Using Micro-Climate Sensing to Enhance RF Localization in Assisted Living Environments

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Outline

- Introduction
- Localization Techniques
  - Signature Database
  - Weighted Centroid
  - Micro-Climates
- FireFly Sensor Networking Platform
- Micro-Climate Experiments

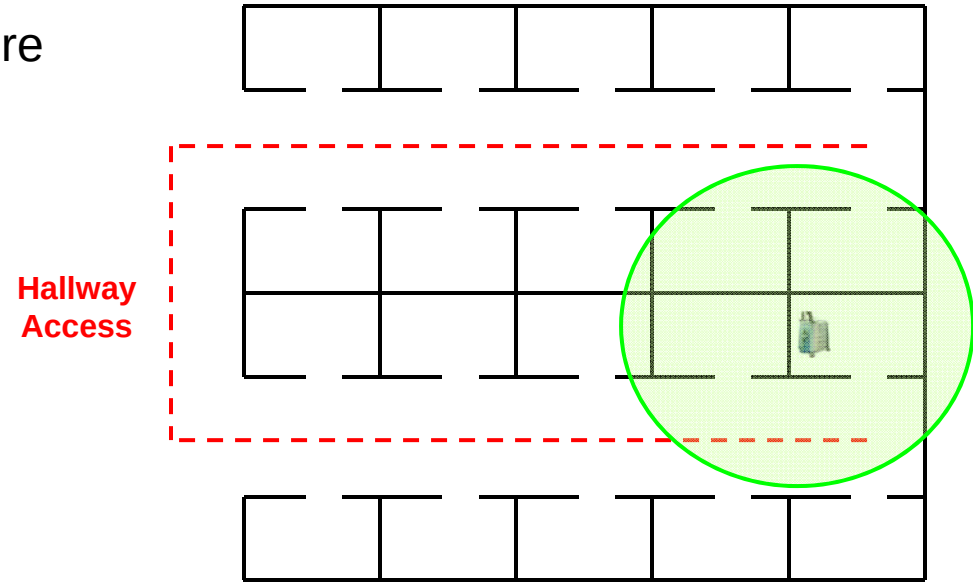
Introduction

- **Location Tracking**
  - Inventory and Patient Tracking
  - Multi-purpose badge or asset tag

- **Dynamic Indoor Environments**
  - Hospitals with movable walls, heavy machinery, and many moving people

Hospital Tracking Requirements

- **At least Room Level Accuracy**
  - 10 meters could span multiple rooms, wings or floors
- **Energy Efficient**
  - Battery Operated Tags
  - Largely Powered Infrastructure
- **Adaptive**
  - Dynamic Environment
  - Little Downtime
- **Extensible**
  - Monitor environment?
  - Monitor Patient Life Signs?



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Signature Database

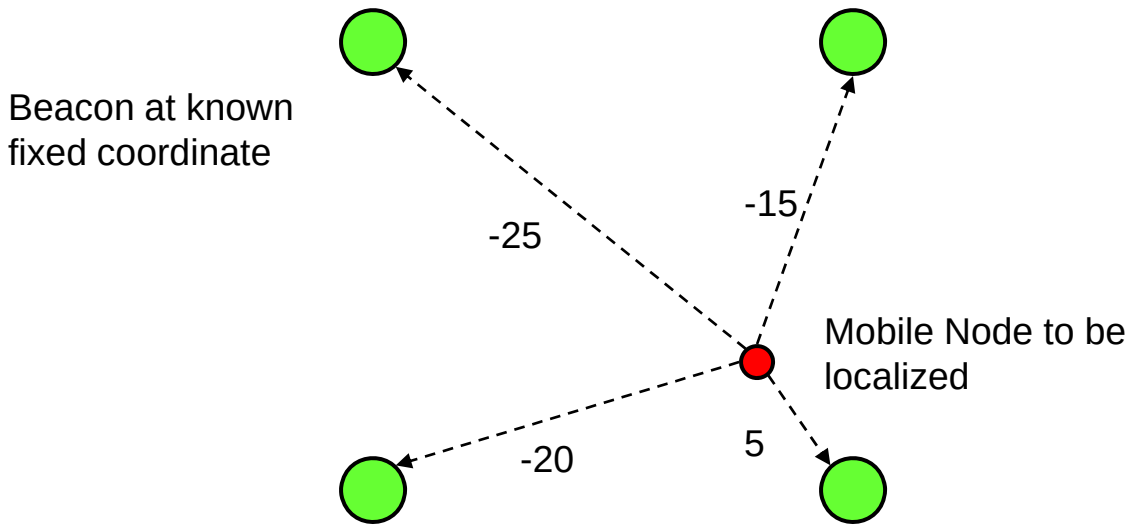
- **Record Signal Strength Values at many locations in the environment**
  - Site Survey
  - Microsoft RADAR project (802.11)
- **Use Matching Scheme to Lookup new sample**
  - Nearest Neighbor

Signature Database

- **Works extremely well**
  - Better than 1 meter accuracy
- **How does it perform over time?**
  - Environment could change
  - People moving around
  - Atmospheric conditions change during the year
- **Site survey is very time consuming...**
  - Could you do a site survey in an intensive care unit?

