Network Localization in Partially Localizable Networks

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Outline

- Network Localization
- Partially Localizable networks -PLNs
- Conditions for Localizability
- Identifying RRT Components
- Simulation results
- Conclusions

Network Localization

- Useful for Coverage, Routing, Tracking
- Perfect localization may not be possible
- Erroneous positions may result in wrong decisions.
- Testing for correctness of localization is possible.

PLN

- PLN
  - Partially Localizable networks
- For realistic networks in many environments, it is unlikely that all of the nodes can be uniquely localized.

PLN and Challenges

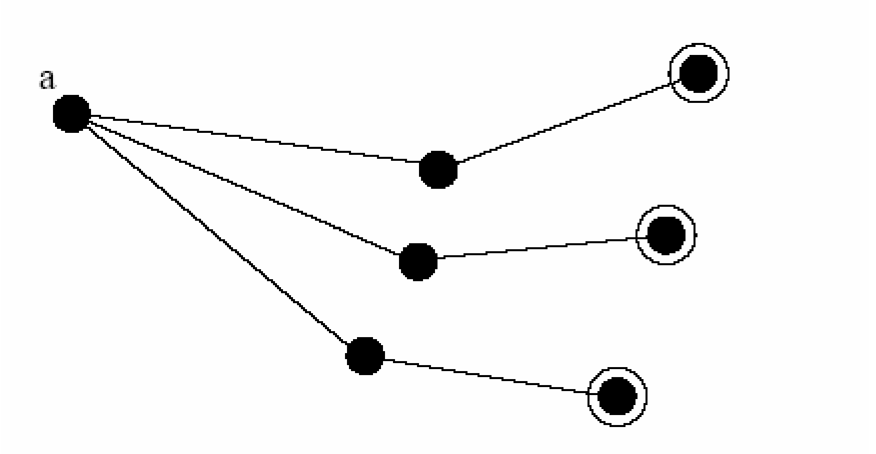
- PLN
  - Partially Localizable networks
- To identify the uniquely localizable nodes.
  - Presented a sufficient graph-theoretic condition for a node to be uniquely localizable.
- To determine how to best make use of nodes that cannot be uniquely localized.
  - Ignored → worst-case
  - Other solutions

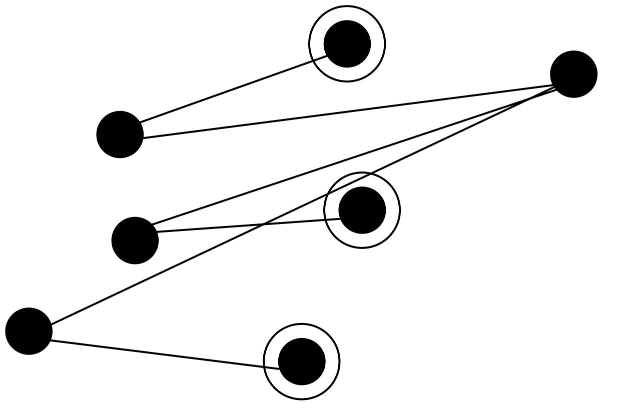
Formulation of Global Network Localizability

- *d* (= 2 or 3) dimensions
- *n* nodes
  - *m* beacons
  - *n-m* non-beacons
- A graph **G** is given
- Exact position of each beacon is known
- Positions of other nodes will be determined

Conditions for Localizability(1)

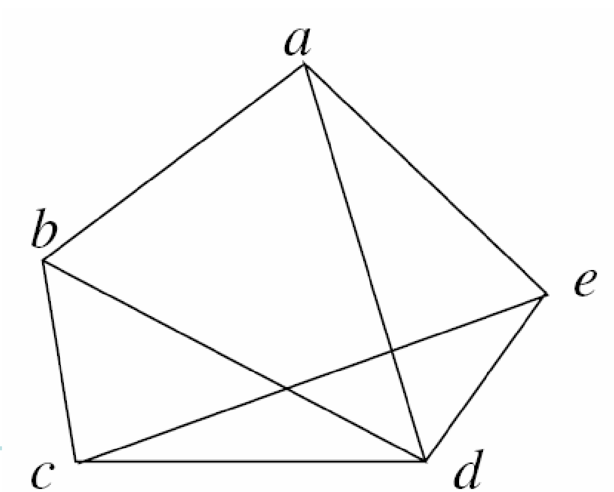
- If a node has three nodes-disjoint paths to three distinct beacons, it is uniquely localizable.
- The position of node **a** is not unique.
- For example

