Universita' Degli Sudi Di Pavia

Localization in Wireless Sensor Networks

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Outline

- Localization in WSNs
- Radio ranging
- Hybrid positioning
- Velocity–Based tracking
- Experimental scenario
- Result
- Future work

Localization in WSNs

- Wireless Sensor Networks (WSNs) are composed by hundreds of sensor nodes which communicate with each other by the wireless connections.

- Positional information is essential in most applications of wireless sensor networks, such as target detecting, tracking and positioning.

Localization in WSNs

Applications

- Tracking
- Medical services
- Rescue operations

Goal

- Accurate
- Low complexity
- Fast
- Low cost

Position Estimation Techniques

- **Anchor based**

Some nodes know their locations, either by a GPS or as pre-specified.

- **Anchor free**

- **Range-based**

Measurements provide some sort of distance /angle information among nodes.

- **Range-free**

REF. A. Savvides, et all, "*Localization in Sensor Networks", Kluwer Academic, Norwell, MA, USA, 2004.*
REF. F. Viani, et all, "Localization, tracking, and imaging of targets in wireless sensor networks: An invited review," *Radio Science, vol. 46, no. 5, 2011*.

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Radio Ranging

Technology

1. 802.15.4
2. UWB (Ultra Wide Band)
3. Bluetooth
4. Infrared

Specification

802.15.4

- Low power
- Low cost
- Ease of use
- Range of 10-100 meters
- Frequency 2.4 GHz

UWB

- Spreading the signal over large bandwidth
- Fine-grained time resolution
- Transmit short pulses to provide accurate ranging capability
- Range of 10-50 meters

Nodes measurements

a. Connectivity
b. Angle
c. Distance

Distance can obtain by :

- Proximity
- ToA -TDOA
- AoA
- RSSI (received signal strength indicator)

RSSI

Advantages

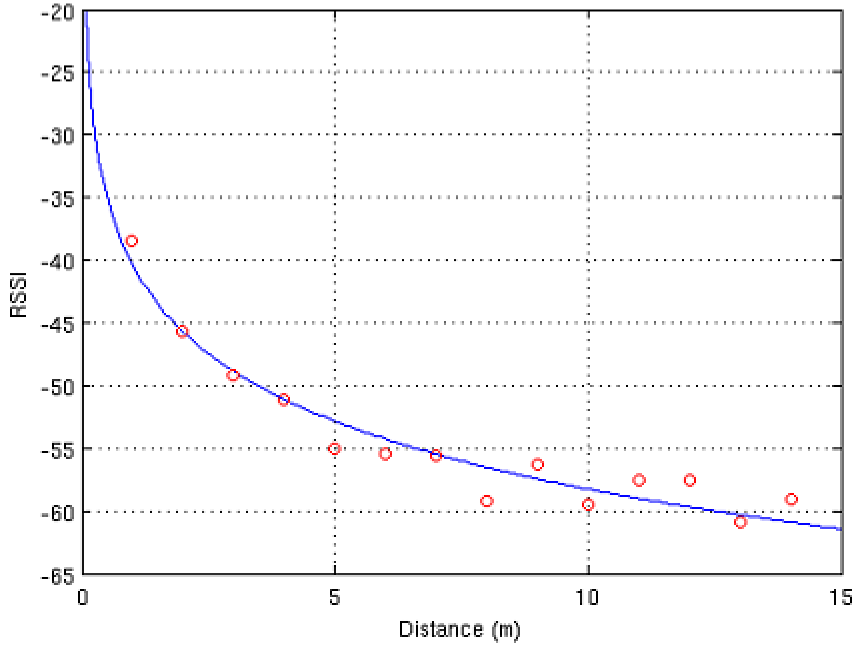
- Inexpensive
- Simple
- Compatible with RF signals

$$P_R = P_T \frac{G_T G_R \lambda^2}{(4\pi)^2 d^n}$$

$$d = 10^{\left(\frac{A-RSSI}{10.n}\right)}$$

A= nominal received power(one meter) n=propagation coef.

