Statistical Learning Strategies for RF-based Indoor Device-Free Passive Localization

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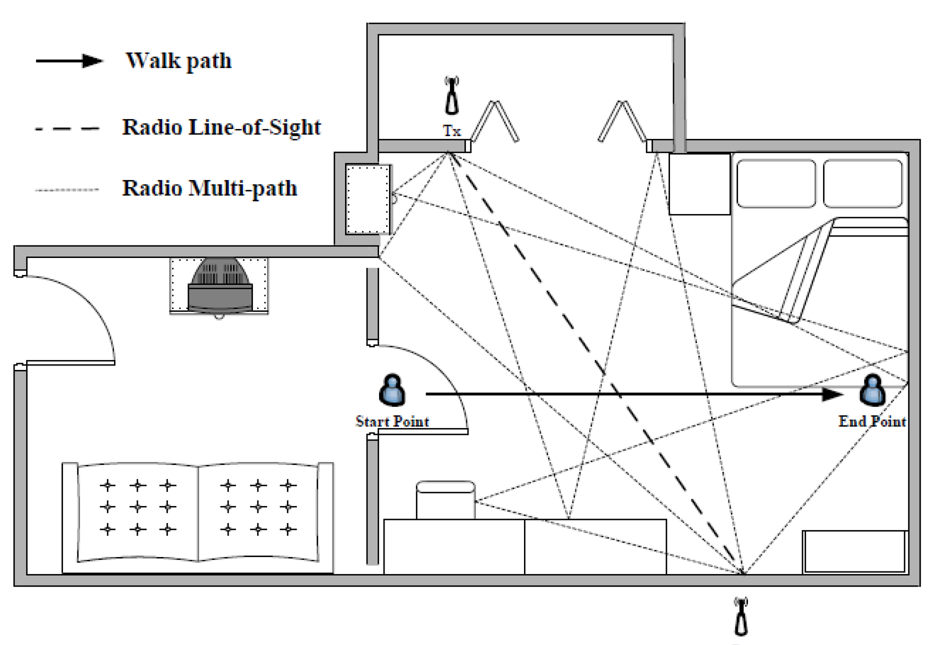
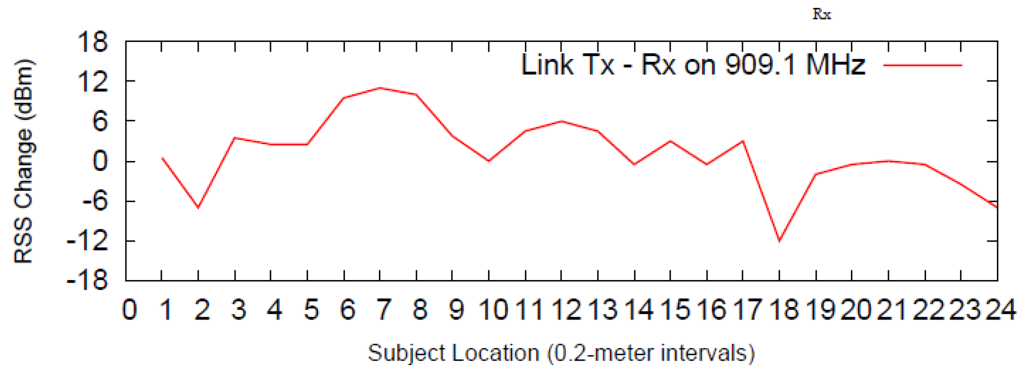
Motivation

- To localize a user without carrying any device
- Assists indoor application based on user-aware environment
- Low cost in deployment and energy

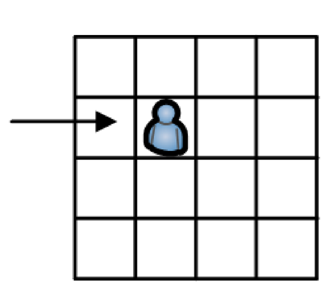
Challenge in Indoor Localization





Proposed Solutions

- Multiple transmitters and receivers
  - More dimensions for RSSI measurements
- Cell-oriented localization
  - Classification approach
  - Take training data for each cell



- Mitigating the multi-path effect
  - Increase training: average the variance caused by multipath effect and subject's different orientation
  - Lower radio frequency: smooth the variance within each cell because stronger diffraction and weaker shadowing effect in radio propagation

