Welcome!

CIS 7000: Special Topics on Mobile and IoT Sensing

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Lecture 3

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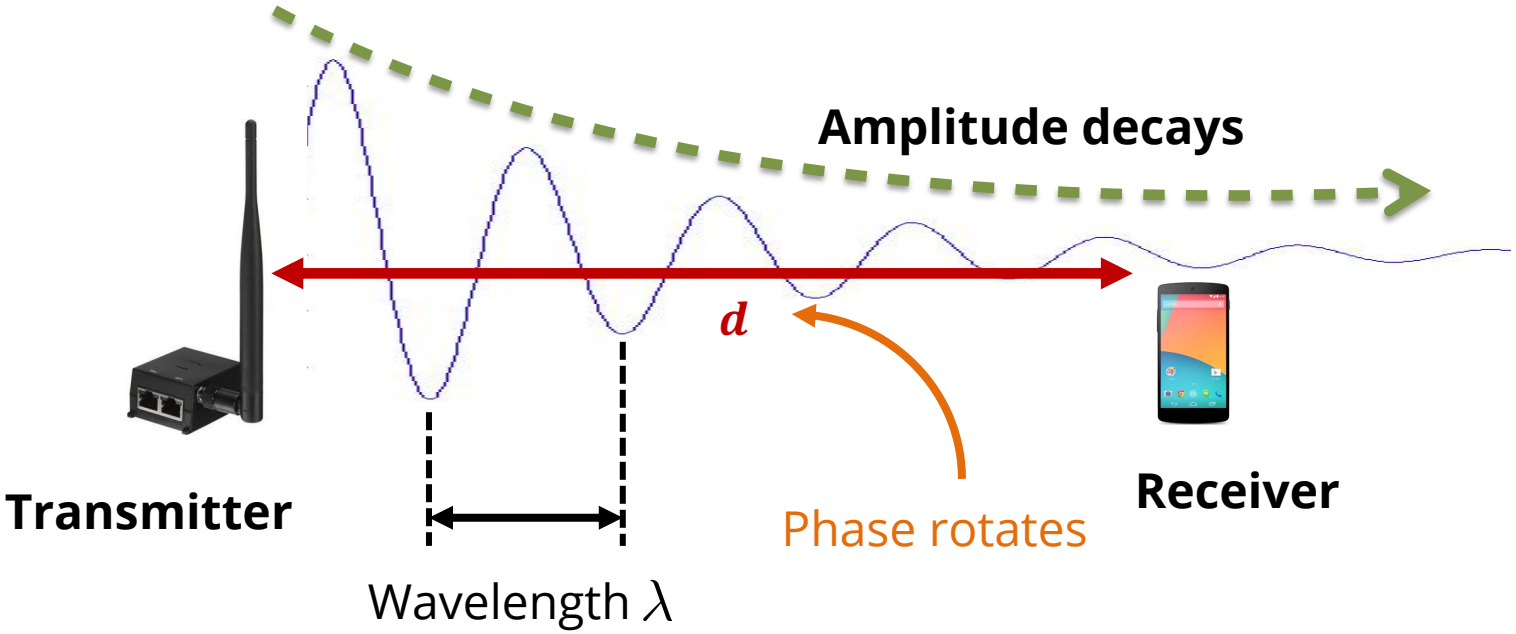
Wireless Signal are Waves



