The Design and Evaluation of a Task-Centered Battery Interface

Khai N. Truong[1], Julie A. Kientz[2], Timothy Sohn[3], Alyssa Rosenzweig[1], Amanda Fonville[2], Tim Smith[1]

[1]University of Toronto
Toronto, Ontario, Canada
{khai, alyssacr, tsmith}@cs.toronto.edu

[2]University of Washington
Seattle, Washington, USA
{jkientz, ajf32}@uw.edu

[3]Nokia Research Center
Palo Alto, California, USA
tim.sohn@nokia.com

Presented by Kevin Lo

Motivation

- Battery interfaces provide detailed information on how much usage time left.
- Default interface only gives a high-level overview; not always reliable or accurate.
- User needs to create her own mental model of how much longer she can use this application
- Most interfaces only display time for 1 app.

Design of TCBI

- Existing indicators inadequate. Goal:

  "To provide users with an estimated amount of time remaining for applications running independently or in combination to eliminate guess work"

- Conducted a survey with 104 participants to understand users' battery usage habits

- 4-week user study to evaluate effectiveness of TCBI

Related Work

- Various research on energy conservation
  - Power management
  - Energy efficient programs
  - Improving human-battery interaction (TCBI)
- Commercial Applications:
  - EZ Battery Life
  - Battery Time
  - Battery Magic

Battery Usage Survey

- Online survey consisted of 26 questions
  - demographics, different portable devices used, use of the battery interface and its perceived accuracy and usefulness, etc.
- 52 male and 52 female participants with diverse backgrounds through email mailing lists and online advertisements
- Incentive: Chance to win 1 of 4 $25 GCs

Device Usage

- 95% own a smartphone/cellphone/PDA and 40% own 2 or more devices.
- 93% own a laptop; 43% own 2 or more.
- 72% own an Internet tablet or media player; 7% own something else (e.g. Amazon Kindle)
- Average of 4.26 devices/person (SD: 2.22)

Device Usage (p2)

- Most use their devices on a daily basis; 6% smartphone & 8% laptop users on a weekly/monthly basis
- Only 57% of Internet tablet/media player users use those devices on a daily basis

Battery Death

- Phones die more frequent while idle than other mobile devices
- 21 participants' phones die at least once a week; 49 once or more per month
- Less frequent battery deaths while in use:
  - 16 participants reported at least once per week; 29 at least once per month

Low Battery Behavior

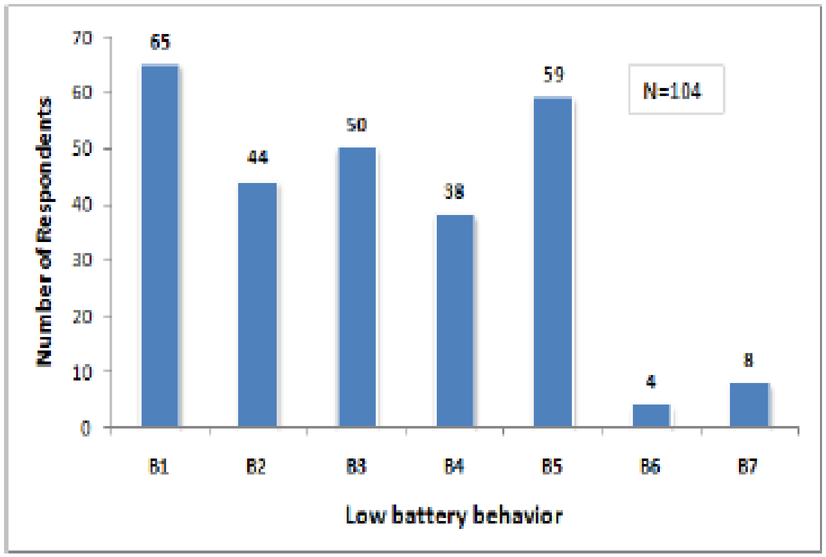

Figure 1: Breakdown of responses for low-battery behavior when user does not have access to an external power source.

- *B1: I limit my use to emergency/absolutely necessary situations*
- *B2: I adjust device settings (e.g., brightness, display time) to conserve power*
- *B3: I change which applications I am using (e.g., only use text messaging, stop Internet use, or phone conversations)*
- *B4: I turn off wireless capabilities*
- *B5: I take measures to preserve my current activities and/or saved documents*
- *B6: I do not take actions to conserve power and I continue to use it as if I did not receive the message*
- *B7: Other behavior*

Better Battery Interface

*"The laptop's battery indicator is so unreliable. It says something like 30% remaining and then it starts warning 3% level at the next moment." –**P58***

