Pazl: A Mobile Crowdsensing based Indoor WiFi Monitoring System

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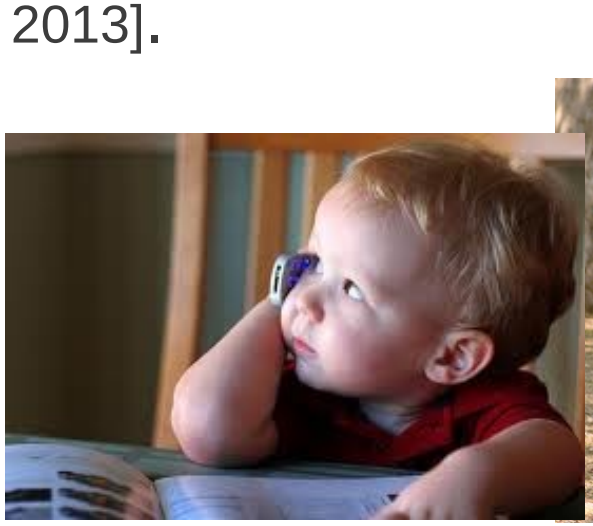
informatics

Introduction

- 6 billion mobile subscriptions in the world [source: UN report, 2013].



- 1.4 billion smartphones will be in use by December 2013 [source: ABI, 2013] and expected to reach 2 billion by 2015 [source: Strategy Analytics, 2013].

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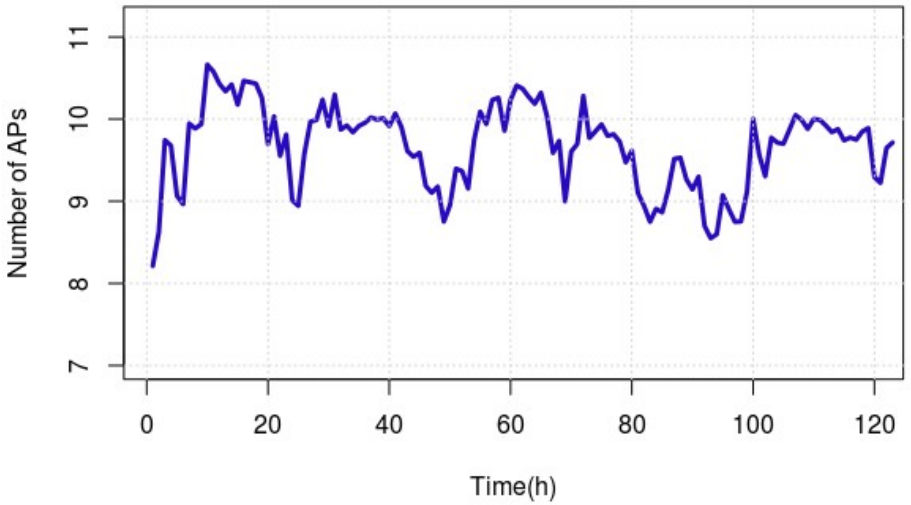
Motivation

WLANs require permanent monitoring to capture all the dynamic aspects.

In the Informatics Forum:



Dynamic fluctuation of APs number at a single location

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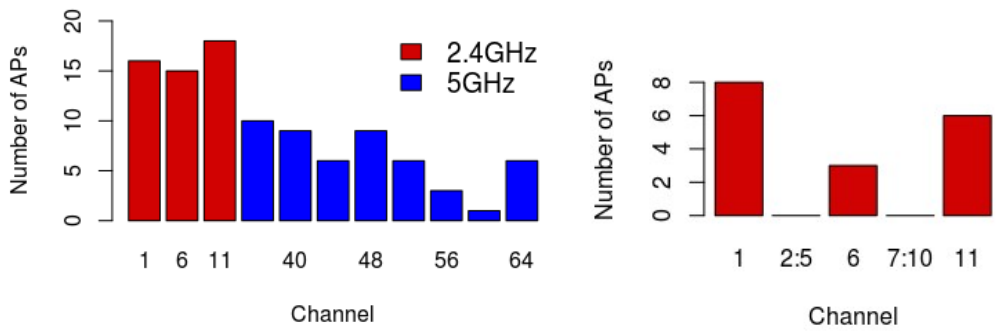
Motivation

In the Informatics Forum:

Manual site survey with Ekahau observing some coverage holes



Channel imbalance

Motivation

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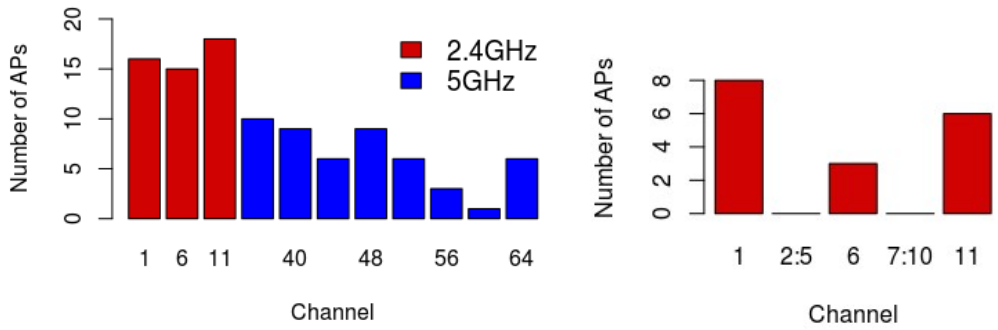

Channel imbalance

Need for continuous monitoring in space and time.

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Motivation

- Traditional site surveys are expensive, intrusive and time consuming.
- People carry smartphones that can perform ubiquitous sensing.

