RADAR: an In-building RF-based user location and tracking system

BY P. BAHL AND V.N. PADMANABHAN

PRESENTED BY:

AREEJ ALTHUBAITY
Agenda

- Goal and Motivation
- Previous Works
- Experimental Testbed
- Basic Idea
- Offline Phase
- Signal Strength
- Empirical Method
- Radio Propagation Model
  - FAF model
- Real Time Phase
- Limitations
- Future Work
Goal and Motivation

- **RADAR** is based on radio frequency; wireless network in an indoor environment
- **Goal:** Tracking and Locating indoor objects using WIFI
- **Motivation:** locations aware services (applications)
Previous Works

- **Infrared (IR) wireless networks:**
  - Poor scalability (limited range)
  - Maintenance and installation are costly.
  - Poor working in direct sunlight
- **Wide-Area Cellular Systems**
  - Good for outdoors but not indoor because of the multiple reflections suffered by the RF signals.
- **GPS**
  - Buildings block GPS transmission
The testbed is located on the 2ed floor.

3 base station is placed in the floor (✱)
- Pentium-based PC
- with wireless adapter
- Record the information from mobile host

Mobile host
- pentium-based laptop running MS Win95
- Broadcast packets (beacons) periodically

Note: Black Dots are the locations where empirical signal strength info was collected
Basic Idea

- **Offline phase**
  - Detect or compute the signal strength (SS) at specific location
  - Process and analysis the collected data
- **Real time phase**
  - Detect the signal strength (SS) at a random location
  - Use **NNSS** (nearest neighbors in signal space) algorithm to search the best match location
Offline Phase

- Two approaches to detect the signal strength at specific location
  - Empirical method
  - Radio propagation model
Signal Strength

- We need an accurate SS to help determine location
  - By:
    - Stronger Signal is the closer to BS
    - Modeling
Empirical method

• Synchronize clock on Mobile Host (MH) and Base Stations (BS)
• The mobile host broadcast UDP packet at the rate of 4/sec
• Each BS records SS at \((t, x, y, d)\):
  - Time stamp \((t)\); direction user is facing \((d)\); location \((x,y)\)
• Merge Data
  - Merge data from 3 BS and mobile host.
  - Generate tuple \((x, y, d, ss(i), snr(i))\) where \(i\) is the base station ID and \(snr\) is signal-to-noise-ratio.
• Data collection phase repeated for 70 distinct locations for 4-directions.
• Limitations:
  - Long time to gather all the empirical data
    - 1\(^{st}\) floor= (70 locations) * (4 directions) * (20 samples)
  - If BS moves, have to recollect all the data
Radio propagation model

- **Goal**
  - Reduce the dependence on empirical data
  - Use mathematical model for indoor RF propagation to directly calculate user location.
- **Challenges:**
  - Have to account for free-space loss / loss due to obstructions
  - Multipath Phenomenon
    - Signal arrives at user through multiple paths
    - Depends on layout of building, construction material, number/type of objects in the building
  - Each building is different
  - If a wall moves, has to be recalculated
- **Chosen model:** FAF model
Floor Attenuation Factor propagation models

propagation model (FAF)

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

- \( P(d) \): the signal strength at distance \( d \)
- \( n \): the rate at which the path loss increase with distance
- \( d_o \): the distance of the reference point
- \( C \): the maximum number of obstructions (walls) up to which the attenuation factor makes a difference
- \( nW \): the walls between T-R
- \( WAF \): the wall attenuation factor
Real time phase

- Synchronize clock on Mobile Host (MH) and Base Stations (BS)
- The mobile host broadcast UDP packet at the rate of 4/sec
- Each BS records the tuple (t, BS, SS)
- Run NNSS (nearest neighbors in signal space) algorithm to search the fittest location
  - Use the Euclidean distance

Euclidian Distance \( = \sqrt{(ss1 - ss'1)^2 + (ss2 - ss'2)^2 + (ss3 - ss'3)^2} \)
Limitations

- Mentioned printing to nearest printer and navigating. What else?
- Power consumption
- Scalability?
  - Large floor → larger search space
  - Time/Space constraints
  - More base stations may mean more complicated Radio Propagation models
- How does clock synchronization work?
- Costs of finding the Radio Propagation parameter values
- How does data get sent back to the user based on his location?
- What if 2 locations have quite similar SS and t? Probability of this happening?
Future Works

- **User-mobility profiles**
  - Better tracking

- **Base station-based environmental profiling**
  - Large-scale variations in the RF signal propagation environment
  - Multiple search spaces determined during different channel conditions
  - Probe channel to see current conditions and then use that search space
References

- “RADAR: An In-Building RF-based User Location and Tracking System”, By Paramvir Bahl and Venkata N. Padmanabhan, Microsoft Research, ppt
- “Smartphone Positioning Systems”, By Romit Roy Choudhury, Duke University, ppt
- “RADAR: An In-Building RF-based User Location and Tracking System”, presented by Michelle Torski, ppt