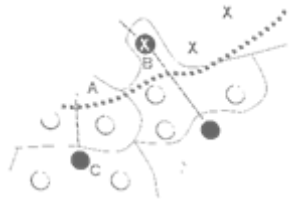
IEEE International Symposium on Intelligent Signal Processing (WISP 2007), Madrid

"Weighted Centroid Localization in ZigBee-based Sensor Networks"



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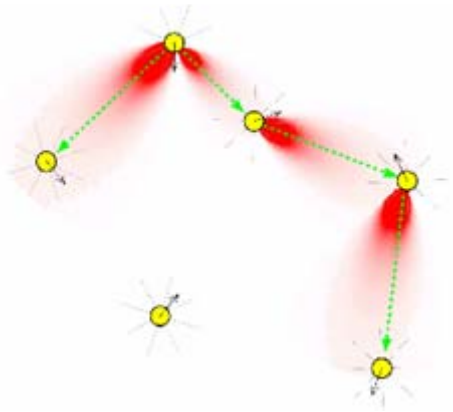
Outline

- Problem Statement
- Classification and Related Work
- Distance Estimation Techniques
- The “Weighted Centroid Localization (WCL)”-Algorithm in General
- Combining WCL and ZigBee
- Results
- Conclusion

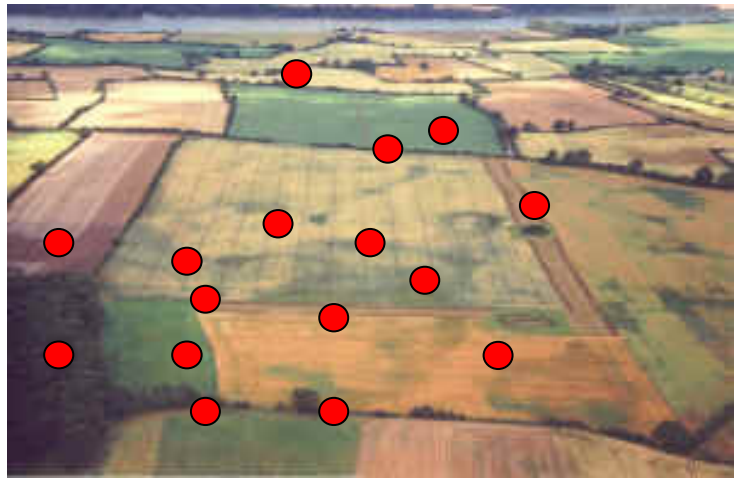


Problem Statement

- Preconditions
  - Hundreds of sensor nodes are randomly deployed
  - Position initially unknown

- Why do we need localization?
  - Position ↔ Measurement
  - Geographic Routing
  - Self organization, -healing

- Constraints/Considerations
  - Nodes strongly resource limited
  - Nodes miniaturized
  - Changing dynamic topology
  - Nodes are error-prone



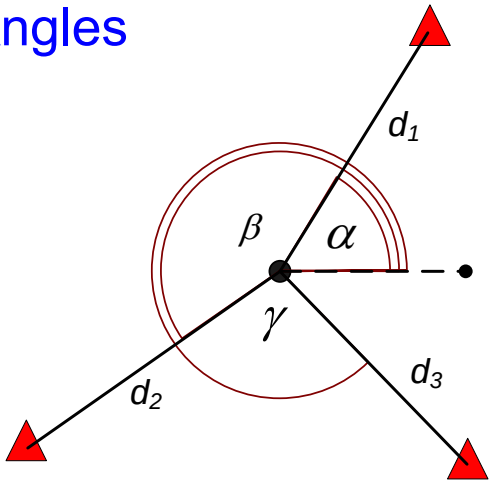
Conceivable Solution

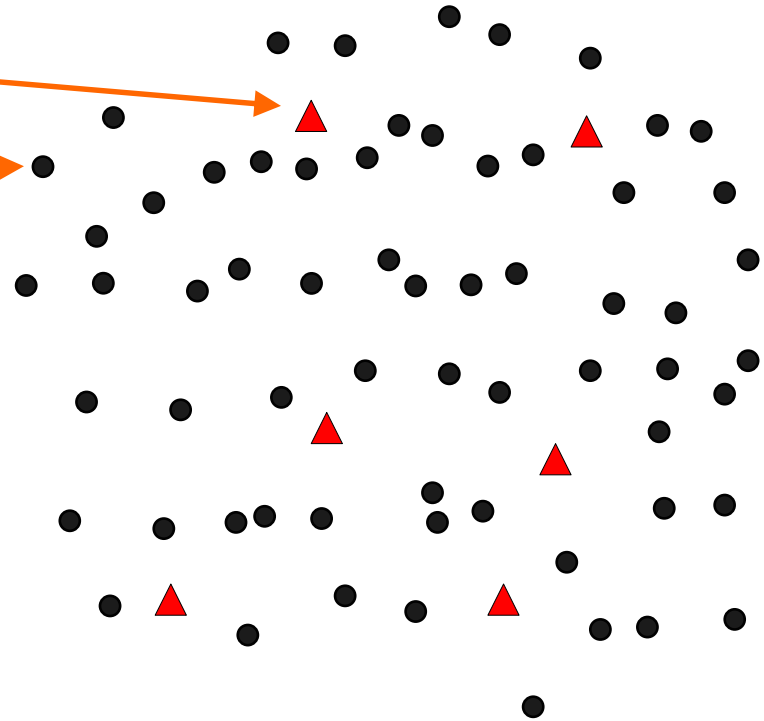
- Integrating existing localization system on every node
  - GPS, GSM, Galileo (from 2012)

