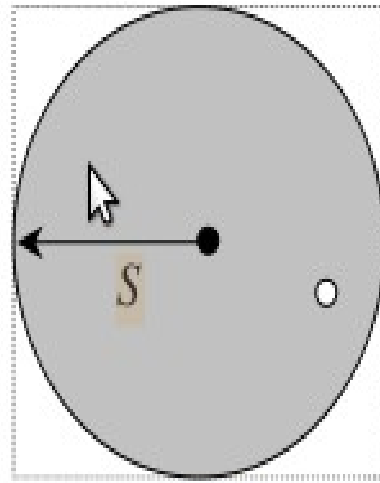
(a) Node sensing beacon for the first time and constraining itself in the shaded region.
(b) Beacon moves to another location, node senses again and reduces its region.

Gradient

- All beacons initiates a gradient by sending its neighbors a message with its location and a count set to one.

- Each recipient remembers the value of the count and forwards the message to its one hop neighbors with the count incremented by one.

- Hence a wave of messages propagates outwards from the beacon, while each sensor maintains the minimum counter value received from all beacons.
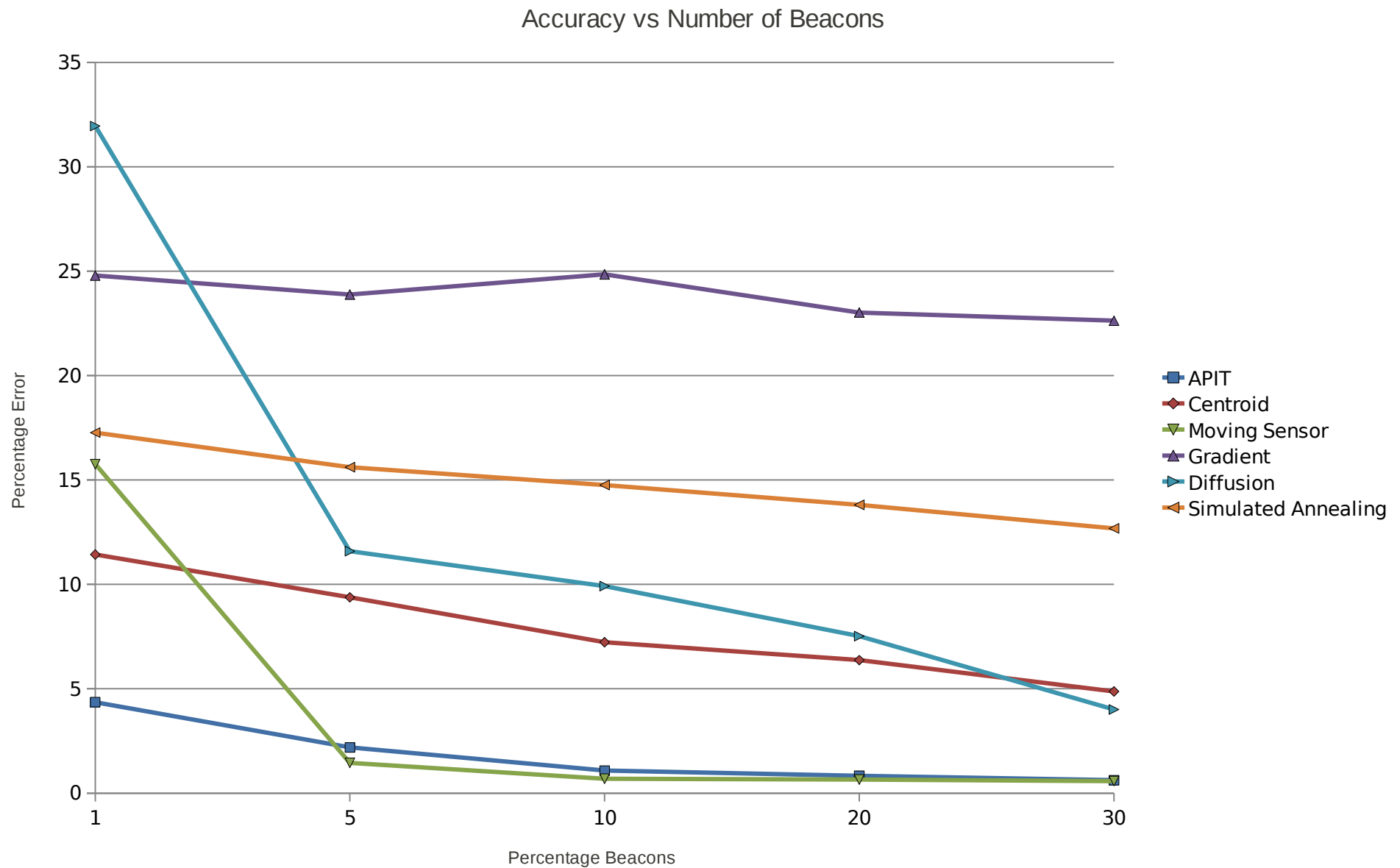
Gradient

- Hop size of each beacon is calculated by using the number of hops and actual distances from other beacons.

