Localization in Wireless Sensor Network

ELEC 619B Presentation

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Outline

1. Introduction
2. Distance/Angle Estimation
3. Position Computation
4. Localization Algorithm
5. Questions?
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Motivation and Problem Statement

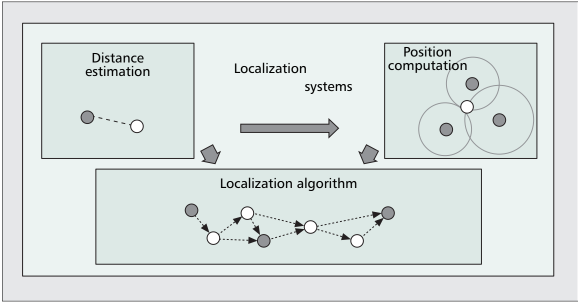
Motivation: Increasing availability of low-cost, portable, smart sensors that can be deployed in large numbers in a wireless sensor network (WSN).

Applications: Environmental monitoring, inventory management, intrusion detection, and traffic monitoring $\rightarrow$ "sensing data without knowing the sensor location is meaningless."

Localization Problem [Boukerche'07]

Given a multihop network $G = (V, E)$, and a set of beacon nodes $\mathcal{B}$ and their positions (x_b, y_b), for all $b \in \mathcal{B}$, we want to find the position (x_u, y_u) of as many unknown nodes $u \in \mathcal{U}$ as possible.

Components of a Localization System [Boukerche'07]



Distance/angle estimation: Estimating position related parameters between two nodes.

Position computation: Computing a node's position based on available information and anchor nodes positions.

Localization algorithm: Manipulating available information in order to localize other nodes in a WSN.

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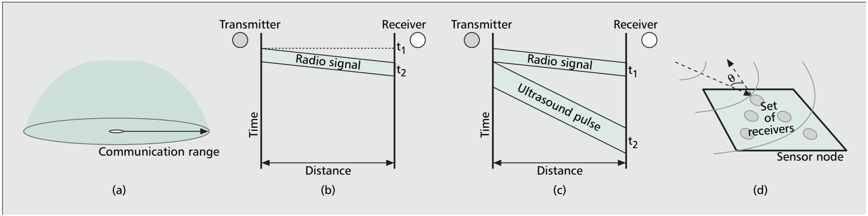
Distance/Angle Measurement Techniques [Boukerche'07]



a) Received signal strength (RSS): $\hat{d}_{ij} = d_0(P_0/P_{ij})^{1/n_p}$ [Patwari'03], low cost but very susceptible to noise.

b) Time-of-arrival (ToA): $\hat{d} = c(t_2 - t_1)$, accurate but requires synchronization.

c) Time-difference-of-arrival (TDoA): $\hat{d} = (c - s_s)(t_2 - t_1)$ or $\hat{d} = \hat{d}_i - \hat{d}_0$, no synchronization necessary but costly.

d) Angle-of-arrival (AoA): $\phi = \frac{2\pi d \cos\theta}{\lambda}$, costly and requires extensive signal processing.

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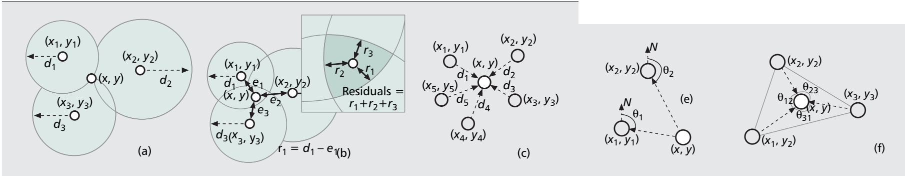
Multilateration/Triangulation/NLS Estimator



- a) – c) Multilateration linear least-squares (LLS): Subtract $\hat{d}_i^2 = (x - x_i)^2 + (y - y_i)^2$, from r-th measurement to obtain $2(x_i - x_r)x + 2(y_i - y_r)y = \hat{d}_r^2 - \hat{d}_i^2 - (x_r^2 + y_r^2) + (x_i^2 + y_i^2)$, for $i = 1, \ldots, N-1$ [Gezici'08a].
- e), f) Triangulation LLS: We have $x = x_i + \hat{d}_i \cos \hat{\alpha}_i$ and $y = y_i + \hat{d}_i \sin \hat{\alpha}_i$, for $i = 1, \ldots, N$ [Sayed'05].

- Non-linear LS (NLS) & maximum likelihood estimator (MLE): $\hat{\theta} = \arg\min_{\tilde{\theta}} \sum_{i=1}^{N} \frac{(z_i - f_i(x,y))^2}{\sigma_i^2}$, requires good initialization [Mao'07, Gezici'08].

