Welcome!

6.1820/MAS.453: Mobile and Sensor Computing

aka IoT Systems

https://6mobile.github.io/

Lecture 3: Indoor Localization

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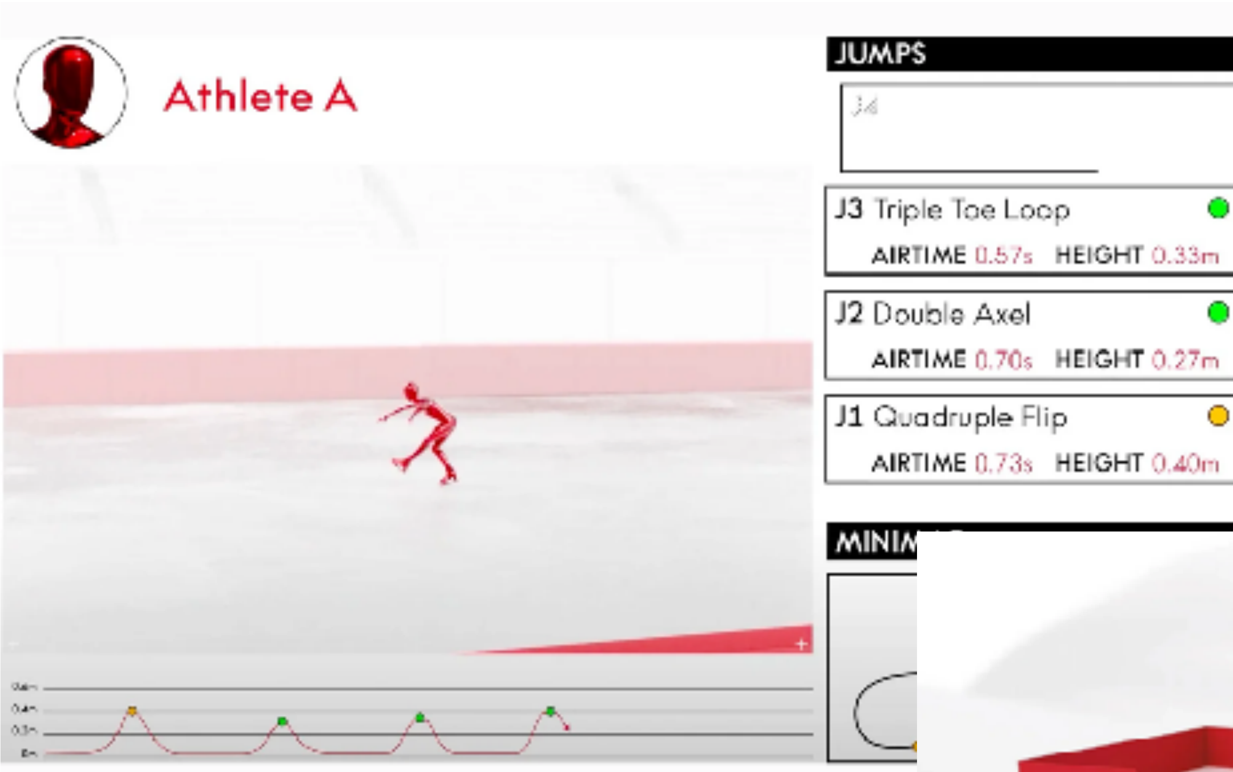
Announcements

1. Did you join Slack, introduce yourself, and add a photo?
2. Lab 0 due Thursday (i.e., checkoff in OH within 1wk)
3. Lab 1 & PSet 1 out
4. Macs & iPhones being distributed for those who asked. Please pick up today if you haven't already.
5. OH posted: Tuesday 2:30-3:30 (Maisy); Thursday 7:30-8:30pm (Laura)
6. #teamformation channel
7. Note-sharing volunteers

This Week in IoT - Winter Olympics

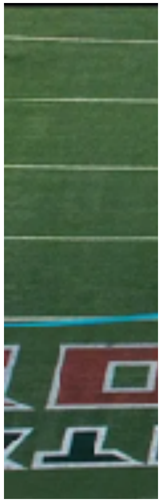


- Cameras + sensors - where would you put the sensors?

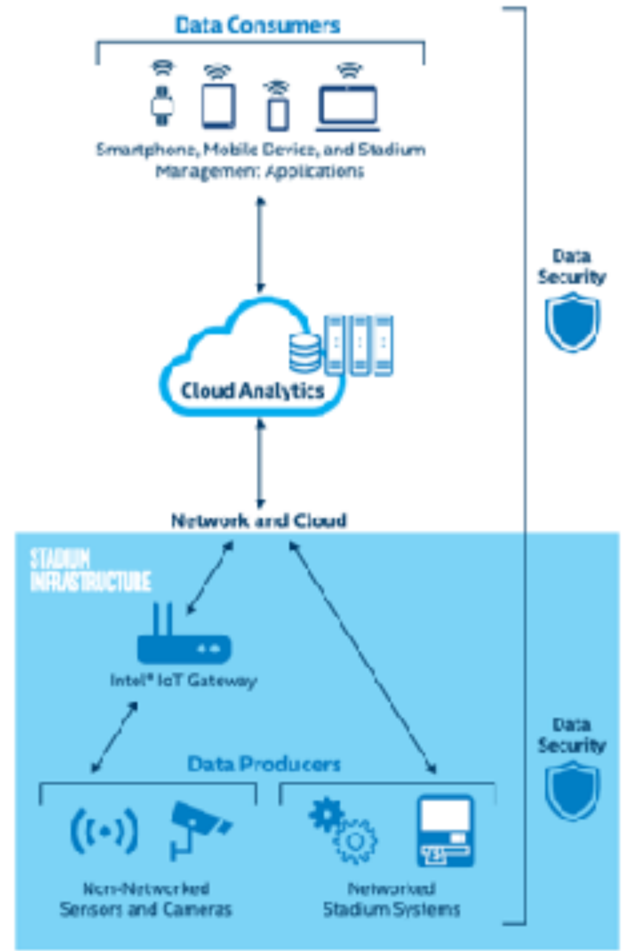
- How are the cameras used?
- How would you build the ML system to perform analysis?

