Localization Procedure

Orchestrating position estimation protocols in randomly deployed WSNs

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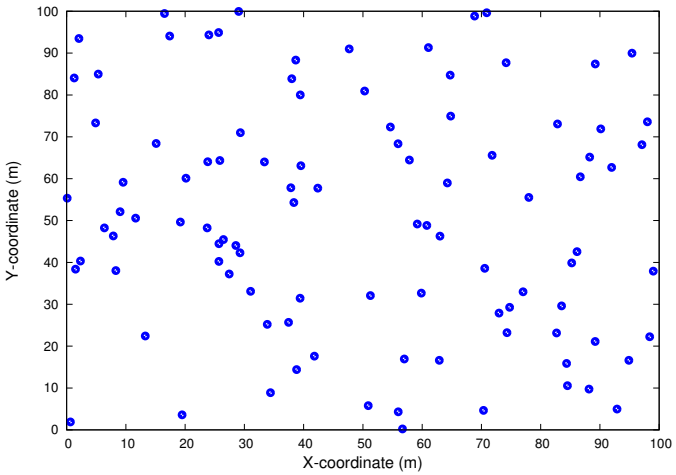
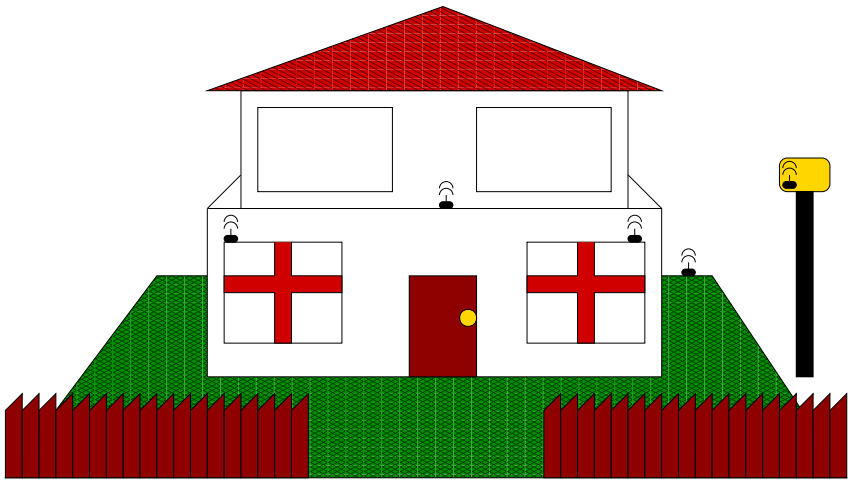
What are Randomly Deployed WSNs?

- Nodes are placed randomly over a field.
- It also encompasses deployments made at convenience.



(a) Example random deployment of nodes



(b) Example home surveillance deployment

Characteristics

- Nodes determine the best route to the sink.
- Ofter are easier to deploy.
- In case of a battery run-out, nodes can be replaced.

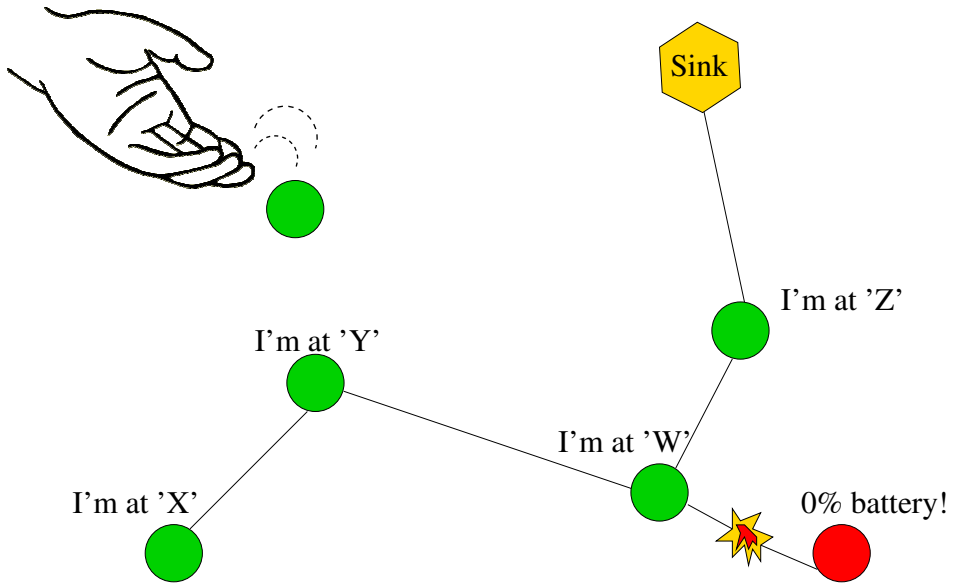


Figure: Replacing nodes

Applications

Because of their ease of deployment, are often used for:

- Volcano activity monitoring.
  - Very dangerous or difficult places for deployment.
- Forest fire detection.
  - Very big areas.

