

Energy Labels for Mobile Applications

EEbS 2012

Claas Wilke

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**YOU ARE LOST, YOU'RE
H/SMARTPHONE AGAIN...**


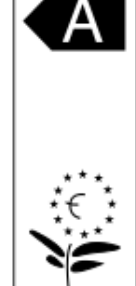




PROBLEM

- Mobile devices have **limited battery** uptime
- Depending on usage, **uptime can vary** heavily
- Although providing similar services, **different applications** consume different amounts of energy
- Users **select** their applications **based on community rankings** but not on power consumption


If you buy a washing machine ...



| Energie | | Waschmaschine |
|---|-----------------------|---|
| Hersteller | | |
| Modell | | |
| Niedriger Energieverbrauch | | A |
|  | |  |
| Hoher Energieverbrauch | |  |
| Energieverbrauch kWh/Waschprogramm <small>(ausgehend von den Ergebnissen der Normprüfung für das Programm „Baumwolle, 60 °C“)</small> | | 0,89 |
| <small>Der tatsächliche Energieverbrauch hängt von der Art der Nutzung des Gerätes ab</small> | | |
| Waschwirkung <small>A: besser G: schlechter</small> | | A B C D E F G |
| Schleudervirkung <small>A: besser G: schlechter Schleuderdrehzahl (U/min)</small> | | A B C D E F G 1800 |
| Füllmenge (Baumwolle) kg | | 5 |
| Wasserverbrauch | | 39 |
| Geräusch (dB(A) re 1 pW) | Waschen Schleudern | |
| <small>Ein Datenblatt mit weiteren Geräteangaben ist in den Prospekten enthalten</small> | |  |
| <small>Norm EN 60455 Richtlinie 95/12/EG Waschmaschinenetikett</small> | | |






If you buy/install an app ...

Neu! Google Play WEITERE INFORMATIONEN


 Google play

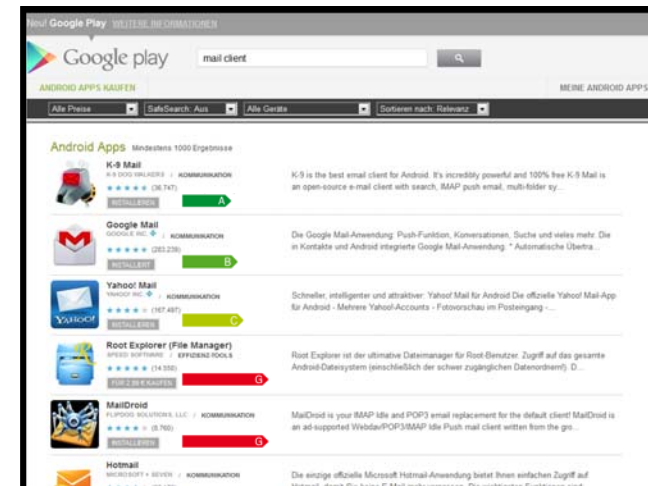
ANDROID APPS KAUFEN
Alle Preise
SafeSearch: Aus
Alle Geräte
Sortieren nach: Relevanz

