The Cricket Location-Support System

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Outline

- What is Cricket
- Design Goal
- How does Cricket work
- Interference & Solution
- Measurement
- Application
- Comparison
- Appraisal

What is Cricket

- A location-support system for in-building, mobile, location-dependent applications.
- Allows application running on mobile or static nodes to learn their physical location.

Design Goal

- **User privacy**
  - Location tracking system
    - Use a database to keep track of the locations of all the entities, including users in the system.
  - Location support system
    - Allow clients to learn their location without centralized tracking.

Design Goal (cont')

- **Decentralized administration**
  - Widespread building-wide deployment
  - Centralized System
    - It is not possible to build a system in a scalable way when all control and management functions are centralized.
  - Decentralized System
    - Location beacon
    - Location receiver hardware (Listener)

Design Goal (cont')

- **Network heterogeneity**
  - Wide variety of network technologies
    - Different types of indoor wireless LANs
  - Automatically learn location independent of technologies
  - How to accommodate them?
    - Decouple the Cricket system from other data communication mechanisms.

Design Goal (cont')

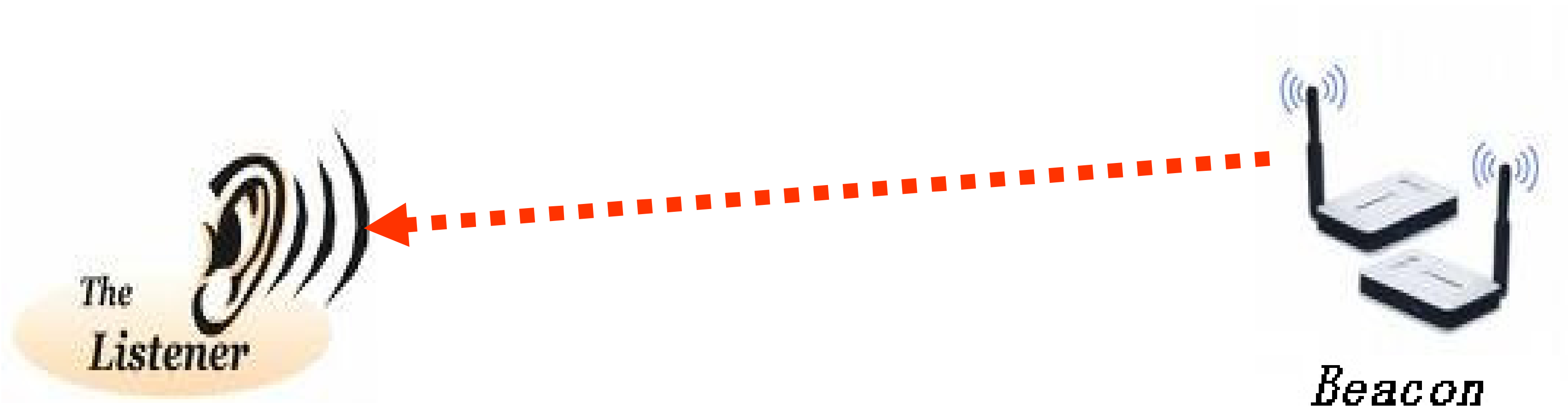
- **Low Cost**
  - Cost-effective components
  - Use commercial, off-the-shelf, inexpensive components beacon and listener
  - No custom hardware and small enough to fit in one's palm

Design Goal (cont')

- **Room-sized granularity**
  - A system where spatial regions can be determined within one or two square feet
  - Ability to demarcate and determine boundaries between regions corresponding to different beacons

How does Cricket Work

- Two kinds of small devices
  - Beacon: Emits signals
  - Listener: Receives signal, estimates distance & location