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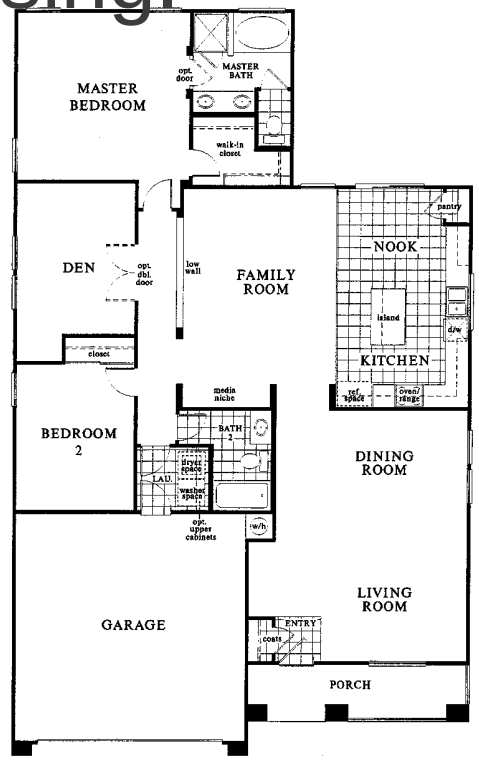

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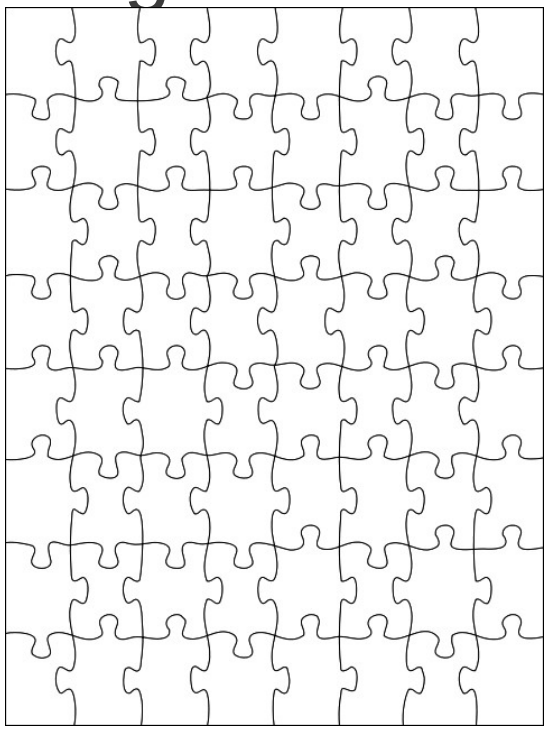

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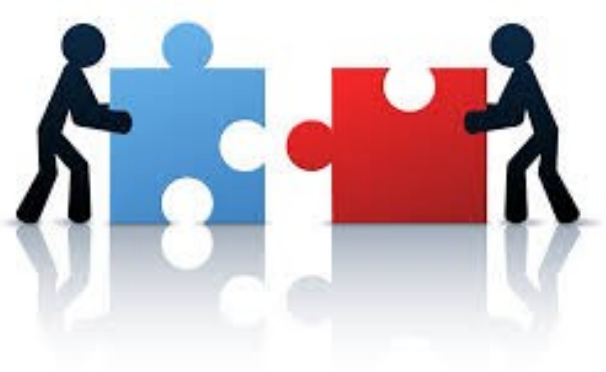
Pazl - a mobile crowdsensing based indoor WiFi monitoring system.



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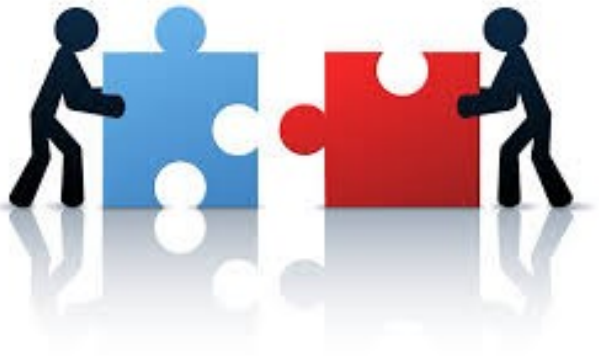

Continuous monitoring of the WiFi environment

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Challenges

- To map any data we need to annotate it with its location.
- GPS is an established localization solution for outdoors, but not very reliable inside a building.
- Indoor localization:
  - WiFi fingerprinting or
  - Pedestrian Dead Reckoning (PDR).

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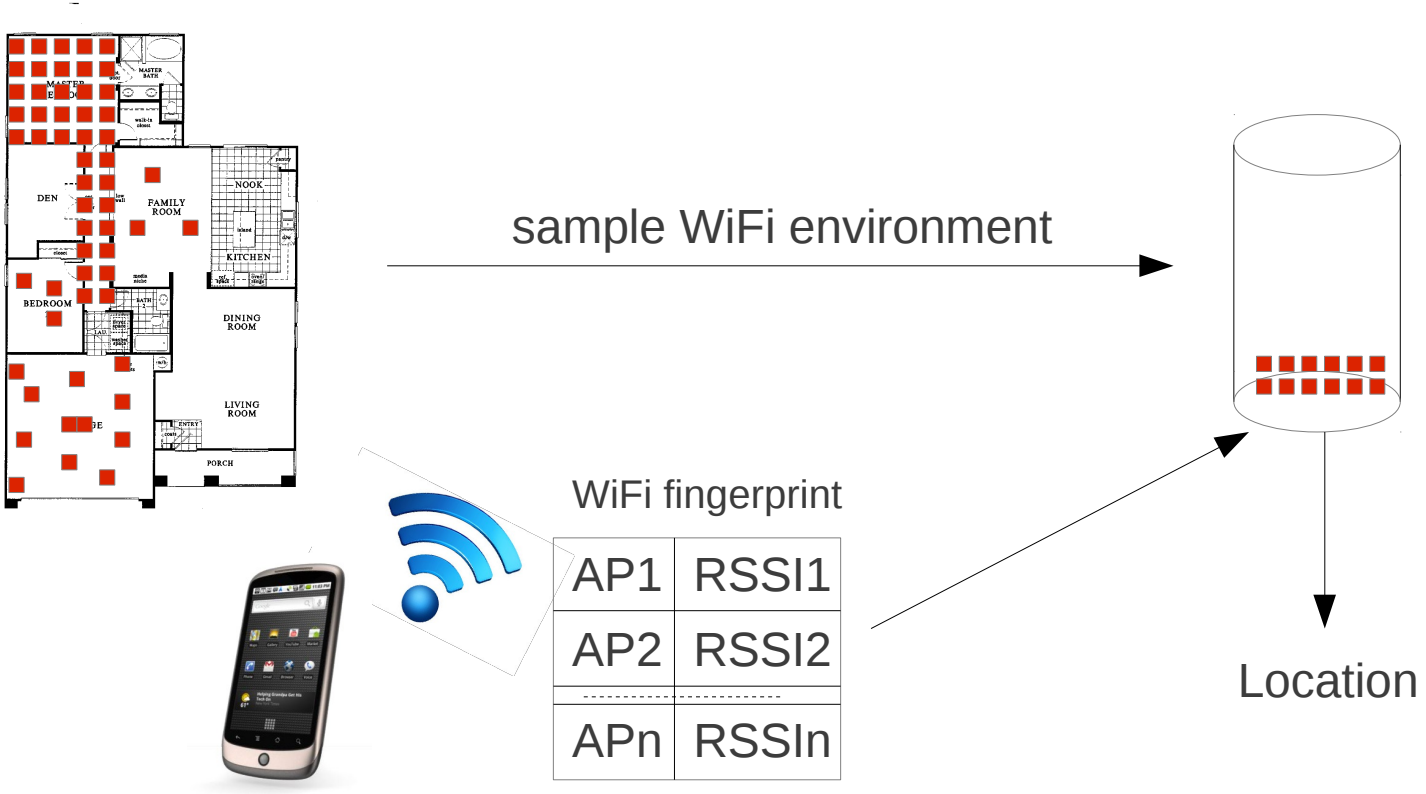
Background – WiFi fingerprinting