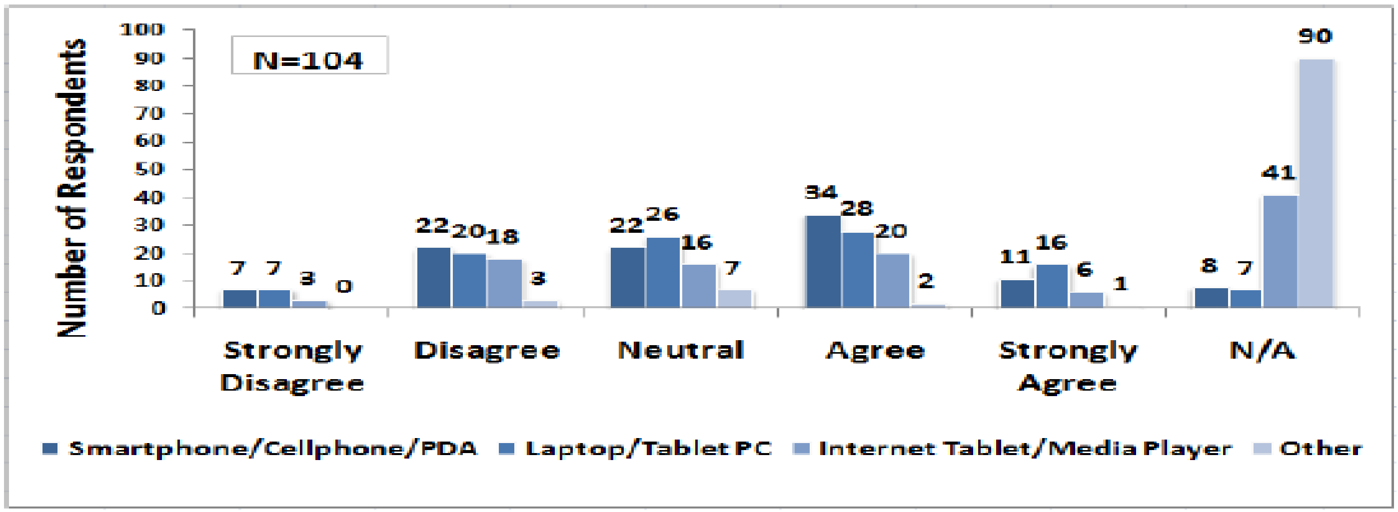

Figure 2: Participant agreement levels when asked "I think the current battery interface on my portable device would be more useful if it showed information that relates specifically to the application I am using."

Implementation

- Prototype built on Nokia N810

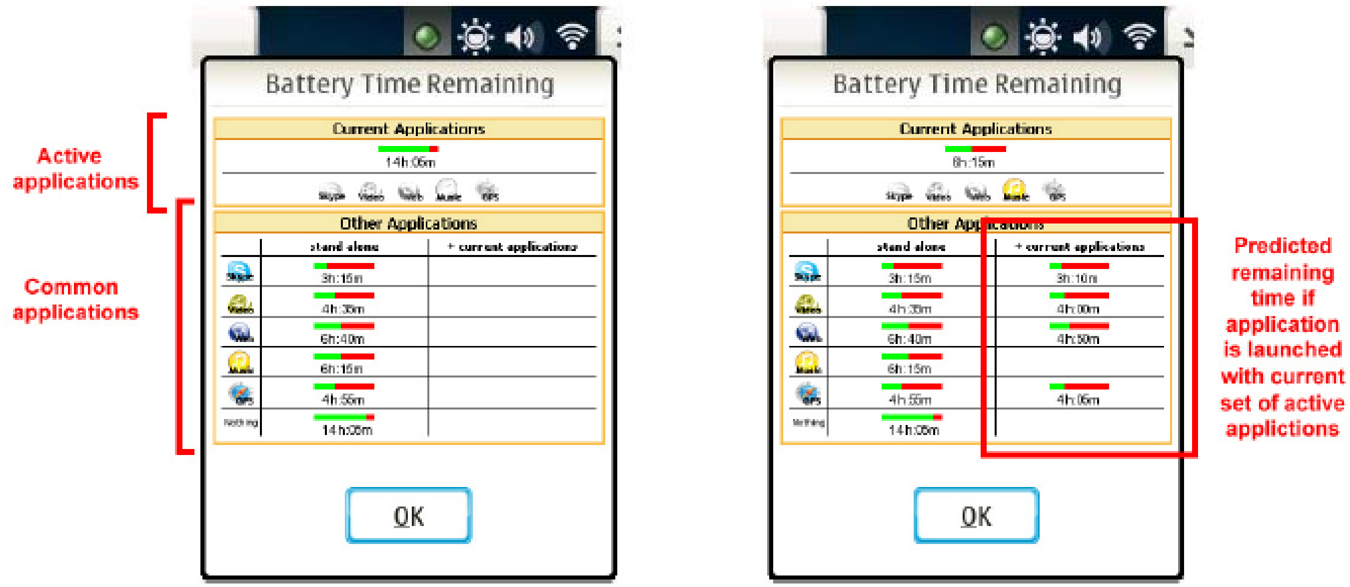

Figure 3: The Task-Centered Battery Interface. The left figure (a) shows the battery time remaining when none of the common applications is running. The right figure (b) shows the battery time remaining when the user is listening to music and estimates.