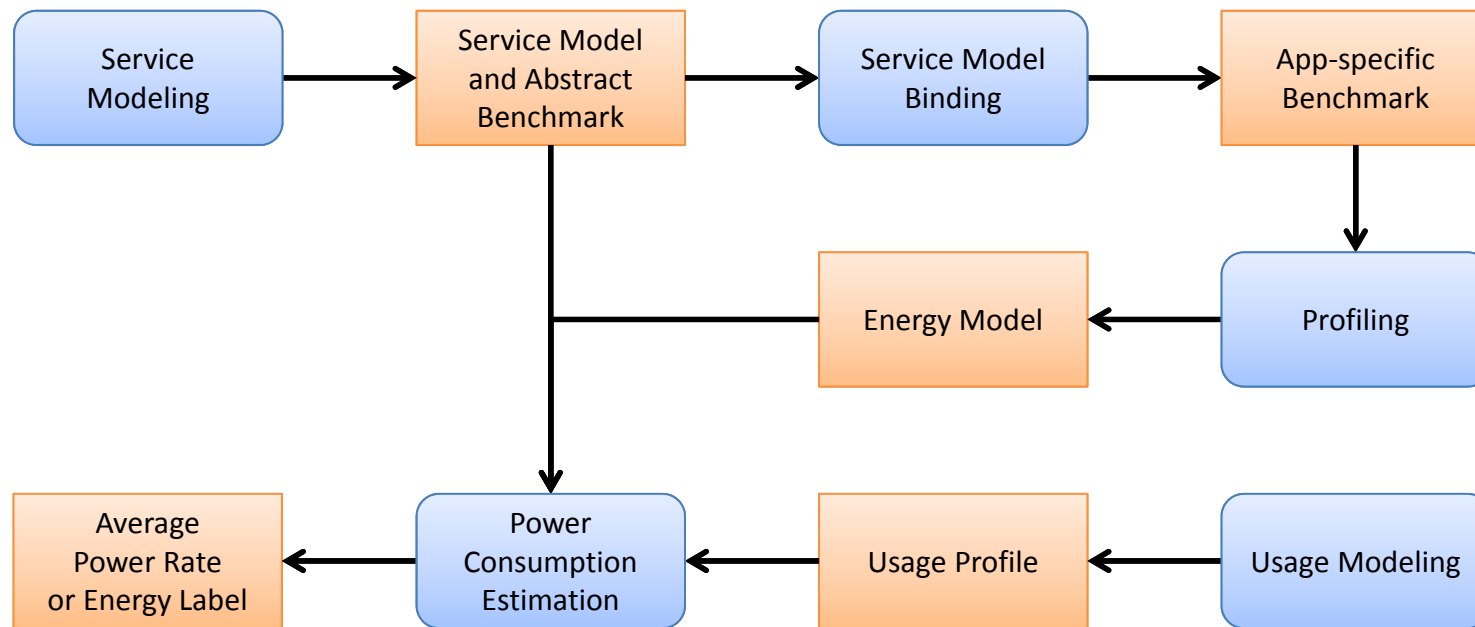
Android Apps Mindestens 1000 Ergebnisse

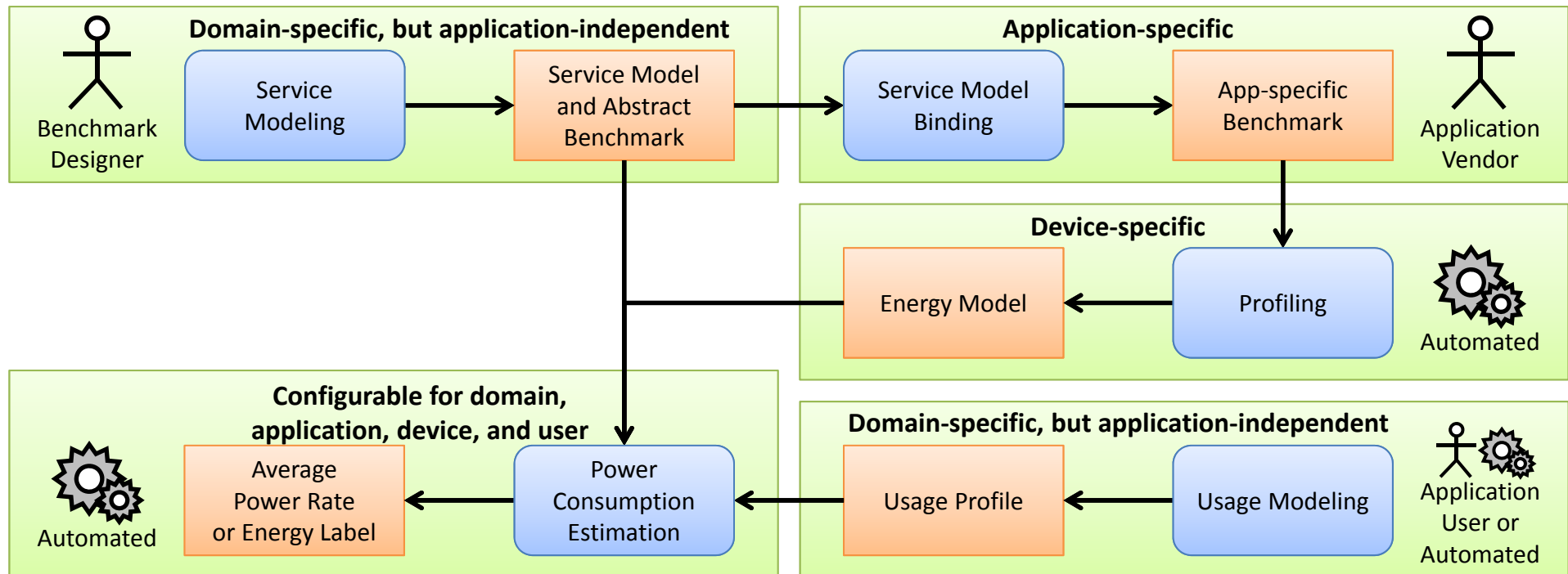
| App Icon | App Name | Developer | Category | Rating | Price | Action | Description |
|---|-------------------------------------|------------------------|-----------------|-----------------|--------|----------------------------|--|
|  | K-9 Mail | K-9 DOG WALKERS | KOMMUNIKATION | ★★★★★ (36.747) | Free | INSTALLIEREN A | K-9 is the best email client for Android. It's incredibly powerful and 100% free K-9 Mail is an open-source e-mail client with search, IMAP push email, multi-folder sy... |
|  | Google Mail | GOOGLE INC. | KOMMUNIKATION | ★★★★★ (283.239) | Free | INSTALLIERT B | Die Google Mail-Anwendung: Push-Funktion, Konversationen, Suche und vieles mehr. Die in Kontakte und Android integrierte Google Mail-Anwendung: * Automatische Übertra... |
|  | Yahoo! Mail | YAHOO! INC. | KOMMUNIKATION | ★★★★★ (167.497) | Free | INSTALLIEREN C | Schneller, intelligenter und attraktiver: Yahoo! Mail für Android Die offizielle Yahoo! Mail-App für Android - Mehrere Yahoo!-Accounts - Fotovorschau im Posteingang -... |
|  | Root Explorer (File Manager) | SPEED SOFTWARE | EFFIZIENZ-TOOLS | ★★★★★ (14.550) | 2,99 € | FÜR 2,99 € KAUFEN G | Root Explorer ist der ultimative Dateimanager für Root-Benutzer. Zugriff auf das gesamte Android-Dateisystem (einschließlich der schwer zugänglichen Datenordnern!). D... |
|  | MailDroid | FLIPDOG SOLUTIONS, LLC | KOMMUNIKATION | | Free | | MailDroid is your IMAP Idle and POP3 email replacement for the default client! MailDroid is |

