User-Centric Mobile Systems

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Outline

- Motivation
- User-Centric Mobile Systems
- Energy-Efficient Designs with Human Factors
  - Backlight: Dynamic Backlight Optimization Service for Mobile Streaming Applications
  - OLED: Catch Your Attention: Quality-retaining Power Saving on Mobile OLED Displays
  - CPU: User-Centric Scheduling and Governing on Multi-Core Mobile Devices
  - 3G: Extend Your Journey: Introducing Signal Strength into Location-based Applications
- Concluding Remarks

Totally Different Lifestyle

The Past 8 Years!

Mobile Applications Have Coded a Part of Our OS

An Increasingly Connected IoT World

The Next 8 Years?

A Paradigm Shift

- **User Behavior (Diversity)**

- **Application Semantics (Variety)**

- **Device Features (Distinctivity)**

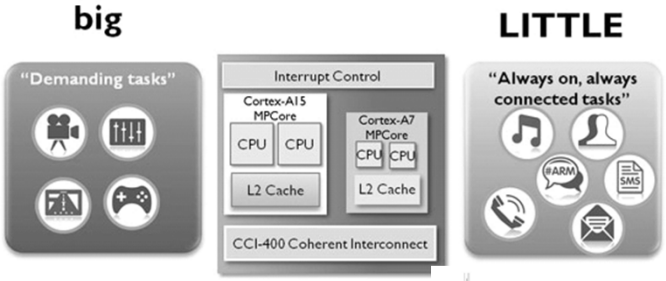
A Major Challenge

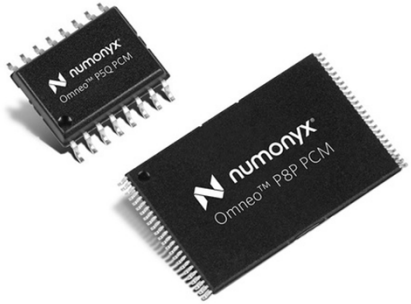
- To sustain more creative mobile applications, next-generation mobile devices need to provide significant improvements in performance, resulting in further pressure on the limited battery capacity.

Possible Solutions

- Battery Extenders

- Emerging Hardware





Motivation

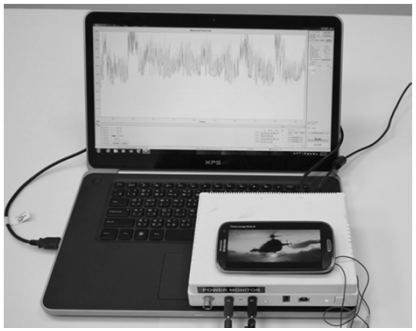
- Hardware solutions have been sought to address the challenge.

- How about software solutions?
- Do existing SW designs fit in with emerging HW solutions?

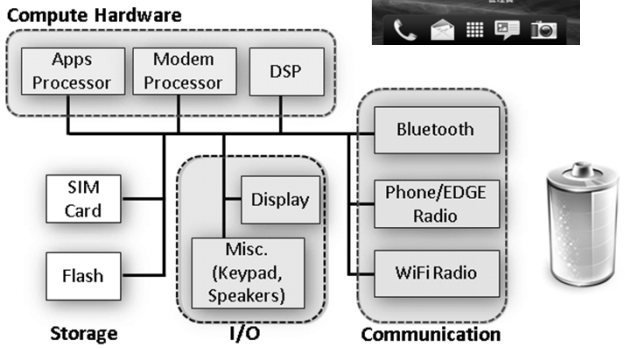
Our Research Scope

- **Observation**
  - Hasty SW solutions that borrow legacy designs intended originally for desktops are not suitable for mobile devices.
- **Principle**
  - Mobile systems should move towards user-centric designs that make much of human factors.

