Display Power Management Policies in Practice

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Summary

Motivation:

- Display power management is important and common
- No prior study of real-world performance

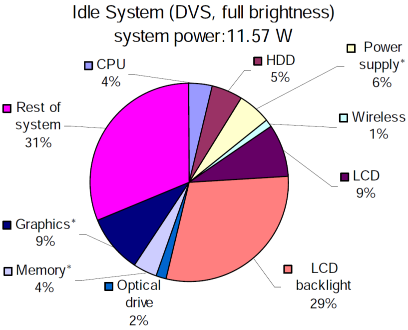
Method:

- Large-scale Internet study of DPM

Results:

- Total system energy saved by common policies
- Theoretical upper-bound on acheivable savings
- Additional savings acheived by a new policy
- Recommendations for OS designers

Display energy



(from Mahesri and Vardhan, PACS 2005)

- ~31% of total system energy is due to LCD
- Should be powered-off whenever user is inattentive
- Energy reduction is proportional to sleep time
- Energy saving mechanisms:
  - full power-off (this work)
  - backlight dimming (future work?)

Display Power Management (DPM) policies

Conflicting goals are to:

- maximize display sleep time
- minimize user irritation events

Policy's aggressiveness can be adjusted:

very aggressive		very conservative
power-off display often	$\leftrightarrow$	rarely power-off display
save lots of energy	$\leftrightarrow$	save little energy
often irritate user	$\leftrightarrow$	**rarely irritate user**

Human Input Device (HID) timeout

Standard policy:

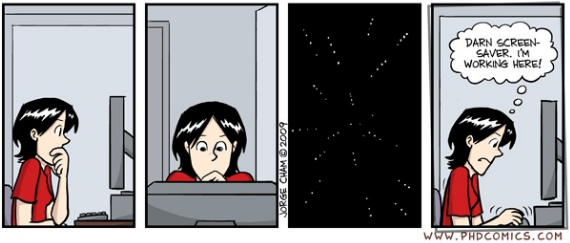
power-off display if mouse and keyboard are inactive for a specified **timeout** interval

Pros:

- simplicity
- few irritation events if timeout is long

Cons:

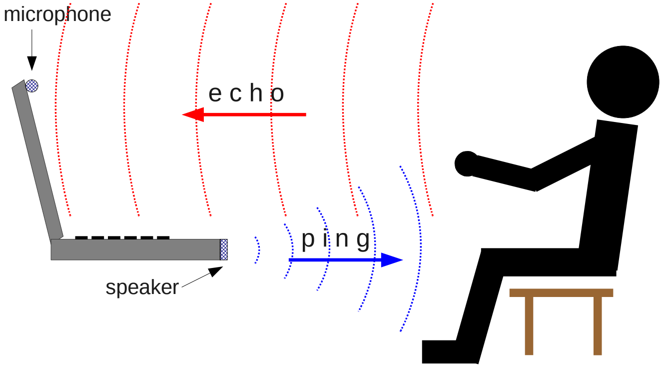
- missed energy saving opportunities
- many irritation events if timeout is short



Inherent tradeoff between energy savings and irritation

Active sonar user presence detection

- computer's speaker and mic
- inaudible ultrasonic tone (22 kHz)



Details in UbiComp'09 paper

User presence detection policy

Proposed policy:

- take sonar reading each second
- if five second sliding window average is lower than the threshold, then power-off the display.