Channel equation: $$h = \frac{1}{d} e^{j2\pi \frac{d}{\lambda}}$$

Practical Indoor Wireless Positioning Systems

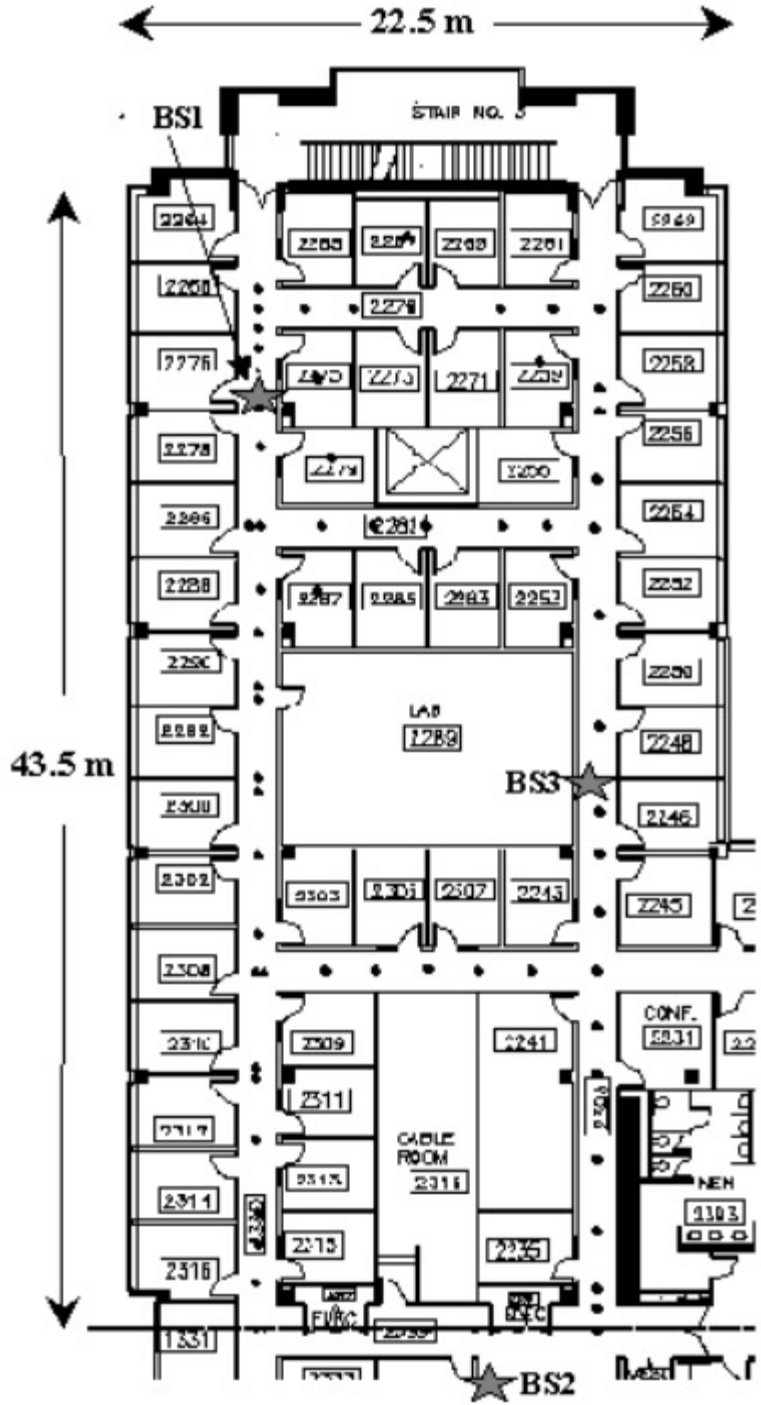
- RADAR [Infocom 2000]
- Cricket [Mobicom 2000]

Paper 1: RADAR [INFOCOM ’00]