- But:
  - Sensor nodes are strongly resource limited
    - GPS has a relatively high power consumption
  - Sensor nodes have to be tiny
    - GPS modules are comparatively large
  - Localization availability
    - GPS does not work everywhere
  - Nodes must be cheap
    - GPS costs additionally

Problem Solution

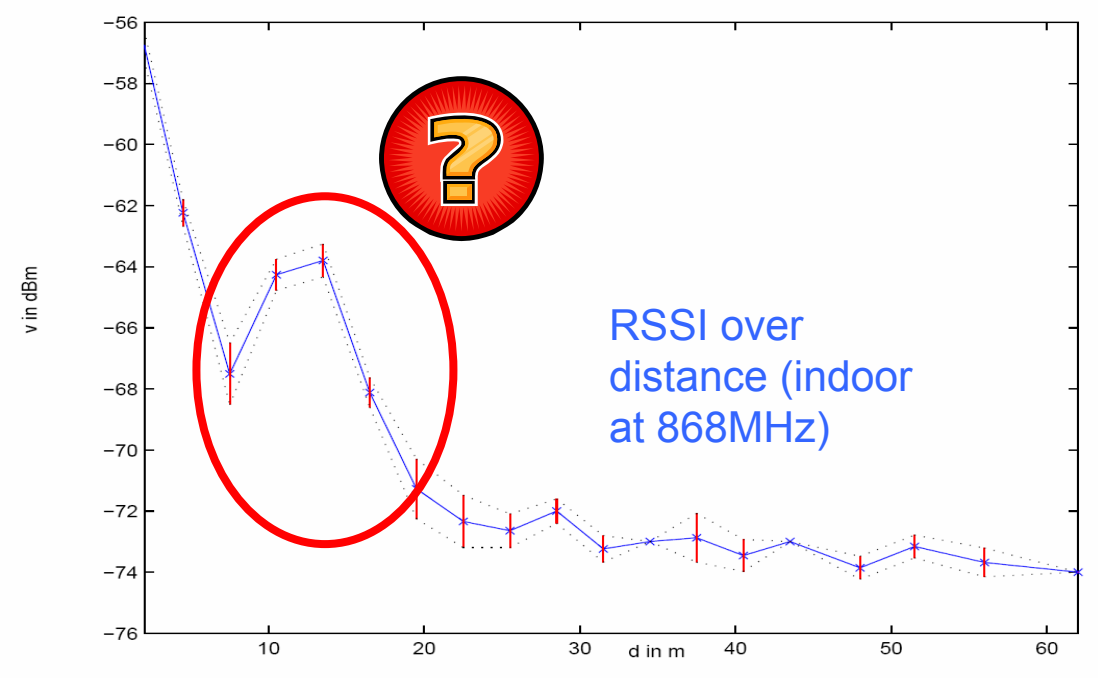
- Equip only some nodes with e.g. GPS
  - Beacons
- Rest of the nodes
  - Unknowns
- Estimation of the position with
  - Distances
  - Angles





Why not just using Trilateration?

- Only 3 beacons needed (2D)
- Simple to calculate
- But:
  - Distance estimations are highly defective!



Classification

Approximate Localization (coarse-grained)

