Collaborative Mobile Device Analytics in the Cloud

Professor Sasu Tarkoma, Head of the Department

Carat team (carat.cs.helsinki.fi)

23 November 2016

University of Helsinki

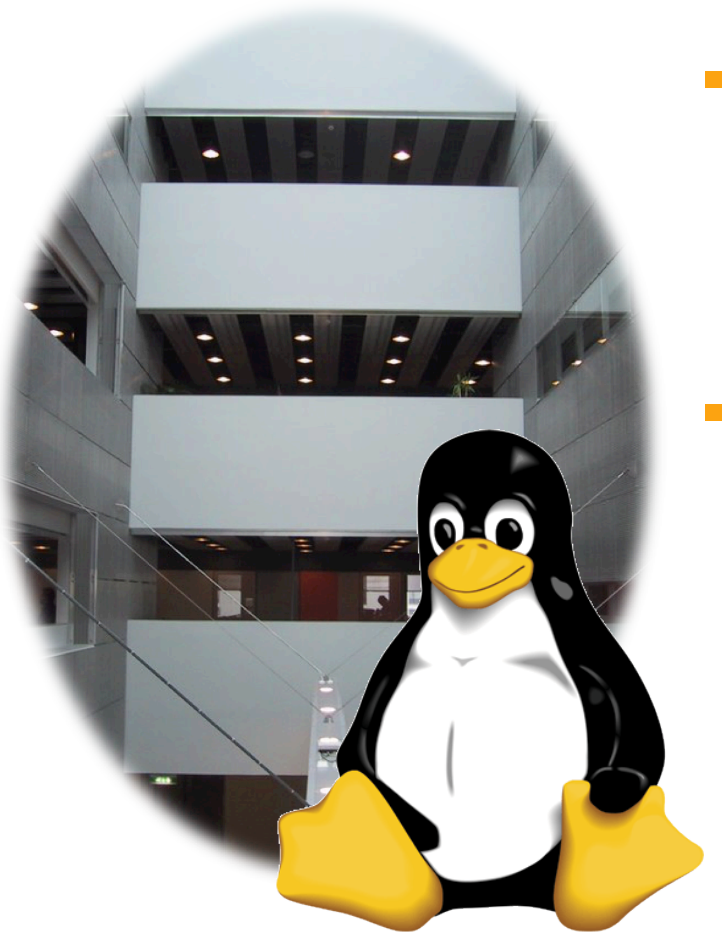
- The largest and the oldest university in Finland
- Key data for 2015
  - 32 000 students
  - 7 900 employees
  - 300 subjects
  - 6 100 degrees/year
  - 530 PhDs/year
- Founded in Turku 1640
- Moved to Helsinki 1828

Faculty of Science at Kumpula Campus

Departments

- Chemistry
- **Computer science**
- Geosciences and Geography
- Mathematics and Statistics
- Physics

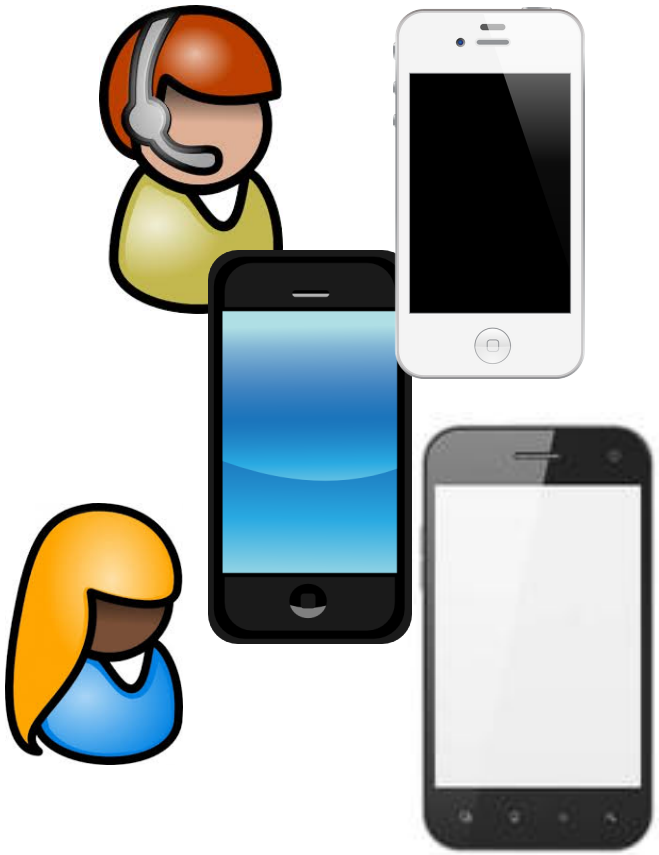
49 Years of Excellence



- **Department of Computer Science**
- Leading institution in Computer Science in Finland
  - #69 in Times Higher Education 2016-2017

- **Core CS and Data Science**
  - Algorithms, Data Analytics and Machine Learning
  - Software Systems
  - Networking and Services
  - Bioinformatics

Motivation



Battery lifetime?

Risk level?

Many heterogeneous, active devices and many users with different intents. – What kind of behavior is **normal** or **typical**?

The Issue of Battery Life

Mobile device's limited battery capacity is a common problem

The typical smartphone battery runs out in 4-6 hours when watching videos

Longer when on standby

Up to a week in airplane mode

How to **save energy** instead of restricting usage?

Introducing Carat

Carat is the **first system** to use the mobile device community to detect and correct energy problems

Our method for **diagnosing** energy anomalies uses the community to infer a specification (expected energy use), and we call deviation from that inferred specification an anomaly

Carat

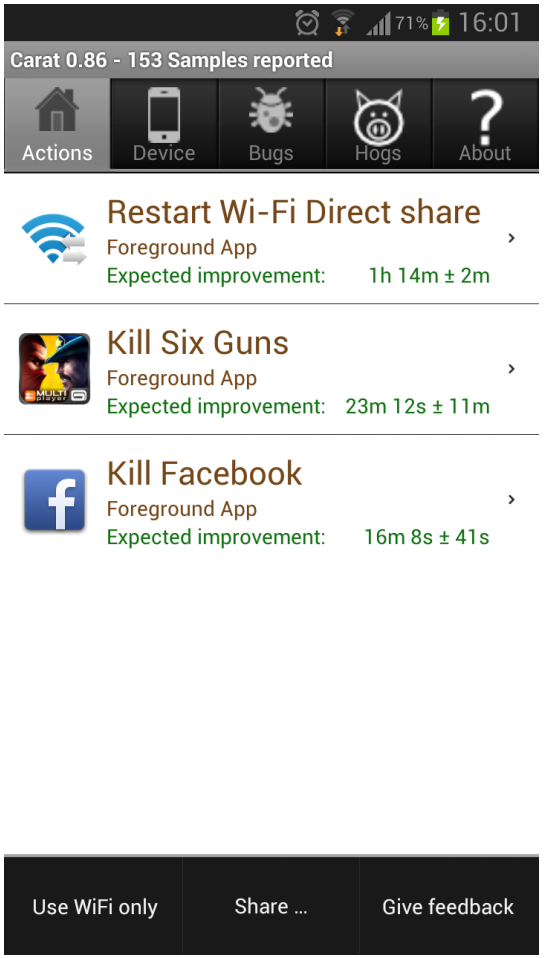
- Originated in UC Berkeley, in collaboration with University of Helsinki
- Mobile app for Android and iOS
- Currently over 850 000 users
- >2.5 TB of data, > 250 million measurements
- Research project with many directions
- http://carat.cs.helsinki.fi

UNIVERSITY OF HELSINKI

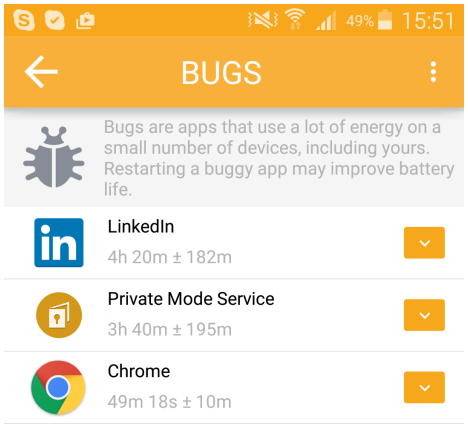
amplab UC BERKELEY

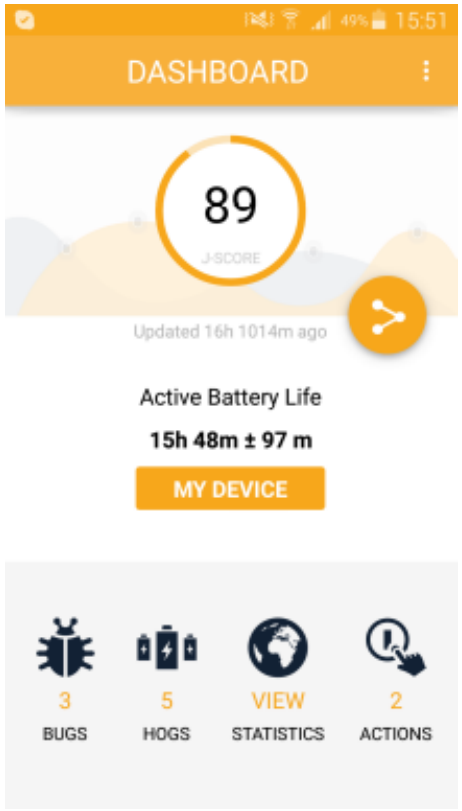
What is Carat?

