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Energy-Efficient WiFi Fingerprint-Based Indoor Localization

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Outline

- Introduction
- Related work
- System architecture
- System design
- Experimental results
- Conclusion

Introduction

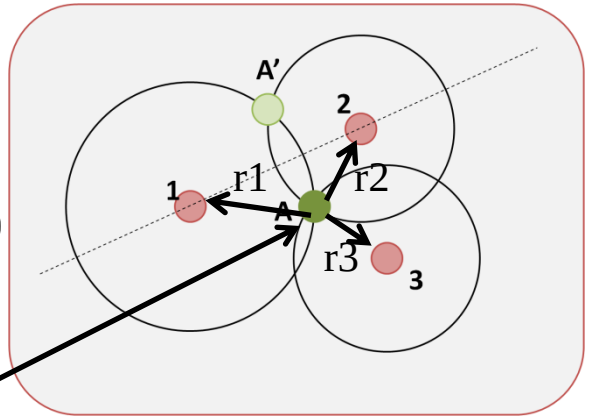
- **Indoor localization is important to Location Based Services (LBS), e.g.**
  - **Navigation within big buildings and airports**
  - **Store navigation**
  - **Augmented reality**
  - **Social networking**
- **However, GPS works poorly indoors. Need other techniques for indoor localization**
- **Many solutions are proposed …**

Introduction

Taxonomy of indoor localization

Distance-based localization

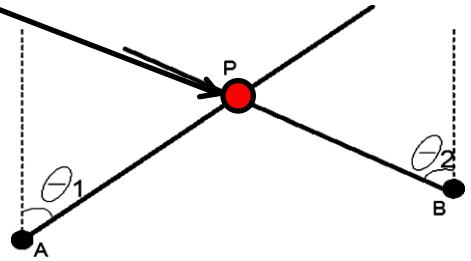
- ✓ Trilateration (TOA/TDOA/RTOF)



target

Trilateration

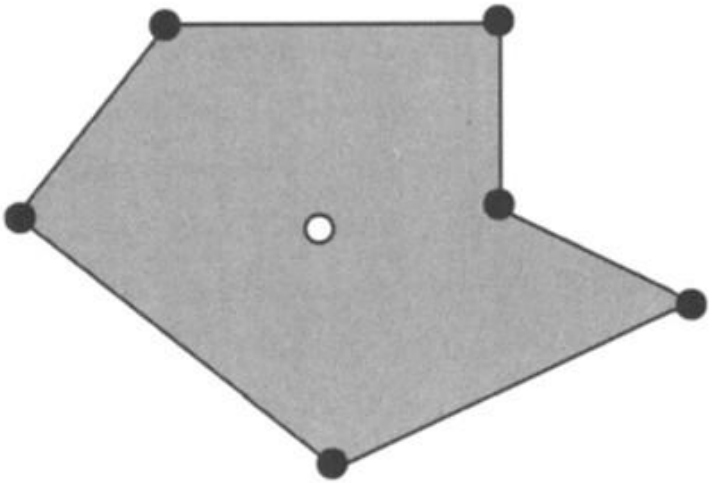
- ✓ Triangulation (AOA/DOA)



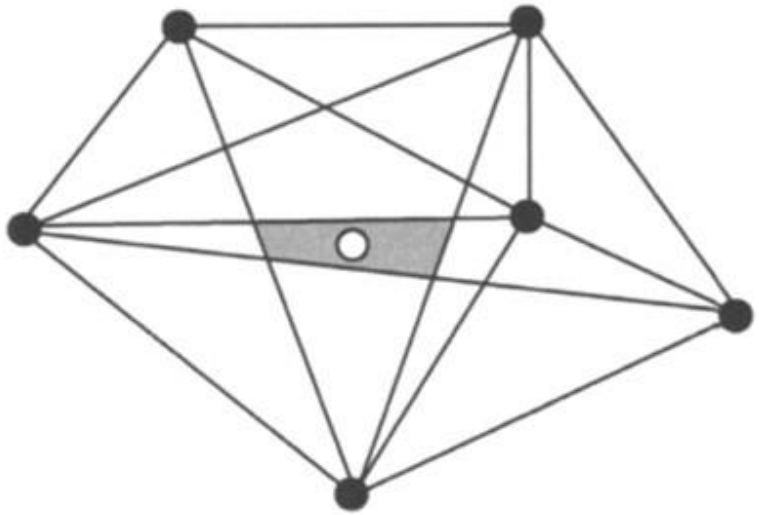
Triangulation

Introduction

- **Distance-free localization**
  - ✓ **Centroid Localization**
  - ✓ **Approximate Point-in-triangulation Test (APIT)**