Weighted Centroid Approach

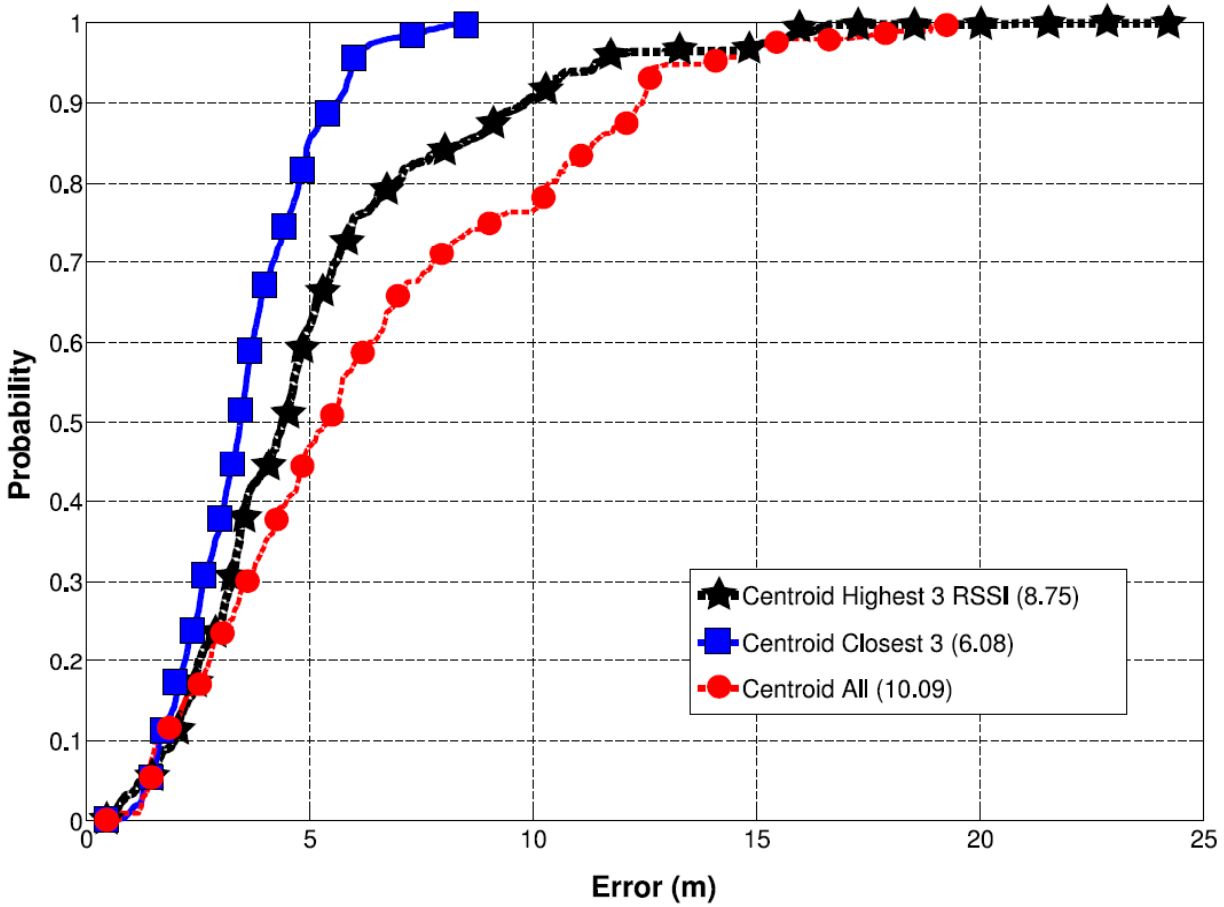
- **Triangulation based on 3 or more signal strength values**
- **RSSI values represent force vectors pulling on mobile node**



