DarkReader: Bridging the Gap Between *Perception* and *Reality* of Power Consumption in Smartphones for Blind Users

Jian Xu*, Syed M. Billah*, Roy Shilkrot, Aruna Balasubramanian

Stony Brook University

PennState


Blind users do not need screens
Source

Screen consumes over 20% battery

[Chen et al., MobiCom 2015]

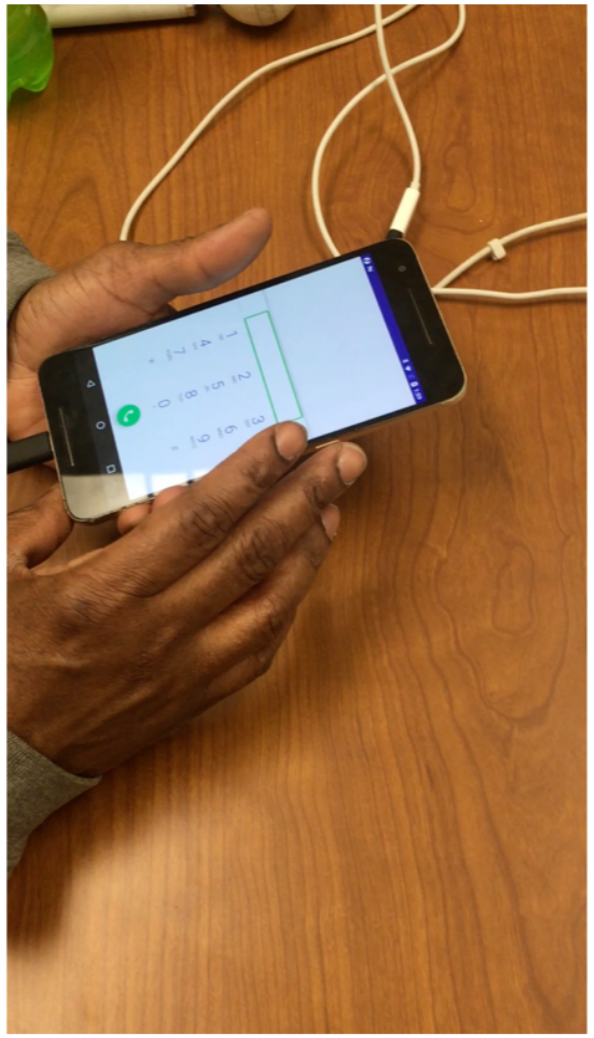
Source

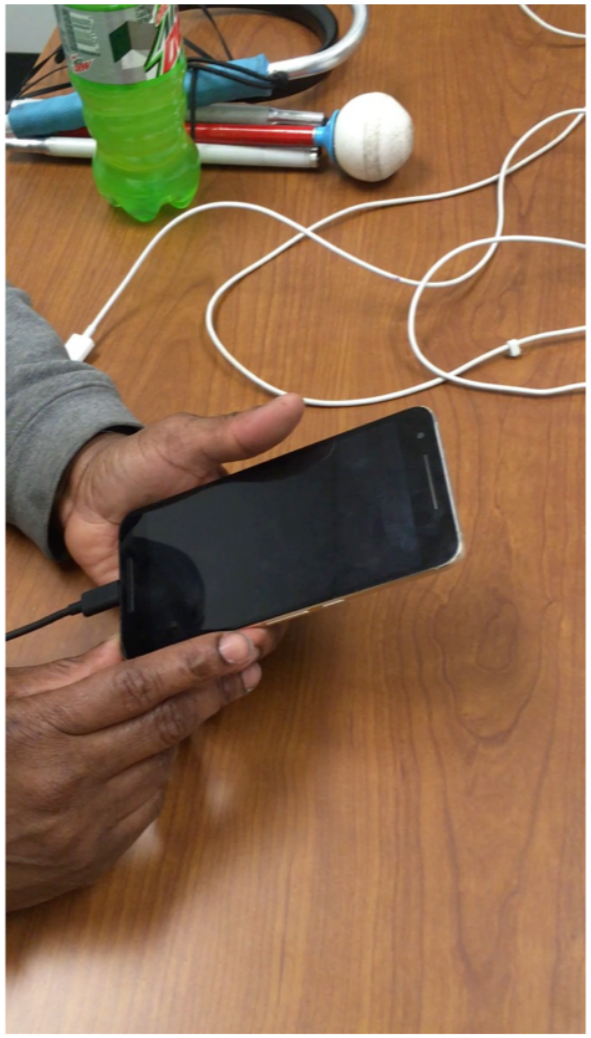
Sleep Mode


No SIM
9:30 PM
60%
Messages
Clock
Reminders
Notes
Weather
Photos
Voice Memos
Navigation
Finance
Productivity
Built-Ins
News
Companion
Health
Entertainment
Duo Mobile
Settings
Skype
Google Maps

Our Contribution

- Understanding the perception of power consumption of blind users