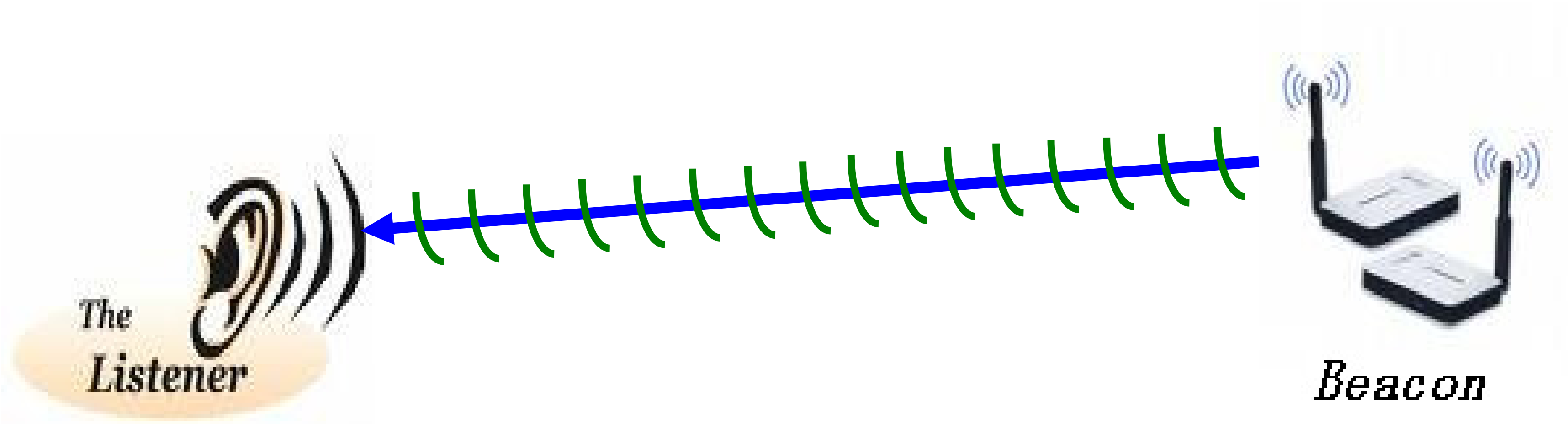


How does Cricket Work (cont')

- Beacon signals (Simultaneously)
  - RF
    - Contains ID and location information of beacon
    - Travels in the speed of light
    - Can travel through certain obstacles
  - Ultrasound
    - Travels in a slower speed comparing with RF (1.13 ft/ms at room temperature)

How does Cricket Work (cont')

- Two steps to estimate distance & location
  - Listener decides which the closest beacon is by detecting the strongest RF strength
  - Use the time difference between the receipt of RF and Ultrasound to infer distance & location



Interference

- Caused by decentralized beacon network
  - RF transmissions collision
  - Listener yields false results
- Caused by ultrasonic reflections
  - Listener suffers from severe multipath effects

Reducing Interference

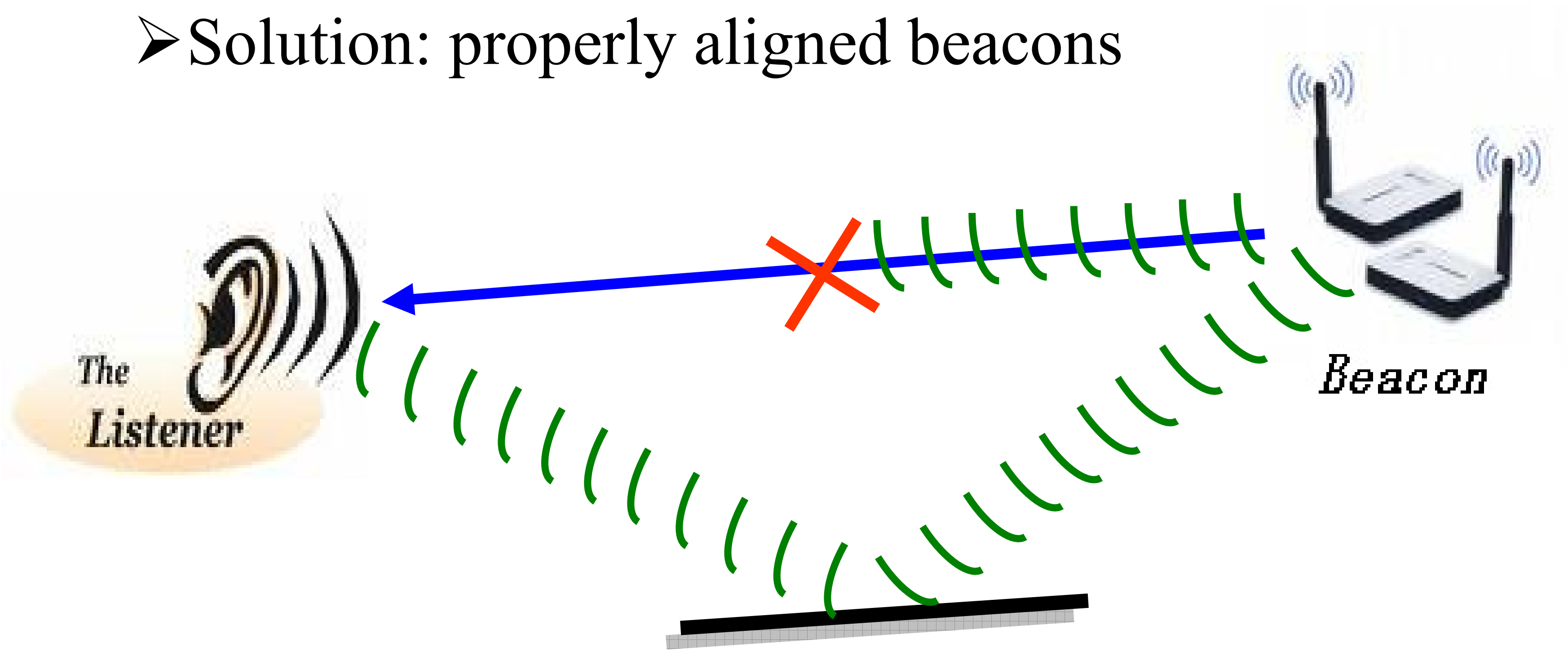
- **Proper system parameters**
  - Unique identifier
  - A relatively *sluggish* RF data transmission rate
    - *Any* potentially correlated ultrasound pulse *must* arrive while a RF message is being received.