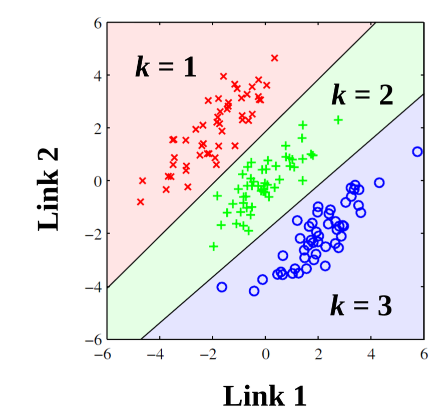
Linear Discriminant Analysis

- Assumption:
  - User's presence in each cell is treated as a class *k*
  - Multivariate Gaussian with common covariance Σ

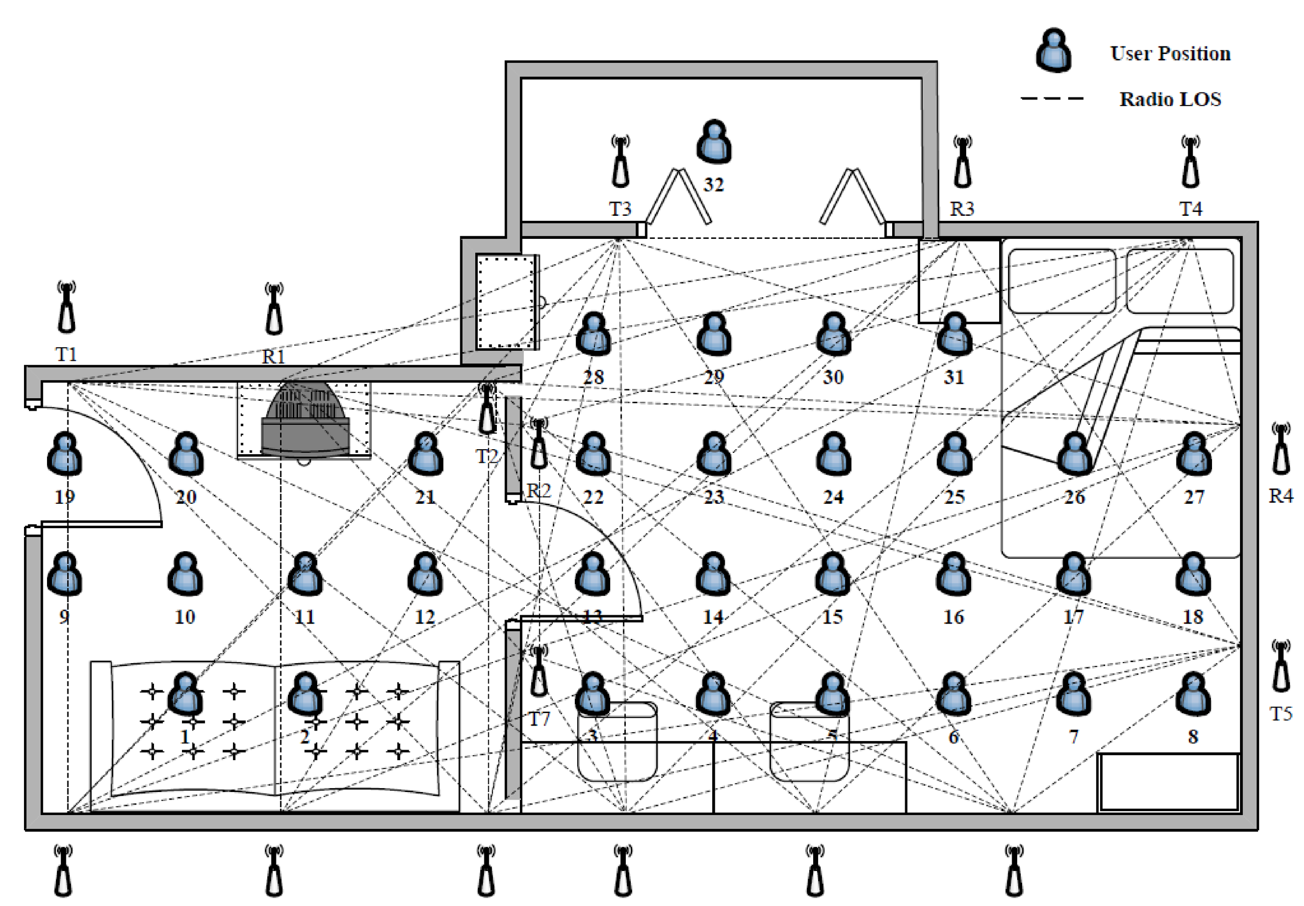
$$f_k(x) = \frac{1}{(2\pi)^{\frac{p}{2}}|\Sigma|^{\frac{1}{2}}} e^{-\frac{1}{2}(x-\mu_k)^T\Sigma^{-1}(x-\mu_k)}$$