Offline phase – data collection



Online phase – localization

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Disadvantages of WiFi Fingerprinting

1. needs WiFi coverage.
2. Scanning the WiFi environment requires substantial amount of energy.
   - one order of magnitude more than the energy requirements for the accelerometer and compass.
   - not suitable for continuous tracking.
3. Many interferences (microwave ovens, people).
4. Disruptions in communication when done excessively.

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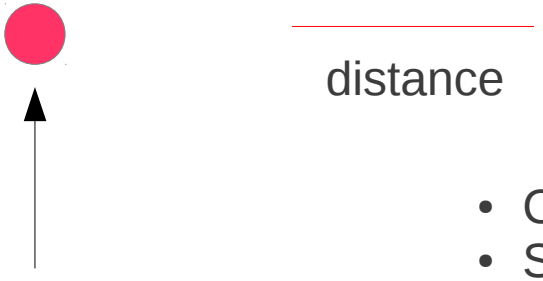
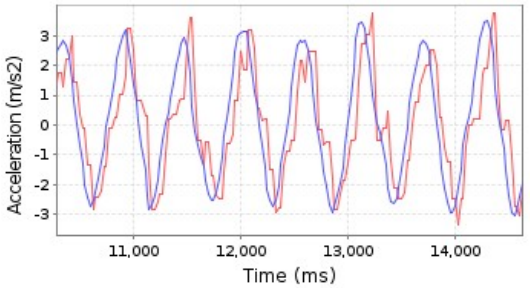
Background - PDR

How it works?

- Compute consecutive positions starting from a known position
- Distance estimation
- Direction estimation





- Counting the number of steps.
- Step detection from acceleration:
  - Zero-crossing – count the number of acceleration crossing 0 value.
  - Peak detection
  - Auto-correlation – repetitiveness of human walking.
- Step length as a linear function of stepping frequency (R. Harle, 2012)

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Background - PDR

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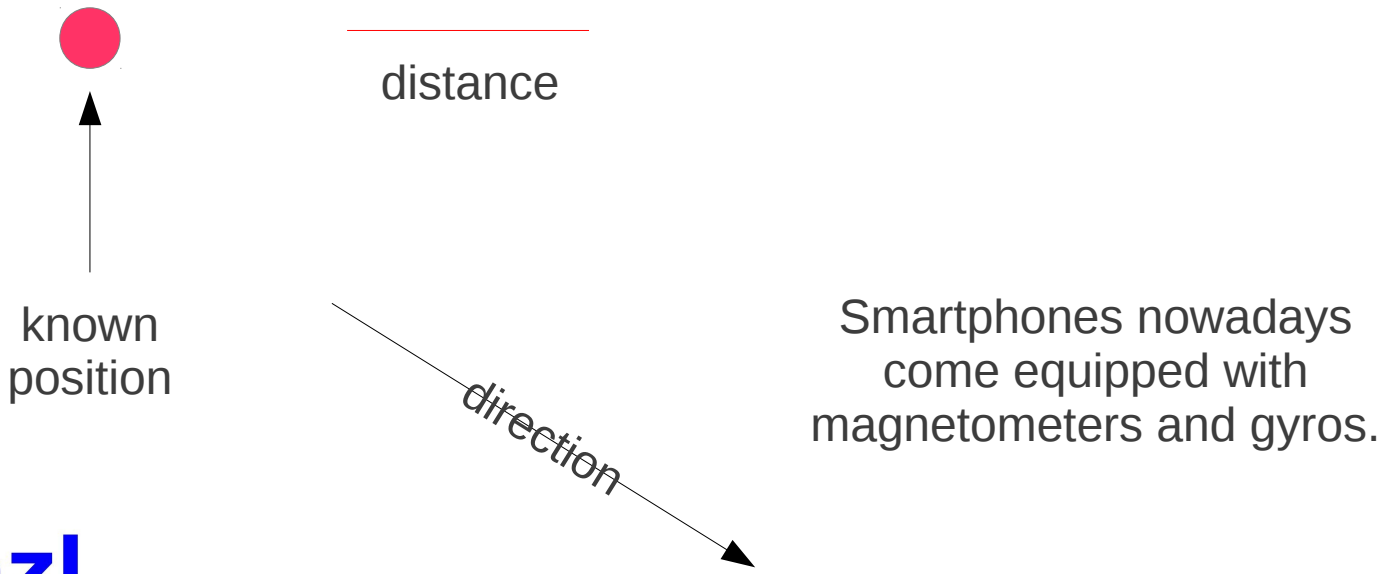

Smartphones nowadays come equipped with magnetometers and gyros.