Low-Power Computation



IEEE/ACM DAC 2014
ACM Trans. on Embedded Computing Systems 2013



Energy-Aware Display

IEEE/ACM DAC 2014
IEEE Trans. on Computers 2014

Energy-Efficient Communication

IEEE INFOCOM 2013
IEEE/ACM Trans. on Networking 2015

Energy-Efficient Designs with Human Factors

Backlight	Dynamic Backlight Scaling Optimization for Mobile Streaming Applications
OLED	Catch Your Attention: Quality-retaining Power Saving on Mobile OLED Displays
CPU	User-Centric Scheduling and Governing on Multi-Core Mobile Devices
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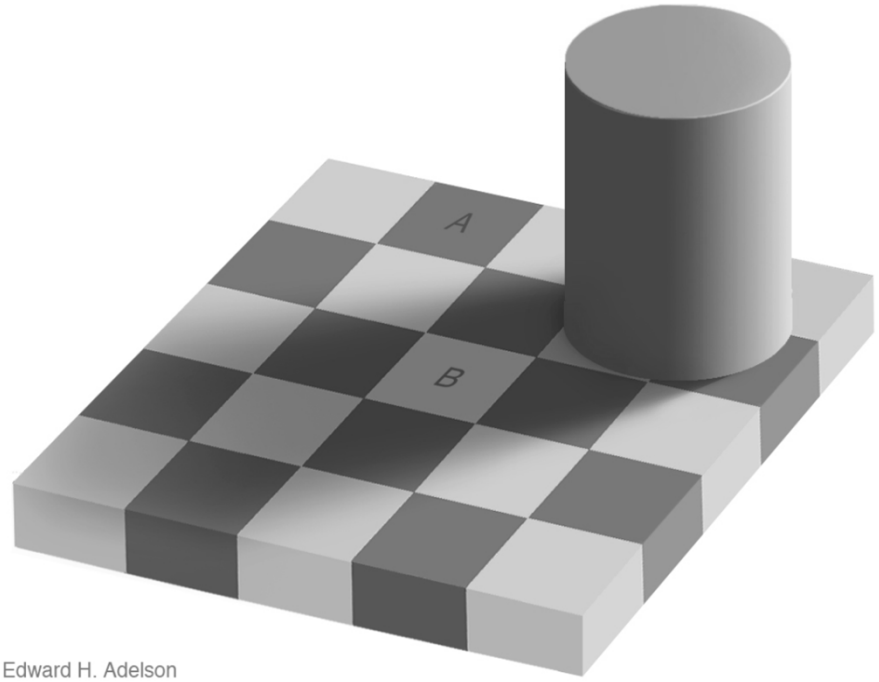
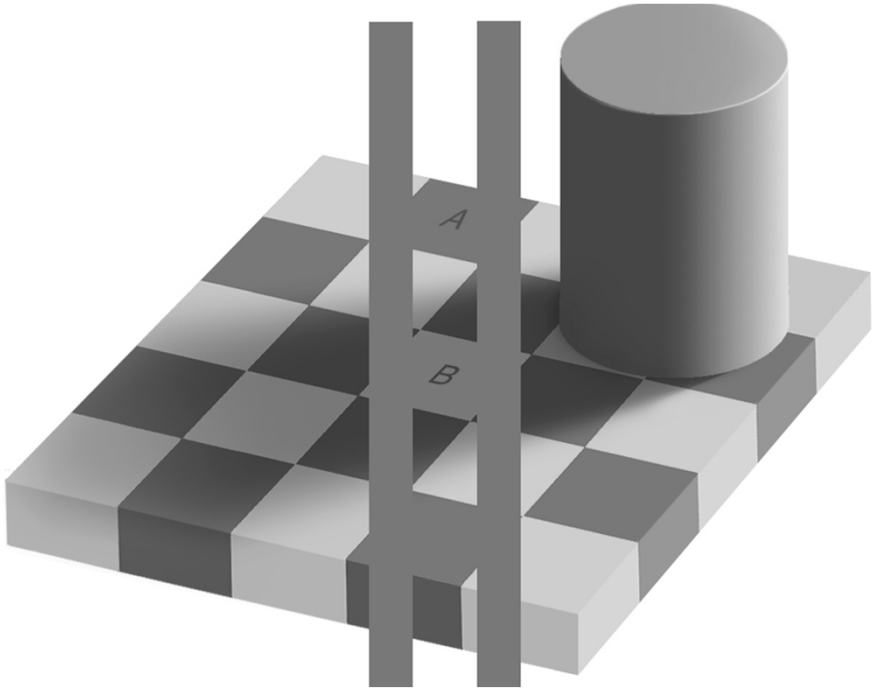
Human Visual System: To see is to believe?

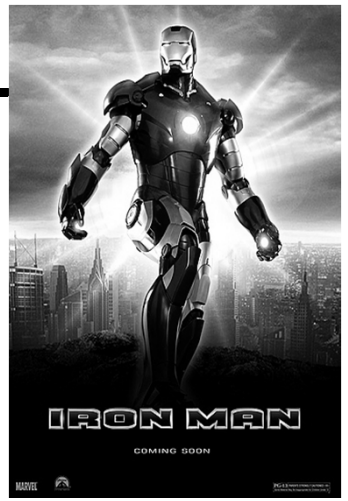


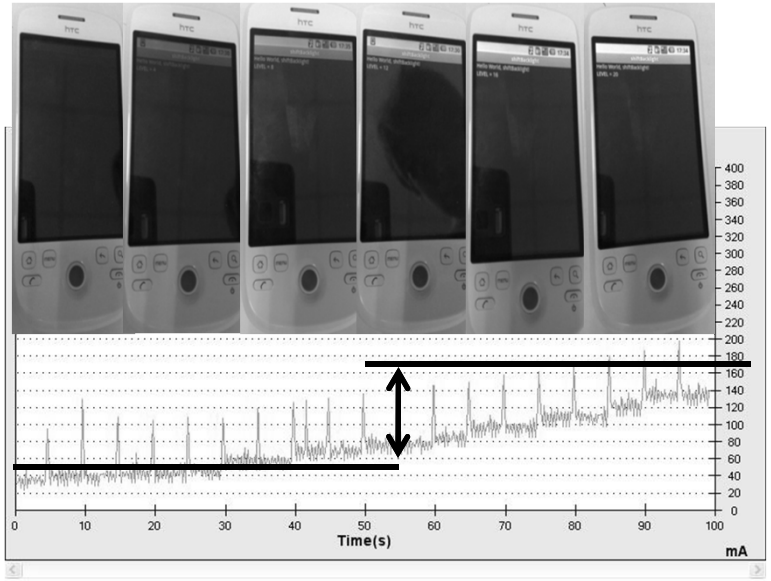
Edward H. Adelson



Dynamic Backlight Scaling Optimization for Mobile Streaming Applications

- **Dynamic backlight scaling**
  - Adjusting backlight levels for different video frames
- **The technical problem**
  - How to dynamically change the backlight without (significantly) changing the user's visual experience?
- **Contributions**
  - A theoretic framework for dynamic backlight scaling optimization and energy-experience tradeoff exploration
  - A cloud-based energy-saving service