- Mobile app shows users advice:
  “Kill Facebook for 16m ± 41s battery life”
- Energy **hogs** and **bugs**
- Tracks user's battery life average since installation
- Places users within community with a ranking called J-Score



New UI


49% 15:51
BUGS
Bugs are apps that use a lot of energy on a small number of devices, including yours. Restarting a buggy app may improve battery life.
LinkedIn
4h 20m ± 182m
Private Mode Service
3h 40m ± 195m
Chrome
49m 18s ± 10m


49% 15:51
DASHBOARD
89
J-SCORE
Updated 16h 1014m ago
Active Battery Life
15h 48m ± 97 m
MY DEVICE
3
BUGS
5
HOGS
VIEW
STATISTICS
2
ACTIONS

Comment 36 Like 1k Tweet Share 309 +1 171

Carat: The Brilliant App That Increases Your Battery Life By Showing What Other Apps To Kill

JOSH CONSTINE

Thursday, June 14th, 2012 **36 Comments**

"Kill Pandora – Expected Battery Life Improvement: 1 hour 50 minutes" This is what you'll learn from **Carat**, an incredibly useful free **new iOS** and **Android app** that's the first to give you personalized mobile battery life-saving recommendations.

Carat quietly takes measurements from you device, does some math, combines it with other people's anonymized data, and sends back tips on if you should update your OS, kill or restart apps, and how many more minutes of tablet or phone fiddling you'll gain.

As battery tech is expected to improve slowly, some say increasing life just 5% a year, and as we get faster processors, more powerful apps, and brighter screens, everyone could use a Carat in their pocket.

Suddenly...

lifehacker

TOP STORIES

t

By

'o Kill

36 Comments

Life Improvement: 1 hour
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Suddenly...

lifehacker

TOP STORIES

171

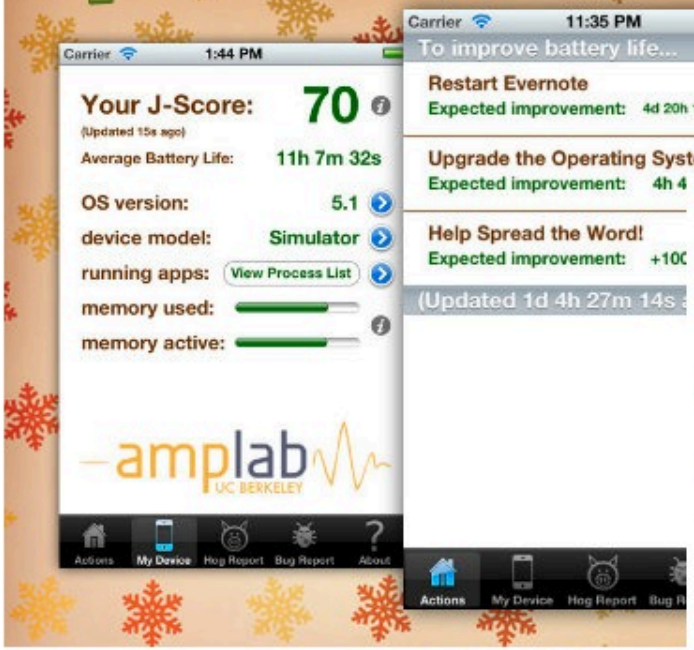
t

By

'o Kill

Free Carat app finds 'energy hogs,' 'energy bugs' on iOS or Android devices

ANDROID | JUNE 14, 2012 | BY: MICHAEL SANTO



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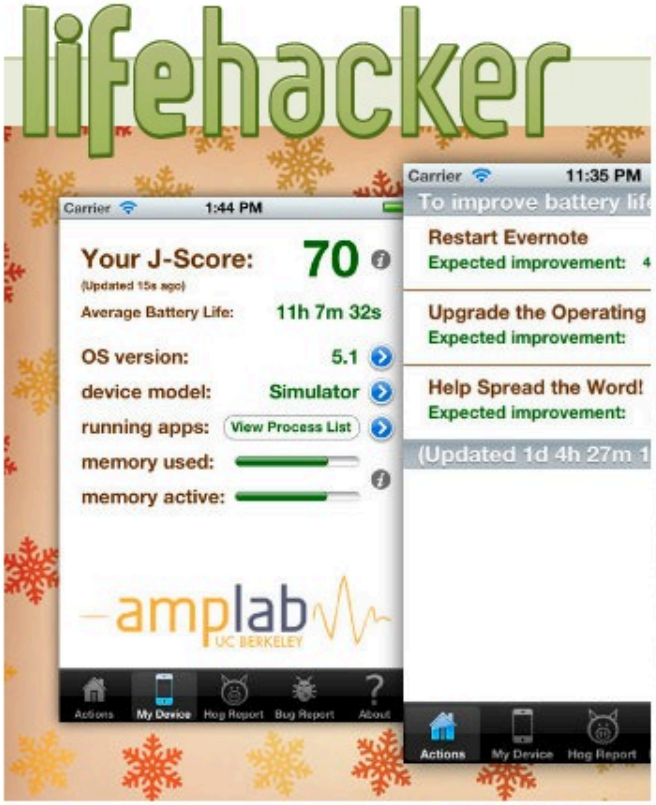
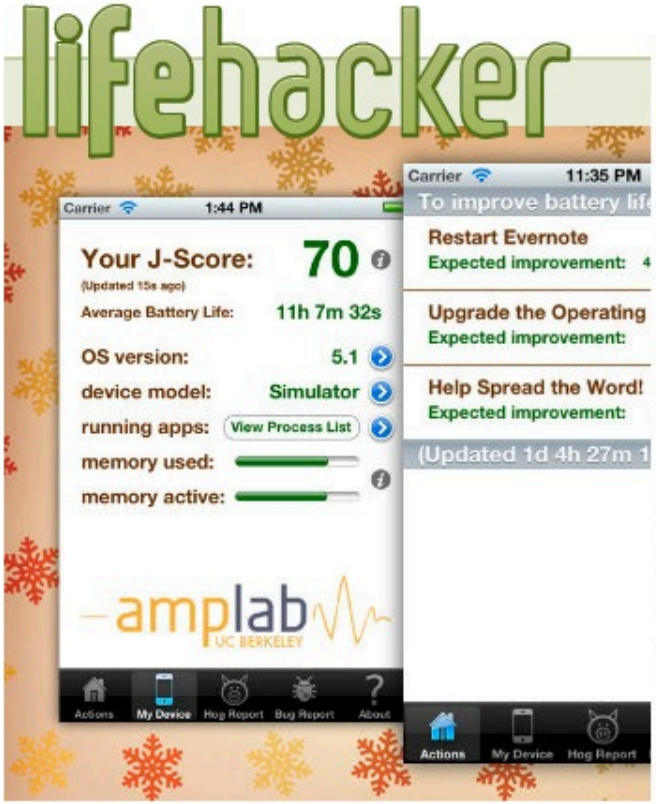


Carat: Extend Your Phone's Battery Life

LESLIE HORN JUNE 19, 2012 2:00 PM

Su



Carat: Extend Your Phone's Battery Life

LESLIE HORN JUNE 19, 2012 2:00 PM

Topic: iPhone

iOS and Android app helps you get more from your battery

Summary: *Carat has been developed by a team of scientists from the UC Berkeley electrical engineering and computer science department's Algorithms, Machines, and People Laboratory (AMP Lab).*

By Adrian Kingsley-Hughes for Hardware 2.0 | June 15, 2012 -- Updated 10:21 GMT (03:21 PDT)

Follow @the_pc_doc

lifehacker

Carat: Extend Your Phone's Battery Life

LESLIE HORN JUNE 19, 2012 2:00 PM

Carrier 1:44 PM

Your J-Score: 70

(Updated 15s ago)

Average Battery Life: 11h 7m 32s

OS version: 5.1

Carrier 11:35 PM

To improve battery lif

Restart Evernote

Expected improvement: 4

Upgrade the Operating

Expected improvement:

Carrier 1:44 PM

Your J-Score: 70

Carat went viral. In 24 hours, there were dozens of articles and we had more than 100,000 users.