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Background - PDR

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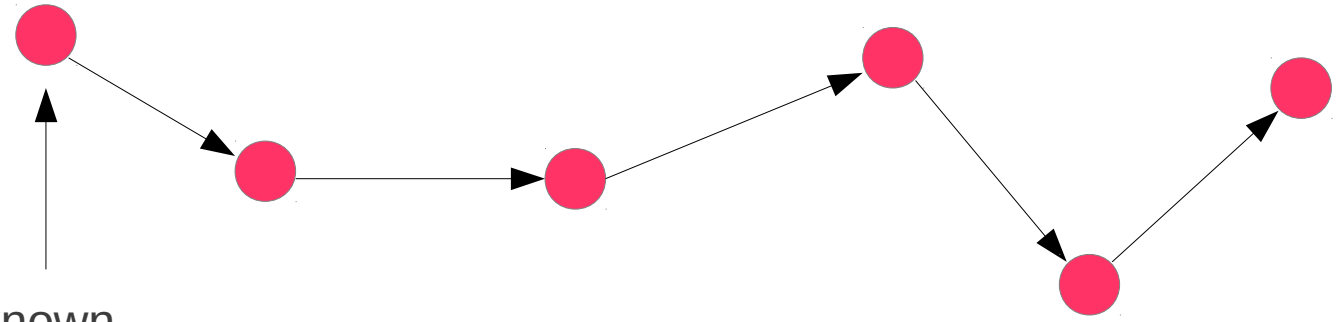

Disadvantages:
- noisy sensors
- error accumulation

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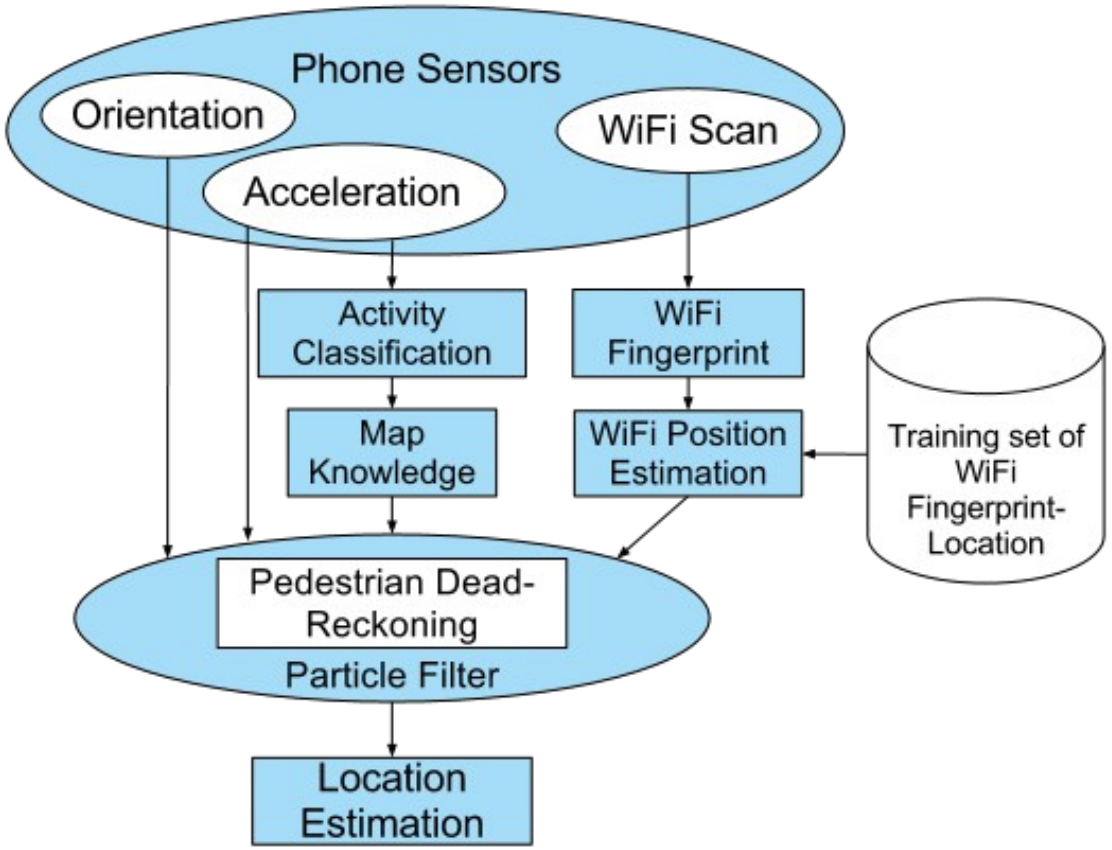
Pazl's localization solution

Application specific – PDR with periodic WiFi fingerprint and map knowledge assistance.



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Activity recognition

- Activity recognition based on acceleration magnitude:

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2} - g$$

- Feature extraction: in time domain (mean, standard deviation, variant, correlation between axes) and in frequency domain (energy and entropy).
- Activity classifier trained for:
  - Walking
  - Static
  - Going up on stairs
  - Going down on stairs
  - Elevator moving up
  - Elevator moving down
  - Opening and closing doors (both in hand and in pocket)

Window size	J48	Naive-Bayes	FT(tree)
128 samples	70.5%	81.7%	80.5%
256 samples	74.2%	85.3%	81.9%

- On the server Weka toolkit was used to classify the acceleration samples to activities.