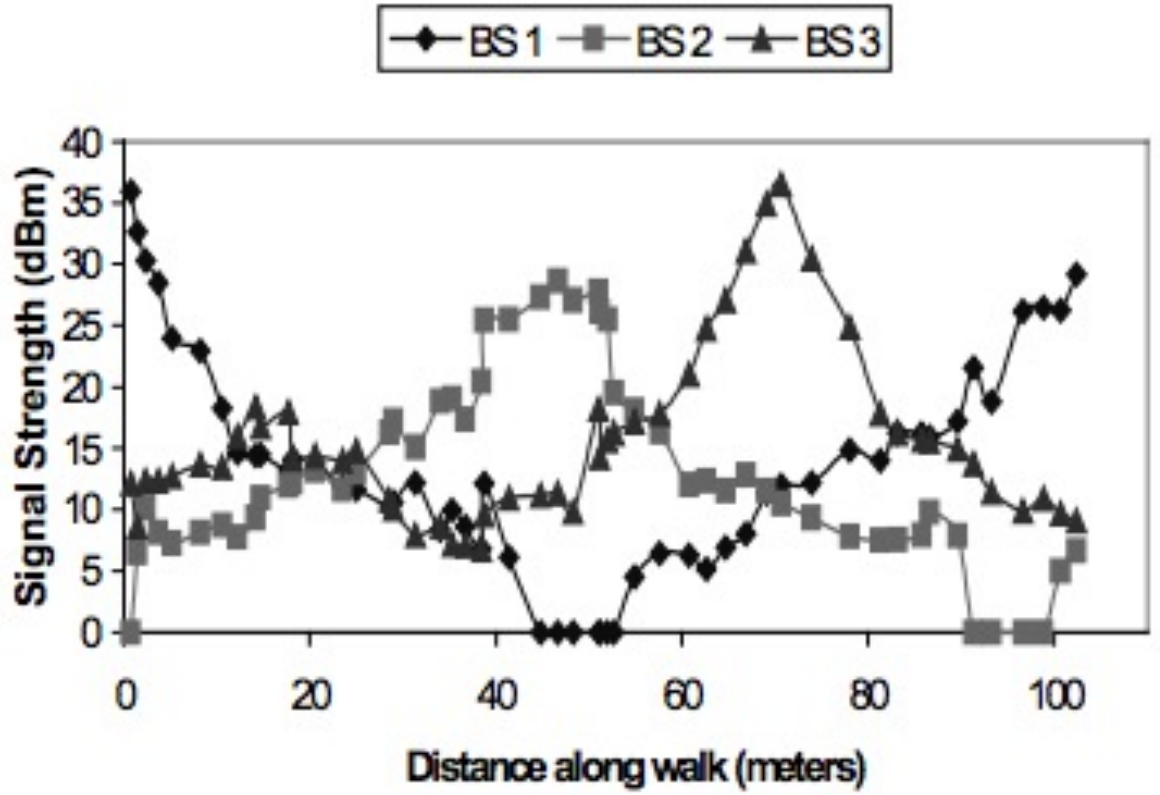
Why are we reading this paper?