Topic: iPhone

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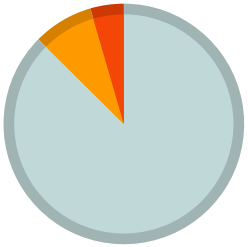
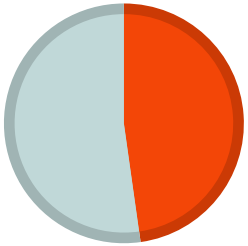
Statistics (October 2016)



471 645 Android and iOS apps
10% energy hogs, 4% energy bugs

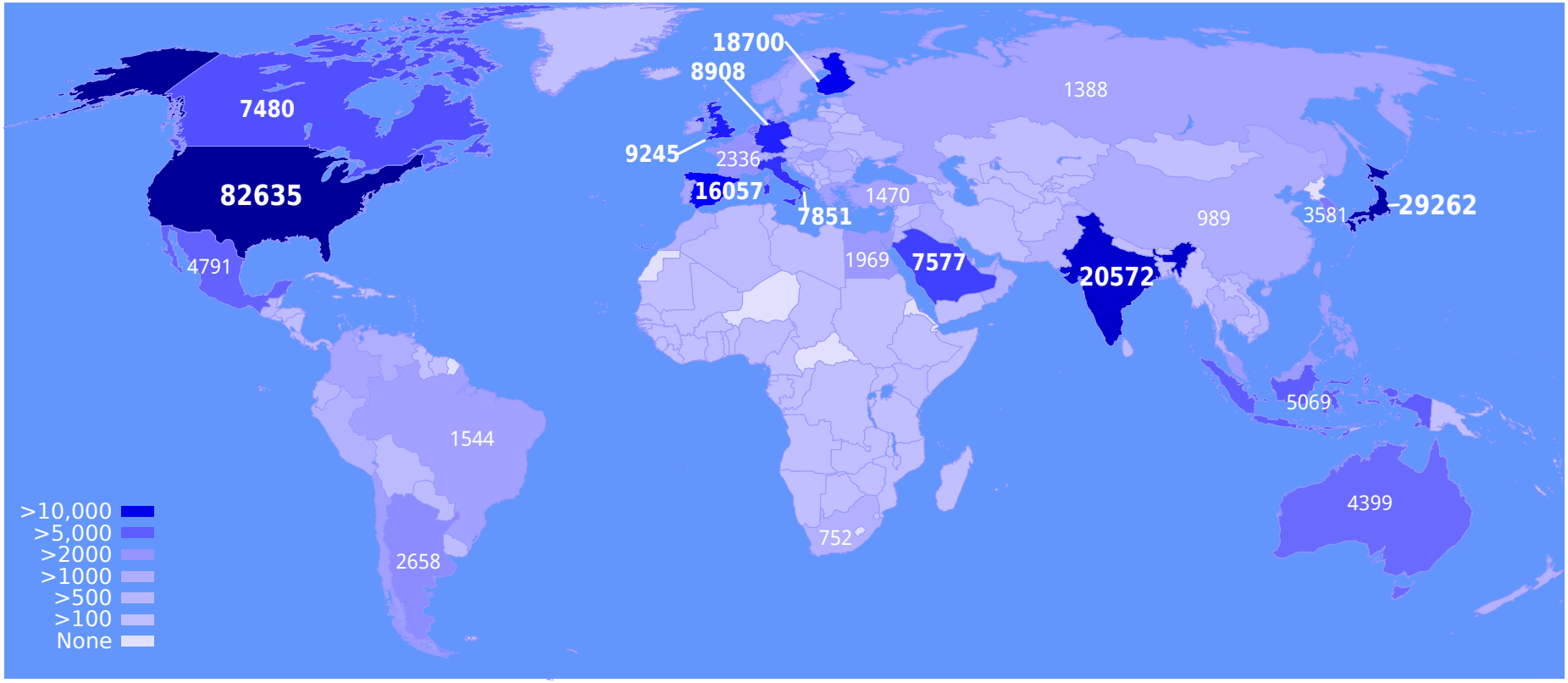


50% of devices have at least one energy bug

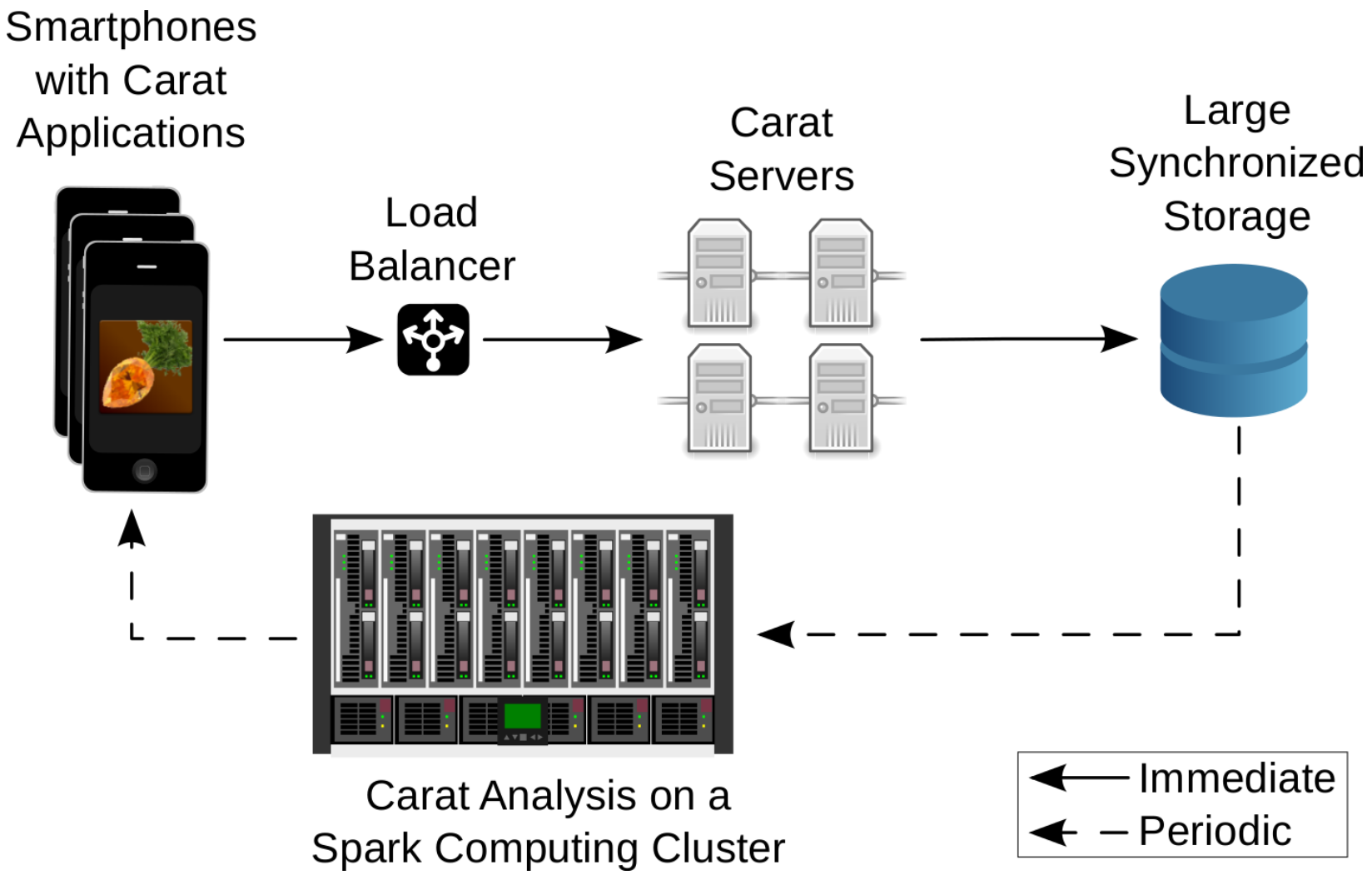
Android has a long tail of different device types.

carat.cs.helsinki.fi/statistics

Geographic distribution of Carat users (Android, 2015)