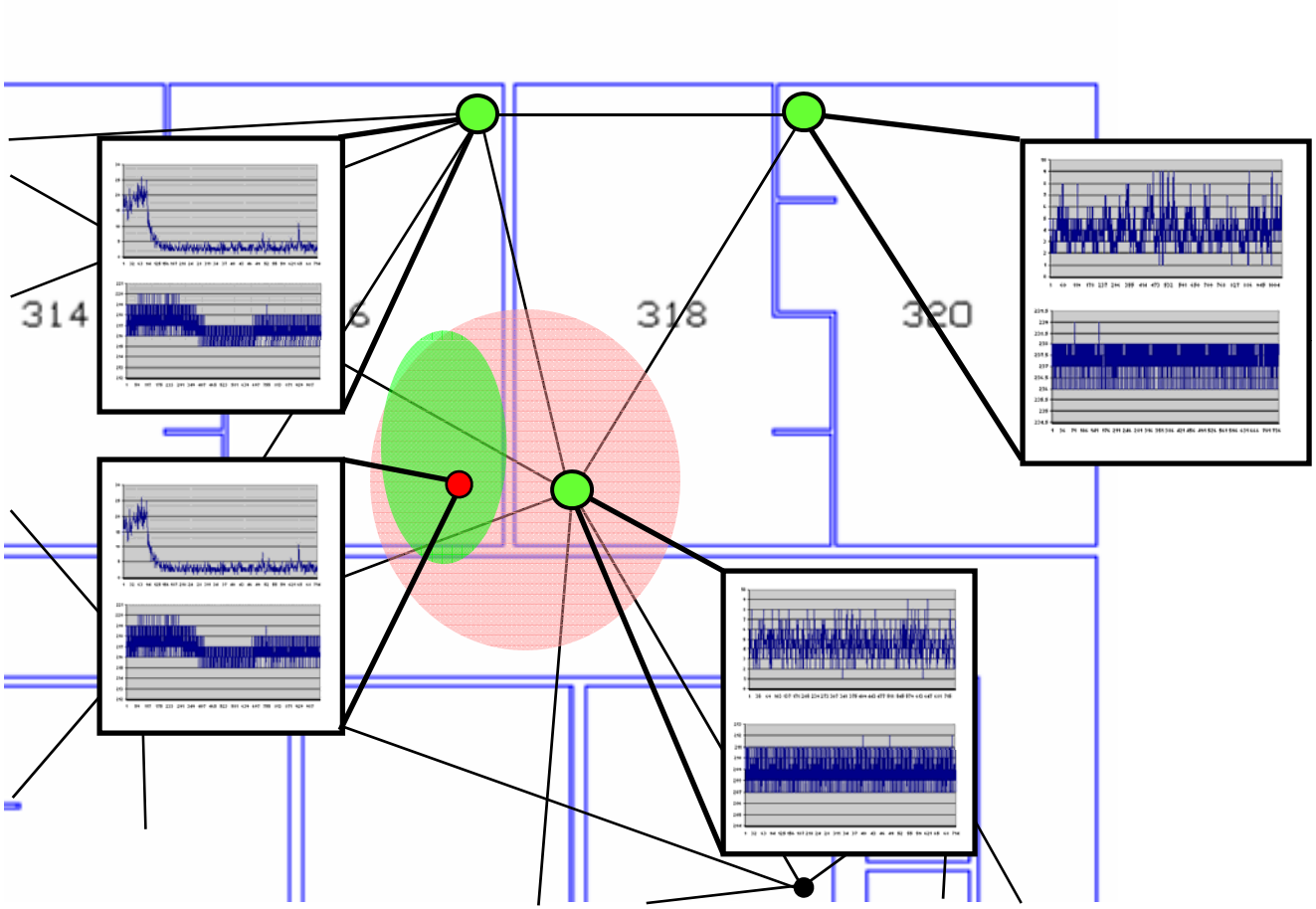
Weighted Centroid Approach

- **Not as accurate as signature based approach**
  - 5 meters on average, but up to 25 meters worst case!
- **Adapts to environment well**
  - Based on Instantaneous data
- **Much easier to deploy**
  - Simply put up beacons at known locations

What if we had a hint about which beacons are closest?