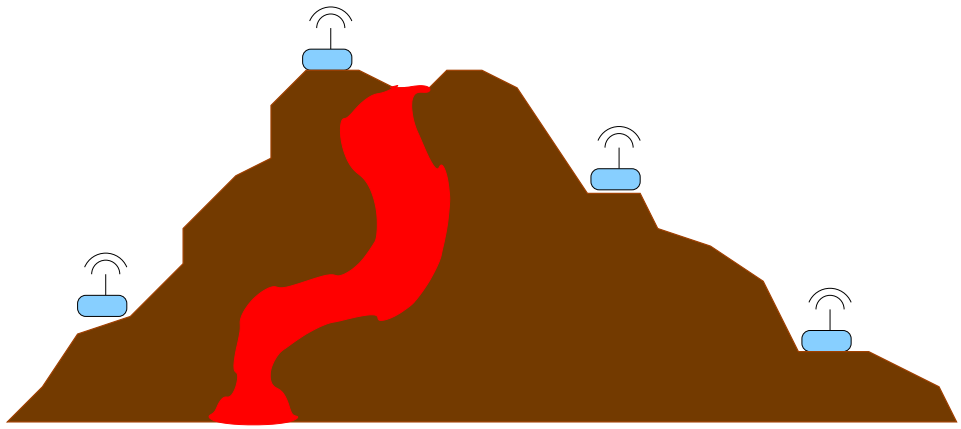


Figure: Volcano monitoring example

Pro's and Con's of random deployments

Pro's:

- Allows rapid deployment.
- Reach very restrictive or dangerous places.
- Allows fast network reinforcement.

Con's:

- It is difficult to trace the metrics.
- Position of the nodes is not know a priori.
- Localization often decreases network lifetime.

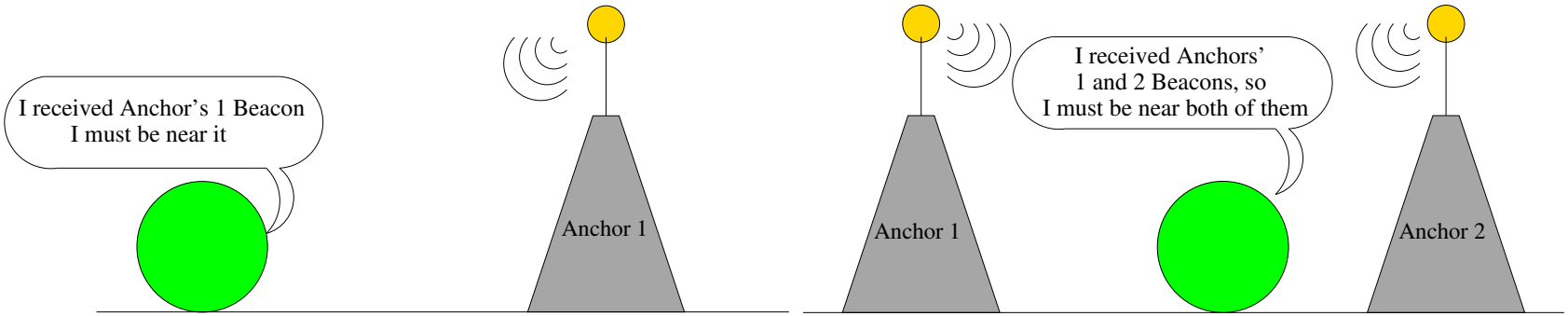
Node Localization

To make metrics traceable:

1. All nodes are equipped with GPS modules.
   - 1.1 Decreasing network lifetime due to the modules ↓.
   - 1.2 Increasing the size and weight of the nodes ↓.
   - 1.3 Augmenting the required budget ↓.
   - 1.4 Very low estimation error ↑.
2. Some nodes use GPS modules
   - 2.1 Nodes derive a position estimation from Anchors: increased estimation error ↓.
   - 2.2 Additional workload is added to the nodes (estimation) ↓.
   - 2.3 Added network traffic (*Beacons*) containing location information ↓.
   - 2.4 Cheaper and scalable approach ↑.