- 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



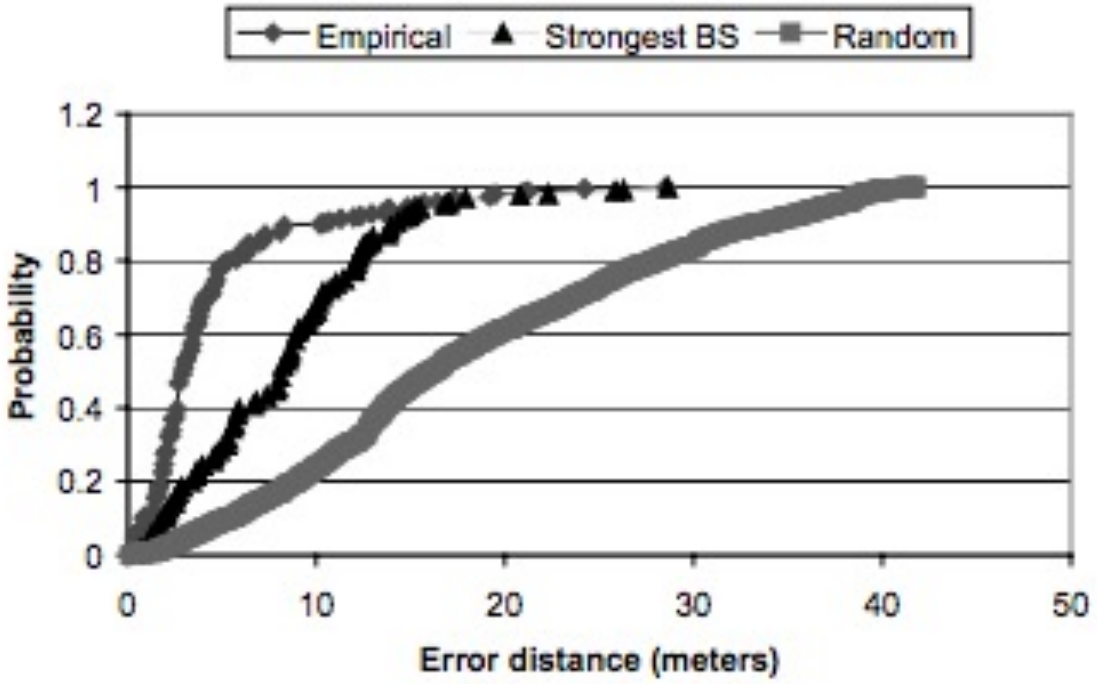
Approach

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

Approach

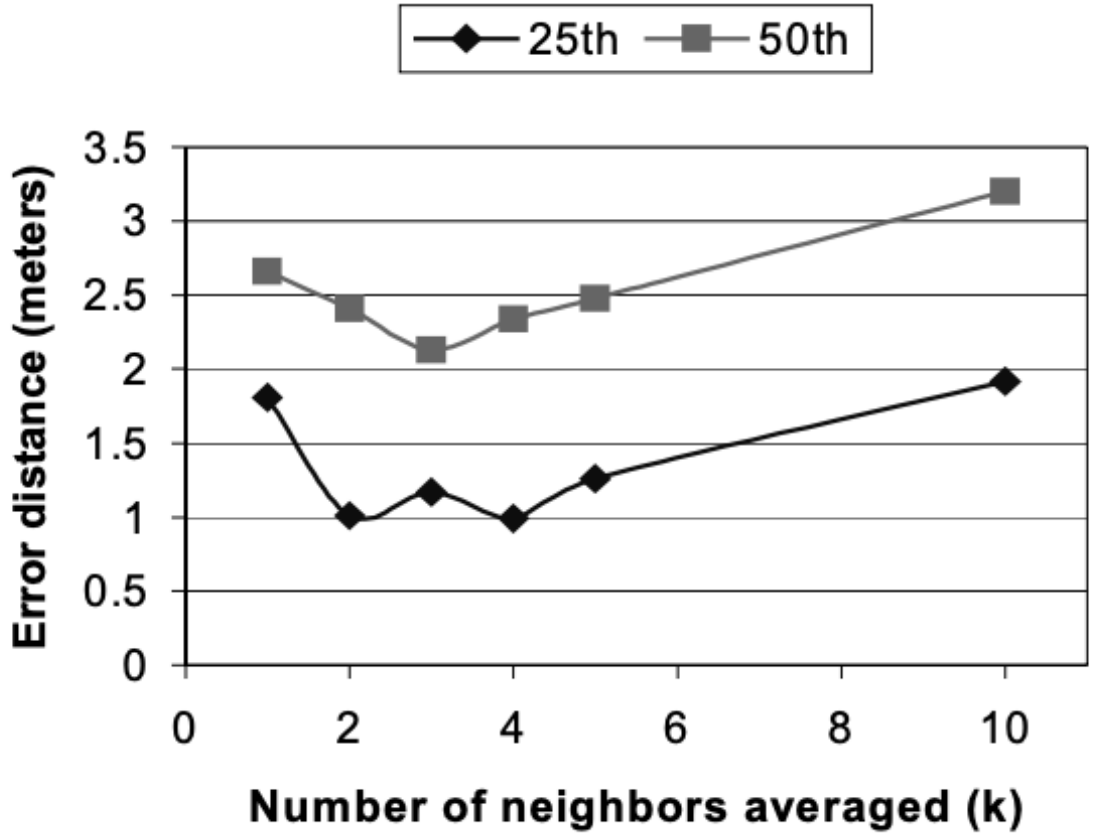
- Summarize signal strength samples at base stations
  - Mean signal strength over a time window
- Determine “best match”
  - Empirical method
  - Signal propagation model
- Metric for determining best match
  - Nearest neighbor in signal space, i.e., Euclidean distance between ss’ and ss vectors