- DarkReader: realizing those perceptions in practice for blind users





Study 1: Research Questions

- RQ1: *Usability issues with the **power-saving settings** in smartphones?*
- RQ2: *Are you aware of privacy-preserving **curtain mode**?*
- RQ3: *How do you react to **battery indicators**?*
- RQ4: *How to deal with the limited **battery capacity** of smartphones?*

Study 1: Participants

- 10 Blind Participants (from Mailing List)

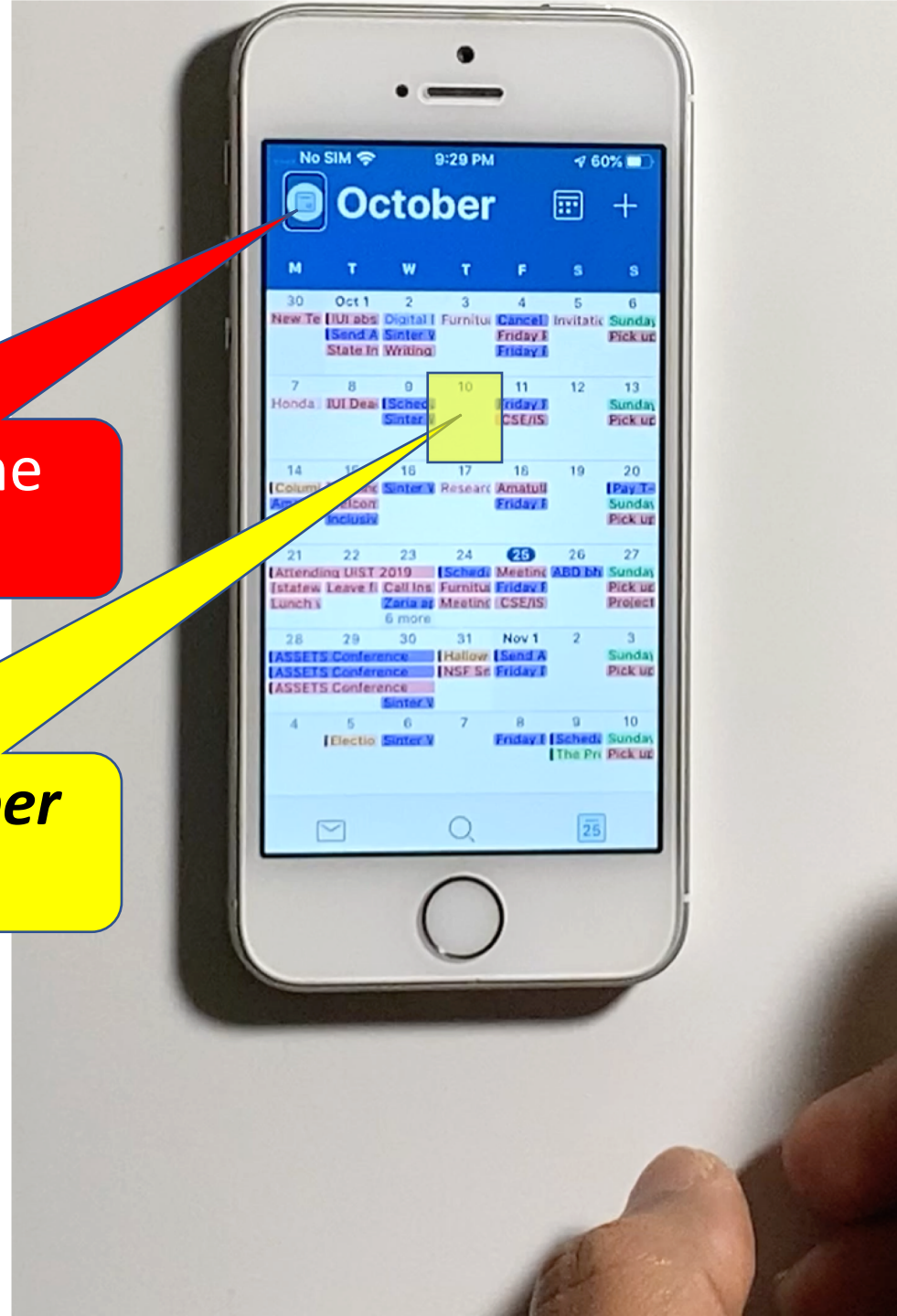
- **Gender:** 6 males, 4 females
- **Age**: *Mean= 40.8*, SD=12.8, Min=27, Max= 60
- **iPhones**: more than 3 years old (except for one)
- **Daily usage:** from 1 to 8 hours
- **Recharging frequency:** 1.8 times/day (avg)

