Indoor Location Tracking Using RF Signal Strength for WLAN Networks

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Outline of the Presentation

- Why Indoor Positioning?
- Existing Solutions
- Wi-Fi Based Location System
  - The Architecture of Wi-Fi Positioning System
  - The Challenge of Wi-Fi Positioning System
- State of the Art
  - Microsoft Research's RADAR (INFOCOM'2000)
  - University of Maryland's Horus (PerCom'2003)
- Proposed Method
- Future Works

Why Indoor Positioning?

- Healthcare
  - Improve quality of care for mentally impaired people and reduce capital and operational expenses and increase safety

- Asset Visibility for Manufacturing Facilities
  - Tracking industrial equipment.

Real-time visibility of assets throughout the manufacturing process to optimize operations, increasing production throughput and cutting costs.

- Security
  - Access control of wireless devices and detecting device positions.

- Entertaining
  - Location based entertainment

Existing Solutions

- **Transponder based positioning systems** :

  Radio frequencies [1]

  Ultrasound [2]

  Infrared [3]

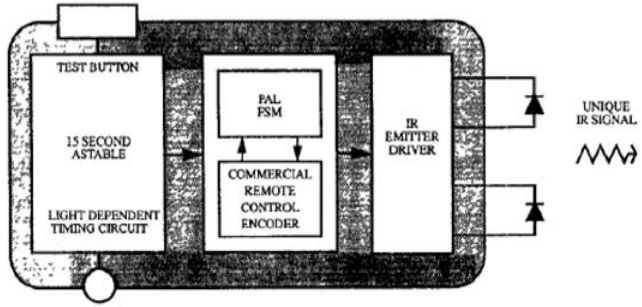


Fig. 1. The ORL Active Badge.

- **Advantage**: Accuracy (1.8meter)
- **Disadvantage**: Need heavy infrastructure

(a) The CC2420DB

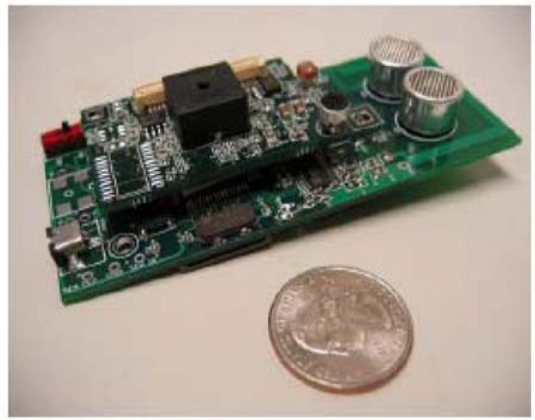
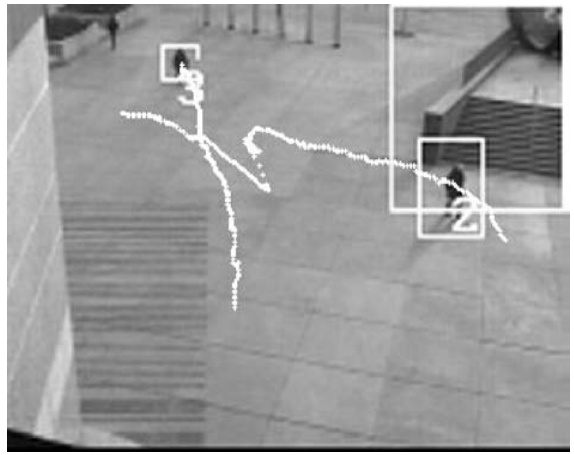


Figure 1-2: A Cricket node with a sensor board attached to it.

Existing Solutions (Cont.)

