European Cooperation in Science and Technology

RSSI-based Cooperative Localization with Energy-efficient Node Selection for Wireless Sensor Networks

Glyfada, Athens/RFCSET meeting

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Outline

- Presentation of the group
- Localization methods in WSN
- Motivation and Proposal
- System model
- Selection criteria
- Simulation Results
- Experimental validation
- Conclusions

Presentation of the group

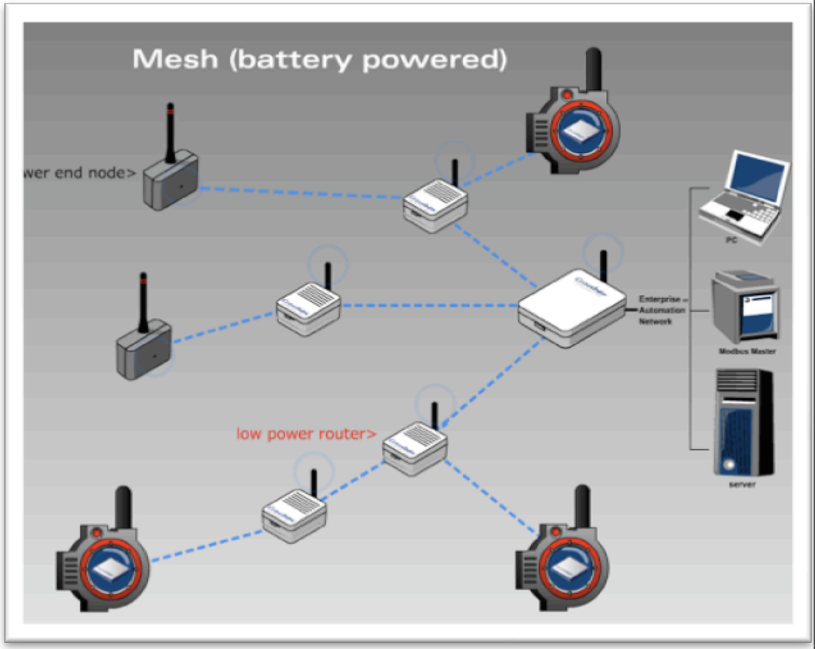
- Signal Processing for Communications and Navigation Group (SPCOMNAV) of the Universitat Autònoma de Barcelona.
- Created in October 2005 by researchers coming from: ESA, CTTC and UPC.
- Formed by:
  - 4 PhD faculty Professors
  - 2 associate professors
  - 5 PhD students

Research Topics

- Our areas of research are:
  - Signal Processing
  - Information Theory
  - Optimization
- Focused on:
  - Wireless Communications
    - Physical layer
    - MAC layer
  - Positioning

