CS 525M – Mobile and Ubiquitous Computing Seminar

Damian Robo

Paper Information

RADAR: An In-Building RF-based User Location and Tracking System

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Outline

- Introduction & Related Work
- Research Methodology
  - Experimental Testbed
  - Data Collection
  - Data Processing
- Algorithms and Experimental Analysis
  - Empirical Method
  - Radio Propagation Method/Model
- Discussion of Future Work

Introduction & Related Work 1 of 2

Aim of this paper is to develop a system for locating and tracking of mobile users in an in-building environment.

RADAR, an RF based system for locating and tracking users inside buildings.

- Uses signal strength information to locate users
- Uses both empirically determined and theoretically computed signal strength information
- Can determine distances within 1 few meters of the user's location.

Introduction & Related Work 2 of 2

Active Badge System

- IR based system, devices emitting IR signal, accurate.
- Very expensive equipment and installation..
- Limited by short range of IR and sunlight.

Daedalus Project

- Wide Area Cellular RF based system
- Accuracy limited by the cell size
- Not effective indoors due to reflections.
- Lack bandwidth and speed

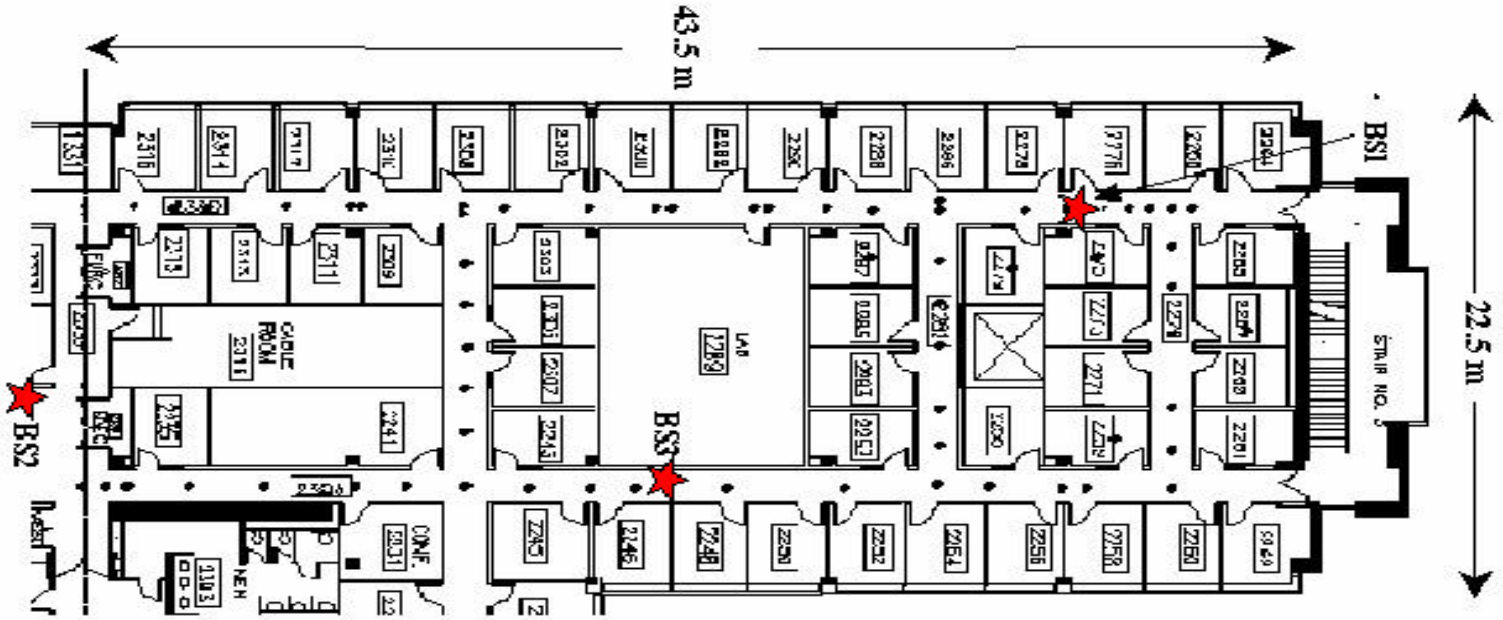
GPS Systems

- Cannot work indoors

Research Methodology

Testbed

- A floor measuring 43.5m x 22.5m, 980 m^2
- 3 base stations running FreeBSD 3.0
- One mobile host running MS Windows 95



Data Collection

Radio signal is recorded as a function of the user's location.

