A Tagging Solution to Discover IoT Devices in Apartments

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Agenda

- Motivation
- Tag models
- Implementation
- Evaluation
- Future work
Motivation
More IoT Devices at Home...

- Smart homes use IoT devices to improve the occupants’ lives.
- As of 2021, 43% of households in the U.S. own a smart device, increasing from 33% in 2019.
Multi-User Smart Homes

Example: rental apartment

- Device owners are not always the users (e.g., landlord vs. tenant).
- Increasing number of devices installed by different people are harder to manage.
- Specific IoT devices can exist out of sight.
How to manage IoT devices from users’ perspectives?

● Discover and locate
  ○ Any IoT devices in the home whether on or off
  ○ WiFi, Zigbee, ...

● Identify and inventory
  ○ Detailed information about the device (e.g., type, vendor, user review, security features, ...)

● The solution must be easy and cheap to use
Our Contribution

- A tagging implementation for discovering and identifying hidden IoT devices
- A user study on the tags that focuses on participants’ comfort levels and price acceptability
- An analysis of our wireless tagging solution’s feasibility
Tag Models
Threat Model

Collaborative setting

- Landlords are willing to introduce the tenants to the loop of managing the devices to use.
- Vendors want to improve public relationship by implementing privacy-friendly products.
Wireless Tags

Different ranges and different power consumptions

- BLE
- UWB
- NFC
Privacy: Two Modes, Two Purposes

- **Discover and locate**
  - Longer detection distance
  - Direction information to the device
  - Not reveal detailed device information

- **Identify and inventory**
  - Only the user can access the detailed device information.
  - Proximity requirement
Two-Tag Model

Two-tag model balances utility and privacy

- **Location mode**
  - BLE with buzzer (i.e., BLE-AC)
  - UWB (i.e., UWB-RAW)

- **Inventory mode with NFC**
  - Detailed device information is stored in the NFC tag.

Tag reader

- Smartphone for BLE and NFC
- UWB adapter connected on smartphone for UWB
Implementations
Tag Models

- **BLE-AC**
  - ItsyBitsy nRF52840 Express with a buzzer

- **UWB-RAW**
  - DWM1001-DEV
Tag Reader App: DIAL

Location Mode

5.38

Devices Found: 2

<table>
<thead>
<tr>
<th>MAC</th>
<th>Distance</th>
<th>Locate</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE:AF:81:39:97</td>
<td>More than 2 meters away</td>
<td>Activate Sound</td>
</tr>
<tr>
<td>BA:88:EF:9C:66</td>
<td>More than 2 meters away</td>
<td>Activate Sound</td>
</tr>
</tbody>
</table>

Inventory Mode

Device URL: shorturl.at/cqBEI
Evaluation
# Accessibility: Cost and Battery Life

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Price</th>
<th>Battery Life Minimum (6000 mAh)</th>
<th>Battery Life Maximum (9000 mAh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLE-AC</td>
<td>$21.66</td>
<td>250 days</td>
<td>375 days</td>
</tr>
<tr>
<td>UWB-RAW</td>
<td>$20.26</td>
<td>3.3 days</td>
<td>5 days</td>
</tr>
</tbody>
</table>
Battery Life Clarification

- UWB-RAW is designed to be an anchor point instead of turning off UWB when unused.

- BLE-AC consumes less than one milli amperes, but our power meter could not read less than that.
Usability of Tags

Tag hunt trials with 23 users

<table>
<thead>
<tr>
<th></th>
<th>UWB-RAW (s)</th>
<th>BLE-AC 1 (s)</th>
<th>BLE-AC 2 (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg.</td>
<td>51.44</td>
<td>22.63</td>
<td>25.62</td>
</tr>
<tr>
<td>Std.</td>
<td>13.59</td>
<td>8.93</td>
<td>22.08</td>
</tr>
</tbody>
</table>

They found our tag models easy to learn and use.
System Usability Scale (SUS)

<table>
<thead>
<tr>
<th>Question</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think that I want to use this system frequently.</td>
<td>4.43</td>
</tr>
<tr>
<td>I found the system unnecessarily complex.</td>
<td>1.30</td>
</tr>
<tr>
<td>I thought the system was easy to use.</td>
<td>4.78</td>
</tr>
<tr>
<td>I think that I would need the support of a technical person to be able to use this system.</td>
<td>1.61</td>
</tr>
<tr>
<td>I found that the various functions in this system were well integrated.</td>
<td>4.74</td>
</tr>
<tr>
<td>I thought there was too much inconsistency in this system.</td>
<td>1.35</td>
</tr>
<tr>
<td>I would imagine that most people would learn to use this system quickly.</td>
<td>4.52</td>
</tr>
<tr>
<td>I found the system very cumbersome to use.</td>
<td>1.48</td>
</tr>
<tr>
<td>I felt very confident using the system.</td>
<td>4.74</td>
</tr>
<tr>
<td>I needed to learn a lot of things before I could get going with this system.</td>
<td>1.56</td>
</tr>
</tbody>
</table>

- Our lowest-scored question is whether the user can interact with this system without a technical person.
- The second lowest-rated question is if the user would use this system frequently.
Future Work

● Evaluation for skyscrapers or stadiums

● Additional user study:
  ○ Price acceptability
  ○ Landlord or vendor willingness to tag the devices

● Add low-power configured BLE to inventory mode
Q & A