Findings: Usability Issue

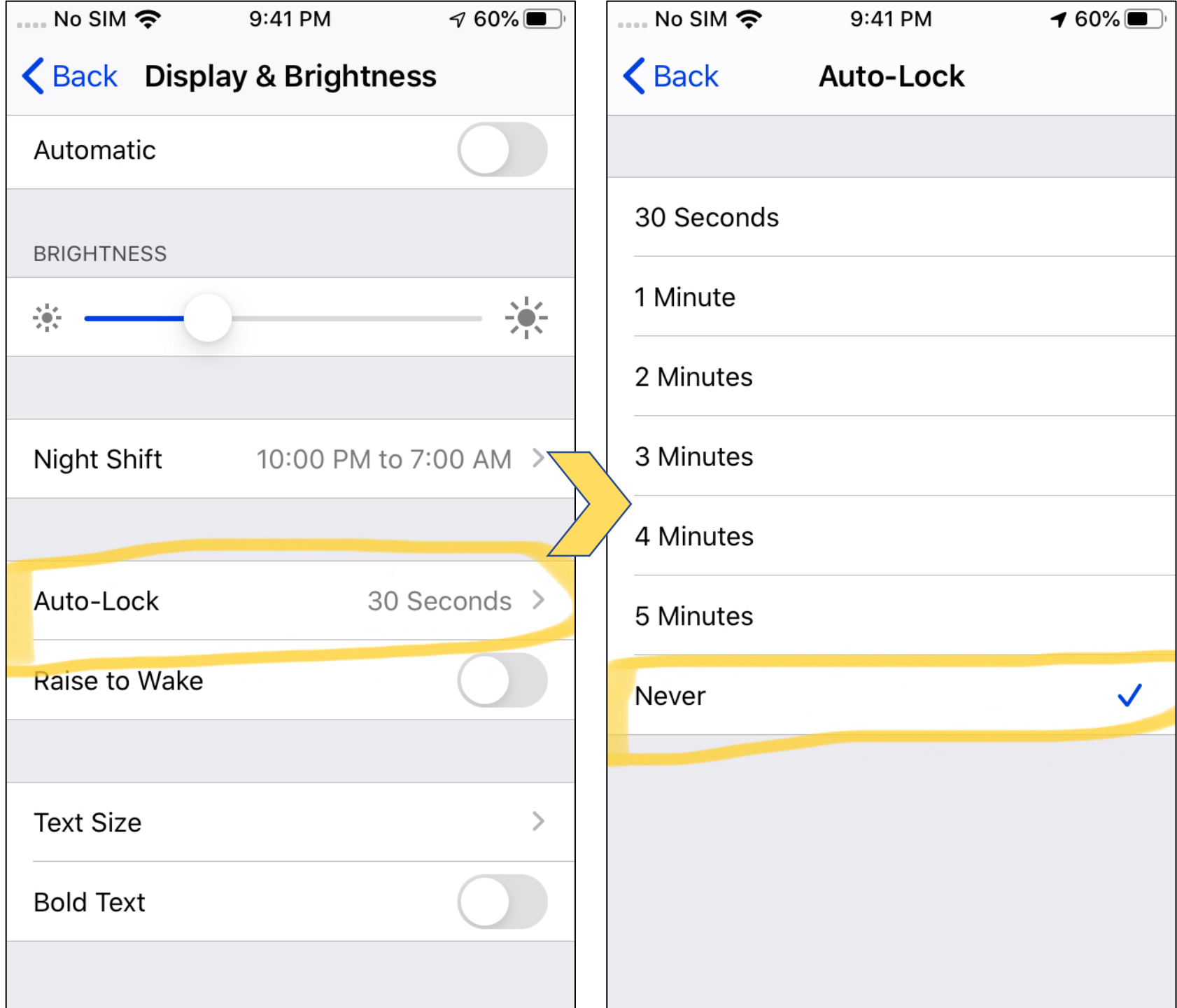
- Screen reader ***cursor*** is ***lost*** in Sleep Mode
- Causes serious usability concern