- **Computer vision[4]**

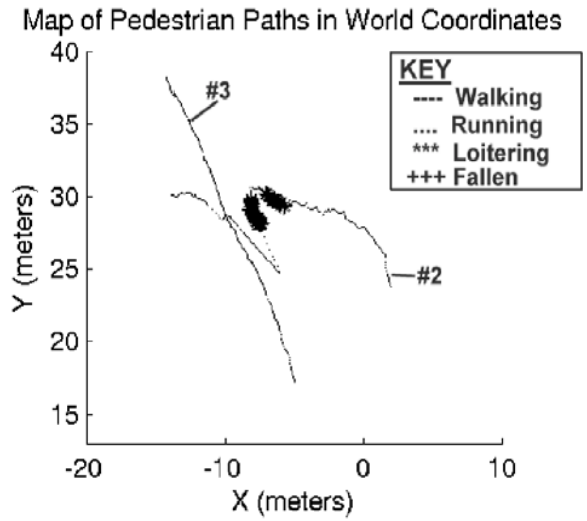


➢ **Advantages:**

- No tags required
- High accuracy

➢ **Disadvantages :**

- Blind spots
- Rapid changes in lightning cause error
- Targets shadow each other



Existing Solutions (Cont.)

- **Current Wi-Fi Base Location System**

➢ **Advantages:**

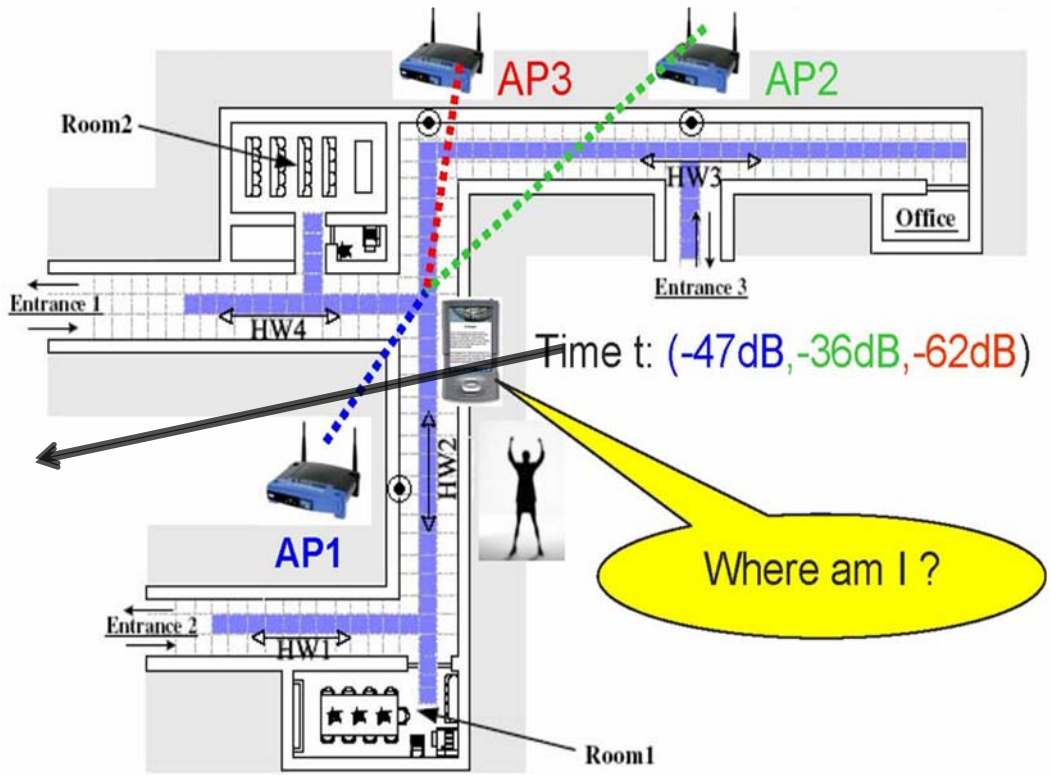
- Accurate (1m<error<4m)
- Low coat: uses the exiting Wi-Fi infrastructure

➢ **Disadvantages:**

- Environmental factors affects the performance and accuracy
- Needs manual calibration on regular base or considerable number of reference tags to update radio map