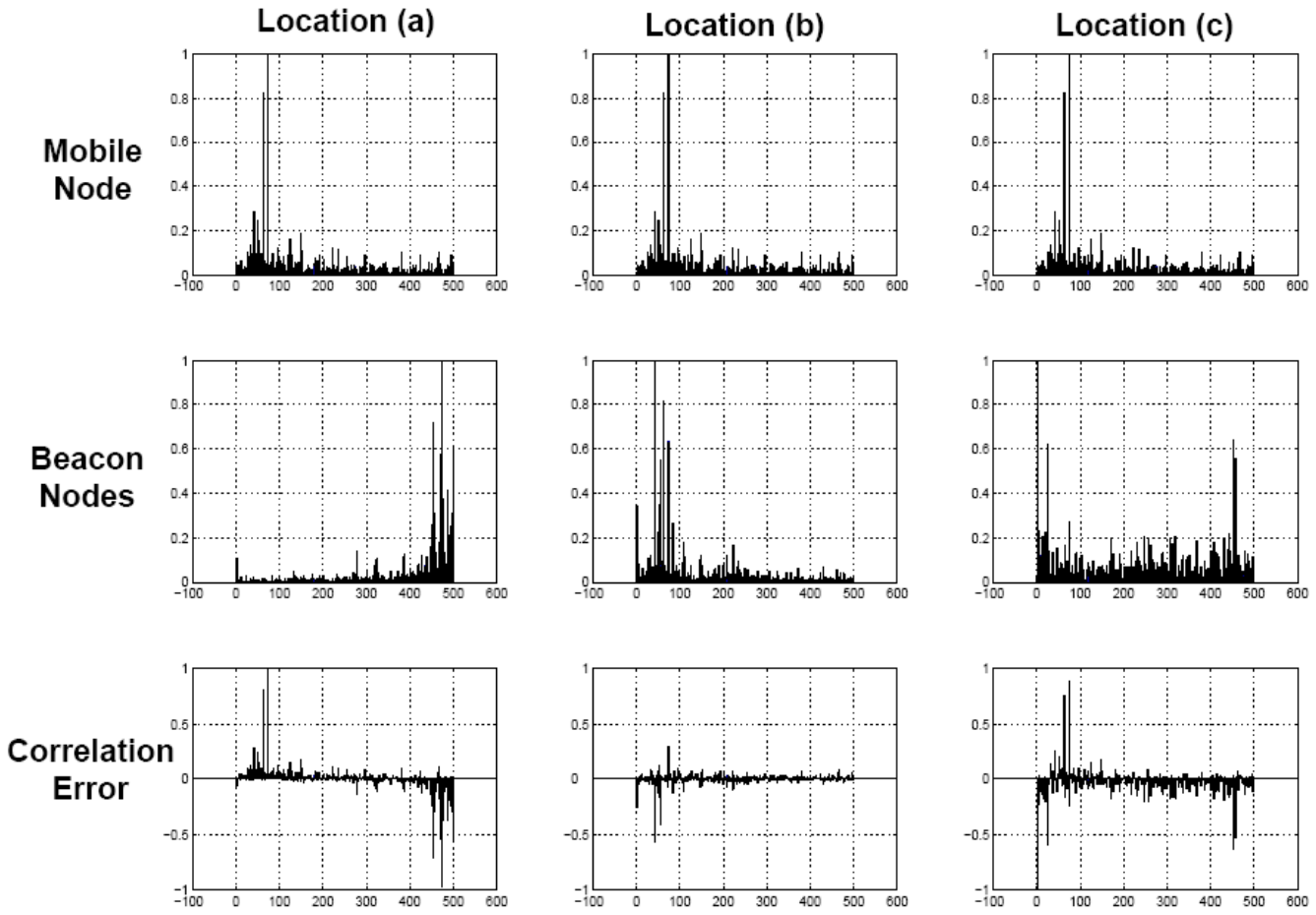
Micro-Climate Approach

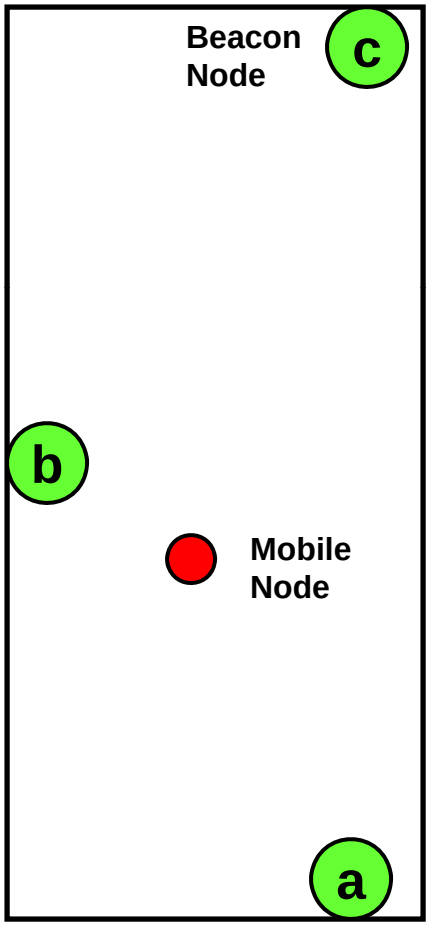


Micro-Climate Features

- **Steady State Features**
  - Temperature, Humidity
  - Compare Averaged Values
- **Rapidly Changing Features**
  - Light, Sound
  - Analyze Frequency Components

Sample Audio Feature Comparison





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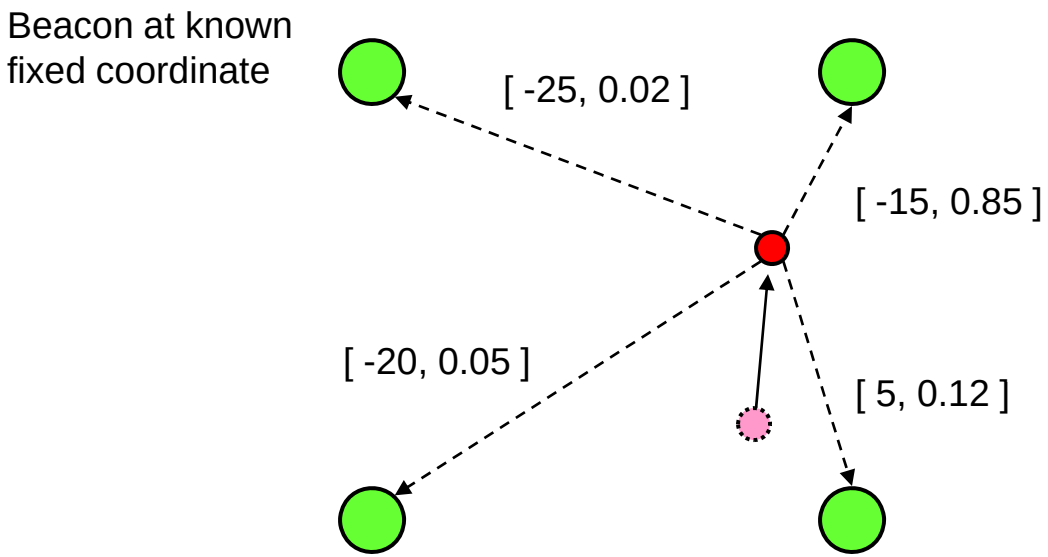
Weighted Centroid + Sensors