TARGET

- A process to **predict power consumption** of applications based on
 - A **consumption model** and
 - A **usage profile**
- Provide **energy labels** for apps comparing their consumption w.r.t. similar functionality
 - App store with energy labels







MAJOR CHALLENGES

1. Energy profiling method

- How to correlate power consumption and executed services?

2. Energy benchmarking

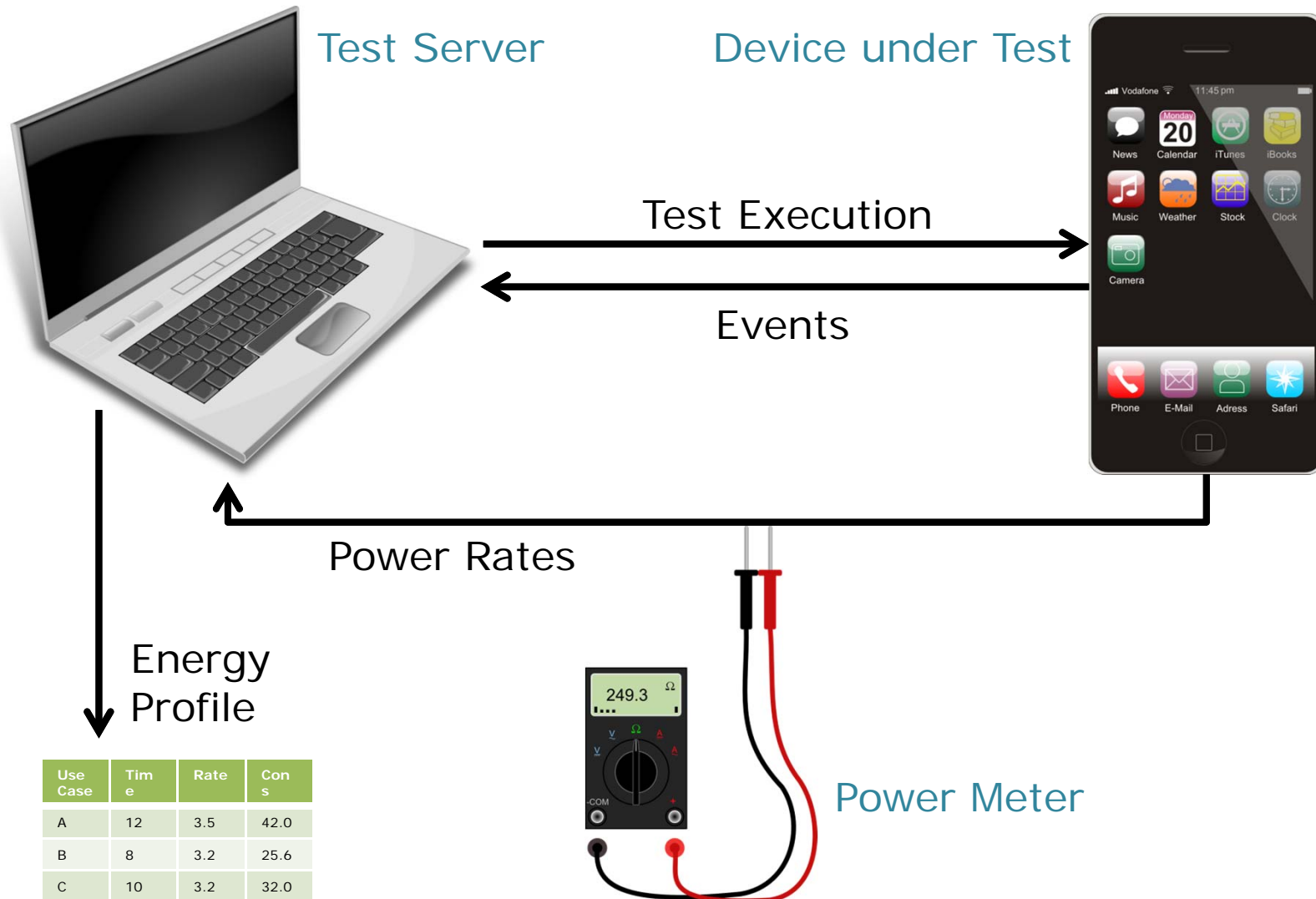
- Do apps influence the energy consumption significantly?
- Can similar services consume different amounts of energy?