Estimating Position by Reference

- Any *Unknown* node (unaware of its position) may derive an estimation from Beacons.
- Beacons packets contain the position of the sender.



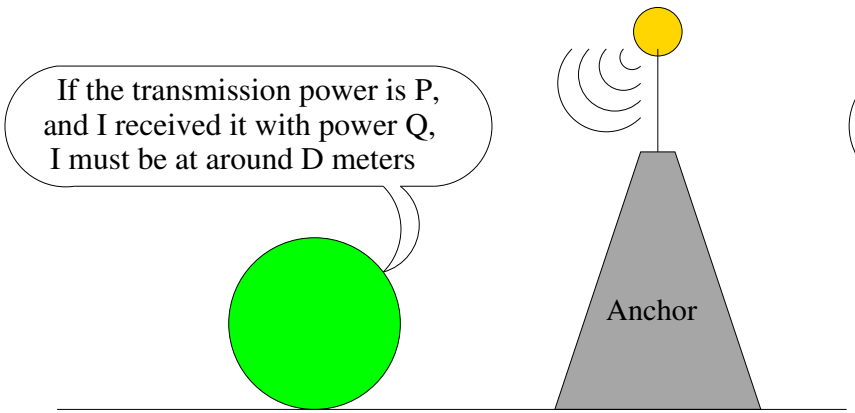
(a) Estimating a position with 1 Beacon

(b) Estimating a position with 2 Beacons

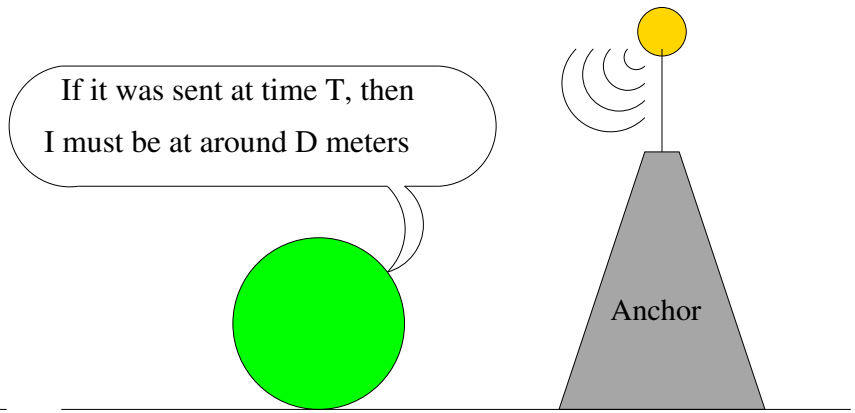
- Applications may tolerate different levels of estimation errors.

Making Range Estimations

- Use the propagation characteristics of Beacons
  - Derive a straight line estimation to the transmitter.



(c) RSSI position estimation



(d) Time of Arrival (ToA)