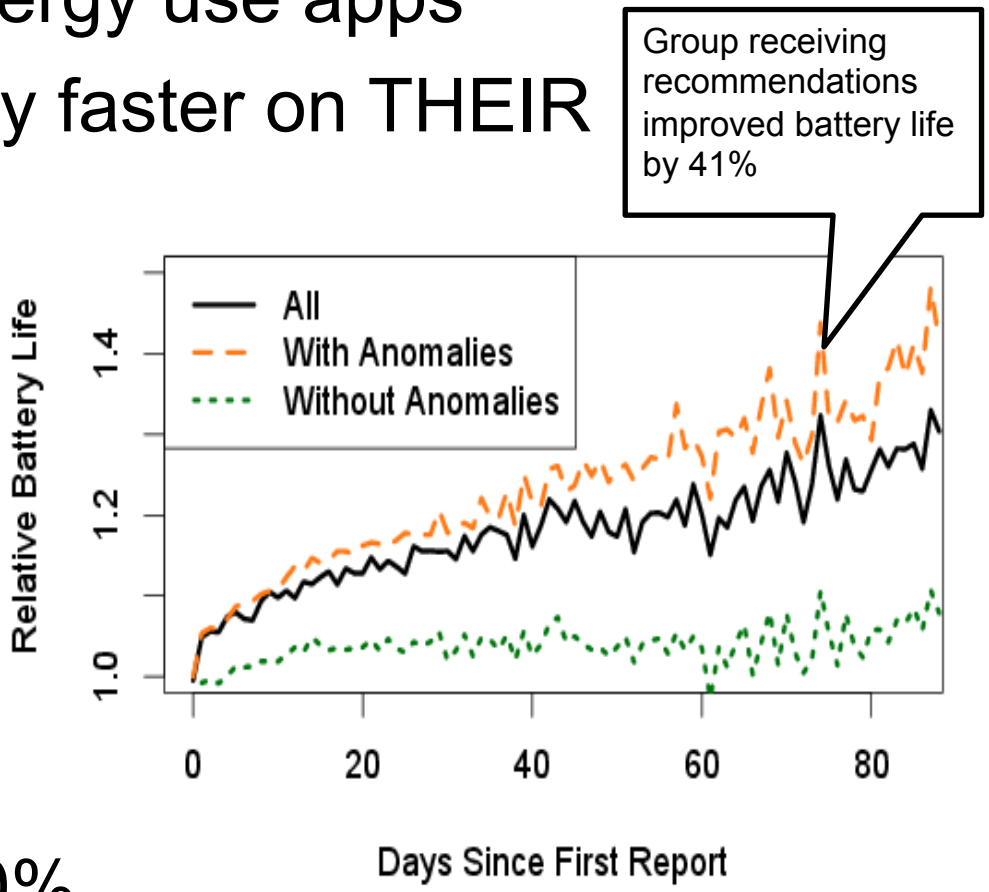


The Carat project: System



What is Carat?

- Users see Hogs, high energy use apps
- And Bugs that use energy faster on THEIR device than on others
- Users with these issues quickly see battery life benefits once they are addressed

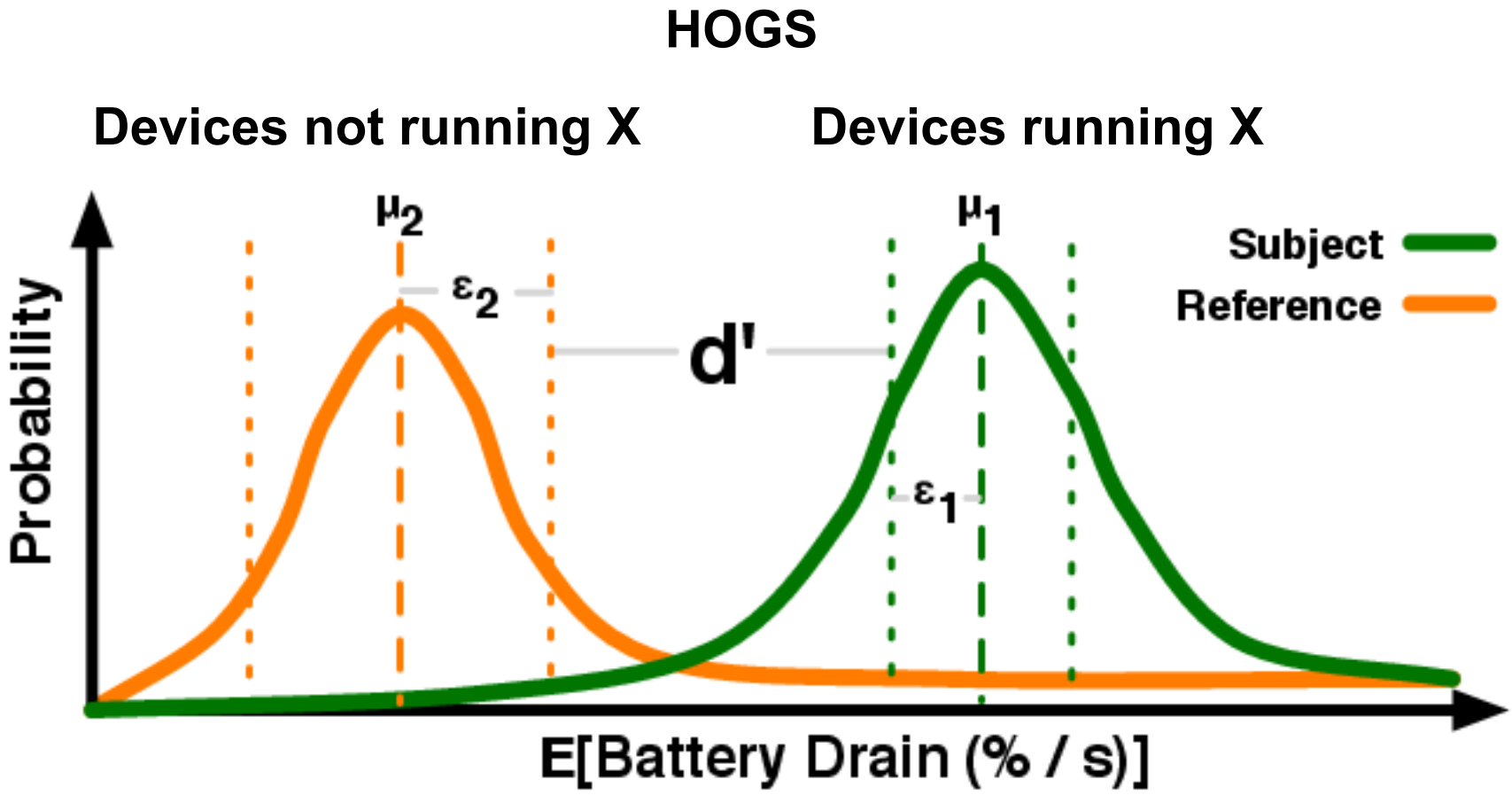


- Average improvement 20%
- Those with energy anomalies can improve 41%

The Data Analysis

- Samples are combined to obtain energy drain probability distributions (with features)
  - Users, Apps, App and User pairs, OS versions, Device models
- Distributions are compared using the distance between their 95% confidence interval error bars
  - If a distribution has a positive distance from another and a higher mean, it is a:
  - **Hog** (for an app vs the distribution for other apps)
  - **Bug** (for app & user combination vs other users of the same app)