3. User behavior profiling and modeling

4. Energy label computation

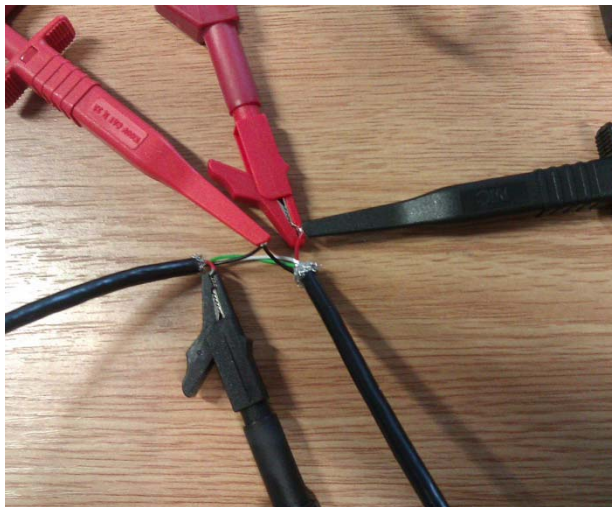
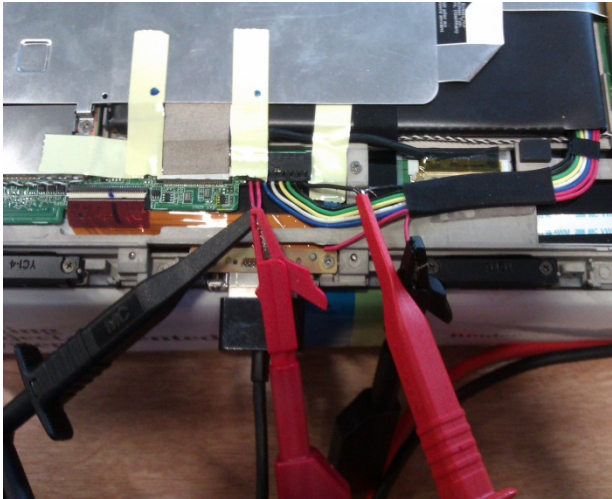
PROFILING

- **Devices** as **black boxes**
- **Execution** of **workloads** represented by **unit tests**
 - **Represent user activities**
 - Click button, enter text, ...
- **Power** rate **profiling** in parallel