Source: https://spectrum.ieee.org/winter-olympics-2026-tech

This Week in IoT - Super Bowl



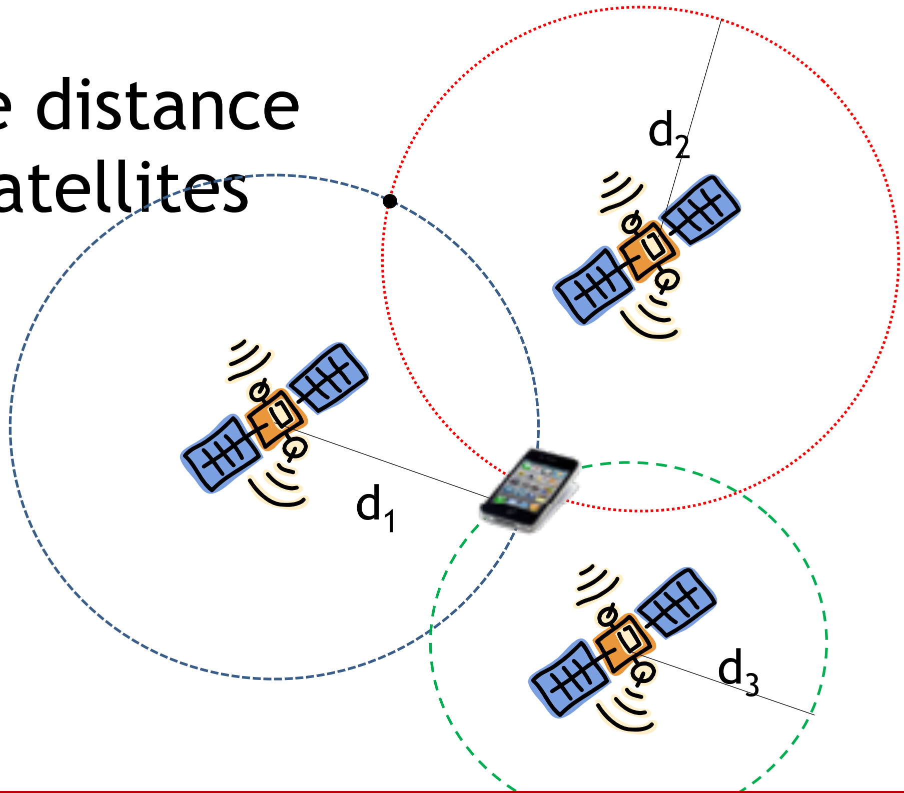
- How is the tracking done?
  - RFID on football, shoulder pads, shirts, ..
  - Tracks location, speed
- Smart stadium - where is it used?
  - WiFi/LTE connectivity
  - bathrooms -> trigger cleaning
  - Wireless security cameras



Source: Zebra, RFID Journal, Intel

GPS

Compute the distance to the GPS satellites

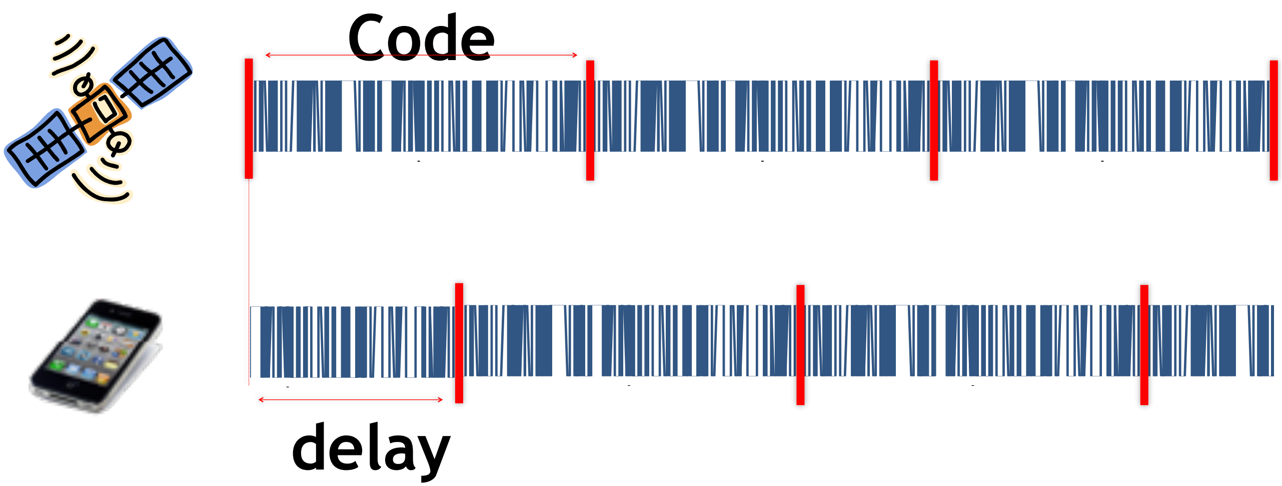


distance = propagation delay x speed of light

How to Compute the Propagation Delay?