Reducing Interference (cont')

- **Interference scenarios** (beacon A vs. interfering beacon I)
  - The listener potentially hears the following signals:
    - RF-A. The RF signal from A
    - US-A. The *direct* ultrasonic signal from A
    - US-RA. The *reflected* ultrasonic signal from A
    - RF-I. The RF signal from I
    - US-I. The *direct* ultrasonic signal from I
    - US-RI. The *reflected* ultrasonic signal from I

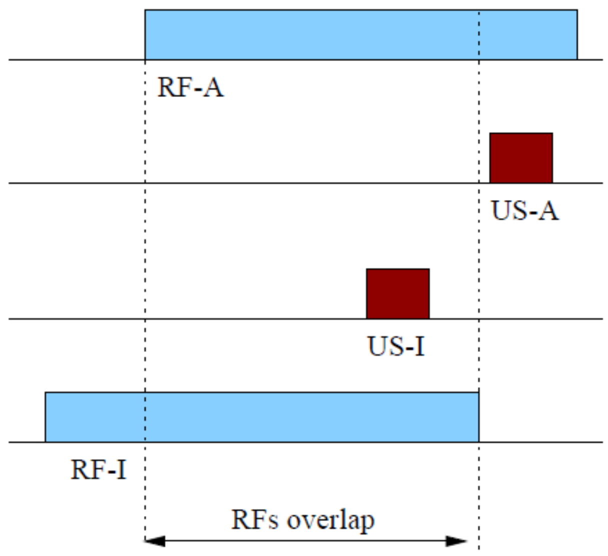
Reducing Interference (cont')

- Case 1: RF-A & US-RA
  - Estimated distance > actual distance
  - Solution: properly aligned beacons



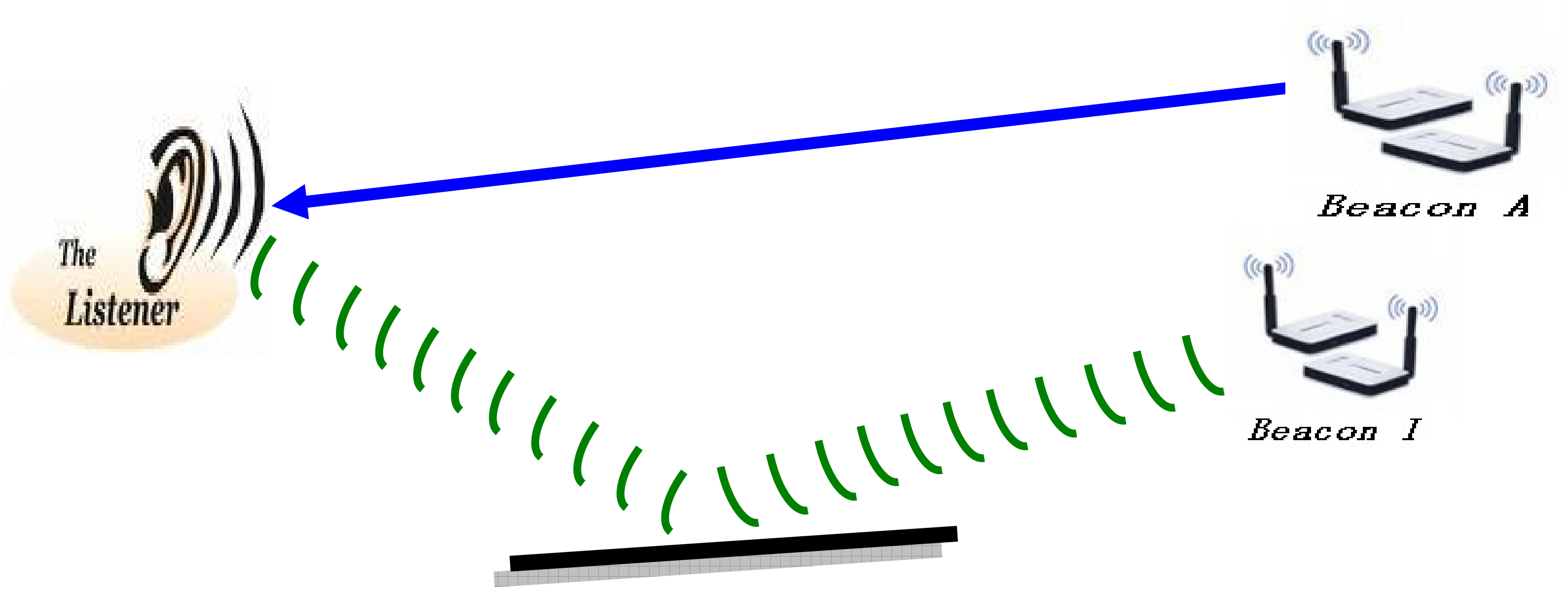
Reducing Interference (cont')