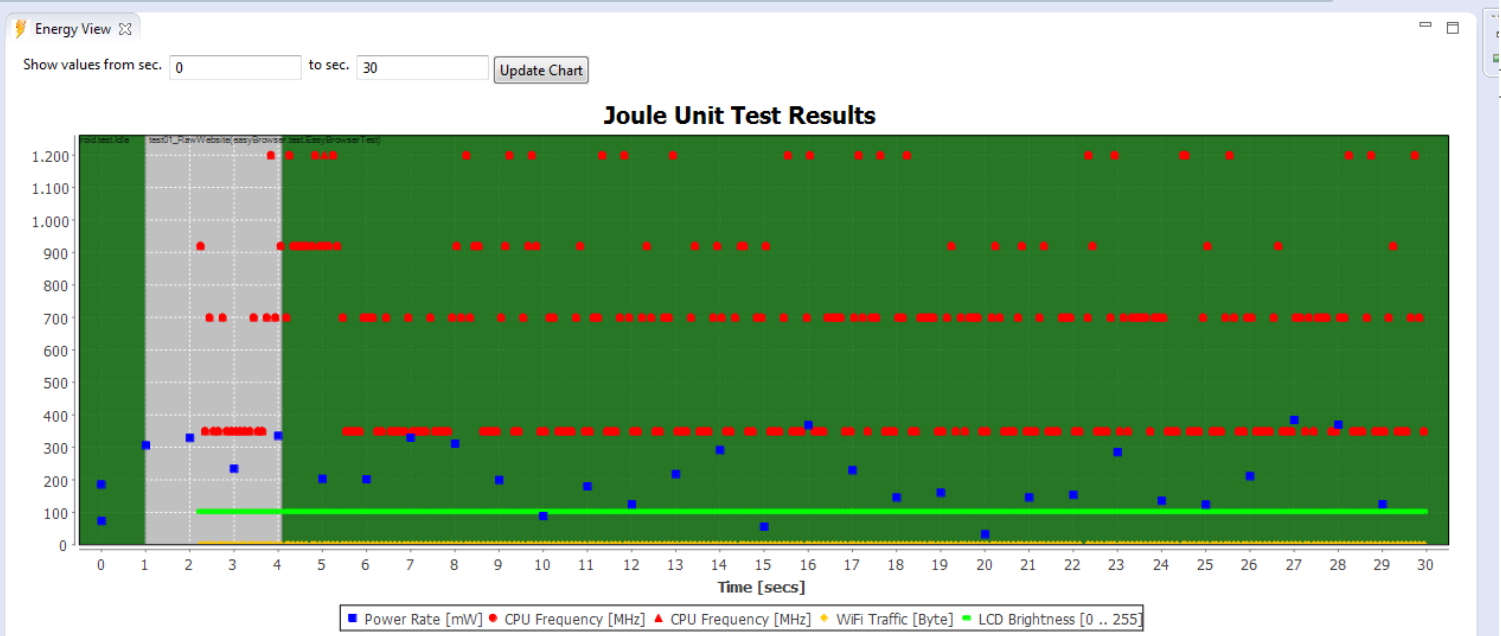
ANDROID PROFILING

- **Extension** of Android **JUnit** runner
 - **Tests** for **third party code** possible
- **Test server**
 - Integration of **external power meter** hardware
 - **Result computation** and presentation **in Eclipse**



Project Explorer

- com.maillroid.test
- droidSurfing 2321 [svn+ssh://svn-st.inf.tu-dresd
- > EasyBrowser 2293 [svn+ssh://svn-st.inf.tu-dre
- k9mail
- k9mail.test
- Maxthon 2321 [svn+ssh://svn-st.inf.tu-dresden.
- Ninesky 2323 [svn+ssh://svn-st.inf.tu-dresden.c
- org.qualitune.jouleunit.android.hwservice
- org.qualitune.jouleunit.android.tests.mail
- > org.qualitune.jouleunit.tests.k9mail 1911 [svn
- org.qualitune.jouleunit.tests.maillroid 1910 [svn



JUnit

Finished after 0 seconds

Runs: 4/30 Errors: 1 Failures: 0

- easyBrowser.test.EasyBrowserTest [Runner: J
 - test01_RawWebsite (7,457 s)
 - test02_CacheRawWebsite (27,490 s)
 - test03_JavaScriptWebsite (26,943 s)
 - test04_CacheJavaScriptWebsite (4,859 s)
 - test05_StyleSheetWebsite
 - test06_CacheStyleSheetWebsite
 - test07_ImageWebsite
 - test08_CacheImageWebsite
 - test09_VideoWebsite