- A error function of two variables x,y for each node is minimized, which is defined by:

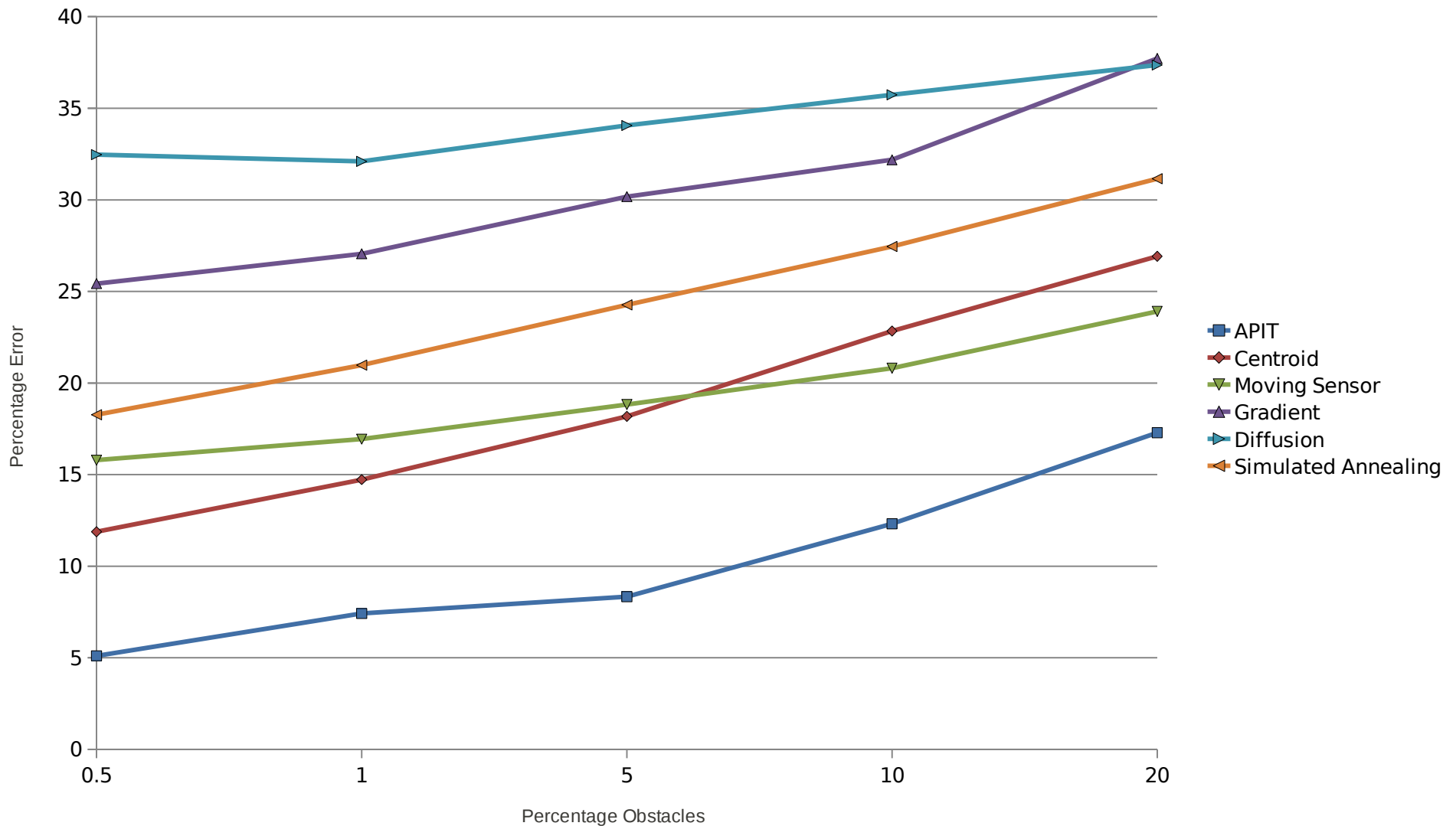Error = $|\Sigma(x-x_i)^2+\Sigma(y-y_i)^2-\Sigma d_i^2|$ summed over all beacon nodes(i).