Cursor resets to the ***first element***

Cursor is at "***October 10th***"



- **6**/10 participants disabled auto-lock
- Others set longer interval (e.g., 5 minutes)



Findings: Misconception

- **9**/10 participants were aware of screen curtain mode

- **6**/9 who disabled auto-lock, used curtain mode frequently
- Others did not use curtain mode frequently
  - Forgot the gesture to enable/disable it
  - Often show the screen to sighted persons
  - Stay-at-home

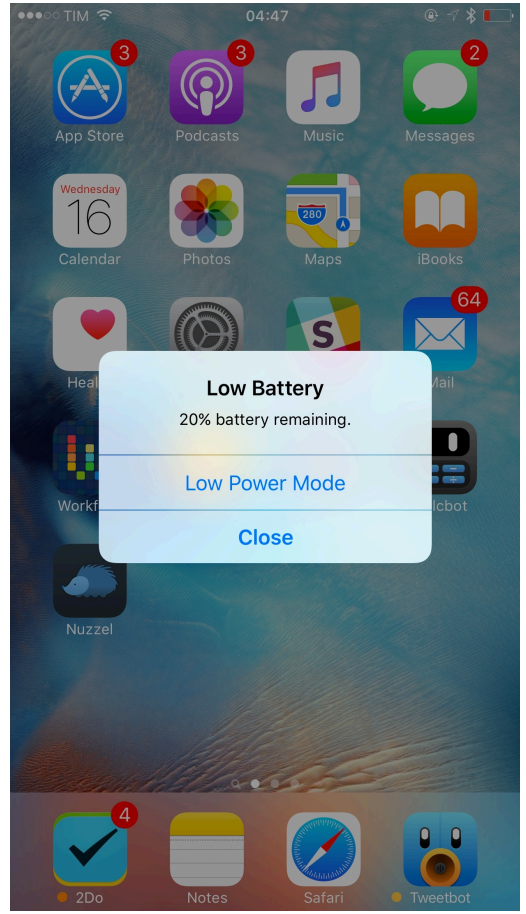
- *All 9 participants believed curtain mode saves power*

Findings: Anxiety

- All participants experienced anxiety hearing the "Low Battery" message

- Routinely used power-hungry apps
  - E.g., BeMyEyes, Seeing AI, Blind Square, Access Rid
- Carried external battery packs
  - E.g., Juice Box, Morphie

