Lost in Space
or
Positioning in Sensor Networks

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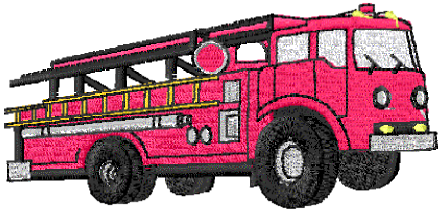
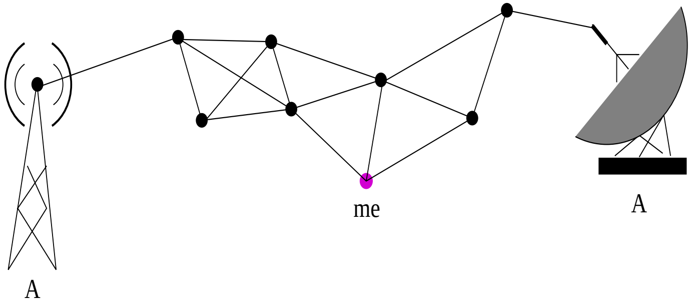
Positioning

- What is positioning (a.k.a. localization)?
  - Deduce coordinates
  - GPS “software version”

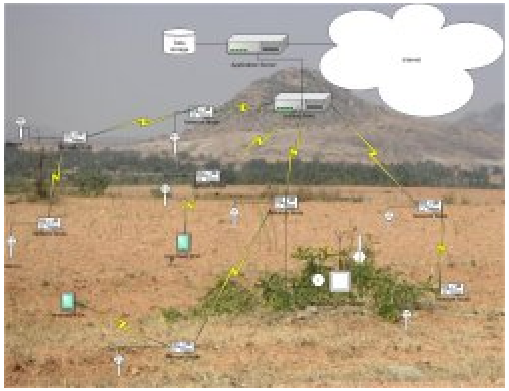


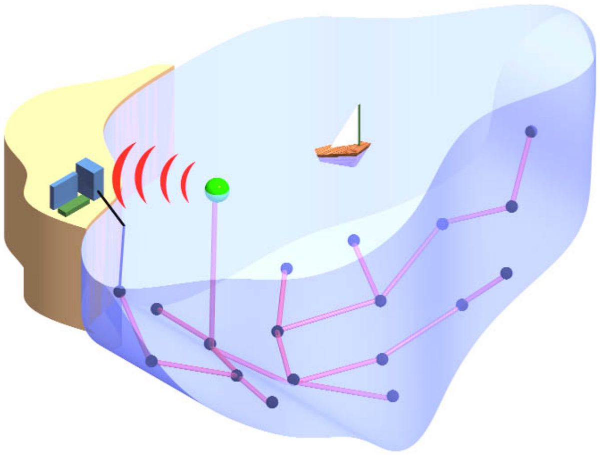
- Why positioning?
  - Sensible sensor networks
  - Heavy/costly localization hardware
  - Geometric routing benefits

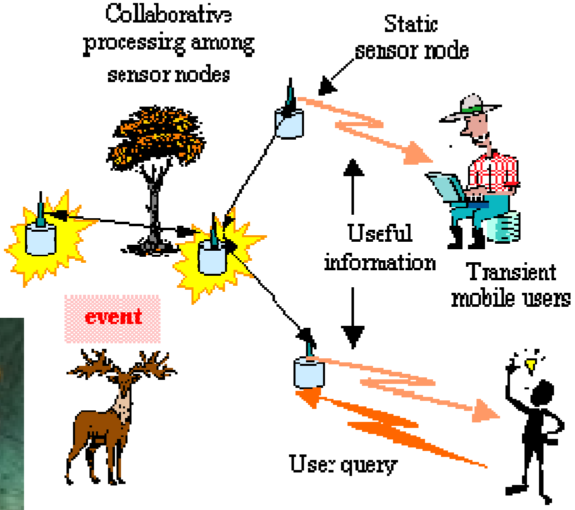


- Idea:
  - (Small) set of anchors
  - Others: location = *f(network,communication,measurements)*

