

# Localization Procedure

Orchestrating position estimation protocols in randomly  
deployed WSNs

Luis Sanabria-Russo, Cristina Cano, Boris Bellalta

Universitat Pompeu Fabra  
NeTS Research Group  
Barcelona, Spain

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# Table of contents

## Introduction

- Characteristics

- Applications

- Pro's and Con's

## Node Localization

- Estimating Position by Reference

- Localization Protocols

- Composability of Localization Protocols

## Localization Procedure

- Definitions

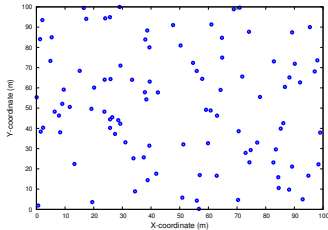
- Pattern Matching Engine

- Evaluation

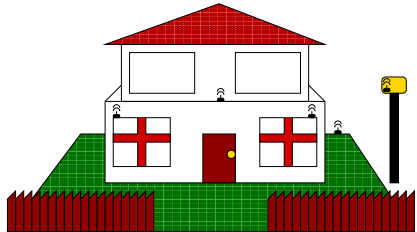
## Remarks

# 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.

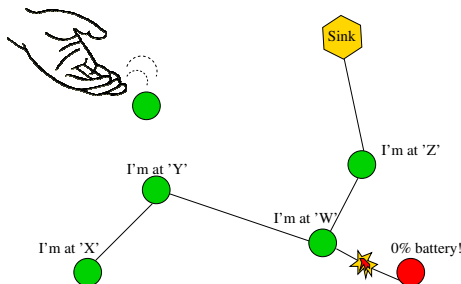


Figure: Replacing nodes

# 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.

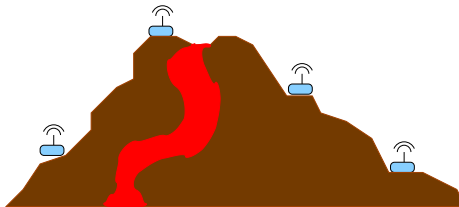


Figure: Volcano monitoring example

# 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 known a priori.
- ▶ Localization often decreases network lifetime.

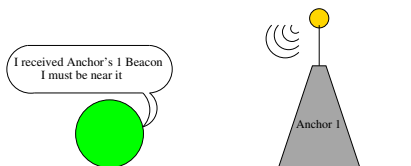
# Node Localization

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



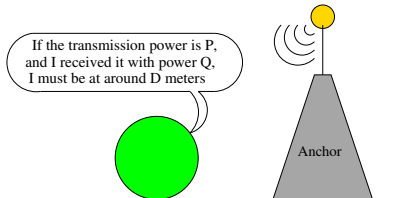
(b) Estimating a position with 2 Beacons

- ▶ Applications may tolerate different levels of estimation errors.

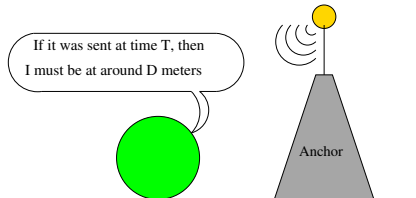


# Making Range Estimations

- ▶ 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

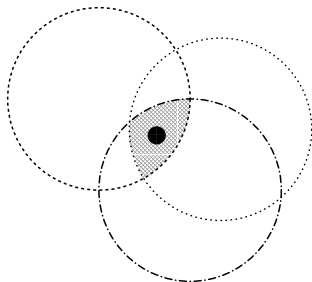


Figure: Bounding-Box example

## Range-based

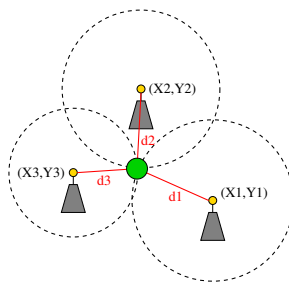


Figure: Lateration example

# 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-**environmental 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.

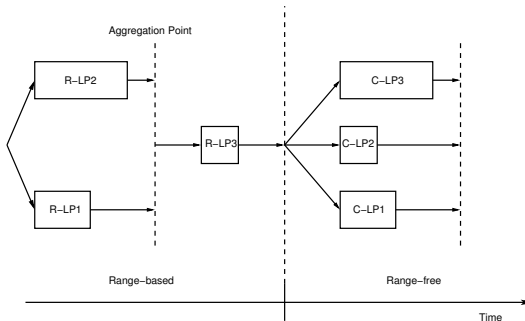


Figure: Composability<sup>1</sup>

<sup>1</sup>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

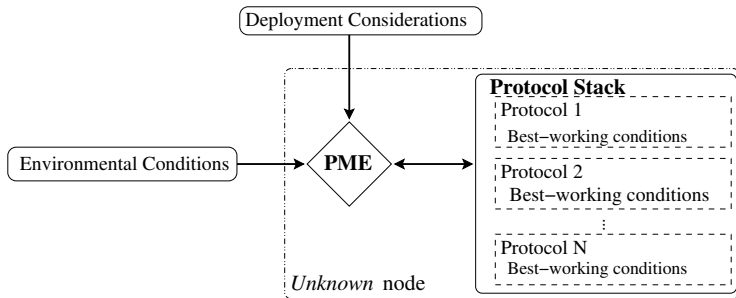


Figure: Localization Procedure



# Localization Procedure

The Pattern Matching Engine (PME):