- Offline Phase: Using signal information to construct and validate models.
  - Base stations record a tuple (t, bs, ss)
  - Mobile hosts record a tuple (t, x, y, d)
- Online Phase: Inferring user's location in real time based on these models
  - Base stations record a tuple (t, bs, ss)

Data Processing

Signal Strength Information

- All timestamps mentioned before are merged into a table with (x, y, d, ss_i, snr_i) i=1,2,3 denoting a base station
- A routine search was written for finding the closest match on the table.

Building Floor Layout Information

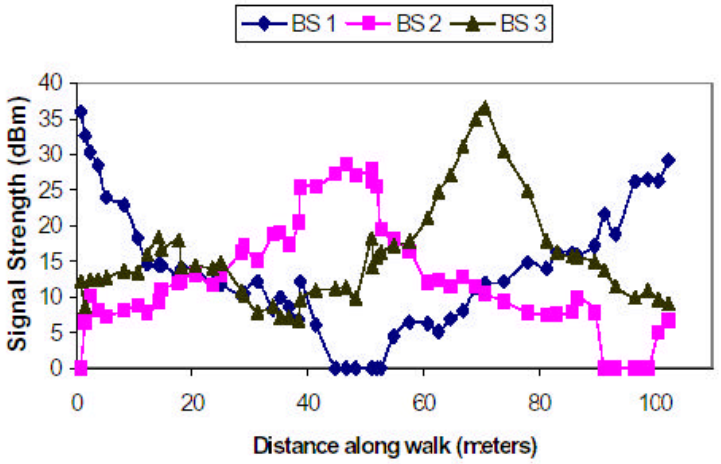
- Coordinates of the floors and base stations were obtained
- Number of walls between the BS and the host were calculated.
- All this information is used to build an accurate propagation model.

Algorithms and Experimental Analysis

Triangulation: Given a set of signal strength measurements at each of the base stations location is determined.

Actions performed:

- Summarize the signal strength samples at BS
- Basis for determining the best match
- Metric for determining the best match



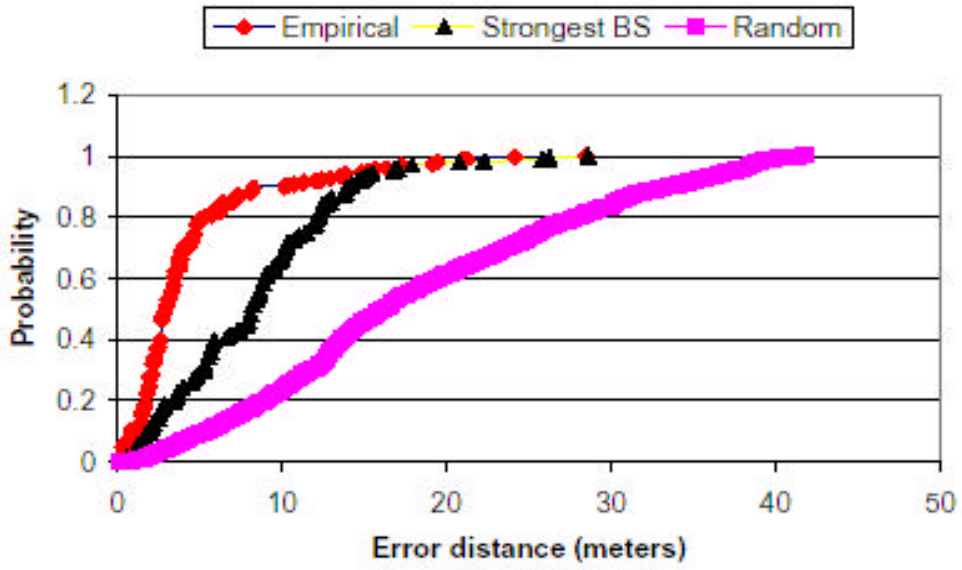
Empirical Method

Empirical data obtained in offline space is used for the NNSS Algorithm.