Sensor Networks







Collaborative processing among sensor nodes

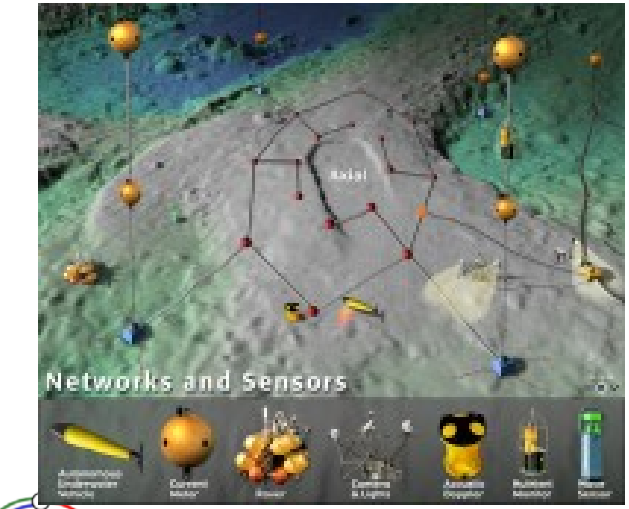
Static sensor node

Useful information

Transient mobile users

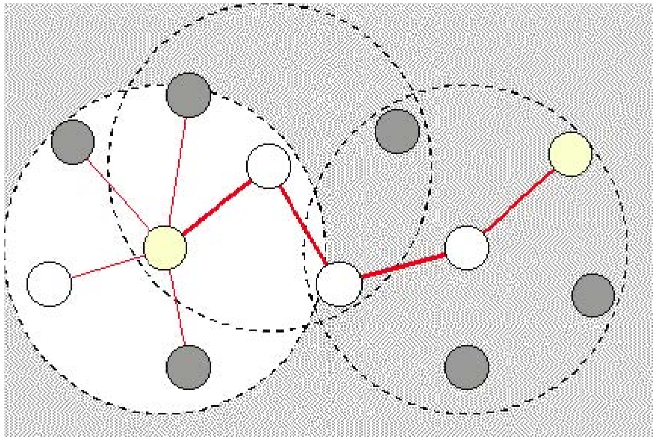
event

User query



Our Perspective

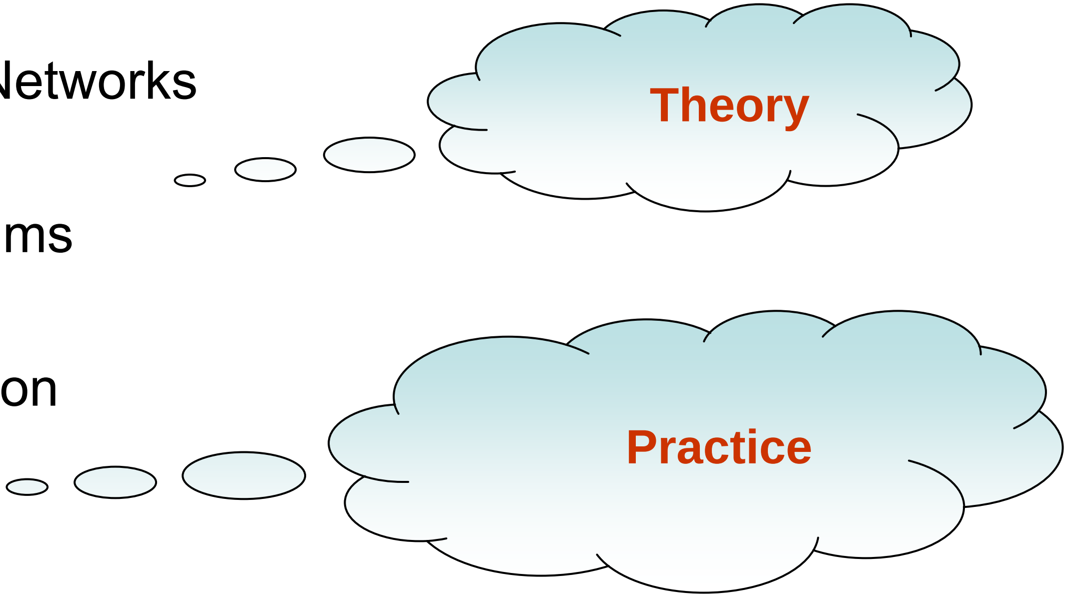
Theory



Practice

Positioning – As We See It

- Models of Sensor Networks
- Positioning Algorithms
- Hardware Description
- Experiments
- Lessons
- Future Work