Centroid

- Triangulation of beacons is used, to determine triangle containing the nodes, based on the signal strength.

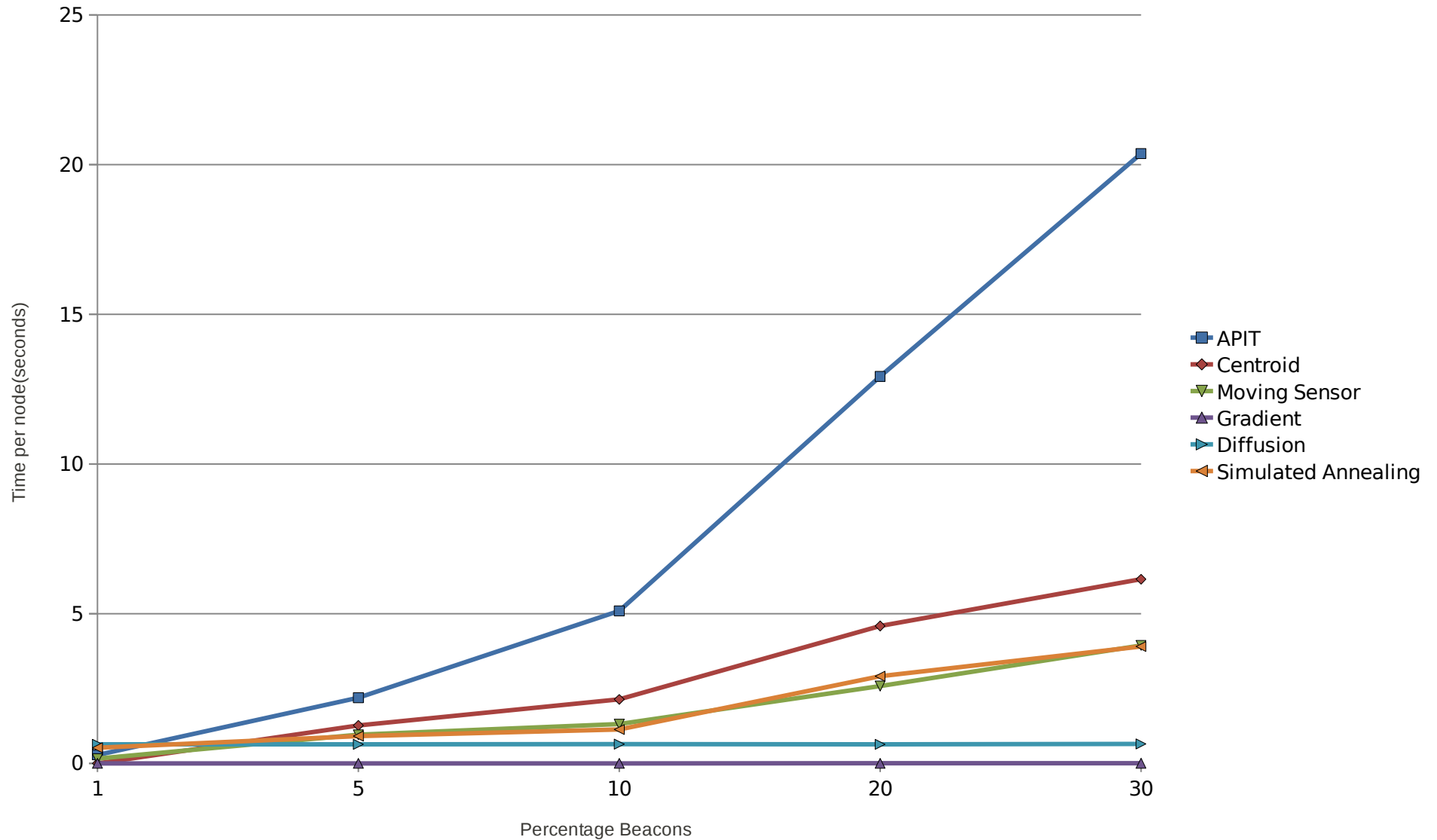- Contribution to localization α 1/Area of Triangle

- Fast Algorithm.