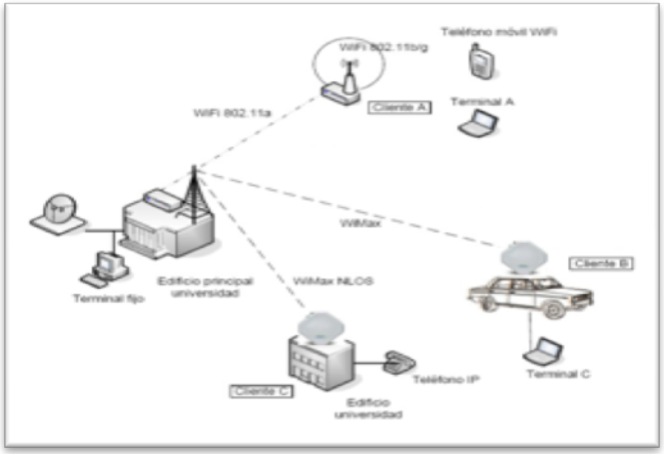
Research Topics

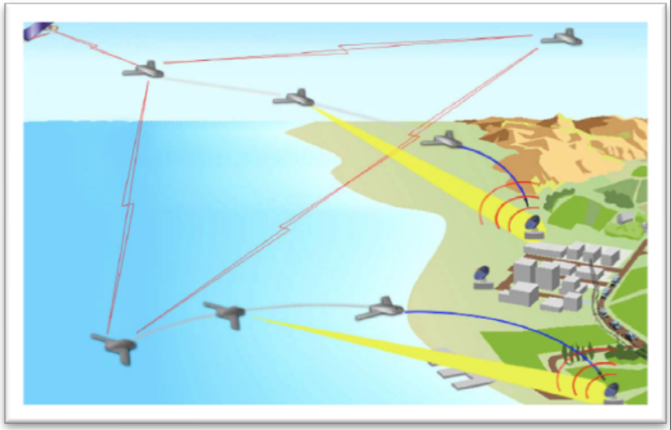
- Cooperative Communications
  - Performance analysis versus imperfect channel state information
  - Relay selection
  - Optimization of power allocation



Research Topics

- Hybrid Networks
  - Experimental platform: Sensor network + WIMAX
  - Unmaned Air Vehicles (UAV)
  - Environment monitorization
- Distributed optimization
  - Design of distributed algorithms for resources allocation
  - Distributed: estimation /synchronization
- Network coding





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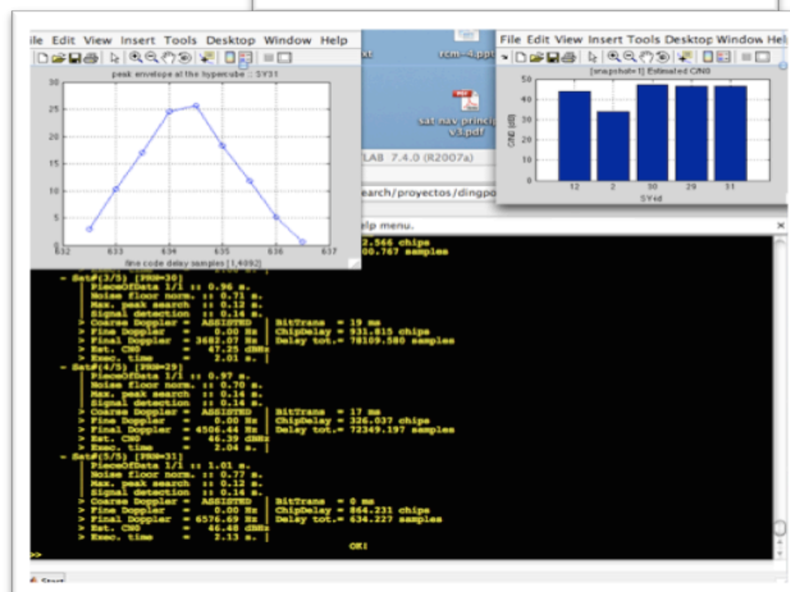
Research Topics

- Communications + positioning
  - Location-aware communications
  - Statistic knowledge of the channel
  - Cooperative positioning
  - Distributed synchronization
  - GPS and Galileo SW receivers



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Research interests

- Interest in the COST WG2: Smart and Reconfigurable RF radio transcievers.
- New signal processing methods to reduce fading issues, in order to:
  - increase communication efficiency.
  - reduce mobile terminals power requirements.
- Design of cooperative positioning systems oriented to reduce the energy consumption.

Localization methods in WSN

- Why we need the localization in wireless sensor networks?
  - Having sensing data without knowing the position of them is meaningless.
- Why we do not use existing techniques, such as GPS?
  - Increase cost and size of nodes. Becomes inappropiate in large scale networks.