Hogs and Bugs



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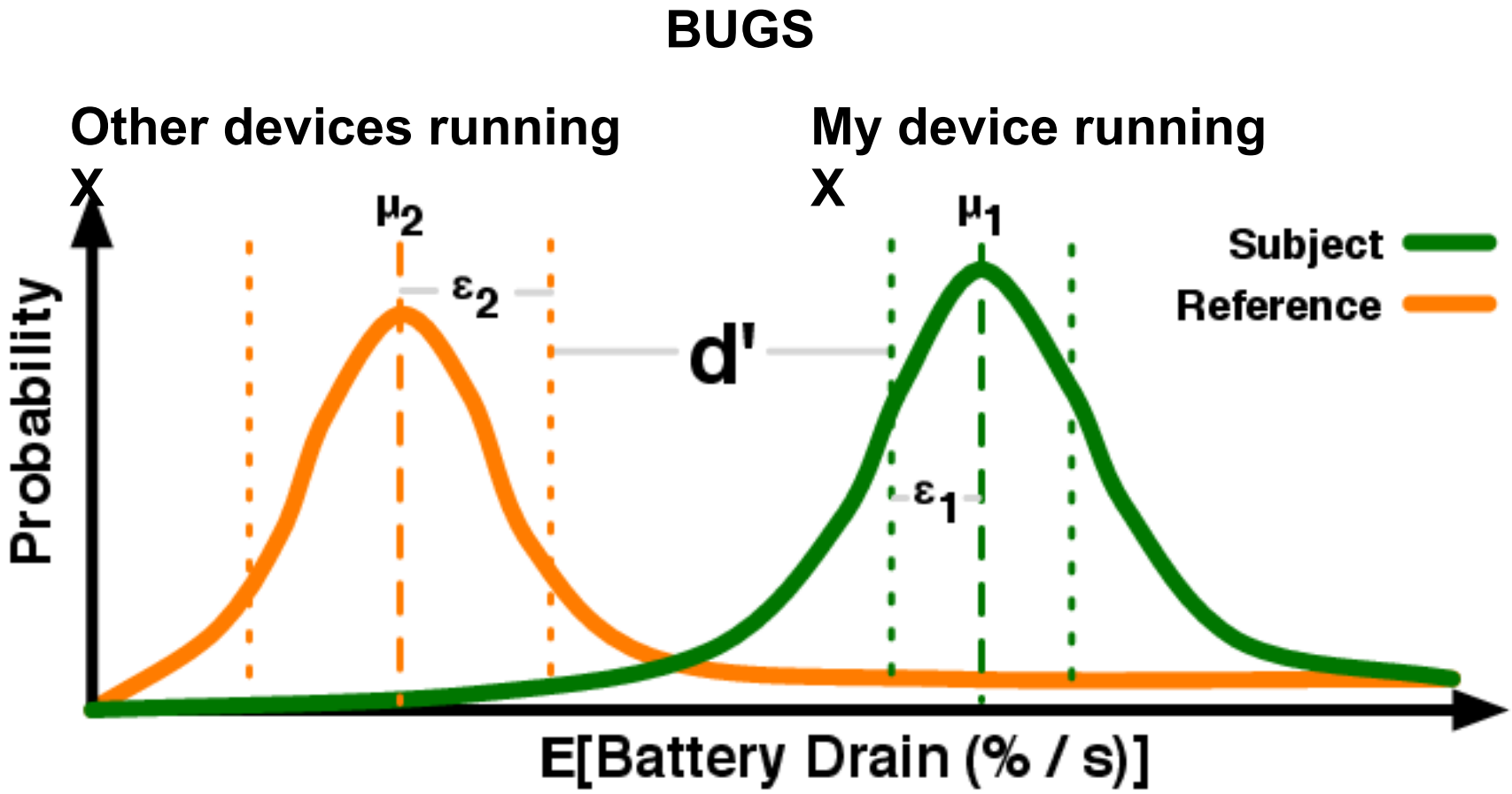
Hogs and Bugs



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Typical Hogs

Collaborative Data Gathering

Each device collects: Battery life, timestamp, running apps, context/system settings

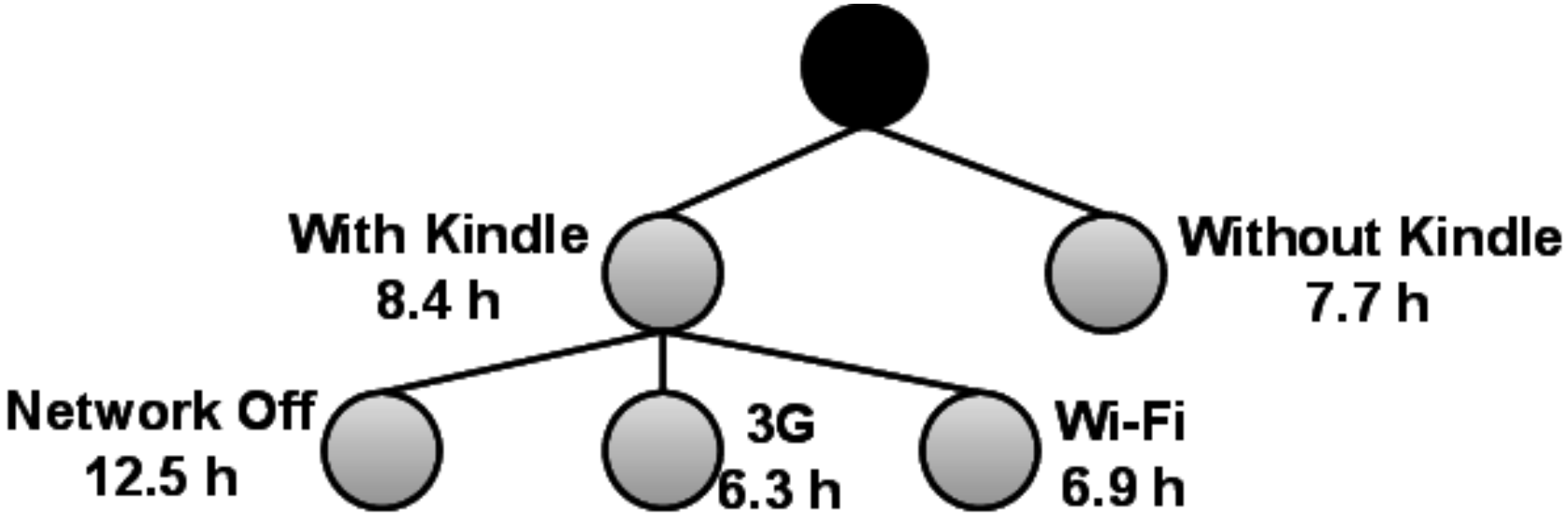
The data is combined and the results for your apps and your device are sent back to you

Context feature analysis: how various context features affect the energy consumption of the device

Collaborative aspect: We observe trends in the community, as well as how your device is different

The method can be used for phones, sensors, houses, base stations, servers, laptops, … anything that generates measurements

Example: The Kindle WhisperSync bug



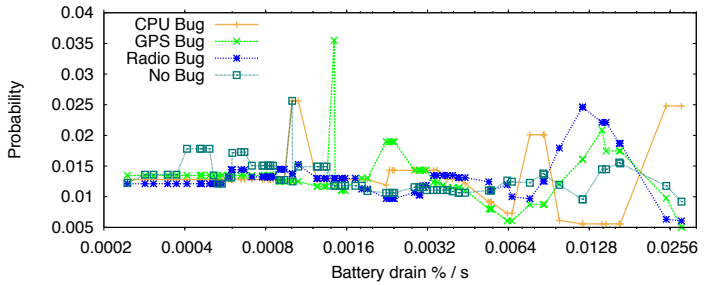
The decision tree allows "what-if" analysis and the generation of recommendations

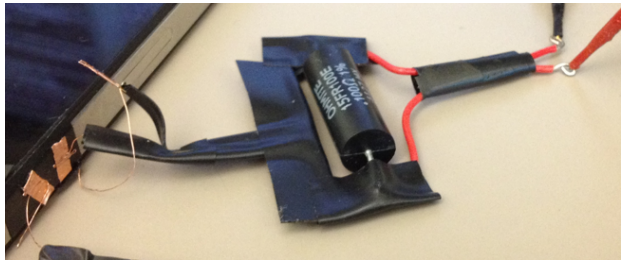
Project Infrastructure

- Data Analysis: Amazon EC2
  - 10 x X-Large VM (4 cores, 15G memory)
- Server facing mobile devices: Amazon EC2
  - 4 x medium VM (1 core, 4G memory)
  - Load balancer, independent DNS name for easy changing of infrastructure when required
- Amazon S3
  - Storage of data (incoming 0.5-1.0 GB / week)

Lessons learned

- Research prototype != product
- It is not easy to scale
  - 100 000 users in one day when we launched
  - Scaling will cost, cloud is not free
  - Managing clusters is not easy
- Design system so that it can evolve (no hardcoding, extensible formats)
- Validation is not easy
  - Ground truth
  - Injected bugs, validated bugs