RSSI versus Distance



Fusion of the measurements

Velocity algorithm uses combined measurements :

- Calculating distance between anchors and target using RSSI(802.15.4) and TOA (UWB) separately then combining and clustering distance measurements together. (*Range fusion)*

- Combining initial estimated position of target obtained by 802.15.4 and UWB. (*Ex-post fusion*)

Time fusion

- Fusion of distance measurements by different sources are obtained based on the target movement time threshold:

$$t = \begin{cases} mean\,(t_{i+1}, t_i) & \Delta t \le \tau \\ t_i & \Delta t > \tau \end{cases}$$

$$\Delta t = t_{i+1} - t_i$$

Where t, τ and i are time stamp, threshold time and the number of registered time respectively.

Threshold level can be 50 and 100 milliseconds.

RSSI measurements set up

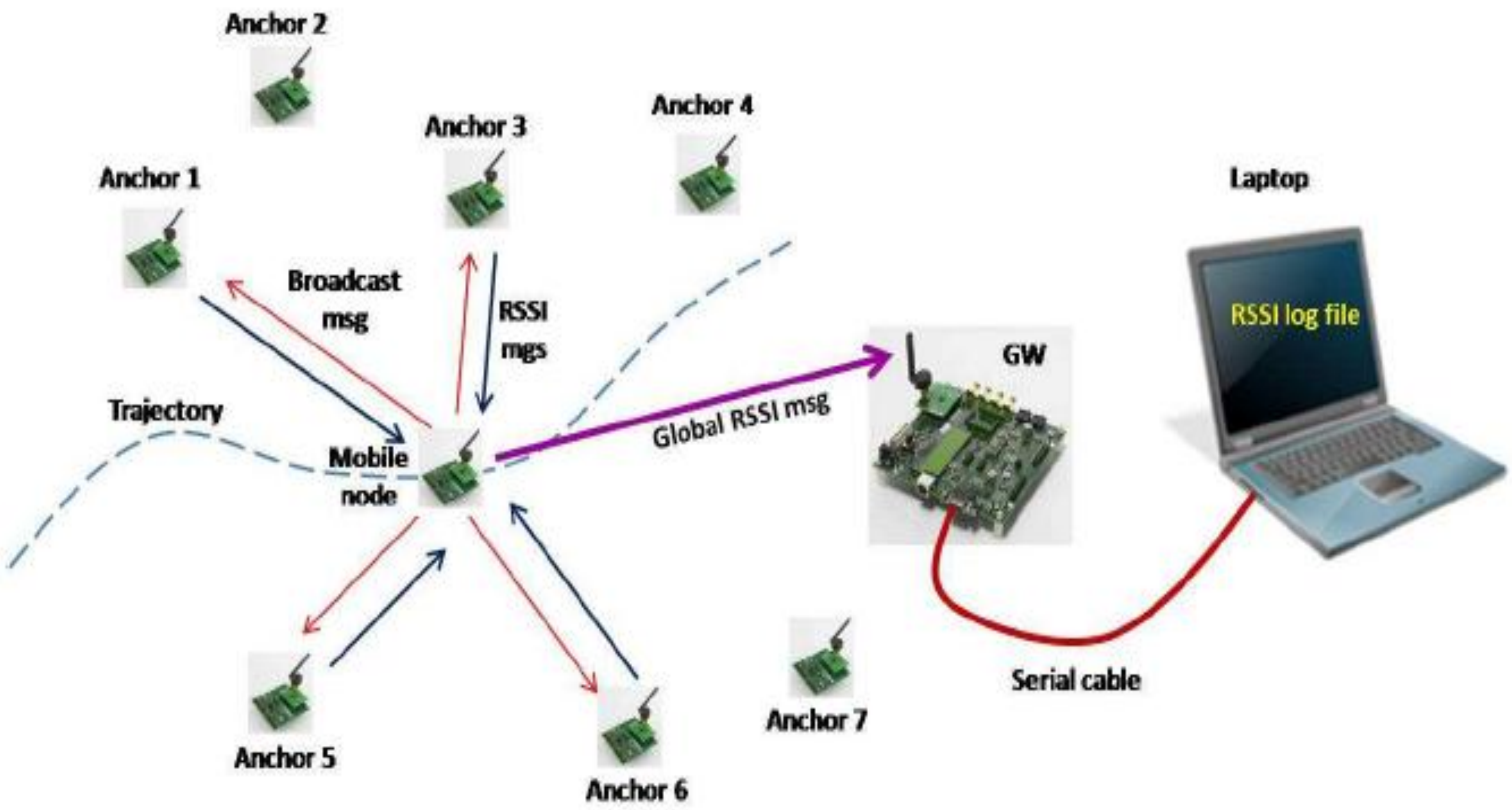


Figure 5: RSSI measurements set up.

Hybrid Positioning

Algorithms

- Multilateration

Geometrical based

- Min-Max

Geometrical based

Low complexity

REF. R. Verdone, D. Dardari, G. Mazzini and A. Conti, "*Wireless Sensor and Actuator Networks , Technologies Analysis and Design,*" *Academic Press, 2007.*

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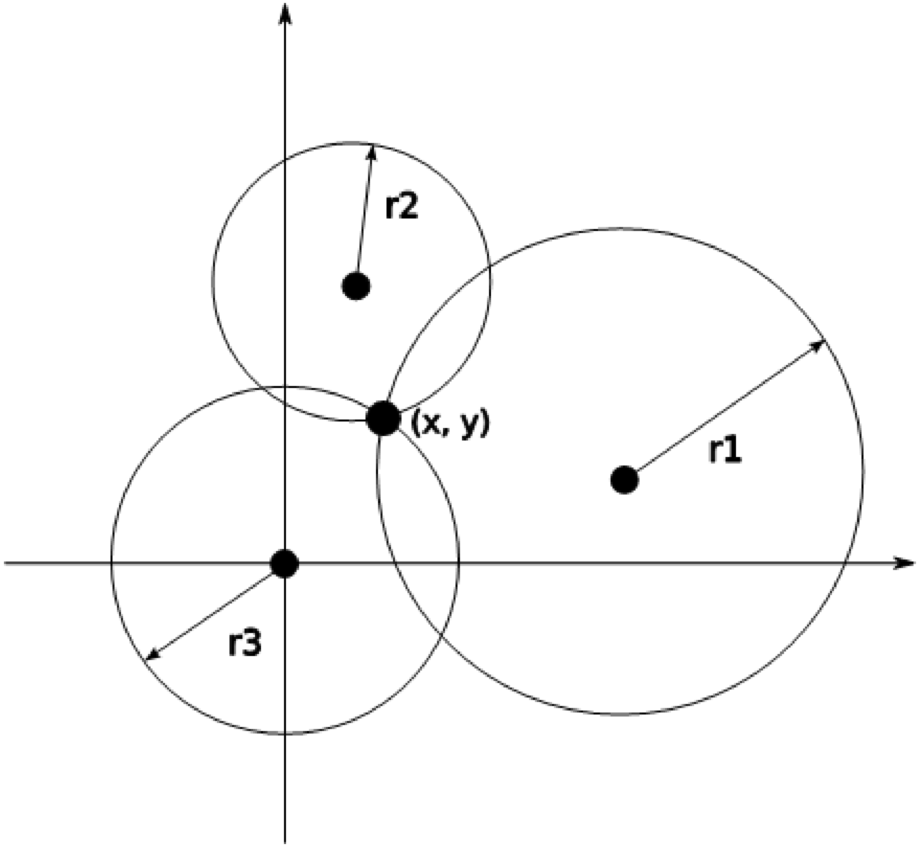
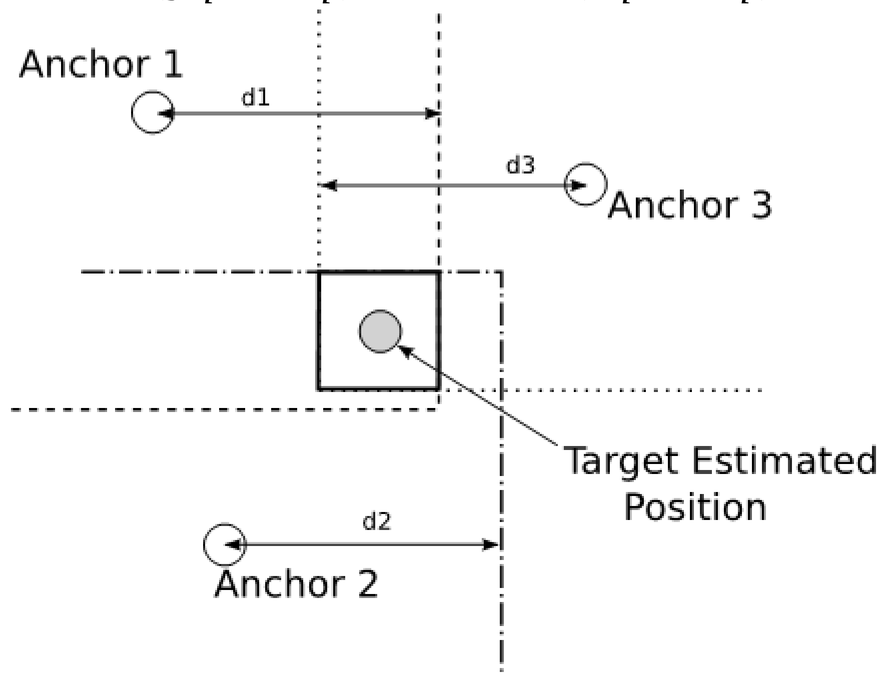
Multilateration