Localization methods in WSN

- In the literature, localization methods are normally divided in two steps [Bachrach2005, Patwari2005] :
  - Measurement phase
    - Time of Arrival (TOA)
    - Angle of Arrival (AOA)
    - Received Signal Strength (RSS)
  - Location-update phase
    - Cooperative versus non-cooperative
    - Distributed versus centralized

Localization methods in WSN

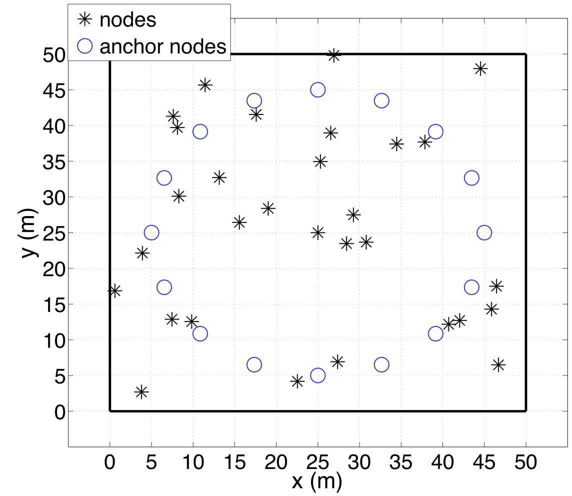
- Cooperative methods have appeared to reduce the necessity of having a high density of anchor nodes or long-range anchor transmissions.
- The capacity of cooperating with anchors and non-anchors nodes can offer increased accuracy and coverage. [Wymeersch2009]
- RSS-based measurements are presented as a low-cost and low-complexity solution. [Li2006]

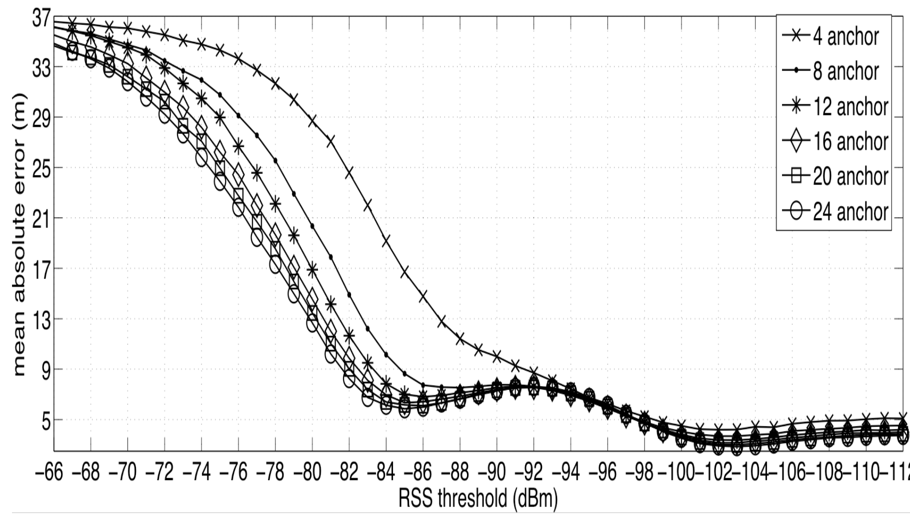
Motivation and Proposal

- We focus on an RSS-based Cooperative Distributed algorithm of localization.
- Pros
  - RSS measurements need less hardware requirements.
  - Less exchange of messages in distributed methods.
  - Anchor node density reduction in cooperative localization.
- Cons
  - The RSS measurements introduce an error multiplicative to the distance.
  - Cooperation with further nodes will have more error at the distance estimation.
  - Cooperation with more nodes increases the energy consumption.

Motivation and Proposal

- We want:
  - To achieve a good trade-off in position accuracy vs. energy consumption.
- We propose:
  - A node selection criterion fixing an RSSI threshold.
  - Each node selects that nodes that have a received RSS above the RSSI threshold.