- NNSS computes the *distance* (in signal space) between the observed set of SS measurements, (*ss1*,*ss2*,*ss3*), and the recorded SS, (*ss'1*,*ss'2*,*ss'3*), at a fixed set of locations, and then picks the location that minimizes the distance. *Euclidean distance* measure, i.e., *sqrt((ss1-ss'1)2+(ss2- ss'2)2+(ss3-ss'3)2)*.
- Basic Analysis
- Multiple Nearest Neighbors
- Max Signal Strength Across Orientations
- Impact of the Number of Data Points
- Impact of User Orientation
- Impact of the Number of Samples
- Tracking a Mobile user

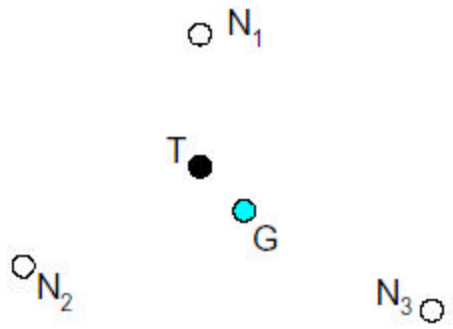
Basic Analysis

- All user location and orientation samples are used
- Process of locating a user in real time is emulated
- Comparisons with random selection and strongest base selection show this method outperforms them



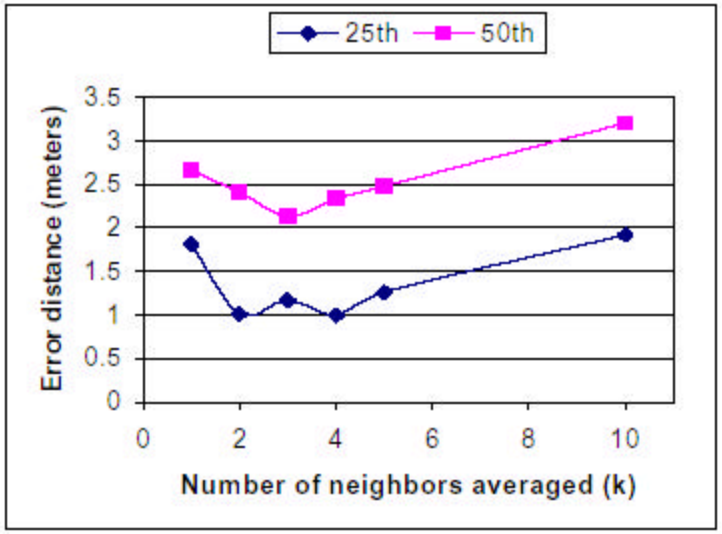
Multiple Nearest Neighbors

- Unlike the basic analysis here k nearest neighbors are considered.
- More accurate than Basic Analysis
- Averaging the coordinates of the neighbors leads to a point closer to the user's location.



