Study of RSS-based Localisation Methods in Wireless Sensor Networks

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Outline

- Wireless Sensor Networks
  - Specifications
  - Senseless WSN Framework
- RSS Based Localisation in WSNs
- Test Environment
- Results
- Conclusion
- Future Work

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Wireless Sensor Networks

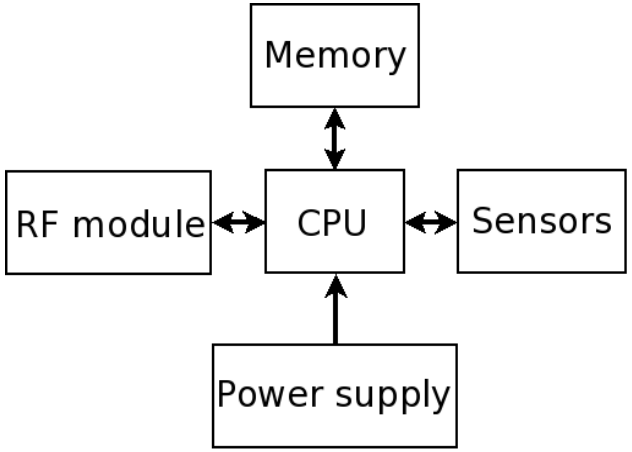
A wireless sensor network is a set of small autonomous systems, called sensor nodes which cooperate to solve at least one common application. Their tasks include some kind of perception of physical parameters [1].

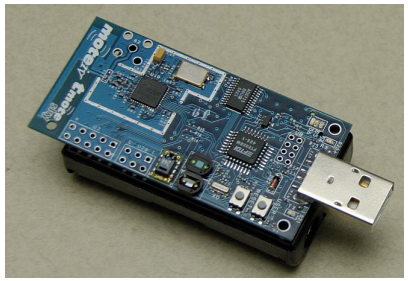
Autonomous motes can measure their environment,

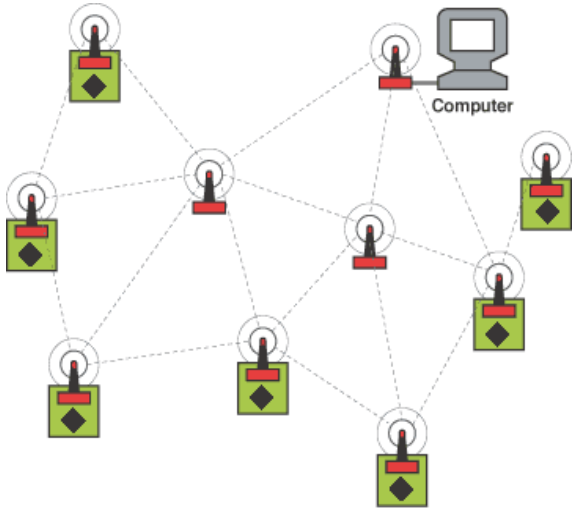
process the data and communicate ...

... to work together towards one or more applications

… which often benefit from location information.