$$(x-x_1)^2+(y-y_1)^2=r_1^2$$
$$(x-x_2)^2+(y-y_2)^2=r_2^2$$
$$(x-x_3)^2+(y-y_3)^2=r_3^2$$



MinMax

$$[\max(x_i - d_i), \max(y_i - d_i)] \times [\min(x_i + d_i), \min(y_i + d_i)]$$



Velocity Based Tracking

How is Speed Estimate useful?

Speed Estimate may be useful in two ways :

1-localization using speed estimate

Position is estimated according to the target speed.

2- location bounded by the speed estimate

First a new position is computed (by means of the algorithms described before) which is then bounded by the maximum displacement consistent with the speed estimate.

Speed localization method

- Target Speed

An estimate of the speed is computed as the mean velocity based on previous estimated positions

V = velocity

N = window size

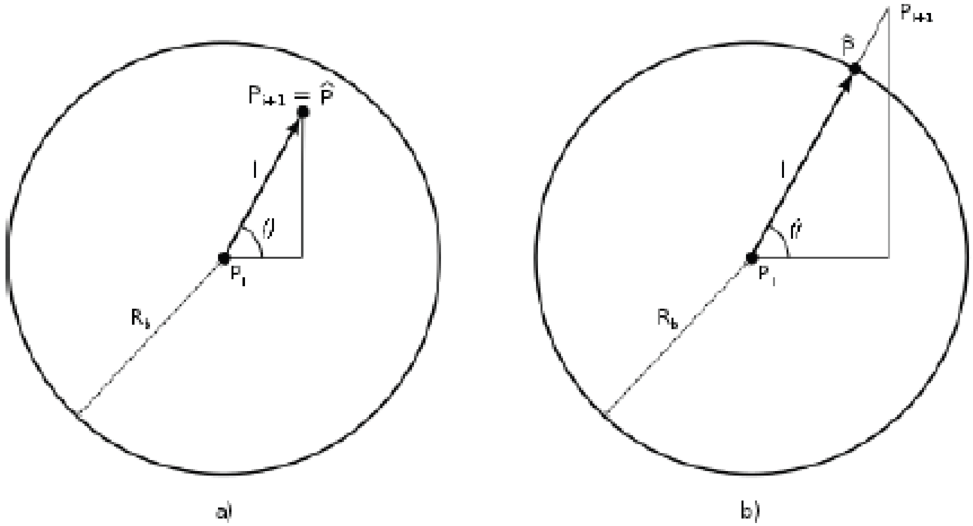
X = estimated position

ΔT = time duration

$i=1,2,3,\ldots\ldots m-N+1$

$$v(i) = \frac{1}{N}\sum_{j=i}^{i+N-1}\frac{x(j+1)-x(j)}{\Delta Tj}$$

Bounding



$$\hat{P}_i = (l, \theta)$$

where θ and l are defined respectively as

$$\theta = atan2\left(\frac{y_i - \hat{y}_{i-1}}{x_i - \hat{x}_{i-1}}\right)$$

$$l = \begin{cases} \left\|P_i - \hat{P}_{i-1}\right\|, & l < R_b \\ R_b, & l \geq R_b \end{cases}$$

and value R_b of the bounding radius is

$$R_b = \bar{v}_{i,i-N} \cdot t_i = t_i \cdot \frac{\sum_{j=1}^{N} l_i}{\sum_{j=1}^{N} t_{i-j}}$$

Experimental scenario

Localization in WSNs

- Techniques
  - MinMax
  - Multilateration
- Distance measurements
  - 802.15.4 (Received signal strength indicator)
  - UWB (Time of arrival)
- Test bed
  - Mobile target moves through pre – defined path