Centroid Localization

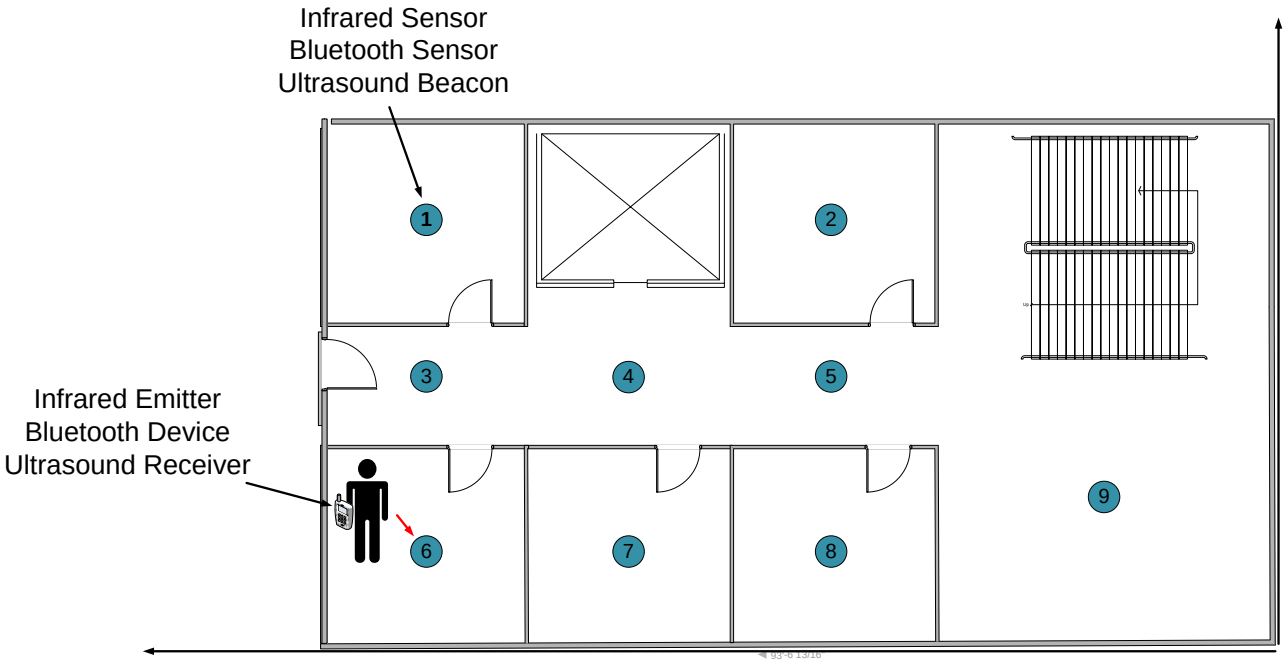


APIT

Introduction

Location-aware localization

✓ **Relative location (sensor, RFID, Marcocell, Femtocell)**

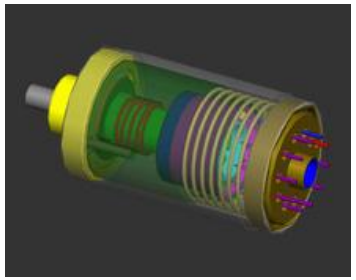


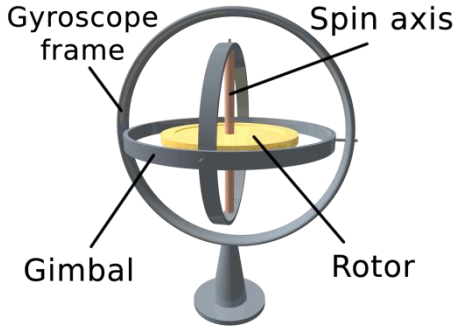
✓ **Fingerprint-based localization**

➢ **Acoustic/light/magnetic/WiFi Fingerprint**

Introduction

- **Mixed approaches**
  - ✓ **Locate a user using a map & Inertial Measurement Units) IMUs, e.g., accelerometer, gyroscope) on smart phones**





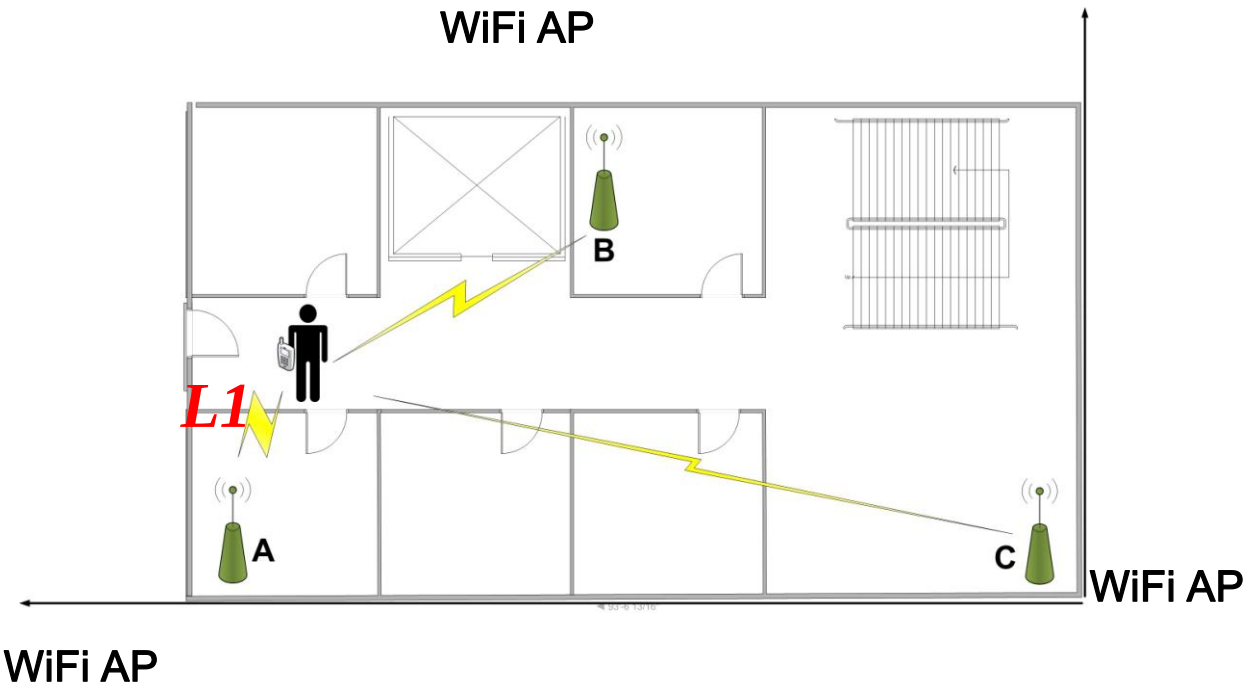
by courtesy of Microsoft Research
http://research.microsoft.com/en-us/projects/indoorloc/

Introduction

➢ **We focus on WiFi fingerprint-based methods …**

Location 1 Fingerprint
A: Strong
B: Moderate
C: Weak

Triplet (S, M, W)

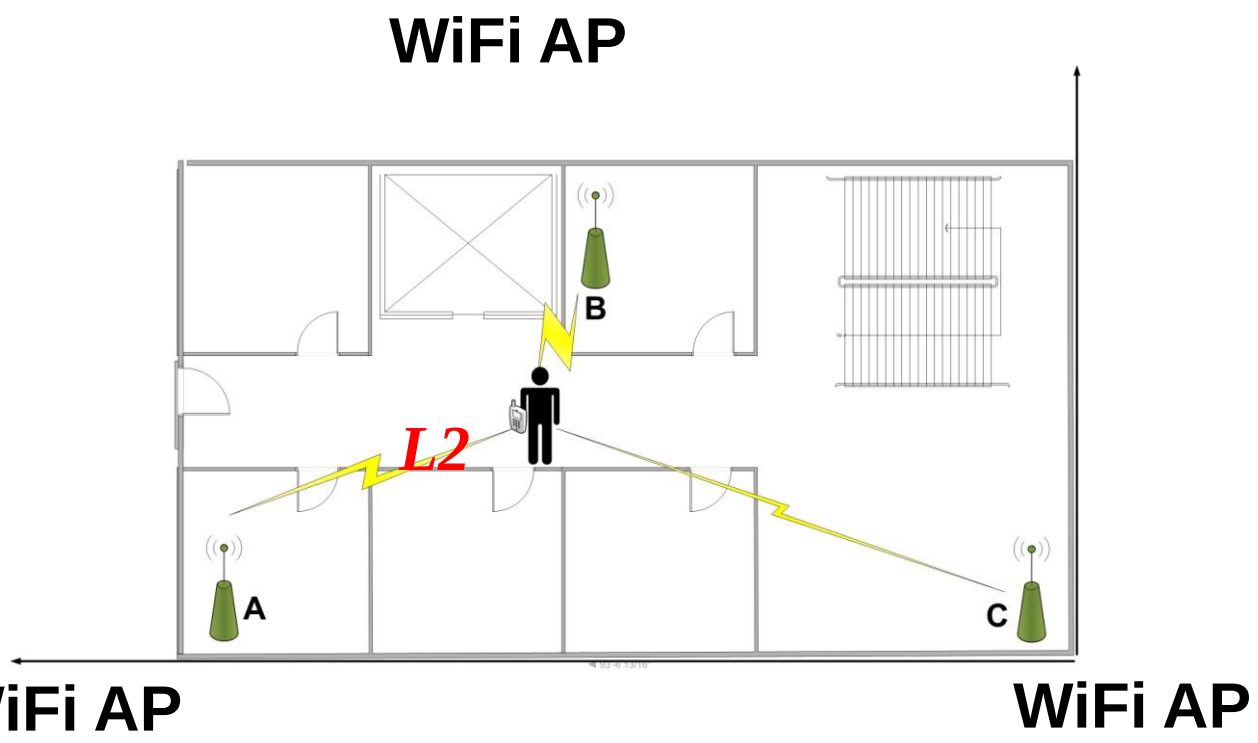


Introduction

- **We focus on WiFi fingerprint-based methods …**

Location 2 Fingerprint
A: Moderate
B: Strong
C: Weak

Triplet (M, S, W)

