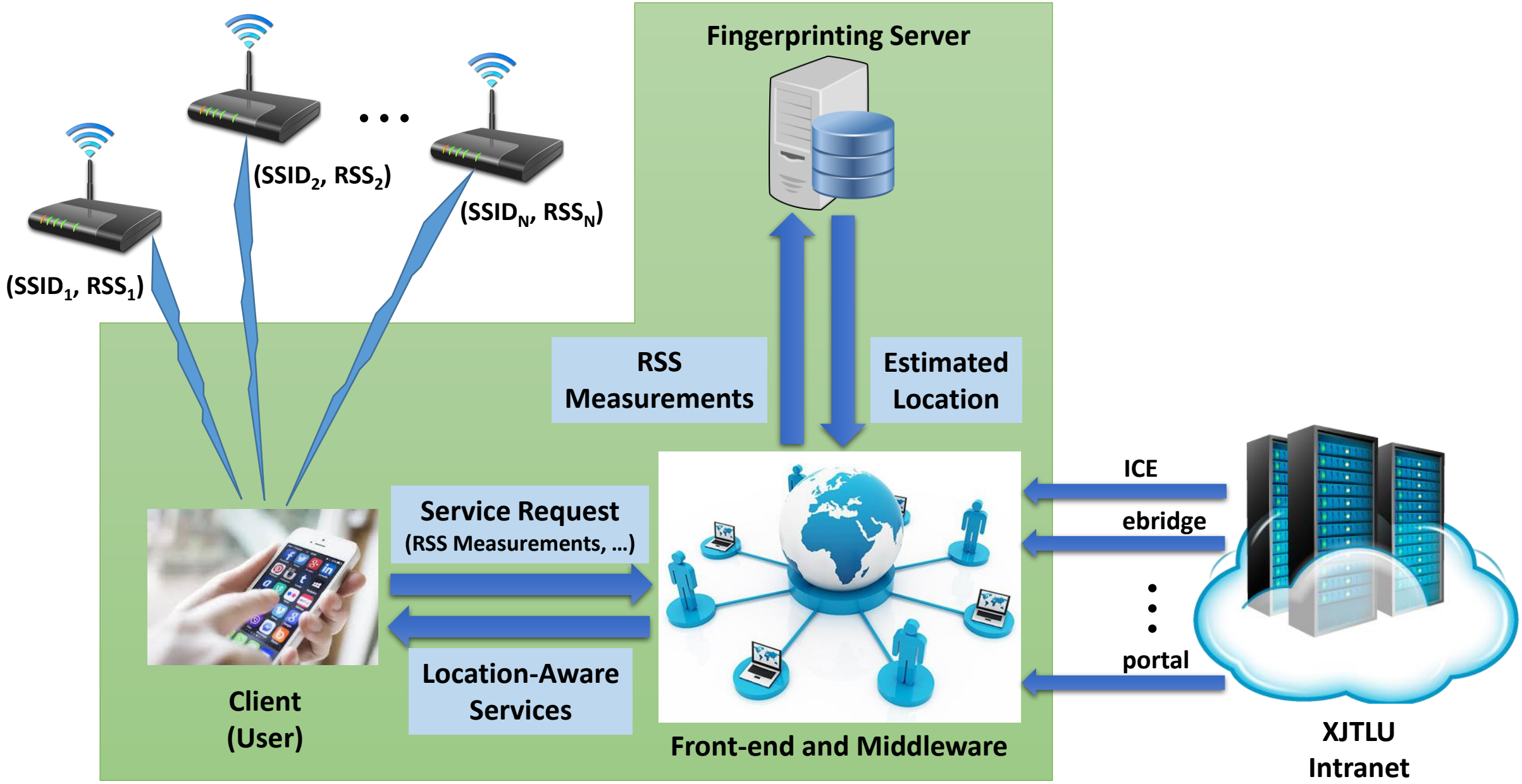
Indoor Localisation Based on Wi-Fi Fingerprinting with Fuzzy Sets