Implementation (p2)

- Python status bar applet
- Obtains 2 piece of data when launched:
  - Battery's current voltage reading
  - List of active processes
- Record time-stamped voltage readings every 10 sec while an application runs alone.

Implementation (p3)

- 6 traces for each application; brightness and volume set to 50%, with brand new battery

- For each set of application traces:
  - Average the logged time remaining for each voltage capacity reading
  - Perform a smoothing function
  - Cross-validate each set of traces against their respective battery usage profile

Results – Single Application

- Predicted battery time within an average of 738.37 sec (12.7%) of actual battery time

Table 1: The average error for each application's battery usage profile. Magnitude error is the average difference between the predicted battery time remaining with the actual battery time remaining. Percentage error is the average percentage difference between the predicted battery time remaining with the actual battery time remaining.

Application	Magnitude Error	Percentage Error
GPS	615.88 sec	13.0 %
Music	859.55 sec	14.4 %
Skype	685.77 sec	26.7 %
Video	649.25 sec	13.8 %
Web	1400.41 sec	21.6 %
Nothing	1696.12 sec	11.9 %

Results – Multiple Applications

- Predicted battery time within an average of 769.3 sec (17.1%) of actual battery time

$$\mathbf{t}_{predicted} = C \times 1 \,/\, (\, 1/\mathbf{t}_1 + \cdots + 1/\mathbf{t}_n), \text{ where}$$
$$C = (n + 1) \,/\, n, \text{ and}$$
$$n = \text{the number of applications running.}$$

Table 2: The average error for our multi-application battery time remaining estimation function.

Application	Magnitude Error	Percentage Error
GPS + Music	388.30 sec	9.4 %
GPS + Skype	500.21 sec	18.1 %
GPS + Video	378.08 sec	8.9 %
Web + Music	981.17 sec	21.9%
Web + Skype	895.76 sec	21.4%
Web + GPS +Music	1472.42 sec	23.1%

Deployment Study

- 2 phases, 1 interface (standard vs. TCBI) per phase

Table 3: Timeline of user study across the 4-week deployment.

	Day	Study Components
Phase 1	0	**First Meeting:** Study explanation, initial interview, first battery interface deployed
	1	Task on web browsing, survey #1-1
	4	Task on Skype, survey #1-2
	7	Task on listening to music, survey #1-3
	10	Task on watching videos, survey #1-4
	13	Task on both web browsing and listening to music, survey #1-5
	14	**Second Meeting:** Interview on first interface, logs copied, switch to second interface
Phase 2	15	Task on web browsing, survey #2-1
	18	Task on Skype, survey #2-2
	21	Task on listening to music, survey #2-3
	24	Task on watching videos, survey #2-4
	27	Task on both web browsing and listening to music, survey #2-5
	28	**Final Meeting:** Interview on second interface, logs copied, devices and journals collected

Deployment Study (p2)

- Send emails on specific day with specific task
- Participants answer set of 7 questions before & after task:
  - Current Time & Battery remaining
  - Prediction on whether the task could be completed; Likert scale used to rate predictions
- Logging software used to track participation

Deployment Study (p3)

- 8 final participants; $60 compensation for completing the study

Table 4: Participants and demographics for the 8 final participants from the TCBI deployment study.

ID	Gender	Age	Occupation	Computer Experience	City	First Interface
DP1	M	20-29	Student	Exp.	Toronto	TCBI
DP2	M	20-29	Student	Exp.	Toronto	Nokia
DP3	F	20-29	Student	Inter.	Toronto	TCBI
DP4	M	30-39	Child care	Inter.	Toronto	Nokia
DP5	F	30-39	Health clinic worker	Exp.	Seattle	TCBI
DP6	F	50-59	Unemployed	Basic	Seattle	Nokia
DP7	M	20-29	Student	Exp.	Seattle	Nokia
DP8	F	30-39	Homemaker	Inter.	Seattle	Nokia

Results

- Definitely and Probably answers are considered correct for affirmative answers
- Definitely Not and Probably Not are considered correct for negative answers
- Participants answered 94.8% of the questions correctly using TCBI and 73.5% using the Nokia Interface

Results (p2)

*"It totally works. I can leave my house without charging the thing, and I don't have to worry about it dying." –**DP6***

*"And for the first one [TCBI], it actually felt like when I was checking it… I felt like I was getting more information. At least I was getting a better idea." –**DP3***

