A New Paradigm for Power Management

MyungJoo Ham / Frontier Computer Science (FCS) Lab
MY PHONE'S LOW BATTERY WARNING

IS THE ONLY WARNING I TAKE SERIOUSLY

http://www.callcentermemes.com
User Experience?

http://memegenerator.net/instance/60729280


http://memecrunch.com/meme/1E7CM/battery-life

Google Image, “battery meme”
What We Had Been Doing?

- **Power Management @ Kernel**

  - Thermal Framework
    - Thermal Driver
  - QoS Framework
    - Device
      - Drivers
  - HOTPLUG
    - SoC
      - HOTPLUG
        - Driver
  - CPUIDLE
    - SoC
      - CPUIDLE
        - Driver
  - CPUFREQ
    - SoC
      - CPUFREQ
        - Driver
  - Suspend
  - LDM
  - Runtime
    - PM
  - DEVFREQ
    - Device
      - Policy
    - Governor
  - OPP
    - Soc OPP Spec
  - Clock
    - Framework
    - SoC Clk Driver
  - Power
    - Domain
    - SoC P/D
      - Drv
  - Regulator
    - Framework
  - PMIC
    - Device
      - H/W
  - SOC
  - CPUFREQ
  - Driver
  - CPUIDLE
  - Driver
  - HOTPLUG
  - Driver
  - SoC
  - H/W
  - PMIC
  - H/W

A Lot… Really A Lot…
Then, What We Have Been Doing Recently?

- **Power Management @ Kernel**

```
Thermal Framework
  |                  |
  | Thermal Driver  |
  |                  |
HOTPLUG       CPUIDLE       CPUFREQ
  |SoC HOTPLUG Driver|  |SoC CPUIDLE Driver|  |SoC CPUFREQ Driver|
  |                  |  |                  |  |                  |
  |                  |  |                  |  |                  |
Suspend       LDM           Runtime PM
  |SoC PM Driver     |  |Device Driver's PM Callbacks|
  |                  |  |                  |
  |                  |  |                  |
OPP            DEVFREQ
  |Soc OPP Spec      |  |Device Policy|
  |                  |  |Governor|
  |                  |  |                  |
  |                  |  |                  |
  |                  |  |                  |
  |                  |  |                  |
Clock Framework
  |SoC Clock Driver |
  |                  |
  |                  |
Power Domain
  |SoC P/D Drv      |
  |                  |
  |                  |
Regulator Framework
  |PMIC Driver       |
  |                  |
  |                  |
PMIC H/W
  |Device H/W       |
  |                  |
  |                  |
SoC H/W
  |                  |
  |                  |
  |                  |
  |                  |
  |                  |
  |                  |
  |                  |
  |                  |
  |                  |
```
Then, What We Have Been Doing Recently?

- **Power Management @ Kernel**
  - Additional Control Flows

- **Power Management @ Kernel: Device-to-Device Relations**
  - Touch Event → DVFS/Hotplug Boost
  - Video En/Decoder Enable → DVFS Boost to guarantee FPS
  - ...

- **Power Management @ Userspace OS**
  - OS Service – DVFS Ties, QoS/Performance related in-OS interfaces
  - ...

- **Power Management based on User Intention/Behavior Inference**
  - Smart Stay
  - Ultra Power Saving Mode
  - ...
User Reaction?

- Power Management @ Kernel
  - Device-to-Device Relations
    - Touch Event
    - DVFS/Hotplug Boost
    - Video En/Decoder Enable
    - DVFS Boost to guarantee FPS

- Power Management @ Userspace OS
  - OS Service – DVFS Ties, QoS/Performance related in-OS interfaces

- Power Management based on User Intention/Behavior Inference
  - Smart Stay
  - Ultra Power Saving Mode
Are We Missing Something?

http://scifi.stackexchange.com/questions/2013/which-episode-is-the-double-facepalm-image-macro-from
Jonghwa Lee

Kernel / Power Management (Tizen Products)
Hyungwon Hwang
(former) App Developer of a Start-up
Maybe That’s Missing.

http://scifi.stackexchange.com/questions/2013/which-episode-is-the-double-facepalm-image-macro-from
Maybe That’s Missing.