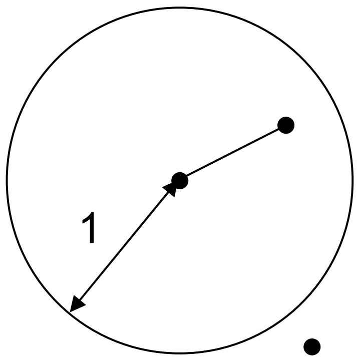
Theory

Practice

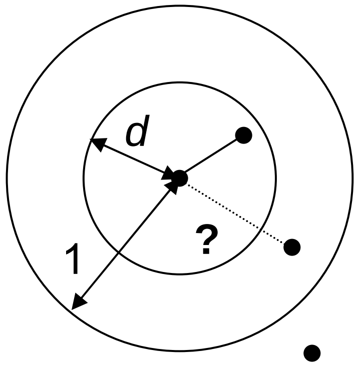
Part I: Theory

Models of Sensor Networks

- Unit Disk Graph (UDG)
  - [Clark *et al*, 1990]
  - Widely used abstraction



- Quasi-Unit Disk Graph (qUDG)
  - [Krumke *et al*, 2001]
  - [Barriere *et al*, 2003]
  - [Kuhn *et al*, 2003]
  - More realistic?



- "well-behaved" ⇒ allow proofs

Available Information

- T[D]oA:time
  - GPS
  - Cricket [Priyantha *et al*, 2000]
- RSS: signal strength
  - RADAR [Bahl, Padmanabhan, 2000]
- Imply distance

- AoA: angle
  - APS using AoA [Niculescu, Nath, 2003]

- Relative distance to anchors
  - APiT [He *et al*, 2003]

Positioning Algorithms

- Based on (q)UDG
  - (sometimes) provable statements
  - Abstraction ⇒ rough idea

- Virtual Coordinates Algorithm [Moscibroda *et al*, 2004]
  - Linear programming
  - Complex, time-consuming
  - 100-node network: several minutes on desktop

- GHoST, HS [Bischoff, W., 2004]
  - Dense networks
  - Optimal in 1D
  - UDG crucial

Positioning Algorithms… cont’d

- APS [Niculescu, Nath, 2001 & 2003]
  - Hop or distance based
  - Given distance estimate, use GPS triangulation
  - Least-squares optimization
  - Isotropic network helpful

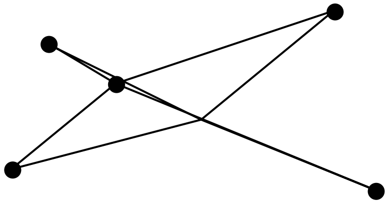
- General graphs
  - Given inter-node distances
  - Also: Internet graph (latencies)

- Example: Spring Algorithms
  - Internet: Vivaldi [Dabek *et al*, 2004]
  - Ad hoc [Rao *et al*, 2003]

Spring Algorithm

- Most practical?
- Originally: graph drawing
- Idea
  - Edge = spring
  - Rest length = distance
  - Embedding = minimal power configuration
- Algorithm
  - Steepest descent, numerical methods
  - Simple:
    - New position = average of neighbors
    - Iterate

Local vs. global



Our View = Assumptions

- Minimal hardware
  - Low storage
  - Low computing power
  - Basic RSS measurements

- Short range
  - Few meters
  - (RADAR: building – several dekameters)

Part II: Practice

Hardware Description

- ESB
  - scatterweb.com
  - 32kHz CPU
  - 2kB RAM
  - Sensors and actuators

Desktop:

  - 3GHz
  - 512MB
  - Factor 10^5

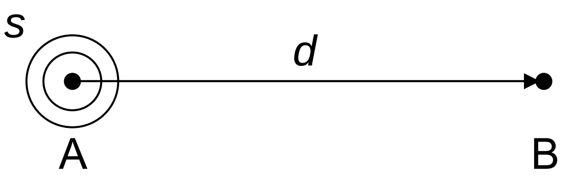
- RSS:
  - Indirectly via packet loss
- New version:
  - Actual RSS measurable at receiver
- “Battery with Antenna”

“software version” RSS

- Older ESB (software) version
  - @sender: vary transmission power
    - Via potentiometer controlling current to tranceiver
    - Value *s* between 0 and 99
    - Write *s* into packet
    - Repeat *x* times
  - @receiver: count number received packets
    - per *s*
  - Measurement: packet loss
- Requirement
  - Distance increase → power increase
  - Correlation: to be determined
- New version (software):
  - Direct read out

Future work!