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System model

- We assumed N_1 uniformly distributed unallocated nodes in a 50mx50m square area.
- The propagation model follows the following formula:

$$RSS_{ij} = P_{ij} = P_0 - 10\alpha \log_{10} d_{ij} - v_{ij} \quad (dBm)$$

- The cost function of the Cooperative Least Squares methods is:

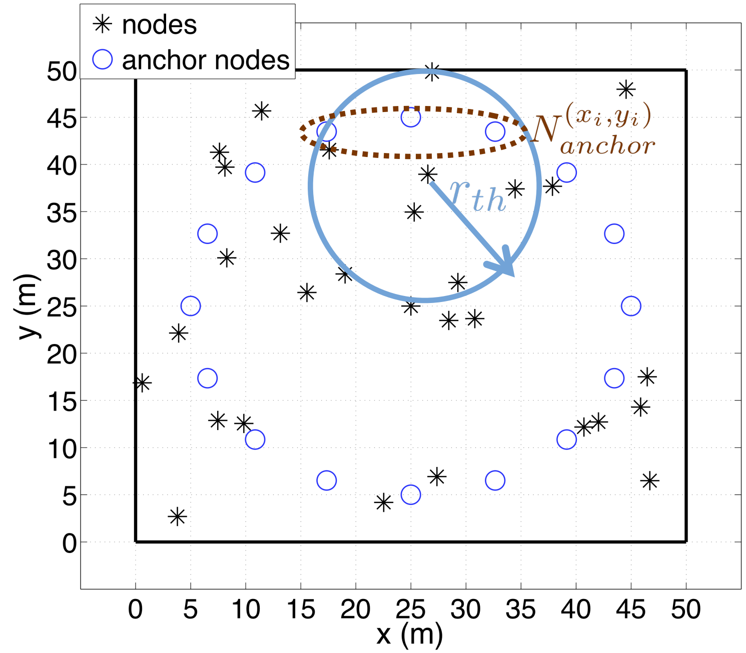
$$C_{LS}(x) = \sum_{i=1}^{N_1} \sum_{j \epsilon S_i} ||\delta_{ij} - \hat{d}_{ij}||^2$$

- Cost function is minimized through an iterative distributed method:

$$\hat{\mathbf{x}}_i(t) = \hat{\mathbf{x}}_i(t-1) + \gamma \sum_{j \epsilon S_i} (\delta_{ij} - \hat{d}_{ij})\mathbf{e_{ij}}$$

Selection criteria

- Finding the optimum threshold is difficult.
- The RSSI threshold is obtained by limiting the mean number of anchor nodes inside the radio range of an arbitrary node i.



- Number of anchor inside r_{th}: $N_{anchor}^{(x_i,y_i)} = \sum_{j=1}^{N_2} I(\|(x_i, y_i) - (x_j^a, y_j^a)\| < r_{th})$
- Mean number of anchor nodes seen by all nodes in the network: $N_m \approx \sum_{j=1}^{N_2} \pi r_{th}^2 \frac{1}{A} = \frac{N_2 \pi r_{th}^2}{A}$

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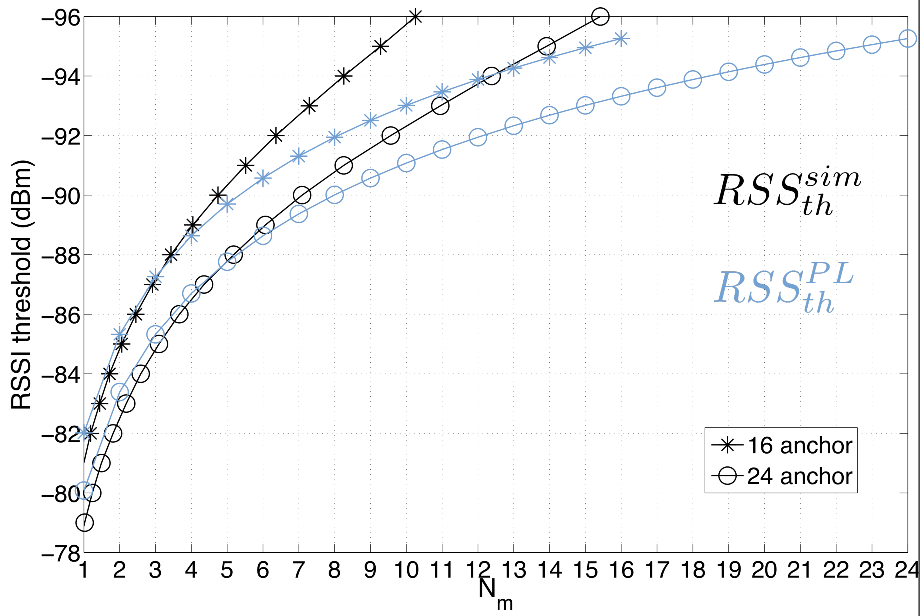
Selection Criteria