APPLICATIONS!

http://scifi.stackexchange.com/questions/2013/which-episode-is-the-double-facepalm-image-macro-from
Maybe That’s’s Missing.

http://scifi.stackexchange.com/questions/2013/which-episode-is-the-double-facepalm-image-macro-from
Is It That BAD?

About 1,580,000 results (0.51 seconds)

What's killing your battery? Android's top 10 performance:
- Top 10 Battery-Draining Game Apps
- Puzzle & Dragons (GungHo Online Entertainment)
- Hay Day (Supercell)
- Candy Crush Saga (King)
- Minecraft – Pocket Edition (Mojang)
- Cookie Jam (SGN)
- Pet Rescue Saga (King)
- Clash of Clans (Supercell)
- Bubble Witch 2 Saga (King)

GSam Battery Monitor - Android Apps on Google Play
- Rating: 4.5 - 39,692 votes - Free

These apps are draining most of your data and battery life:
U.S. smartphone users have about 30 apps on their smartphones, on average. But the most used apps — messaging, social media, and streaming entertainment — happen to be the biggest guzzlers of battery power, according to a new study of Android phones from AVG Technologies, an online security company.

Some of the worst offenders are apps that run automatically when a phone boots up, whether you open them or not. The biggest offenders in that category are Facebook, Kik, WhatsApp, Facebook Messenger and RetailMeNot. These apps are constantly running in the background, checking for updates and messages.

For apps that don’t start automatically, Amazon Kindle, Snapchat, LINE, Spotify, Netflix and Amazon Shopping give battery life the biggest beating — but only when you’re actively using them, unlike Facebook, which drains your battery whether you’re using it or not. Surprisingly, the Wal-Mart app is the top battery drainer among U.S. Android users in this category.
Many of these apps, that are 'secretly' draining your battery, are messaging, social media and streaming apps.
According to AVG, Samsung's AllShareCast Dongle S/W Update, ChatON Voice & Video Chat and Samsung WatchON Tablets apps are all among the biggest battery drainers among apps that start up when you turn your phone on. Other battery-killing apps include magicApp, Facebook and Path. When it comes to mobile games, meanwhile, AVG says that the top three worst battery drainers are Puzzle & Dragons, Supercell's Hay Day and Candy Crush Saga.

In addition to tracking battery-draining apps, AVG also tracks apps that hurt your phone's overall performance (Facebook is No. 1, Path is No. 2 while Instagram is No. 4) and that eat up your phone's storage space (NY Times’ Breaking News app is No. 1). To check out all the apps that are hurting your Android phone in various ways, check out CNET's summary by clicking the source link below.

TAGS: ANDROID
SOURCE: CNET
Examples of App Energy Bugs

- **Apps w/ Wakelock Bugs (Android)**
  - Frequency: even major apps…

  - Severity: drains the battery while not using

  * Data from http://mobed.yonsei.ac.kr/wakescope
  ** Data from NSDI’13, “eDoctor: Automatically Diagnosing Abnormal Battery Drain Issues on Smartphones”
  *** Data from MobiSys’12, “What is keeping my phone awake?: characterizing and detecting no-sleep energy bugs in smartphone apps”

While you are not using it.
E.g., sleeping, driving, …

5 ~ 25% / hr***
Examples of App Energy Bugs

- Apps w/ Wakelock Bugs (Android)
  - Frequency: even major apps...
  - Severity: drains the battery fast

Properly optimized phone sleeping: < 10mW
Energy bug apps + phone sleeping: ~ 1W

x 100 energy usage!

Your sleepless nights to reduce 10% of sleeping energy are TOTALLY

* Data from http://mobed.yonsei.ac.kr/wakescope
** Data from NSDI'13, "eDoctor: Automatically Diagnosing Abnormal Battery Drain Issues on Smartphones"
*** Data from MobiSys'12, “What is keeping my phone awake?: characterizing and detecting no-sleep energy bugs in smartphone apps” picture from https://www.youtube.com/watch?v=jeYQp0Mt2hA (GTA V screenshot)
Examples of App Energy Bugs

• Apps w/ Unnecessary & Excessive Peripheral Device Usage
  – Frequency: even major apps...

  * GPS
  Installs: 10M-50M

  – Severity: drains the battery fast

  You expect normal (mostly idle) usage.
  Your device executes heavily

  ~ 15% / hr***

  * Data from MobiSys'12, “What is keeping my phone awake?: characterizing and detecting no-sleep energy bugs in smartphone apps”
Examples of App Energy Bugs

- Apps w/ Unnecessary Loops or Immortal Apps

  - Severity: drains the battery while not using.