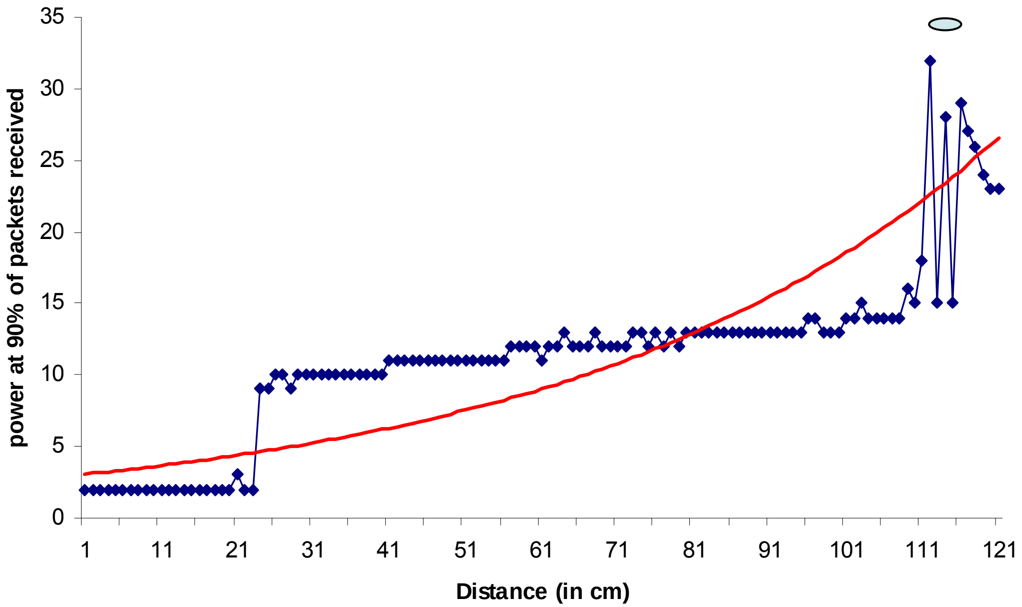
Experiment 1 – “Laboratory”



- Power vs. Distance
  - A sends at power level *s*
  - *x* = 100 times
  - *d* = 1..120cm

- Minimum
- 90%

Coffee machine?



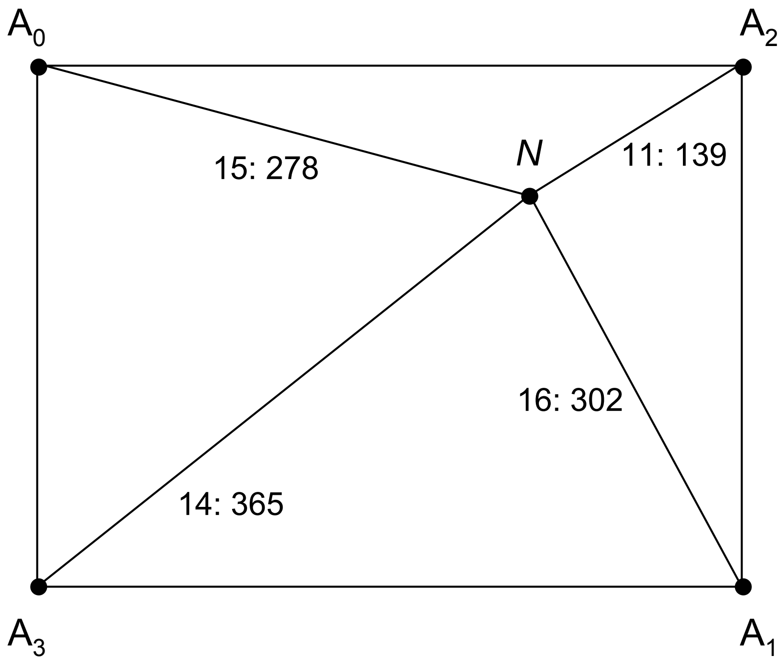
Original Algorithm

- Spring Embedding
  - Good for “easy” networks
- Power-to-distance
  - Inverse of previous experiments