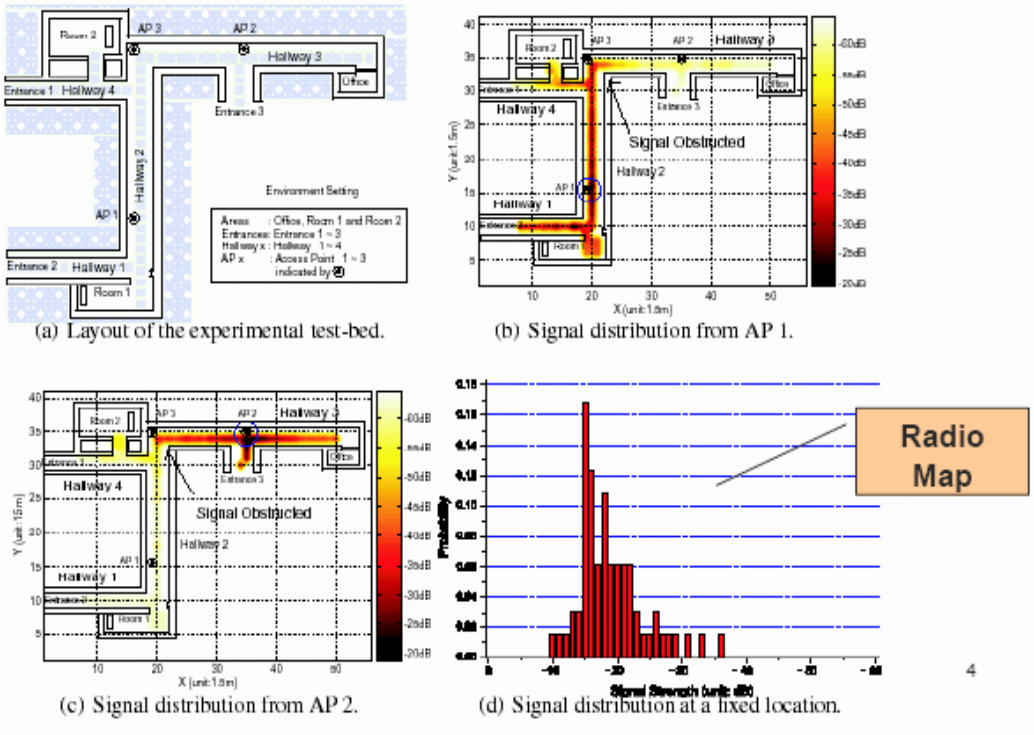
The Architecture of Wi-Fi indoor Positioning System

The strength of the Wi-Fi signals received from different access points is used as a signature to determine the location of a user.



Challenges of Wi-Fi Based Positioning Systems

- Signal propagation suffers from severe multipath fading, and interference in an indoor environment.
- Dynamic factors: people presence and movements, humidity.



(a) Layout of the experimental test-bed.

(b) Signal distribution from AP 1.

(c) Signal distribution from AP 2.

(d) Signal distribution at a fixed location.

Wi-Fi Based Positioning Process

- Two phases: (a) offline Training and (b)online Localization
- Offline phase – collect samples from signal space to build a radio map

Loc.	Time	(AP1,AP2,AP3)
(1,0)	1s	(-60,-50,-40) dB
(2,0)	2s	(-62,-48,-35) dB
…..	….	(… , … , …)dB
(9,5)	9s	(-50,-35,-42) dB

Mapping function F

- Online phase – Capture the Received Signal Strength (RSS) of access point s and then find the best match in the radiomap to determine the location.

State of the Art (Academia)

- Microsoft Research's RADAR [5]
  - K-Nearest – Neighbor Method
  - Offline – for each location, compute the signal mean
  - Online – estimate location with KNN and triangulation
- Strength
  - Small number of samples could estimate the signal with a reasonable accuracy
- Weakness
  - Positioning accuracy is relatively low (error >3m)

State of the Art (Academia)

- University of Maryland's Horus [6]
  - Maximum Likelihood Estimation (MLE)
  - Offline – for each location, build the Radio Map of each AP
  - Online – apply ML algorithm for estimation
- Strength
  - Good accuracy (error <3m)
- Weakness
  - Needs relatively large number of samples to construct radiomap
  - Environmental factors can deteriorate the performance