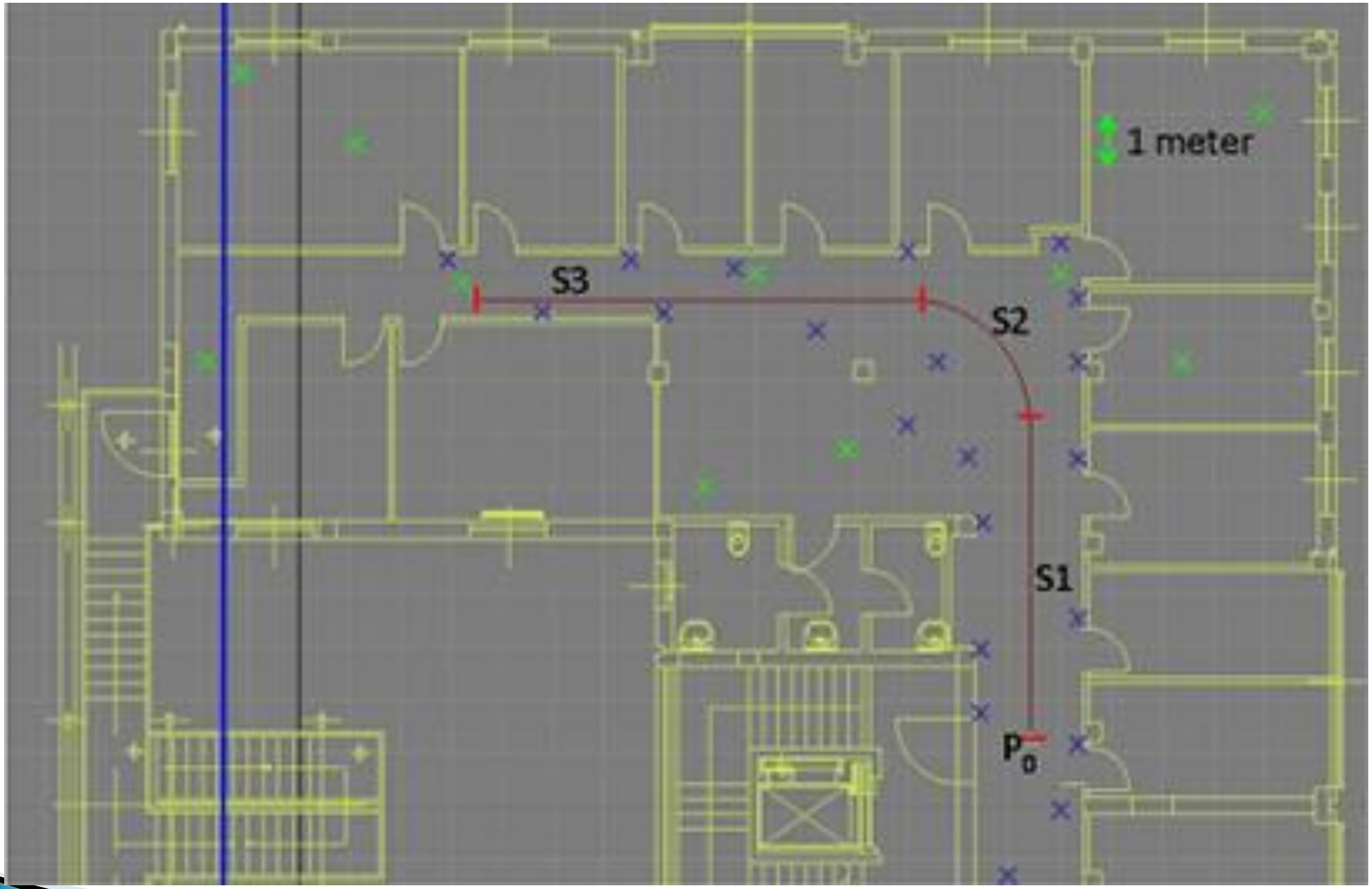
Experimental scenario

- A mobile target moves on a pre-defined path and sends message to anchors every 50(RSSI) and 500 (TOA)milliseconds.
- 21 802.15.4 and 12 UWB anchors nodes fixed on known positions.