- ▶ Manages the execution of *characterized*<sup>2</sup> localization protocols.
- ▶ Selects a set of protocols based on the environmental conditions.
- ▶ Reorders the execution based on the deployment considerations.

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<sup>2</sup>Their best-working conditions are known.

- ▶ 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.

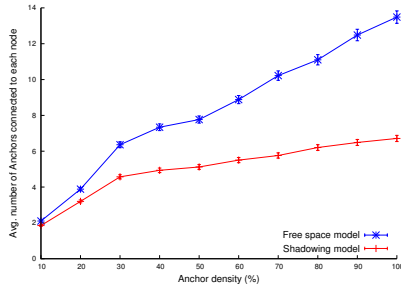
Characteristic	Lateration	Bounding-Box
Env. Conditions	At least 4 <i>Anchors</i>	At least 1 <i>Anchor</i>
Accuracy	2-10 meters	Coarse <sup>3</sup>
Energy Consumption	Low	Very low <sup>4</sup>

<sup>3</sup>Location area upper-bounded by *Anchor*'s radio range (R).

<sup>4</sup>Can be treated as a discrete problem.

# Evaluation tools

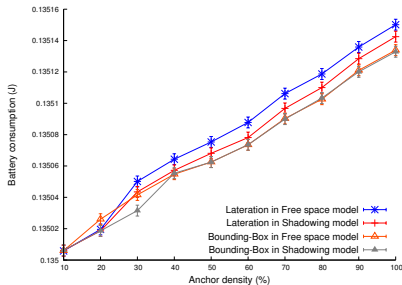
- ▶ Modified version of the SENSE simulator<sup>5</sup>
- ▶ Deployment considerations: high accuracy and long network lifetime.
- ▶ Two channel models: free space and shadowing.



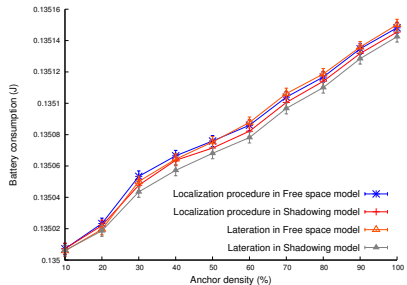
<sup>5</sup> Chen, G., Branch, J., Pflug, M., Zhu, L., Szymanski, B., "SENSE: a wireless sensor network simulator,"

# Battery Consumption

- Similar battery consumption.



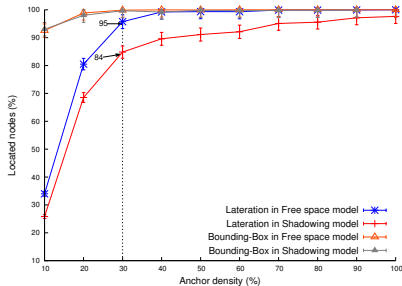
(a) Individual execution



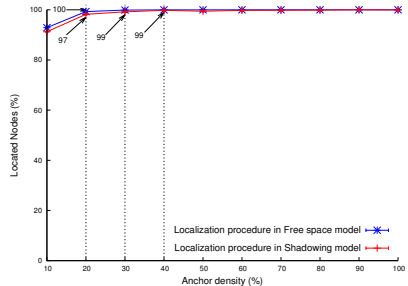
(b) Localization Procedure

# Located Nodes

- Increased number of located nodes.



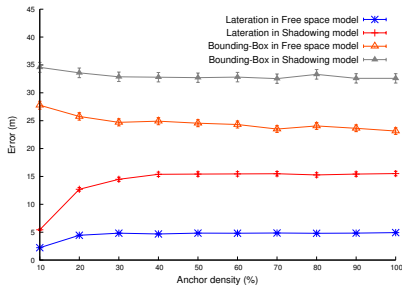
(c) Individual execution



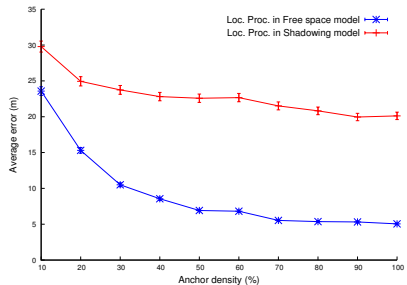
(d) Localization Procedure

# 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.

# Q&A

Thank you!