

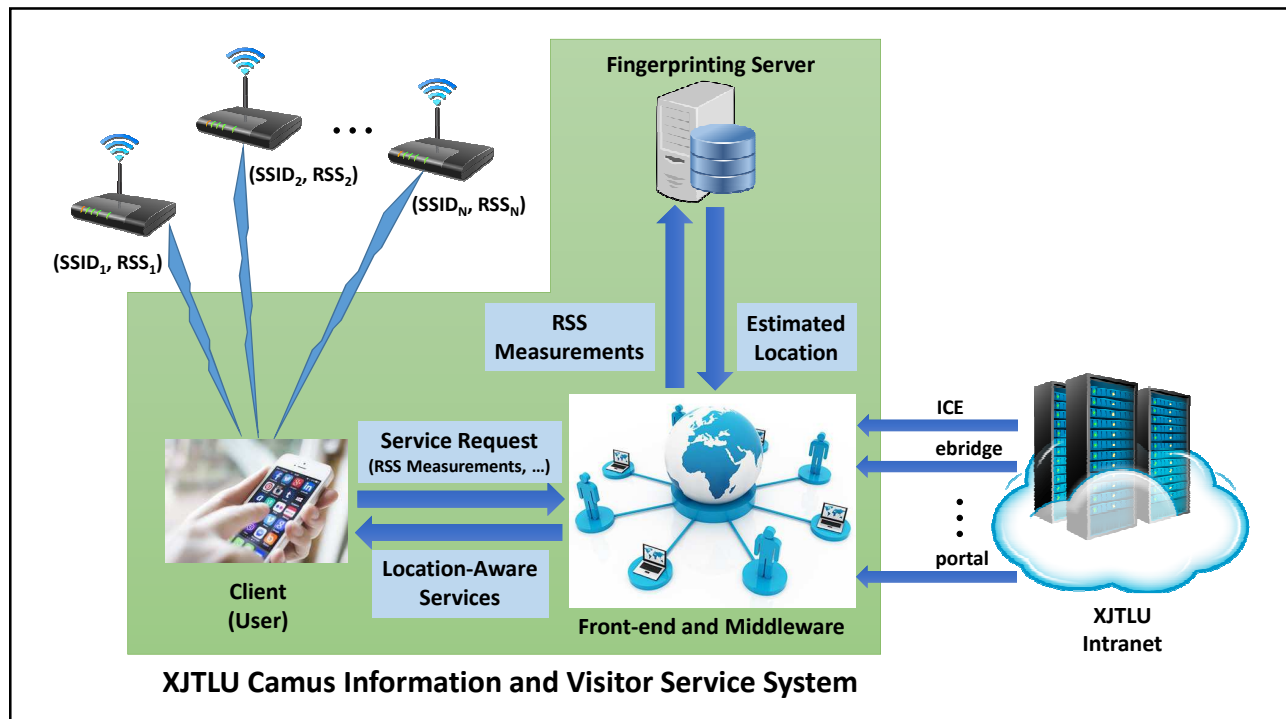
Indoor Localisation Based on Wi-Fi Fingerprinting with Fuzzy Sets

