PADA: Power-aware Development Assistant for Mobile Sensing Applications

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How do you optimize the power use?
Power-aware Development is Difficult!!

Extremely BURDENSOME due to REPETITIVE power evaluation
Mobile sensing applications make it more challenging!!
Suppose You Develop

*Transport Mode Tracker*

How to measure *power use* of mobile sensing apps in *real-life situations*?
Power should be evaluated in REAL-LIFE situations, REPETITIVELY!!
Making solitary swimming **EXCITING** and **ENJOYABLE**!
Survey of 46 professional mobile developers

**Age**
- 19 in their 20s
- 22 in their 30s
- 5 in their 40s

**Development experiences (years)**
- 12 with 0-2 years
- 6 with 2-4 years
- 14 with 4-6 years
- 7 with 6-8 years
- 7 with > 8 years

**Self-reported Skill**
- 78% are experts
- 23 are intermediate
- 10 are beginners

Survey of 46 professional mobile developers
Do you measure the power use of an application?

- No: 35%
- Yes: 65%

35% do not measure
When do you start considering the energy efficiency?

- Before full impl.: 30%
- No: 35%
- After full impl.: 35%

35% do not measure
35% measure after full implementation
How do you or your team measure the power? (Check all that apply)

- Battery level: 8 QA, 9 Developer
- H/W usage observation: 3 QA, 8 Developer
- Power monitor: 15 QA, 0 Developer
- I don’t know: 5 QA, 2 Developer
- No: 5 QA, 2 Developer
- Other: 1 QA, 1 Developer
Rank the power cost of screen, GPS, storage, and accelerometer.

- Correct: 25%
- Incorrect: 69%
- I don't know: 6%
Key Takeaways

Mobile developers mostly

• Perceive the energy efficiency very important
• Often fail to consider the power
• Use inconvenient, inaccurate methods
• Have limited understanding on energy use
PADA: Power-aware Development Assistant for Mobile Sensing Applications

- Facilitating **REPEETITIVE** power evaluation
- Supporting various **REAL-LIFE** situations
- Providing **ENRICHED** power information

http://static6.businessinsider.com/image/554ce87e69bedd9438d97cdd-1200-924/happy-programmer-work.jpg
We propose **PADA**, a system tool that assists power-aware development of mobile sensing applications.
PADA Architecture

- Sensor Trace Collector
- Developer
- APIs for power evaluation
- Power analysis result
- Context-labeled sensor trace
- App executables
- Evaluation settings
- Power emulator
- Emulation manager
- Power analyzer
- PADA front end
Approach: Context-driven Record & Replay

Output: power

H/W usage tracking

App execution

Sensor trace

Record

Replay
Power Emulator

Sensing app

Sensor Manager
BT/WiFi Manager
Location Manager

Sensor Emulator

trace

H/W Usage Monitor

Power Estimator

Alarm Manager

power data

Kernel
Power Evaluation Request
Web Demo: http://pada-web.github.io

Upload APK file

Select scenarios to test
In-depth Analysis
Web Demo: http://pada-web.github.io

In-depth analysis of oe5YBAcE on Trace 3

6 minutes

Thu Mar 03 2016 22:00:12 GMT+0900 (KST) ~ Thu Mar 03 2016 22:05:54 GMT+0900 (KST)

<table>
<thead>
<tr>
<th>Avg. power</th>
<th>Wakelock time</th>
<th>Alarm count</th>
<th>Idle Time</th>
<th>Accelerometer</th>
<th>GPS</th>
<th>Bluetooth</th>
</tr>
</thead>
<tbody>
<tr>
<td>134.01 mW</td>
<td>55.233 sec</td>
<td>45 times</td>
<td>255.031 seconds</td>
<td>39.955 seconds</td>
<td>10.378 seconds (3 times)</td>
<td>10.004 seconds</td>
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Power consumption over time
In-depth Analysis
Web Demo: http://pada-web.github.io

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<tr>
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Power Consumption (W)

Hardware use pattern
In-depth Analysis

Web Demo: http://pada-web.github.io

Avg. power 134.01 mW
Wakelock time 55.233 sec
Alarm count 45 times

Idle Time
- Accelerometer: 39.955 seconds
- GPS: 10.378 seconds (3 times)
- Bluetooth: 10.004 seconds

Power Consumption (W)

context and custom logs
Comparative Analysis
Web Demo: http://pada-web.github.io

Location interval
10sec? 20sec? 30sec?