- Case 2: RF-A & US-I
  - Wrong estimated distance
  - Solution:
    - Using randomization (Uniform Distribution) to avoid such collisions
    - Using RF signal with longer range than US signal



Reducing Interference (cont')

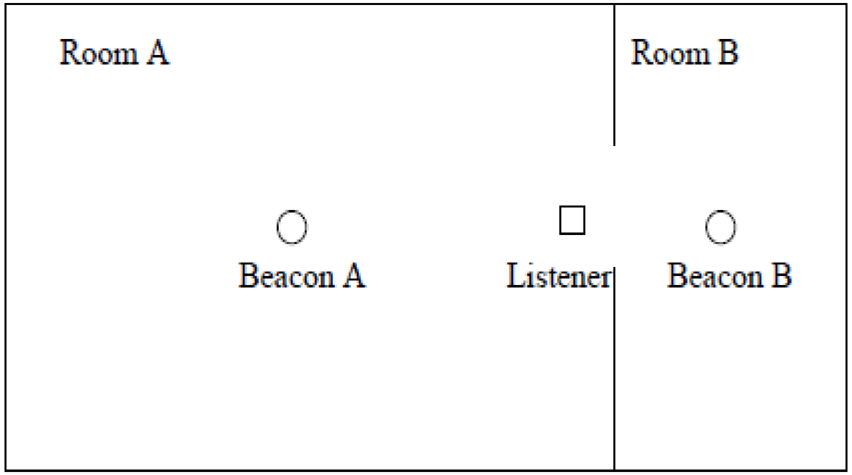
- Case 3: RF-A & US-RI
  - Wrong estimated distance
  - Solution:
    - Using randomization (Uniform Distribution) to avoid such collisions
    - Reducing the number of beacons in the range of each other

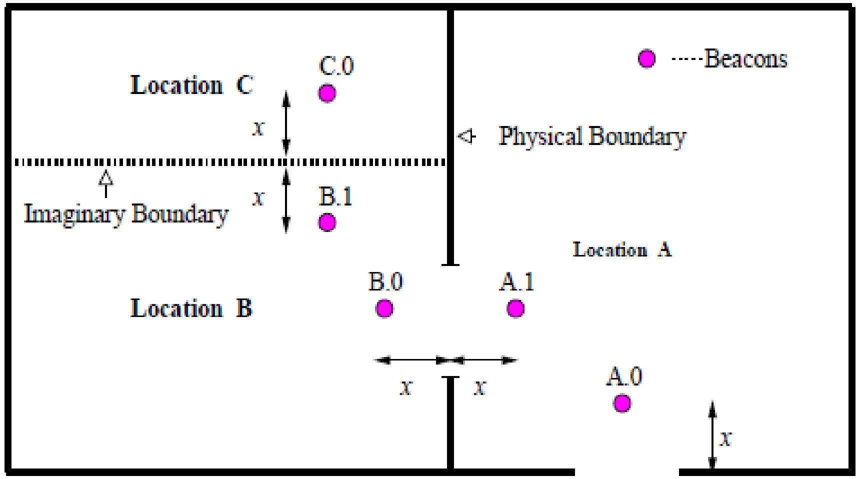


Reducing Interference (cont')