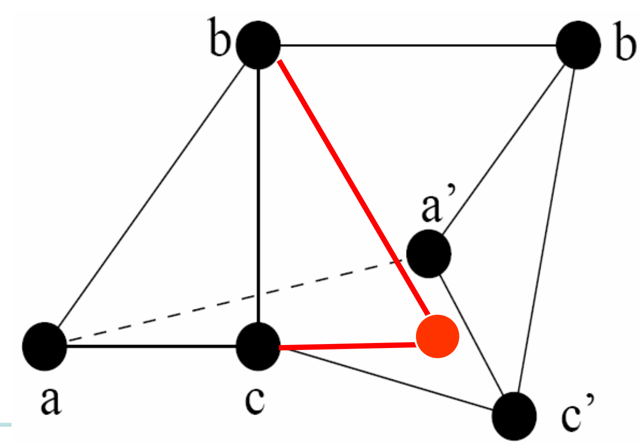




Conditions for Localizability(2)

- Triconnected graph
  - A connected graph such that deleting any two vertices results in a graph that is still connected.
- Redundant rigidity
  - A framework is rigid *iff* continuous motion of the points of the configuration maintaining the bar constraints comes from a family of motions of all Euclidean space which are distance-preserving.
  - At least **2n-3** edges are necessary (Laman's theorem)





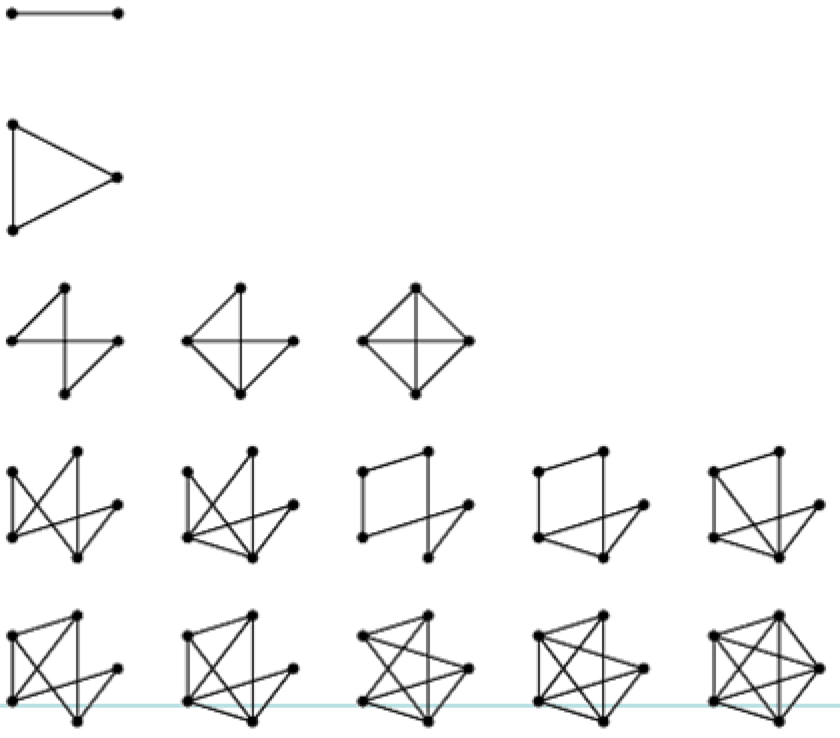
Identifying RRT Components

- RRT-3B
  - **R**edundantly **R**igid subgraph that is **T**riconnected and contains three beacons
- 3 Non-collinear beacons
- Triconnected – 3 node disjoint paths between any two nodes.
- Redundant Rigidity

```
FindRRTComponents(Graph G)
    if not triconnected then
        recurse on each triconnected component
    else if not redundantly rigid then
        recurse on each redundantly rigid component
    else return "graph G is an RRT"
```