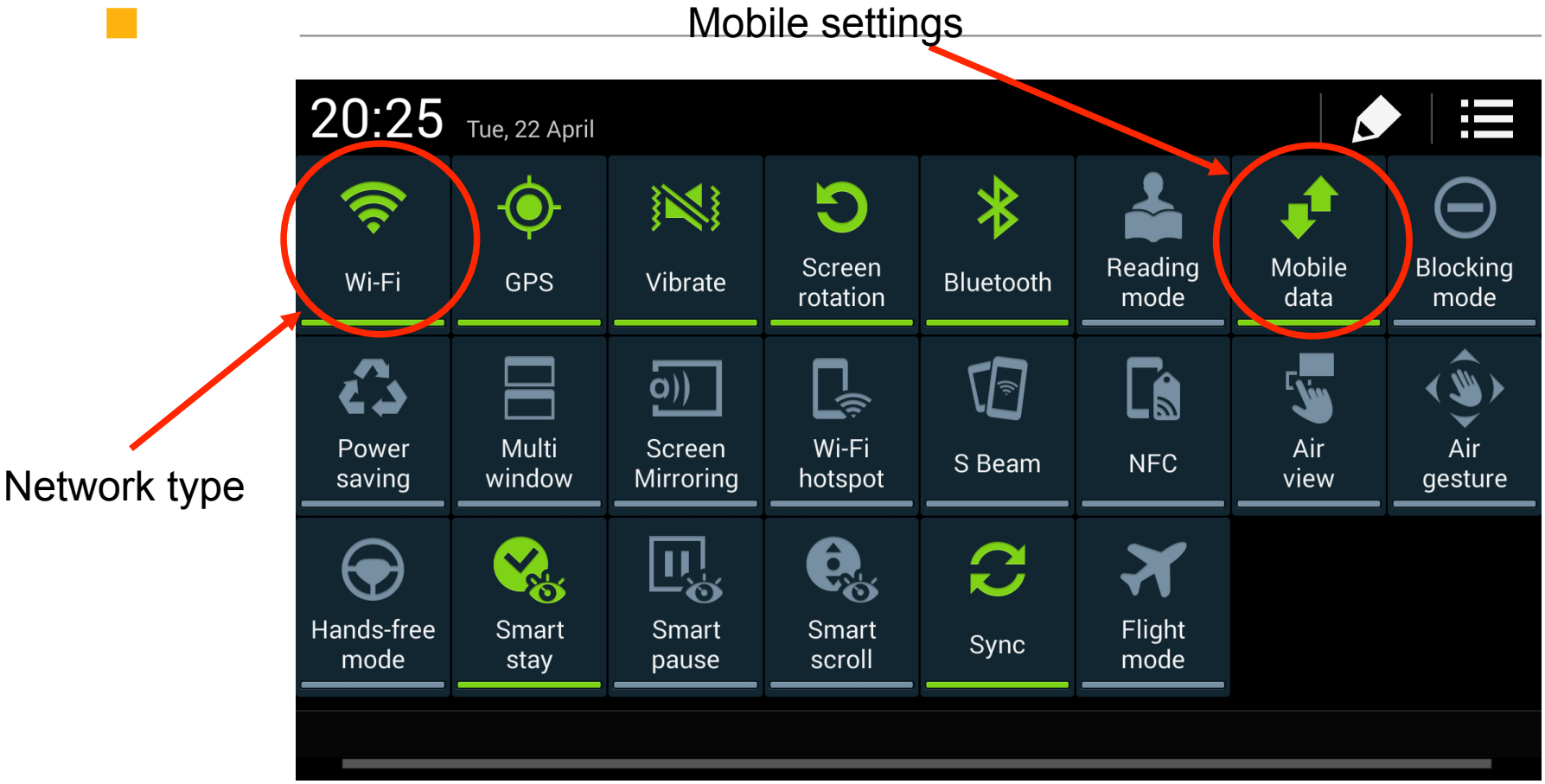


Energy efficient configuration?

Energy efficient configuration?

Network type

Energy efficient configuration?



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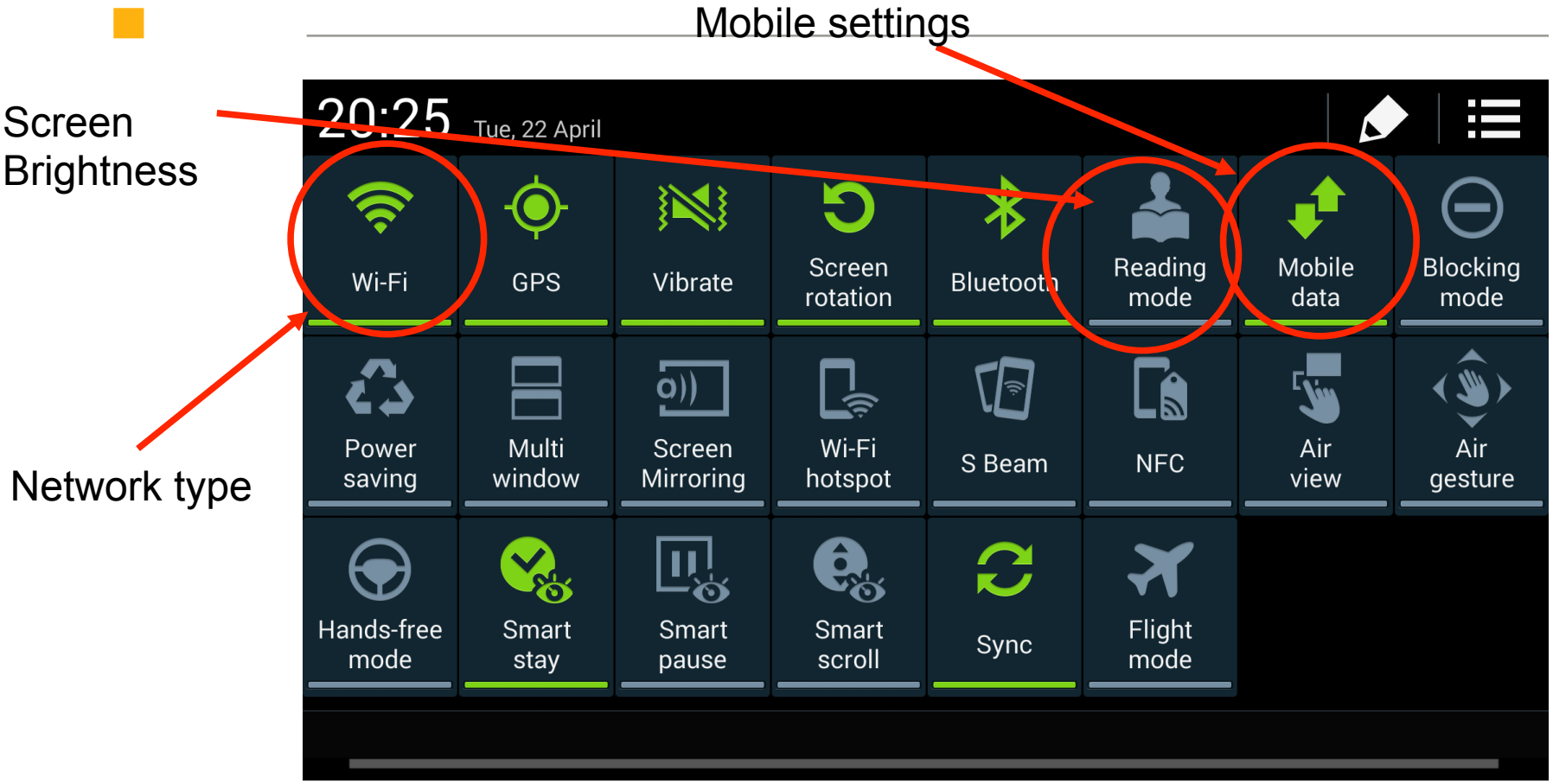


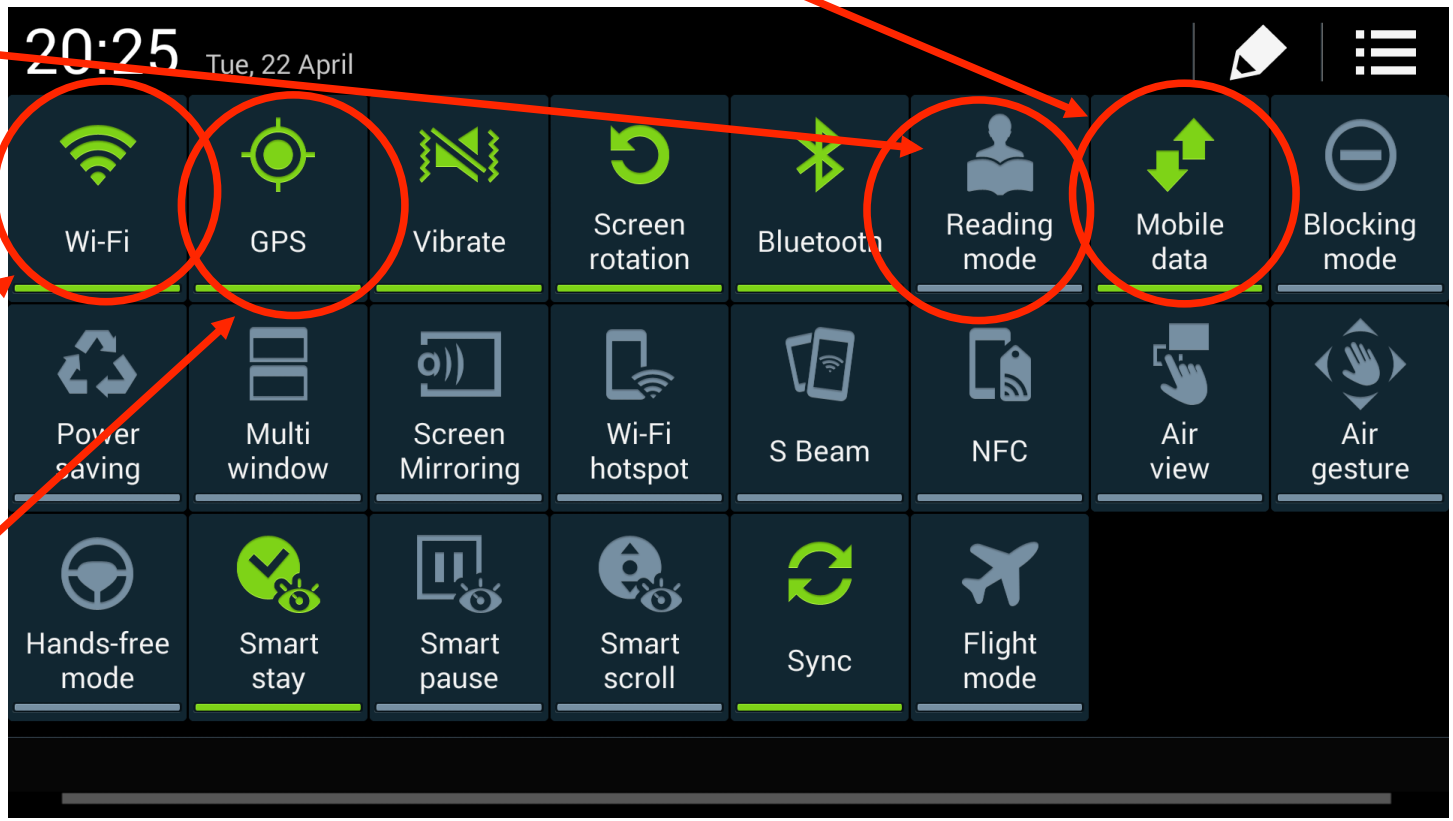
Energy efficient configuration?