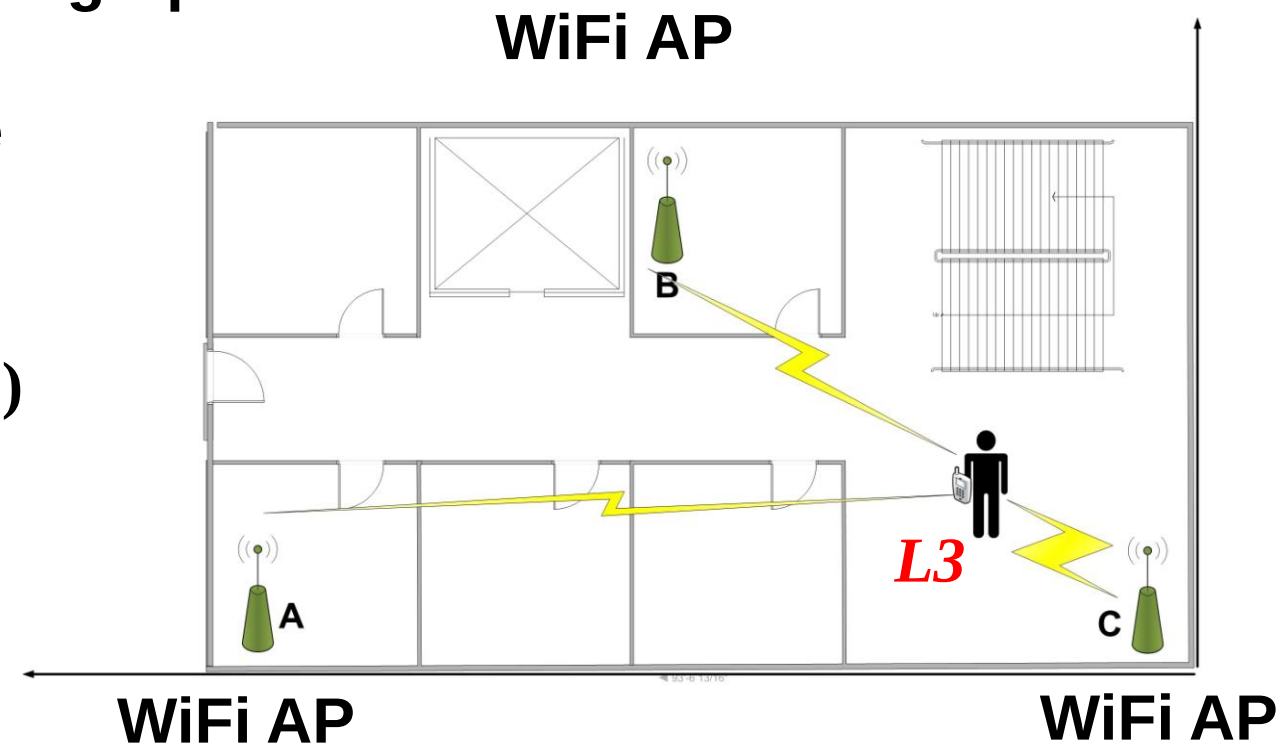


Introduction

- We focus on WiFi fingerprint-based methods …

Location 3 Fingerprint
A: Weak
B: Moderate
C: Strong

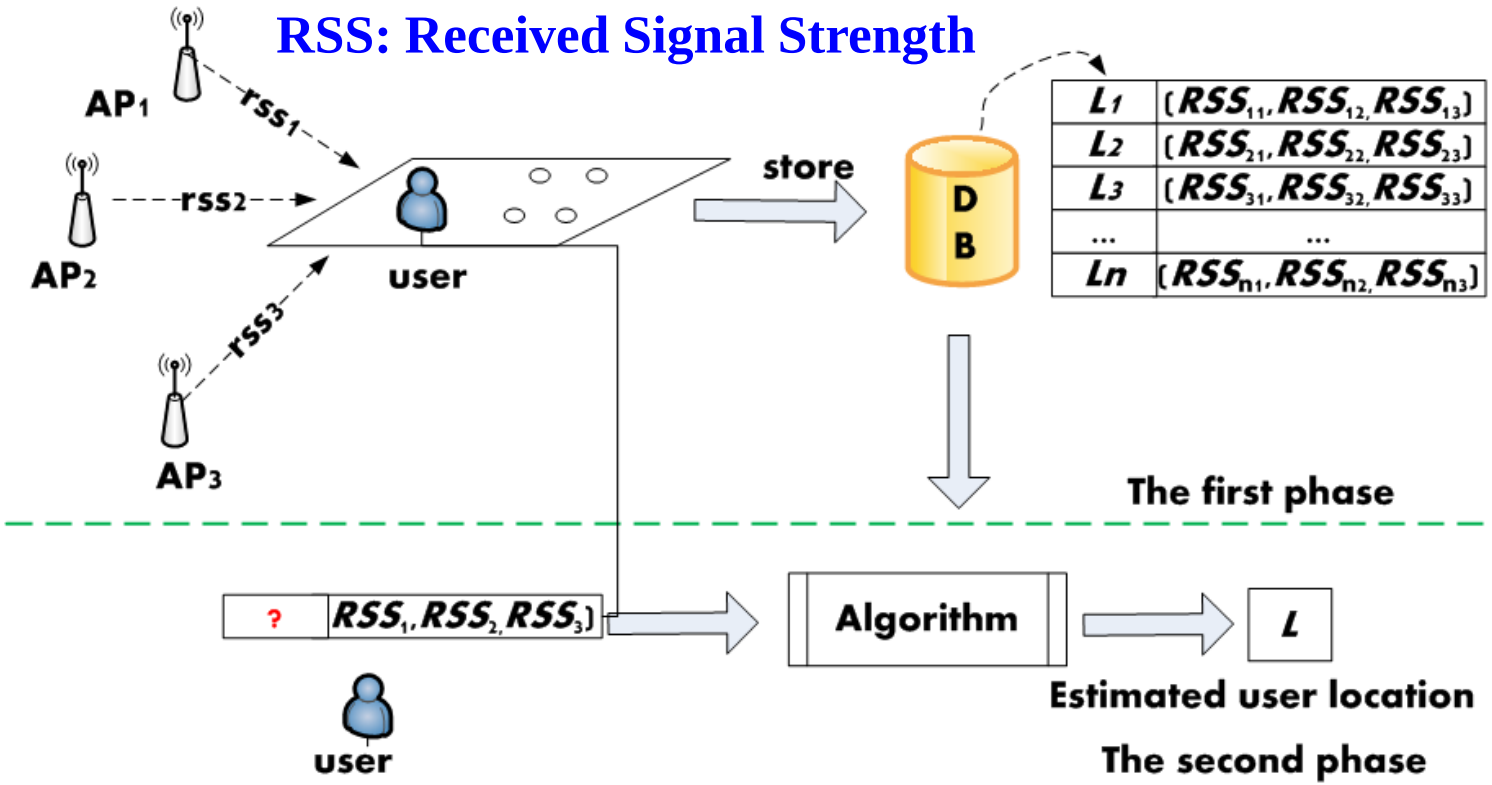
Triplet (W, M, S)



