The Airplace Indoor Positioning System

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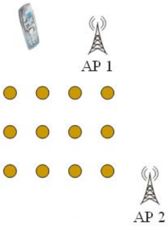
WiFi RSS Fingerprinting

Fingerprint-based Positioning



- **Offline phase:** Build RSS radio map
  - n APs deployed in the area
  - Fingerprints $r_i = [r_{i1}, \ldots, r_{in}]^T$
  - Averaging $\overline{r}_i = \frac{1}{M} \sum_{m=1}^{M} r_i(m)$
- **Online phase:** Positioning
  - Fingerprint $s = [s_1, \ldots, s_n]^T$ is observed
  - Obtain an estimate $\widehat{\ell}$ using the radio map

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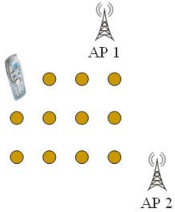

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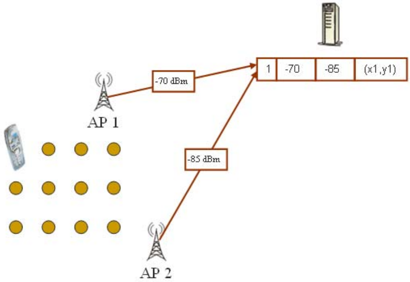

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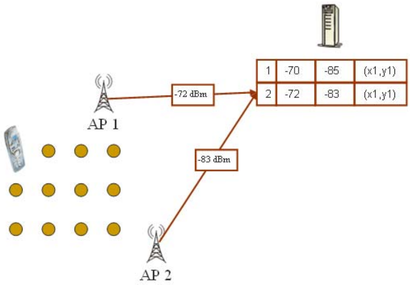

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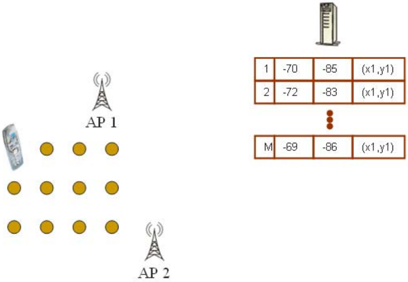

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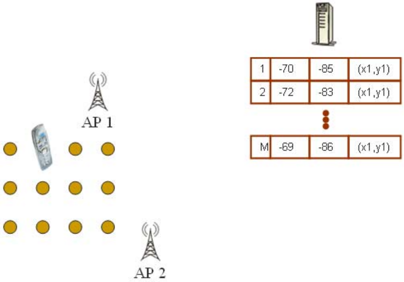

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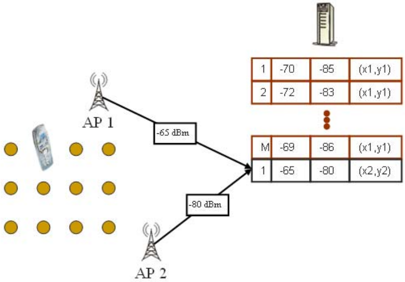

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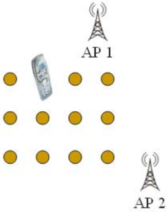

1	-70	-85	(x1,y1)
2	-72	-83	(x1,y1)
⋮			
M	-69	-86	(x1,y1)
1	-65	-80	(x2,y2)
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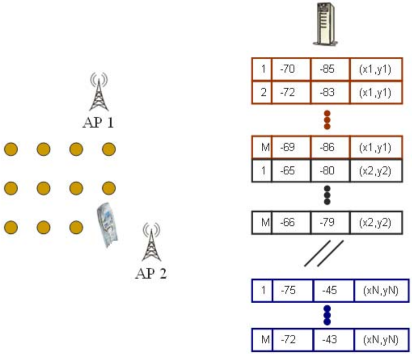

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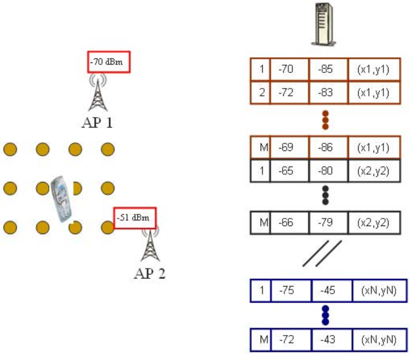

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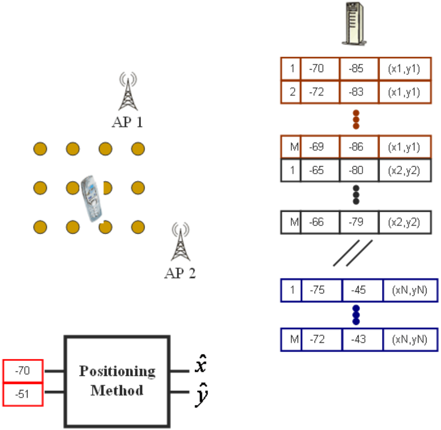