Mobile settings

Screen Brightness

Network type

Moving or not?



Selected findings

- Wi-Fi signal strength dropping one bar can result in over 13% battery loss
- High temperature can cause 50% battery loss, and high temperature is not always related to high CPU load
- Automatic screen brightness is, in the most cases, better than manual setting
- In addition to CPU, battery temperature and distance traveled are useful in predicting battery lifetime

Power meter validation

- We used Monsoon power monitor to evaluate our data-driven results
- *Mobile Energy Measurement Platform (MEMe)*

Battery lifetime – an example

Battery Temperature	Distance Traveled	CPU Use Level	Screen Brightness	Estimated Battery Life (h)
Under 30°C	>0	Low	Automatic	8.83 – 9.12
Under 30°C	>0	Low	Manual	8.49 – 8.82
Under 30°C	>0	High	Automatic	8.09 – 8.24
Under 30°C	>0	Medium	Automatic	7.65 – 7.89
Under 30°C	>0	Medium	Manual	7.34 – 7.60
Under 30°C	>0	High	Manual	7.27 – 7.41
Under 30°C	None	Medium	Automatic	6.57 – 6.64
Under 30°C	None	Low	Automatic	6.28 – 6.35
Under 30°C	None	Medium	Manual	6.13 – 6.20
Under 30°C	None	Low	Manual	5.88 – 5.96
Under 30°C	None	High	Automatic	5.78 – 5.82
Over 30°C	>0	Low	Automatic	5.08 – 5.22
Under 30°C	None	High	Manual	5.00 – 5.04
Over 30°C	>0	Low	Manual	4.73 – 4.88
Over 30°C	>0	High	Automatic	4.62 – 4.69
Over 30°C	>0	Medium	Automatic	4.59 – 4.70
Over 30°C	>0	Medium	Manual	4.28 – 4.39
Over 30°C	None	Medium	Automatic	4.25 – 4.29
Over 30°C	>0	High	Manual	4.08 – 4.14

Just want to play a game?
High CPU use?

[2] Ella Peltonen, Eemil Lagerspetz, Petteri Nurmi, and Sasu Tarkoma. Energy Modeling of System Settings: A Crowdsourced Approach. PerCom '15. Best Paper Award.

Battery lifetime

Keep high CPU level constant

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Battery lifetime

Try to keep your phone relatively cold

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Battery lifetime

→ 78% more expected battery life

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Battery lifetime

Switch screen brightness to automatic

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Battery lifetime

→ 5% more expected battery life

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Battery lifetime

Go cooler place AND switch screen to automatic

Battery Temperature	Distance Traveled	CPU Use Level	Screen Brightness	Estimated Battery Life (h)
Under 30°C	>0	Low	Automatic	8.83 – 9.12
Under 30°C	>0	Low	Manual	8.49 – 8.82
Under 30°C	>0	High	Automatic	8.09 – 8.24
Under 30°C	>0	Medium	Automatic	7.65 – 7.89
Under 30°C	>0	Medium	Manual	7.34 – 7.60
Under 30°C	>0	High	Manual	7.27 – 7.41
Under 30°C	None	Medium	Automatic	6.57 – 6.64
Under 30°C	None	Low	Automatic	6.28 – 6.35
Under 30°C	None	Medium	Manual	6.13 – 6.20
Under 30°C	None	Low	Manual	5.88 – 5.96
Under 30°C	None	High	Automatic	5.78 – 5.82
Over 30°C	>0	Low	Automatic	5.08 – 5.22
Under 30°C	None	High	Manual	5.00 – 5.04
Over 30°C	>0	Low	Manual	4.73 – 4.88
Over 30°C	>0	High	Automatic	4.62 – 4.69
Over 30°C	>0	Medium	Automatic	4.59 – 4.70
Over 30°C	>0	Medium	Manual	4.28 – 4.39
Over 30°C	None	Medium	Automatic	4.25 – 4.29
Over 30°C	>0	High	Manual	4.08 – 4.14

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Battery lifetime

→ 98% better expected battery life

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Malware Infection Rates

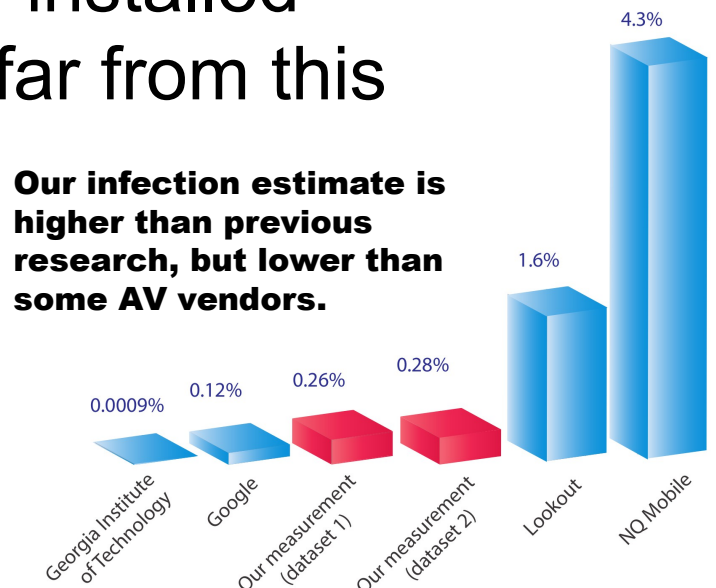
We studied malware based on the dataset

McAfee, Mobile Sandbox, MalGenome, …

Malware infection rates are higher than conservative estimates (0.26% of devices)

Google says 0.12% of manually installed packages are malware, not very far from this number