- Geometric
- Proximity
- Scene analysis

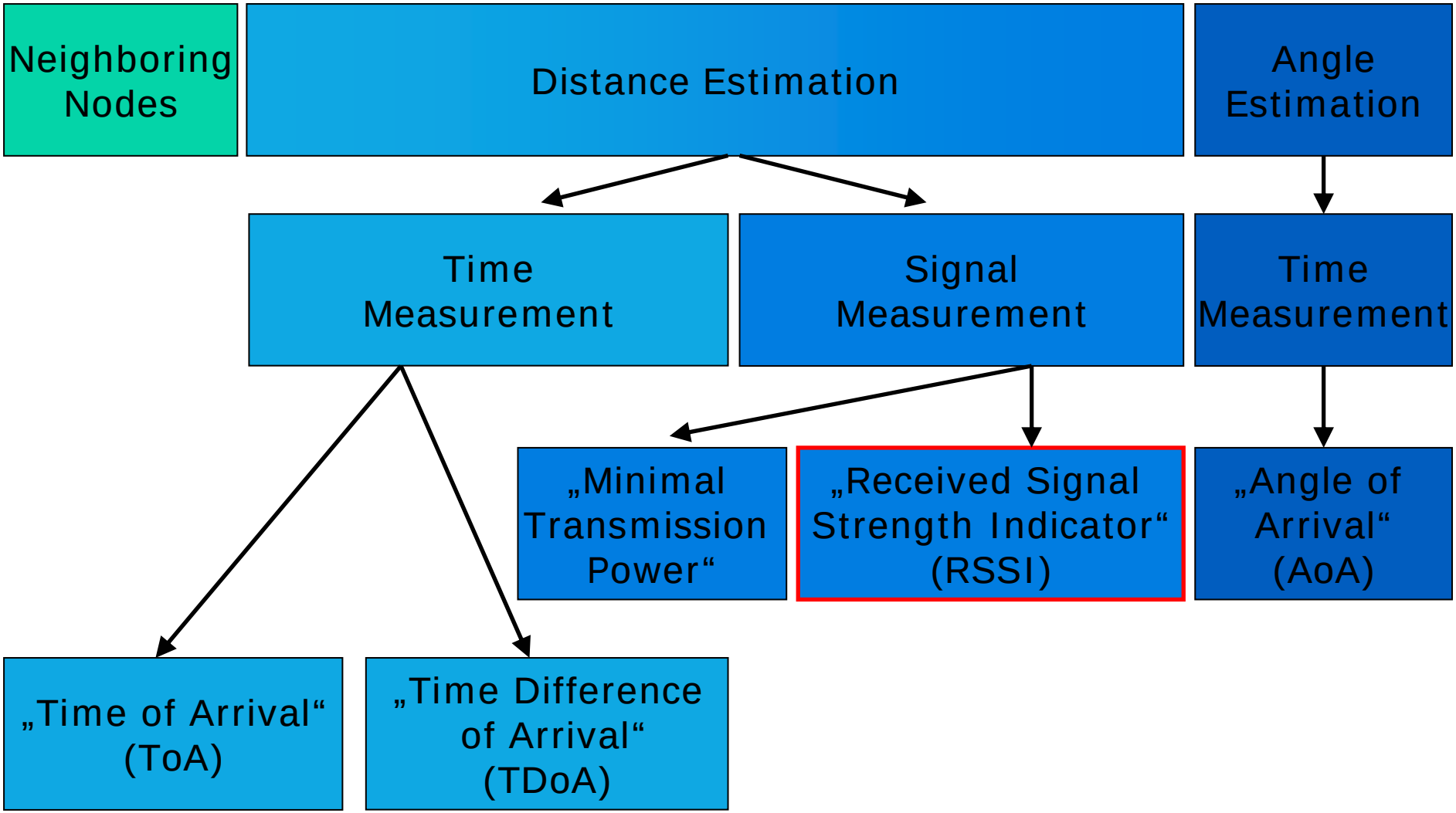
Most cited:
- *Coarse Grained Localization* (Bulusu)
- *APIT* (He et al.)
- *Convex Position Estimation* (Doherty et al.)

Exact Localization (fine-grained)

- Angulation
- Trilateration
- Least Squares
- Kalman Filter

Most cited:
- *Dynamic Fine Grained Multilateration* (Savvides et al.)
- *Acoustic with Least Squares* (Kwon et al.)

Observation Techniques

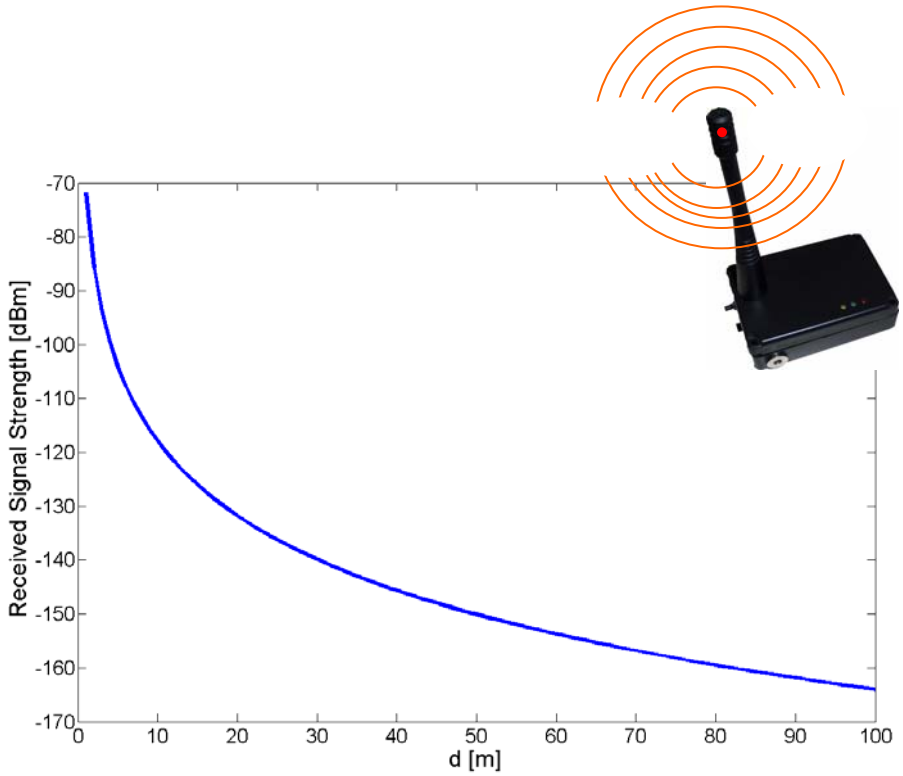


Distance Estimation with RSSI in Theory

- RSSI supported by hardware
  - Cheap and always available
- Circuit measures the received energy of a signal
- Compared to a reference voltage

