An Analysis of Power Consumption in a Smartphone

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Motivation
Problem

- Where and how is power consumed in a smartphone?
- Approach: fine-grained instrumentation of a real device
Methodology

- **OpenMoko Freerunner**
  - 2.5G smartphone, c. 2008
  - 400 MHz ARM9
  - Lacking camera, 3G modem
  - Open design
  - Amenable to power instrumentation
Methodology

\[ I = \frac{V_d}{R} \]
\[ P = IV \]
Methodology
Methodology

- Instrumented components
  - CPU
  - RAM
  - GSM
  - GPS
  - Bluetooth
  - LCD panel
  - WiFi
  - Backlight
  - Audio codec
  - Amplifier
  - NAND flash
  - SD card
Benchmarks

- **Micro-benchmarks**
  - Suspend
  - Idle
  - Backlight
  - CPU/RAM
  - Flash storage
  - Network
  - GPS

- **Usage scenarios**
  - Audio
  - Video
  - SMS
  - Email
  - Web
  - Call
Idle Power

<table>
<thead>
<tr>
<th>Component</th>
<th>Power (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM</td>
<td>30</td>
</tr>
<tr>
<td>CPU</td>
<td>10</td>
</tr>
<tr>
<td>GPU</td>
<td>60</td>
</tr>
<tr>
<td>LCD</td>
<td>50</td>
</tr>
<tr>
<td>Rest</td>
<td>10</td>
</tr>
</tbody>
</table>

Suspend: 69 mW
Idle: 269 mW
Display Power

- GSM
- CPU
- Display
- Rest

Power (mW)

Backlight
Email

Total: 610 mW

Power (mW)

<table>
<thead>
<tr>
<th>Component</th>
<th>Power (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM</td>
<td>350 mW</td>
</tr>
<tr>
<td>CPU</td>
<td>50 mW</td>
</tr>
<tr>
<td>Display</td>
<td>150 mW</td>
</tr>
<tr>
<td>Rest</td>
<td>50 mW</td>
</tr>
</tbody>
</table>
Video

Total: 454 mW
Audio

Total: 320 mW
Validation

- Benchmarks repeated on two devices:
  - HTC Dream (G1)
  - Google Nexus One (N1)
- Total system power only
- 3-4 years of mobile technology
Validation

Graph showing the % power difference across various activities and devices:
- Suspend
- Idle
- Phone call
- Web (cell)
- Web (WiFi)
- Network (cell)
- Network (WiFi)
- Video
- Audio

Activities and devices are compared to two categories:
- G1
- N1

The chart illustrates the power differences across these categories for different activities and devices.
• Dynamic Voltage and Frequency Scaling
• DVFS reduces power
  … but does it reduce energy?
DVFS

% energy saving

Freerunner
G1
N1

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From imagination to impact
Conclusions

• Major consumers: display & cell radio
  - WiFi power low in most situations

• CPU can be significant
  - Future power driver

• Where power is not going:
  - RAM
  - Audio
  - Bluetooth
  - Storage
Conclusions

• Both dynamic and static power important
• DVFS hanging on (for now)
• Networking power not increasing