Localization Protocols

Range-free

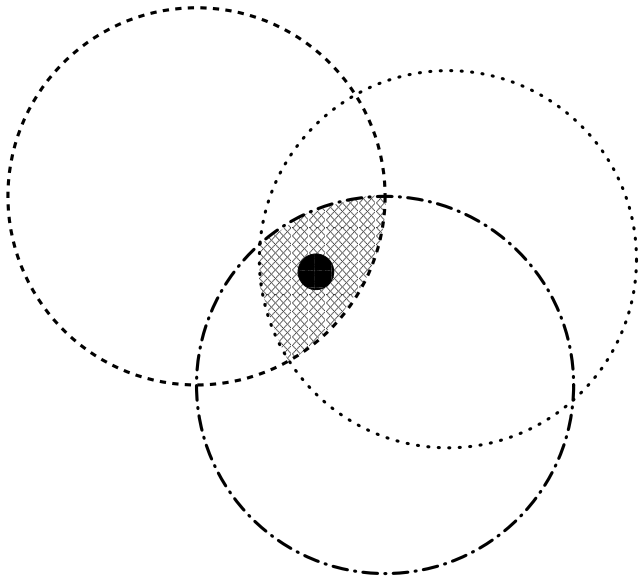


Figure: Bounding-Box example

Range-based

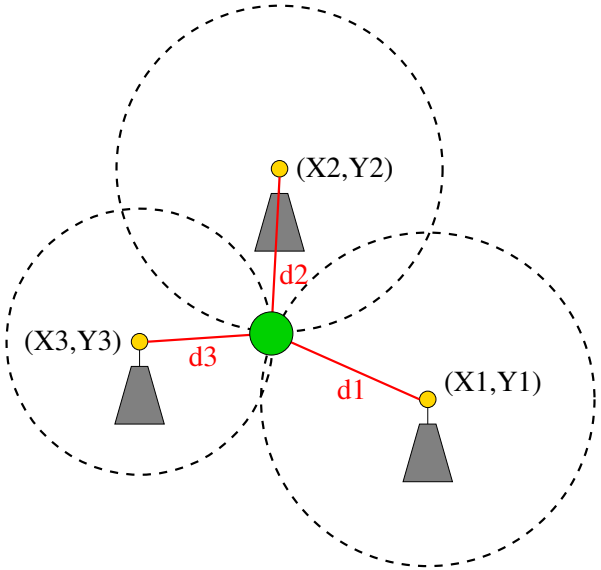


Figure: Lateration example

Range-free and Range-based

Range-free protocols:

- Only consider the effective connection with Anchors.
- Usually consume less battery.
- Error is subject to the number of connections to Anchors.

Range-based protocols:

- Use ranging techniques to constrain the estimation.
- Increased battery consumption related to the ranging technique.
- Error is usually reduced due to the availability of more data.

Locating Nodes

- Applications dictate the maximum estimation error.
- Protocol performance is limited by the network-**environmanetal conditions** surrounding each node:
  - # of surrounding Anchors.
  - Network delay.
  - Available throughput.
  - Processing capabilities.
- **Deployments** may have different **considerations** regarding:
  - Network lifetime.
  - Location accuracy.
  - Traffic overhead.
  - Convergence time.

One protocol cannot perform well in all possible scenarios

Composability

- Combines different protocols to achieve better results.

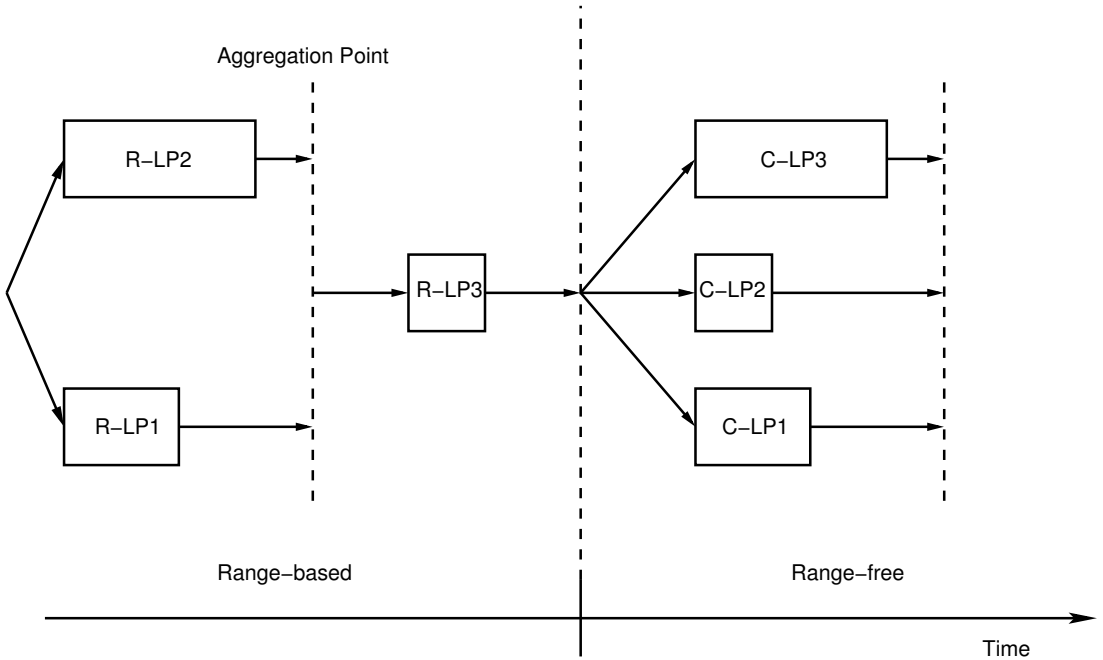


Figure: Composability[1]

[1] Redrawn from Stoleru, R., Stankovic, J., Son, S.H., "On Composability of Localization Protocols for Wireless Sensor Networks," Network, IEEE, vol. 22, no. 4, pp. 21–25, 2008.