- From the previous expression, r_{th} is transformed to an RSSI threshold following propagation model.
- Pathloss model of the distance

$$RSS^{PL} = \frac{P_0}{r^{\alpha}}$$

$$RSS_{th}^{PL} = \left(\frac{N_2 \pi P_0^{2/\alpha}}{N_m A} \right)^{\alpha/2}$$



Selection Criteria

- From the previous expression, r_{th} is transformed to an RSSI threshold following propagation model.

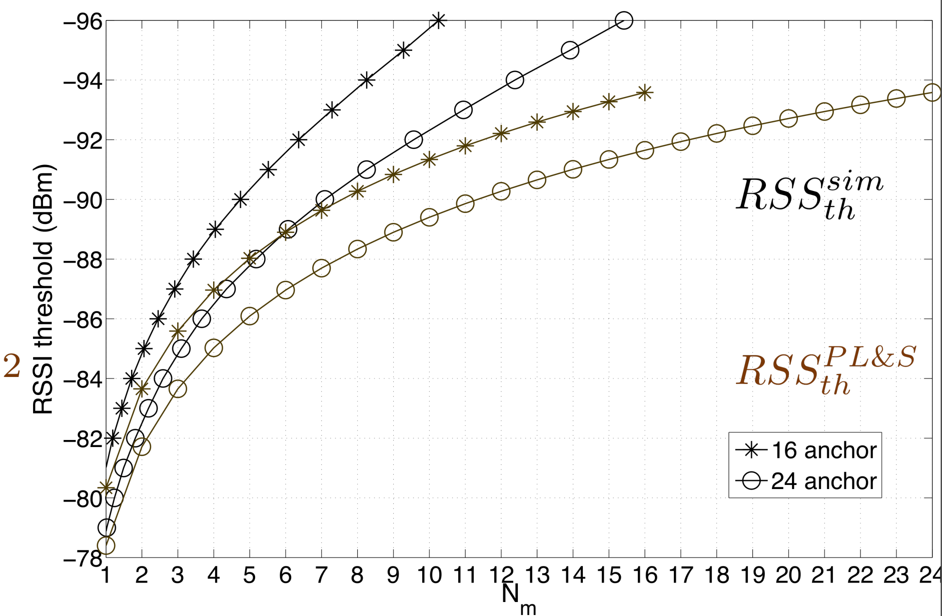
- Pathloss & shadowing model of the distance

$$RSS^{PL\&S} = \frac{P_0}{r^{\alpha}} z$$

$$RSS_{th}^{PL\&S} = \left(\frac{N_2 \pi P_0^{2/\alpha} e^{\frac{\sigma_v^2 2 (\log 10)^2}{100 \alpha^2}}}{\bar{N}_m A} \right)^{\alpha/2}$$