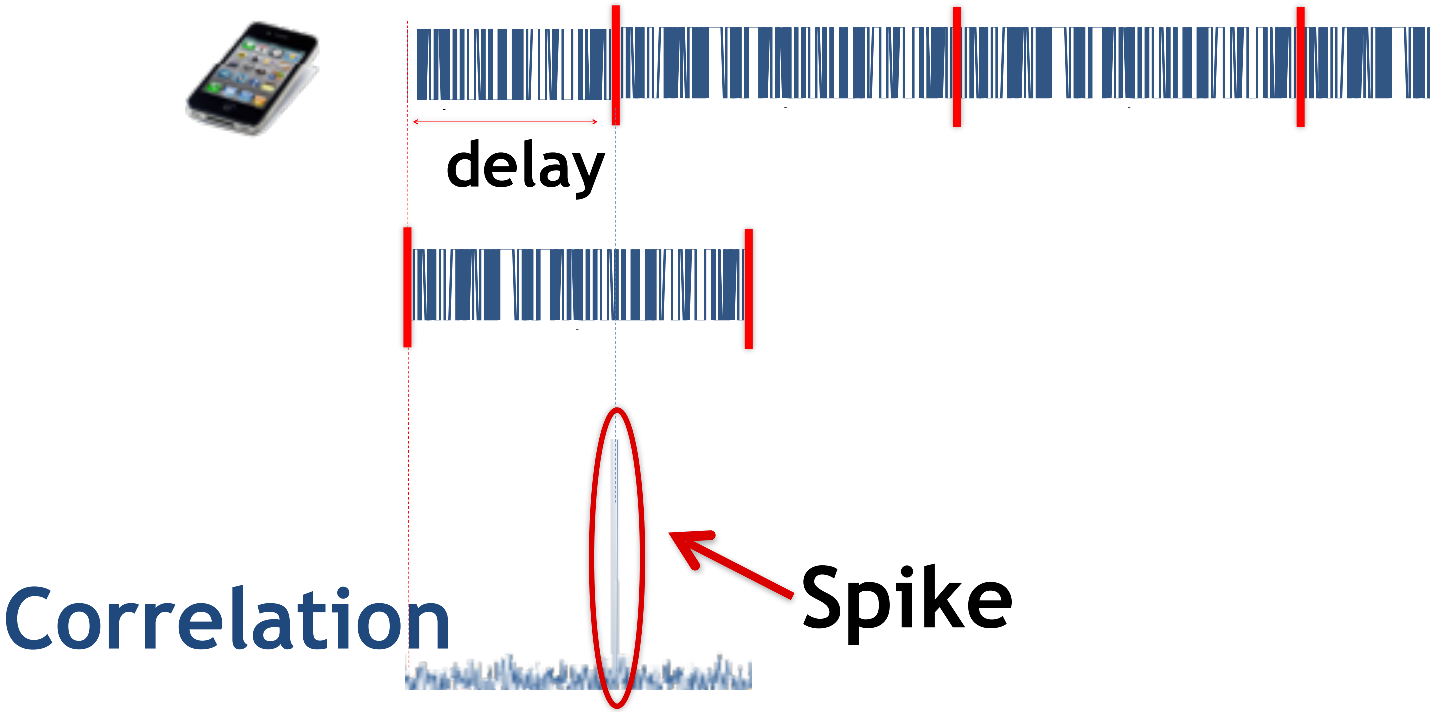
Each satellite has its own code

How to Compute the Propagation Delay?



Code arrives shifted by propagation delay

How to Compute the Propagation Delay?



Spike determines the delay

use it to compute distance and localize

GPS Data Packet

- Almanac & ephemeris data
  - Satellite location, clock, orbital parameters, etc.
  - Bitrate?
    - 50 bits/second
  - Takes about 12.5 minutes to download

- How do today's systems use it?
  - A-GPS (Assisted GPS)
  - WiFi APs are mapped — war-driving