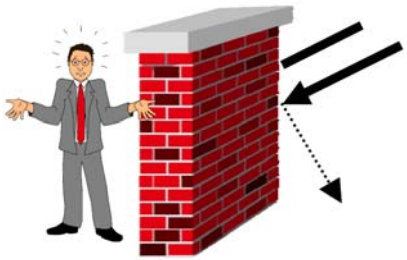
- Received Power:

$$\frac{P_R}{P_S} = \left(\frac{\lambda_0}{4\pi d} \right)^2 G_R G_S$$

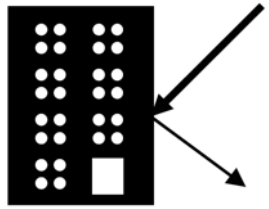


Problems with RSSI in Practice

- Transceiver sensitivity
- Signals in real world are strongly influenced
- Attenuation when passing objects
  - 876MHz → 8-20dB by a tree
  - 2.4 GHz → bricks 3dB, tinted glass walls 19dB
- Signal propagation characteristics can change frequently
- Received Signal Strength depends on battery level



Blocking



Reflection

Scattering

Diffraction

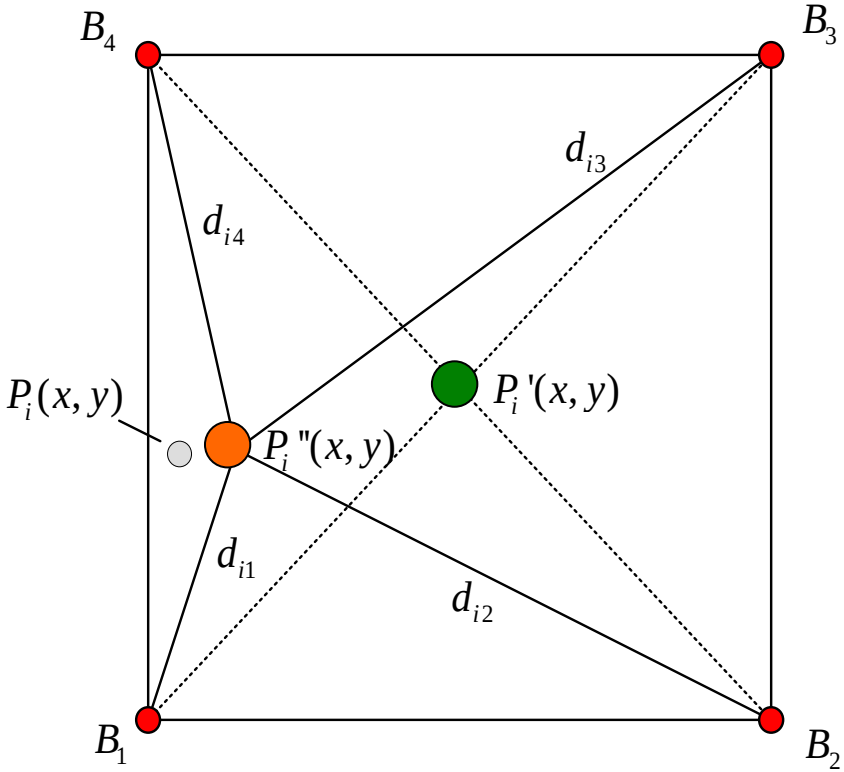
Weighted Centroid Localization (WCL)

- Approach:
  - Using only neighbor information → Coarse Grained Localization:

$$P_i'(x,y) = \frac{1}{n}\sum_{j=1}^{n} B_j(x,y)$$

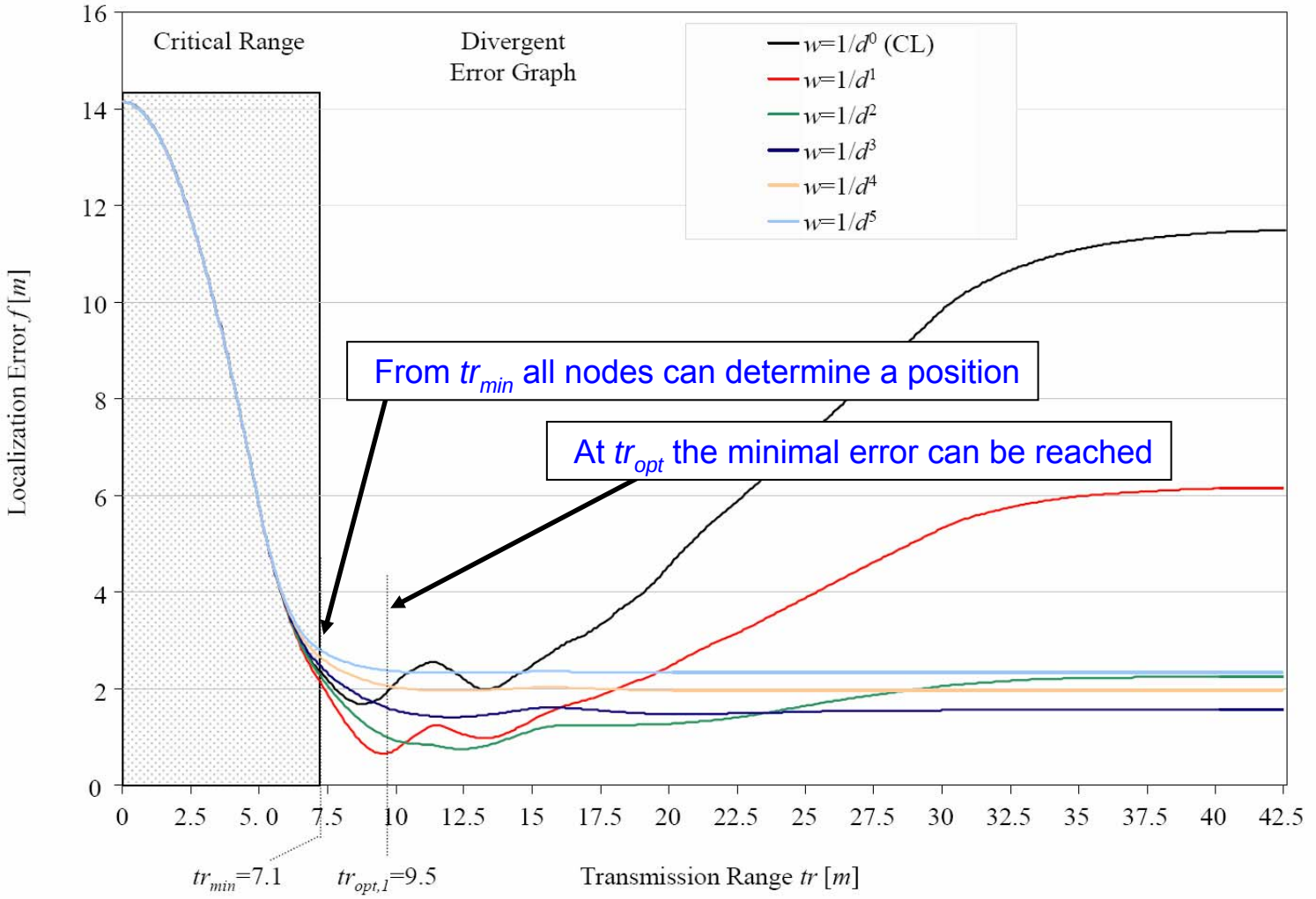
  - Now: Including also distances
  - Define a function for the weight $w_{ij}(d)$
  - Weighted Centroid Localization:

$$P_i''(x,y) = \frac{\left(\sum_{j=1}^{b}\left(w_{ij}\cdot B_j(x,y)\right)\right)}{\left(\sum_{j=1}^{b} w_{ij}\right)}$$

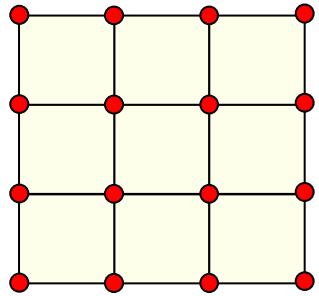


Determination of the Optimal Weight (Matlab Analysis)

$$P_i''(x,y) = \frac{\left(\sum_{j=1}^{b}\left(w_{ij}\, B_j(x,y)\right)\right)}{\left(\sum_{j=1}^{b} w_{ij}\right)}$$