Hypothetical pros:

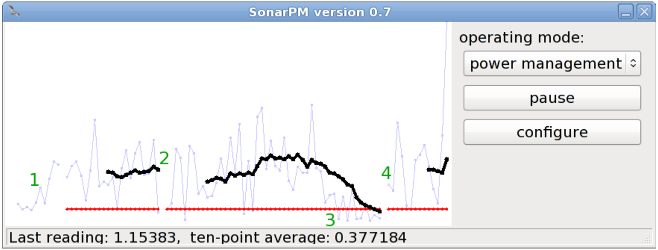
- more energy savings possible
- irritation events should not occur

Cons:

- more complex than HID timeout
- requires ultrasound-capable audio hardware (40% of population)
- measurement overhead

Implementation

Sonar Power Manager

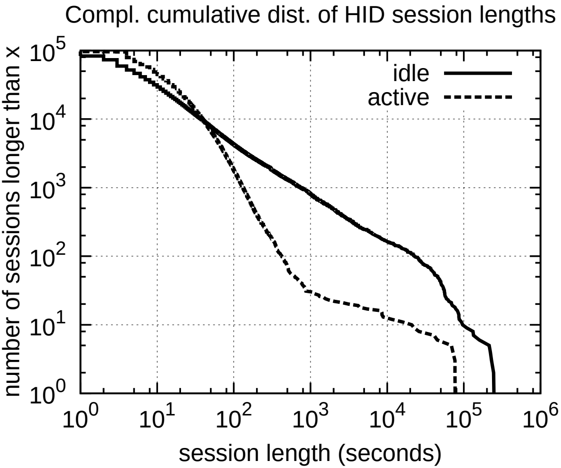


- implements both policies in parallel
- open source, compatible with Windows and Linux
- available at `http://empathicsystems.org`

User study

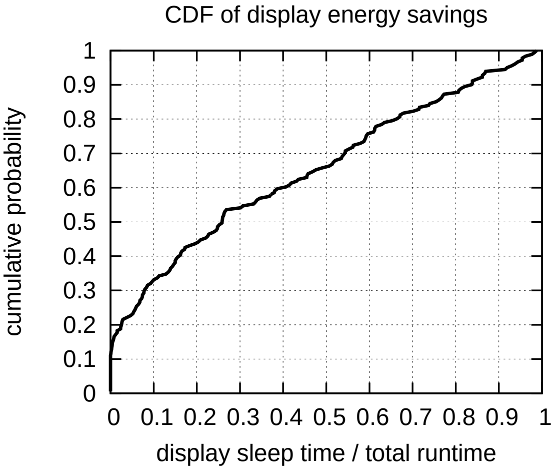
- press release on `slashdot.org`, Oct 15 2009
- downloaded over 10,000 times
- logged user input periods, sonar readings, and power management events (users can opt-out of logging)
- we retained 3,738 hours of usage logs by 181 volunteers

Idle/active periods



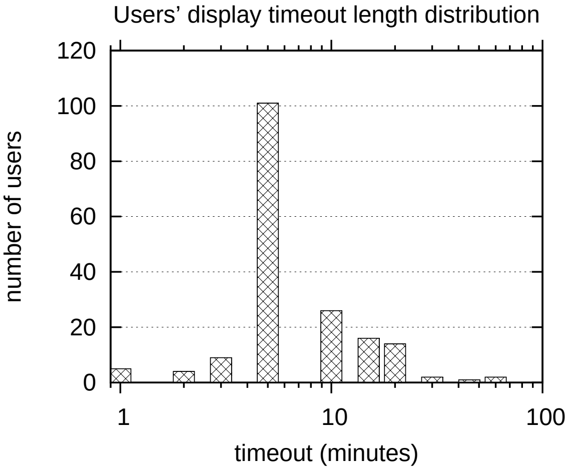
- idle periods follow power-law distribution
- predict idle period length based on memory property

HID timeout policy sleep times



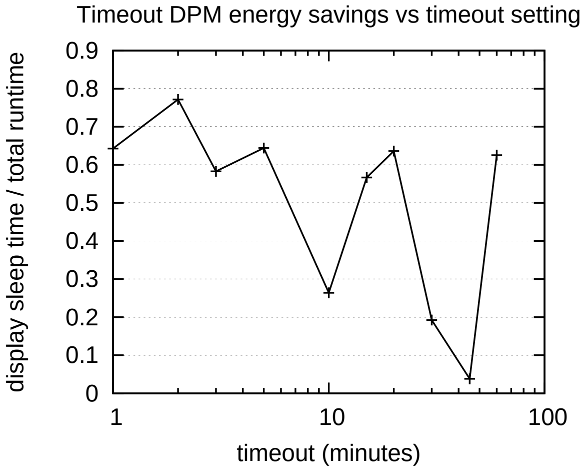
- energy savings varied widely among users
- DPM is critical for some “commonly absent” users