Practical Indoor Wireless Positioning Systems

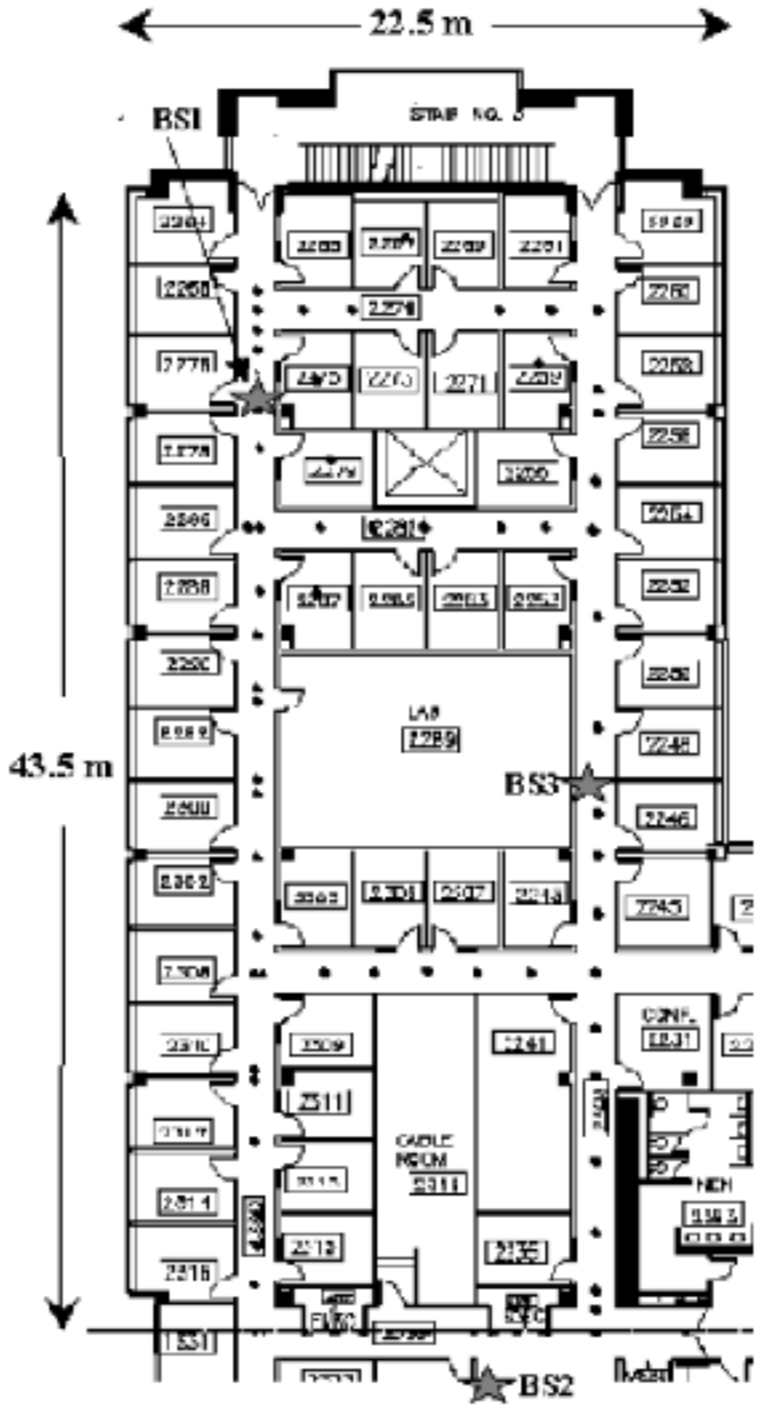
- RADAR [Infocom 2000]
- Cricket [2000]

Paper 1: RADAR [INFOCOM ’00]

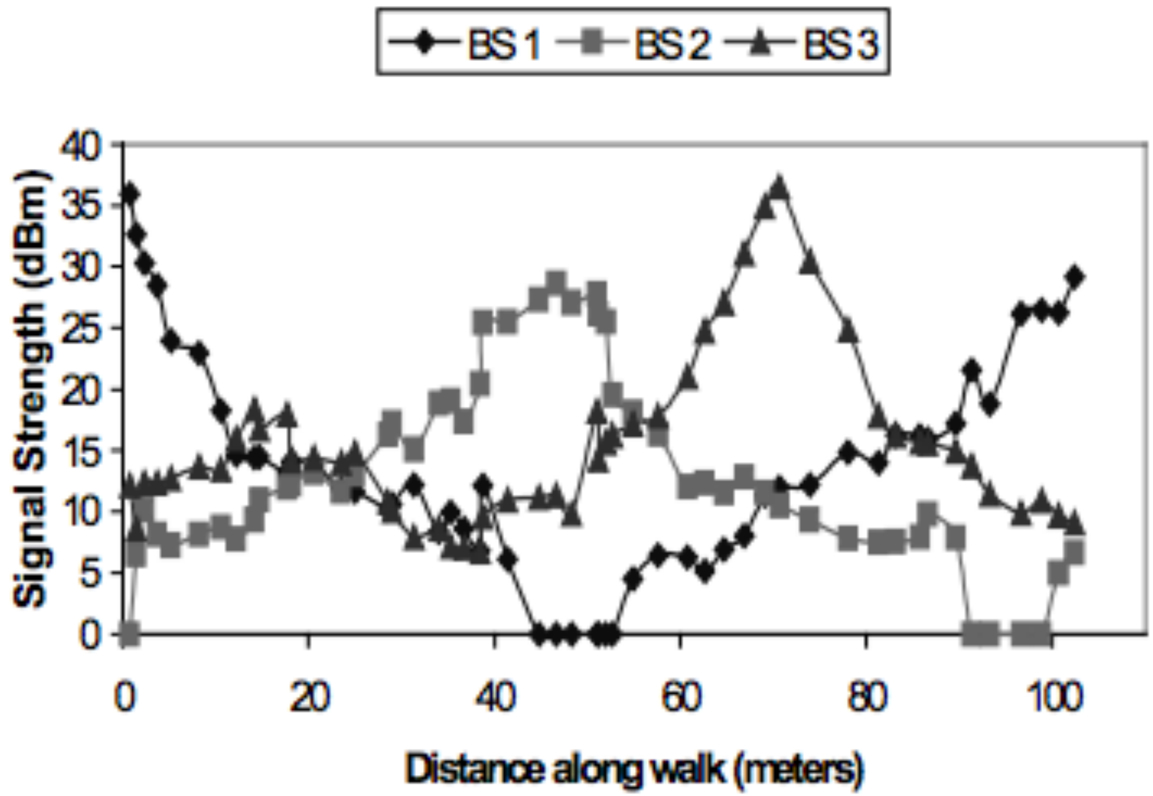
Why are we reading this paper?