Composability

- Leverages weaknesses of some protocols with strengths of others.
- Protocols are executed sequentially according to accuracy thresholds.
- Brings some questions:
  - How are protocols selected?
  - How are thresholds set?
  - Is it static-sequential execution the way to go?

Localization Procedure

Is based on:

- Protocol's performance is dependent on the environmental conditions.
- Selected protocols must comply with the deployment considerations.

The Localization Procedure:

- Analyzes the node's environmental conditions.
- Identifies a suitable set of protocols.

Localization Procedure

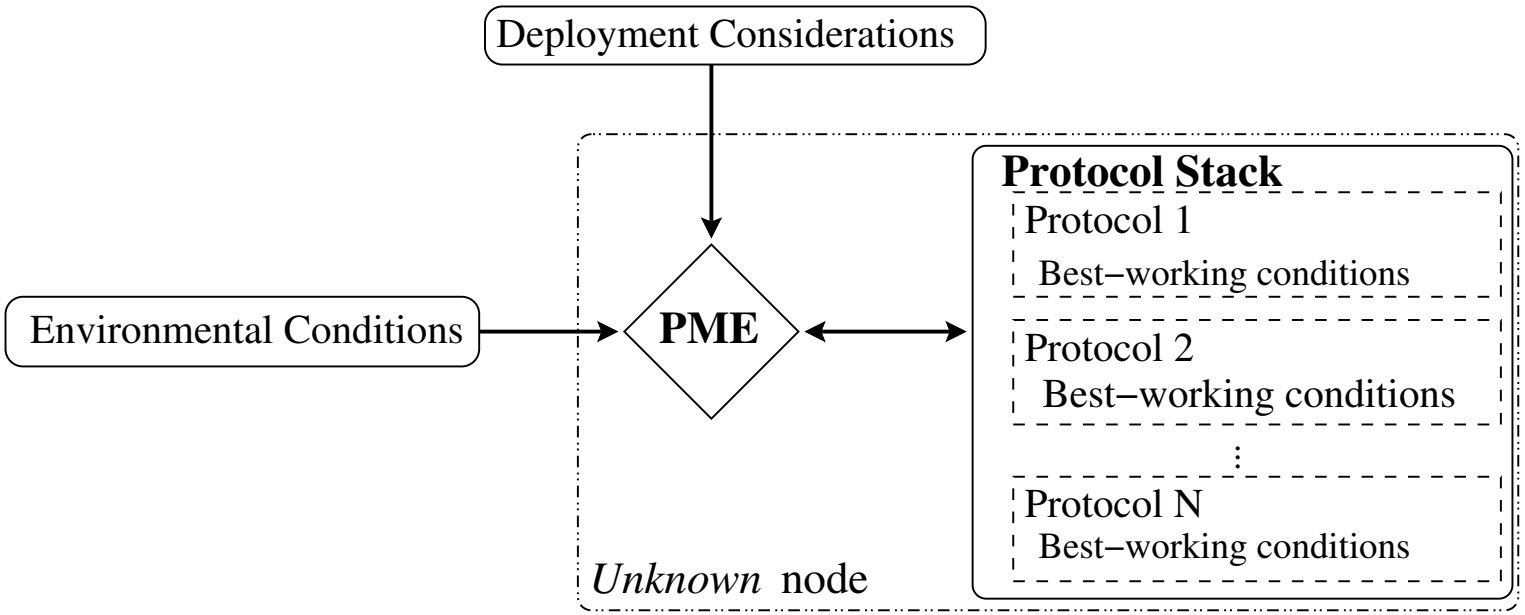


Figure: Localization Procedure

Localizatitheon Procedure

The Pattern Matching Engine (PME):

- Manages the execution of *characterized*[2] localization protocols.
- Selects a set of protocols based on the environmental conditions.
- Reorders the execution based on the deployment considerations.