Timeout choice



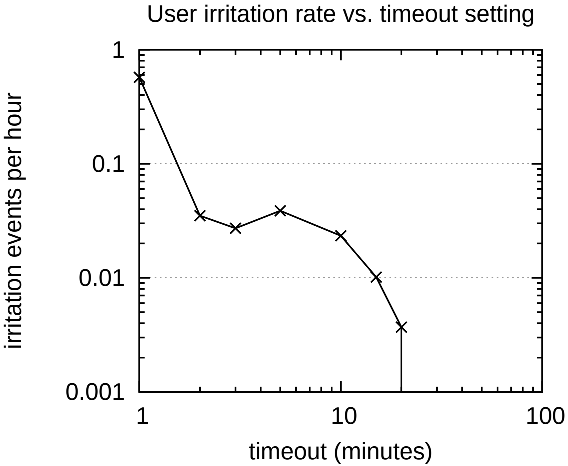
- lots of users at the Windows default timeout of 5 minutes
- users have varied preferences

Effect of timeout



- energy savings don't decrease monotonically with timeout!
- mean sleep fraction is 51%

Irritation rates

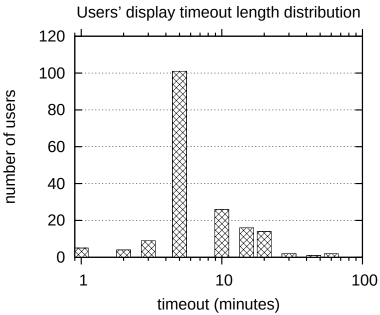


- irritation rates low for all timeout settings (except 1 min)
- surprising peak at 5 min

