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Presented by: Vikram P. Munishwar
Outline

- Introduction
- The MiNT-2 Node Architecture
- RFID-based Localization
- Experimental Evaluation
- Conclusion & Future Work
Introduction

- Two predominant techniques for wireless protocols development and evaluation:
  - Simulations (NS2, QualNet, GlomoSim)
    - Difficult to capture real-world RF propagation characteristics such as: *Non-uniform path loss, interference, multipath fading*
  - Large-scale, custom-built testbeds (Roofnet, CMU Network)
    - *Limited scenarios, large physical-space requirement, expensive for setup and routine maintenance*
Small-scale testbeds

- **MiNT (Miniaturized Network Testbed):**
  - Originally developed at the *Stony Brook University*
  - Combines benefits of both simulations and large-scale testbeds

- **Architectural Features:**
  - **Mobility:** by mounting embedded computing boards on robots
  - **Miniaturization:** using RF attenuation & Tx-power control
Small-scale testbeds

- ORBIT
  - Topology formation: Explicit noise-injection to control pair-wise SNR
  - Mobility: based on migration of execution state

- Mobile Emulab
  - Motes mounted on robotic platforms
  - Needs manual recharging of robots

- CMU Wireless Emulator
  - Emulation of RF propagation (FPGA based DSP Engine)
  - Performance depends on accuracy of models
Localization Techniques

To accurately estimate the nodes positions for:
- Automatic topology formation & reconfiguration
- Providing fairly accurate node mobility

Vision based localization
- Cameras mounted on ceiling
- High accuracy when calibrated
- However, inaccuracy may grow over time due to:
  - Slight camera movements
  - Fading of color patterns

Infrared/Ultrasonic localization
- Expensive in terms of the cost and processing capacity required
- Needs line-of-sight
Contributions

**MiNT-2**: The next generation of the original MiNT testbed.

- **Node design:** Reproducing the testbed using efficient but inexpensive hardware
- **Decentralized localization:** RFID-based localization mechanism
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The MiNT-2 Node
(Architecture)
The MiNT Node

(Mobility & Miniaturization)

- **Mobility base:** Create robot
  - Wide range of 2D mobility:
    - Forward and reverse straight lines, Arcs of arbitrary radius, Rotation in place
  - Well-powered
    - Up to 4 hours of battery life

- **Miniaturization:**
  - 20dB fixed attenuator
  - Transmission power control
The MiNT Node
*(Processing)*

- Soekris net5501 x86 embedded board
- 433MHz processor
- 256MB RAM
- 2GB Flash card
- Support for external router board
The MiNT Node

(Wireless Communication)

- One 802.11g interface used for control
- Up to four simultaneous 802.11a interfaces for experiments
The MiNT Node
(Localization Hardware)

- **RFID**: Radio Frequency Identification
  - *Passive* RFID technology
  - Short-distance reading range
  - Inexpensive tags and readers

- **RFID Reader**
  - mounted on the base of each robot
  - Connected via serial interface to the Soekris board

- **RFID Tag**
  - Array of tags on floor
  - Each RFID tag is associated with $(x,y)$ coordinate

- **Error margin for position estimation**: 2.25cm
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RFID-based Localization
(Motivation)

- Localization support from iRobot Create
  - Angle and distance sensors (readings w.r.t. last query)
  - Significant inaccuracies due to:
    - rounding error,
    - wheel slippage,
    - encoder error

Thus, a need for additional localization mechanism.
RFID-based Localization
(Advantages)

- Position error is bounded by the reading range of the tag
- Each node can independently determine its own position – thus, easily scalable
- Inexpensive in terms of processing and overall cost
- No line-of-sight requirement
RFID-based Localization

(Approach)

- Position calibration: upon tag detection
- Frequency of reading position sensors: 50 milliseconds
- Orientation calibration:
  - Necessary to estimate position between two tags

\[ \theta = (\tan^{-1}[(y_2 - y_1)/(x_2 - x_1)] + \theta_{\text{RFID}/2}) \mod 360 \]
RFID-based Localization

- Initial calibration:
  - To support dropping off of the robot at any place in the testbed
  - Cross two tags in a straight line to determine orientation
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The MiNT Node
*(Energy dissipation)*

**Idle:** 3 hours 55 minutes  
**Constant WiFi Transmission:** 3 hours 36 minutes  
**Constant Movement:** 2 hours 15 minutes
Experimental Evaluation

(RF Attenuation)
Experimental Evaluation

(Localization)

- Sensors-based vs RFIDs-based localization

Position error has been reduced to avg. 6cm with more recent improvements
Experimental Evaluation

(Localization)

- Effect of parameters: Robot velocity
Outline

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- Conclusion & Future Work
Conclusion & Future Work

- In this work, we proposed
  - Design and construction of MiNT-2 nodes
  - Design and development of RFID-based localization mechanism

- In future, we plan to
  - Improve the accuracy of the localization technique
  - Automatic topology formation
  - Fault injection support
Thank you!
Questions?
The MiNT Node

(Processing)

- Operating System: Voyage Linux
  - Debian-based, light Linux distribution
  - Preconfigured for Soekris net5501
  - Designed to run off a Compact Flash card
    - Optimized to minimize writes

- Distributed, hybrid NS2
  - Pass packets over physical network interfaces
  - Maintain ability to run NS2 scripts
## The MiNT-2 Node

### (Cost)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>iRobot Create with battery and charger</td>
<td>$250</td>
</tr>
<tr>
<td>Soekris net5501 x86 embedded board</td>
<td>$260</td>
</tr>
<tr>
<td>PCI to 4x miniPCI adapter card</td>
<td>$65</td>
</tr>
<tr>
<td>4x R52 802.11a/b/g cards</td>
<td>$200</td>
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<tr>
<td>4x antennae</td>
<td>$60</td>
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<tr>
<td>3x attenuators</td>
<td>$100</td>
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<td>ID-12 RFID reader</td>
<td>$30</td>
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<tr>
<td>Small miscellaneous components</td>
<td>$35</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$1000</strong></td>
</tr>
</tbody>
</table>
Experimental Evaluation
(Sensors Accuracy)

- Distance Sensor

![Graph showing position error vs. distance between tags.](image)

- RFID tags deployment: Uniform
- Straight line movement
Experimental Evaluation
(Sensors Accuracy)

- **Angle Sensor**

- RFID tags deployment: Pyramid-like structure
- Straight line movement from the tip to the base
Experimental Evaluation

(Localization)

- Effect of parameters: frequency of updates