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Outline

- Overview
- Wi-Fi Fingerprinting
- Plan
- Discussion

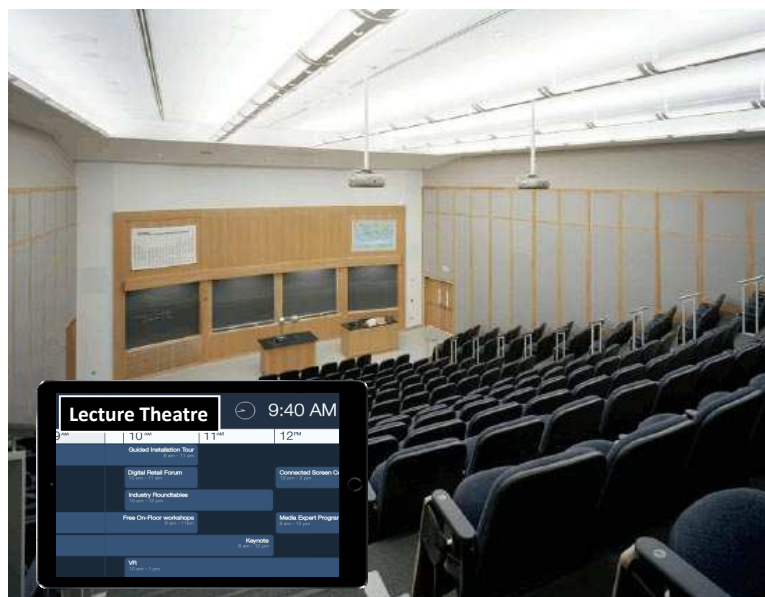
Overview



Service Example: Indoor Localisation/Navigation



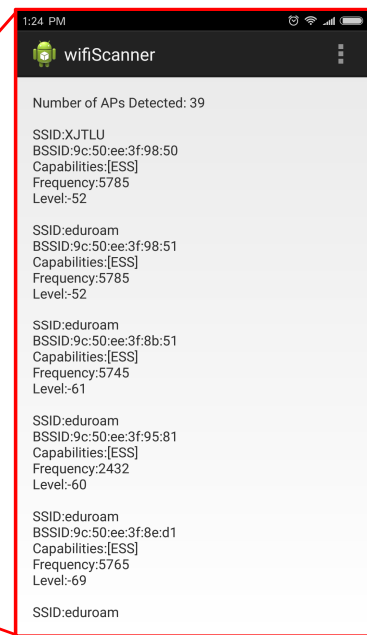
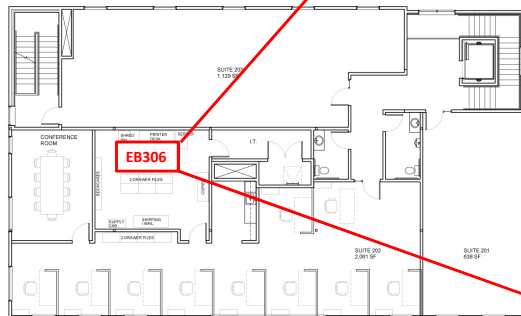
Service Example: Location-Aware Service



Wi-Fi Fingerprinting

Location Fingerprint

- A tuple of $(\mathcal{L}, \mathcal{F})$
 - \mathcal{L} : Location information
 - Geographic coordinates or a label (e.g., "EB306")
 - \mathcal{F} : Vector/function of RSSs
 - e.g., $(\rho_1, \dots, \rho_N)^T$ where ρ_i is the RSS from i_{th} access point (AP).



Location Estimation

- Deterministic
 - **Nearest Neighbour Methods**
 - Neural Network Methods
- Probabilistic
 - Bayesian Inference
 - Support Vector Machine (SVM)
 - Gaussian Process Latent Variable Model (GP-LVM)

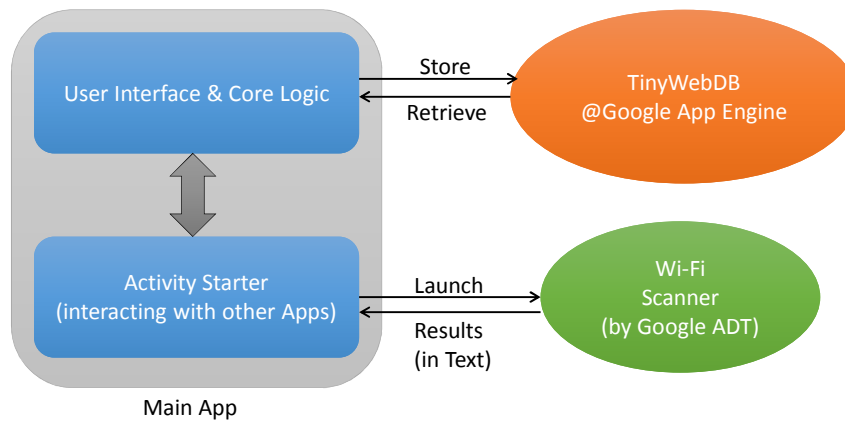
Nearest Neighbour Methods*

- A simple approach based on the notion of distance in the signal space:
 - Given a fingerprint of $(\mathcal{L}, (\rho_1, \dots, \rho_N)^T)$ and an RSS measurement of $(s_1, \dots, s_N)^T$, the *Euclidean distance* measure between them is defined as

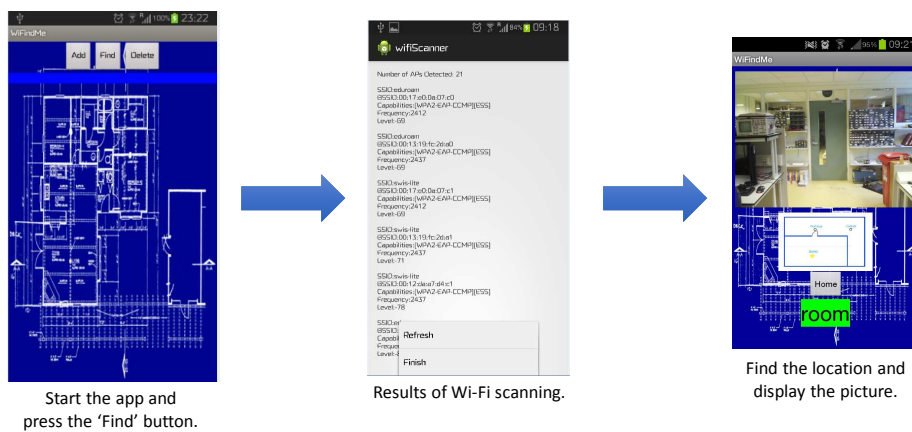
$$\sqrt{\sum_{i=1}^N (s_i - \rho_i)^2}$$
 - Then, we find a fingerprint providing a minimum distance, \mathcal{L} of which is the estimated location.