Introduction

➢ Fundamental of Wi-Fi fingerprint-based methods

- Locate a user by matching the user's current WiFi fingerprint (RSS_1, RSS_2, RSS_3) with those in database

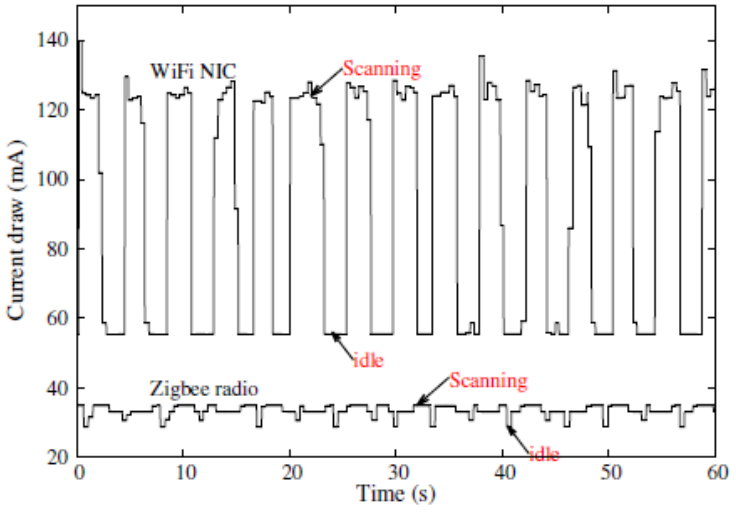


Introduction

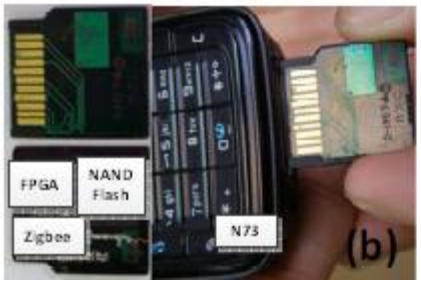
- **Advantages of Wi-Fi fingerprint-based methods**
  - **Rely on existing WiFi infrastructure only**
  - **Not require knowledge of APs (placement, power)**
  - **Not require any explicit user participation**
- **Drawbacks**
  - **Consume significant power**
  - **AP scanning will interrupt normal data communication**
  - ***Could we overcome these two drawbacks?***

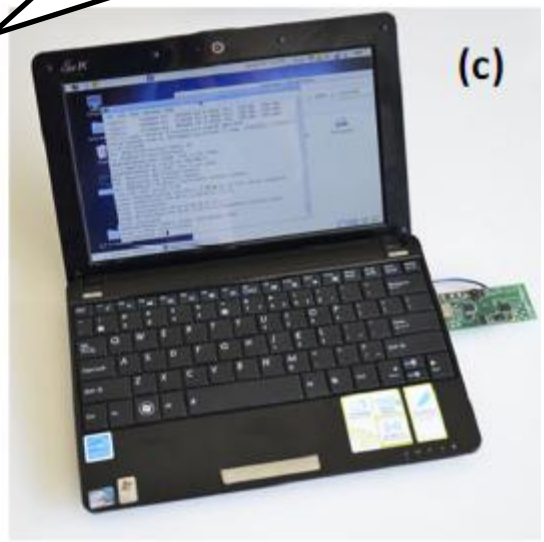
Observations for a New Approach

- More mobile devices are equipped with secondary low-power interfaces besides WiFi, such as Bluetooth and Zigbee
- Can low-power radios, such as ZigBee, detect WiFi fingerprints?



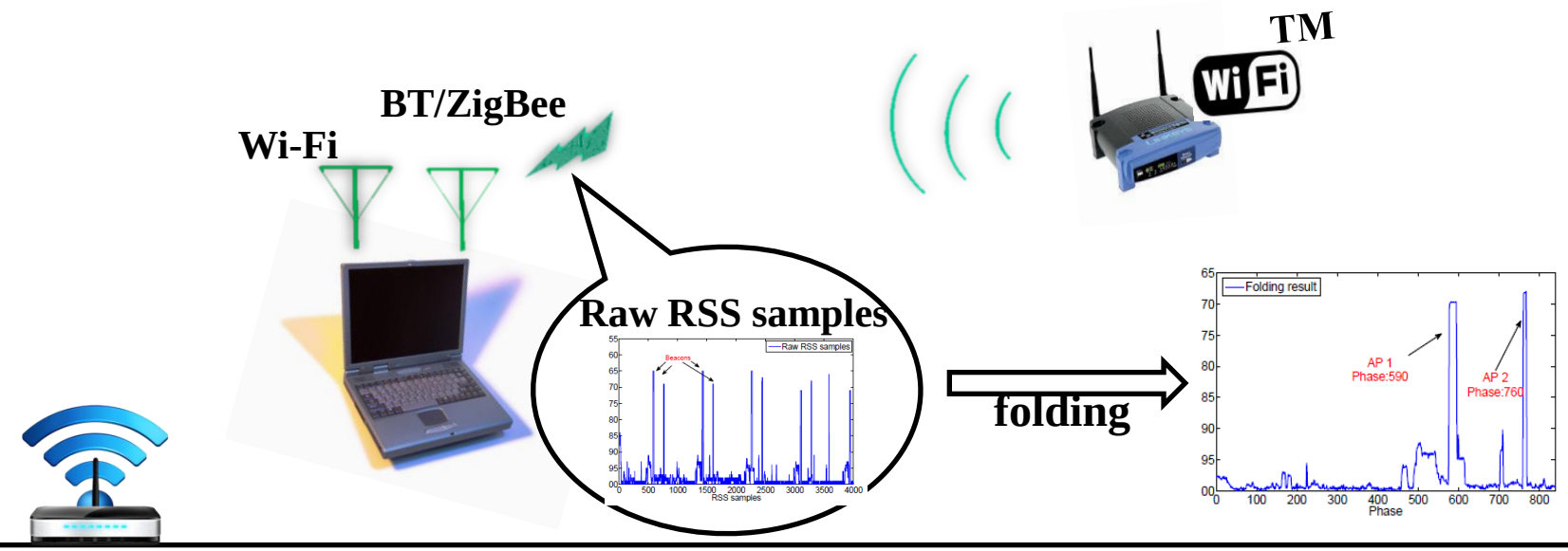
Different Zigbee Interfaces





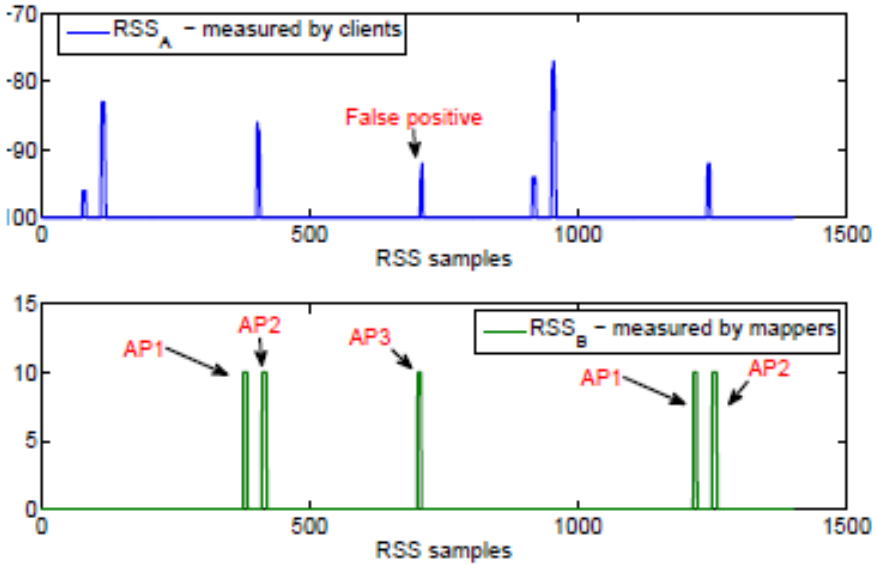
Basic idea of our approach

- **Low-power Zigbee interfaces detect WiFi signatures (RSS, ID of AP) as location fingerprints.**
- **A novel classification algorithm (*R-KNN*) is proposed to deal with the noises in the fingerprints and classify the signatures into different clusters (rooms).**