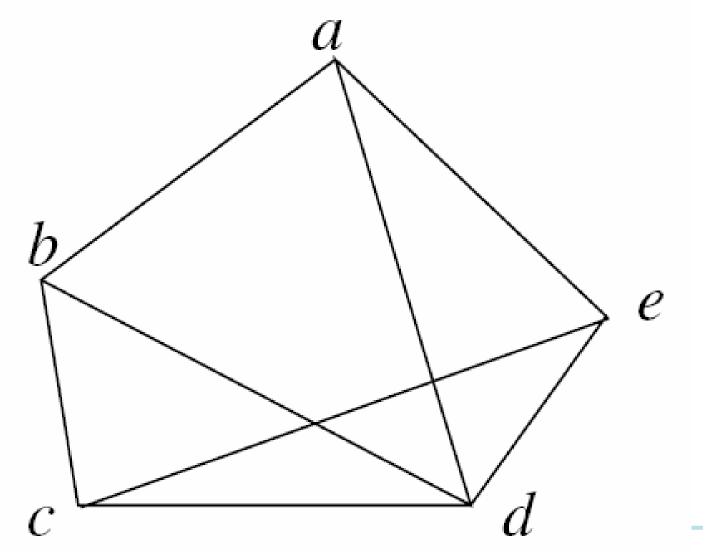
Identifying RRT Components

- Triconnected
  - For each vertex in a subgraph, we remove it, test the reduced component for biconnectivity, and replace the vertex.