[2] Their best-working conditions are known.

Evaluation tools

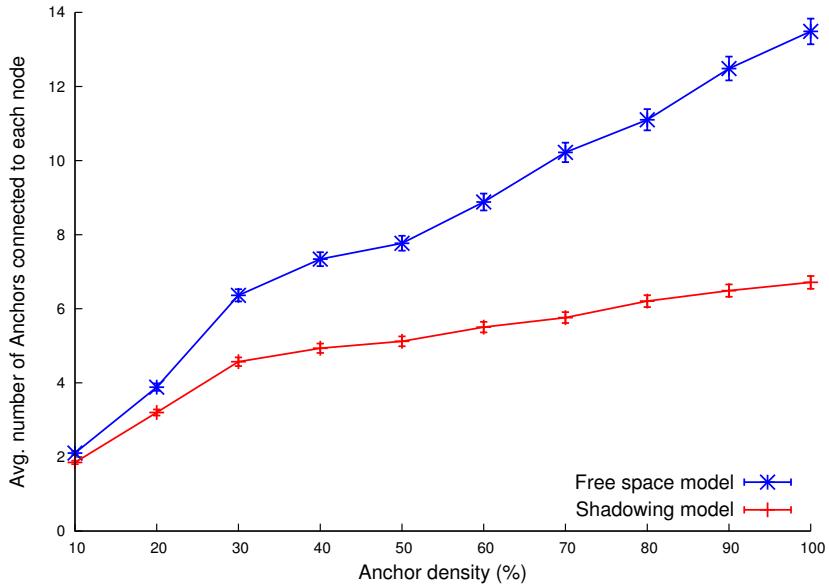
- Bounding-Box and Lateration are tested.
  - Popular.
  - Some of their best-working conditions are known.
  - Range-free and range-based example.
  - 100 m x 100 m flat surface.

Characteristic	**Lateration**	**Bounding-Box**
Env. Conditions	At least 4 *Anchors*	At least 1 *Anchor*
Accuracy	2-10 meters	Coarse[3]
Energy Consumption	Low	Very low[4]

[3] Location area upper-bounded by *Anchor*'s radio range (R).
[4] Can be treated as a discrete problem.

Evaluation tools

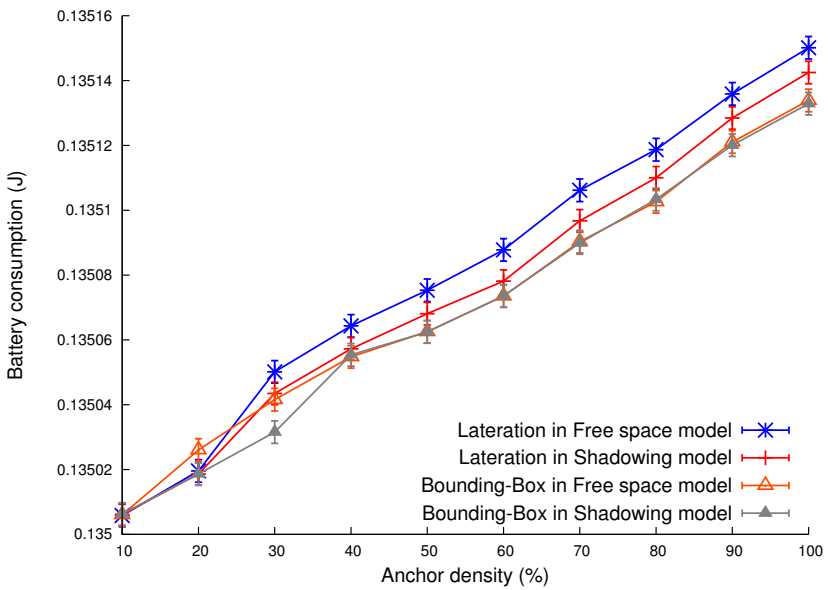
- Modified version of the SENSE simulator[5]
- Deployment considerations: high accuracy and long network lifetime.
- Two channel models: free space and shadowing.