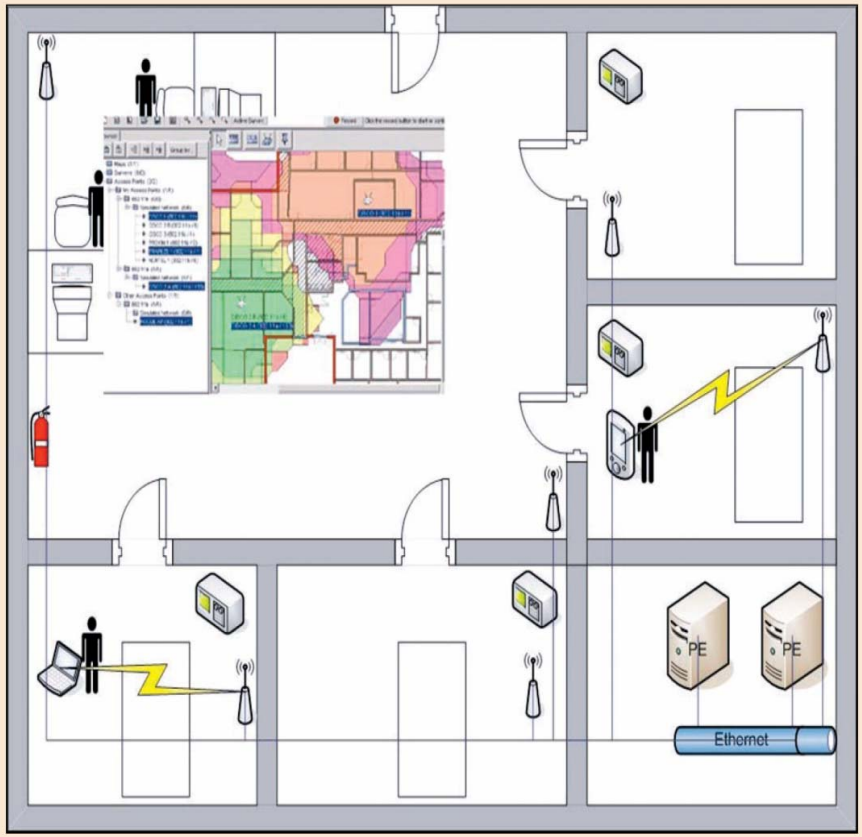
State of the Art (Industry)

Ekahau

- Probabilistic Model adopted
- Gives (x , y, floor)
- Reference tag needed
- Accuracy of about 1-3 meters

*Aero*Scout

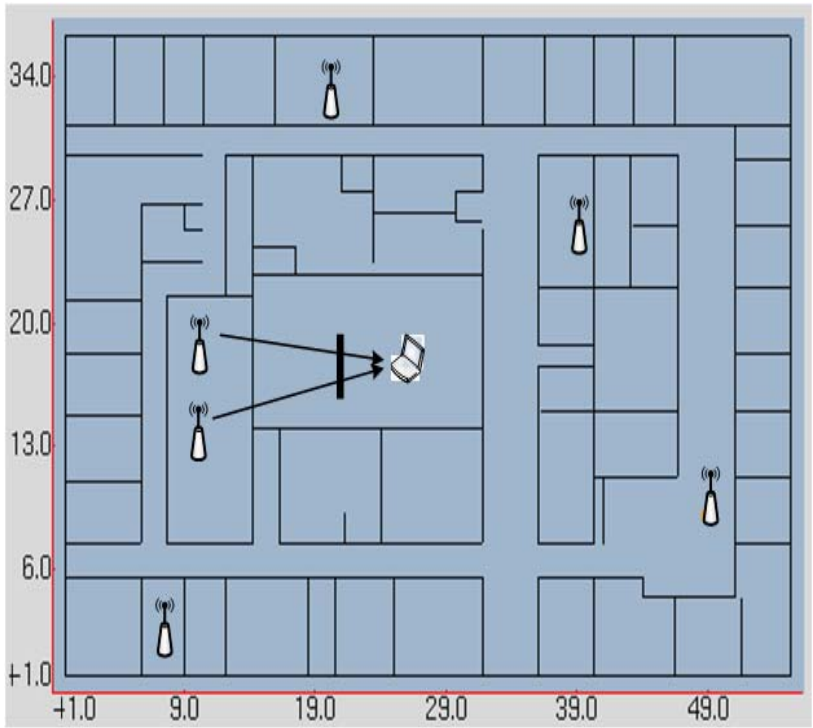
- Probabilistic Model adopted
- Gives (x , y, floor)
- Ultra-Wideband (UWB) needed
- High accuracy