Failure Trace

Test failed to run to completion. Reason: java.io.IO

Joule Unit Test Results

| Test Case | Start [ms] | Stop [ms] | Duration [ms] | Avg. Power Rate [mW] | Energy Consumption [mJ] |
|--|----------------|----------------|---------------|--------------------------------------|--------------------------------------|
| org.jouleunit.android.test.Idle | -1346068501185 | -1346068500186 | 999,00 | Argument 'start' is out of bounds... | Argument 'start' is out of bounds... |
| test01_RawWebsite(easyBrowser.test.EasyBrowser... | -1346068497291 | -1346068468924 | 28367,00 | Argument 'start' is out of bounds... | Argument 'start' is out of bounds... |
| test02_CacheRawWebsite(easyBrowser.test.EasyBr... | -1346068468924 | -1346068441448 | 27476,00 | Argument 'start' is out of bounds... | Argument 'start' is out of bounds... |
| test03_JavaScriptWebsite(easyBrowser.test.EasyBro... | -1346068441440 | -1346068414487 | 26953,00 | Argument 'start' is out of bounds... | Argument 'start' is out of bounds... |

Console

Android

A FIRST CASE STUDY

- **Comparing email clients**



K9 Mail

(> 1,000,000 downloads)



Mail Droid

(> 500,000 downloads)

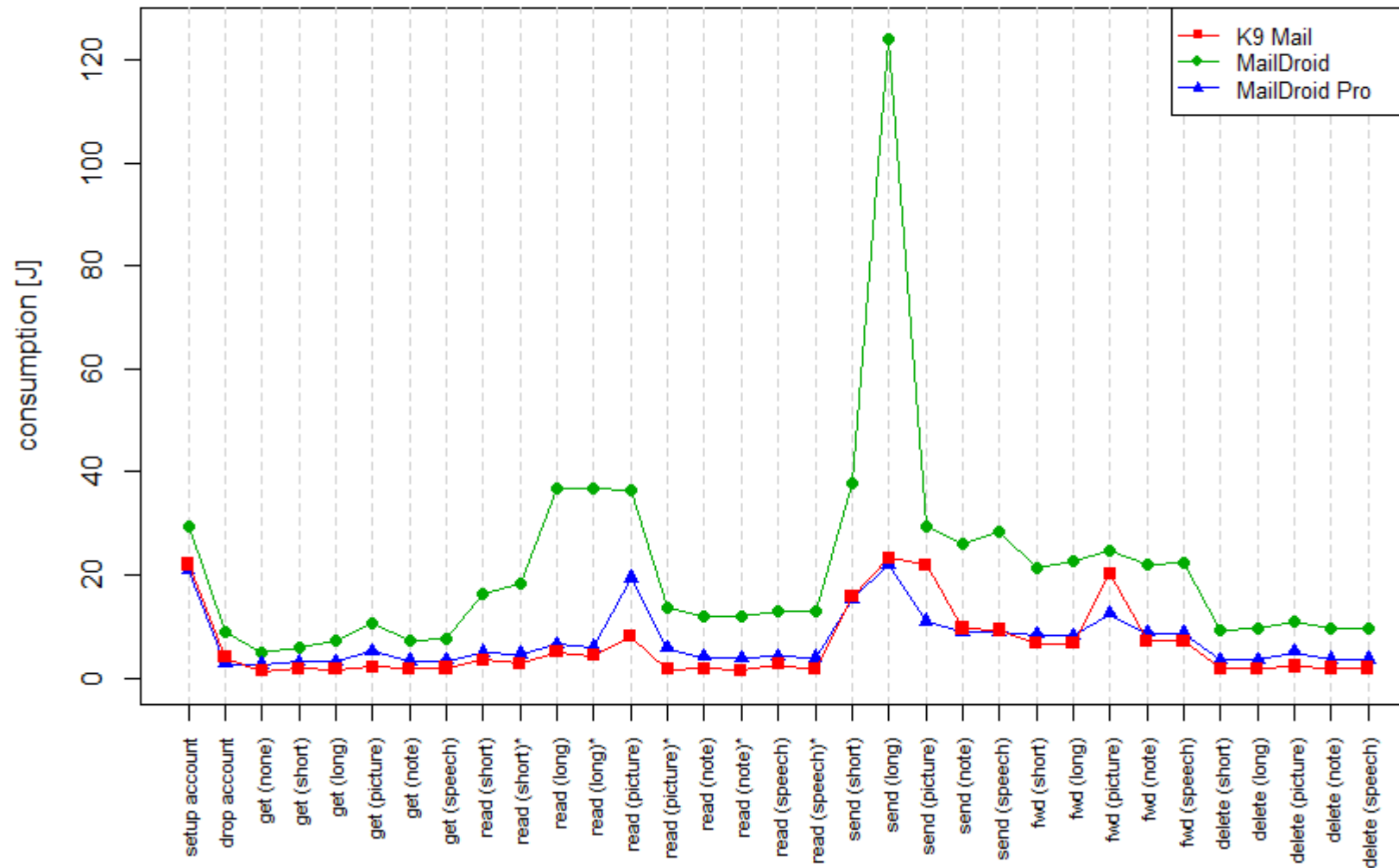
- **Power consumption** for **simple use cases**
(check mails, open mail, open attachment, background service)