Results

Accuracy vs Number of Beacons

Results

Accuracy vs Number of Obstacles

Results

Time vs Number of Beacons

- APIT
- Centroid
- Moving Sensor
- Gradient
- Diffusion
- Simulated Annealing

Results

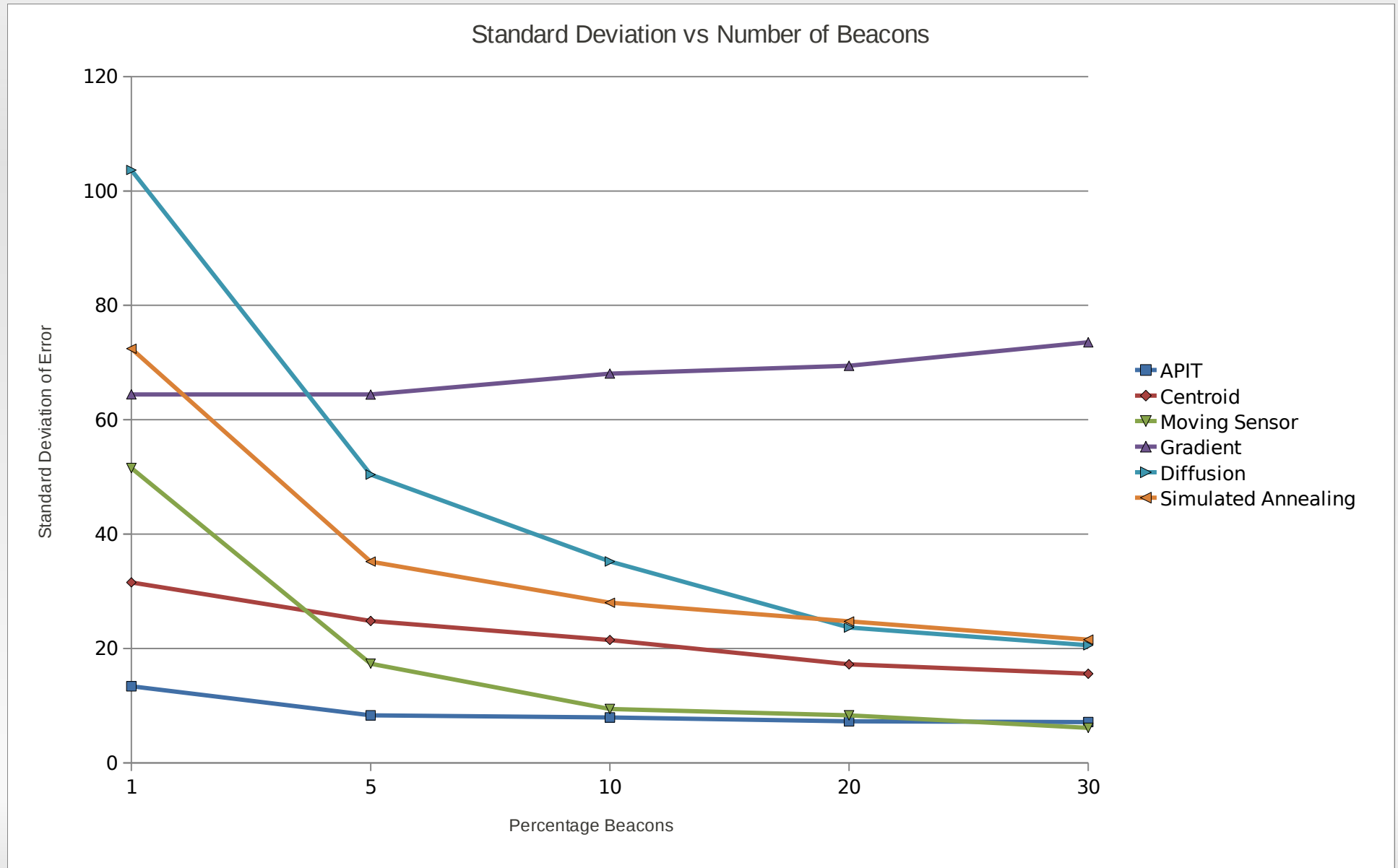Standard Deviation vs Number of Beacons

Conclusion

- Based on the qualities required by the system, a cost function of the system can be obtained in terms of **accuracy, tolerance due to obstacles, time required for computation and variation in error**.

- Based on the obtained cost function an appropriate algorithm could be used which **minimizes** the cost.