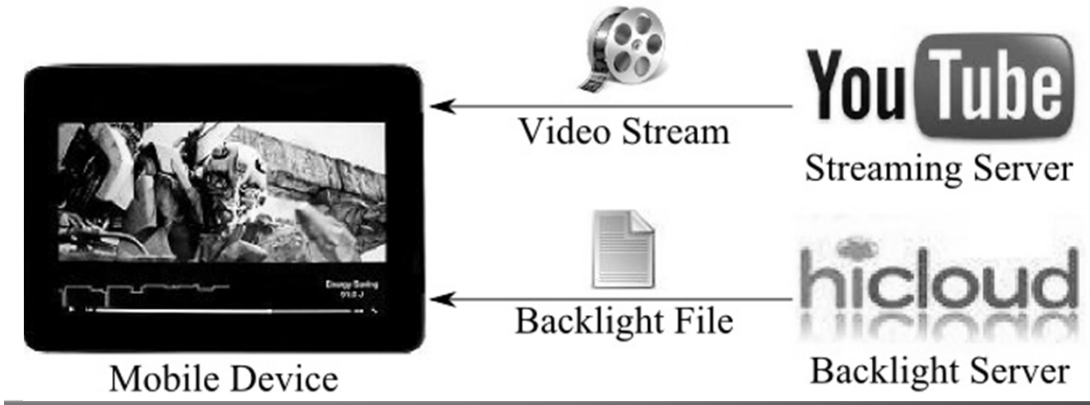




* IEEE/ACM ISLPED 2011 (Design Contest Winner)
* IEEE Trans. on Computers 2014 (Y. Z. Hsu Scientific Paper Award)

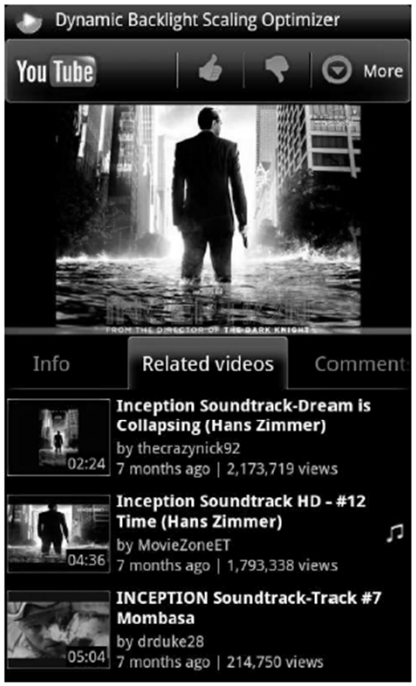
Dynamic Backlight Scaling Service

- A service deployed on Chunghwa Telecom's hicloud to reduce backlight energy.
- Mobile apps developed for Android smartphones and Apple iPads to access the service.



Demo 1 - HTC Desire & Apple iPad

Approach Validation



Performance Evaluation

Summary

- This work explores how to minimize the energy consumption of the backlight when displaying a video stream without adversely impacting the user's visual experience.

- We have deployed the dynamic backlight scaling service on CHT hicloud.
  - A mobile application program was developed for Google's Android and Apple's iOS to access the service.
  - With the service applied, HTC Desire and Apple iPad achieved energy savings of 11-20% and 31-41% when browsing videos on YouTube.

Energy-Efficient Designs with Human Factors

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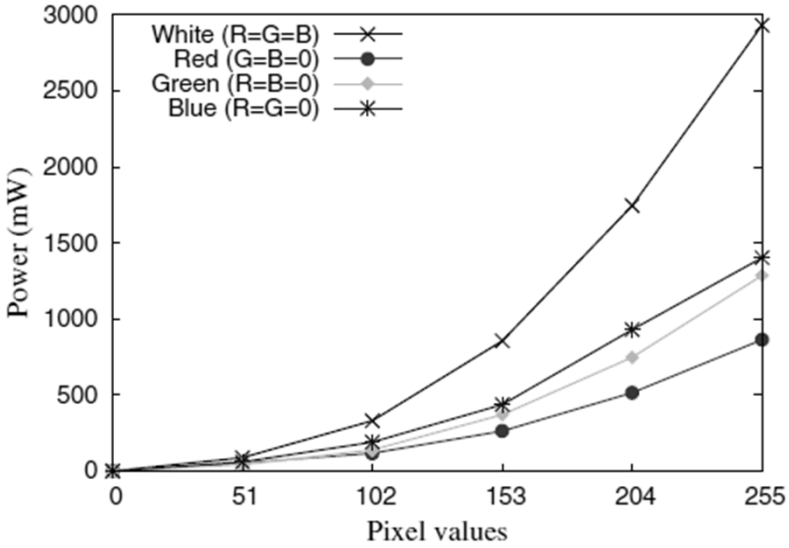
Low-Power Display

- OLED's power increases dramatically with the pixel values of the displayed image
  - Black (≃ 0 watt)
  - White (2xLCD's power)
- Existing Techniques
  - Partial display disabling
  - Color transformation
  - OLED dynamic voltage scaling