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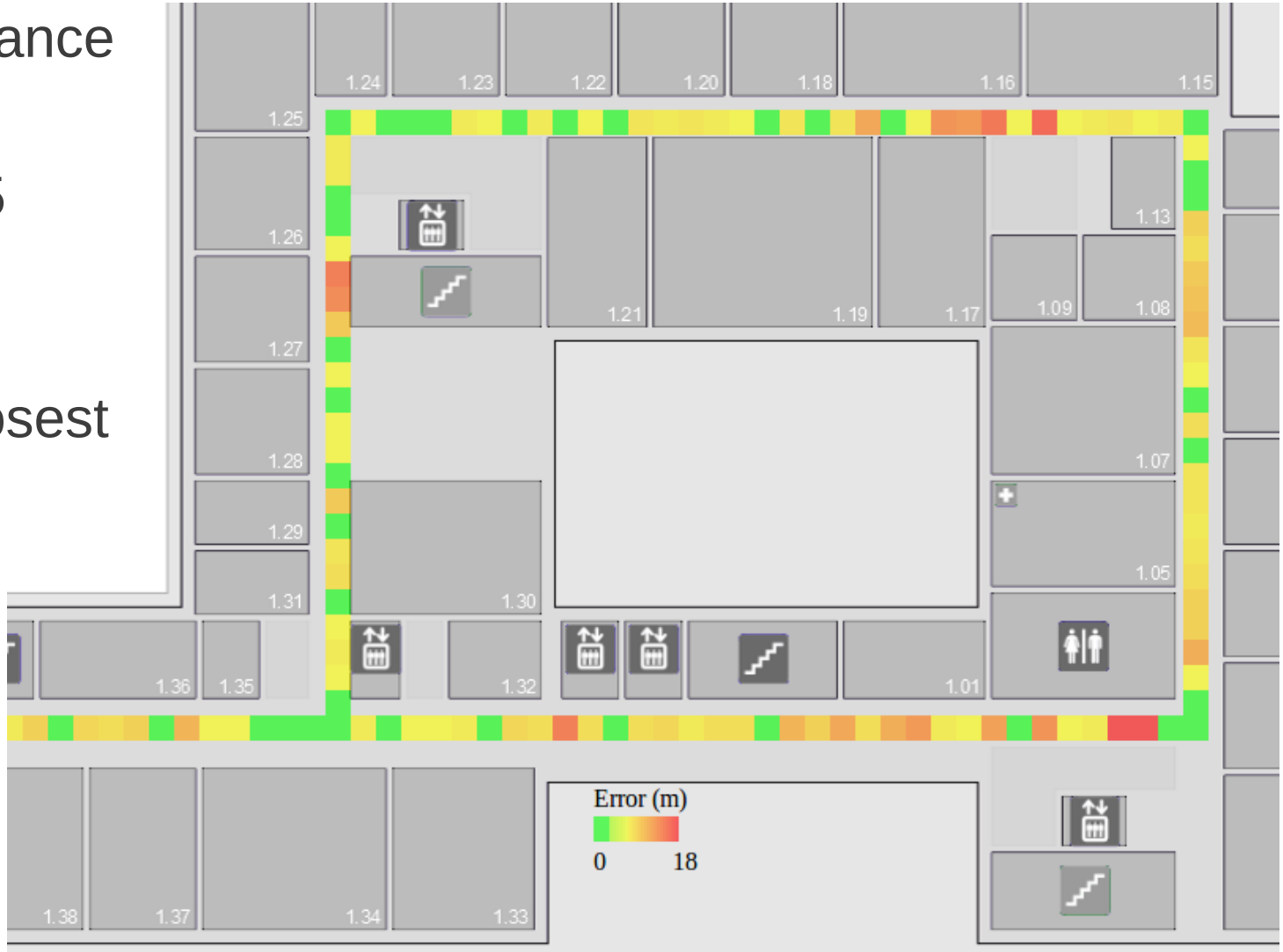
WiFi fingerprinting

- Euclidean distance approach.
- Vector of top 5 APs in signal strength
- Centroid of closest three matches
- Cells 1x1m



We have observed that some locations have consistently better accuracy.

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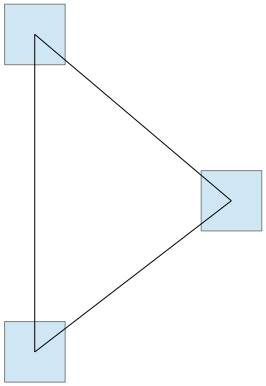
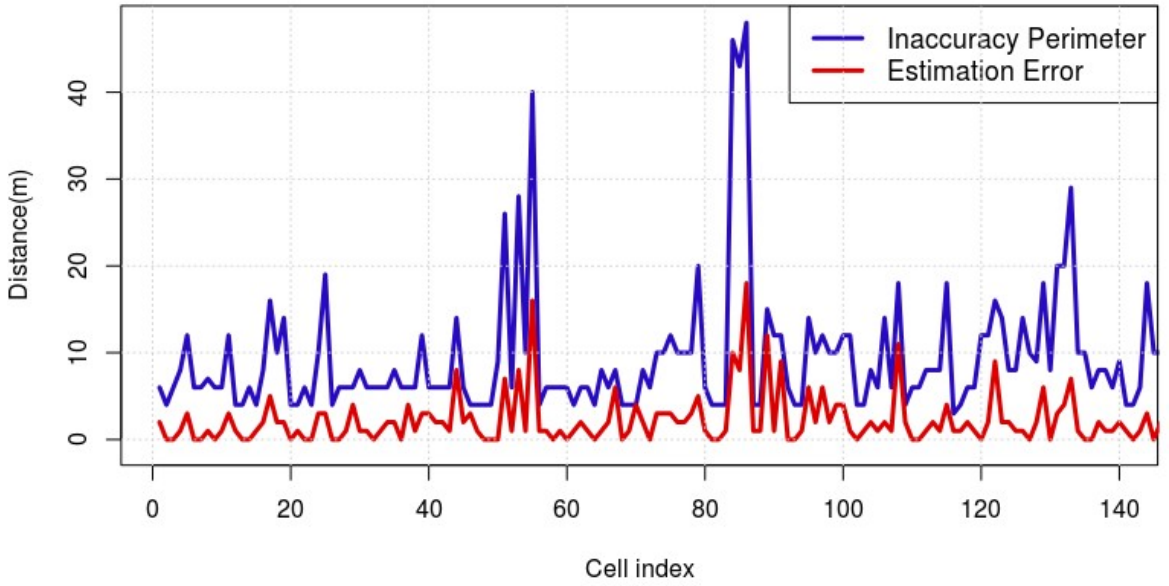
WiFi fingerprinting

- Inaccuracy perimeter – the perimeter defined by the first three closest matching fingerprints in the database.





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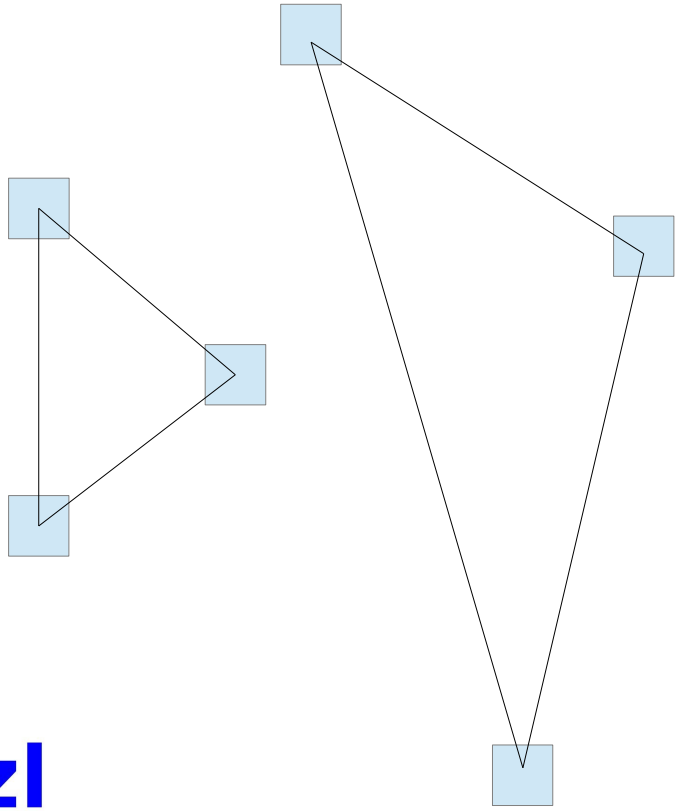