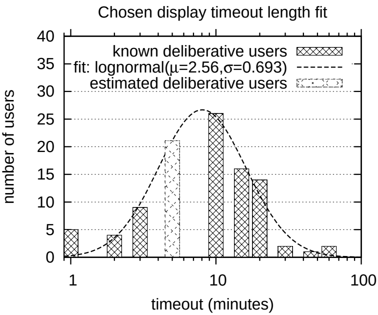
Default users

Projected number of "non-optimizing" users

Observation

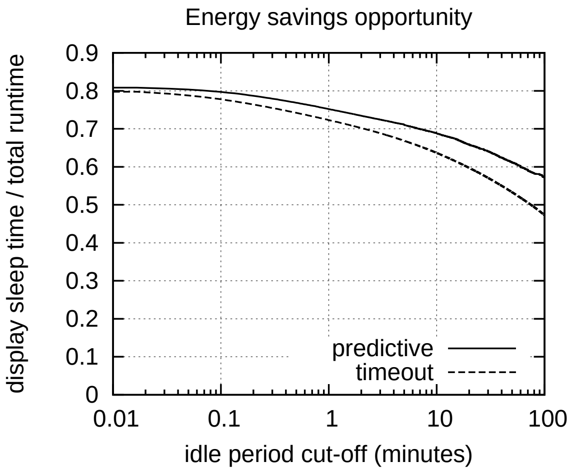


Interpolation



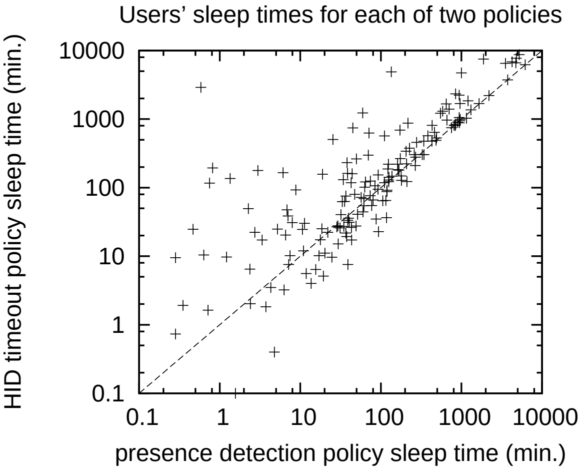
- projected 44% of all users did not adjust timeout
- forcing them to choose a timeout setting may reduce irritation

Savings upper bounds



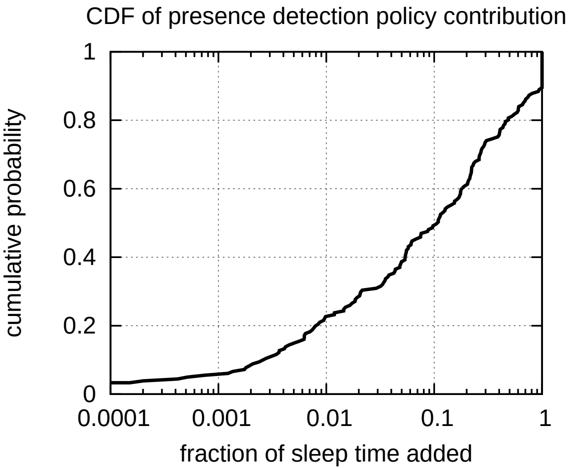
- "loose" upper bound of 81% on display sleep fraction
- savings are sensitive to timeout setting

Relative performance of sonar presence detection policy



- relative benefit of each policy varied among users
- a few users saved much more from timeout policy

Combined DPM policy



- median of 10% of energy savings due exclusively to presence detection
- 20% of users doubled energy savings by adding presence detection

Policy irritation rates

- presence detection has higher irritation rates than timeout (one per hour versus one per day)
- some users have low irritation rates with presence detection

Presence detection irritation vs. energy savings tradeoff:

- Accross users, some correlation between savings and irritation
- but some users had both high savings and low irritation!

Additionally...

See the paper for more results on:

- idle/active period correlation
- sensing overhead
- details of irritation/savings tradeoff
- ultrasound capabilities

Conclusions

- First study of DPM in practice
- HID timeout DPM is effective: reduces display energy by 51%
- Sonar presence detection gives an avg. of 10% more savings
  - "Good users" gain much more: 20% doubled their savings
  - proposed adaptive combined timeout-sonar policy
- Better presence detection may increase savings: up to 81%
  - dedicated hardware can improve accuracy and reduce overhead
- Forcing users to choose a timeout setting would reduce irritation rates for HID timeout policy

Thanks!

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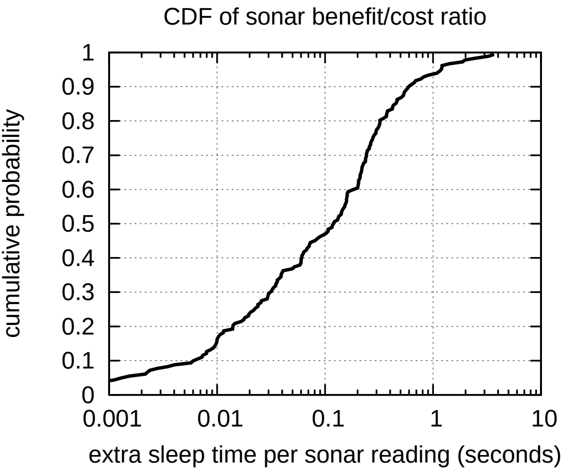
Sensing overhead

measured 7% average power overhead during sensing



- for 67% of users overhead $\geq$ gains
  (for them, sonar can and should be disabled)