Proposed Method (Differential Access Points)

- The proposed method is an analogy to the traditional differential amplifiers where noise and interference are eliminated through a differential operation.

- The method assume two access points are placed at different distances from a receiver inside a room, hence path loss between them and the receiver remains equal.



Mathematical Model of the Proposed Method

- The strength of the received signals from the two access points fixed in same room are given :

$$P_{r1} = P_{t1} + G_{t1} + G_r + 20\log\frac{\lambda}{4\pi} - 10n\log d_1 - X_{a1}$$

$$P_{r2} = P_{t2} + G_{t2} + G_r + 20\log\frac{\lambda}{4\pi} - 10n\log d_2 - X_{a2}$$

X_a is a normal random variable with zero mean in dB representing the shadowing effects.

- Therefore the difference between the received signal strengths can be estimated by:

$$P_{r1} - P_{r2} = 10n\log\frac{d_2}{d_1} + \varepsilon$$

- So, from above equation, we can see that the effect of shadowing is significantly reduced.

Search Algorithm

- Maximum Likelihood (ML) as a most popular searching algorithm is adopted to find the best match in the radiomap:

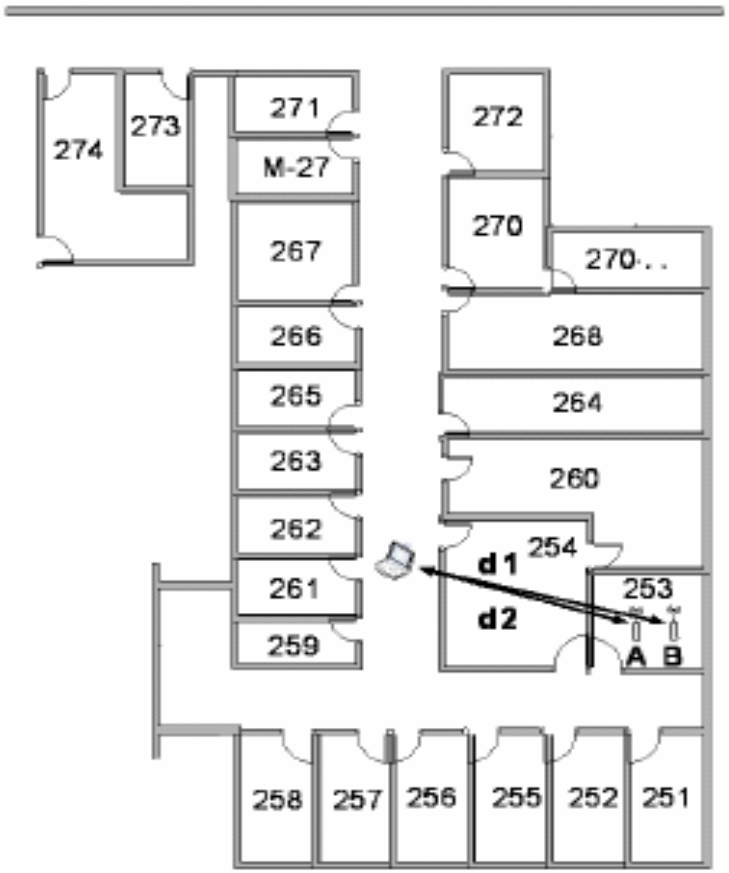
$$P(o \mid \omega_r) = \prod_{m=1}^{M} \frac{1}{\sqrt{2\pi \sum_r (m,m)}} . \exp\{\frac{-(o_d - \mu_{rd})^2}{2\sum_r (m,m)}\}$$

Where $O = [o_1, o_2 .... o_M]$ is the Online RSS vector, ω_r represent the coordinate of the r_{th} reference location. μ_r is a mean vector and covariance matrix are calculated and stored for each ω_r $\sum_r$ during the off-line stage.