⇨ Changing user experience, so not applicable to natural images

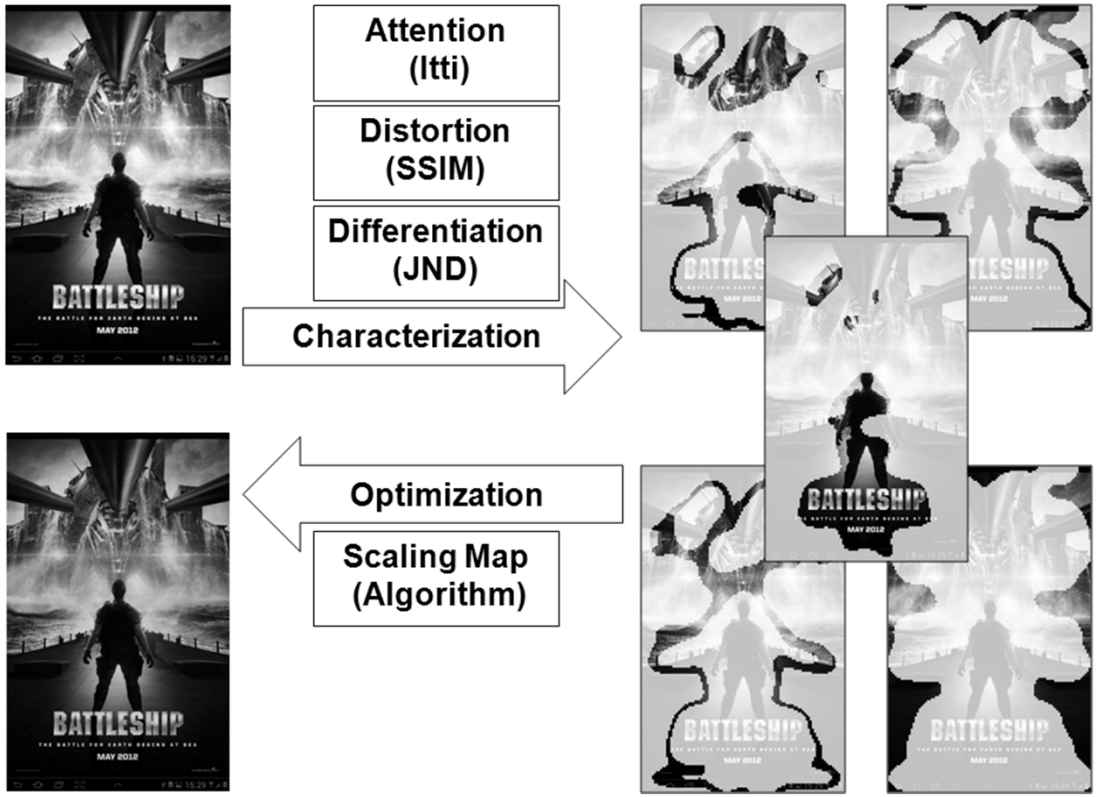
Catch Your Attention: Quality-retaining Power Saving on Mobile OLED Displays

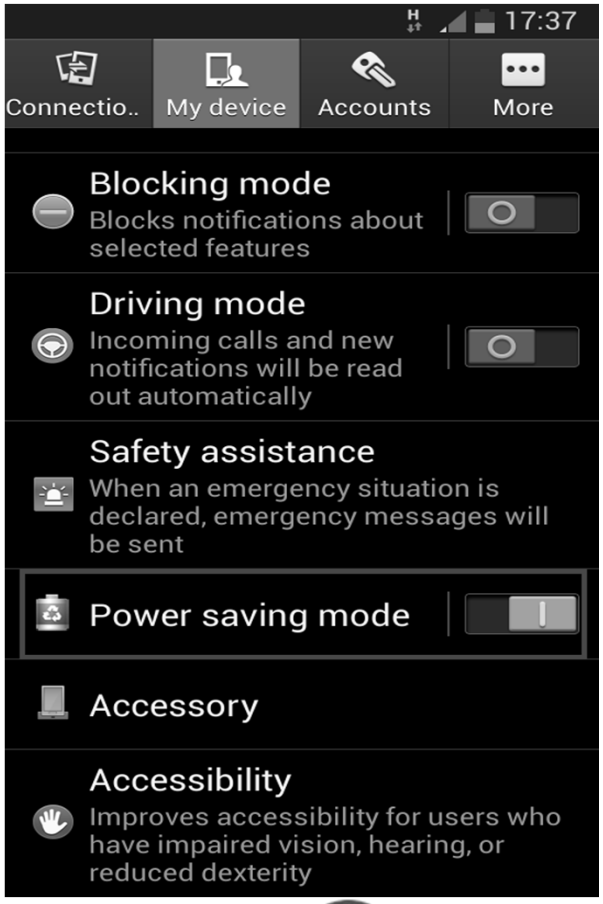
- **Human visual attention**
  - Not every pixel or region receives the same level of attention
- **Technical problems**
  - How to determine an appropriate scaling ratio for each region?
    - Retaining the original quality
    - Minimizing OLED power
- **Contributions**
  - Linking visual attention to OLED power saving
  - An optimal algorithm w/o accurate power models
  - Implementing an OLED power-saving mode on Samsung tablets

*IEEE/ACM DAC 2014

An Image Converter & A Power-Saving Mode

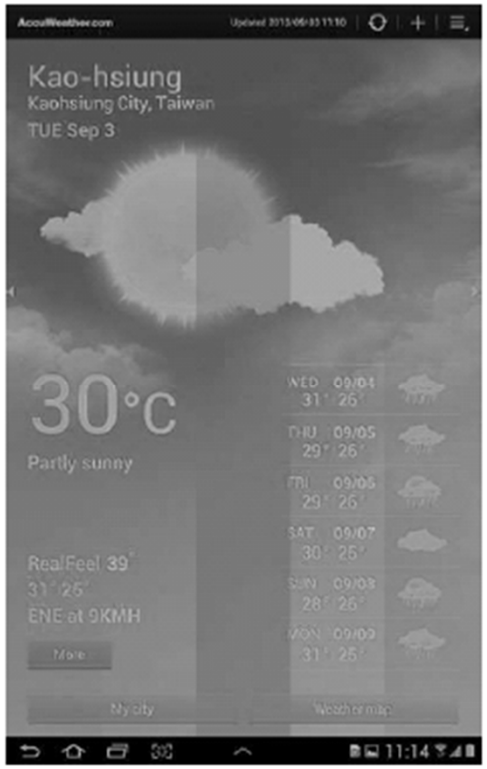
- Two practical applications on a commercial OLED mobile tablet





Demo 2 – Samsung Galaxy Tab 7.7

Original Image



GRID

GURA

Summary

- This work introduces visual attention into the quality-retaining power-saving design on mobile OLED displays.