A FIRST CASE STUDY

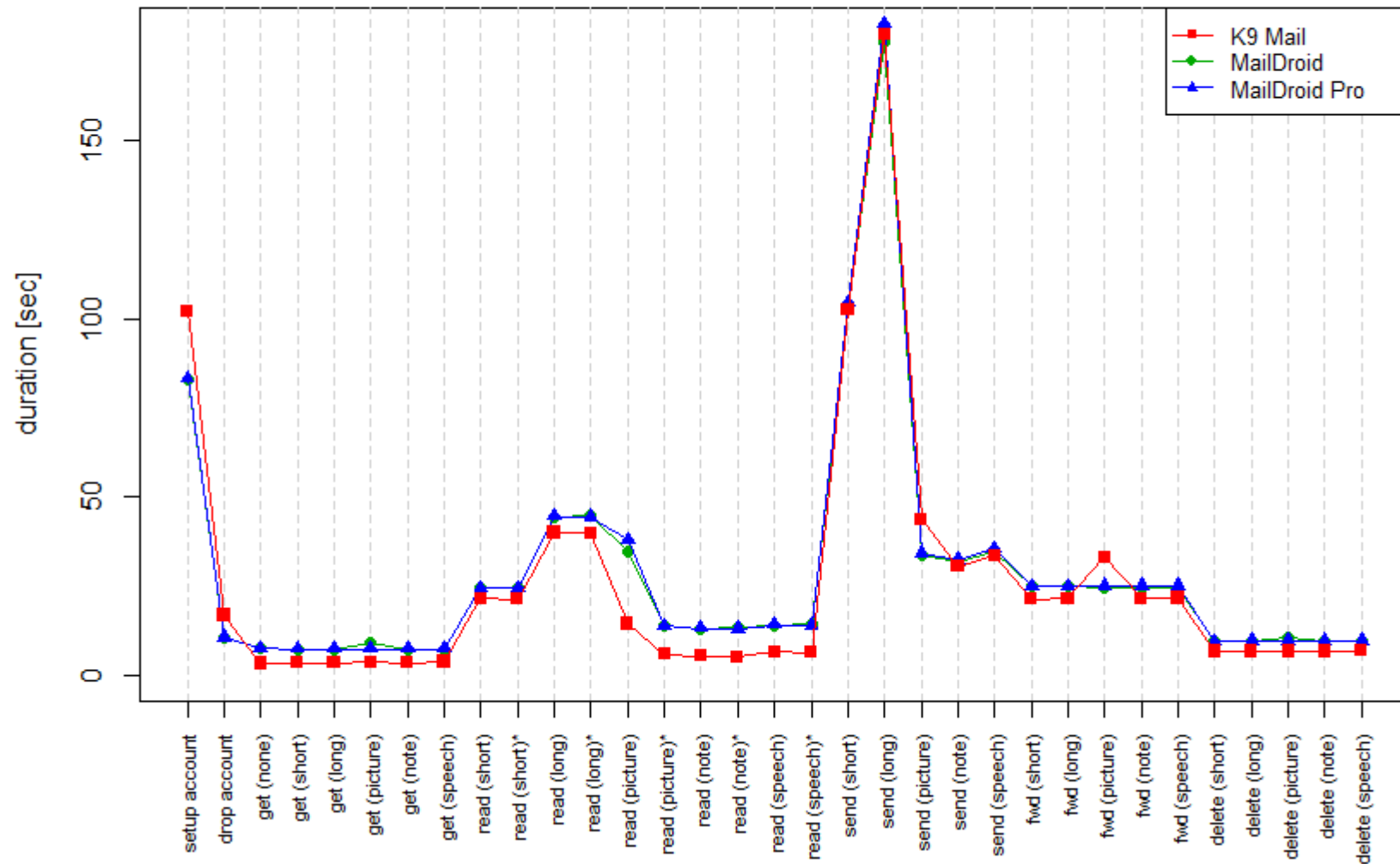
| Use Case | App | Ø power rate [W] | % |
|---------------------------|-----------|------------------|-------|
| Check inbox | K-9 Mail | 0.356 ±0.020 | -17.8 |
| | MailDroid | 0.433 ±0.020 | |
| Read mail | K-9 Mail | 0.259 ±0.017 | -23.4 |
| | MailDroid | 0.338 ±0.011 | |
| Open attachment | K-9 Mail | 0.286 ±0.016 | -31.9 |
| | MailDroid | 0.420 ±0.028 | |
| Background service | K-9 Mail | 0.037 ±0.010 | -75.7 |
| | MailDroid | 0.152 ±0.026 | |