- Using this method, each location in the area of interest is represented by a set of PDF Models in the radio map. The location of the receiver is where the mean squared error is reduced to its minimum level.

Experimental Setup

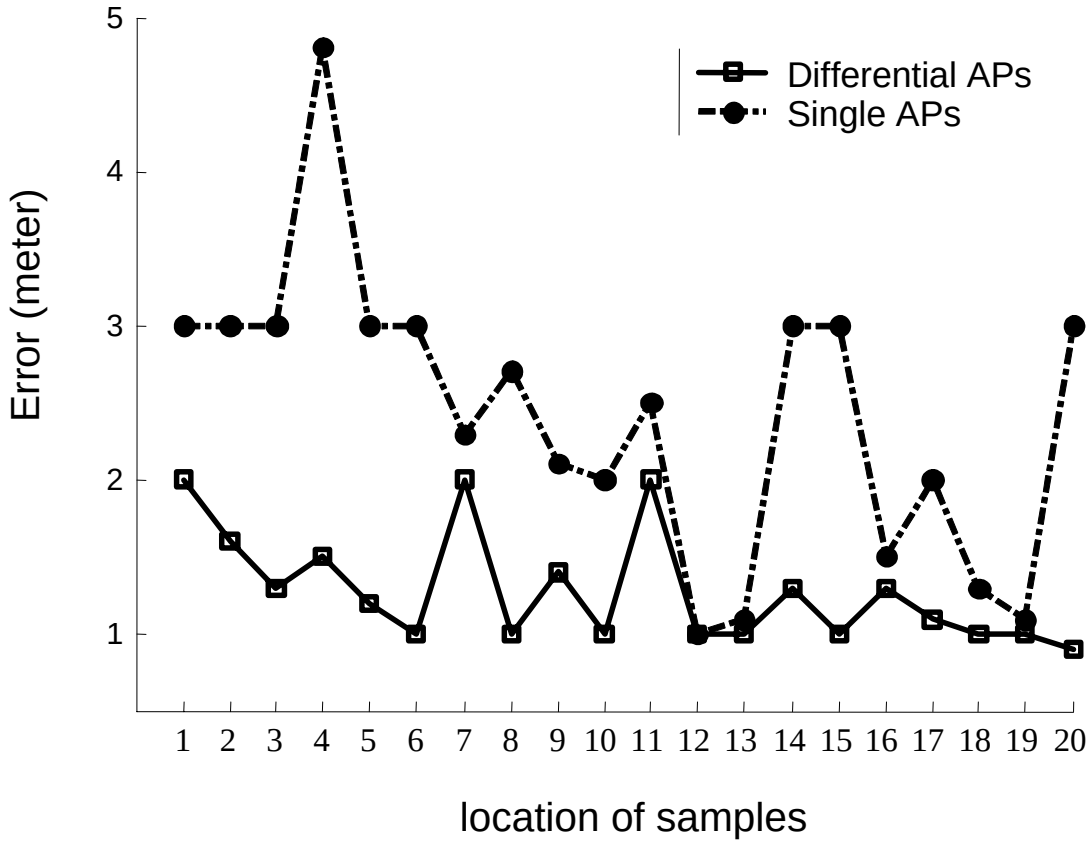
- Test-bed: Department of ECE, University of Windsor



- 60 locations (3 by 3 meter)
- 50 samples per location
- 65% for training, 35% testing
- Repeat each measurement 5 times

Experimental Results

- Differential APs methods can reduce the signal strength's deviation.



Future Works

- Develop necessary software tools for real-time indoor localization using differential access points
- Compare the performance of the proposed method with the state of the art techniques using real-time data.
- Implement kernel-based smoothing method to eliminate the RSS variation by small scale fading.

References

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