- We present CURA to realize the notion and have implemented an image converter and a power-saving mode.
  - CURA scales down pixel values by different magnitudes appropriately according to their tolerable distortion.
  - Samsung Galaxy Tab 7.7 can save 38-42% OLED power while retaining visual quality.

Energy-Efficient Designs with Human Factors

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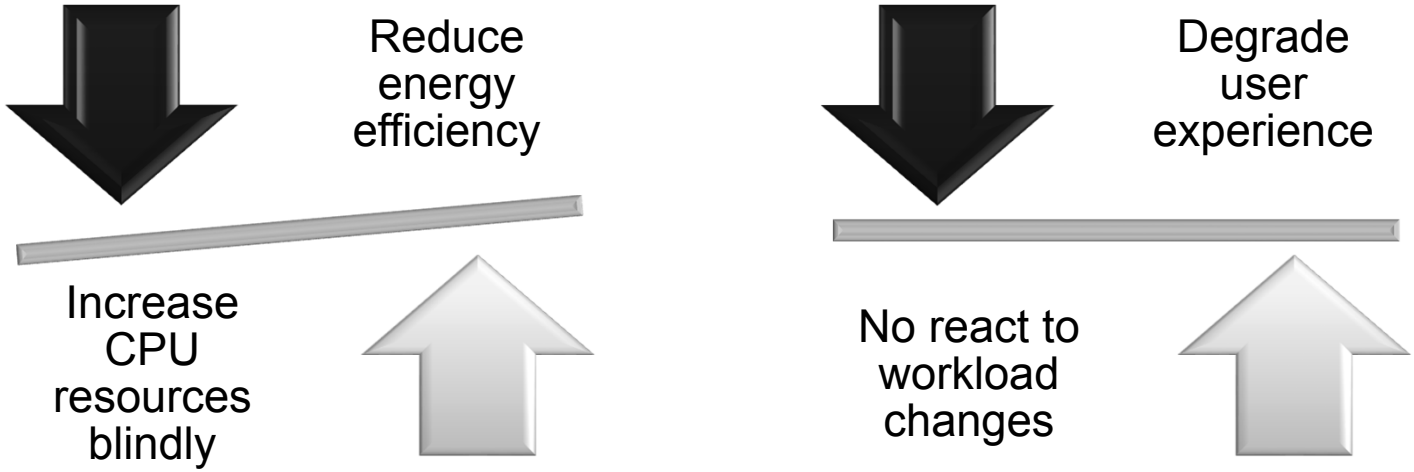
Power-Aware Computation

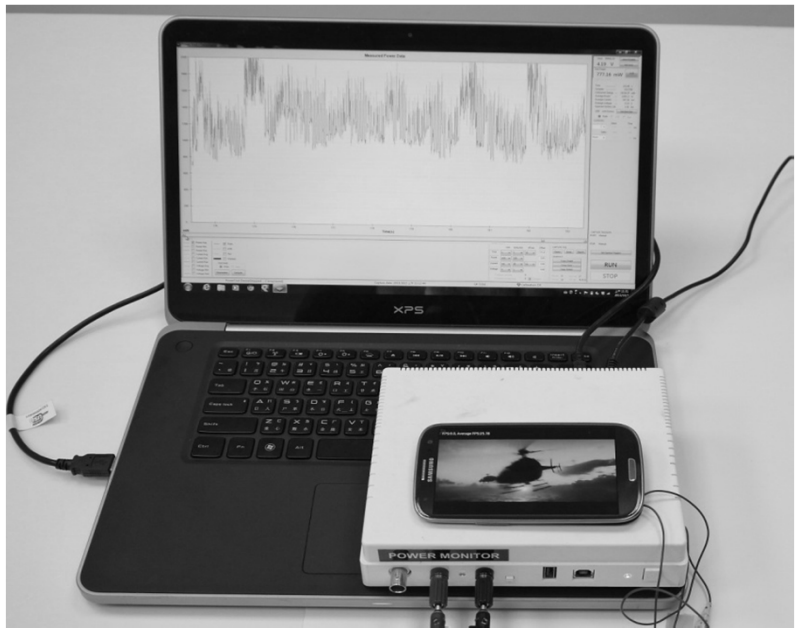
- ~~Completely Fair Scheduling degrades either~~ user experience or energy efficiency



- Google has introduced unfair scheduling into Android
  - Yet, the two conflicting objectives cannot be improved simultaneously

User-Centric Energy-Efficient Scheduling on Multi-Core Mobile Devices

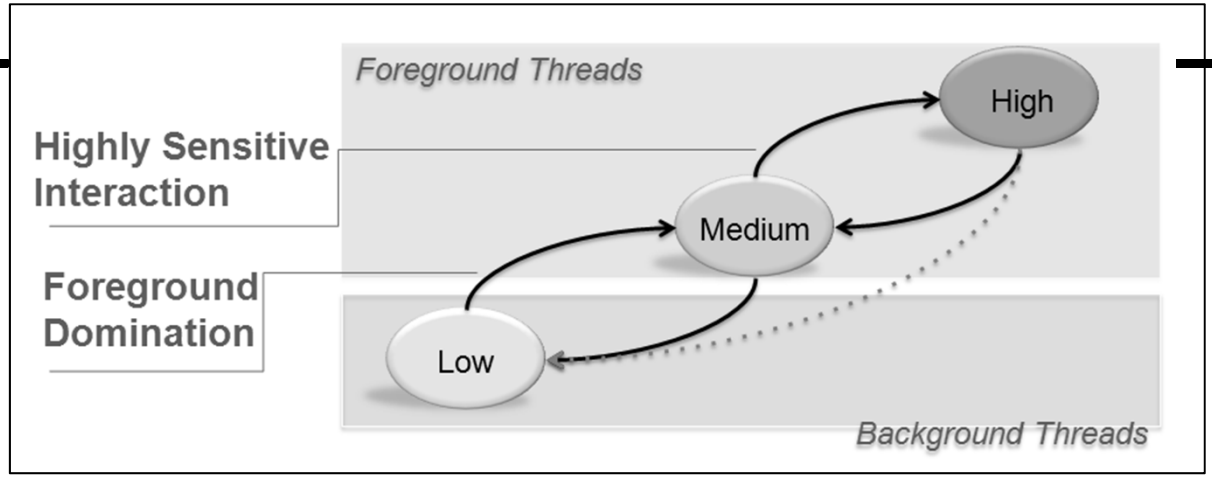
- **User-centric scheduling**
  - Applications have different “sensitivity” with respect to user perception
- **Technical problems**
  - How to quantify the user’s attention on each application?
  - How to schedule threads and manage CPU cores to improve both objectives?
- **Contributions**
  - Introducing application sensitivity into scheduler and governor designs
    - Determine sensitivity based on the user’s attention
    - Thread prioritization, allocation, and migration
    - DPM, DVFS, and cluster switching
  - Integrating our design into Android