- Mobile node collects RSSI an TOA measurements from anchors.

Goal

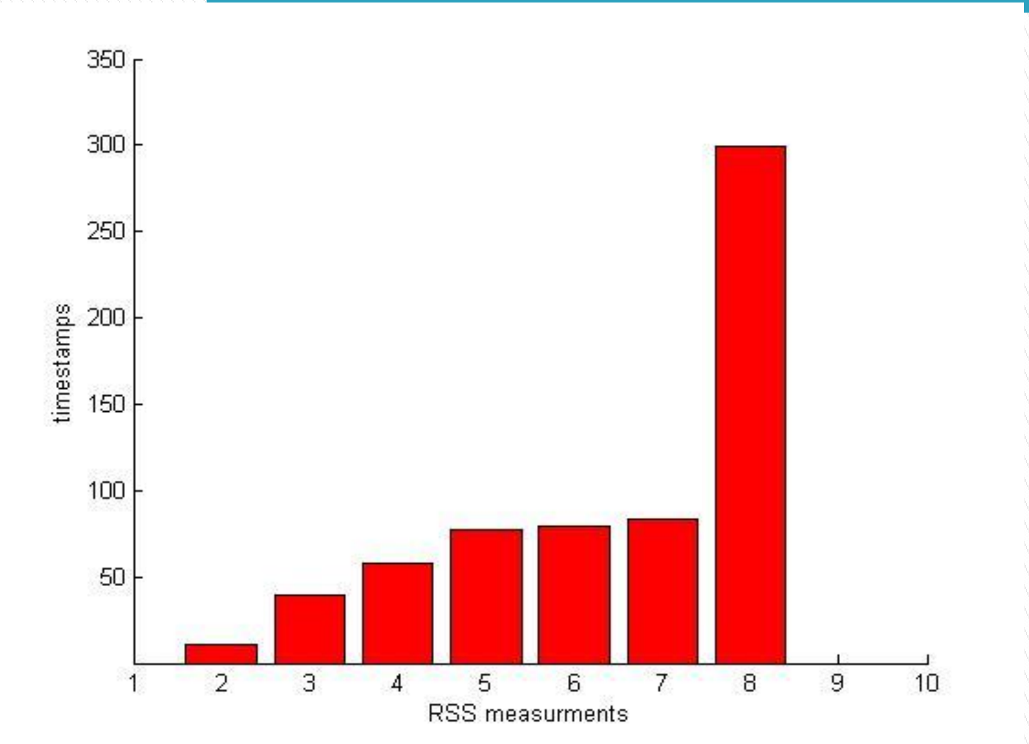
- Accurate Tracking

Plan



Improvement in localization accuracy techniques

measurements



Only positions with at least Six RSSI measurements are selected.