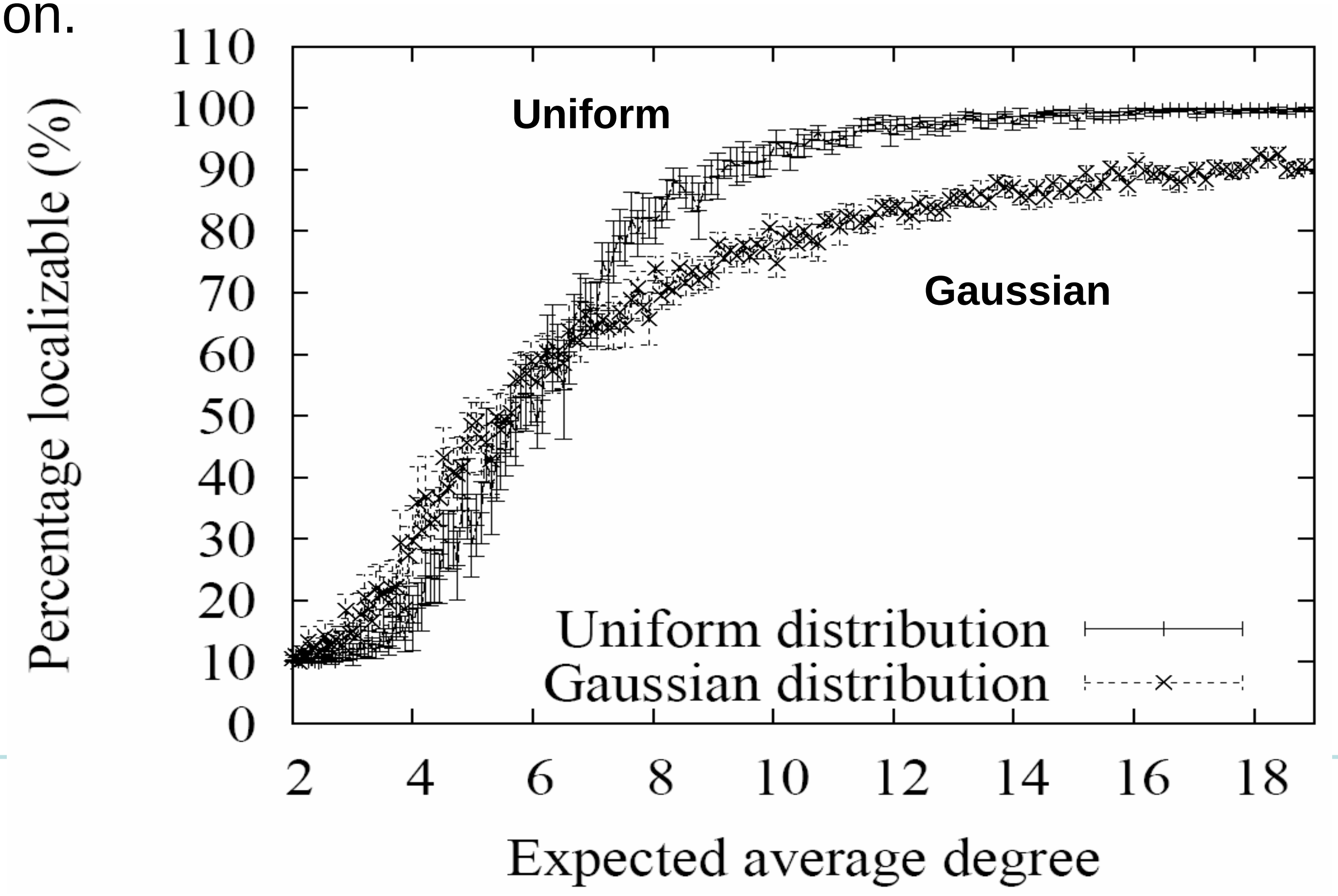
Identifying RRT Components

- Redundant Rigidity (2n-3 edges)
  - Using pebble game to get RR subgraphs.
  - There is at least 3 free pebbles in the assignment, representing the three degrees of freedom.
  - Three copies of an edge will be always be successfully covered.
- For exampe



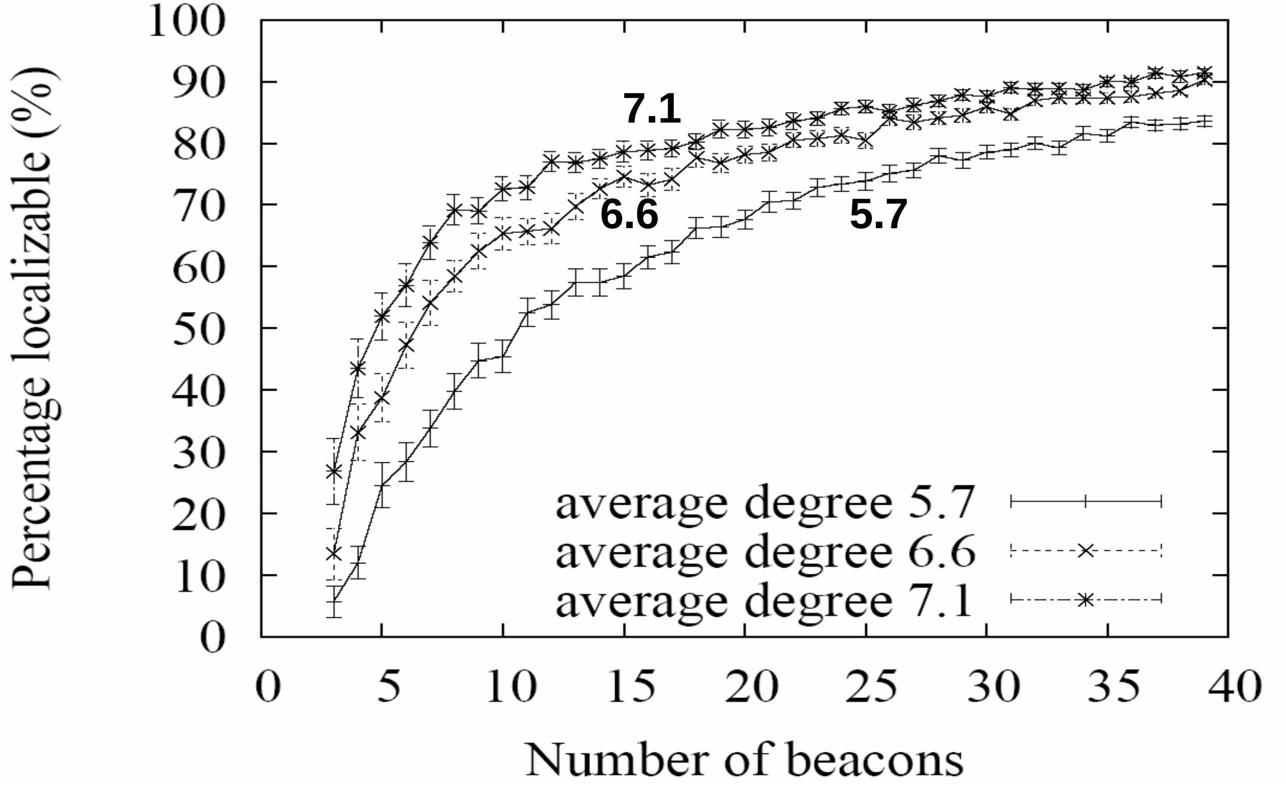
Simulation – Distribution of Localizable Nodes