  * Background Load
  Installs: 100M-500M

  * Background Load
  Installs: 1B-5B

  Anytime your device is on, secretly…

  * -30 ~ -40% battery life.

* Data from AVG 2014 Q4 Report, “Android App Performance Report”
OK. Then,
What Should We Look At?
The Whole Ecosystem
The Big Picture, The Ecosystem

Consumer

Market Place

Operator

SW Platform (OS) Vendor

Manufacturer

Photos from wikipedia, pixabay
The Big Picture, The Ecosystem, Extended

- Consumer
- Operator
- Market Place
- SW Platform (OS) Vendor
- Manufacturer
- Component Manufacturer
- In-house / 2nd-party App Developer
- (3rd party) App Developer

Photos from wikipedia, pixabay
The Big Picture, Relations: Money Flows

- Consumer
- Operator
- Manufacturer
- SW Platform (OS) Vendor
- App Developer

Need Longer Battery Life.

Ok, I’ll Do…

Yes, Sir!
(Uh.. Hey.. I need OS to take care as well.)
The Big Picture, Relations

Don’t know which app is bad. (Whatever… the phone maker is bad.)

My Product is affected by them. But I can do nothing about it…

Affecting Energy Efficiency Greatly

Operator

消费者

(3rd party)
App Developer

Consumer

Manufacturer

App Developer

Operator

Manufacturer

SW Platform (OS) Vendor

MyungJoo Ham, Frontier Computer Science Lab

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The Big Picture

What If 3rd Party App Developers Also Address Energy Efficiency?
Observation? Stereotypes? OR... Paranoia?

- It appears that App developers mostly
  - Do NOT care power consumption
  - Do NOT want to optimize energy efficiency
  - Do NOT know how to optimize energy efficiency
Observation? Stereotypes? OR… Paranoia?

• It appears that USERS mostly
  – DO care energy efficiency
  – DO blame manufacturers for energy efficiency
  – DO not have effective mechanisms
to look at the energy efficiency
“Ability is what you're capable of doing. Motivation determines what you do. Attitude determines how well you do it.”

Lou Holtz
WHAT CAN WE DO
device/user-centric to ECO-CENTRIC?

In-house / 2nd-party App

Userspace OS

HW, Kernel/BSP

Marketplace (Ecosystem)

Motivation

Ability (methods)

3rd Party Apps

MONKIES, Eatalotis

CHIMPUS, Imbecillus

APEIS, Stupidius

NEANDERSLOB

HOMER SAPIEN

Copyrighted by Twentieth Century Fox
“Working hard for energy efficiency”

Ability
Motivation
….. & Attitude
What Can We Do?: Ability

- Observation
  - Highly skilled and system-understanding app developers have the ability: RARE!

- How Can We Let 3rd Party App Developers Be Able to Improve Energy Efficiency? (trade off power--performance)
What Can We Do?: Ability – Case: TURBO Diaries

- Wamhoff, et al., USENIX ATC 2014
  “The TURBO Diaries: Application-controller Frequency Scaling Explained”

![Diagram showing thread A on Core 2 needs to be boosted and core 2 running thread 100 needs to be boosted.](image-url)
What Can We Do?: **Ability – Case: Heartbeat**

- **Application Heartbeats (Carbon Research Group, CSAIL, MIT)**
  - App tells OS how fast the App is running: “Heartbeat”
  - OS throttles (e.g., DVFS) accordingly

http://groups.csail.mit.edu/carbon/?page_id=94
What Can We Do?: Ability – Case: FPS/IO-Latency

- **Generalizing Heartbeat → Frame-per-second (FPS)**
  - Transparent to applications.
  - Does not require anything to app developers

- **We don’t know whether INPUT-C is related to OUTPUT-3 or OUTPUT-4.**
  - Even if we have high FPS (60?), there might be input-output sluggish.
  - Unless we do “TAINT” for UI frameworks and apps?

![Diagram showing input and output frames with question marks indicating potential latency issues.](Diagram)
What Can We Do?: Ability – Case: AppScope

- Yoon, et al., USENIX ATC 2012
  - Shows energy usage per device for each thread.