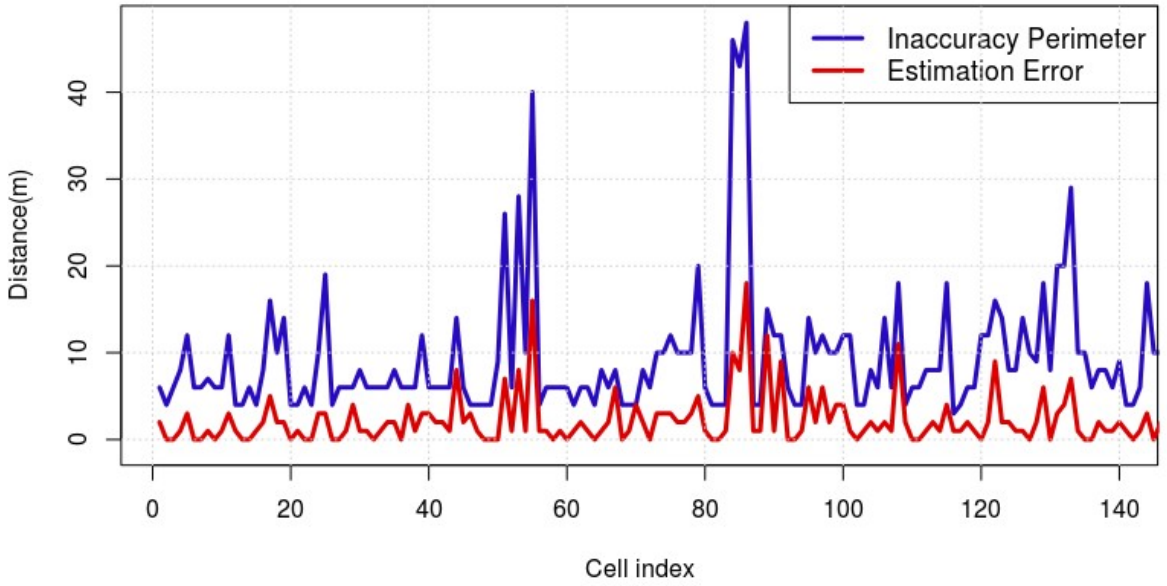

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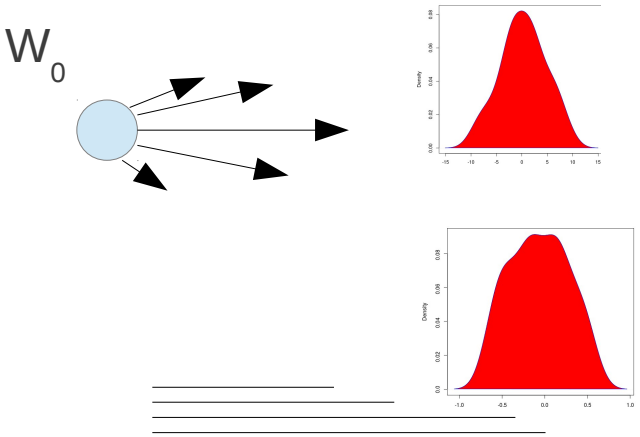
Particle filter

- In the PDR, we observed that compass deviations and distance deviations between estimations and ground truth follow a close to normal distribution.



Activity selection

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

W_c – Weight on the orientation choice

W_d – Weight on the distance choice

W_a – Weight from activity confidence.

W_f – Weight on distance to WiFi fix

$$W = W_0 + W_d + W_c + W_a + W_f$$

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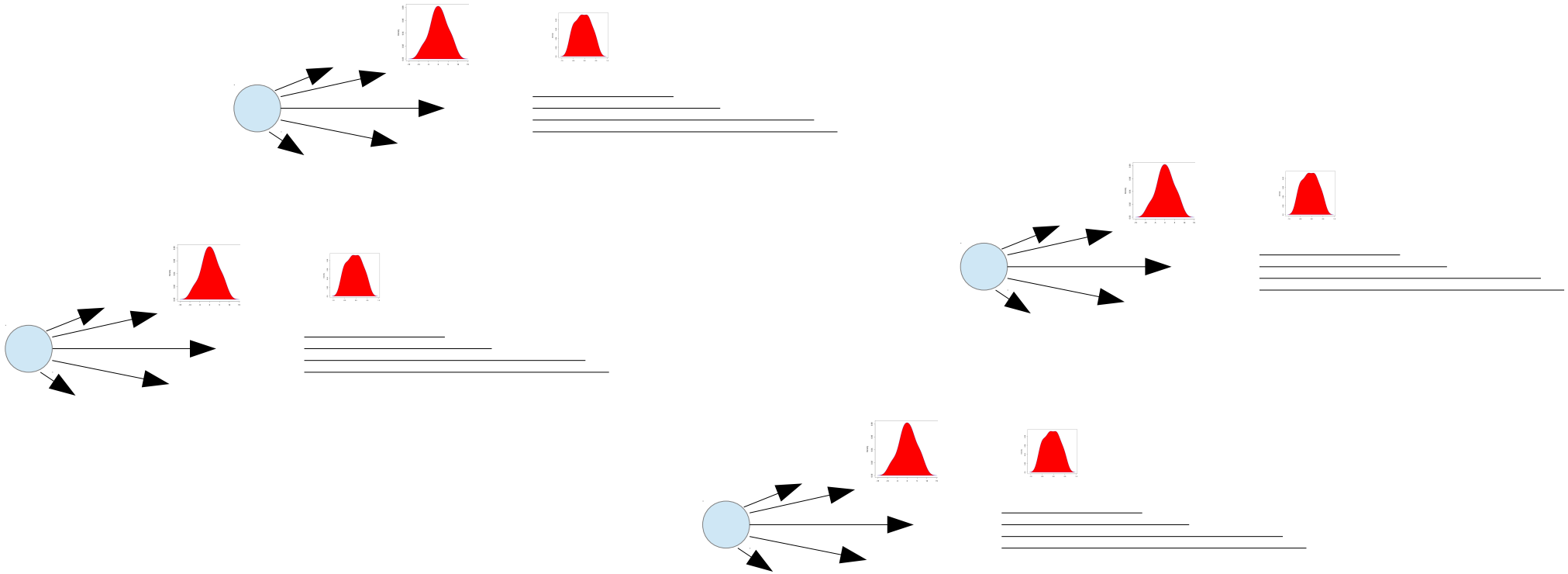
Particle filter