- **Software Solution**
  - Majority
    - Selects beacon with the **highest frequency of occurrence**
    - Simplest—without using US
    - Does not perform well
  - MinMean
    - Selects beacon with the **minimum mean**
    - Easy to compute
    - Cannot reflect the actual beacon position
  - MinMode
    - Selects beacon with **highest-likelihood estimate**
    - Computes based on certain mode of the distribution
    - Performs well in both static and mobile cases

Reducing Interference (cont')

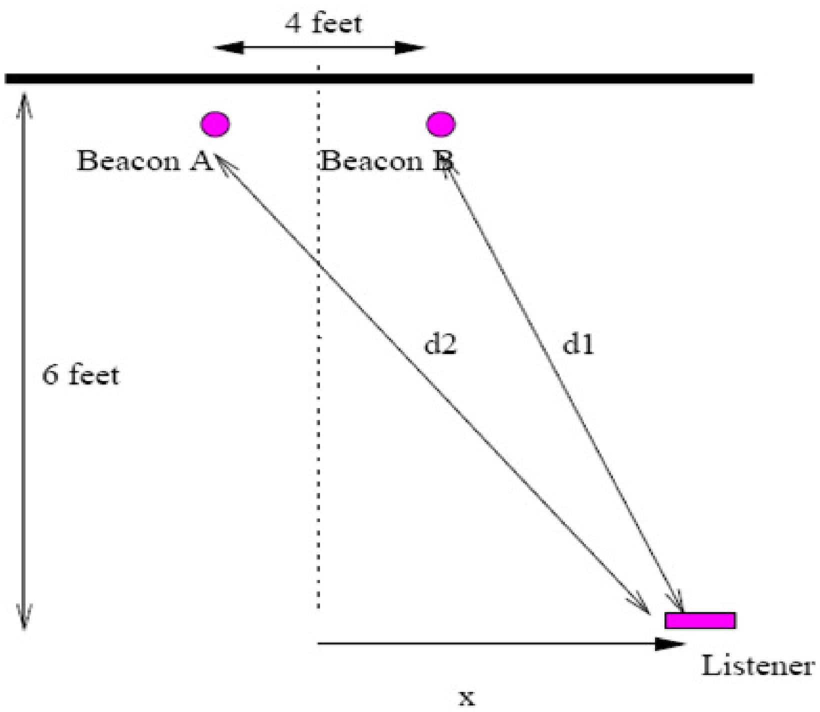


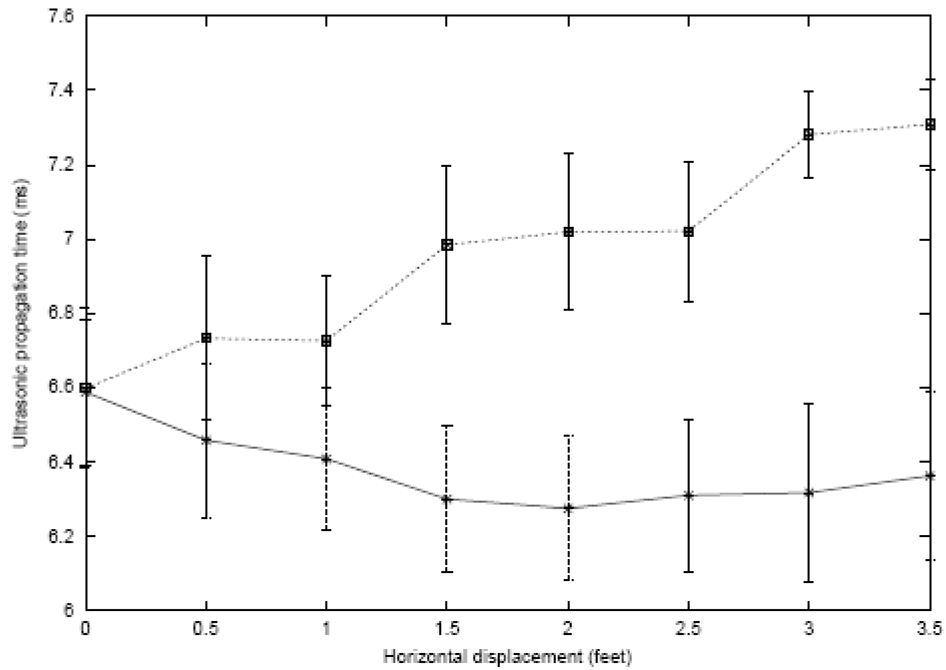


- **Engineering solution**
  - ➢Centralized repository of the physical locations of each beacon
  - ➢Fixed distance away from the boundary