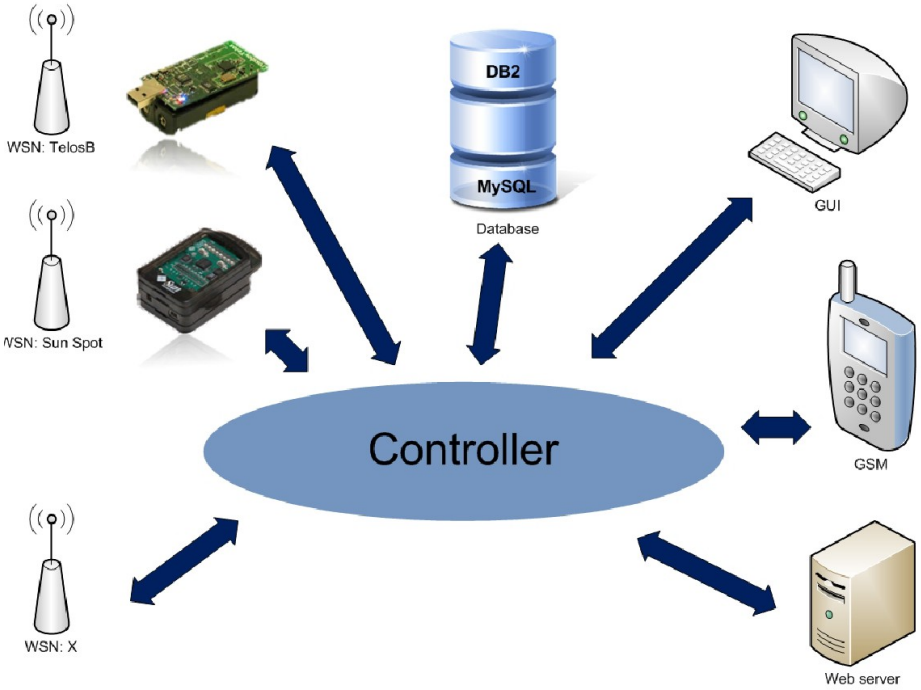
[1] An FDL'ed Textbook on Sensor Networks, Thomas Haenselmann.

WSN Specifications

- Hardware: CrossBow TelosB
  - TI MSP430 microcontroller with 10kB RAM
  - Ultra low-power
  - IEEE 802.15.4 compliant radio
  - Integrated temperature, light, humidity and voltage sensor
  - Programmable via USB interface
  - Integrated antenna
- Embedded software: TinyOS 2.1
  - Most popular OS for Wireless Sensor Networks
  - Open source
  - Energy efficient – low power
    - Hurry up and go to sleep
    - Split phase programming
  - Multi-platform

Senseless WSN Framework

- Distributed system:
  - Common data & command interface to different WSNs
    - Wireless Sensor Network: TelosB, SUNspots (TinyOS, Squawk VM)
    - Databases: MySQL, DB2 (ODBC)
    - GUIs: PHP, .NET, C#, AJAX, XML over TCP, WCF
    - Controller: JAVA