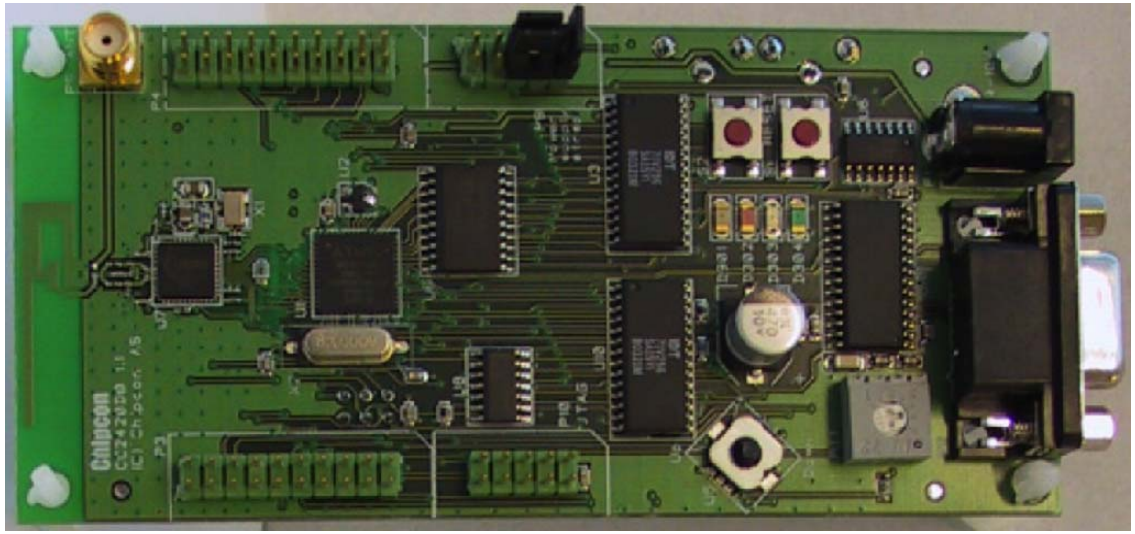
Beacon Configuration



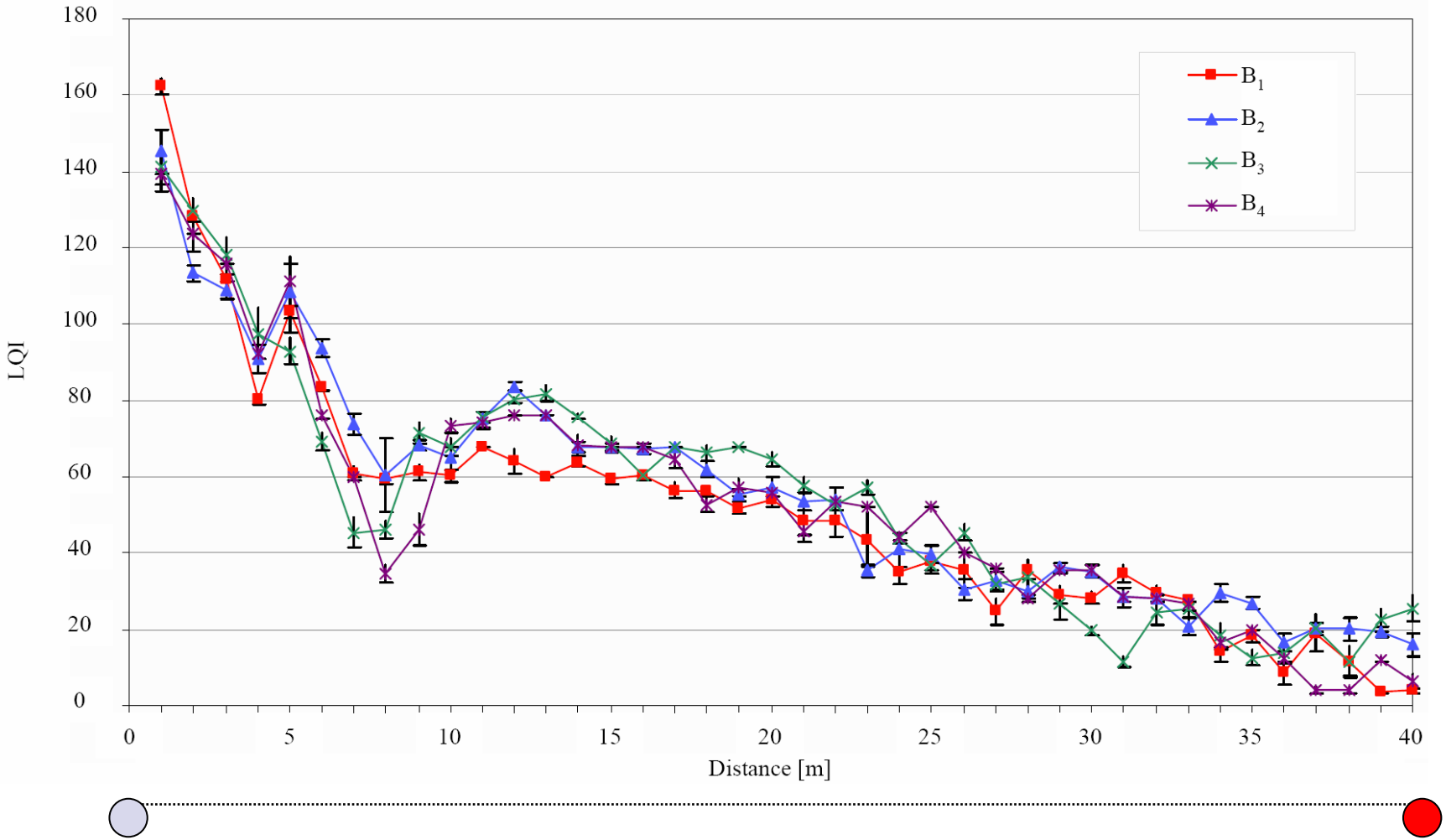
30mx30m

Hardware Platform

- CC2420 Demonstration Board
- Single chip IEEE 802.15.4 compliant
- ZigBee™ ready RF transceiver
  - 2.4 GHz
  - Atmel Atmega128L