- *Preferred to know the remaining usage time (e.g., 1 hour and 20 minutes)*



Dark Reader

DarkReader: Low-Power Screen Reader

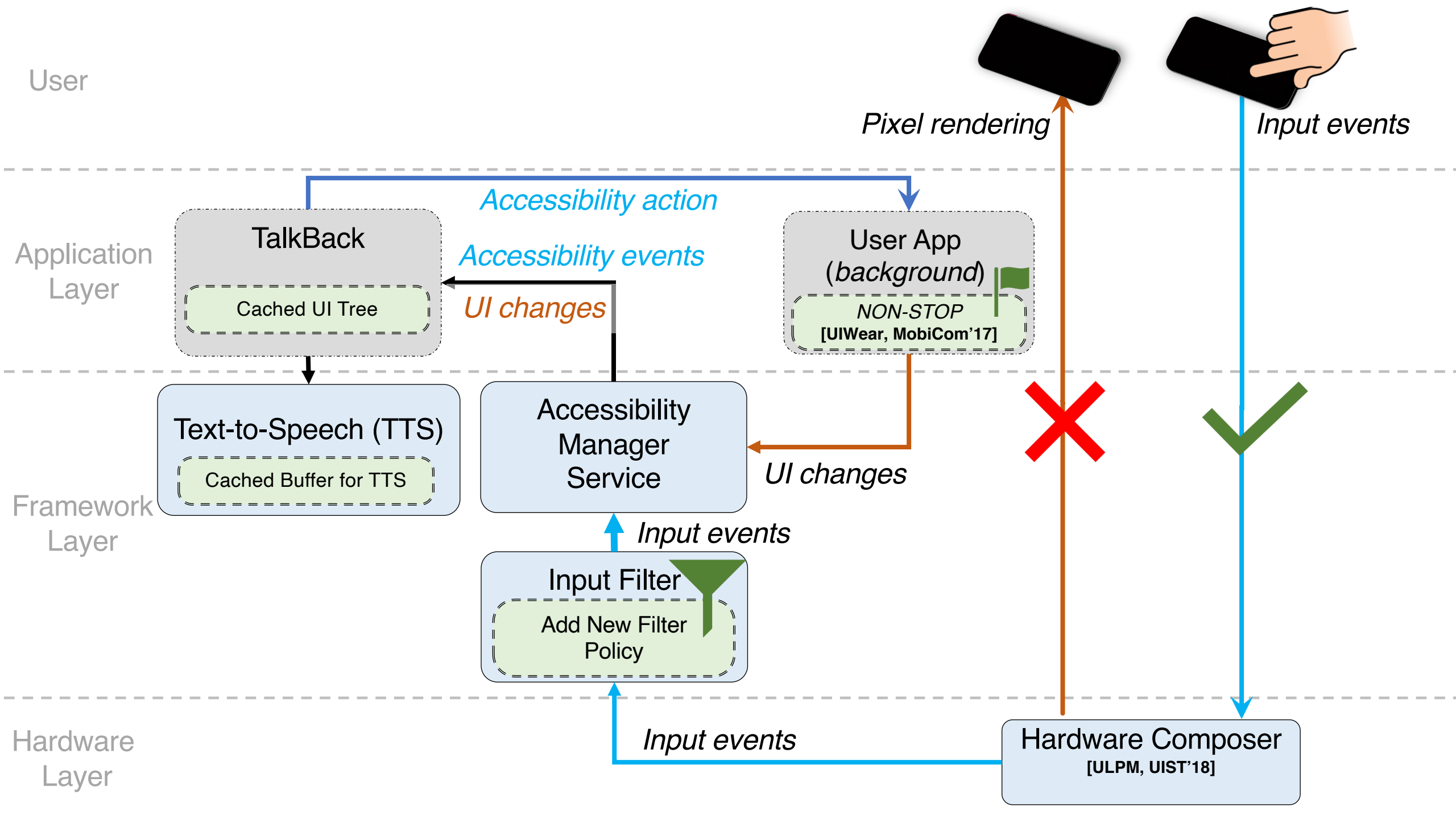
- Built on top of Android's screen reader, TalkBack

- *Sleep mode + Curtain mode* = ***DarkReader mode***
  - Keeps screen reader and apps interactive, as if they were in curtain mode
  - Keeps the screen truly off, as it were in sleep mode
  - Users can use any gesture to enable/disable it

- Reports remaining usage time in discrete intervals (in-progress)

Technical Challenges

- Deliver ***user inputs*** to the ***hardware driver*** (ULPM)
- Deliver ***user inputs to screen readers***
- ***Update*** applications' ***UI*** (UIWear)
- ***Retain*** the screen reader ***cursor***