- First paper to propose using wireless LANs for indoor location estimation
- Measurement-based / analysis paper (not a system)
- Key pioneering idea: fingerprinting / pattern matching

- Database
- Different orientations



Signal strength at the base stations as user walks



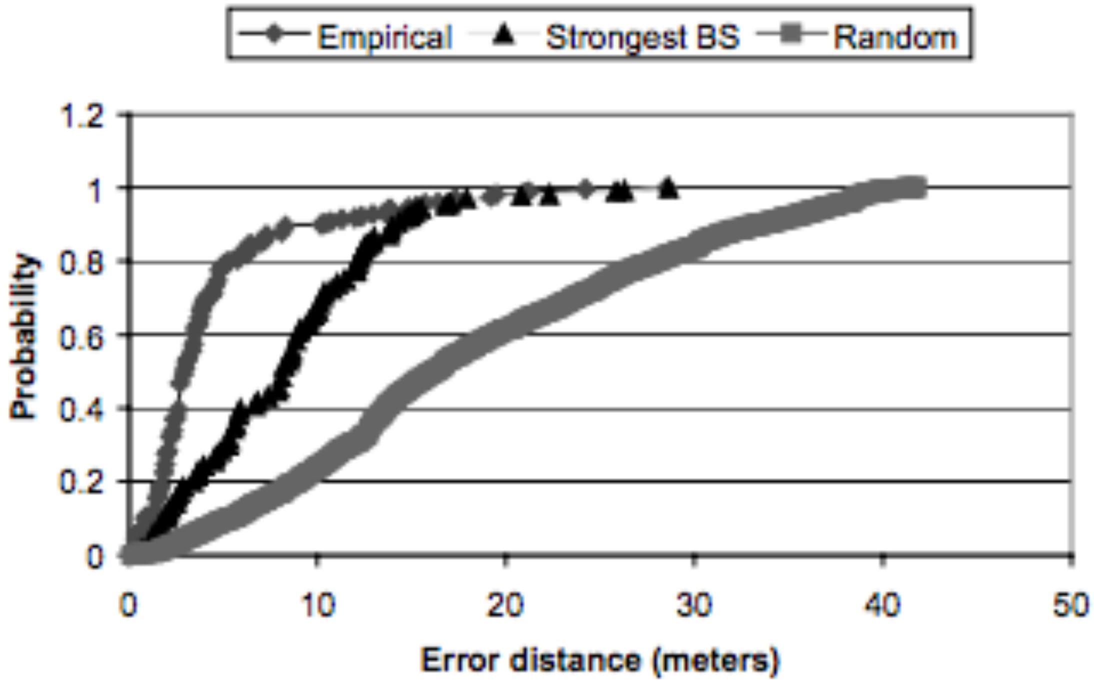
Approach

- Summarize signal strength samples at base stations
- Metric for determining best match
- Determine “best match”

Approach

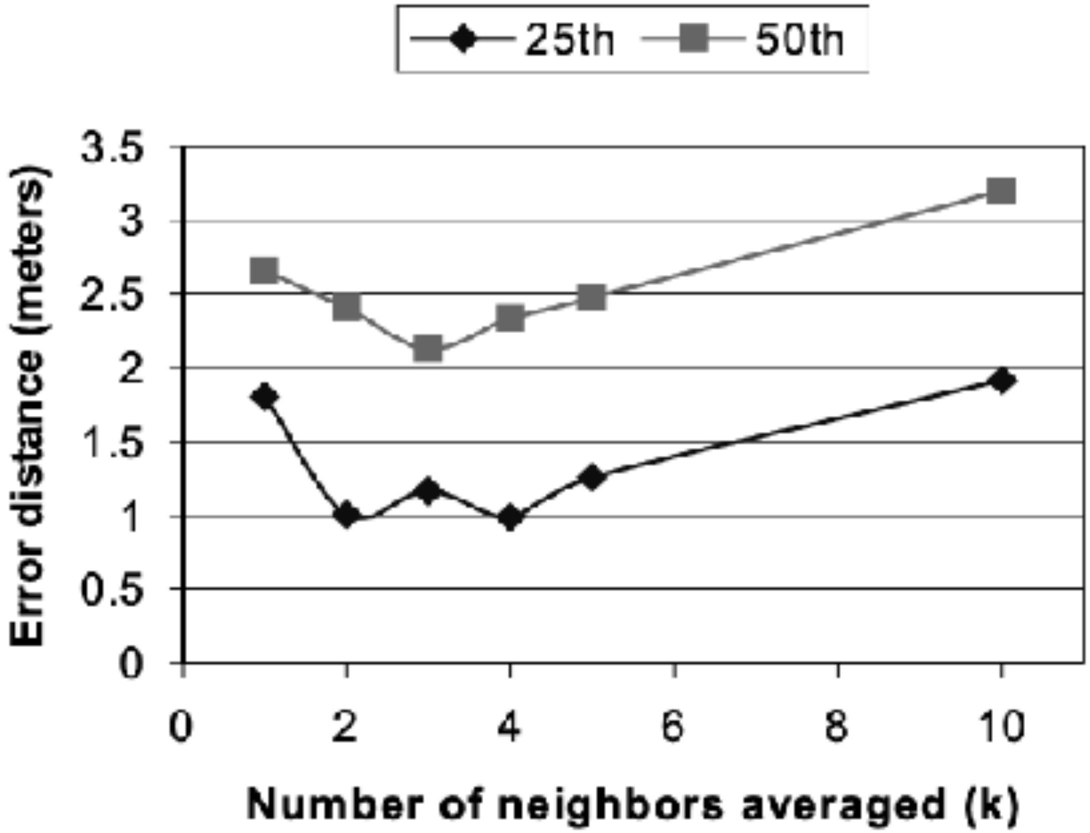
- Summarize signal strength samples at base stations
  - Mean signal strength over a time window
- Determine “best match”
  - Empirical method
  - Signal propagation model
- Metric for determining best match
  - Nearest neighbor in signal space, i.e., Euclidean distance between ss’ and ss vectors