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)?

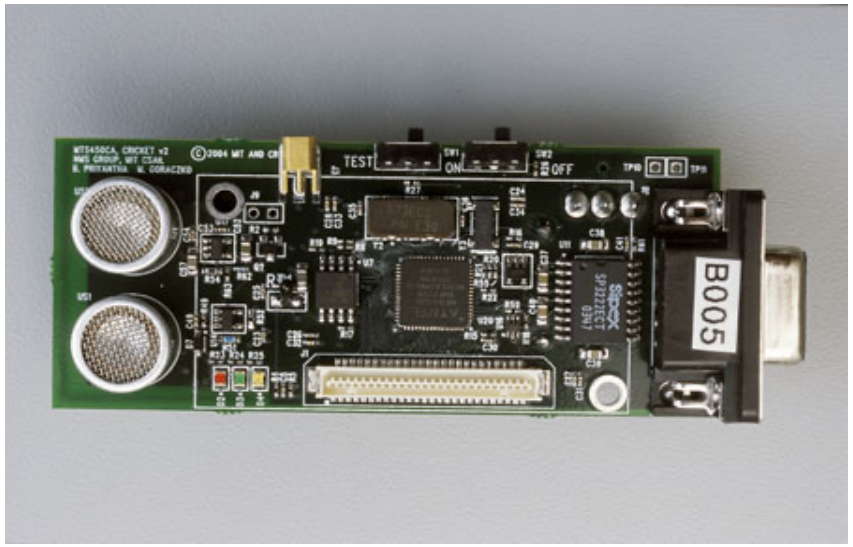
Averaging multiple nearest neighbors

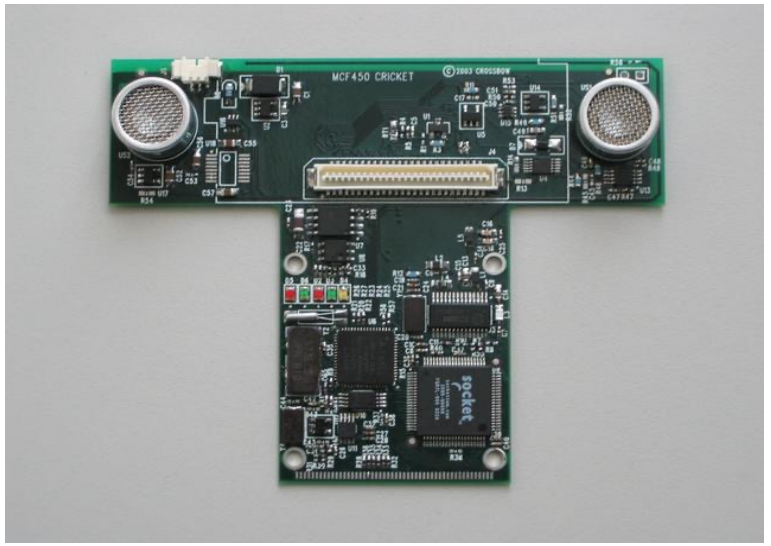


Why does the graph look like this?
1. On the right, too many far-away neighbors
2. Would weighted averaging work better?