Measurement

- **Boundary Performance**
  - Examine & analyze listener performance near location boundaries
  - Location granularity of 4*4 feet is achieved

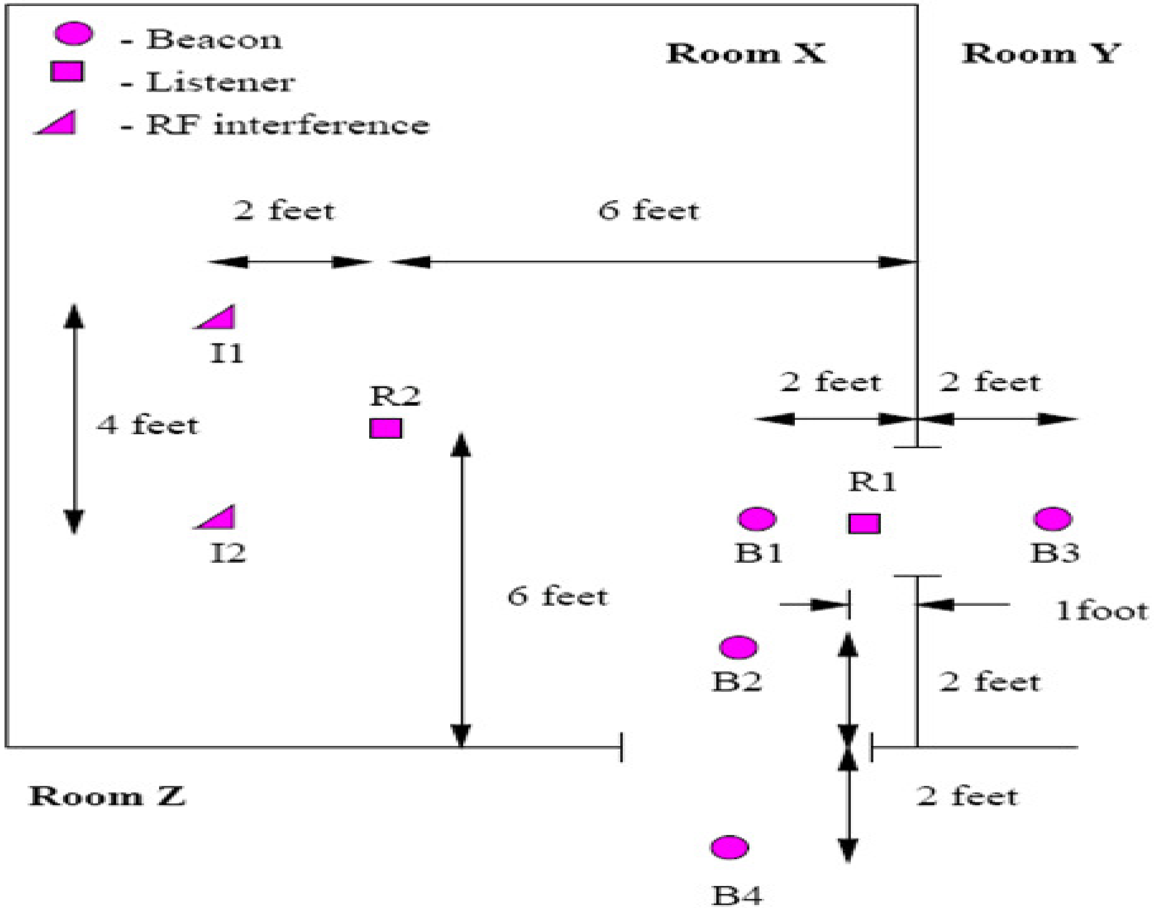