Max Signal Strength Across Orientations

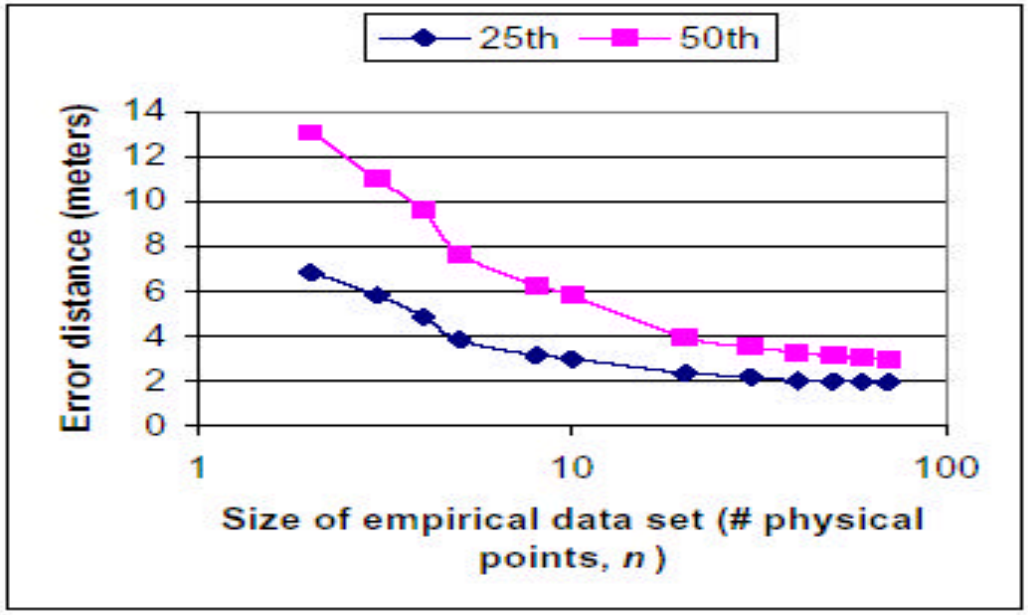
Method	25th (meter)	50th (meter)	75th (meter)
Empirical	1.92	2.94	4.69
Strongest	4.54 (2.4x)	8.16 (2.8x)	11.5 (2.5x)
Random	10.37 (5.4x)	16.26 (5.5x)	25.63 (5.5x)



- This analyzes how well the empirical method would perform if orientation were not an issue
- Goal is to emulate the case where the signal generated by the mobile host is not obstructed by the user's body.
- Test results showed that the use of maximum SS data set improves the accuracy of location estimation

Impact of the number of data points

- Impact of number of data points
  - As the number of data point increases the error distance decreases.
  - There exists a threshold as seen in the graph below



Other issues

- Impact of the number of samples
  - The more samples we have less the error rate.
  - Only a few number of real time smaples are needed.
- Impact of user orientation
  - A significant degradation in the accuracy of location estimation is observed.
  - Should obtain empirical data for multiple orientations
- Tracking a mobile user
  - 4 SS samples/sec at each base station
  - Able to determine the line of movement
  - Problem is reduced to tracking a user in a sequence of locations

Radio Propagation Model

Alternative for constructing the Search Space for NNSS algorithm.

- Aims to reduce the dependency on empirical data
- Data for building the search space are generated theoretically
- Data points correspond to locations spread uniformly on the floor
- Location then would be computed by comparing the real time tuples with the theoreticl ones.

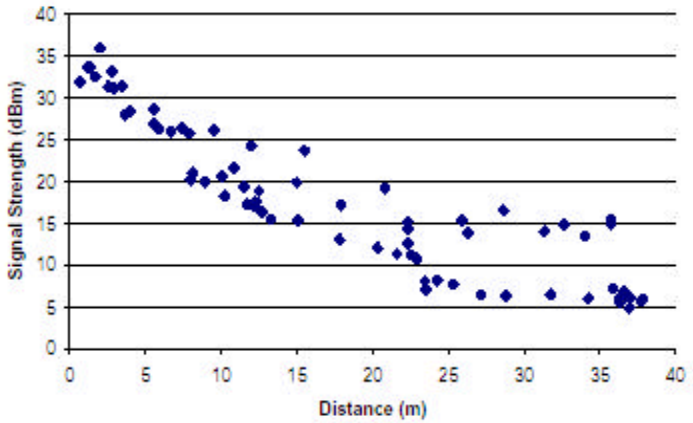
Determination of Model

- Signal propagation is influenced by reflections, diffractions, scattering of radio waves etc.
- Rayleigh fading model, although interesting and simple, assumes that the signal arriving at BS have equal strength (!?)
- Rician Ditribution Model was also considered but it suffered many asumptions that were made.
- Wall Attenuation Factor was considered instead.