One Dimensional LQI Measurements

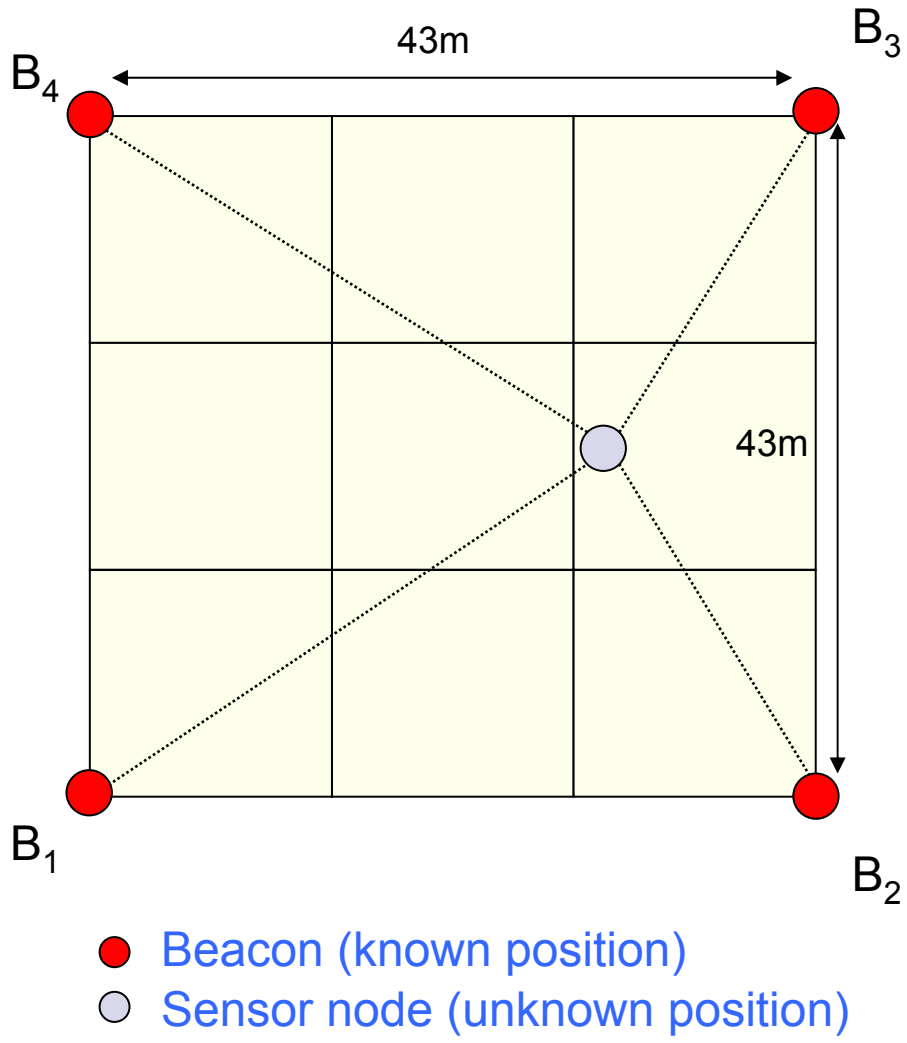


LQI – Value between 0-255, calculated on basis of RSSI

Realization of a Real World Localization

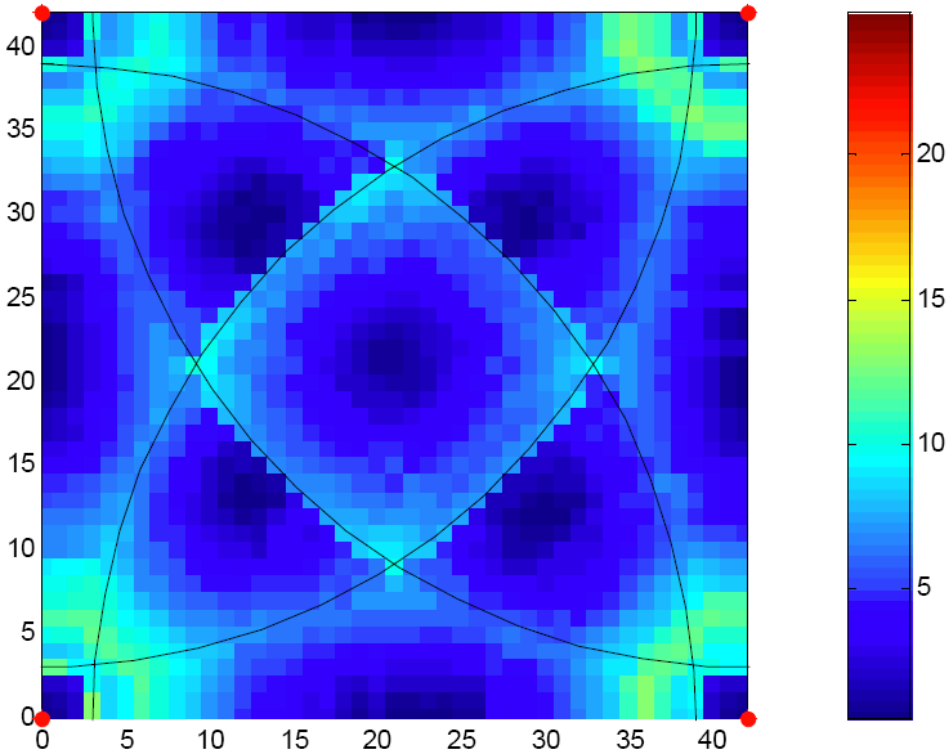
- 43m×43m field, 4 Beacons
- 13×13 testpoints on a grid