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Related work

- Building radio maps for WiFi fingerprinting using PDR.
  - WiFi-SLAM (B. Ferris et al., 2007)
  - ZEE (A. Rai et al., 2012).

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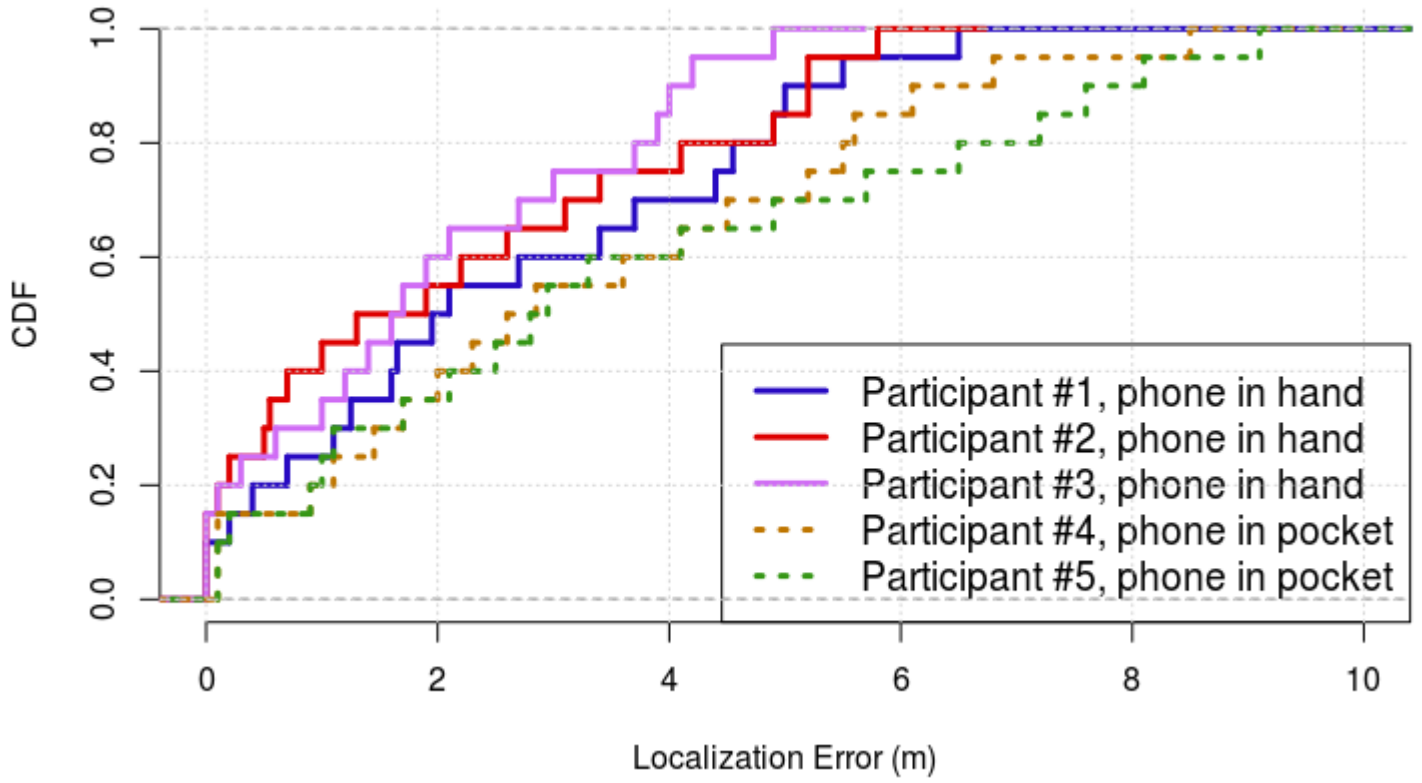
Evaluation – Pazl localization system

- 5 participants on a track of 100 meters.



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System Design

- Mobile application collecting sensor data on the phone
- Opportunistic data upload to the server for computations
- Server application running in the cloud
- Data is annotated with a location
- Create WiFi status reports

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Evaluation – Pazl

- WiFi database was built by two participants.
- Activity classifier trained with the samples from two participants.
- In the experiment, 5 participants moved freely in the building for the period of a working day (10am-6pm).
- Monitoring at first floor in Informatics Forum.