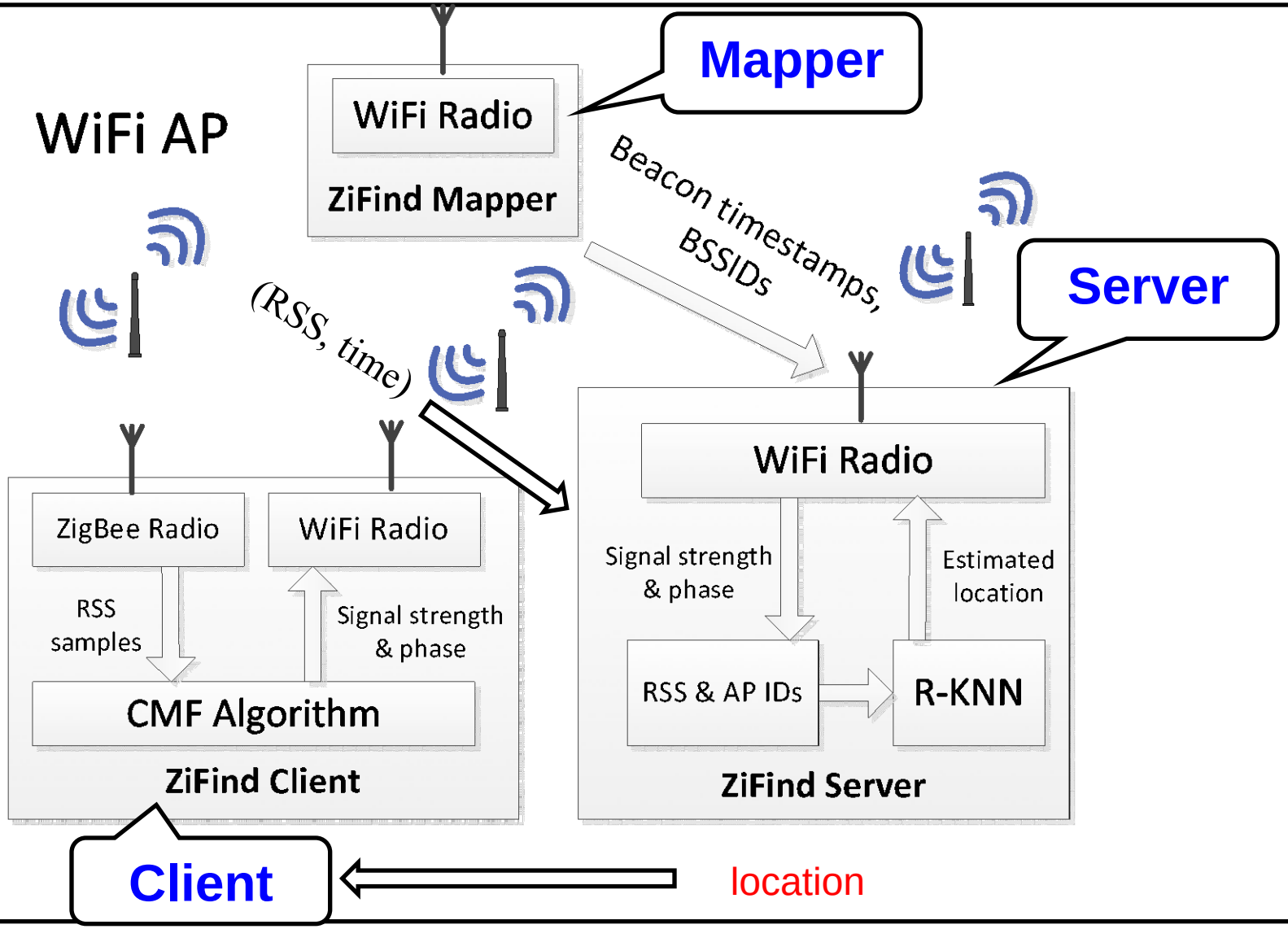


Challenges

- Zigbee radios cannot resolve beacon frames of AP, though can detect RSS of APs.
- WiFi fingerprints detected by ZigBee radios often contain some noises.
- Built ZiFind to address these challenges.



System Architecture



Client

Server

ZigBee radio

WiFi radio

Mobile Device

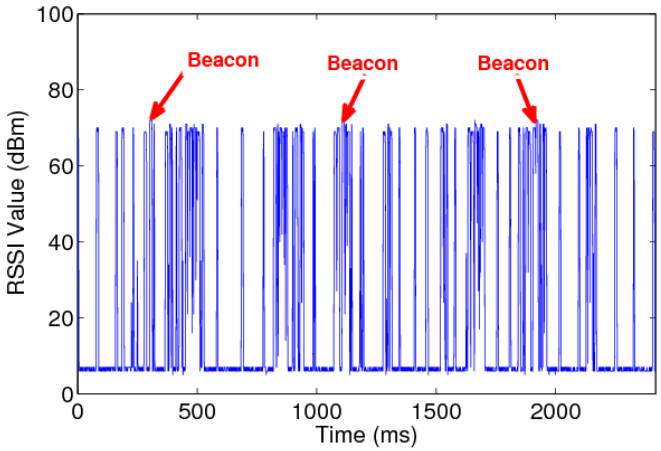
Wi-Fi Access Point

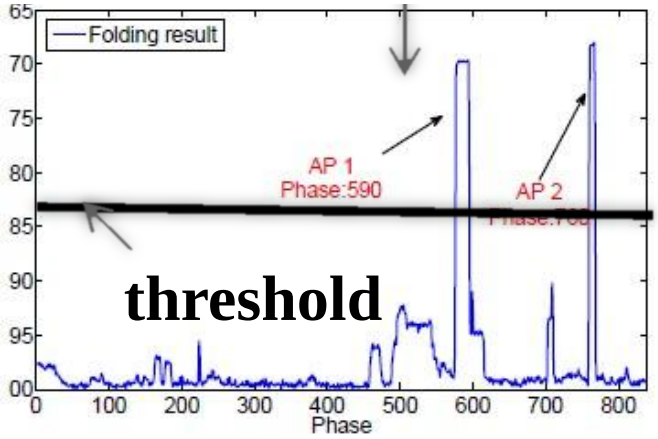
RSS Sampling & Shaping

Common Multiple Folding

Constant False Alarm Rate Detector

amplify periodic signals





Fingerprint:
<(590, 69), (760,66)>

(RSS, timestamp)