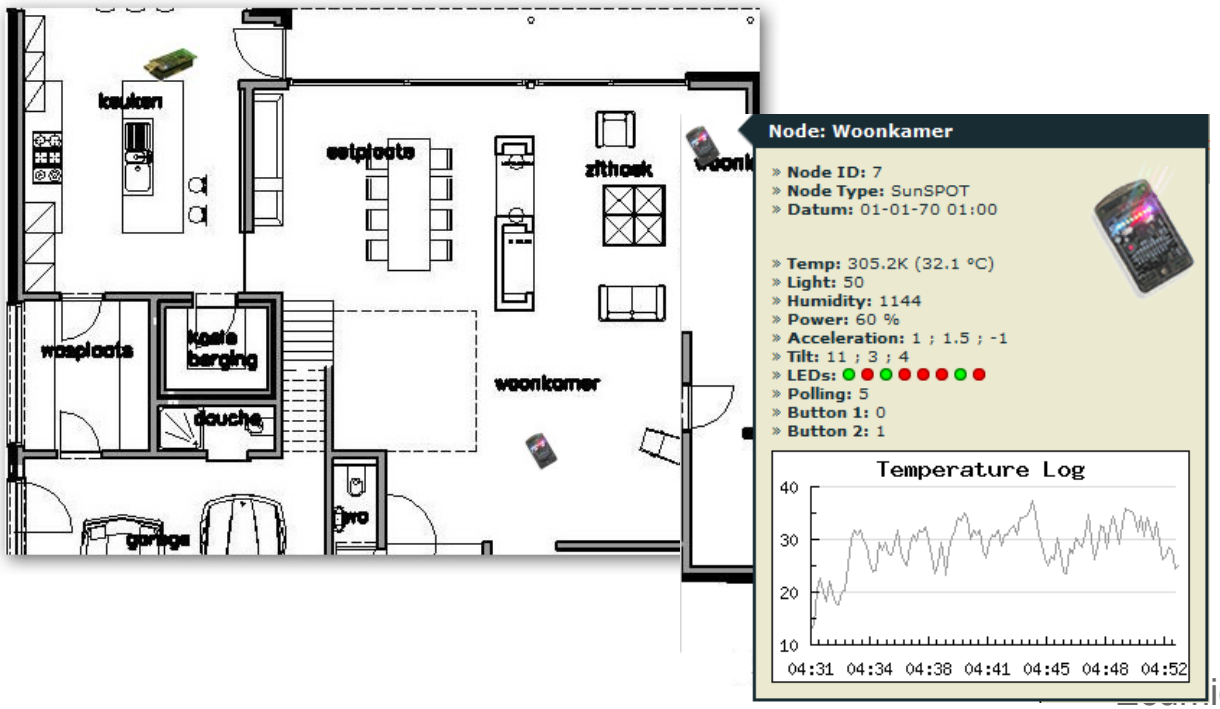
Senseless WSN Framework

Summary

All the sensorvalues of the nodes placed on the map selected below will be shown in a table. By selecting the option '*' all sensors will be shown.

Choose a map: plan.jpg (66 KB) Set map

Nodeid	Type	Date	Temp(K)	Light	Humidity	Power(%)	Accel x;y;z	Tilt x;y;z	Leds	Buttons
6	TelosB	01-01-70 01:00	305.2	50	NA	60	NA	NA	●●●	●
7	SunSPOT	01-01-70 01:00	305.2	50	1144	60	1 ; 1.5 ; -1	11 ; 3 ; 4	●●●●●●●●	●●
20	SunSPOT	01-01-70 01:00	400	100	200	60	1 ; 1.5 ; -1	11 ; 3 ; 4	●●●●●●●●	●●



RSS Based Localisation in WSNs

- Received signal strength based ranging (RSS)
  - RSS attenuates with distance due to free-space losses
- RSS based ranging has several drawbacks
  - Environmental errors
    - Rapid time varying
      - Movement of nodes, objects and people
      - Noise, interference
    - Static environment dependent
      - Layout of the environment: e.g. placement of doors
      - Multipath, shadowing
  - Device errors
    - Inter-device differences
    - Depleting batteries
    - Antenna orientation
    - Receiver/transmitter variability

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RSS Based Localisation in WSNs

- Localisation Requirements:
  - RSS based → ranging 'piggybacks' on the existing network
    - No extra hardware needed
  - Channel should be modeled accurately
    - Difficult on nodes with limited energy and processing power
  - Distributed and self-organising
    - No central dependency
    - Individual nodes and links between nodes are prone to failure
  - Energy usage
    - Processing and communication should be minimised
  - Adaptive
    - Number of Anchor nodes and network density is variable
  - Responsiveness
    - Mobile nodes are possible

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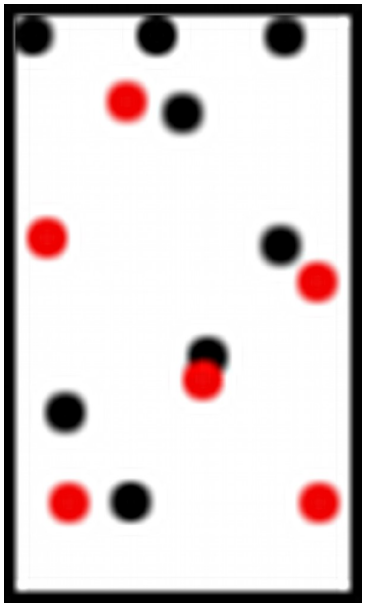
Test Environment