Paper 2: Cricket [MobiCom ’00]

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

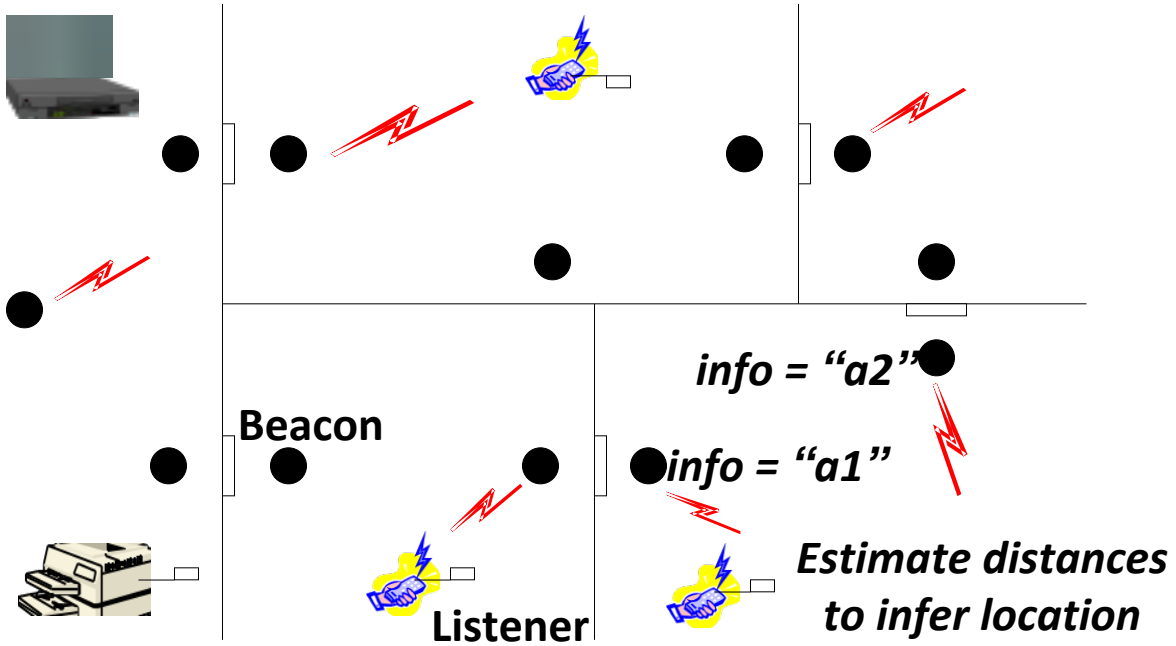




Cricket Design Goals

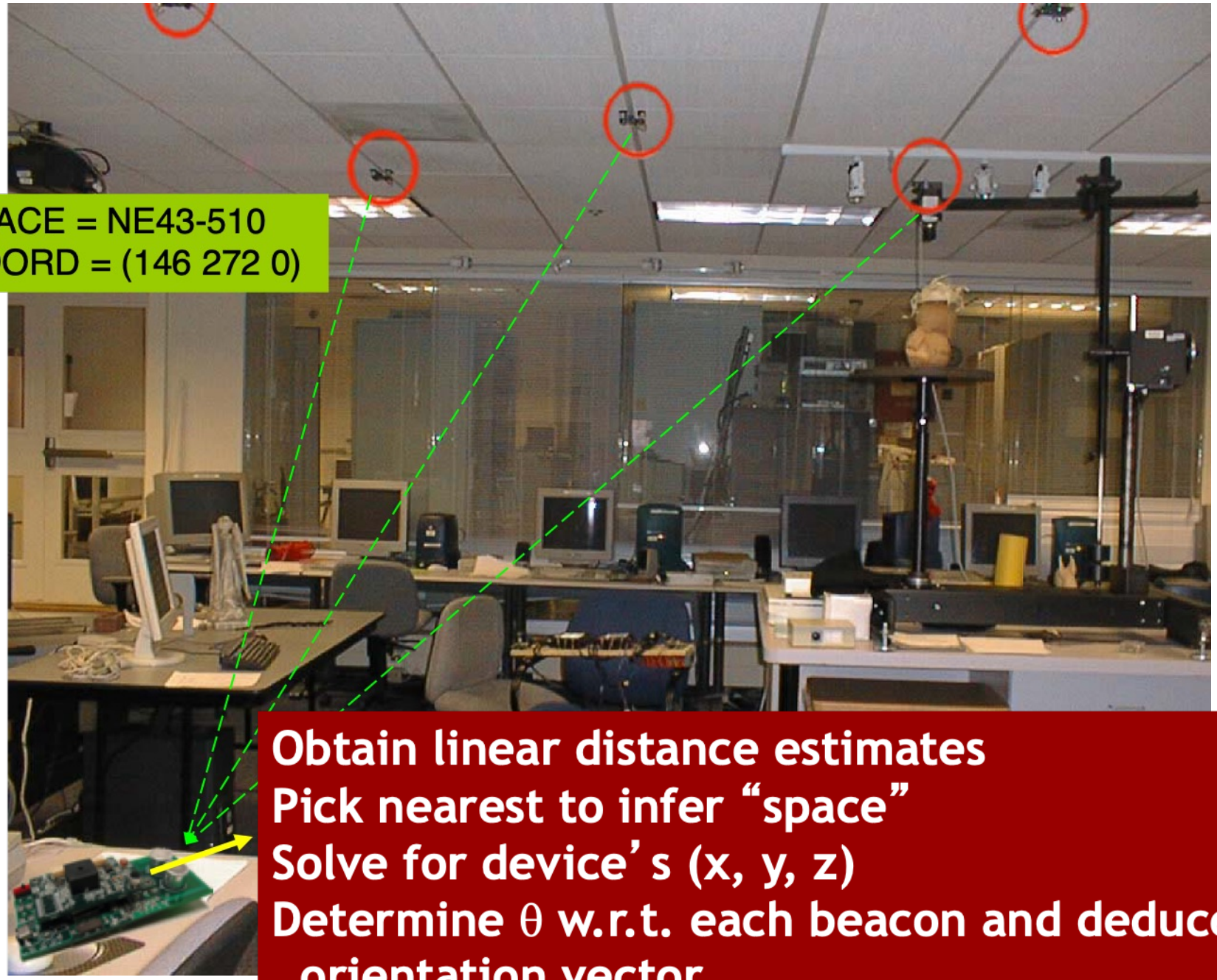
- Must work well indoors
- Must scale to large numbers of devices