Result

Result

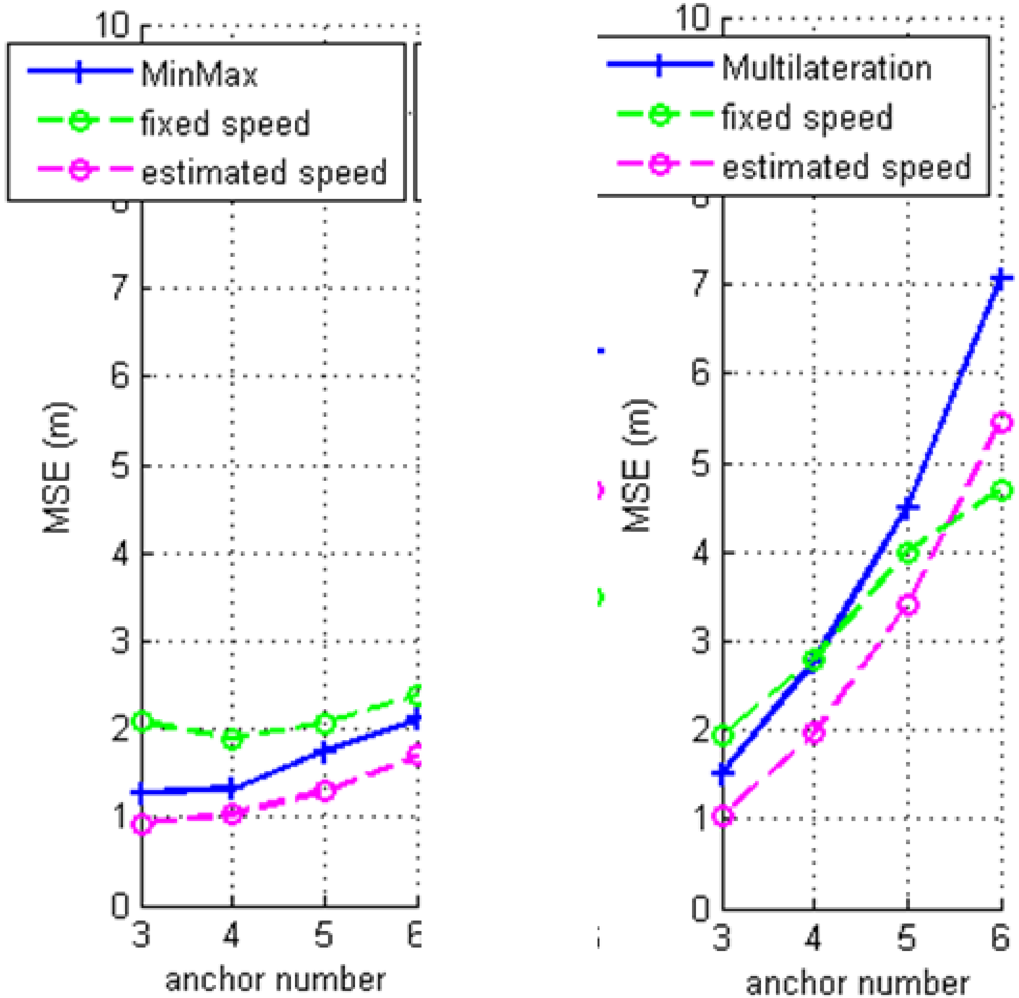
Root mean square error (in meter) for localization using separately either the UWB or the 802.15.4