Kyeong Soo (Joseph) Kim
Department of Electrical and Electronic Engineering
Centre of Smart Grid and Information Convergence
Xi'an Jiaotong-Liverpool University (XJTLU)

Outline

- Overview
- Wi-Fi Fingerprinting
- Plan
- Discussion

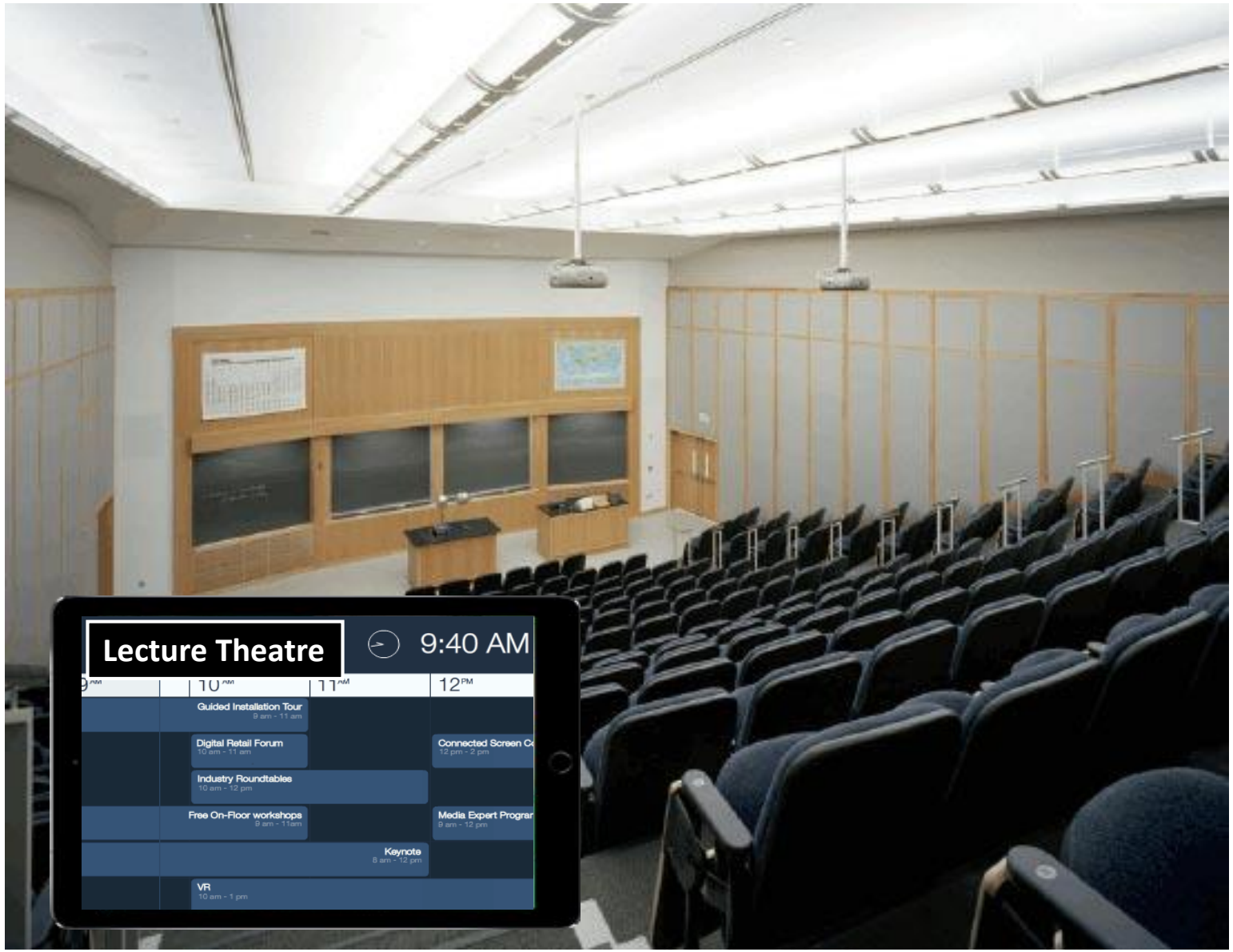
Overview



XJTLU Camus Information and Visitor Service System

Service Example: Indoor Localisation/Navigation

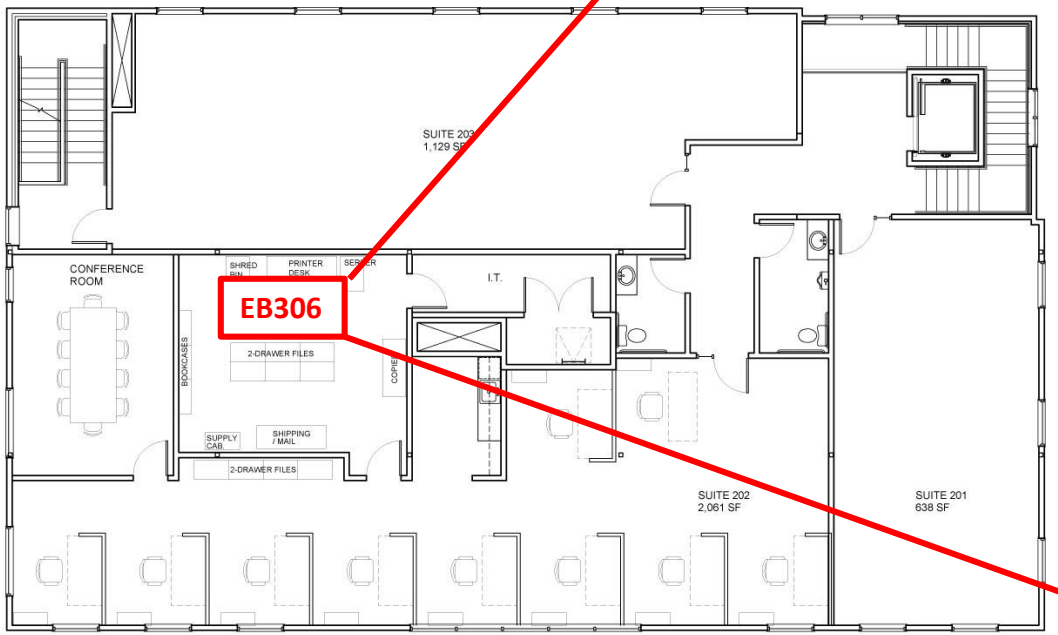
Service Example: Location-Aware Service