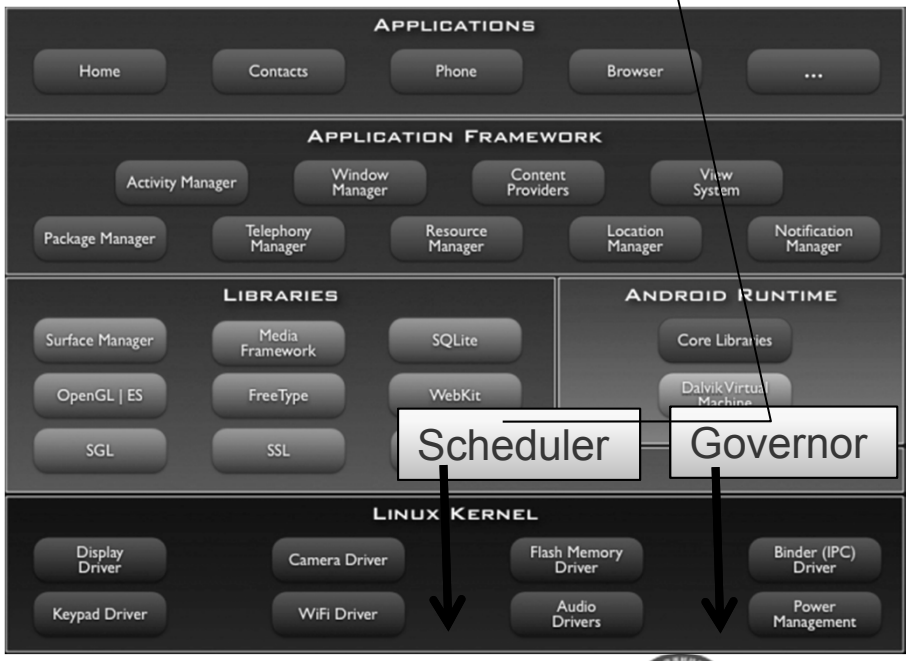
*IEEE/ACM DAC 2014

* ACM Trans. on Embedded Computing Systems

Android Scheduler & Governor



- A user-centric scheduler and governor that allocate computing resources to applications according to their sensitivity



Demo 3 - Samsung Galaxy S4

Summary

- This work introduces application sensitivity into scheduling and governing designs on mobile systems.

- We integrate our user-centric scheduler and governor (UCSG) into Android.
  - UCSG allocates computing resources to applications according to their sensitivity.
  - Samsung Galaxy S3 can save 25% CPU energy while improving the response time by 31%.

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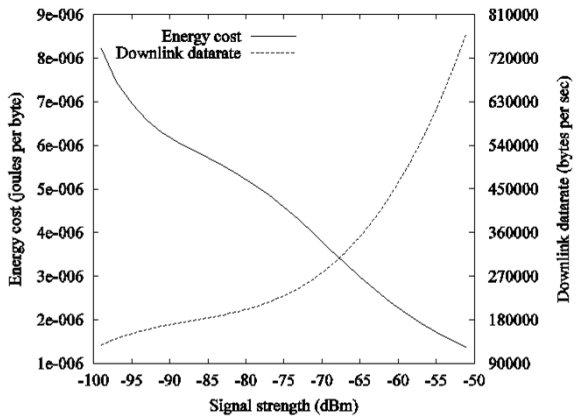
Energy-Efficient Communication

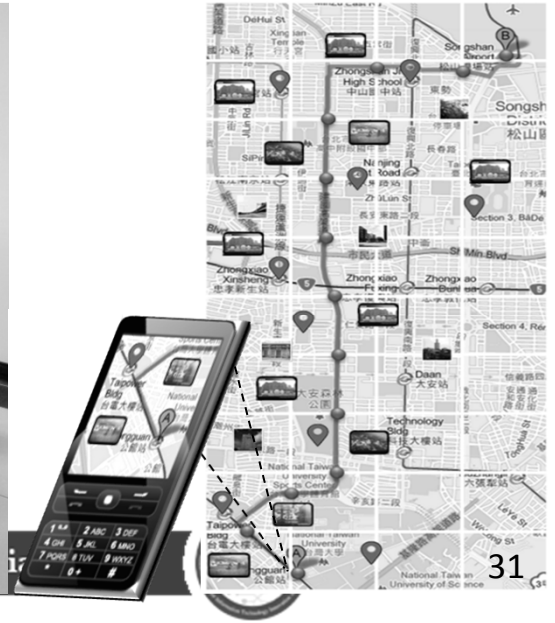
- Reducing the communication energy is an imminent challenge in stimulating mobile applications.
- Basically, existing approaches leverage the complementary characteristics of WiFi and 3G
  - ➢WiFi to improve energy efficiency
  - ➢3G to maintain ubiquitous connectivity