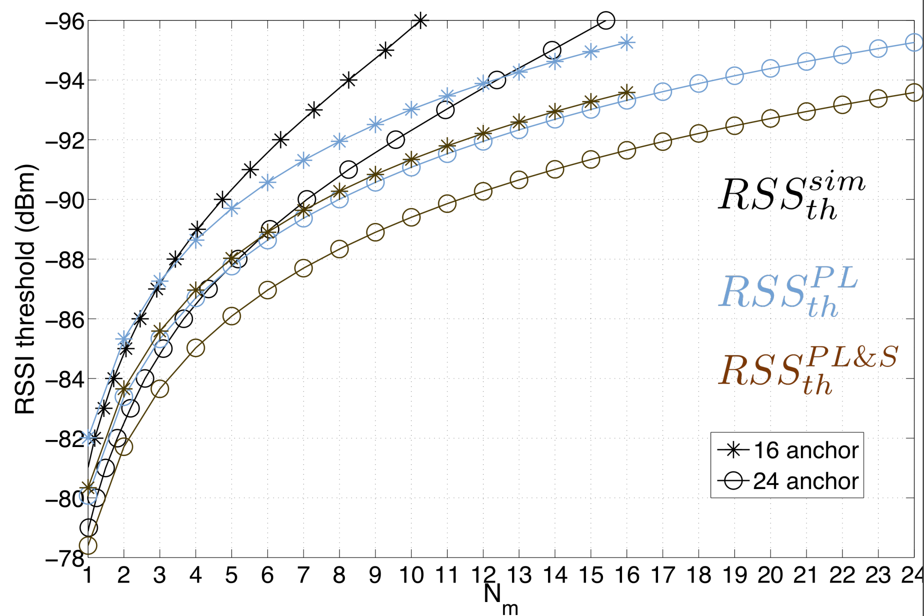
being z a lognormal variable

$$z = 10^{v/10} \sim \log \mathcal{N}(0, \sigma_v^2)$$



Selection Criteria

- From the previous expression, r_{th} is transformed to an RSSI threshold following propagation model.
- High mismatch at lower values of RSSI due to consideration of an extra area.
- The pathloss model is the one that has less mismatch.