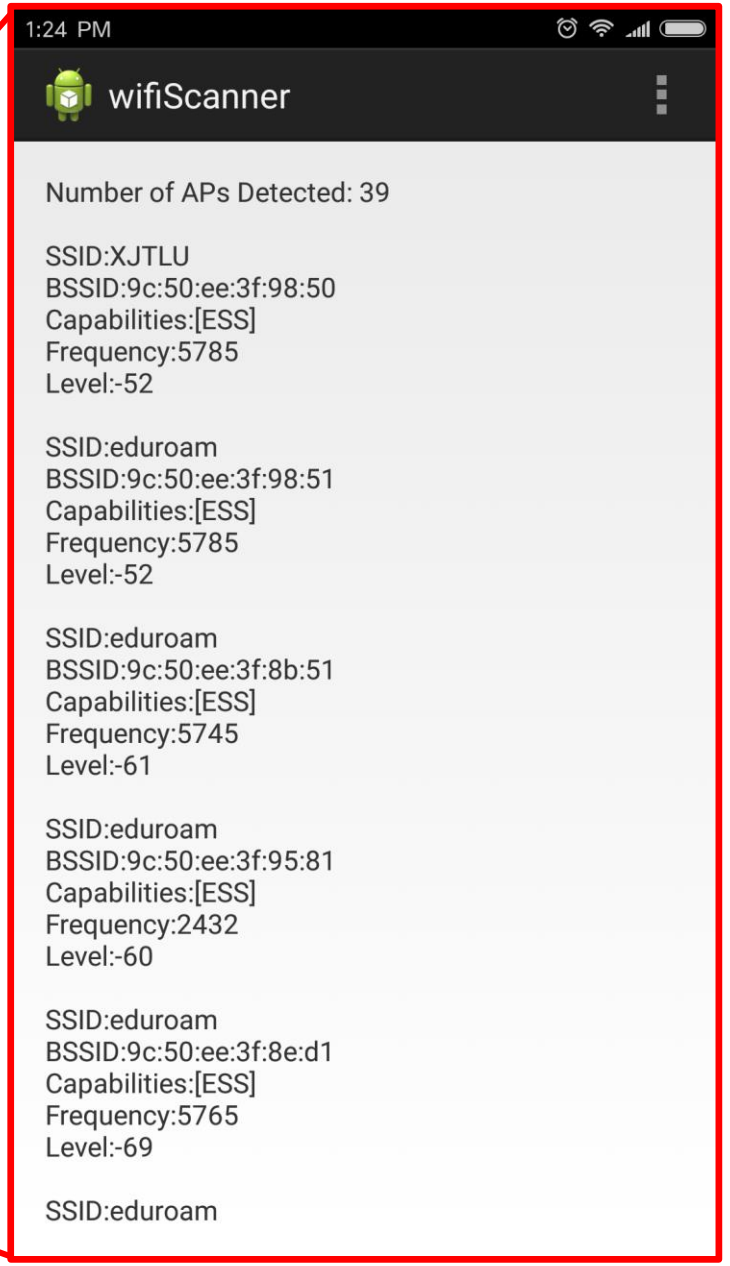


Wi-Fi Fingerprinting

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., $(\rho_1, \cdots, \rho_N)^T$ where ρ_i is the RSS from i_{th} access point (AP_i).