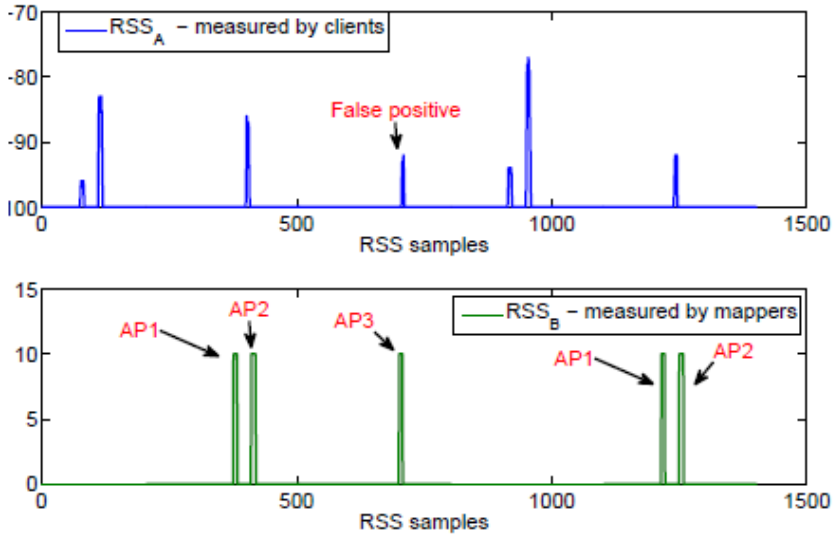
Mapper

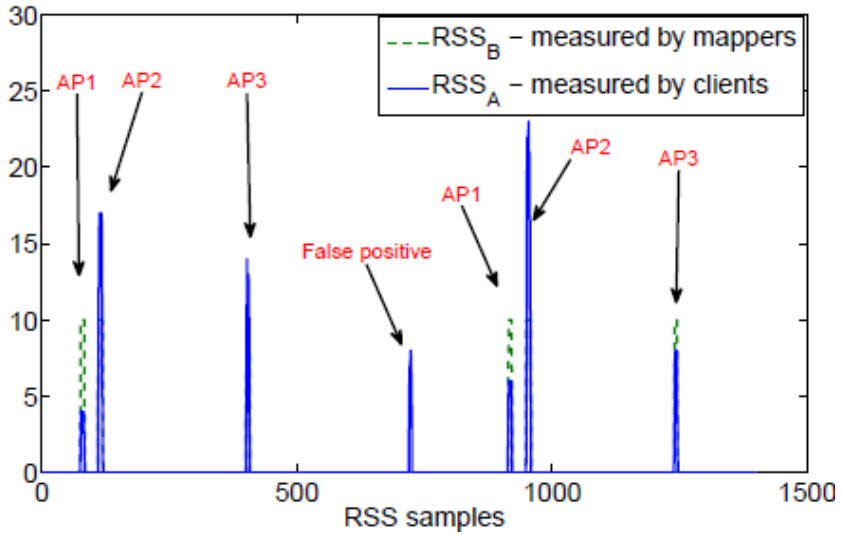
- **Collecting (SSID, timestamp) pair of APs upon Server's requesting**
  - **Beacons are always transmitted at the maximum power and lowest modulation rate.**
  - **only a small number of mappers (non-mobile computers) are required to collect the beacons of all APs in the service area.**

Server

- First, receive a set of pairs (RSS, timestamp) of WiFi APs from a client and pairs (SSID, timestamp) from mappers.
- Then, align the RSS series from the client and data from mappers. After alignment, the RSS from the client can be tagged with WiFi SSIDs.
- Finally, feed the tagged RSS values (RSS, SSID) to the *R-KNN* algorithm to locate the client (mobile user).

Server: Aligning the Two RSS series





- **Different APs suffer different clock drift rates**
- **Alignment algorithm computes the cross correlation between the RSS series from mappers and from clients, and finds an offset to best align the two series**

Experimental Setup

- Test-bed includes over 100 APs, 2 clients, 10 mappers and 1 server
- Evaluation metrics
  - Localization accuracy
  - energy consumption of client devices