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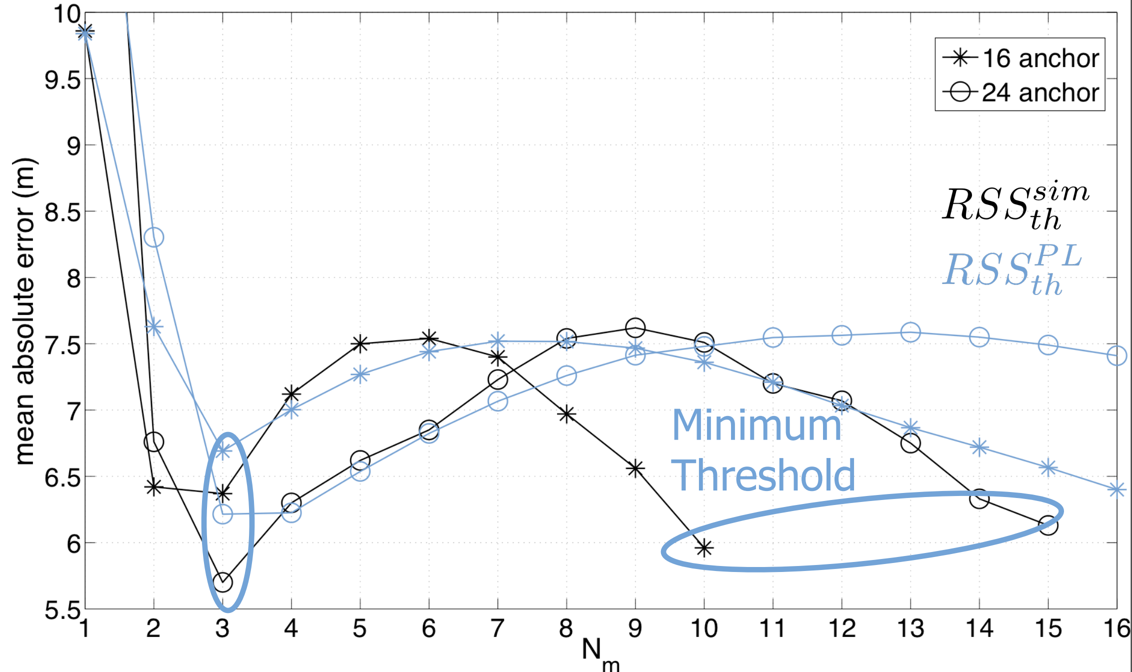
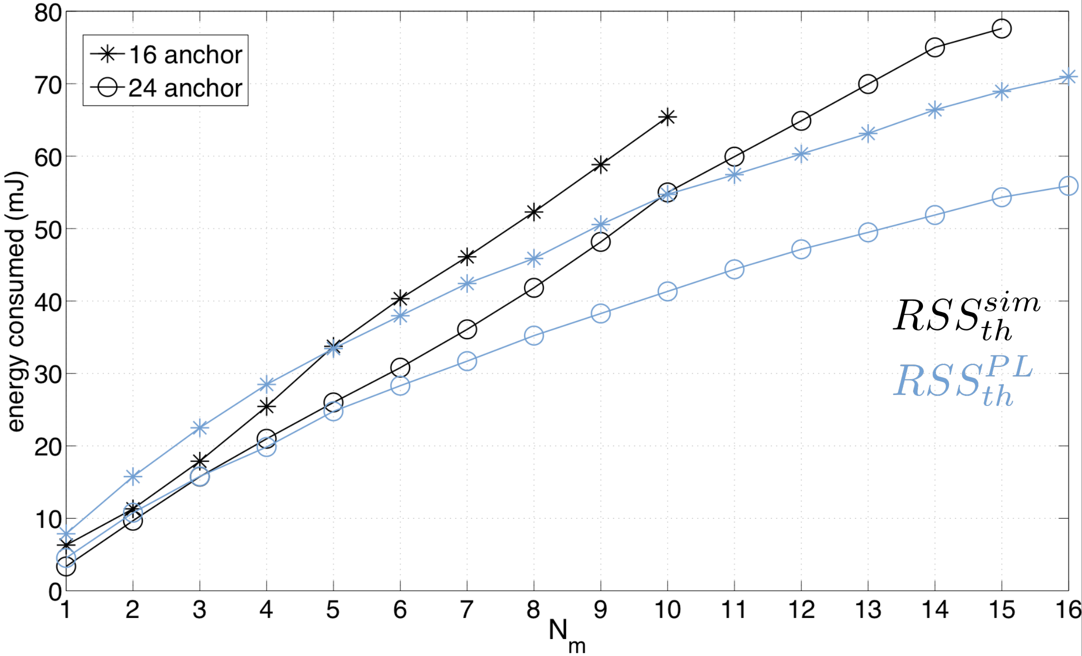
Simulation results

- Mean absolute error versus mean number of anchor nodes.
- Similar performance with a value of Nm=3 compared to the result obtained at maximum RSSI threshold.



Simulation results

- Energy consumed versus mean number of anchor nodes.
- Lower values of energy consumption with a lower value of anchor nodes in the network.