What Can We Do?: **Ability – Case: 1\textsuperscript{st}/2\textsuperscript{nd} Party Apps**

- Privileged APIs for In-House / Contracted (2\textsuperscript{nd} party) Apps
  - E.g., DVFS\_LOCK( CPU, 1000, 200 );
    - For the next 200 ms, run CPU at 1000MHz or faster.

- Solves most “performance issues”,
  allowing more aggressive energy policies.

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F.S. Church, “Pandora”

https://en.wikipedia.org/wiki/Pandora
What Can We Do?: **Ability – Case: Abuse**

- **App Developers (Even In-House & 2nd-party)** Abuse The System!

  - My company wants to use 2CPU > 1GHz for App X
  - My service D requires all cores active & > 800MHz!
  - My dept’s app Y needs 2GHz!
  - My service E requires 2CPU > 1.2GHz for API F
  - Let’s get my app guaranteed **secretly**. Don’t tell kernel guys. They nag you with energy consumption.
  - My dept’s service C needs GPU > 500MHz guaranteed
  - Oh! Turn DVFS OFF while my company’s app Z runs!
  - My service E requires 2CPU > 1GHz for App X
  - Let’s get my app guaranteed secretly. Don’t tell kernel guys. They nag you with energy consumption.
What Can We Do?: Ability – New Requirements

• Easy to Use
  – Should not become another heavy burden for developers.
  – Optional features for “advanced” developers for fine tuning?

• Abuse Prevention or Avoidance
  – Do NOT trust their ability or intention.

• Device/System Transparency
  – App developers should not care whether it’s “Galaxy S6” or “Galaxy S2”
    “Tizen 2.3” or “Tizen 3.0”
    “On Wifi” or “On LTE”
  
  • This is not a simple engineering problem, but an inherent problem of computer systems:
    “How can we normalize the performance across different machines?”

• (Additional) Maintainability
  – Compatible with conventional OS
“Working hard for energy efficiency”

Ability
Motivation
..... & Attitude
What Can We Do?: **Motivation**


Quoted from [http://startupbros.com/killing-the-7-motivation-murderers/](http://startupbros.com/killing-the-7-motivation-murderers/)
What Can We Do?: **Motivation, Hint**

Top 12 Free Apps / Top 12 Paid Apps / Top 12 Grossing Apps (For Galaxy S4 Active @ SKT)

Quoted from http://startupbros.com/killing-the-7-motivation-murderers/
What Can We Do?: Motivation, Hint

Top 12 Free Apps / Top 12 Paid Apps / Top 12 Grossing Apps (For Galaxy S4 Active @ SKT)

- Big (>1000 employees or >$1B revenue): 18
- Mid (>100): 9
- Small (>5): 4
- Self-Employed: 4
- Public/NPO/Hobbyist: 1
What Can We Do?: Motivation, Hint

35 of 36 Top Popular Apps: For Profit

Top 12 Free Apps / Top 12 Paid Apps / Top 12 Grossing Apps (For Galaxy S4 Active @ SKT)

Big (>1000 employees or >$1B revenue) 18
Mid (>100) 9
Small (>5) 4
Self-Employed 4
Public/NPO/Hobbyist 1
What Can We Do?: Motivation, Hint

35 of 36 Top Popular Apps: For Profit

# Users (Paid) and
# Users x Activity (Ad or In-App Purchase) Matters

Top 12 Free Apps / Top 12 Paid Apps / Top 12 Grossing Apps (For Galaxy S4 Active @ SKT)

<table>
<thead>
<tr>
<th>Category</th>
<th># of Apps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big (&gt;1000 employees or &gt;$1B revenue)</td>
<td>18</td>
</tr>
<tr>
<td>Mid (&gt;100)</td>
<td>9</td>
</tr>
<tr>
<td>Small (&gt;5)</td>
<td>4</td>
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<tr>
<td>Self-Employed</td>
<td>4</td>
</tr>
<tr>
<td>Public/NPO/Hobbyist</td>
<td>1</td>
</tr>
</tbody>
</table>
What Can We Do?: Motivation, Hint

- Motivate App Developers by Ensuring
  - Energy Efficiency DIRECTLY Affects #DOWNLOADS (#users)
  - Energy Efficiency DIRECTLY Affects User Activities (usage hours/user, …)
What Can We Do?: Motivation.

Roadblock Ahead
What Can We Do?: Motivation.