Mapper

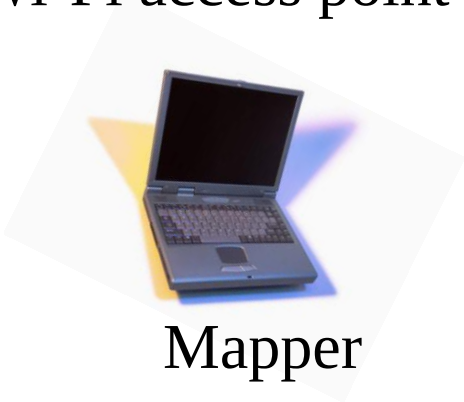

Mobile Client


Wi-Fi access point


Wi-Fi access point

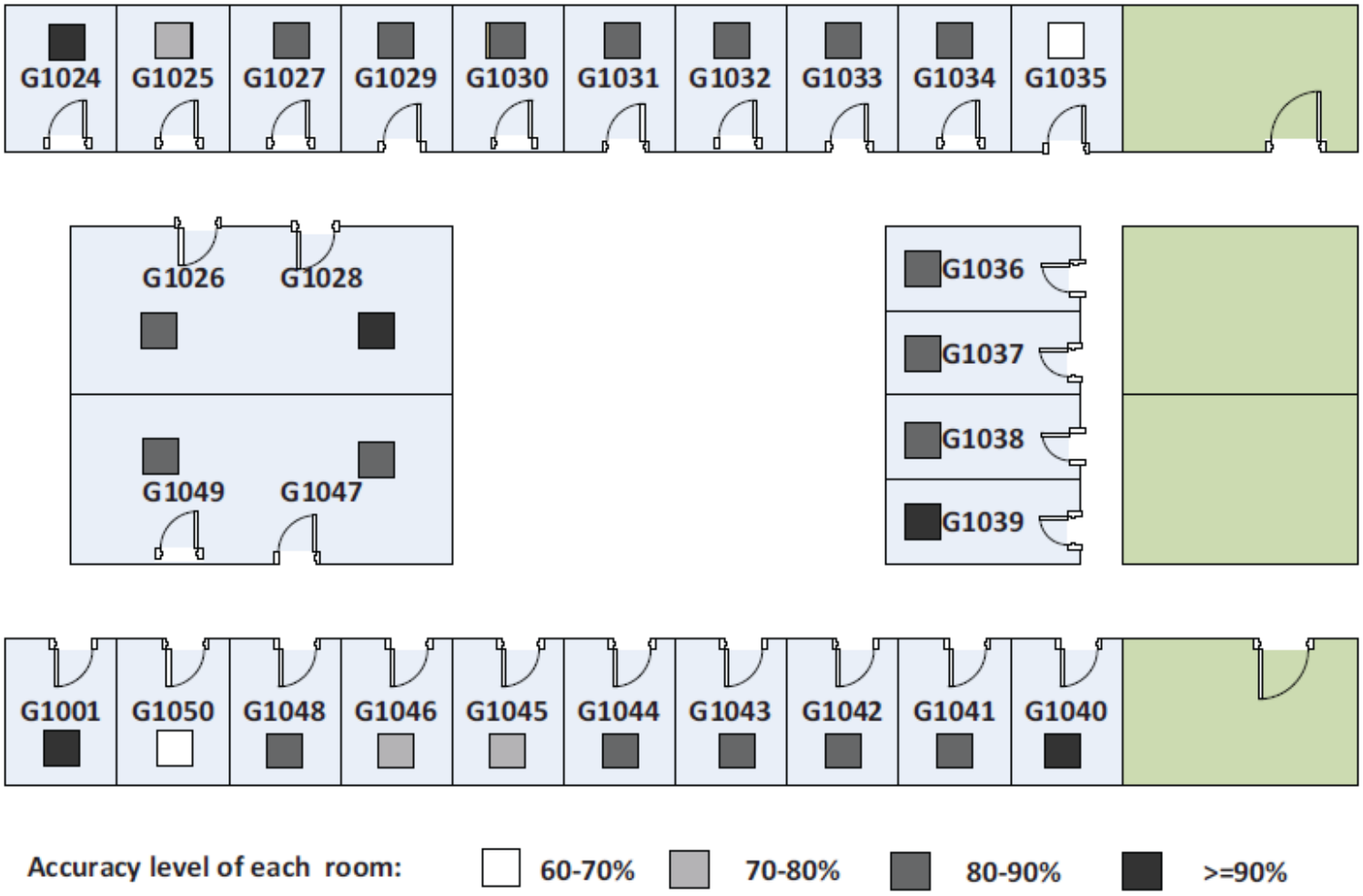

Server

Mobile Client


Mapper

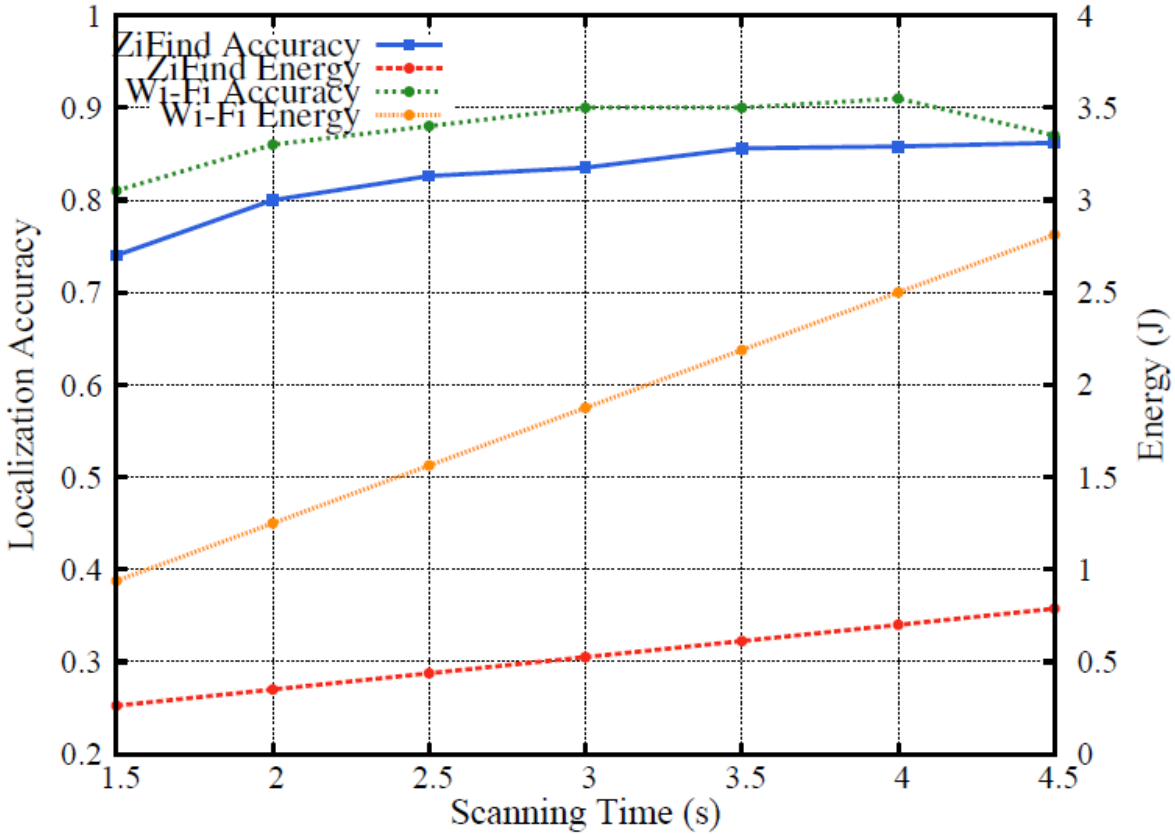
Localization Accuracy

- **Average accuracy 85%, in a 16,000 square feet area, 28 rooms**



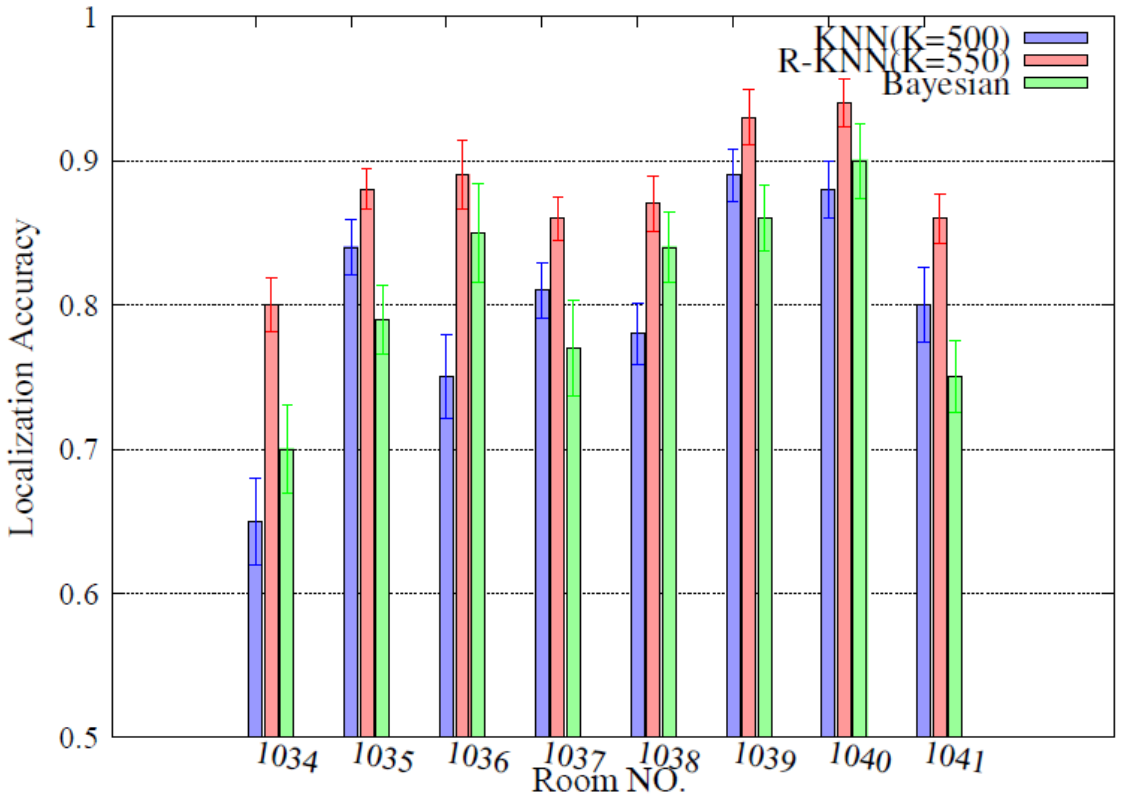
Accuracy vs. Energy Consumption

- **Accuracy: Similar to the Wi-Fi-based method**
- **Energy: only 32% of the Wi-Fi based method**