(Each use case profiled five times per app)

Mail Client Power Consumption



Mail Client Execution Time



INTERPRETATION

- **Execution time is no major concern**
 - **K9 Mail is a bit faster** (easier navigation)
- The **major power consumer** in MailDroid is **advertisement**
- **K9 Mail and MailDroid Pro** behave rather **similarly**
 - However, **MailDroid Pro costs 15 Euros ...**

LABELS



K9 Mail

(> 1,000,000 downloads)



Mail Droid

(> 500,000 downloads)



Mail Droid Pro

(> 10,000 downloads)



COMPARING APPLES AND ORANGES?

- **Apps including both, similar and different functionality?**
- Of course, **only similar features** can be **compared**
- Different features are excluded by **setting** their **usage rate to 0**
→ **Comparison of similar features only**
- Only sensible, **if user is not interested** in these features

ONGOING RESEARCH

- **Further case studies**
 - Browsers
 - MP3 players
- Realization of **energy labeling process**

RELATED WORK

ZHANG et al.

- A **model** for smart phones **power consumption based on their hardware utilization**
 - Linear regression model
- **Android app** for applications' **power consumption** approximation
 - **Live approximation based on regression model**
- Identification of **major consumers**
- **No systematic comparison** of similar applications

[ZTQ+10] Zhang, L.; Tiwana, B.; Qian, Z.; Wang, Z.; Dick, R.; Mao, Z. & Yang, L.: *Accurate online power estimation and automatic battery behavior based power model generation for smartphones*. In: Proceedings of the eighth IEEE/ACM/IFIP international conference on Hardware/software codesign and system synthesis, 2010, 105-114.

PALIT et al.

- **Similar profiling** infrastructure
- **Average power consumption** for **typical application use cases**
- Different **devices vary in power consumption** for similar use cases
 - E.g., **energy** consumed **by WiFi** during **Internet browsing**
- **Focus on platforms**, not on applications

- [PANS11] Palit, R.; Arya, R.; Naik, K. & Singh, A.: *Selection and Execution of User Level Test Cases for Energy Cost Evaluation of Smartphones*. In: Proceeding of the 6th international workshop on Automation of software test, 2011, 84-90.
- [APNS12] Abogharaf, A.; Palit, R.; Naik, K. & Singh, A.: *A Methodology for Energy Performance Testing of Smartphone Applications*. Proceedings of the ICSE-AST 2012, Zurich, Switzerland, June 2-3, 2012., 2012.

PATHAK et al.

- Profiling and identification of **energy bugs**
 - **Approximation method** based on FSMs expressing the phone's energy behavior and system call traces
- Investigation of **several popular Android apps**
 - **Up to 75%** of free app's energy is spent for **advertisement**
 - **I/O operations** consume the most energy
- **Static analysis** tool to find **energy bugs**

[PHZ+11] Pathak, A.; Hu, Y.; Zhang, M.; Bahl, P. & Wang, Y.: *Fine-grained power modeling for smartphones using system call tracing*. In: Proceedings of the sixth conference on Computer systems, 2011, 153-168.

[PHZ12] Pathak, A.; Hu, Y. & Zhang, M.: *Where is the energy spent inside my app?: fine grained energy accounting on smartphones with Eprof*. In: Proceedings of the 7th ACM European conference on Computer Systems, 2012, 29-42.

CONCLUSION

- Mobile **applications consume too much** energy
- **Apps influence power consumption** significantly
- Different apps for **similar services can** significantly **vary in** their **power consumption** (e.g., advertisement)
- **Energy labels** can help **to guide users** to the „green“ apps
- **Comparison** can also **identify major drawbacks** in specific apps' implementation
- Summing up this talk in 4 minutes: **<http://is.gd/energyLabel>**

THANK YOU!

- Summing up this talk in 4 minutes: <http://is.gd/energyLabel>
- More information on our project: <http://www.qualitune.org/>
- Contacting me: claas.wilke@tu-dresden.de