Display Power Management Policies in Practice

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Introduction

- LCD Displays are major contributors to energy consumption.
- LCD and backlight together can draw 38% of system power.
- Display Power Management Policies
  - Determine when to toggle display
  - More aggressive policies can mean higher user annoyance
Display Power Management Policies

- Display Power Management Policies
  - Determine when to toggle display
  - More aggressive policies can mean higher user annoyance
  - How well do current DPM policies work?
  - How much better could an optimal DPM policy do?
  - How can current DPM policies be improved?
- Human Interface Device (keyboard/mouse) timeout
  - Widely Implemented across all Operating Systems
- User Presence Detection
  - Tries to improve upon HID timeout
Display Power Management Policies

• DPM on laptops lengthens battery life
• Desktops have larger displays that consume more energy
  o Desktop LCDs cannot be dimmed
• Wear-out costs associated with display toggling ignored.

<table>
<thead>
<tr>
<th>description</th>
<th>CPU type</th>
<th>LCD size</th>
<th>CPU idle</th>
<th>CPU busy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>LCD off</td>
<td>LCD dim</td>
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<td>desktop examples:</td>
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<tr>
<td>Dell Vostro 410</td>
<td>Intel E8400 3 GHz</td>
<td>22&quot;</td>
<td>63 W</td>
<td>92 (34%)</td>
</tr>
<tr>
<td></td>
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<td>laptop examples:</td>
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<tr>
<td>Lenovo T61</td>
<td>Intel T7500 2.2 GHz</td>
<td>14.1&quot;</td>
<td>13</td>
<td>14 (7%)</td>
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<tr>
<td>Dell Inspiron 8600</td>
<td>Intel Pentium-M 1.6 GHz</td>
<td>15.4&quot;</td>
<td>18</td>
<td>22 (18%)</td>
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<td>IBM Thinkpad 240</td>
<td>Intel Celeron 300 MHz</td>
<td>10.5&quot;</td>
<td>8</td>
<td>8 (12%)</td>
</tr>
</tbody>
</table>

average contribution of LCD to total laptop power: 12% 31% 21%

Figure 1: Total system power consumption in Watts for various system states. Fraction of power due to the LCD is reported in parentheses. Note that desktop LCD backlights typically cannot be dimmed.
Human Interface Device Timeout

- Powers down display after time interval elapses from last HID event
- Attentive if the time since last HID event is less than time interval
- Inattentive if HID event is greater than time interval
- Unable to distinguish between inattentive and user reading display
- Conservative interval of 5 minutes-default on Windows
User Presence Detection

• Sensor-based measurement of user presence.
• Sonar using laptop speakers
  o Speaker emits a ping
  o Microphone records the echo
• User detected by variation in the echo
  o High Variation corresponds to presence
  o Little Variation corresponds to absence
• Calibration
  o Readings taken when mouse is in motion--user presence
  o Adapts to changes in volume levels
  o Threshold lowered at irritation event
    ▪ Display powered off and immediately back on
  o Re-calibrated hourly
Implementation

- Sonar Power Manager
  - Works on Windows/Linux
  - Tests both HID and user presence policies
  - Either policy can turn off display
  - Uses minimal power and CPU time
    - Sonar sensing uses about 3% of CPU cycles on one core
User Study

• Users installed Sonar Power Manager
  o Posted to slashdot--10,000 downloads
• Some users logged sonar and power management events
• Logging data created
  o Start and End time of HID events
  o Irritation events
  o Value of sonar measurement
  o Time when logging starts and stops
• 3,738 hours of usage by 181 volunteers
  o 177 Windows users and 4 Linux users
Figure 3: CDF of installed time and logging time. The difference is the time that the computer was off or logging was disabled.
Idle and Active Periods

- Usage is a sequence of idle and active periods
- HID active—no more than one second between events
- HID idle—more than one second between events
Timeout Setting Distribution

Figure 6: Distribution of users’ HID timeout values.
Energy Savings

- Distribution of energy savings based on HID timeout
- Measure by fraction of time which display was shut off
  - Sleep fraction

(a) CDF of display energy savings achieved by the HID timeout policy.
Energy Savings

- Sleep fraction vs. timeout values
- Mean aggregate sleep fraction 51%
- Users chose own timeout values
Aggregate vs. Individual

• Aggregate
  o Joins collective data from all users
  o Each observation weighed equally
• Individual
  o Results computed for users first, then averaged across users
  o Each user weighted equally
• Since users provide different amounts of data, averaging methods give different results
Default Users

- Users who chose a timeout of two or three minutes had less irritation
- Five minute interval
  - Windows Default
  - Half the users
  - Irritation may be reduced by optimizing HID timeout setting

Figure 8: User irritation rate as a function of the user’s DPM timeout setting.
Default Users

- Some five-minute users would have deliberately chosen that value.

- Estimated by lognormal distribution
  - 21% deliberately choose 5 minutes
  - 79% by default

- Underestimated default users

![Graph showing distribution of timeout lengths with fit lognormal distribution parameters μ=2.56 and σ=0.693.](image)

*Figure 9: Distribution of deliberative users from Figure 6. The curve is fit to all users except those with the default five minute value.*
Energy Savings Upper Bound

Figure shows upper bound any DPM policy can achieve.

Display can be powered down when no HID input for given duration.

Predictive--knows idle time length.

Timeout--powers off display after certain duration.

Max energy savings 81%
User Presence Detection Policy Results

Users where sonar worked well

• HID timeout and sonar run together
• Either HID or sonar can turn off display
• Above diagonal HID timeout had more energy savings
• Users below diagonal presence detection yielded more energy savings
User Presence Detection Policy Results

- Energy Savings lost if sonar were disabled
- Presence detection contributes to 10% of energy savings for half of the users
- Presence detection doubled energy savings for 20% of users
Irritation Rates

- Higher irritation rates for Presence Detection
- Combined - good users
  - Combined policy where it is most effective
  - Tradeoff between energy savings and user irritation
  - Fewer irritation events than 2 per hour

Figure 13: CDF of irritation events per hour.
Characterizing Sonar

Calibrated by testing 10 different frequencies

Signal to Noise Ratio must be greater than 10.

Lower frequencies have higher SNR

Only 40% of machines are capable of producing adequate audio
Conclusion

- Maximum power reduction is 81%
- HID time-out saves 51% in energy
- Presence detection combined with HID timeout can save additional 10%
- Detection of Irritation Events
  - Timeout interval adjusted at irritation event to determine optimal time interval
- Future Research
  - dedicated biometric sensors
  - LED displays
  - Partially lit displays
  - Reduction in Visual Clutter
Questions?