Challenges of Large-Scale Smart Home Studies

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Electrical Mains
Water Mains
More than:
1200 Sensors
20 Homes
1 year
Indoor Sensor Networks?

Outdoor Deployment

Indoor Deployment

Photo courtesy of: Jan Beutel
# Sensors > # Outlets
# Homes > # Researchers
# Days > ~1 month
Scaling #Sensors
Homes are Not a Power Panacea

- 30-40 outlets per house
- Long wires
- 2.3x more down time than batteries
- More maintenance calls
Homes Have Poor Connectivity

- **Wireless connectivity**
- **Power line communications**
  - Wires
  - 180bit/s
  - 5 min polling rate

Exploiting Home Automation Protocols for Load Monitoring in Smart Buildings
COTS Are Double-edged

Internet

Central Database

Thermostat

Temperature Sensors

Light Switches

Relay Machine

Doorway Sensors

Internet

Central Database

Thermostat

Temperature Sensors

Light Switches

Relay Machine

Doorway Sensors
Scaling #Homes
Homes are Remote Environments

• Minimize installation time
  – Scout
  – Lab assembly and configuration
  – Checklists
Scaling #Days
Expect Limited User Participation

- Button Tracking
- Wearable Tracking
- Self-reporting
- Surveys
Aesthetics Matter in Homes

• Disappear into the woodwork
• Leave no trace
• No LEDS at night
• Noise
Homes are Hazardous Environments

- Children
- Mobile objects
- Roomba
- Guests and cleaning services
Summary of Challenges

• AC Power is not abundant or reliable
• Wireless connectivity is worse than expected
• COTS are a double-edged sword
• Houses are remote environments
• User participation is limited
• Aesthetics are important
• Unexpected environmental hazards
Credits and Questions
## Root Failures

<table>
<thead>
<tr>
<th>Root Cause</th>
<th>House G</th>
<th>House H</th>
<th>House I</th>
<th>House J</th>
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<tbody>
<tr>
<td>Sensing sub-system</td>
<td>4107</td>
<td>642</td>
<td>4757</td>
<td>274</td>
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<tr>
<td>Gateway Down</td>
<td>5596</td>
<td>0</td>
<td>3</td>
<td>136</td>
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<td>Plug Disconnected</td>
<td>509</td>
<td>30</td>
<td>474</td>
<td>10</td>
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<tr>
<td>Battery Dead</td>
<td>452</td>
<td>17</td>
<td>168</td>
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<tr>
<td>Wireless Link Loss</td>
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<td>122</td>
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<tr>
<td>Internet Down</td>
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<td>9</td>
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<tr>
<td>Power Outage</td>
<td>21</td>
<td>0</td>
<td>87</td>
<td>2</td>
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</table>
Fault Analysis

Central Database

Internet

Thermostat

Relay Machine

Temperature Sensors

Doorway Sensors

Light Switches

Central Database

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Fault Analysis

Sensor-Days – down time × number of sensors
Fault Analysis

- Hard drive failure
- Sub-system failure
- Plug disconnections

Reinstall