Extend Your Journey: Introducing Signal Strength into Location-based Applications

- **A characteristic of communication systems**
  - Receive energy ∝ 1/signal strength
- **The technical problem**
  - How to prove if the concept of introducing SS into LBS works in real environment?
- **Contributions**
  - A virtual tour system
  - A fundamental algorithm for data fetch scheduling
  - Postoptimal analysis w.r.t signal fluctuation

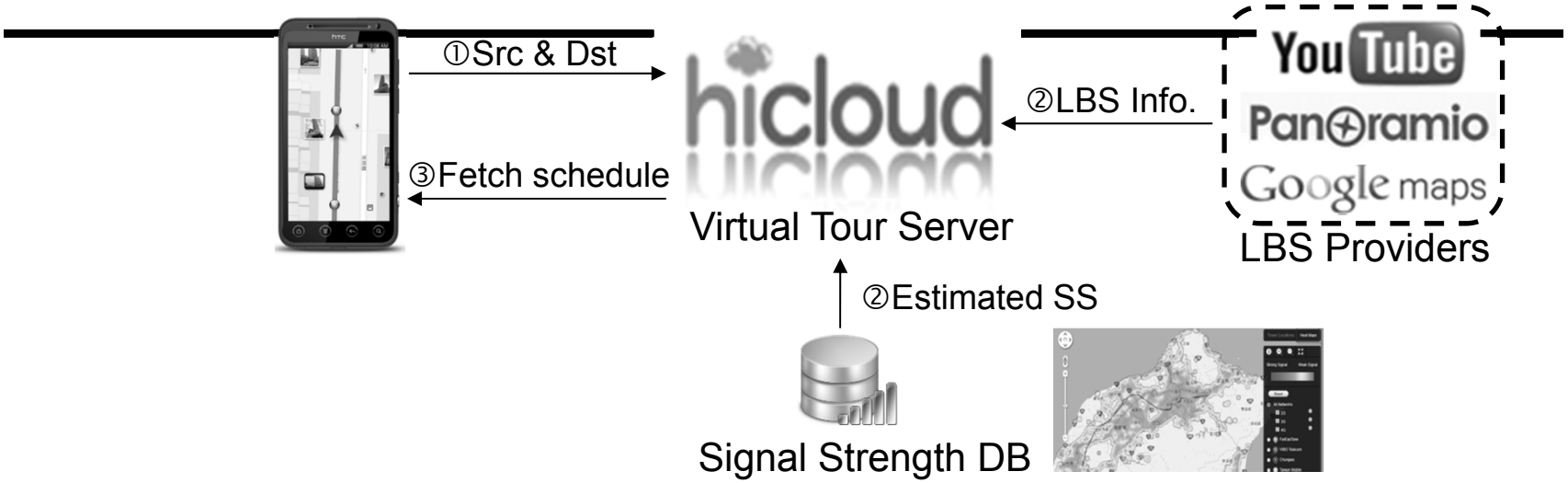


Signal strength (dBm)	-50	-60	-70	-80	-90	-100
Energy cost (Joule/byte)	0.00001	0.00002	0.00004	0.00005	0.00006	0.00008