- At low expected node degree, more nodes are localizable under the Gaussian than the uniform distribution, whereas for higher expected degree, more nodes are localizable under the uniform distribution.



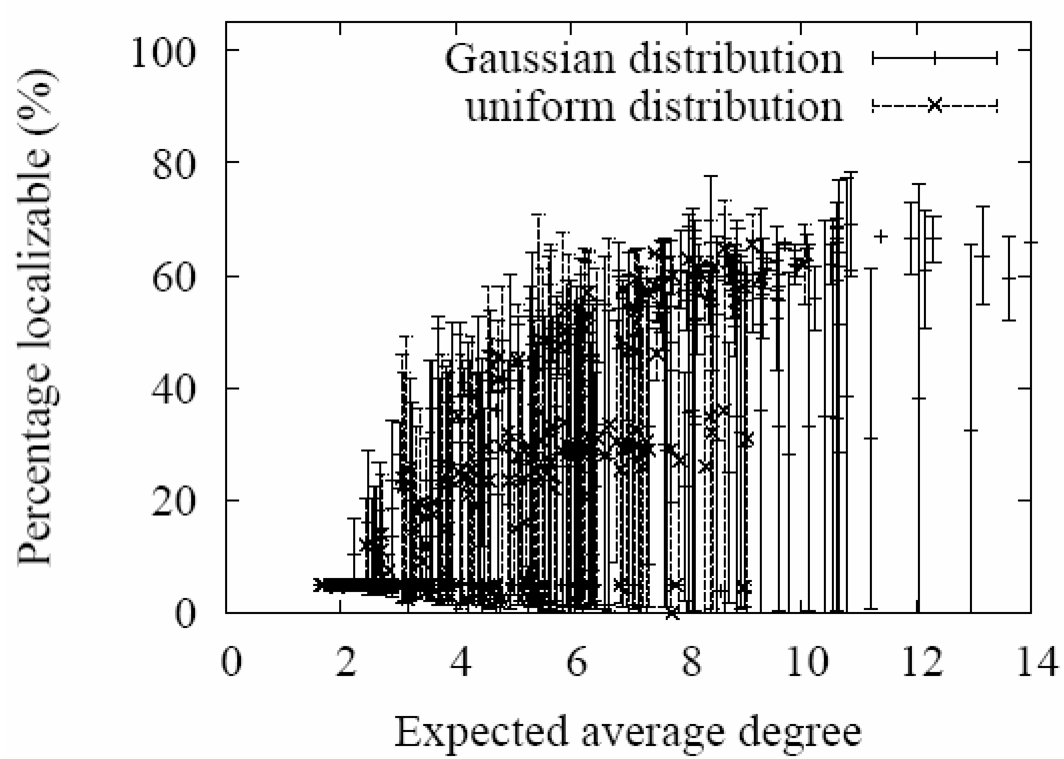
Simulation – Increasing number of Beacons

- By adding beacons past the point at which 10% of the nodes are beacons, the number of nodes rendered localizable per beacon is less than one.