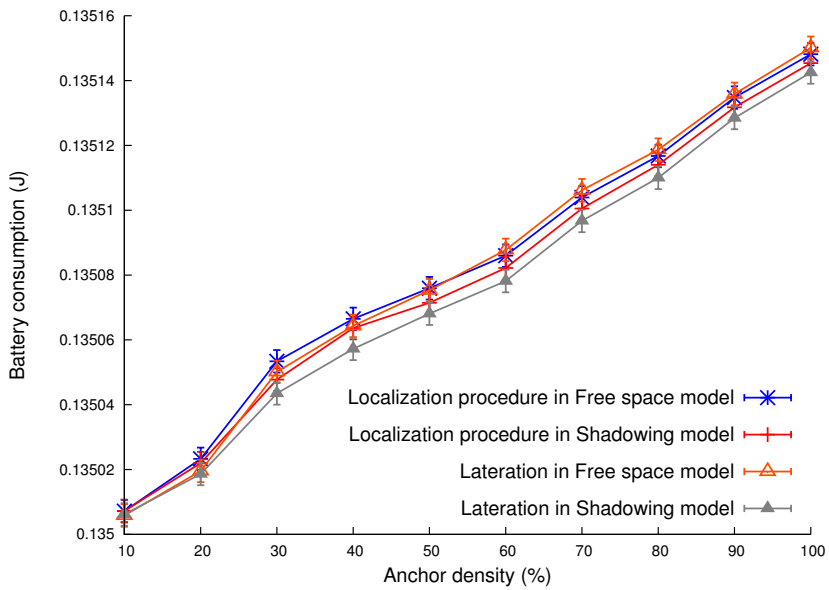
[5] Chen, G., Branch, J., Pflug, M., Zhu, L., Szymanski, B., "SENSE: a wireless sensor network simulator,"

Battery Consumption

- Similar battery consumption.



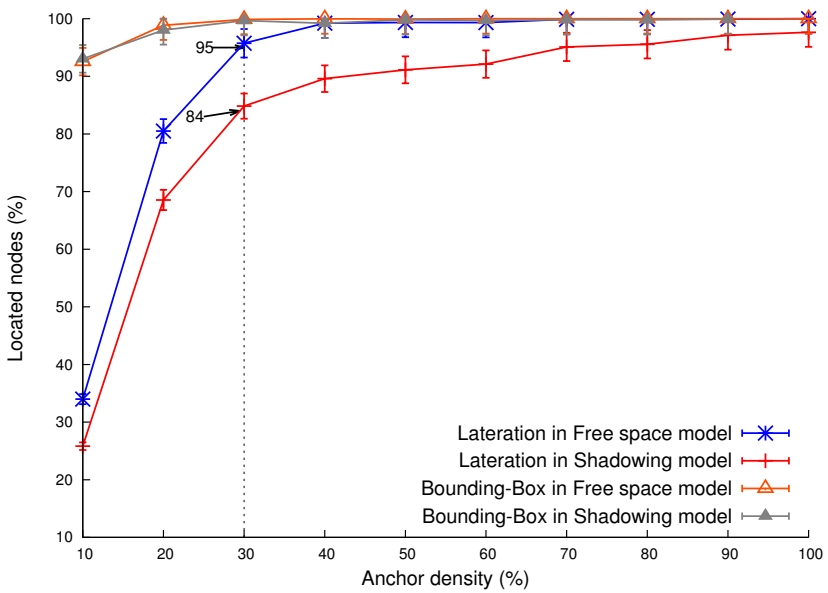
(a) Individual execution



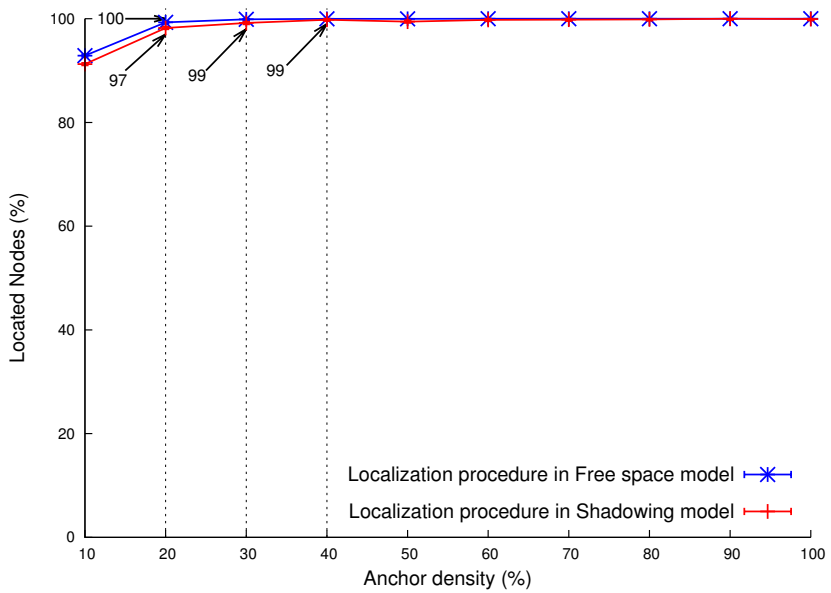
(b) Localization Procedure

Located Nodes

- Increased number of located nodes.