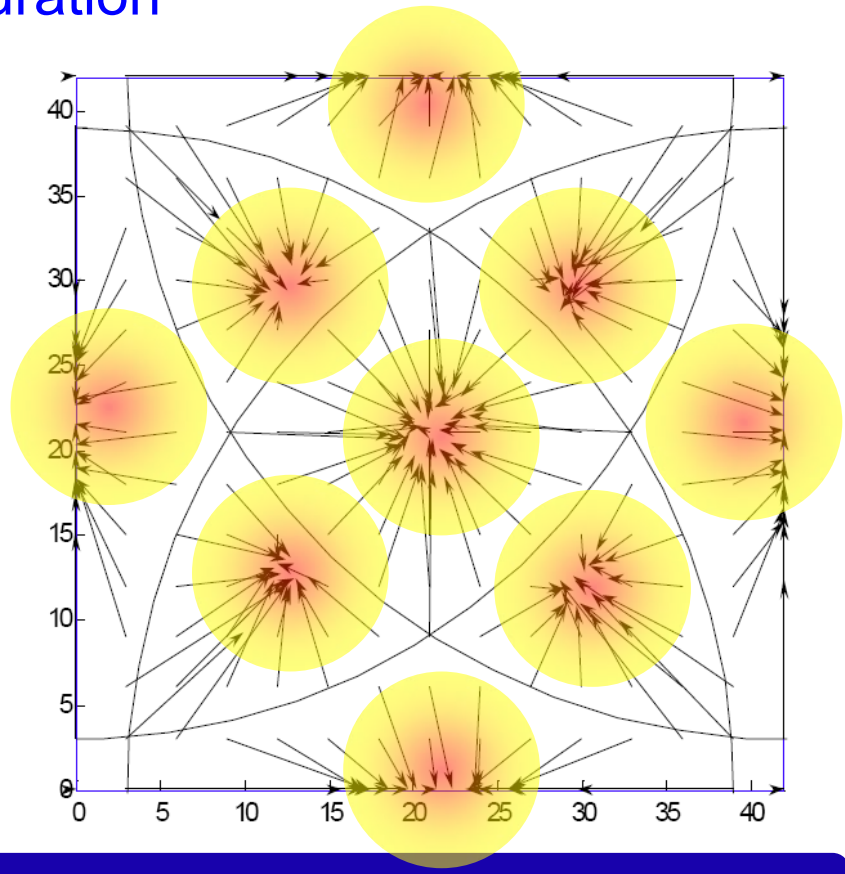
- Beacons (ZigBee Router) transmit position with optimal transmission range = 39m
- Node (Coordinator) receive beacon positions
- Node (Coordinator) measure the LQI to every beacon
- If b>3 then localization via WCL
- Averaging 20 WCL-coordinates per testpoint



Results

- Mean error 5.3m, max error 13.1m
- Estimated coordinates move to 9 hot spots
- Due to the specific beacon configuration

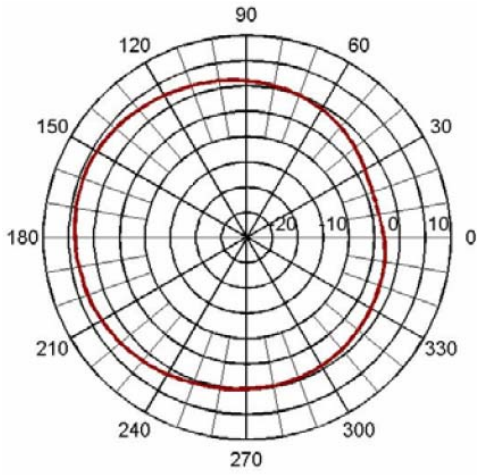




Discussion

- Pros
  - Incomplex Calculation (WCL) → O(*n*)
  - Fully distributed computation
  - Only receiving activity on beacons
  - Relatively robust against defective inputs

- Cons
  - Errors arise by non-circular borders
  - Limited precision
  - Hardware- and battery-dependent



Conclusions

- Running localization in WSN is strongly demanded
- Most classical observation techniques are defective (esp. indoor)

- New Approach: WCL combined with ZigBee

- Real world test was completed
- Precision is sufficient for a bunch of applications

Thank You!

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