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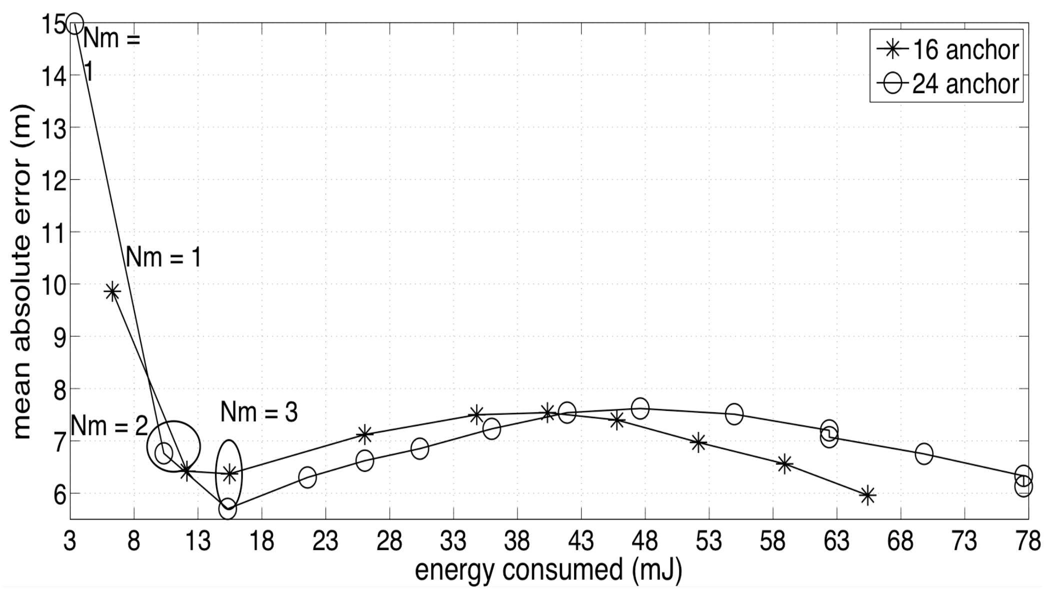
Simulation results

- Mean absolute error versus energy consumed.
- Comparing the results at Nm=3 with those obtained at maximum radio range, we achieve:
- Similar performance in terms of error.
- Reduction in the energy consumption.
- Good trade-off with Nm=3 for both scenarios.



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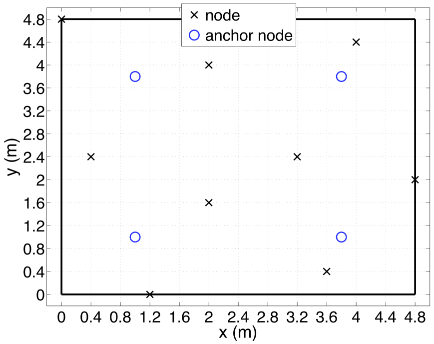
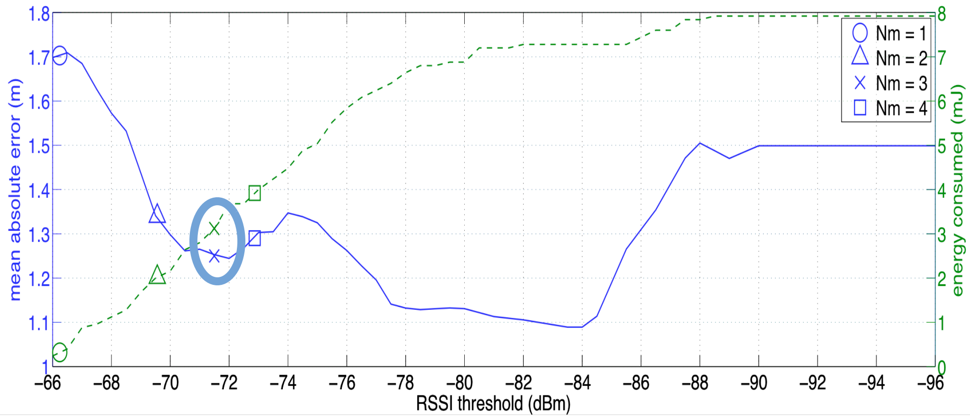
Experimental validation

- Experimental results in a real WSN based on IRIS motes (Crossbow) are presented.
- Behaviour of the error is similar to that predicted theoretically.
- Again, Nm=3 can be considered a good choice.





Conclusions

- A node selection criteria aimed at optimizing the position accuracy versus energy efficiency trade-off has been proposed.
- The proposed scheme is a node selection mechanism that fixes an RSSI threshold (any additional cost in size or hardware is implied).
- An excellent behaviour in terms of accuracy versus energy trade-off is obtained by setting the mean number of anchor nodes (Nm) equal to 3.
- We present experimental validation that confirms the efficiency of the proposed strategy.