- Should not violate user location privacy — location-support rather than track
- Must be easy to deploy and administer
- Should have low energy consumption

Cricket Architecture



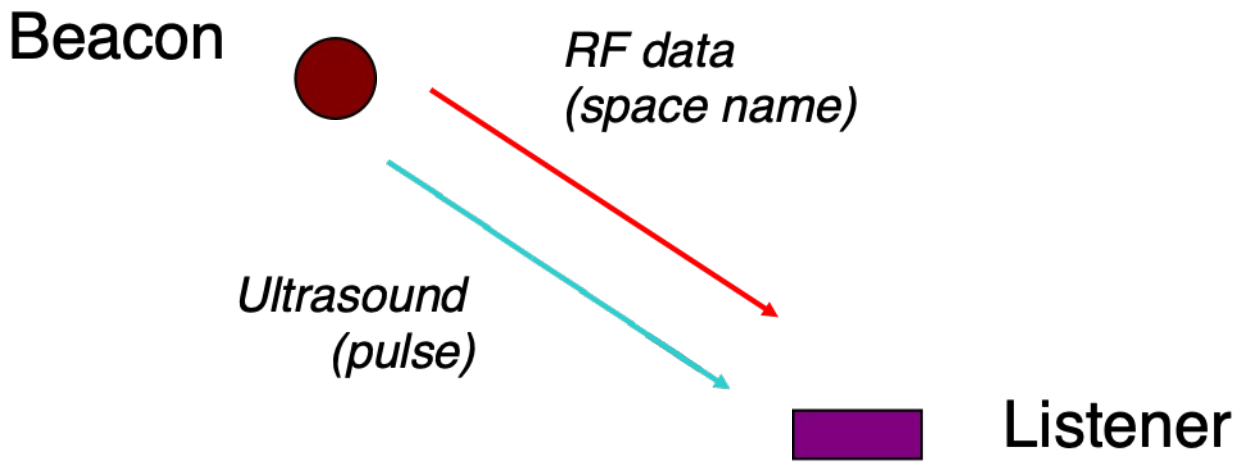
Passive listeners + active beacons scales well, helps preserve user privacy