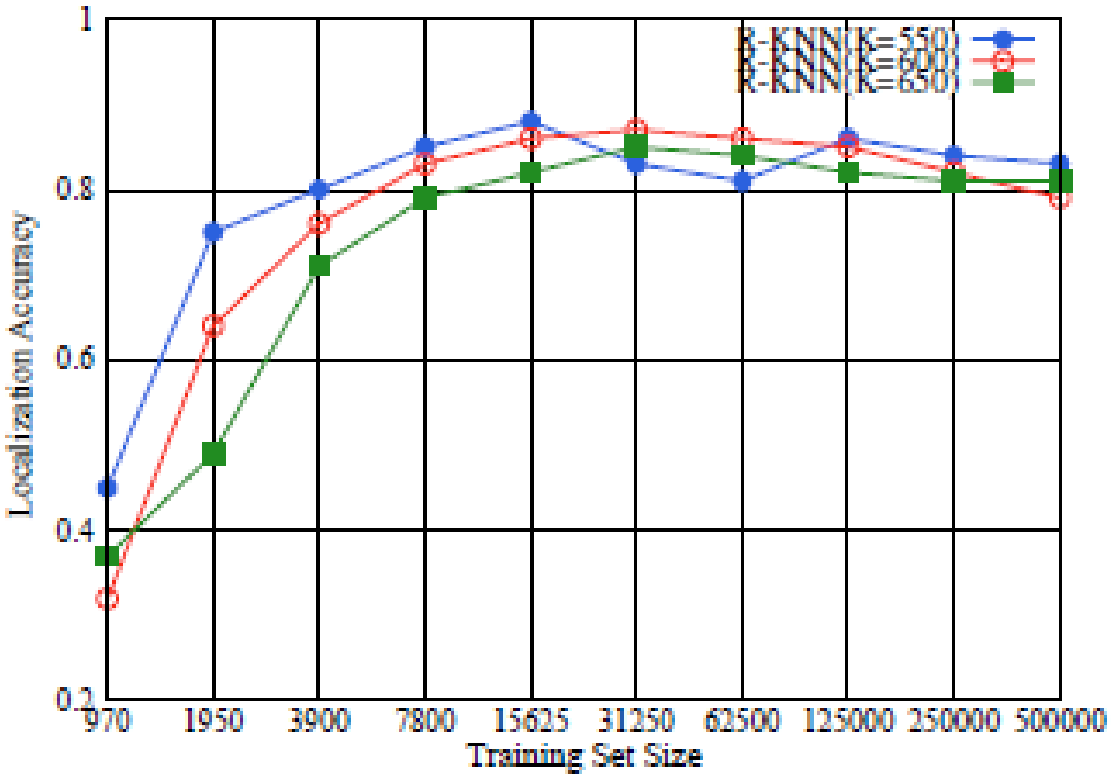


Comparison with Other Algorithms

- **Stable: The accuracy of our approach (R-KNN) does not change much across different testing rooms while keeping a favorable accuracy**



Accuracy over Training Set Size

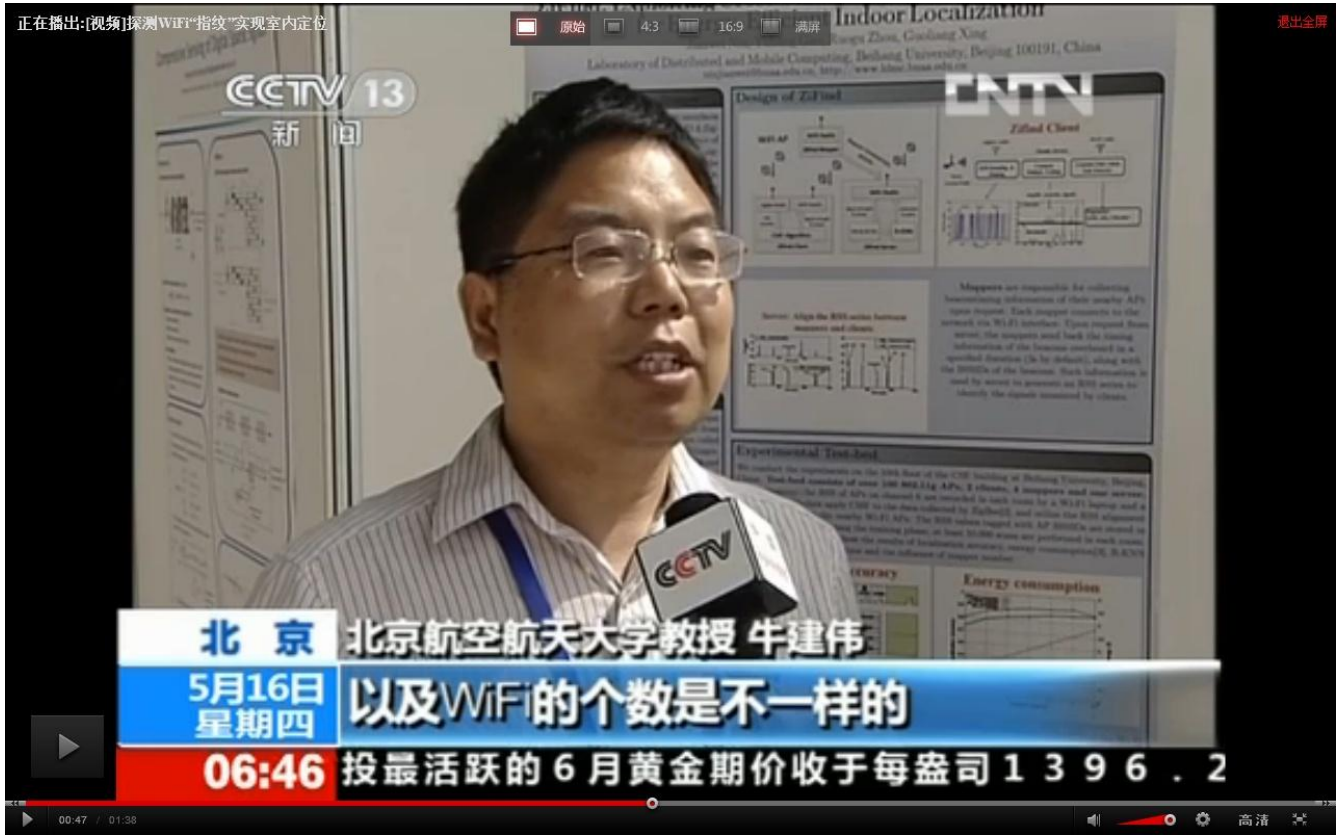


***15,000 samples* are sufficiently large for our system to keep high and stable accuracy**

Conclusion

- ZiFind: a novel system for indoor localization system using ZigBee radios to detect Wi-Fi fingerprints
  - A novel architecture to use ZigBee radio to detect WiFi fingerprint.
  - A modified KNN (R-KNN) algorithm to cluster WiFi fingerprints
- Results show ZiFind yields robust performance in the presence of significant temporal variations in WiFi signals.
- More details, please refer to
  - this project: www.ldmc.buaa.edu.cn/ZiFind
  - In-Location Alliance: www.in-location-alliance.com

Visibility



Thanks very much for your attention!