* P. Bahl and V. N. Padmanabhan, "BADAR: An in-building RF-based user location and tracking system," Proc. of INFOCOM 2000, vol. 2, pp. 775-784, Mar. 2000.

Implementation Example - 1



Implementation Example - 2



Major Challenges in Large-Scale Implementation

- Scalability
- Localisation accuracy
- Non-stationarity of location fingerprints
 - Incremental/online learning algorithms with pruning/forgetting mechanisms*
- Passive vs. active location estimation
- Integration with other services
- Security/privacy issues

* R. Elwell and R. Polikar, "[Incremental learning in nonstationary environments with controlled forgetting](#)," Proc. IJCNN'09.

Plan

Work Packages

- **Theoretical and simulation study**
 - Build a membership function from RSS measurements.
 - Select or newly define a fuzzy similarity measure.
 - Apply the proposed scheme to RSS measurement databases available online and analyse its localisation performance.
- **Prototyping and demonstration**
 - Build a sample RSS measurement database at XJTLU.
 - e.g., for the 3rd floor of EE building.
 - Implement the proposed algorithm and demonstrate indoor localization with the sample database.
 - Offline demonstration with a PC
 - (*Optional*) Online demonstration with a smartphone

Task 1: Building Fingerprint Database - 1

- How to measure fingerprints?
 - Devices
 - Smartphones
 - Notebooks
 - Arduino & Raspberry Pi
 - ...
 - Measurement techniques
 - Time (e.g. 9 AM, 3 PM) and Frequency
 - Positions and directions
 - ...

Task 1: Building Fingerprint Database - 2

- Where and how to store fingerprints?

- Format of fingerprint
 - Timestamp
 - (Anonymised) User/device ID
 - RSSI levels
 - ...

- Structure of DB

- DB and server implementation

- Our own server
 - Physical box
 - Virtual private server (VPS): Linode, DigitalOcean, ...
- Database services from Third Parties
 - [ThingSpeak](#) by MathWorks (MATLAB company)

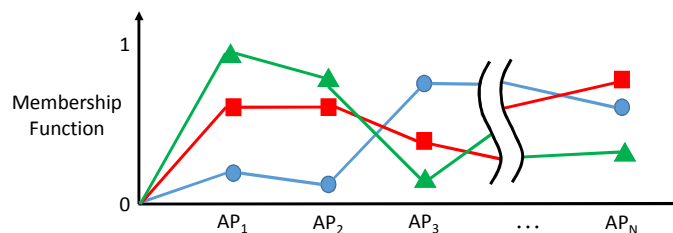
001-520	RSSI levels
521-523	Real world coordinates of the sample points
524	BuildingID
525	SpaceID
526	Relative position with respect to SpaceID
527	UserID
528	PhoneID
529	Timestamp

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Task 2: Location Estimation Techniques - 1

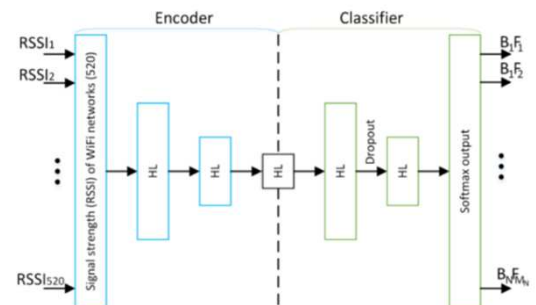
- Fuzzy similarity measure-based techniques

- How to build a *membership function* of a fuzzy set from RSS measurements for a given location?
- What *similarity measure* to use in finding the closest match among those fuzzy sets for optimal localisation performance?



Task 2: Location Estimation Techniques - 2

- Artificial neural network-based techniques
 - ANN (especially deep learning) can significantly lower the burden of localization system design.
 - But what *ANN architecture* and learning *algorithm* to use?



Task 3: Evaluation and Demonstration

- Offline demonstration with a PC.
- Online demonstration with a smartphone inside a building.