Roadblock Ahead

- Energy efficiency of an APP affects INDIRECTLY!
  - Hard to identify who’s at fault & how bad it is.
  - Hard to know beforehand
What Can We Do?: Motivation. How?
What Can We Do?: Motivation. How?

• Making it Direct & Transparent
  – Assess & Publish the App Energy Rating

→ Won’t download or use inefficient apps
What Can We Do?: Motivation. Open Problems.

Assess App Energy Rating

- Problem 1-1.
  - "Need For Speed" used 60J for 1min play
  - "RSS Reader" used 60J for 1min read
- Problem 1-2.
  - "RSS Reader 1" used 5J for 1min, 2msg read.
  - "RSS Reader 2" used 6J for 1min, 4msg read.
- Problem 1-3.
  - "Movie Play 1" used 5J for 1min, 30FPS, "abc.mpeg"
  - "Movie Play 2" used 4J for 1min, 20FPS, "abc.mpeg"
- Problem 1-4.
  - "App A" used 4J for 1min, 200 frames, 10 touches, 10 packets
  - "App B" used 4J for 1min, 300 frames, 4 touches, 9 packets
- Problem 1-5.
  - "App A" is rated "A-" @ Galaxy S5. "A0" @ Galaxy Note4.
  - How is it at my Galaxy S6 Edge?

Publish App Energy Rating

- Problem 2-1.
  - “App B” served “App A”
- Problem 3-1.
  - Get user’s attention
  - Without bloating the interface
  - Without merging with traditional rating system?
- Problem 2-2.
  - How to make test sets & the process automated and generalized?
- Problem 2-3.
  - Each user has his/her own usage pattern
- Problem 2-4.
  - An App is just released. We do not have enough data for it.
  - "App B" served "App A". Is it App A’s energy usage? Or B’s? Or partially?
- Problem 2-5.
  - A New Device is just released.
  - Customize results per device
  - Customize results per user
  - We do not have enough data for it.
- Problem 2-6.
  - Prevent abuses & exploits?
  - Won’t we get a backlash from angry developers?

How Are We Going To Rate Them?

- Need to be totally ordered?
What Can We Do?: **Attitude?** "Determines how well you do it"

- **Tools: “PoCoMon”**
  (Power Consumption Monitor, embedded in Tizen mainline, tizen.org)
  - Gorelkina et al., “Power consumption profiling and optimization”, ELCE 2013
  - Monitors energy usage w/ dynamic instrumentation: energy per function call

<table>
<thead>
<tr>
<th>#</th>
<th>Function</th>
<th>mAh</th>
<th>Ncalls</th>
<th>CPU, %</th>
<th>Read, %</th>
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<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**System power consumption**

- est: 2.16 | real: 2.28 | err: 5%

- est: 0.88 | real: 1.05 | err: 15%

- Not Easy for App Developers. (Integrating with SDK)
- Not (Yet) Working for Web Apps (W.I.P.)
What Can We Do?: **Attitude?** "Determines how well you do it"

- **Tools: AppScope (Energy per thread x device)**
  - Low overhead, Peripheral usage tracking.
  - Shows fine-grained energy usage.

- **Tools: XCode energy impact tools**
  - iOS only….
  - Shows coarse-grained energy usage.
    (not in “J” or “W”, but in “#packets”, “%CPU”.)

- **What will be future requirement?**
  - Fine-grained & user friendliness
  - Useful: Off-loaded cost tracking, Per-function/module profiling
  - Energy-bug pointing,
Besides...

- Extend the scope to UX/UI design as well!
  - Example: LPD, Low Power Display Mechanism for Mobile and Wearable Display
- Presenting Friday.
- Energy-Aware Programming Language?
- How do we encourage cross-layer optimization where each layer has different entities with different interest.
  - E.g., hobbyist, app vendor, device manufacturer, accessory manufacturer, OS vendor,

Have a Poster Session As Well.
Eco-Centric Power Management

Service Providers

App Developers

(Third Party)

We also work hard for energy efficiency with strong Ability & Motivation

App Developers

Market Place

Consumers

Operators

(in-House / Preloaded / Second Party)

App Developers

SW Platform (OS)

Developers

iOS

Device Manufacturers

Component Manufacturers

We also work hard for energy efficiency with strong Ability & Motivation

Energy Efficiency