An Analysis of Power Consumption in a Smartphone

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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

- **GSM**: 50 mW
- **CPU**: 30 mW
- **GPU**: 80 mW
- **LCD**: 40 mW
- **Rest**: 20 mW

**Idle: 269 mW**

**Suspend: 69 mW**
Display Power

- **GSM**, **CPU**, and **Rest** have minimal power consumption compared to the **Display** which shows a significant portion dedicated to the **Backlight**.
CPU and RAM

100 MHz

400 MHz

Power (mW)

<table>
<thead>
<tr>
<th></th>
<th>equake</th>
<th>vpr</th>
<th>gzip</th>
<th>crafty</th>
<th>mcf</th>
<th>idle</th>
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<tbody>
<tr>
<td>100 MHz</td>
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<td>400 MHz</td>
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</table>

RAM

CPU

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Email

Total: 610 mW

- GSM
- CPU
- Display
- Rest

Power (mW)
Video

Total: 454 mW

Power (mW)

GSM

CPU

RAM

Display

Rest

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From imagination to impact
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

% power difference

-80 -60 -40 -20 0 20 40

Suspend  Idle  Phone call  Web (cell)  Web (WiFi)  Network (cell)  Network (WiFi)  Video  Audio

G1  N1
DVFS

- Dynamic Voltage and Frequency Scaling
- DVFS reduces power
  … but does it reduce energy?
DVFS

% energy saving

equake vpr gzip crafty mcf

Freerunner G1 N1

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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