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*

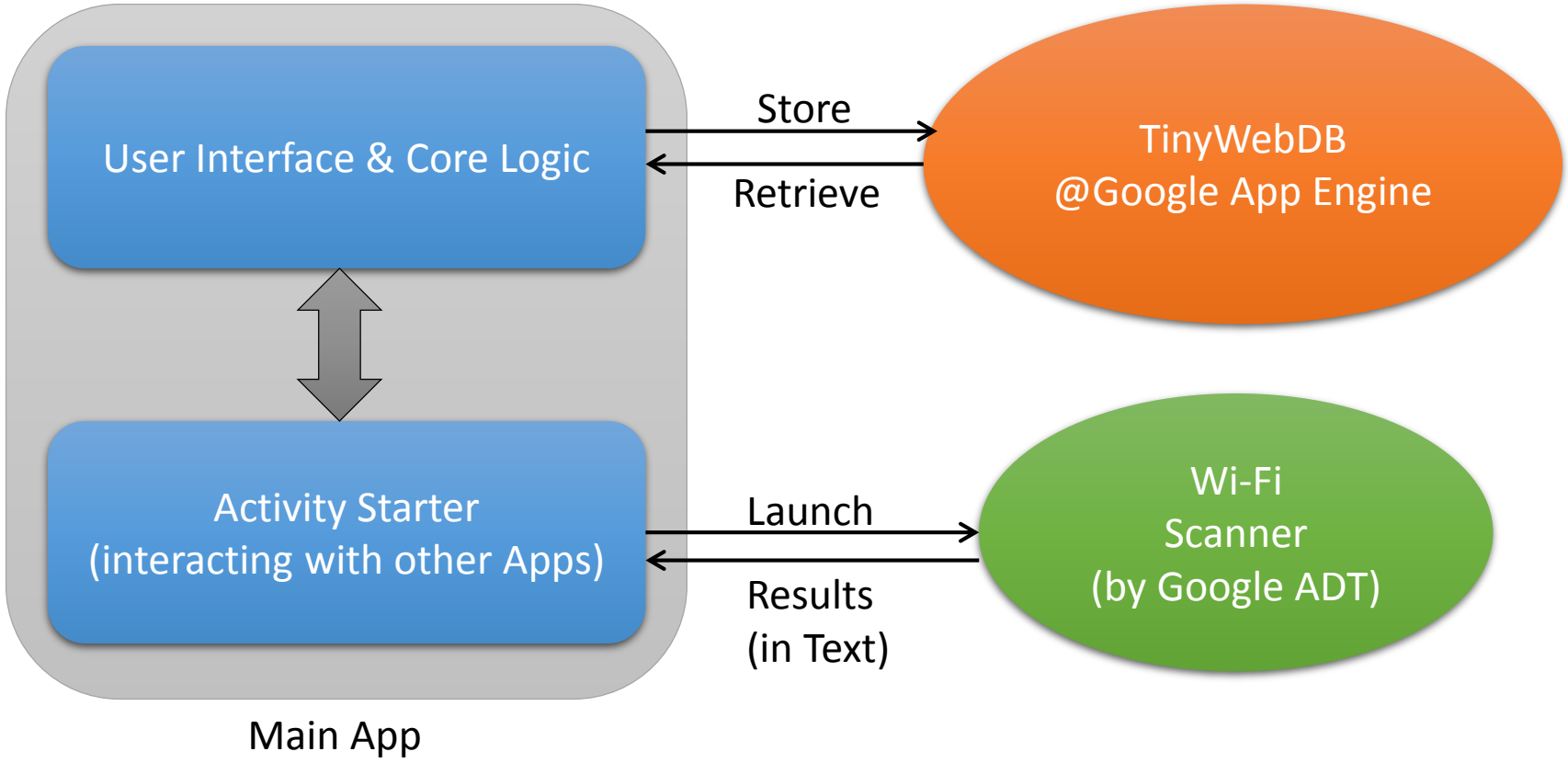
- A simple approach based on the notion of distance in the signal space:
  - Given a fingerprint of $(\mathcal{L}, (\rho_1, \cdots, \rho_N)^T)$ and an RSS measurement of $(s_1, \cdots, s_N)^T$, the *Euclidean distance* measure between them is defined as

$$\sqrt{\sum_{i=1}^{N} (s_i - \rho_i)^2}$$

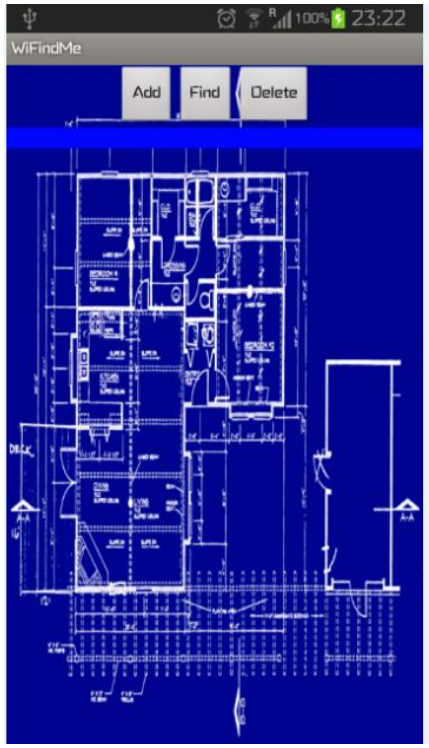
  - Then, we find a fingerprint providing a minimum distance, $\mathcal{L}$ of which is the estimated location.

** P. Bahl and V. N. Padmanabhan, "RADAR: 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



Start the app and
press the ‘Find’ button.

Results of Wi-Fi scanning.

Find the location and
display the picture.