*IEEE INFOCOM 2013
*IEEE/ACM Trans. on Networking 2015

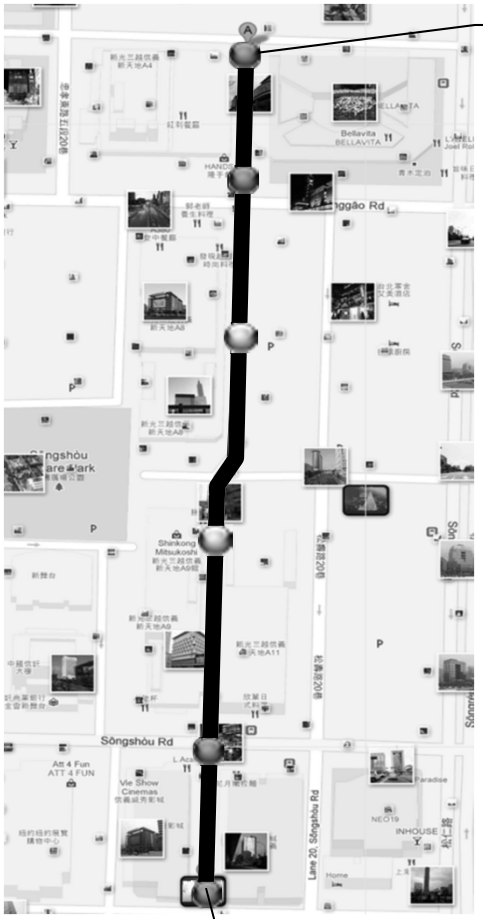
A Virtual Tour System



Example applications

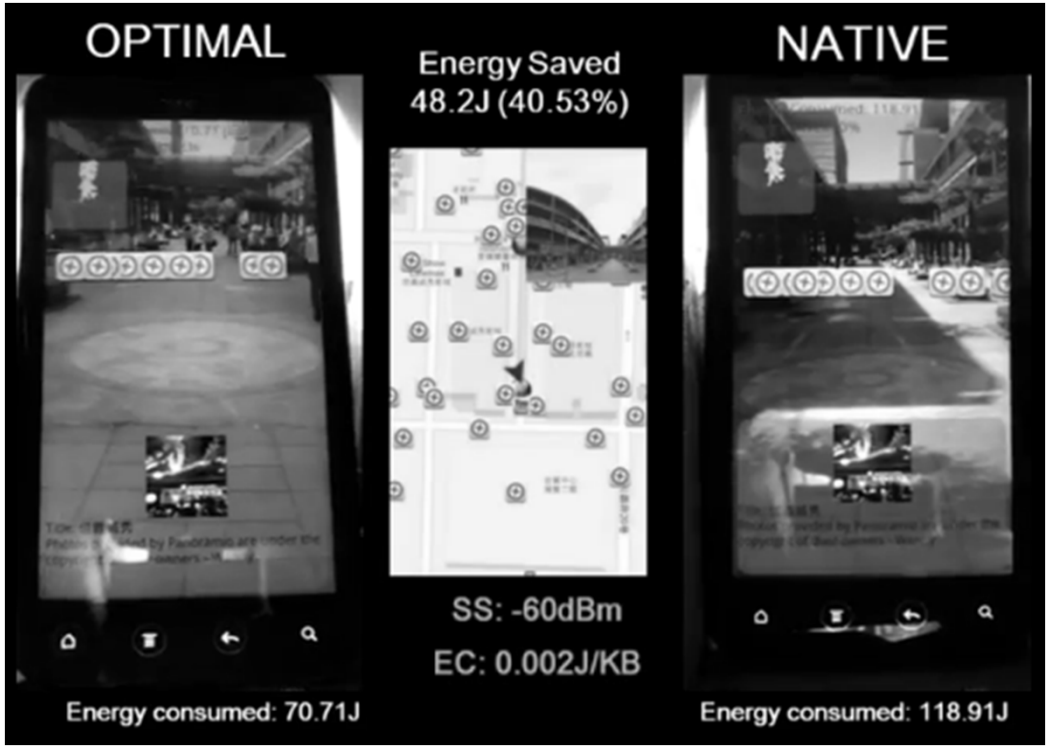
The mobile platform

Demo 4 – HTC EVO 3D



Taipei City Hall

VIEWSHOW



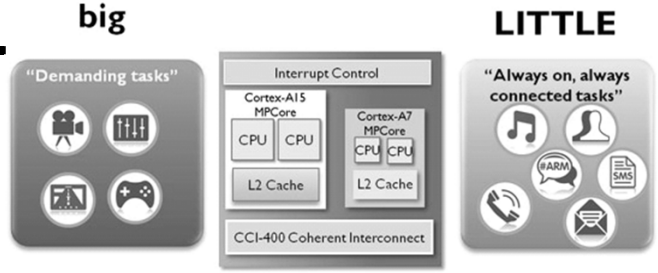
Summary

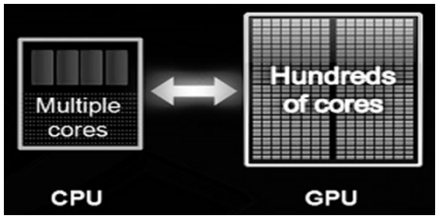
- This work introduces signal strength into location-based applications to reduce the energy consumption of mobile devices for data reception.

- We have deployed a virtual tour system to prove this concept.
  - The system schedules the fetching locations of objects based on signal strength without changing the application's semantics.
  - An HTC EVO 3D smartphone can achieve 30-70% of energy savings for data reception.

Ongoing Research

- **Compt.: Asymmetric & Heterogeneous**

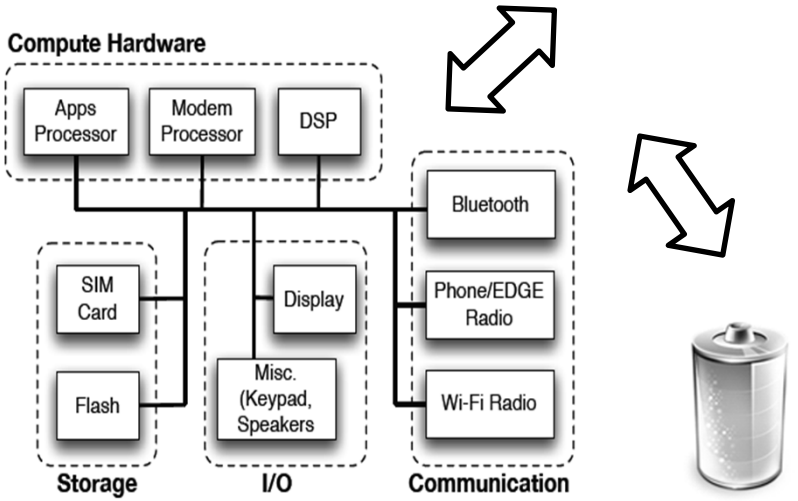




* IEEE/ACM ICCAD 2015
* ACM Trans. on Embedded Computing Systems

- **Comm.: Remote Sensing**

- **Standby: Wakeup Management in Connected Standby**



Concluding Remarks

- Mobile systems should move towards user-centric designs that consider human factors
  - Original concepts and prototype systems
- Tight collaboration with the industry
  - Technology transfer to have practical impact
  - Project collaboration to identify real problems
  - Partnership to accelerate technology transfer
- Future focuses
  - Scientific and engineering research to affect the future designs of mobile systems in the interconnection of smartphones, wearables, and the cloud

Epilog

- It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow.

  – Robert H. Goddard

- The past years have witnessed fallen giants
  - Kodak, Sony, Nokia, Apple, …?

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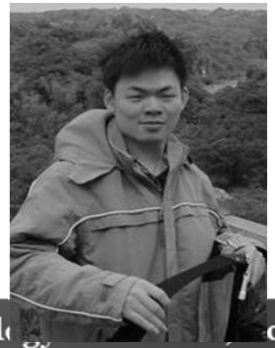

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Thank You