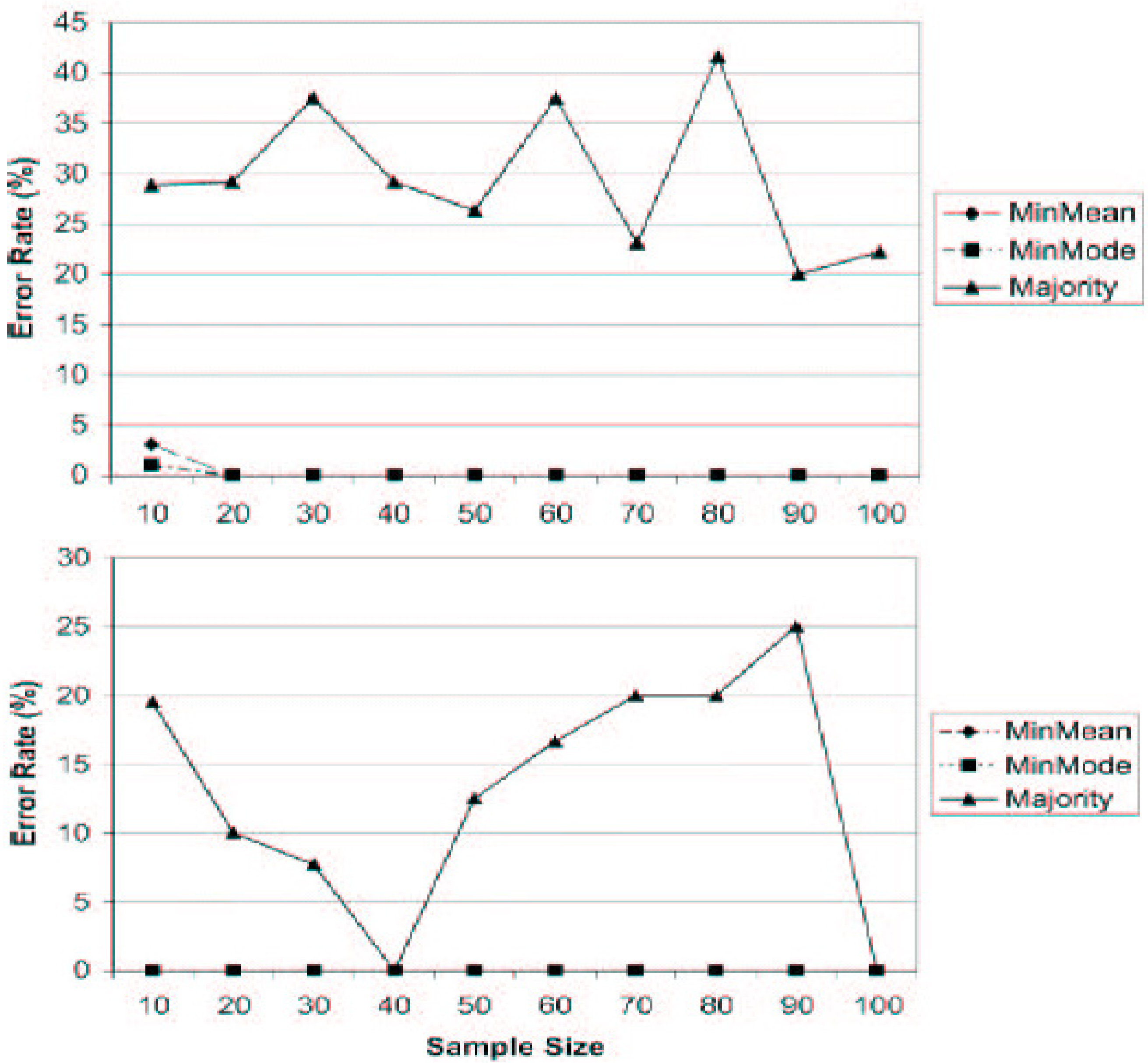
Measurement (cont')

Static Performance

- Observe the robustness of the system to the interference amongst beacons



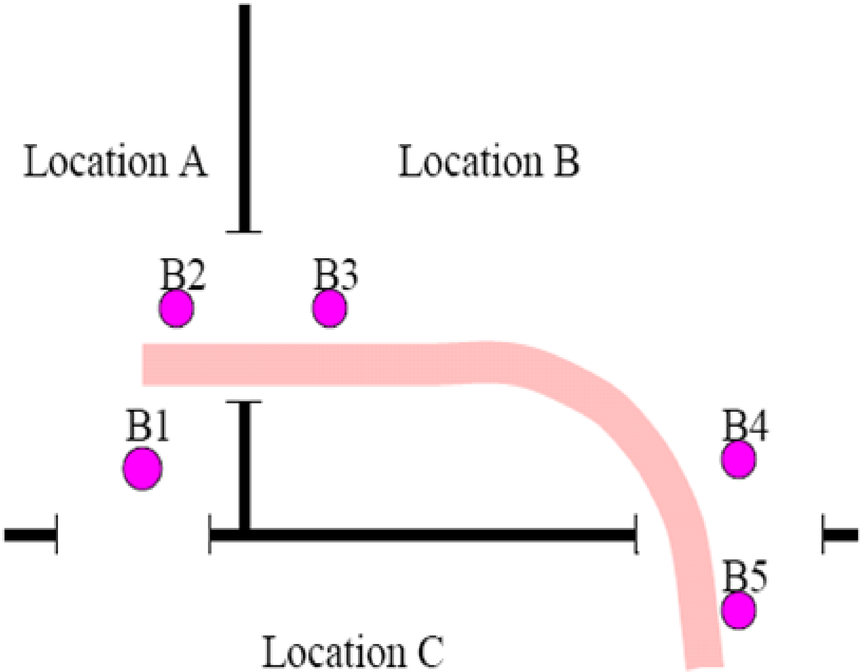
Measurement (cont')