[RSSI, Sensor Correlation]

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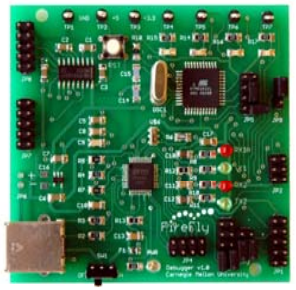
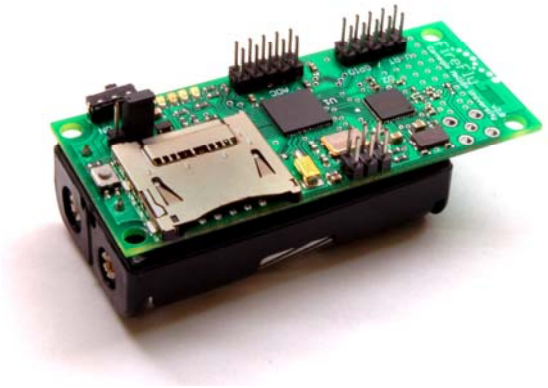
FireFly
Sensor Networks



Development Interface

Energy Harvesting

Vision Sensor



FireFly 2.0 Node

eWatch

Time Synchronization

Various Sensors

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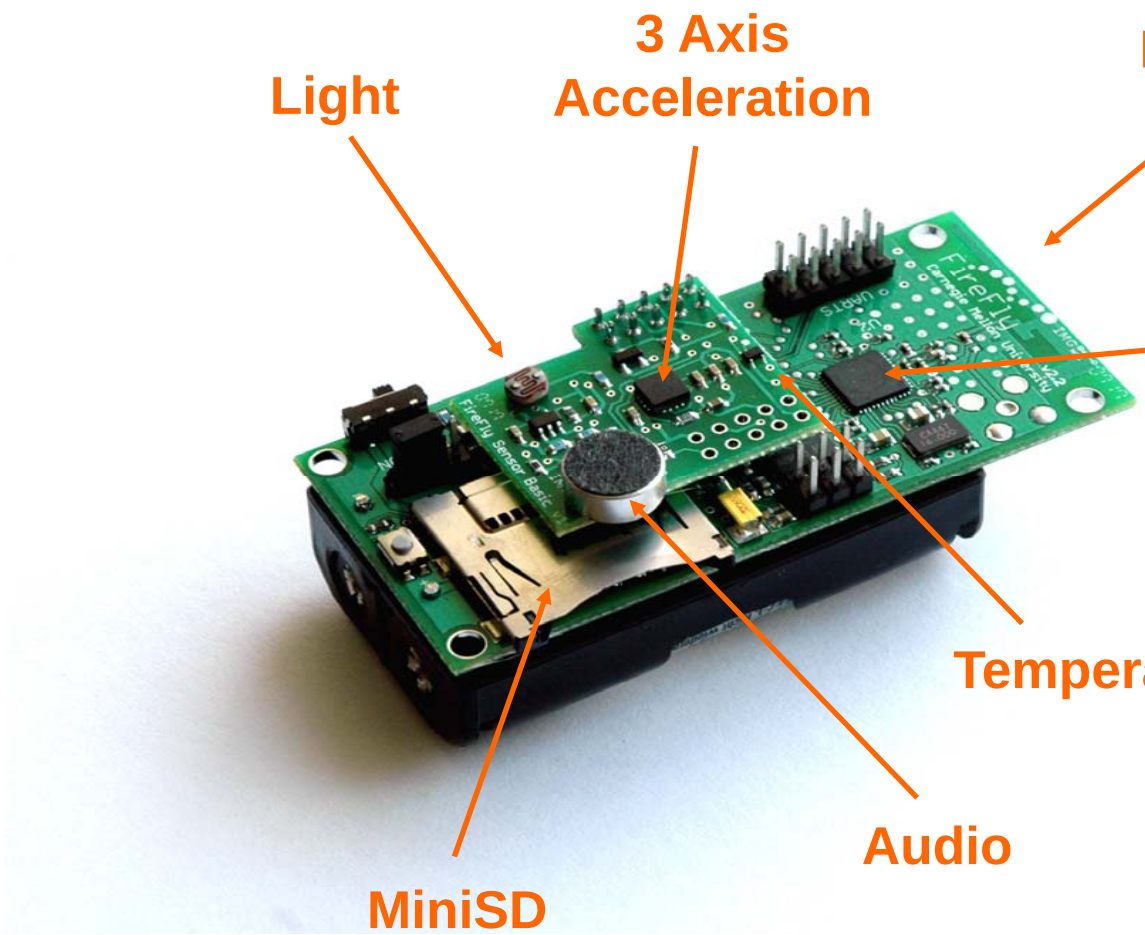
FireFly 2.2 Node



What makes FireFly unique?