- Randomly placed Anchor nodes (black) & blinded nodes (red)
- Log-normal-shadowing model
  - Translate RSS measurements to distances

$$RSS(d) = PT - PL(d0) - 10 \times n \times \log(\frac{d}{d0}) + Xo$$

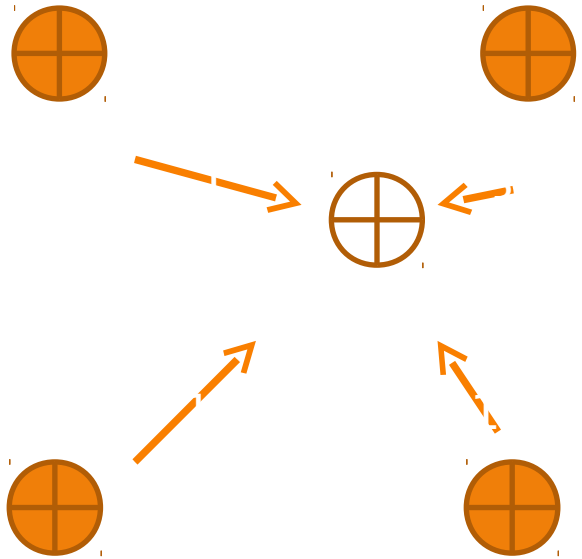
  - PT Transmitted power [dBm]
  - RSS Received Signal Strength[dBm]
  - P(d0) Path loss in dBm at a distance of d0
  - n Path loss exponent
- Range less Location estimation
  - Centroid Localisation
  - Weighted Centroid Localisation
- Range based Location estimation
  - Tritilateration
  - Min-Max Localisation
  - Least-Square Trilateration



(Weighted) Centroid Localisation

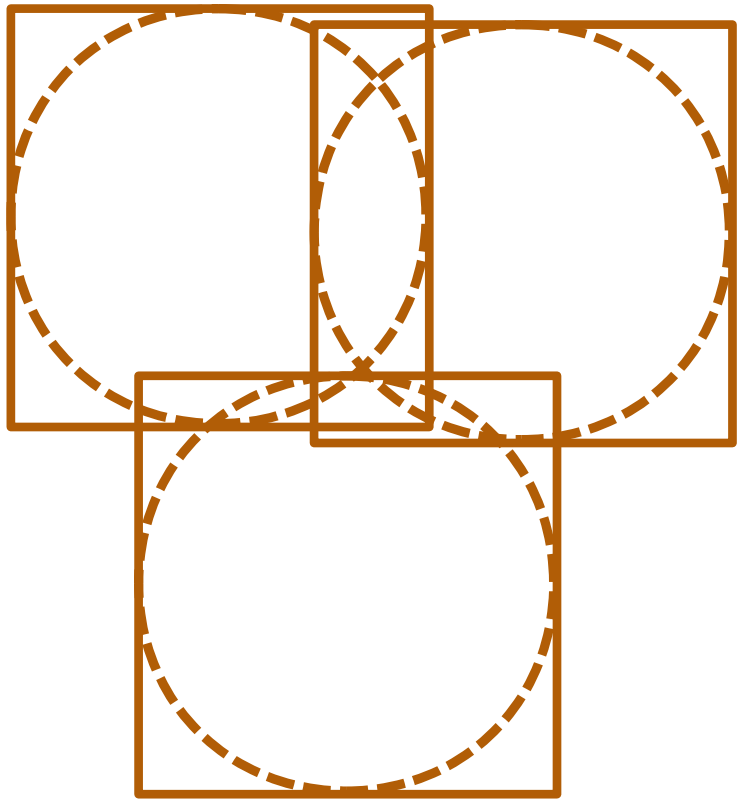
- Centroid Localisation
  - Coarse grained localization
  - Calculate the unknown position as the centroid of the anchor nodes within their communication range
- Weighted Centroid Localisation
  - A weight is coupled to the position of each anchor node by its RSS.