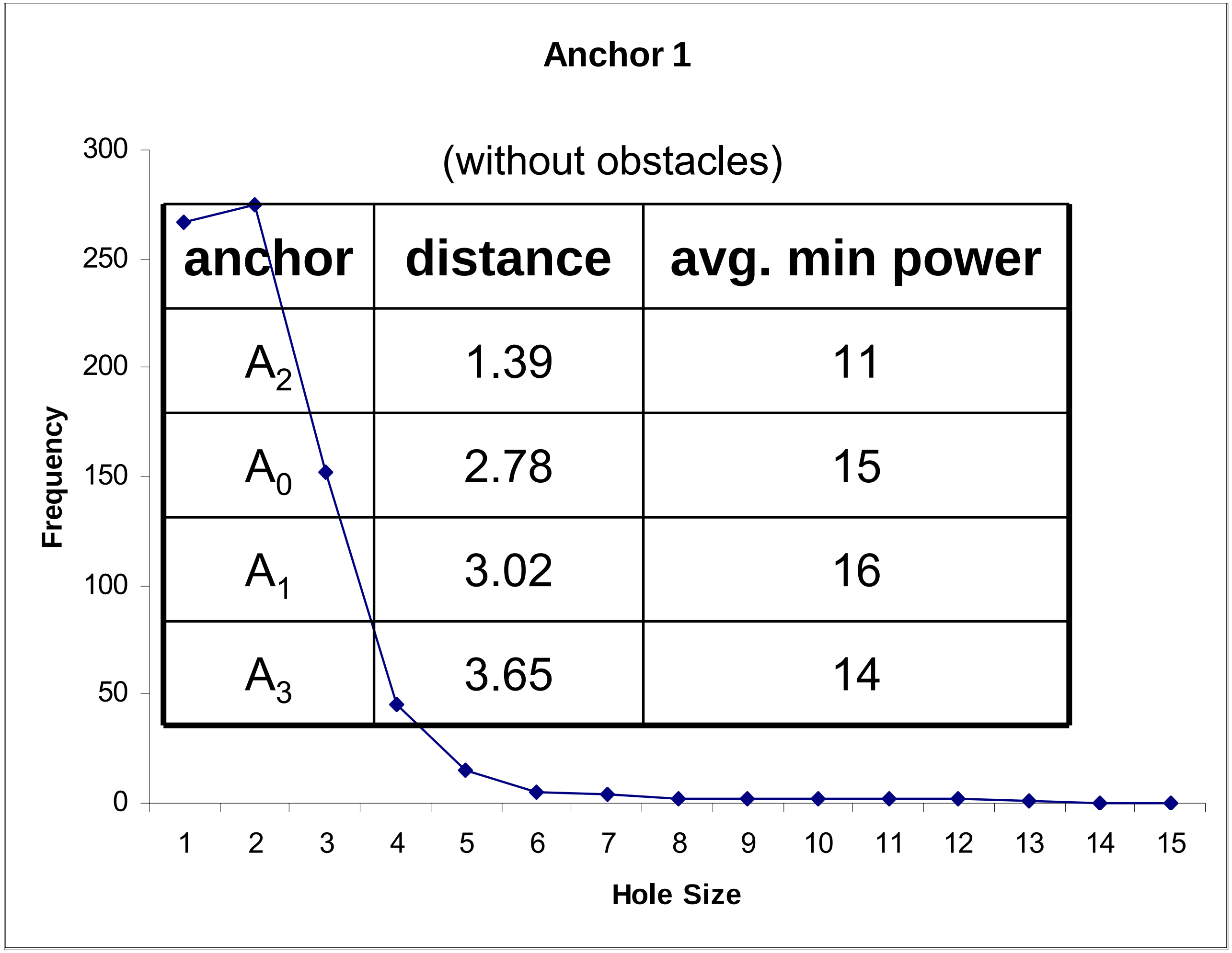
- Results
  - **Unusable!**

Experiment 2 – “Room”

- Localization in the plane
  - Rectangle: 4m x 3m
  - 4 anchors: corners
  - Test node: inside
- Each anchor A_i
  - Send packet s = 0..99
  - Next anchor
- Test node N
  - Record packets received