*"It [TCBI] was definitely more informative than the first one, and I felt like I could answer the questions that were being posed with more confidence." –**DP1***

*"I felt like I could mostly trust it. I tested it out once, just to see if it was really accurate down to the minute. It was, it said in 2 hours the battery would go dead, and in like, 2 hours and 1 minute, the battery went dead." –**DP5***

Results (p3)

- Participants were asked to rate their confidence based on the interface they were using
- Average ratings: 1.76 (TCBI) 1.31 (Nokia)

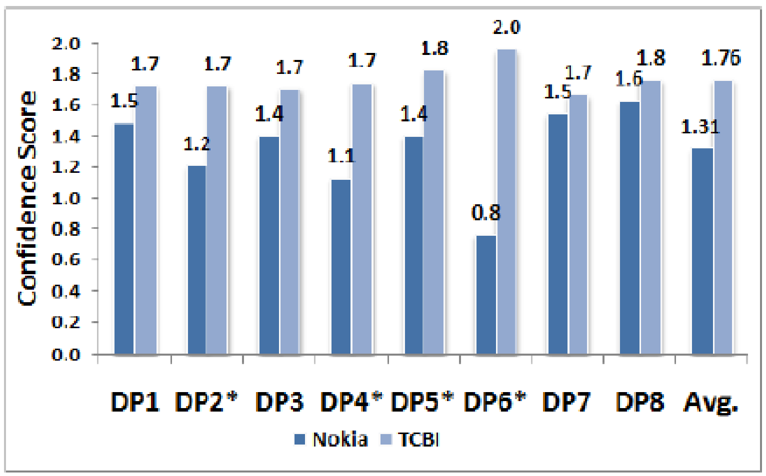

Figure 7: Average confidence scores for all participants in the user study. Statistically significant comparisons ($p < 0.05$) are marked with an asterisk.

Possible Improvements

- Increase the font size on TCBI
- Only 1 battery meter graphic needed
- Make screen less cluttered
- Ability to explore different application combinations (without actually opening them)
- A more interactive desktop icon

Possible Improvements (p2)

- Display warning (in different color or style) when model is more prone to error

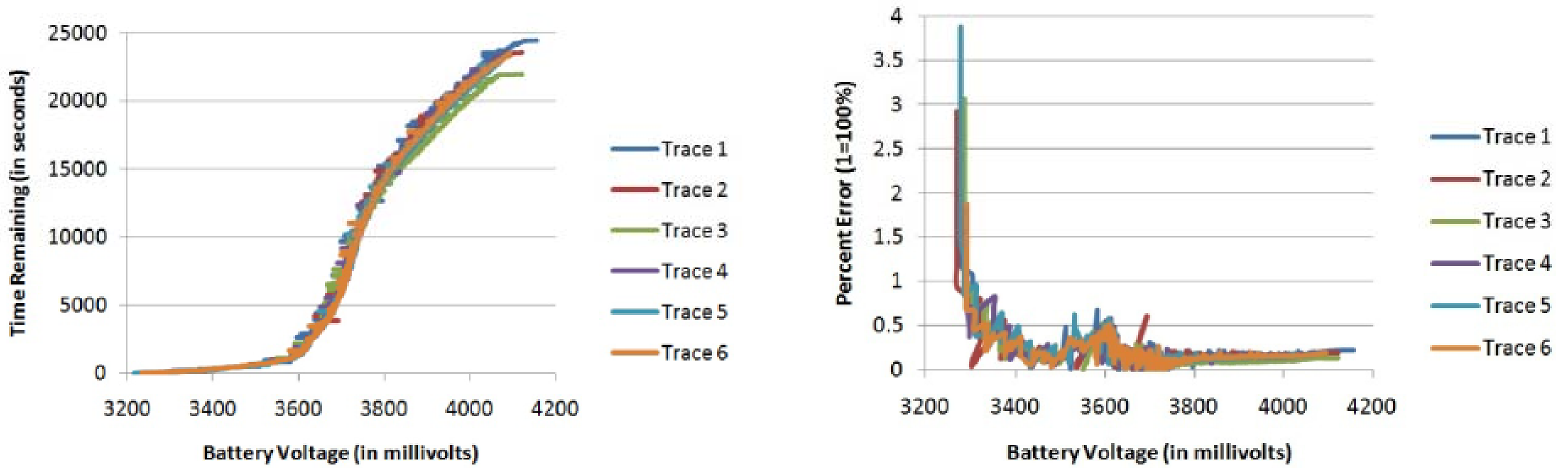

Figure 4: Graphs showing video playback battery traces (left) and the percent error in the predicted value in relation to the actual time remaining (right).

Possible Improvements (p3)

- Use crowdsourcing to gather a large number of battery traces over a wide range of hardware settings
- Per-device training for each application for a more accurate model for that device when there are other background processes running
- Generalizing TCBI to other platforms