$$Weight = \frac{1}{RSS^g}$$



Min-Max Localisation

- Lateration is computation-heavy.
- A good simplification models around each anchor node a bounding box and estimates position at the intersection of boxes



Test Environment: WSN

- Three different roles:
  - Root Node: datasink
  - Anchor Node: known location
  - Blind Node: unknown location
- WSN Messages
  - Sensor
    - Mote id, Battery (voltage), Light, Humidity, Temperature, Button pressed
  - Location
    - Mote id, Anmoteid, VANs, VANr, Hop count, RSSI
  - Status
    - Mote id, Active, AN, leds
    - Posx, Posy
    - Samplerate, locRate

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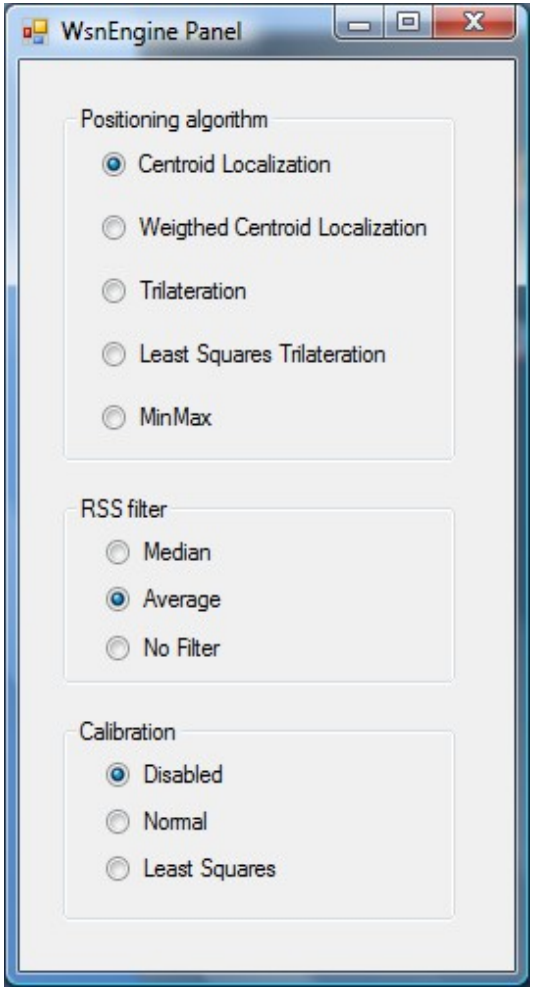
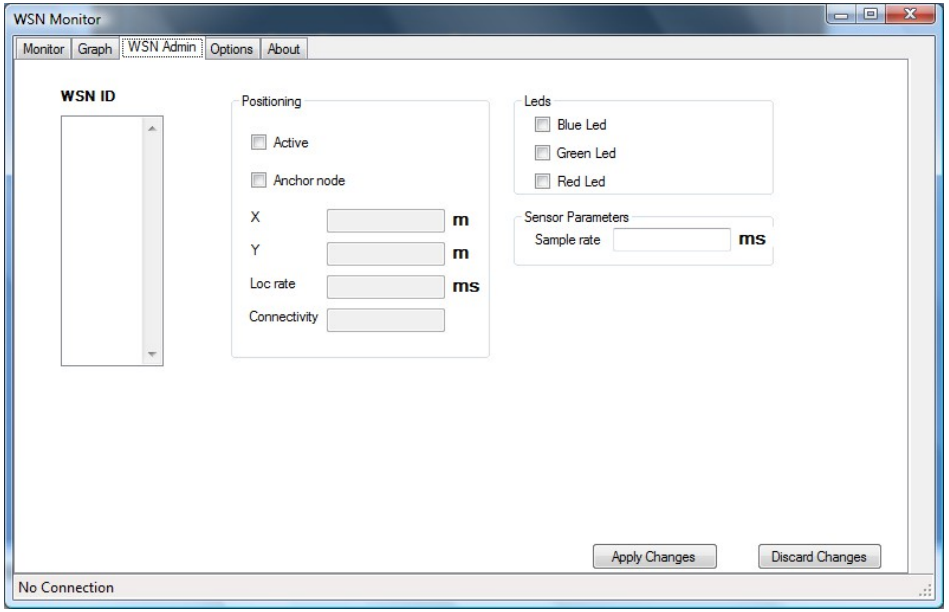
Test Environment: Software