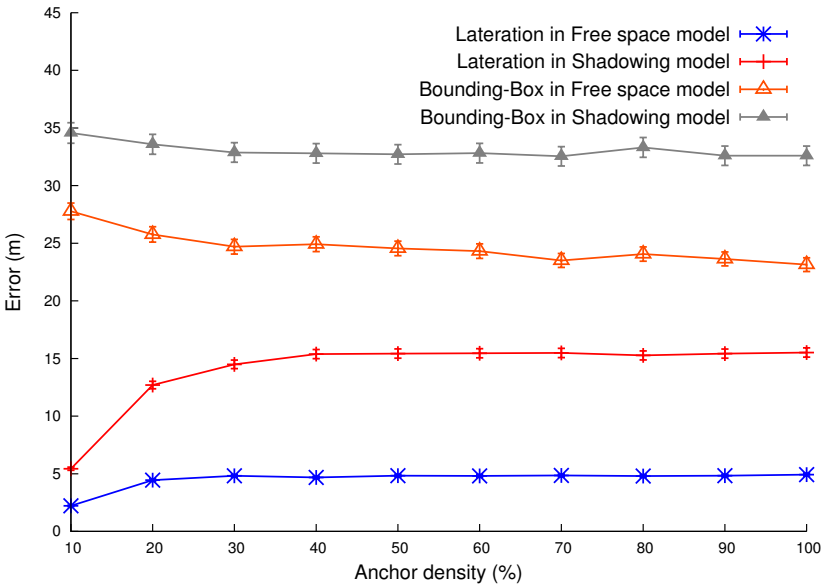
(c) Individual execution



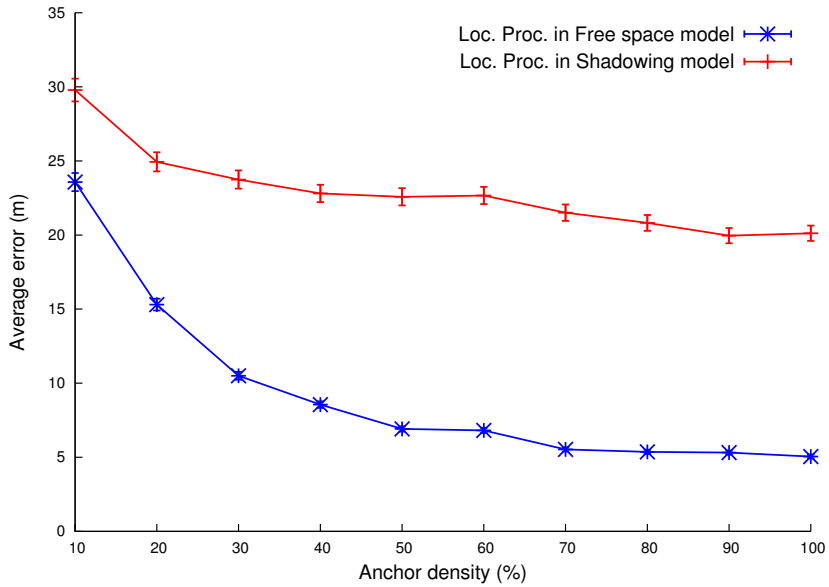
(d) Localization Procedure

Straigh-line Error

- Greater *average* error than in Lateration-only scenarios.



(e) Individual execution



(f) Localization Procedure

Remarks

- Despite of greater error than Lateration:
  - Number of located nodes is increased.
  - In the individual execution, these nodes have infinite error.
  - Similar battery consumption.
- A carefully selected set of protocols can work on more scenarios.
- Allowing node-*Beacoming* and location information exchange:
  - Cetralized protocols.
  - More scenarios: NLoS, anisotropic topologies.