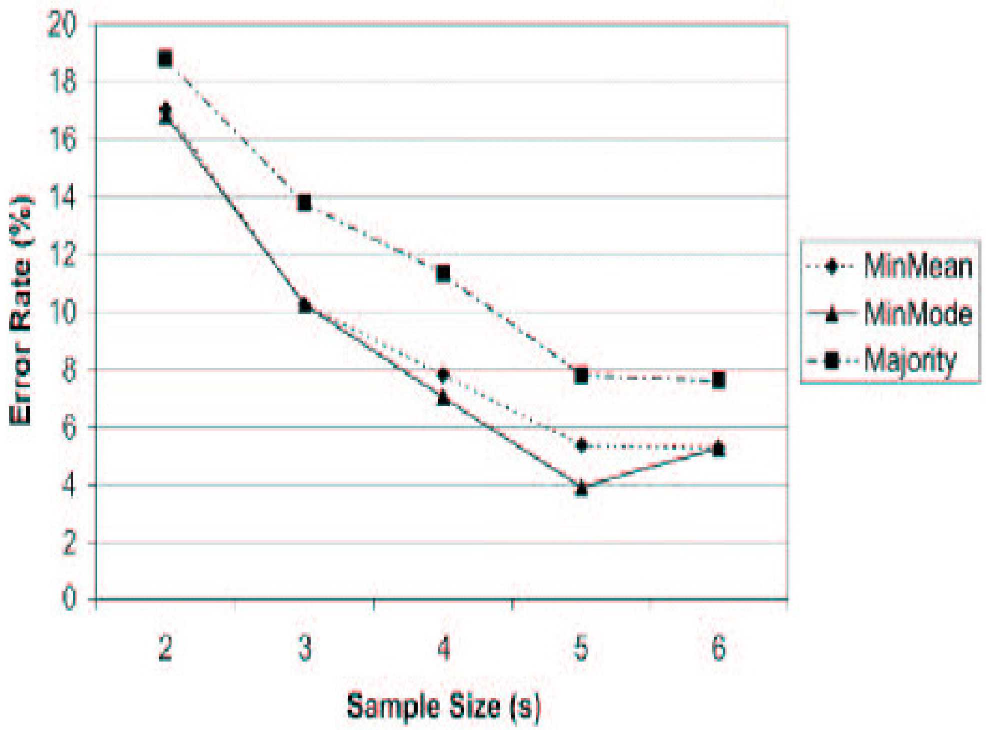


Measurement (cont')

◈ Mobile performance

- ➢ Examine the performance of three interference algorithms when listener is mobile





Application using Cricket

- How does the host device get location information from Cricket Listener
  - Attach Listener component via serial port
  - LocationManager
  - Listener API

Application using Cricket (cont')

- INS (Intentional Naming system)
  - Uses vspace (room, floor, etc.) which is a collection of applications & services.
  - Name resolver resolves entities in vspace
  - Beacon advertises the name of vspace; Listener uses the name to learn about services in the vspace.
- Floorplan
  - An active map navigation application that uses Cricket and a map server to provide location-dependent active map to the user.
  - It shows the list of services that are located in the adjoining region of the user.

Comparison table of Cricket & other systems

System	Bat	Active Badge	RADAR	*Cricket*
User privacy	No	No	Possible, with user computation	*Yes*
Decentralized	No	No	Centralized RF signal database	*Yes*
Heterogeneity of networks	Yes	Yes	No	*Yes*
Cost	High	High	No extra component cost, but only works with one network	*Low (U.S. $10) component cost*
Ease of deployment	Difficult; requires matrix of sensors	Difficult; requires matrix of sensors	RF mapping	*Easy*

Appraisal

- Innovative aspects
  - Beacon with combined RF and Ultrasound signal
  - Decentralized, uncoordinated architecture
- What should be improved
  - Accuracy
    - More beacons, smaller granularity
    - Multi-beacon estimation
  - Efficiency
    - Beacon ID in Ultrasound

Summary

- Location-support system for mobile, location-dependent applications.
- Achieves 5 design goals: user privacy, decentralized administration, network heterogeneity, low cost, portion-of-a-room granularity
- Achieves satisfactory performance by avoiding interference using algorithms and engineering methods.

Question?