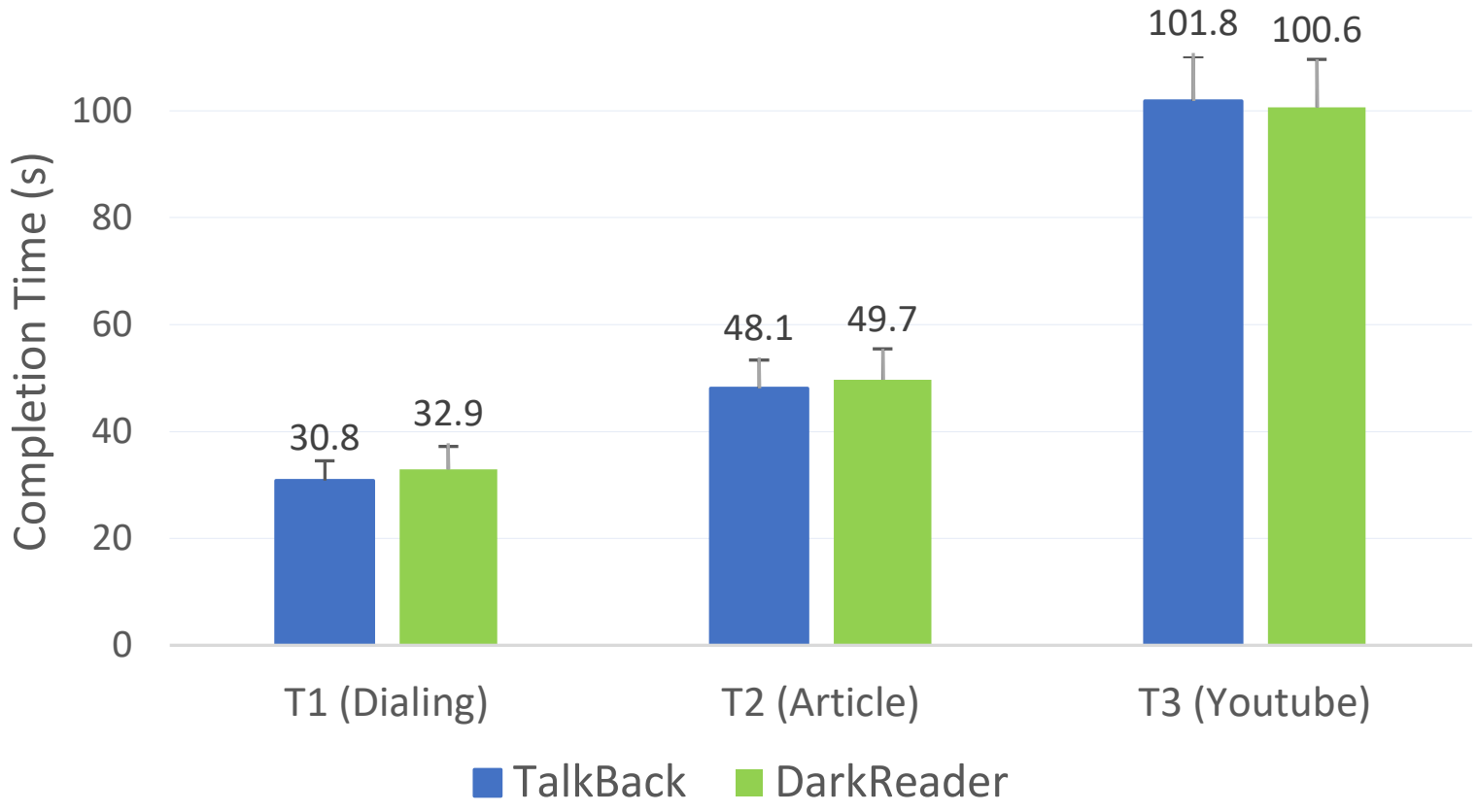

User
Application Layer
Framework Layer
Hardware Layer
Pixel rendering
Input events
Accessibility action
Accessibility events
UI changes
TalkBack
Cached UI Tree
User App (background)
NON-STOP
[UIWear, MobiCom'17]
Text-to-Speech (TTS)
Cached Buffer for TTS
Accessibility Manager Service
UI changes
Input events
Input Filter
Add New Filter Policy
Input events
Hardware Composer
[ULPM, UIST'18]