Evaluation



- Critique the evaluation
- Is it reasonable to evaluate the accuracy on 1 out of 70 points, treating the other 69 as “known”?
- What happens when they have only 40 points in the signal database (see paper)?

Averaging multiple nearest neighbors

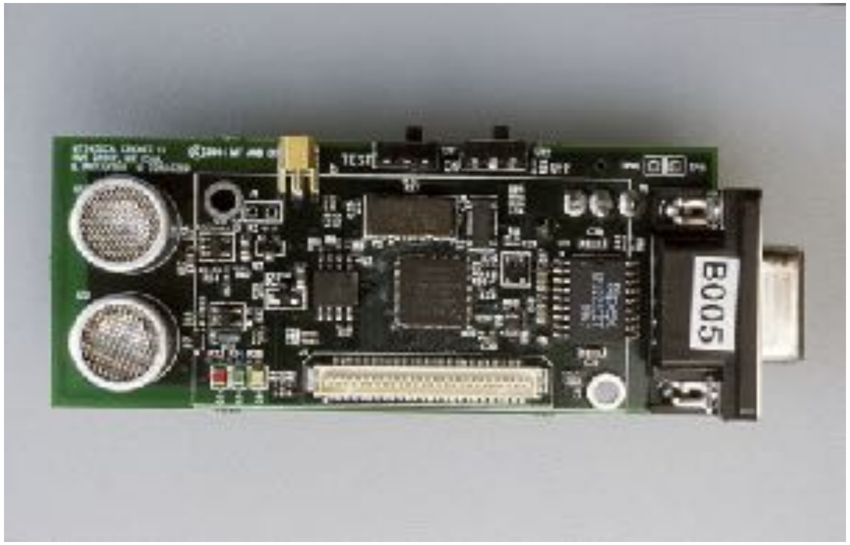


Why does the graph look like this?

1. On the right, too many far-away neighbors
2. Would weighted averaging work better?

Paper 2: Cricket [MobiCom '00]

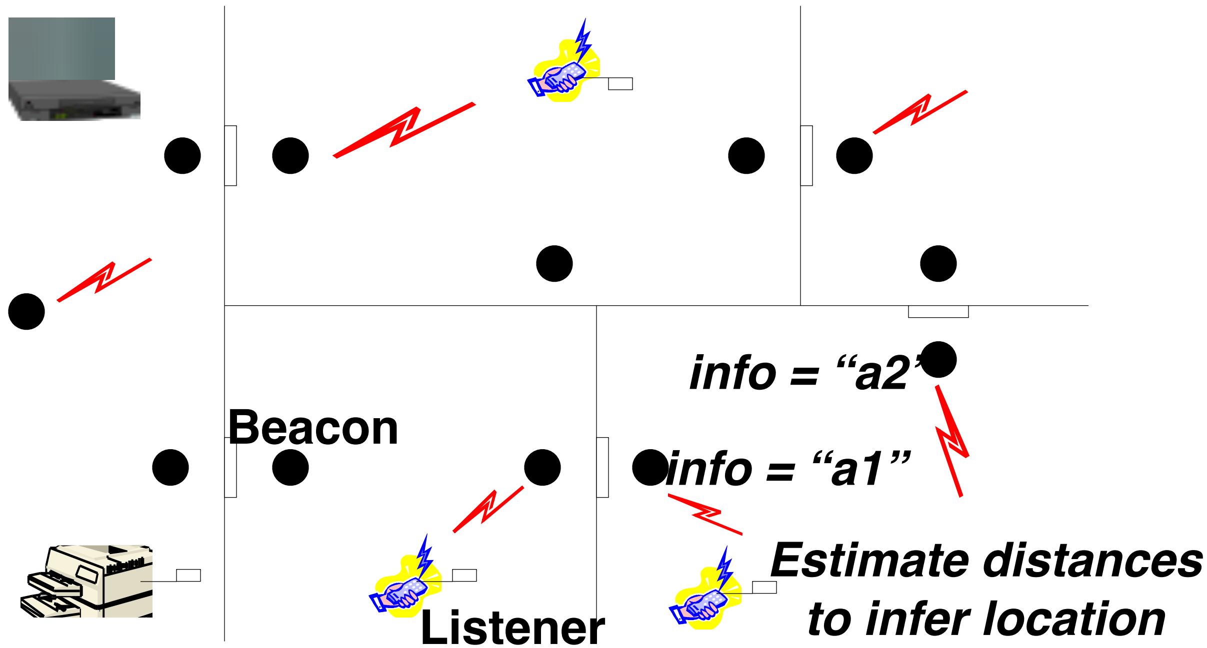
A general-purpose indoor location system for mobile and sensor computing applications