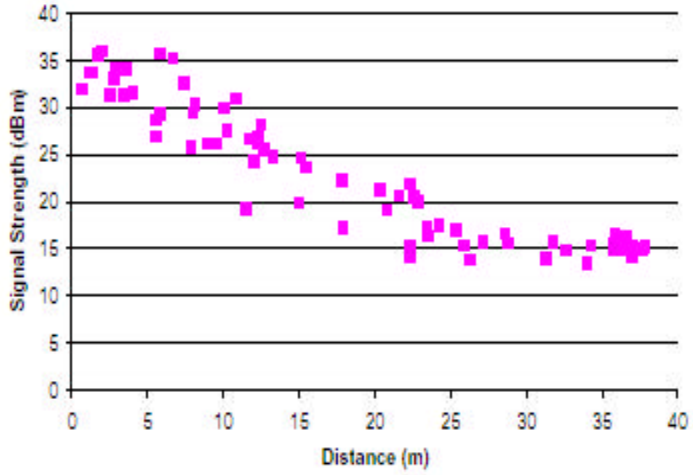
$$P(d)[dBm] = P(d_o)[dBm] - 10n\log\left(\frac{d}{d_o}\right) - \begin{cases} nW * WAF & nW < C \\ C * WAF & nW \geq C \end{cases}$$

WAF Propagation Model

The chart on the right shows the signal strength as measured by using the empirical data

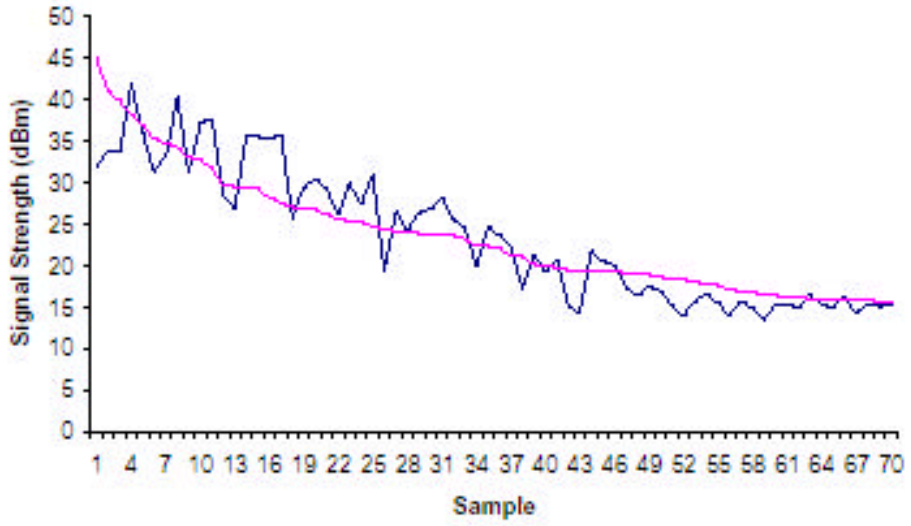


This other graph shows the signal strength as measured by intervening walls between the base station and the mobile host



WAF Propagation Model Cont'd

The predicted values generated with the propagation model after compensating for walls match good with the actual measurements.



Results using the Propagation Model

- Propagation Model provides a less accurate location estimation than the Empirical Model
- Propagation Model is cheaper to implement since it does not need measurements for each floor where it is to be implemented
- This model is portable to other environments without need of prior Empirical Measurements

Future Work & Current Implementations

How user mobility profiles can supplement signal strength information in locating and tracking users. (Moving patterns)

Investigating Base Station-based Environmental Profiling in order to make RADAR robust in the face of large scale variations of RF signal.

NATO will use RF technology to manage supplies from Europe to Afghanistan.

> “NATO will use the system to track the movement of military supplies to the pallet and container level” www.informationweek.com