Decentralized, self-configuring network of autonomous beacons



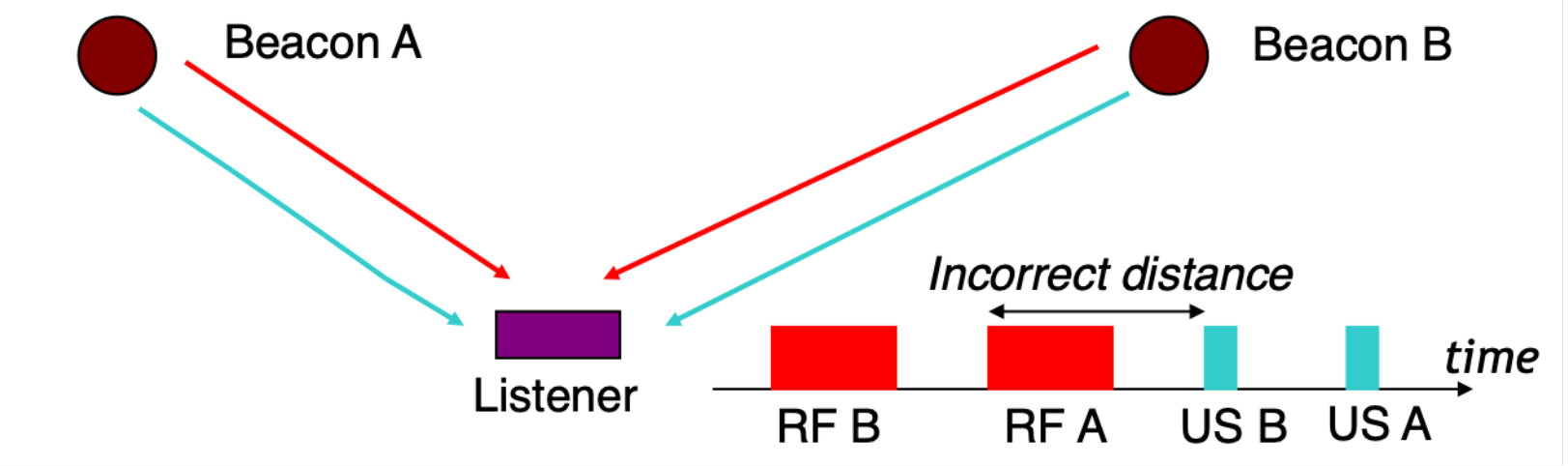
Obtain linear distance estimates
Pick nearest to infer “space”
Solve for device’s (x, y, z)
Determine θ w.r.t. each beacon and deduce orientation vector

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

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 mean distance)

- Other proposals?
- Intrinsic Challenges?
- Extending to orientation?

Summary: Device-Based Localization

- Case Study 1: RADAR
  - first WLAN-based system
  - used RSSI+fingerprinting
- Case Study 2: Cricket
  - ToF based / trilateration
  - new challenges with interference
- Case Study 3: GPS
  - trilateration

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 contact tracing 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)?

Next class

- Wed Sep 13
- Device-free Localization
  - Required: WiTrack

- Lab 0 due by the end of Sep 17 (11:59 PM)