Experiment 2 – “Room” … Results



(without obstacles)

anchor	distance	avg. min power
A_2	1.39	11
A_0	2.78	15
A_1	3.02	16
A_3	3.65	14

Experiment 3 – “Network”

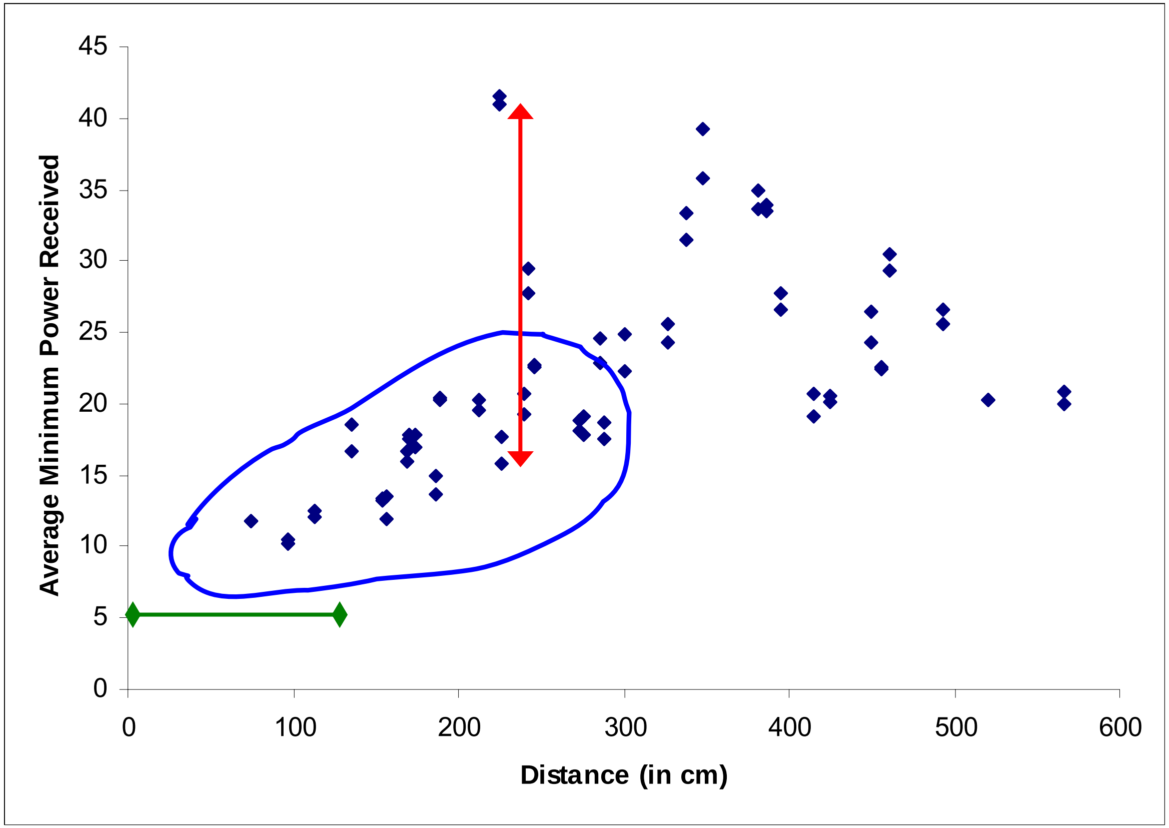
- 9 nodes in a room
  - Distances: 1..6m
- 1 sender at a time
  - Send 1 packet at each level
  - Others: record minimum received
  - Report previous minima
- Round robin

- Minima:
  - Good approximation
  - Storage: save factor 100 per round

Experiment 3 – “Network” … Results

- Error
  - Almost 30 units for same distance
  - Exp. 1: “nicer” curve
- Longer range effects?

- Symmetry!



Lessons

- Average minimum
  - Stable
  - Good approximation
  - Saves storage

- Symmetric links

- Power versus Distance
  - Strongly environment dependant
  - Measurements between two nodes

    ➔ Not generalizable

- RSSI in sensor networks: good, but not for “reasonable” localization

Future Work

- Here: more questions than answers
- Hardware RSS measurements
  - Indication given by reviewer

Similar results

- Same experiments – different hardware
  - Same results/trend?

mica2:
in progress

- Long range vs. short range
- More environments
- New models

Questions?
Comments?

Distributed
Computing
Group