RMSE	802.15.4	UWB
MinMax	1.14	1.42
Multilateration	1.24	1.48

Root mean square error (in meter) for localization using joint the UWB and the 802.15.4

RMSE	Joint 802.15.4& UWB Ex-post fusion	Joint 802.15.4& UWB Range fusion
MinMax	1.15	1.08
Multilateration	1.22	1.12

Comparison velocity technique with Min-Max and Multilateration



Comparison result with different radio sources

RMSE(in m) for 802.15.4 and UWB separately and joint measurements using velocity algorithm

RMSE	802.15.4	UWB	Joint 802.15.4& UWB E-post fusion	Joint 802.15.4& UWB Range fusion
Min Max	0.75	0.8	0.74	0.72
Multilateration	0.8	0.91	0.76	0.74

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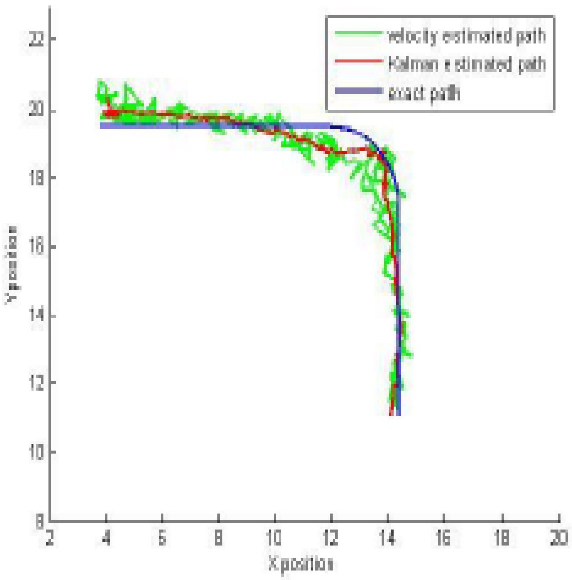
Comparison result with Kalman Filter

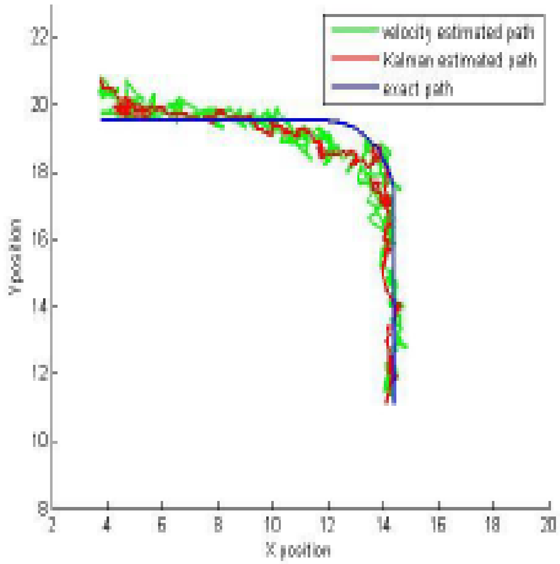
Comparison of th RMSE(in m) obtained using our novel technique or a kalman filter

Radio resource	802.15.4	UWB	Joint 802.15.4& UWB Ex-post fusion	Joint 802.15.4& UWB Range fusion
Velocity -based	0.75	0.81	0.74	0.72
Kalman	0.62	0.87	0.57	0.58

Result



(a)



(b)

Fig. 1. Graphical comparison of the actual path ("exact path"), estimated path using velocity information ("velocity estimated path") and estimated path using Kalman filtering ("Kalman estimated path") for both (a) "ex post fusion" and (b) "range fusion" of ZigBee and UWB measurements.

Research activity

- S. Kianoush, E. Goldoni, A. Savioli and P. Gamba "***Low-complexity Localization and Tracking in Hybrid Wireless Sensor Networks***" (in press for publication) Journal of ISRN-Sensor Networks, July- 2012.

Future work

- Using other sources for distance measurements e.g, 802.11
- Localization problem in mobile Cognitive Radio Networks using localization algorithm in WSNs.

Question