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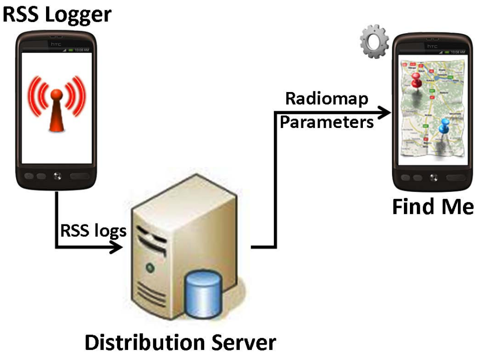
Airplace System

Terminal-based Infrastructure-assisted Architecture

- **Low Communication Overhead**: Avoids uploading the observed RSS fingerprint to the positioning server
- **User Privacy & Security**: Location is estimated by the user and not by the positioning server



RSS Logger Application

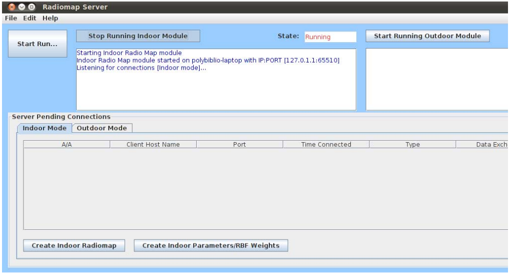
Facilitates collection and storage of the RSS data on the device.

- Developed around the Android RSS API for scanning and recording data samples in specific locations
- User-defined number of samples
- Users can contribute their data to Airplace for constructing and updating the radiomap through crowdsourcing

Distribution Server

Constructs the RSS radiomap and disseminates it to the requesting clients.

- Listens for connections from clients, that either contribute their RSS data or request the radiomap for positioning
- Parses all available RSS log files and merges them in a single compact radiomap file
- Fine tunes algorithm-specific parameters and stores them in a configuration file which is distributed with the radiomap



Find Me Application

Implements the positioning client running on the users device.

- Connects to the server for downloading the radiomap and algorithm-specific parameters
- Algorithm bank with several algorithms (KNN, MMSE, etc.)
- Dual Operation Mode: **Online** (real-time positioning) or **Offline** (evaluation of algorithms)

Thank you for your attention
Questions?

Contact
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`www2.ucy.ac.cy/~laoudias/pages/platform.html`

Deterministic Approach

Deterministic positioning methods

Location is estimated as a convex combination of the reference locations ℓ_i by using the K locations with the shortest distances between $\bar{r}_i$ and s.

$$\widehat{\ell} = \sum_{i=1}^{K} \frac{w_i}{\sum_{j=1}^{K} w_j} \ell'_i \tag{1}$$

where $\{\ell'_1, \dots, \ell'_l\}$ denotes the ordering of reference locations with respect to increasing distance $\|\bar{r}_i - s\|$.

K-**Nearest Neighbor (KNN) variants**

- NN: $K = 1$
- KNN: $K \neq 1$, $w_i = \frac{1}{K}$
- Weighted KNN: $K \neq 1$, $w_i = \frac{1}{\|\bar{r}_i - s\|}$

Probabilistic Approach

Probabilistic positioning methods

Location ℓ is treated as a random vector that can be estimated by calculating the conditional probabilities $p(\ell_i|s)$ (*posterior*) given s.

$$p(\ell_i|s) = \frac{p(s|\ell_i)p(\ell_i)}{p(s)} = \frac{p(s|\ell_i)p(\ell_i)}{\sum_{i=1}^{l} p(s|\ell_i)p(\ell_i)} \quad (2)$$

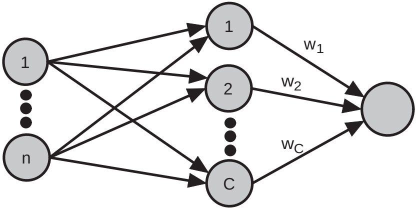
$$p(s|\ell_i) = \prod_{j=1}^{n} p(s_j|\ell_i) \quad (3)$$

$p(s|\ell_i)$ is the *likelihood*, $p(\ell_i)$ is the *prior* and $p(s)$ is a constant.

Positioning variants

- Maximum Likelihood: $\widehat{\ell} = \arg\max_{\ell_i} p(s|\ell_i)$
- Maximum A Posteriori: $\widehat{\ell} = \arg\max_{\ell_i} p(s|\ell_i)p(\ell_i)$
- Minimum Mean Square Error: $\widehat{\ell} = \mathbf{E}[\ell|s] = \sum_{i=1}^{l} \ell_i p(\ell_i|s)$

Radial Basis Function Networks



$$\ell(s) = \sum_{i=1}^{C} w_i u(s, c_i)$$

$$u(s, c_i) = \frac{\varphi(\|s - c_i\|)}{\sum_{j=1}^{C} \varphi(\|s - c_j\|)}$$

- C: number of centers
- c_i: n-dimensional center
- $\varphi(\|s - c\|) = \exp\left(-\frac{1}{2}\|s - c\|^2\right)$
- w_i: 2-dimensional weights