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

Location (a)  Location (b)  Location (c)

Mobile Node

Beacon Nodes

Correlation Error
Weighted Centroid + Sensors

Beacon at known fixed coordinate

[ -25, 0.02 ]
[ -15, 0.85 ]
[ -20, 0.05 ]
[ 5, 0.12 ]

[ RSSI, Sensor Correlation ]
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FireFly 2.0 Node

Development Interface

Energy Harvesting

Vision Sensor

eWatch

Time Synchronization

Various Sensors

Electrical & Computer Engineering
FireFly 2.2 Node

- Light
- 3 Axis Acceleration
- PCB Antenna
- CC2420 802.15.4 Radio
- Temperature
- Audio
- MiniSD slot
- ATmega1281 128K Flash 8K RAM, 8 MHz
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
Example Micro-Climates

Floor Plan

Temperature Map

Light Map

Humidity Map

Server Machines
How does performance change with time?
Centroid, Signature Database, Centroid + Sensors
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