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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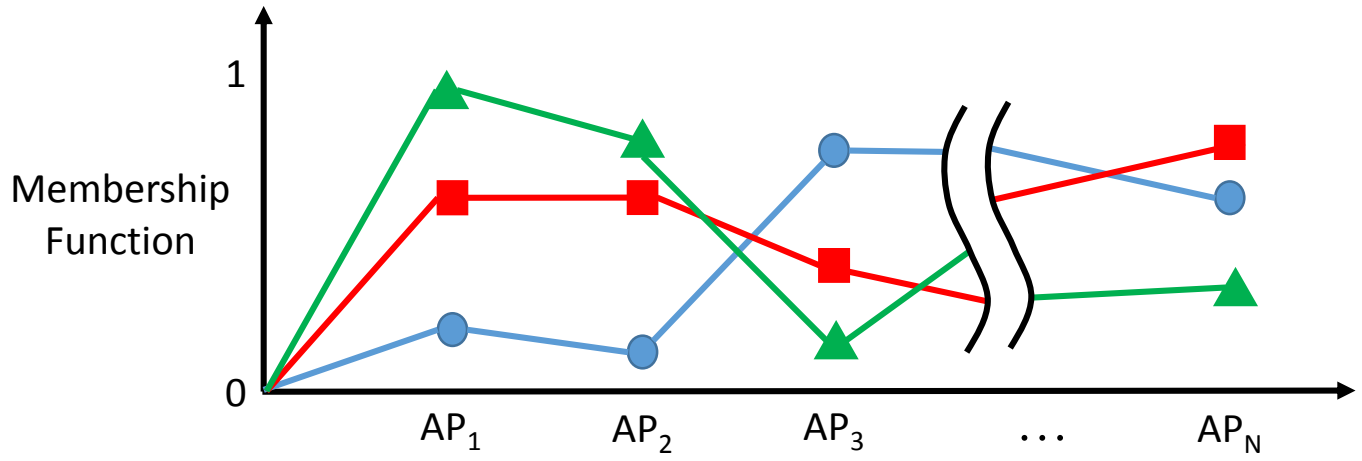
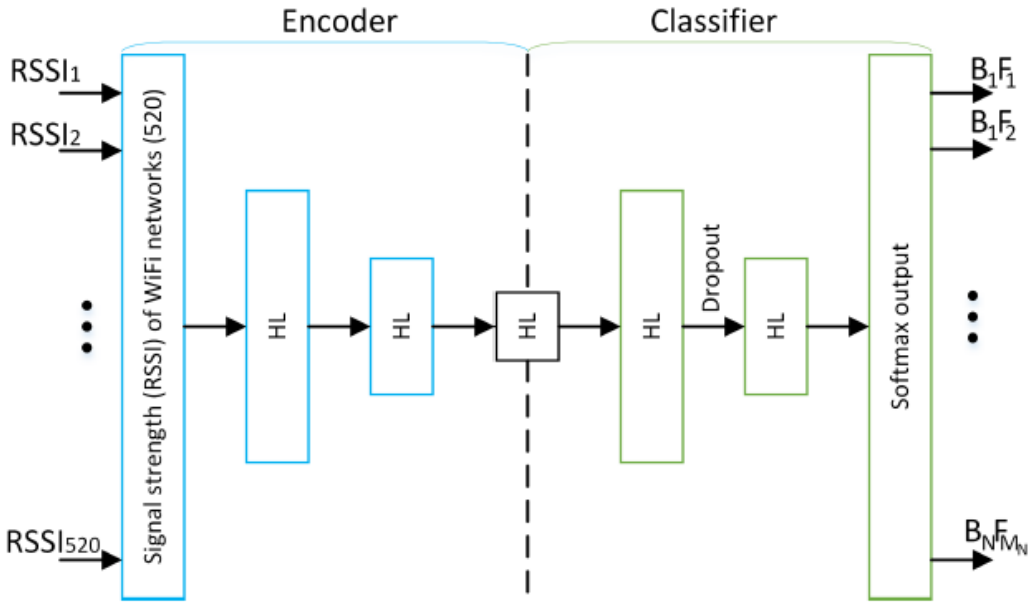
Task 2: Location Estimation Techniques - 1

- 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.