Test Environment: Calibration

- Configure anchor nodes with dissemination protocol
- ANs Broadcast in order to measure RSSI
- ANs Send back RSSI with the collection protocol
- Use least square to calibrate anchor nodes

$$\begin{bmatrix} RSS1 \\ \cdot \\ \cdot \\ \cdot \\ RSSi \end{bmatrix} = \begin{bmatrix} -1 & -10log\frac{d1}{d0} \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ -1 & -10log\frac{di}{d0} \end{bmatrix} \times \begin{bmatrix} P(d0 \\ n \end{bmatrix}$$

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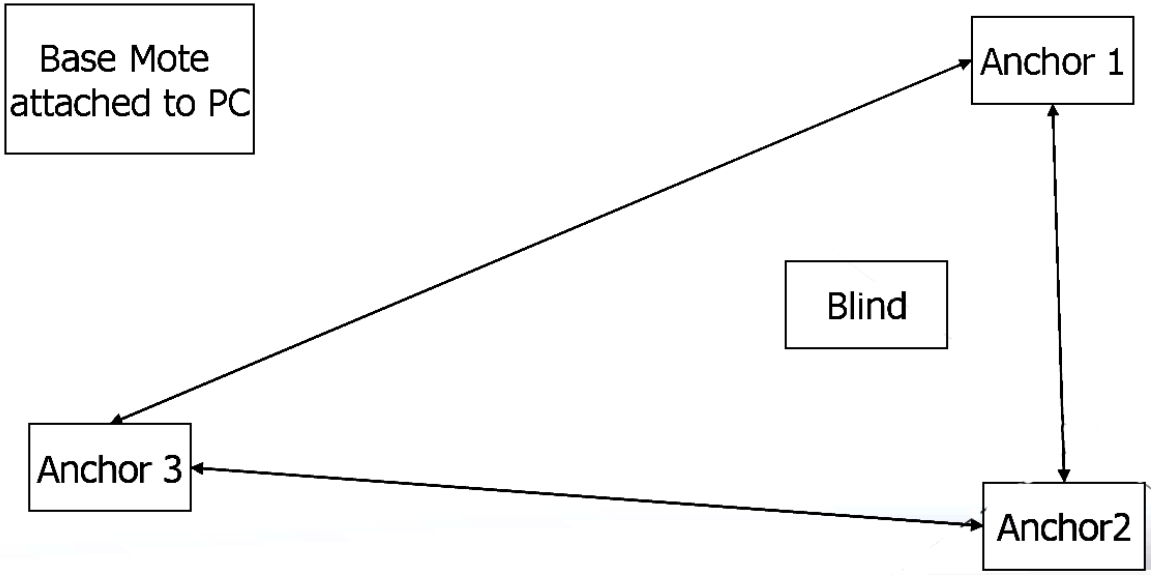
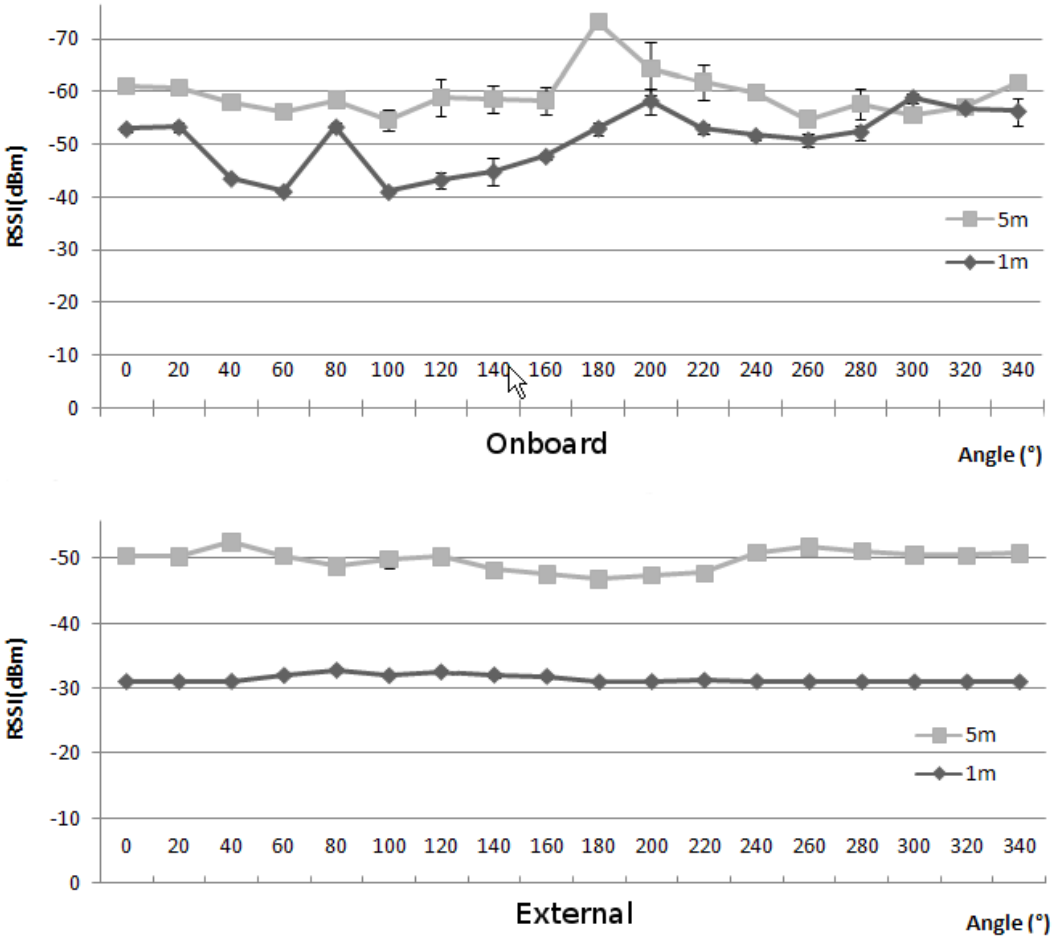