Study 2: Evaluation of DarkReader

- Another study with 10 blind participants
  - User experience
  - Power saving

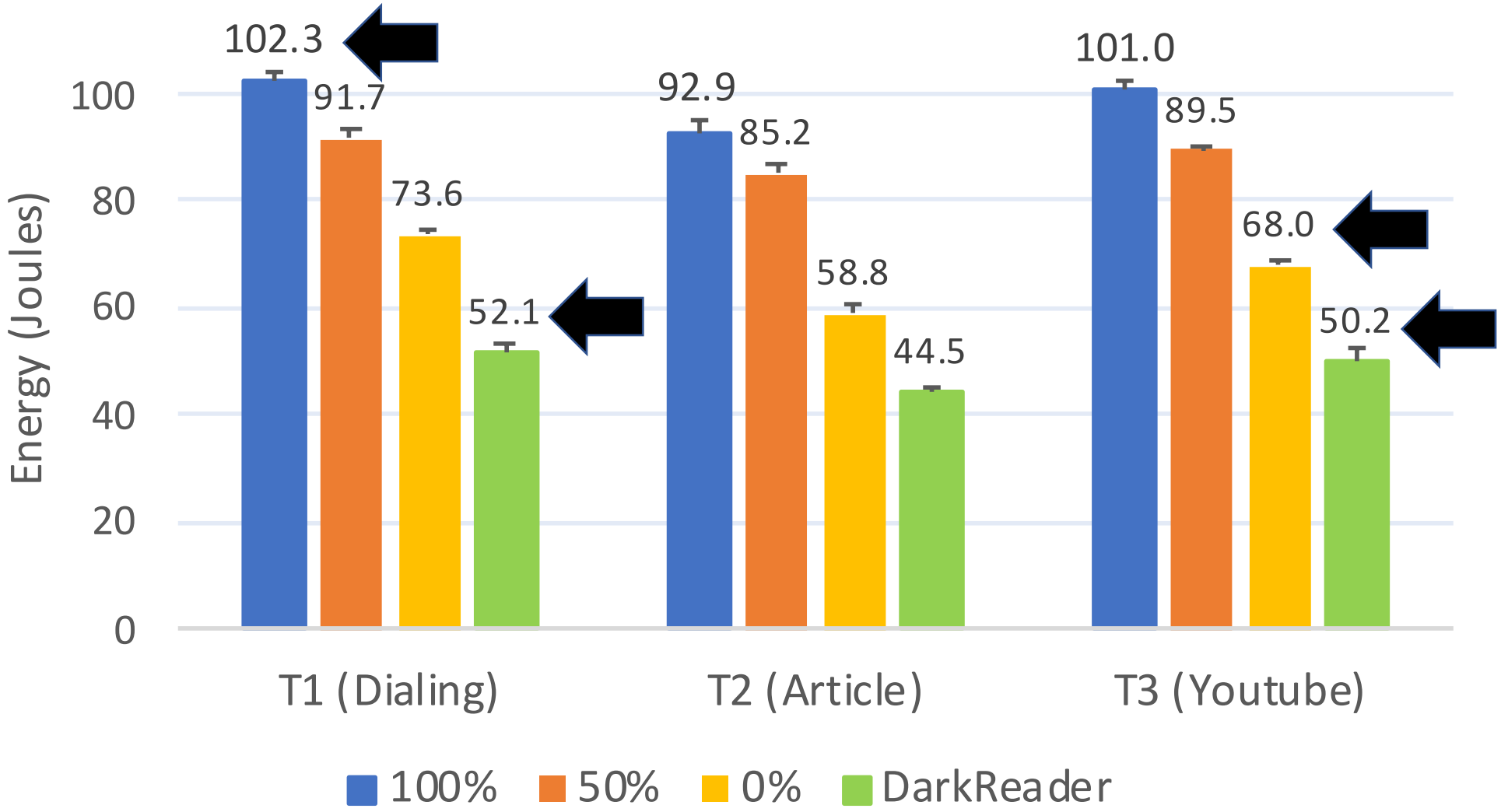
- 3 regular tasks:
  - T1: Making a phone call
  - T2: Reading an article
  - T3: Watching YouTube

Results: Task Completion Time



No statistically significant difference in completion time

Results: Power Consumption in different Screen Conditions



Drastically saves power consumption, up to 50%

Conclusion

- Sleep mode has usability concern for screen reader users
- Blind users incorrectly assume curtain mode saves power

- DarkReader truly switches the screen off, yet interactive
- We hope smartphone vendors will incorporate DarkReader

sbillah@psu.edu