Cricket Design Goals

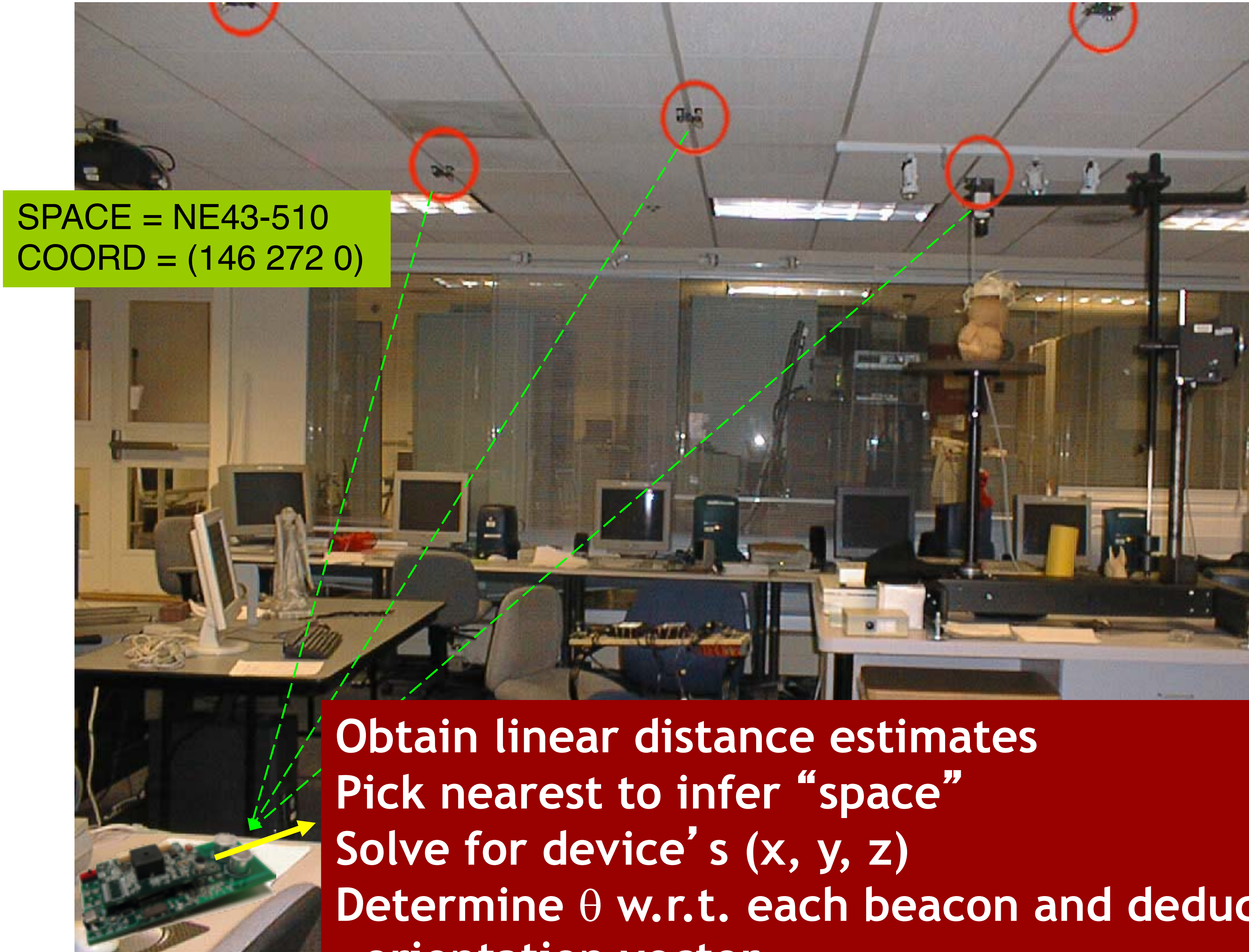
- Must work well indoors
- Must scale to large numbers of devices
- Should not violate user location privacy – location-support rather than track
- Must be easy to deploy and administer
- Should have low energy consumption