- Linear discriminant function separates the classes:

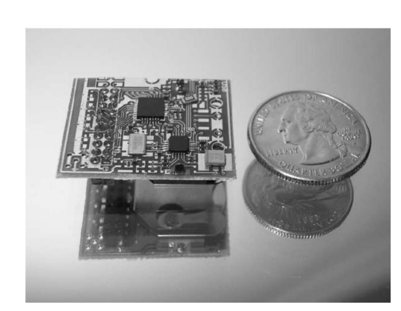
$$\delta_k(x) = x^T\Sigma^{-1}\mu_k - \frac{1}{2}\mu_k{}^T\Sigma^{-1}\mu_k$$



Experimental Deployment



- Hardware: RFID tag
  - Microprocessor: C8051F321
  - Radio chip: CC1100
  - Power: Lithium coin cell battery



- Protocol: Unidirectional heartbeat (Uni-HB)
  - Transmission interval: 100 milliseconds

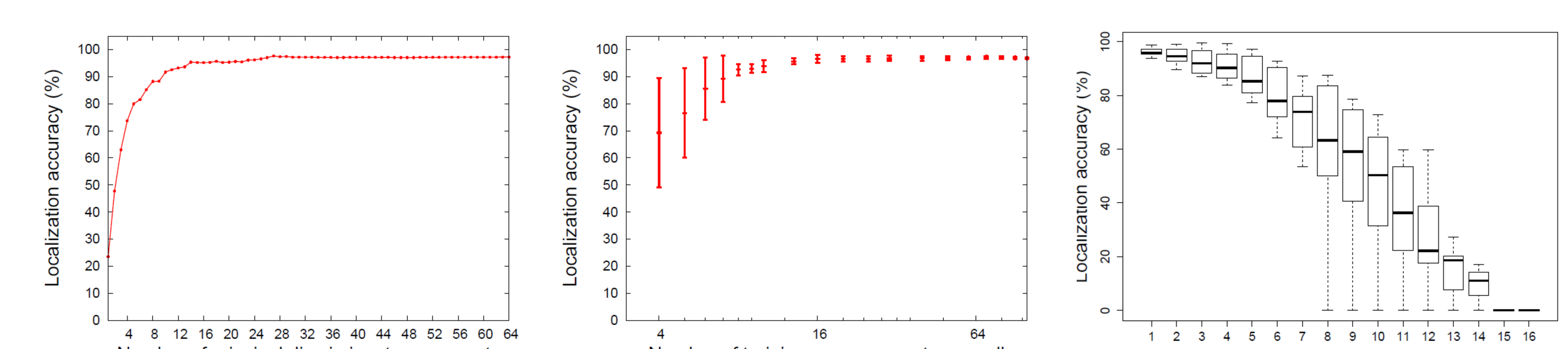
Parameter	Default value	Meaning
K	32	Number of cells
S	30 × 30	Cell size (inch)
P	64	Number of pair-wise radio links
f	433.1 MHz	Radio frequency
N_{trn}	100	Number of training data per cell
N_{tst}	100	Number of testing data per cell

Experimental Methodology

- Identical training-testing procedure
  1. In training phase, take the RSSI measurements for each cell when containing the subject.
  2. Construct a multi-class classifier from training data.
  3. In testing phase, plugin the RSSI measurements into the classifier when a subject appear in a random position, and ask the classifier for the estimated cell containing the subject.

Performance Evaluation

- Metrics
  - Localization accuracy: for one person in the room, the success rate for correctly identifying the occupied cell.
  - Average error distance: average distance between the actual point of the subject location and the center of the estimated cell.
- Results
  - Out of 3200 independent tests, we achieve 97.2 % localization accuracy and 0.36 m average error distance.
  - Computational cost, training data and devices can be reduced:



- We can achieve 90% localization accuracy when we only:
  - use the first 10 of 64 principal discriminant components
  - use 8 of 100 RSSI measurements per cell for training
  - have 9 of 16 RFID devices working

On-going and Future Work

- Reduce the number of devices
- Simplify the training methodology
- Localize multiple people

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