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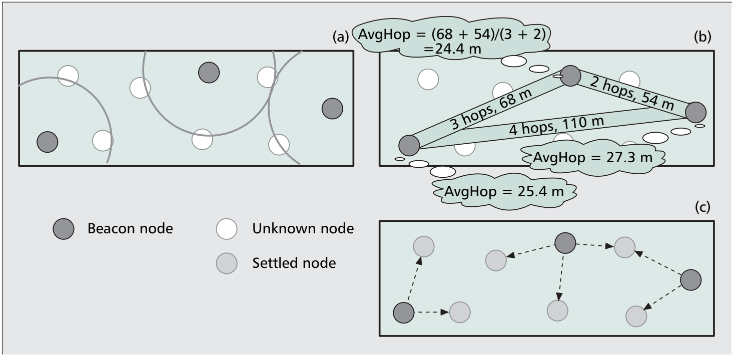
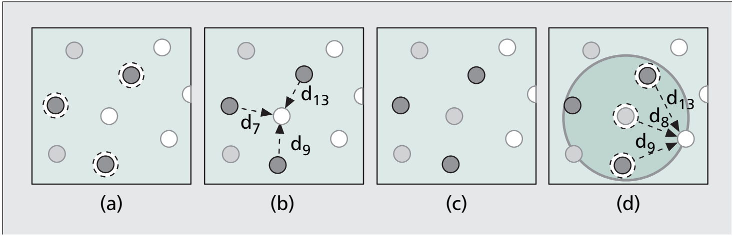
Dv-Hop Ad Hoc Positioning System [Niculescu'01]



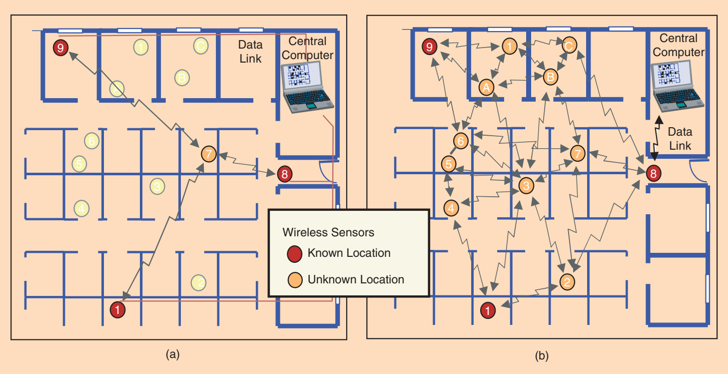
a) Beacon nodes broadcast their position information;
b) Beacon nodes compute the average one hop size from position information of other Beacons;
c) Unknown nodes convert number of hops from a beacon to distance.

Recursive Position Estimation (RPE) [Albowicz'01]



a) An unknown node determines its reference nodes;
b) The unknown node estimates its distance to these references;
c) The unknown node computes its position using multilateration;
d) Now, the unknown node becomes a settled node and assists other nodes in position estimation.

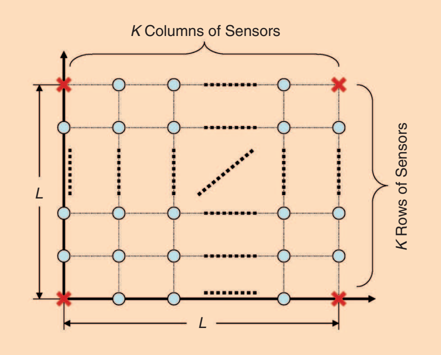
Traditional vs. Cooperative Localization [Patwari'05]

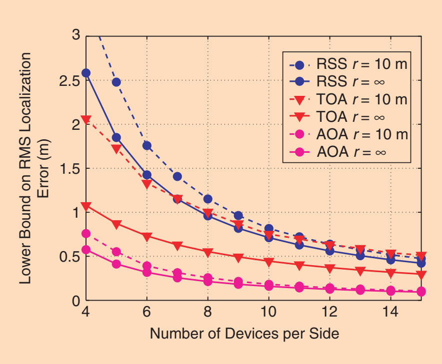


Centralized: MLE [Patwari'03], Convex Optimization, e.g., SDP [Doherty'01, Biswas'06], MDS [Cheung'05, Shang'03] etc.

Distributed: APS [Niculescu'01], RPE [Albowicz'01, Savvides'01], MDS [Ji'04], dwMDS [Costa'06], SOCP [Srirangarajan'08], etc.

Performance of Cooperative Localization [Patwari'05]





Left: K^2 sensors with 4 anchors $(\times)$ and $K^2 - 4$ unknown nodes $(\bullet)$ in a $L \times L$ m^2 area.

Right: $\sigma_{dB}/n_p = 1.7$, $\sigma_T = 6.3$ ns, $\sigma_\alpha = 5$, r is radius of connectivity in a 20×20 m^2 area.

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Thank You!

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