- **Nano-RK Real-Time Operating System**
  - Energy Efficient Operation with Predictable Network Lifetime
  - Fully Preemptive OS with Priority Based Scheduling
  - Open Source (visit: www.nano-rk.org)

- **RT-Link TDMA Mesh Communication Protocol**
  - Bounded End-to-End Multi-hop Latency
  - High Throughput on Demand
  - Collision Free Communications

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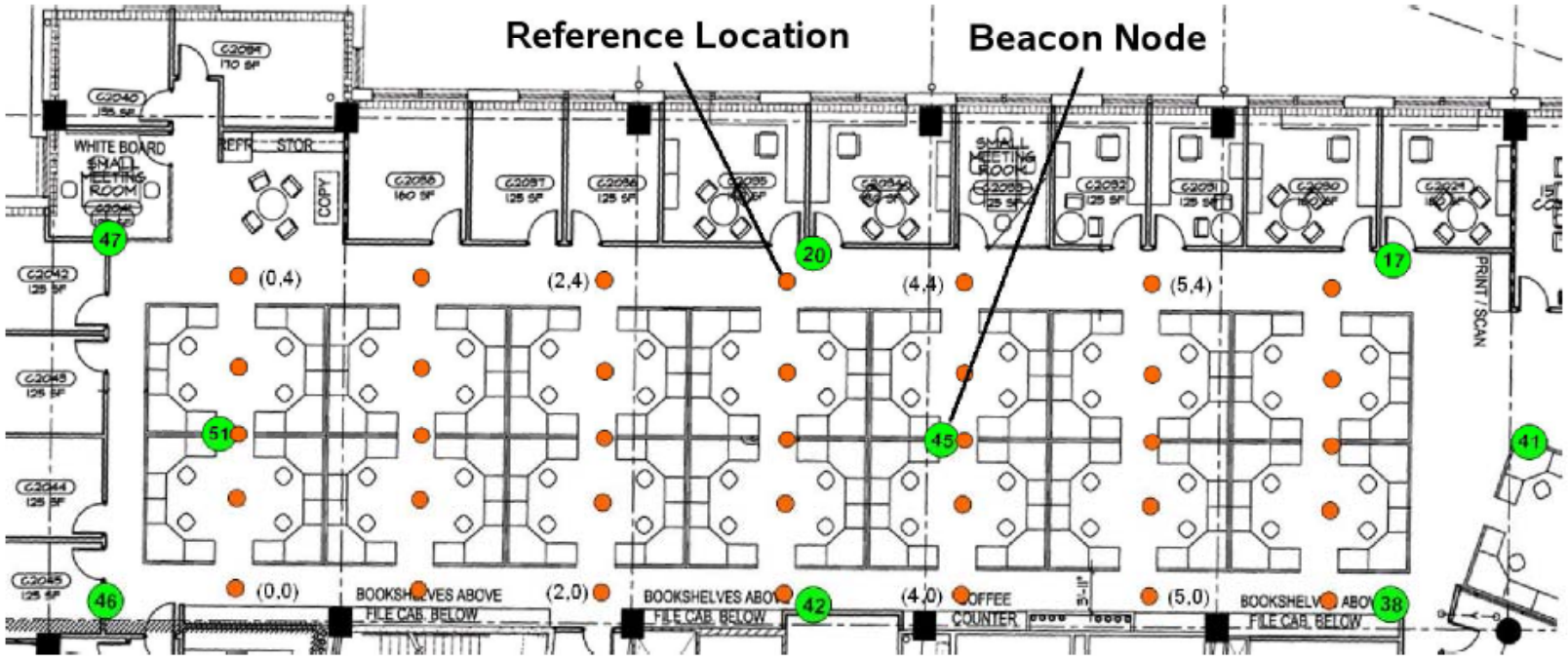
Experimental Setup



- 3 site surveys (42,000 packets each)
  - Night Survey, Day Survey, 1 month later
  - 4 Directions Through Body
- 35 Reference Points
- 9 Beacon Nodes

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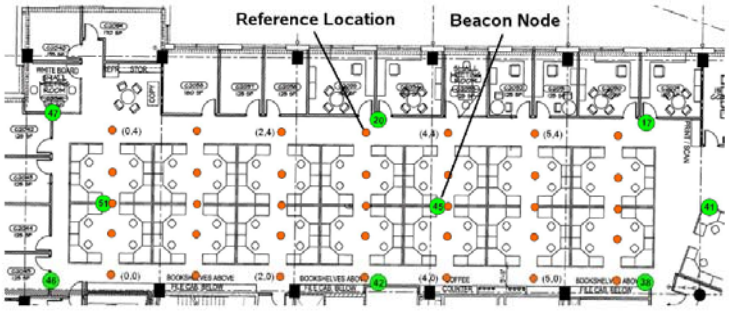
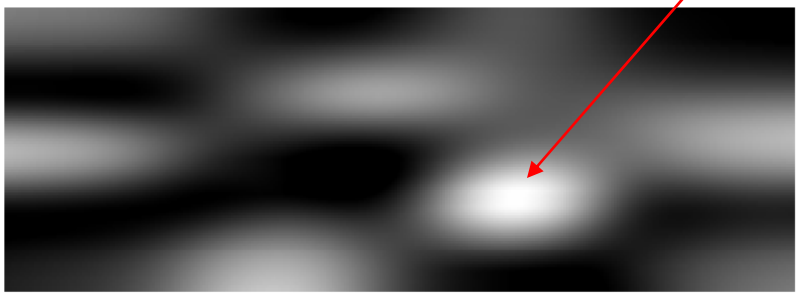
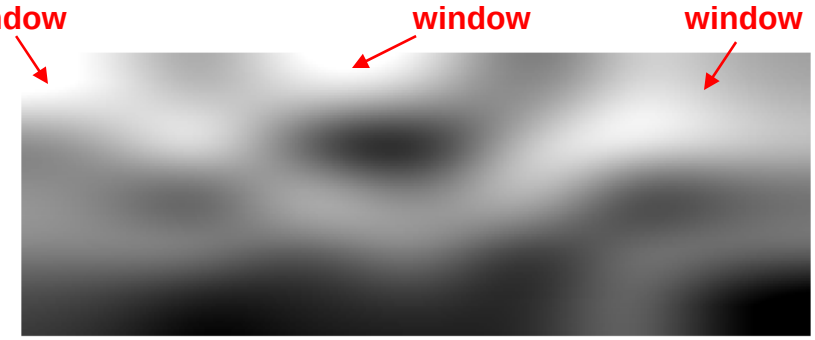
Example Micro-Climates