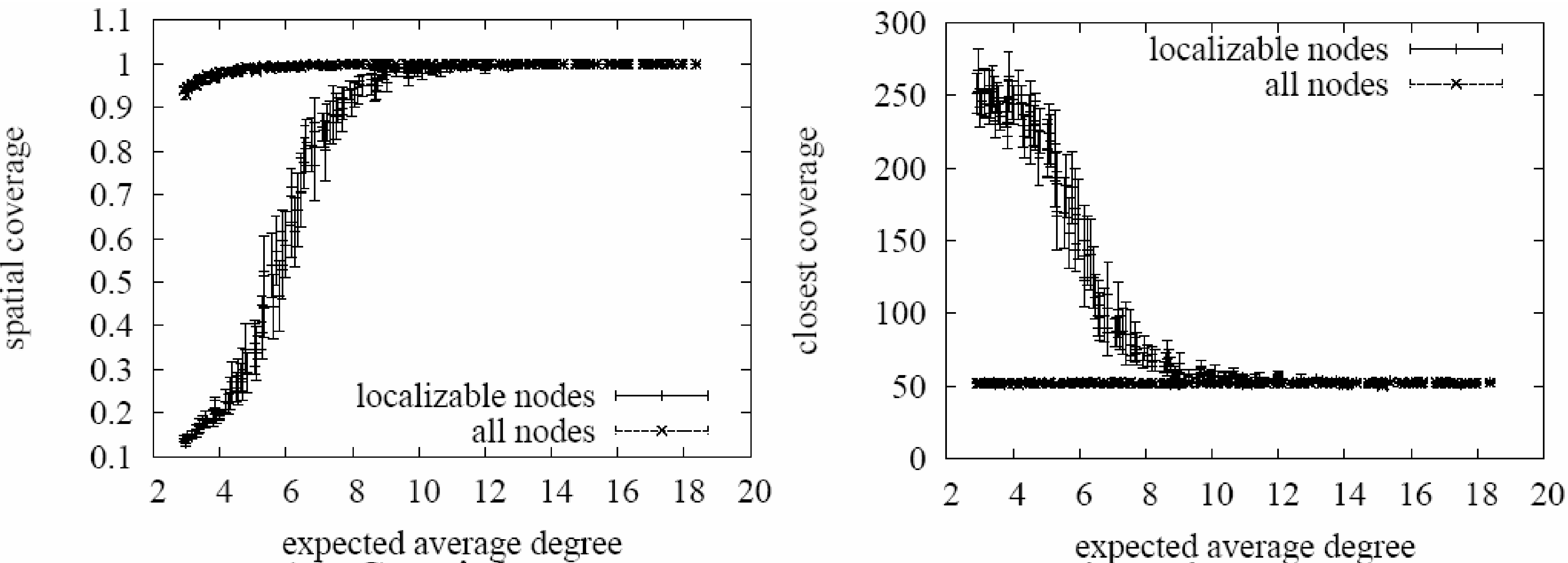
Obstacle

- We observe that for virtually all practical node densities, randomly deployed networks are only partially localizable.



