Improving Power Efficiency Using Sensor Hub Without Re-Coding Mobile Apps

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Continuous sensing apps provide a wide range of services

BeWell, Acoustic: Lifestyle monitoring

Ambulation: Healthcare monitoring

MobiPerf: Participatory sensing
but are huge energy consumers...

Locale app, $10
Why consume so much energy?

10.00s: (0.1, 0.2, 9.8)
10.02s: (-0.2, 0.1, 9.8)
10.04s: (-0.3, -0.2, 9.7)

……
……
……
10.56s: (-4.2, 2.1, 9.5)
Low power dedicated sensor hub

How to use the sensor hub?
MobileHub: rewriting existing apps

- Sensor Hub: simply buffering
- App: use sensor hub without re-coding

Use information flow tracking to figure out buffer size
MobileHub: Three Components

• Information flow tracking
  – Study how apps use sensor data

• Protocol, API, and policies design
  – Provide an easy-to-use toolkit for developers

• Re-architecting the OS and rewriting the apps
  – Enabling sensor hub in the mobile system
Overview

Instrument taint tracking

Learn sensor usage pattern

Rewrite binary to leverage sensor hubs appropriately

Modified, energy-efficient Version of the same app
Data flow tracking

• Adapt TaintDroid system to track explicit information flow
  – Taint source: all different types of sensors
  – Taint sink: UI update, send to network and save to disk
Control flow tracking: instrumentation

1: void onSensorChanged(SensorEvent value) {
2:     avg = (value.x+value.y)/2;
3:     if (avg > THRESHOLD) {
4:         stepCounter++;
5:         updateUI(stepCounter);
6:     }
7: }
Control flow tracking: instrumentation

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Control flow tracking: instrumentation

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5:     taint(stepCounter);
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Control flow tracking: instrumentation

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2:     avg = (value.x+value.y)/2;
3:     if (avg > THRESHOLD) {
4:         stepCounter++;
5:         taint(stepCounter);
6:     }
7: }
```

Captured!
## Tainted fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Total fields</th>
<th>Total tainted fields</th>
<th>Data flow taint</th>
<th>Control flow taint</th>
</tr>
</thead>
<tbody>
<tr>
<td>nWalk</td>
<td>506</td>
<td>28</td>
<td>10.7%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Walking</td>
<td>497</td>
<td>12</td>
<td>66.7%</td>
<td>58.3%</td>
</tr>
<tr>
<td>Pedometer</td>
<td>304</td>
<td>27</td>
<td>11.1%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Pedometer Pro</td>
<td>689</td>
<td>27</td>
<td>44.4%</td>
<td>66.7%</td>
</tr>
<tr>
<td>Universal</td>
<td>440</td>
<td>8</td>
<td>87.5%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Step Counter</td>
<td>685</td>
<td>5</td>
<td>20.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Simple Steps</td>
<td>125</td>
<td>18</td>
<td>38.9%</td>
<td>61.1%</td>
</tr>
</tbody>
</table>
Pedometer Pro
API

boolean registerListener(
    SensorEventListener listener,
    Sensor sensor,
    int rate,
    int bufferSize,
    Conditions cond);

void unregisterListener(
    SensorEventListener listener,
    Sensor sensor,
    Conditions cond);
Policy

• Foreground
  – No buffering

• Background
  – Buffersize depends on different condition
  – Still / Walking / Running / …
Prototype

- Galaxy Nexus
  - Android 4.2.2
- Atmel AVR XMegA-A3BU
- Connection: USB On-The-Go
Energy consumption comparison

Percentage energy improvement

Mobility
No mobility

Pedometer
StepCounter
nWalk
Trace Comparison

![Bar chart showing percentage energy improvement for different users and devices: Pedometer, StepCounter, nWalk.](chart.png)
Conclusion

• Design and implementation of MobileHub

• An information flow tool that tracks data and control flows

• An evaluation that shows using MobileHub can achieve up to 80% power gain