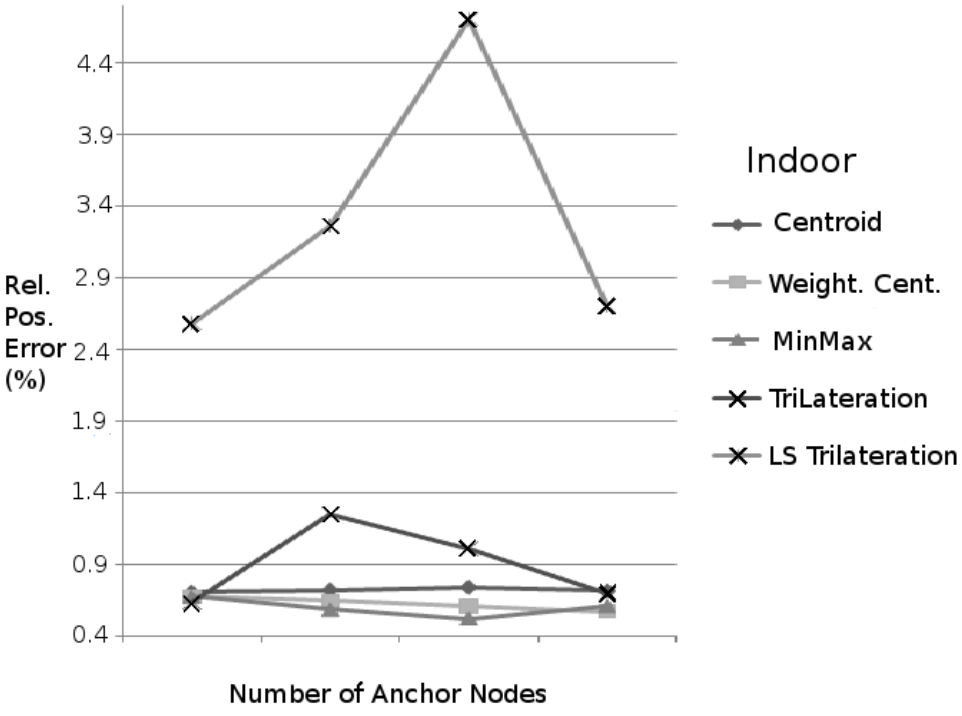
Results

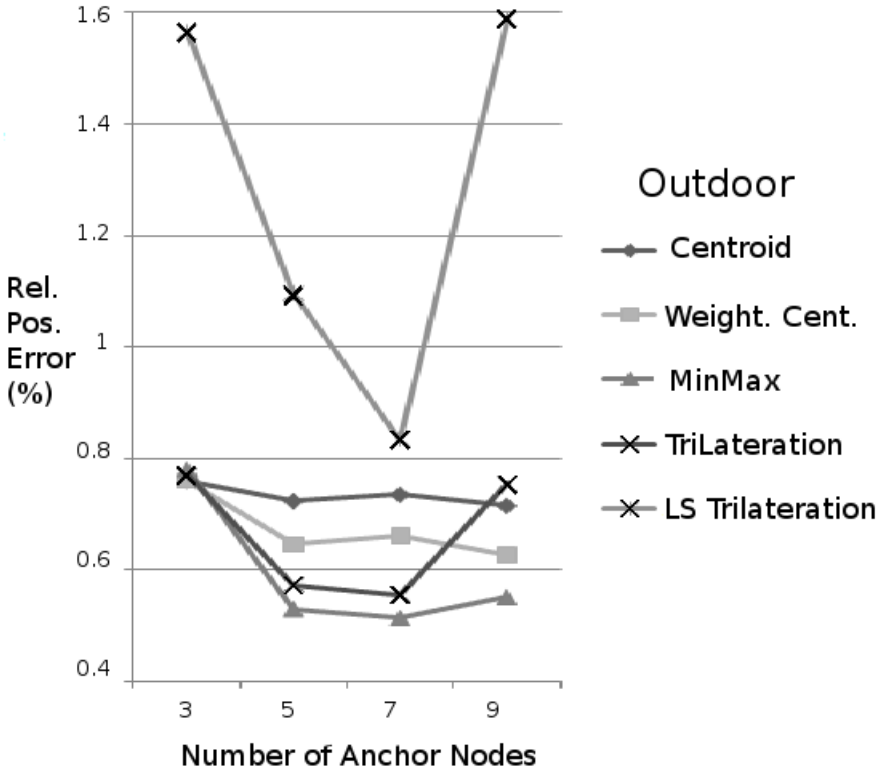
- Antenna orientation
  - Non-uniform antenna radiation pattern
  - Onboard microstrip antenna vs omnidirectional antenna



Results

- Comparison of different algorithms
- Outdoor vs Indoor





Conclusion

- Overview of WSN localisation algorithms and literature
- Developed a WSN software framework
- Influence of node orientation and antenna selection on RSS
- Comparison of different localisation algorithms
  - In our tests the relatively simple Min-Max algorithm is the best solution

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Future Work

- Develop extra applications using the system
- Add new types of WSN networks to the system
- Interfacing microcontroller based wall-units

- Use the localisation of nodes in practical applications
- Refine localisation tests
- Test more algorithms

Thank you for your attention!

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