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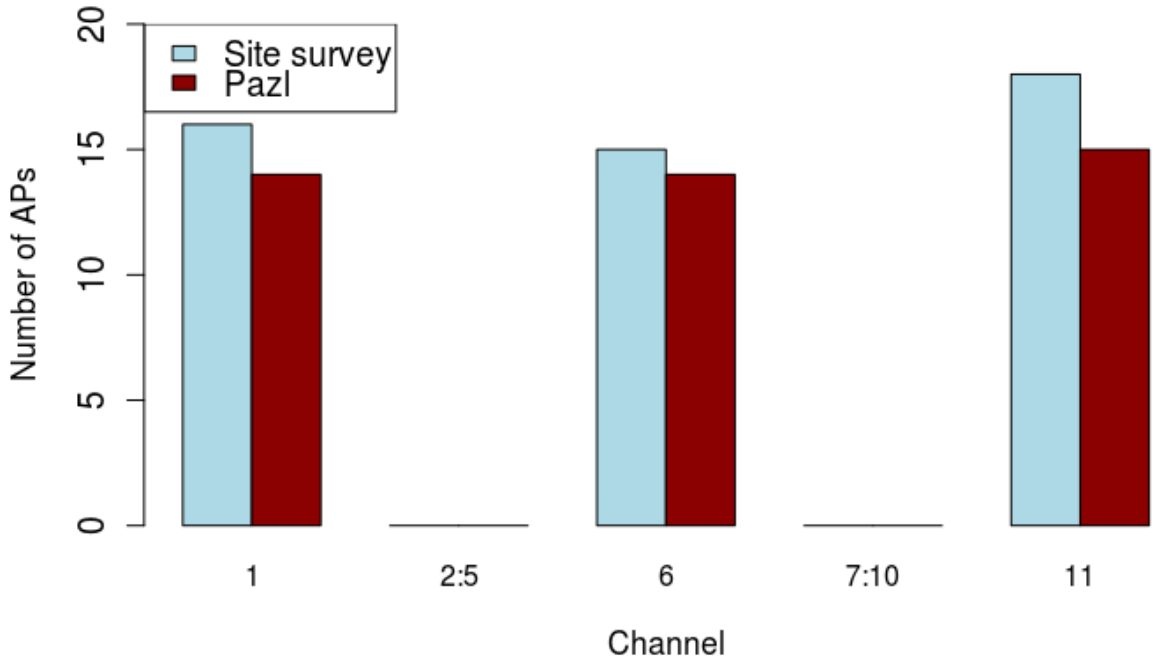
Pazl site survey



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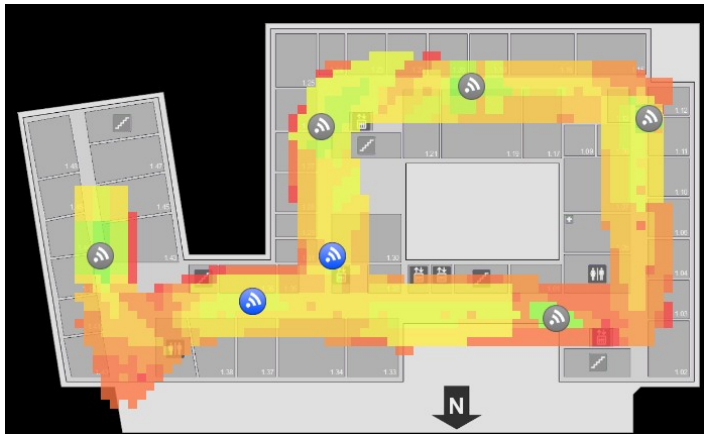
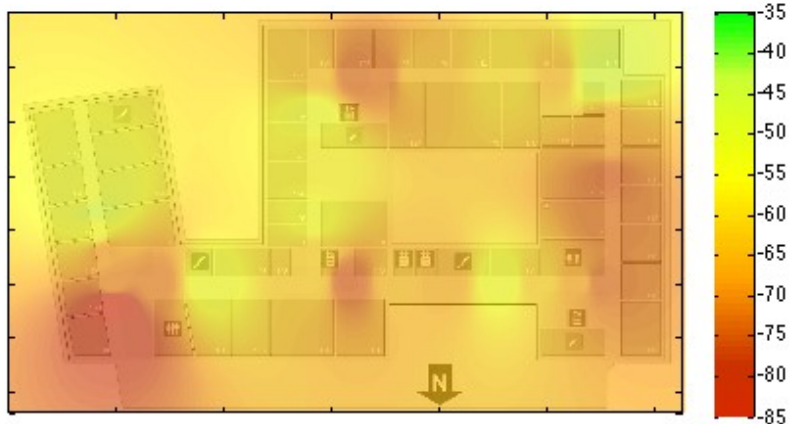
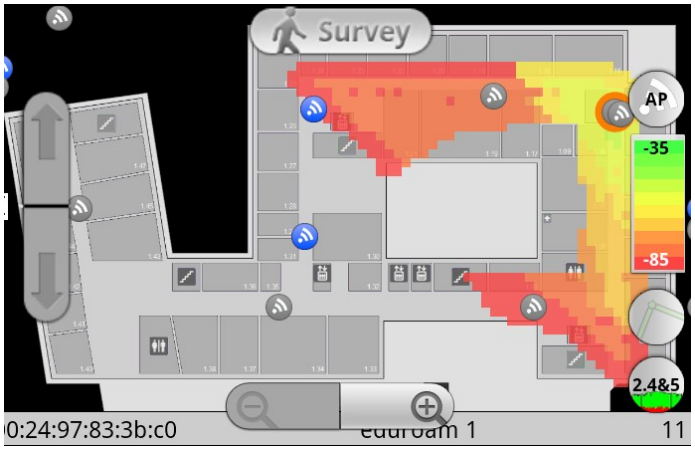
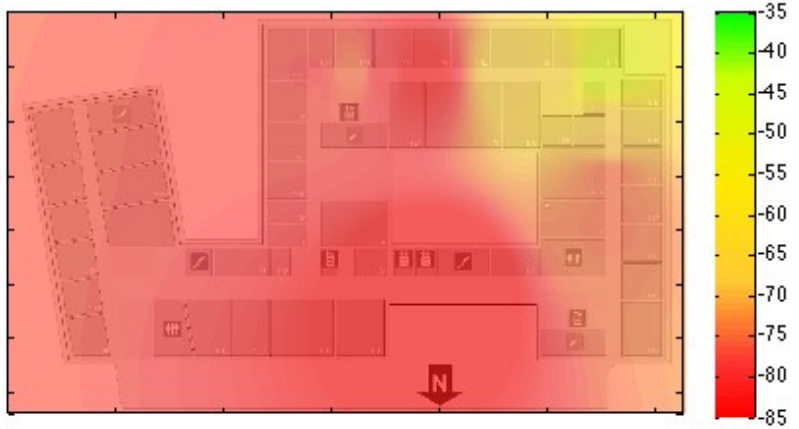
Pazl compared to Ekahau









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Future Work

- Remaining challenges
  - Energy-efficiency for long term running systems
  - Bootstrapping the application with indoor-outdoor transition detection
- Automate network management decisions using Pazl reports.
- Monitor other wireless environments.

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Conclusions

- We move the monitoring perspective from the infrastructure to the client.
- Continuous monitoring through users mobility.
- Crowds map phenomena of common interest.
- Application specific indoor localization using a hybrid approach.

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Thank you!

Questions?

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WiMo Group

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