Green Mining and the Perils of Mining Energy Profiles

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http://softwareprocess.es/

with
Eleni Stroulia, Bram Adams, Ahmed Hassan, Daniel German
What is Green Mining?

Static Analysis

Dynamic Analysis

Tests!

Software Change

Corpus of test runs related to software changes
Green Mining's Goal

To reason about the energy consumption of source code changes based on a corpus of power regression tests.
Programmers are responsible for Software Power Use!

I should use more polling...

or less?
What about a spinlock..
In general, programmers lack knowledge about software energy consumption, but they are more knowledgeable about software energy consumption on mobile devices than on desktop computers.

http://webdocs.cs.ualberta.ca/~hindle1/2014/green-programmers/  
[Pang et al.]
how MOV [bufferloc], EAX turns into an expensive operation

Android, Flip that buffer!

Screen, Show this buffer instead!

The new buffer is brighter, I'll use more backlight
Android, Save this data!

I'll tell the sdcard about this later.
Android, Play this sound!

I'll spend the next feeding 4kb buffers to the sound card!

1n s

43 interrupts

Android

seconds

records

Active audio amplifier
Energy Profile of Single Versions

Chenlei Zhang and Daniel German
Energy Profile: Same test, Same Device
Energy Profile: Different device, different response

1_Suite 1000msg Joules
Errors

That silver band is the manufacturing error tolerance.
Errors

Multiple instances of the same model of phone will produce different measurements due to error tolerances in Manufacturing!

This implies a need for normalization and repeated tests!
Elaborate Job Queue
How does it work?

- Acts as a job queue.
- GreenMiner downloads jobs.
- TestbedDevice manages and measures a device's power use.
- TestDevice measures.
- Test executes job's test.
- Test in the queue.
Control the USB Connection

![Diagram showing a circuit with Arduino, TIP127, and USB connection components. The diagram illustrates the wiring connections with labels for Digital 4, GND, 1k, and the USB phone.]
Timeseries graph and Component Breakdown

Power Consumption for Test: 107.53J
Average Power Use (Entire Test): 0.860W
Maximum Power Consumption: 2.705W at 9.610s
Minimum Power Consumption: -0.215W at 0.019s
Aggregate Plotting

How does my energy profile change over time?
Aggregate by Component and Version! How does power use differ across scenarios and versions?
This colour is what happens
When you don't specify UI
Look and feel requirements.
## Per Component Breakdown

<table>
<thead>
<tr>
<th>Partition</th>
<th>Time</th>
<th>Joules</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wait for Wattlog</td>
<td>9.08s</td>
<td>5.99J</td>
<td>0.659W</td>
<td>1.260W at 1.218s</td>
<td>-0.215W at 0.019s</td>
</tr>
<tr>
<td>Open Calculator</td>
<td>8.70s</td>
<td>8.23J</td>
<td>0.946W</td>
<td>2.705W at 9.610s</td>
<td>0.601W at 14.732s</td>
</tr>
<tr>
<td>6.3 Gallons to L</td>
<td>15.18s</td>
<td>13.12J</td>
<td>0.864W</td>
<td>1.638W at 28.346s</td>
<td>0.606W at 18.593s</td>
</tr>
<tr>
<td>32 Miles to km</td>
<td>14.33s</td>
<td>12.30J</td>
<td>0.859W</td>
<td>1.645W at 42.333s</td>
<td>0.607W at 47.201s</td>
</tr>
<tr>
<td>150 CDN to USD</td>
<td>13.34s</td>
<td>11.47J</td>
<td>0.860W</td>
<td>1.655W at 55.831s</td>
<td>0.608W at 60.579s</td>
</tr>
<tr>
<td>$120 After GST (5%)</td>
<td>13.16s</td>
<td>11.37J</td>
<td>0.864W</td>
<td>1.564W at 64.794s</td>
<td>0.610W at 62.529s</td>
</tr>
<tr>
<td>Quadratic Equation x^2 + 2x - 2 = 0</td>
<td>40.68s</td>
<td>36.71J</td>
<td>0.902W</td>
<td>1.693W at 106.599s</td>
<td>0.598W at 76.831s</td>
</tr>
<tr>
<td>Exit &amp; Wait</td>
<td>10.55s</td>
<td>8.36J</td>
<td>0.792W</td>
<td>1.761W at 116.764s</td>
<td>0.612W at 116.251s</td>
</tr>
</tbody>
</table>

### Info

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Power Supply</th>
</tr>
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<tr>
<td>Current Sense</td>
<td>ina219</td>
</tr>
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</table>

### Statistic

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Charge</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Battery Health</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Battery Temperature</td>
<td>33°C</td>
<td>33°C</td>
</tr>
<tr>
<td>Airplane Mode</td>
<td>On</td>
<td></td>
</tr>
</tbody>
</table>
Sometimes we need to debug the tests with some context.