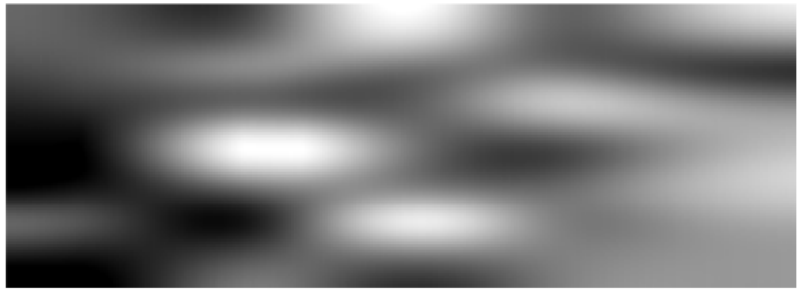
Floor Plan



Temperature Map

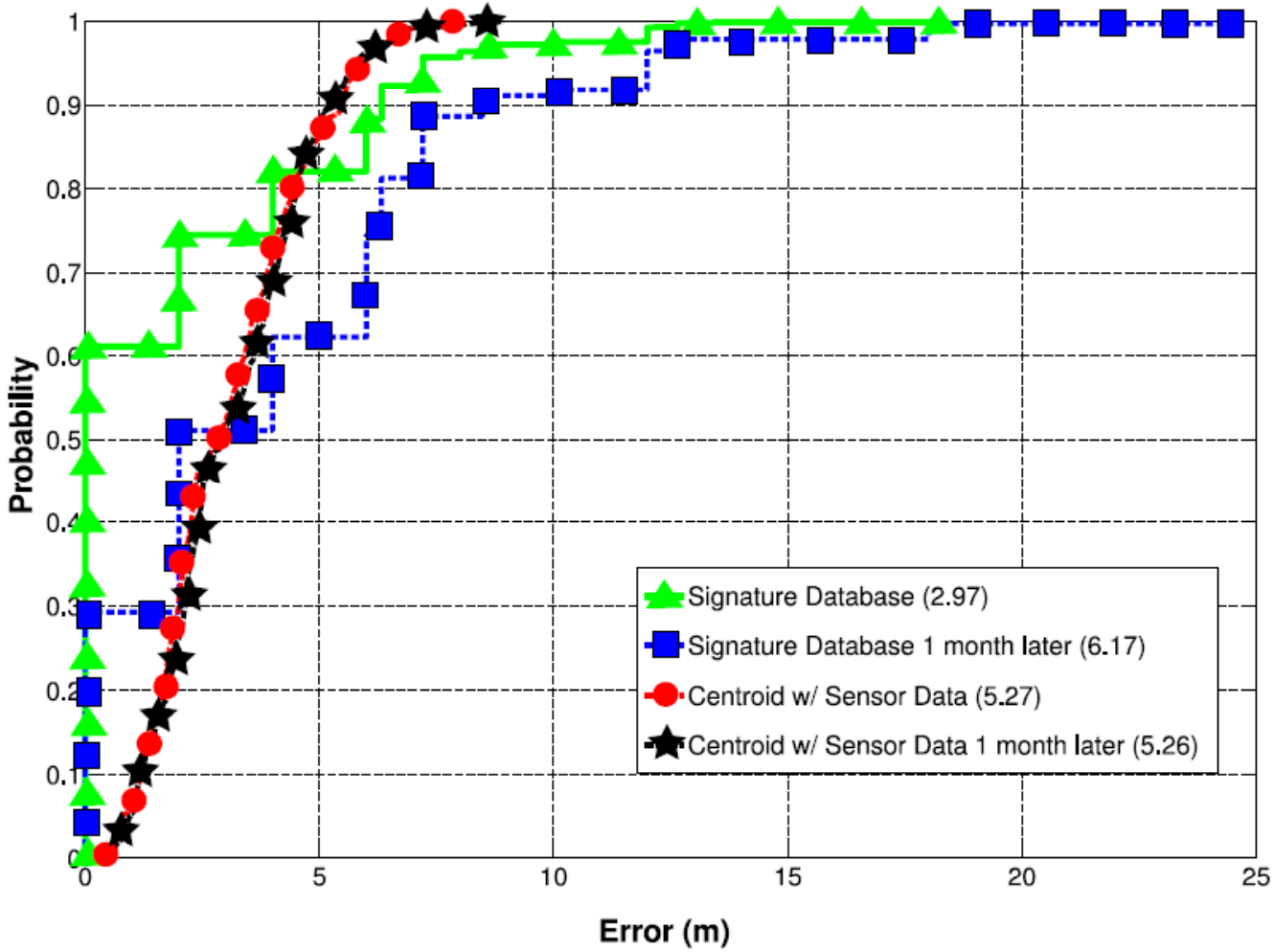


Light Map

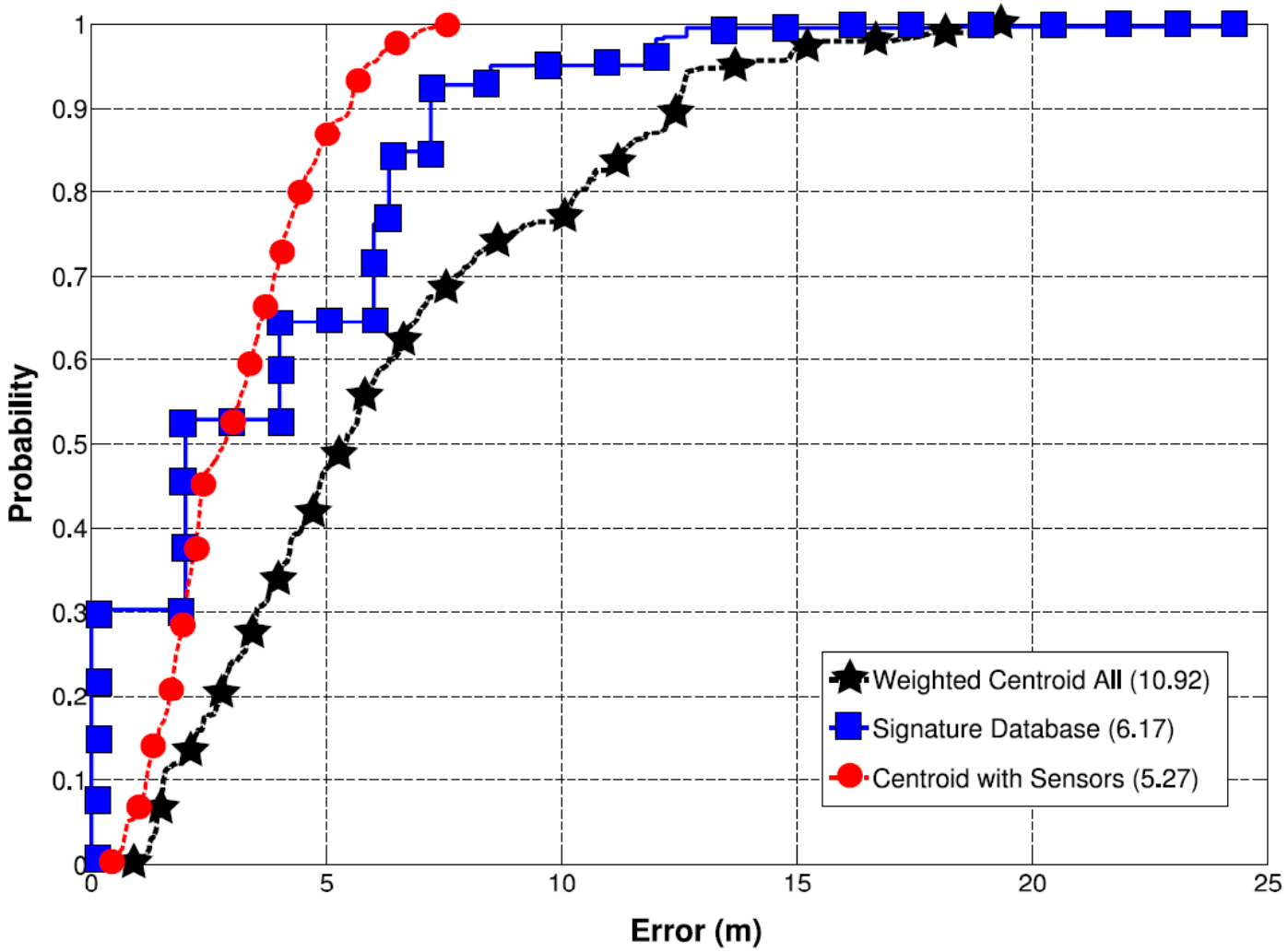


Humidity Map

How does performance change with time?



Centroid , Signature Database, Centroid + Sensors



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Conclusions

- **Micro-Climates Improve Accuracy of RSSI triangulation approaches**
  - **Signature database approaches deteriorate over time**
- **Sensors may already be available**
- **No Worse than Original RSSI based scheme**
- **Adapts to environmental changes nearly instantly**
- **Scalable Distributed Operation**