Cricket Architecture



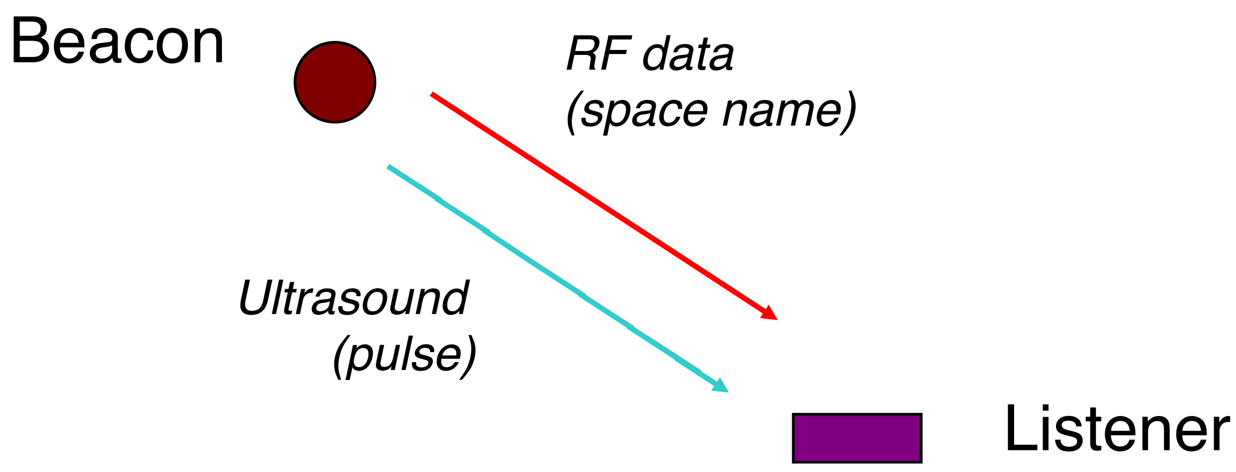
Passive listeners + active beacons scales well, helps preserve user privacy

Decentralized, self-configuring network of autonomous beacons



Obtain linear distance estimates
Pick nearest to infer “space”
Solve for device’s (x, y, z)
Determine θ w.r.t. each beacon and deduce orientation vector

Determining Distance



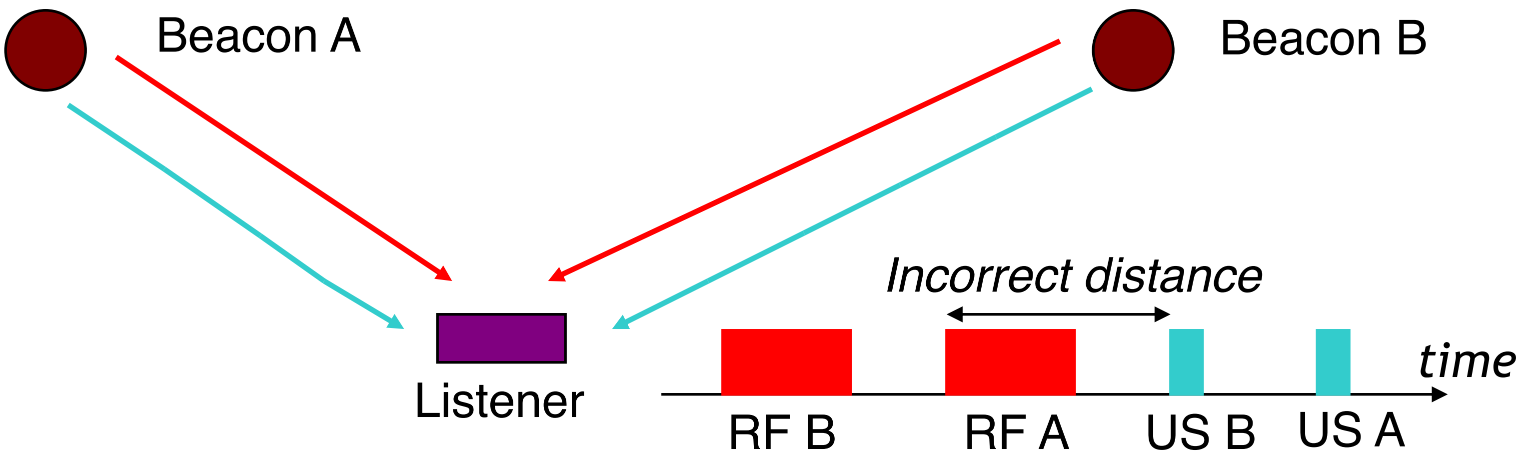
•A beacon transmits an RF and an ultrasonic signal simultaneously

–RF carries location data, ultrasound is a narrow pulse

•The listener measures the time gap between the receipt of RF and ultrasonic (US) signals

–Velocity of US << velocity of RF

Multiple Beacons Cause Complications



•Beacon transmissions are uncoordinated
•Ultrasonic pulses reflect off walls
These make the correlation problem hard and can lead to incorrect distance estimates
Solution: Beacon interference avoidance + listener interference detection

Choosing the bitrate of transmission

- How long should the packet be?
  - tau: 2 x ultra-sound longest TOF
  - packet size: S bits
  - bitrate < S/tau
  - “Long radio”

- Other proposal for dealing with interference?

Localization Schemes

- How to localize?
  - majority (pick beacon with highest freq of occurrence)
  - minmean (pick beacon with smallest mean distance)
  - minmode (pick beacon with smallest mode distance)

- Other proposals?
- Intrinsic Challenges?

Objectives of the Three Lectures Series

Learn the fundamentals, applications, and implications of
wireless localization and sensing

1. What are the unifying principles of wireless positioning? ✓
2. How do practical systems like GPS, WiFi positioning, Bluetooth positioning work? ✓
3. What is wireless (aka WiFi) sensing? **next lecture**
4. What are the industry opportunities and societal implications of wireless sensing (today and in the near+far future)?

TODO:
1) Lab 0 Due Thursday at midnight (i.e., checkoff in OH in 1wk)
2) Lab 1 and Pset 1 out
3) Survey for feedback on class soon