<parameter.xml>
  <parameter type="location_interval">
    <value>10</value>
    <value>20</value>
    <value>30</value>
  </parameter>
</parameter>

<application code>
  interval = PADA.getParameterValue(
      "location_interval", "parameter.xml");
  requestLocation(GPS_PROVIDER, interval, 0, this);
</application code>
## Comparative Analysis

Web Demo: [http://pada-web.github.io](http://pada-web.github.io)

### Inter-Task Analysis: 6 tasks

<table>
<thead>
<tr>
<th>#3Aii07z</th>
<th>Avg. power</th>
<th>Wakelock time</th>
<th>GPS time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>162.09 mW</td>
<td>60.4 sec</td>
<td>18.5 sec</td>
</tr>
</tbody>
</table>

Trace #2 - Run outdoor 2 mins, Stay outdoor 3 mins
ALARM_INTERVAL = 10000, ACCEL = FASTEST

<table>
<thead>
<tr>
<th>#3Aii07za</th>
<th>Avg. power</th>
<th>Wakelock time</th>
<th>GPS time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>143.13 mW</td>
<td>43.8 sec</td>
<td>20.6 sec</td>
</tr>
</tbody>
</table>

Trace #2 - Run outdoor 2 mins, Stay outdoor 3 mins
ALARM_INTERVAL = 20000, ACCEL = FASTEST

<table>
<thead>
<tr>
<th>#3Aii07zb</th>
<th>Avg. power</th>
<th>Wakelock time</th>
<th>GPS time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>210.44 mW</td>
<td>97.7 sec</td>
<td>18.6 sec</td>
</tr>
</tbody>
</table>

Trace #2 - Run outdoor 2 mins, Stay outdoor 3 mins
ALARM_INTERVAL = 5000, ACCEL = FASTEST

<table>
<thead>
<tr>
<th>#3Aii07zc</th>
<th>Avg. power</th>
<th>Wakelock time</th>
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Power-aware implementation

Power Tuning
Power-aware Implementation: Experimental Setup

**Goal:** implement *iTrack* while meeting power requirements

14 programmers

3 hour-long development

*iTrack*: energy-efficient location tracker

<table>
<thead>
<tr>
<th>#</th>
<th>Traces [minutes, context]</th>
<th>Power requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[5, staying]</td>
<td>Duty_{CPU} \leq 20%, # of BT/GPS calls = 0, ...</td>
</tr>
<tr>
<td>2</td>
<td>[5, walking]</td>
<td># of BT calls = 1, # of GPS calls = 5, ...</td>
</tr>
<tr>
<td>3</td>
<td>[3, walking], [2, staying]</td>
<td>Duty_{ACC} \leq 15%, # of alarm calls \leq 50, ...</td>
</tr>
<tr>
<td>4</td>
<td>[5, staying]</td>
<td>Duty_{CPU} \leq 20%, # of BT/GPS calls = 0, ...</td>
</tr>
<tr>
<td>5</td>
<td>[5, walking]</td>
<td>Time_{BT} \leq 120s, # of GPS calls = 0, ...</td>
</tr>
<tr>
<td>6</td>
<td>[3, walking], [2, staying]</td>
<td>Duty_{CPU} \leq 40%, # of BT calls = 3, ...</td>
</tr>
</tbody>
</table>
Power-aware Implementation: Key Findings

Lowering burden of power evaluation

“While using PADA, I didn’t need to go out for testing GPS and I really liked it.” [P7]

Repeatability of power evaluation

Logical bug detection
Power-aware Implementation:  
*Key Findings*

Lowering burden of power evaluation

Repeatability of power evaluation

“When I saw the power report of my modified application, I realized that my modification was really bad. Without PADA, it could be harder to notice this mistake”  
[P9]

Logical bug detection
Power-aware Implementation:  
*Key Findings*

Lowering burden of power evaluation

Repeatability of power evaluation

Logical bug detection

*Two alarm services for periodic sensing of accelerometer and Bluetooth with the same identifier [P₁₂]*
Power Tuning: Experimental Setup

**Goal:** tune *SocioHotspot* to balance energy efficiency and accuracy

- **5 programmers**
- **select BT scan interval** with/without PADA

*SocioHotspot:* Social hotspot tracker with BT scanning
Power Tuning without PADA: Key Findings

Inconsistency of daily behavior

“I tried to move around similar to yesterday, but it was practically infeasible.” [PB]

Nontrivial burden

Limited result
Power Tuning without PADA: Key Findings

Inconsistency of daily behavior

Nontrivial burden

“It may need ten more days to find satisfactory values.” [PD]

Limited result
Power Tuning without PADA: Key Findings

Inconsistency of daily behavior

Nontrivial burden

Limited result

Due to own intuition and limited trials
Conclusion

• Challenge of power-aware development for mobile sensing applications
  • Repetitive power evaluation in real-life situations

• PADA: Power-aware development for mobile sensing applications
  • Context-driven record-and-replay

• We show the usability of PADA with two developer studies
THANK YOU

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