Coverage of PLNs

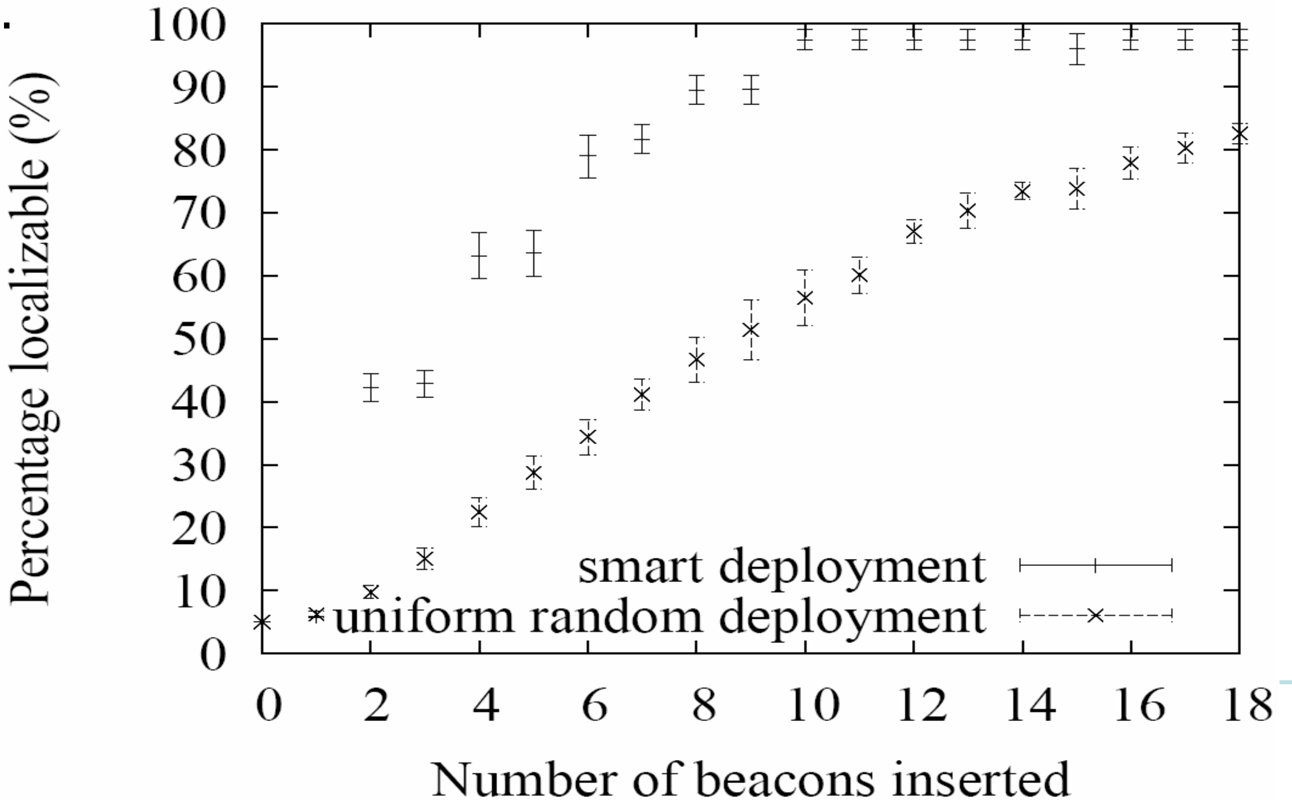
- Coverage performance of 100 uniformly distributed nodes in a 1000 by 1000 field.
- We make a distinction between localizable and non-localizable coverage because the value of sensed data may depend heavily on the ability to associate it with a physical position.



(a) Spatial (b) Closest

Smart Beacon Deployment

- Randomly deploys m beacons, where m is the number of RRTs in the network.
- It places additional beacons deterministically near placed beacons connected to an RRT until the entire connected RRT is made localizable.



Conclusions

- We propose the novel PLN paradigm. We develop efficient algorithms to ascertain which nodes can be uniquely localized and which cannot.
- Implementing our system, we conduct comprehensive experimental evaluations of network localizability, and describe implications on both network design and on the use of novel network deployment algorithms.
- We study an integration of geographic routing without location information and standard geographic routing.

Future Work

- We further studied routing in partially localizable networks.
- Node deployment errors, eg. Beacon deployment errors like in systematic beacon deployment.
- Looking at existing applications/algorithms with the consideration of partial localizability.

References

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