<table>
<thead>
<tr>
<th>Description</th>
<th>Power Source</th>
<th>Current Sense</th>
</tr>
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<tr>
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</tr>
<tr>
<td>Battery Temperature</td>
<td>33°C</td>
<td>33°C</td>
</tr>
<tr>
<td>Airplane Mode</td>
<td>On</td>
<td>1</td>
</tr>
<tr>
<td>Wireless</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERL-EMPLAB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplicant state: COMPLETED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSSI: -47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Link speed: 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net ID: 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metered hint: false</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bluetooth</td>
<td>Off</td>
<td></td>
</tr>
<tr>
<td>Screen Auto Brightness</td>
<td>Disabled</td>
<td></td>
</tr>
<tr>
<td>Screen Brightness</td>
<td>120/255</td>
<td></td>
</tr>
<tr>
<td>Screen Timeout</td>
<td>30s</td>
<td></td>
</tr>
<tr>
<td>Haptic Feedback</td>
<td>Disabled</td>
<td></td>
</tr>
<tr>
<td>OS Version</td>
<td>4.2.2</td>
<td></td>
</tr>
</tbody>
</table>
Green Miner is an enabler

- Continuous Integration and Testing for Energy Regressions
- Repeatable, logged, measurable framework.
- Enables asking of questions and repeating experiments.
- Some examples to follow
Ads in the browser use power

Network I/O

Events

reporting back home and updates

Hardware

Screen and memory

Animations

BUY

BUY

BUY

BUY
Does Adblocking Save Power?

AdBlock Plus and implement /etc/hosts files can save power!

Adblock Saves power Versus Nothing or very large /etc/hosts files

[GREENS 2014]
Does Adblocking Save Power?

Adblocking saved 0.01 to 0.06W per test (~5J every 100 seconds)

[GREENS 2014]
Which UI Theme would use More Power?

White on Black UI Theme

Black on White UI Theme
Mean Power Consumption (watts)
What Causes Software Power Use?

- Applications
- C library functions
- System calls
- Kernel

[Aggarwal et al.]
What causes Software Power Use?

Syscalls matter but Syscalls can always Vary per run of the Same test!

[Aggarwal et al.]
What causes Software Power Use?

If the system call profile changes significantly from the previous version, it is probable (~50%) that the application’s energy consumption profile has changed as well.
What causes Software Power Use?

- Rule of thumb model:
  If a cumulative count of a syscall changes significantly between versions there's a good chance of a significant change in power use and energy consumption!

<table>
<thead>
<tr>
<th>sendto</th>
<th>0</th>
<th>0</th>
<th>0.89</th>
</tr>
</thead>
<tbody>
<tr>
<td>stat64</td>
<td>1.00</td>
<td>0.55</td>
<td>0.98</td>
</tr>
<tr>
<td>cacheflush</td>
<td>0.34</td>
<td>0.91</td>
<td>0.98</td>
</tr>
<tr>
<td>Sum of calls</td>
<td>0.35</td>
<td>0.72</td>
<td>0.96</td>
</tr>
<tr>
<td>Coin flip</td>
<td>0.11</td>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>fcntl64</th>
<th>0.04</th>
<th>0.10</th>
<th>0.94</th>
</tr>
</thead>
<tbody>
<tr>
<td>ioctl1</td>
<td>0.26</td>
<td>0.50</td>
<td>0.96</td>
</tr>
<tr>
<td>lstat64</td>
<td>0.08</td>
<td>0.60</td>
<td>0.95</td>
</tr>
<tr>
<td>Sum of calls</td>
<td>0.18</td>
<td>0.60</td>
<td>0.97</td>
</tr>
<tr>
<td>Coin flip</td>
<td>0.06</td>
<td>0.50</td>
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[Aggarwal et al.]
Does logging matter?

Buffering hides, delays and defers
The cost of IO

[Di Nardio et al.]
Does logging matter?

Buffering hides, delays and defers The cost of IO

[Di Nardio et al.]
Methodological Bottleneck

Applied Exhaustively to all revisions

Revisions are measured multiple times for stability
The Research Hurdle: Measuring every revision takes too long!
Pareto frontier: Most cost effective approximations per time spent
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Less revisions tested
Lower final accuracy

More revisions tested
Higher final accuracy
Pareto frontier: Most cost effective approximations per time spent

Half of the work
Small Difference in RMSE
Pareto frontier: Most cost effective approximations per time spent

Half of the work
Small Difference in RMSE
Pareto frontier: Most cost effective approximations per time spent

A third of the work
Small Difference in RMSE
Pareto frontier: Most cost effective approximations per time spent

1/3 to 1/20th of the Work
Larger Difference in RMSE
Pareto frontier: Most cost effective approximations per time spent
Green Mining Needs You

Got a question about power?

Looking for collaborators.

Green Miner is usable remotely.
Conclusions

1 measurement is not enough

Energy profiles change

Measurement Granularity

Software evolves, and forks, -- it's not always now.

http://greenmining.softwareprocess.es/

Green Miner is available
For collaboration!