Lookout Antivirus predicts >1%

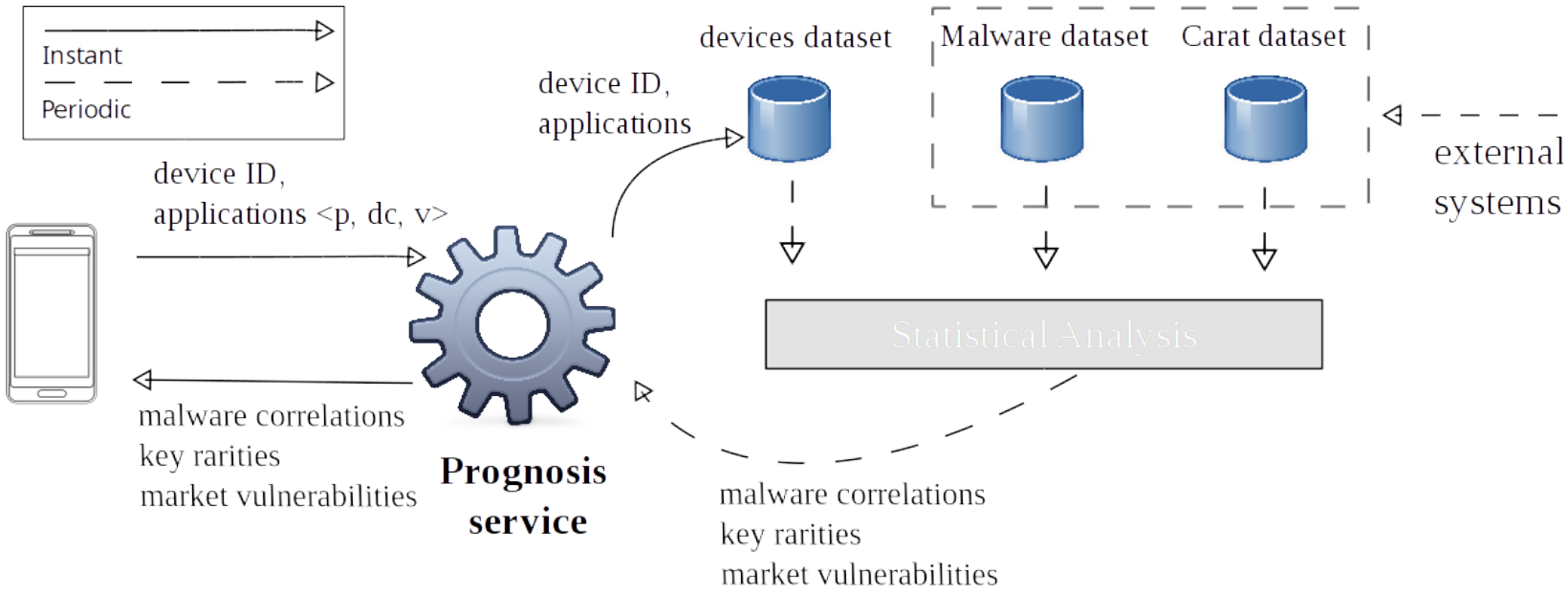


An Early Warning System for Malware

A lightweight technique for identifying devices at risk

By looking at applications that occur with malware, it is possible to predict infection 5x better than choosing devices at random

- Useful for administrators, organisations (**Bring Your Own Device** scenario)

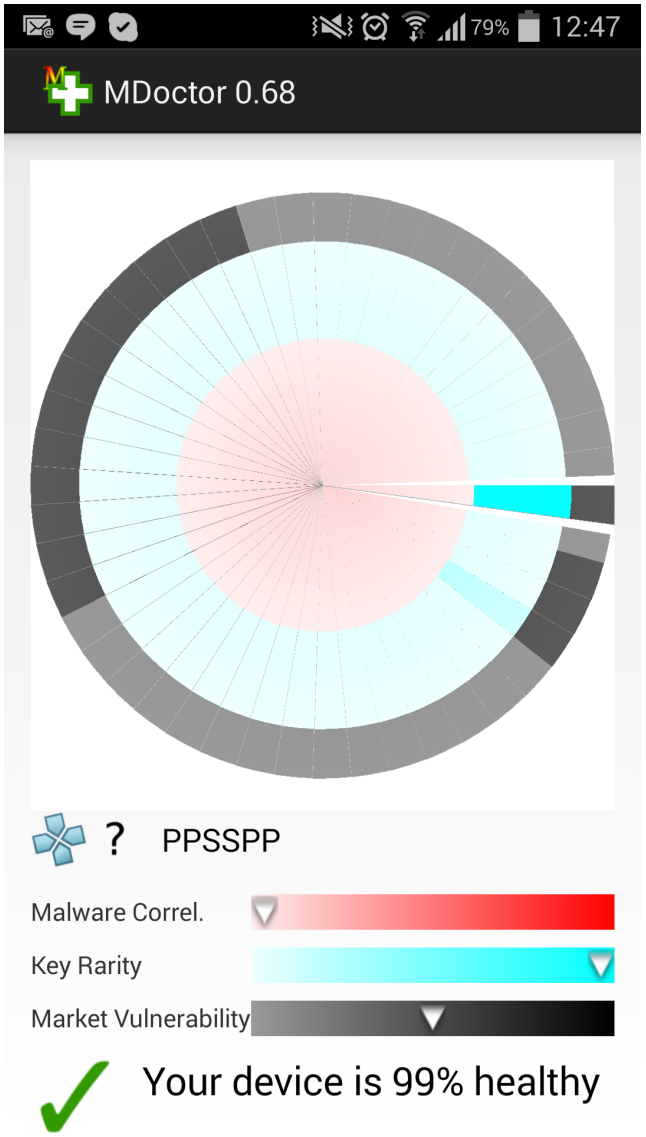


MDoctor: Increasing Awareness of Infection Vulnerability

MDoctor shows status of applications according to a malware dataset

Infection vulnerability can be seen from device health

Three metrics for application analysis: malware correlation, key rarity, and market vulnerability



Impact

Crowdsourced approach captures system state and application use cost-effectively from real life

Reveals new and more complex insights to battery consumption

With enough data, we can average out the bias

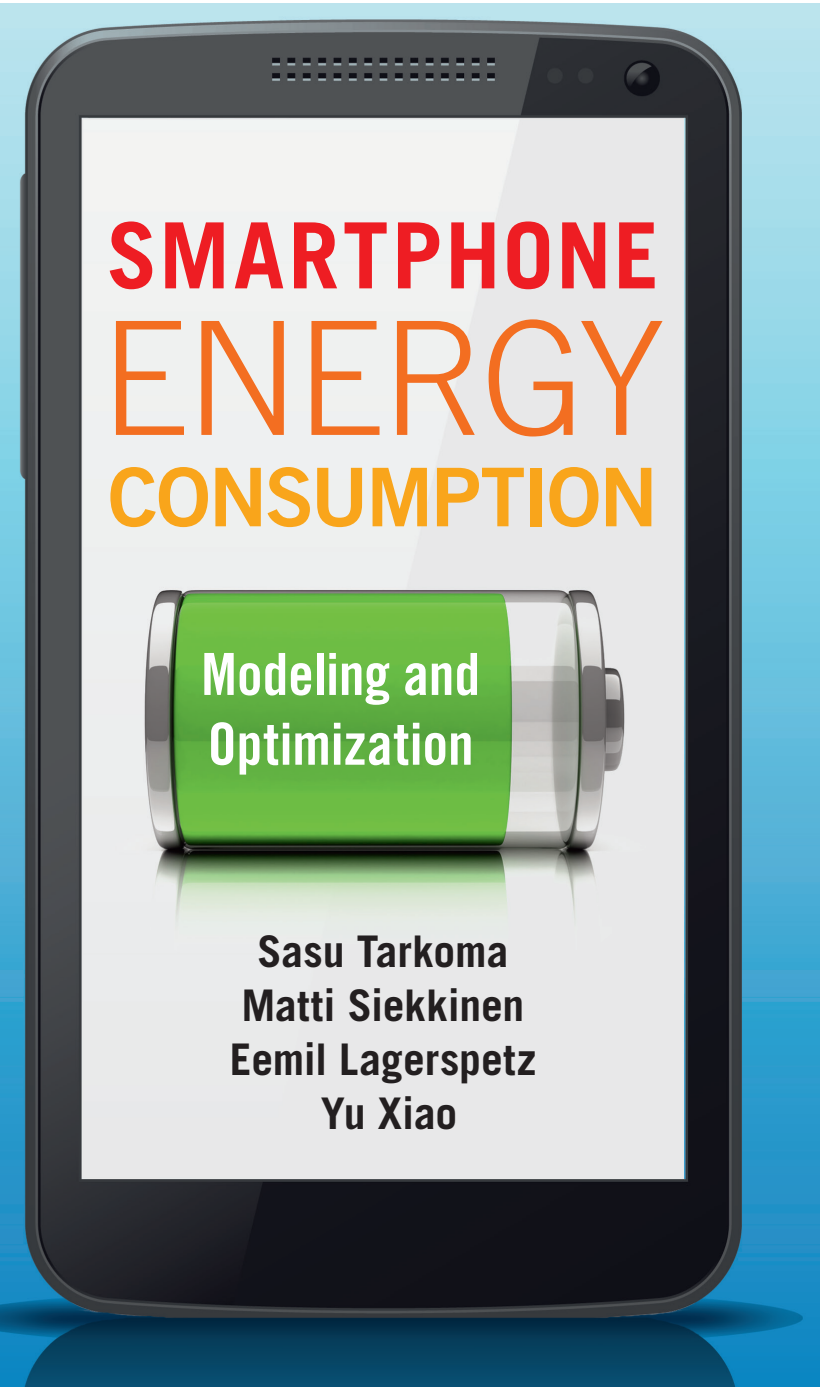
Carat gives advice to improve battery life

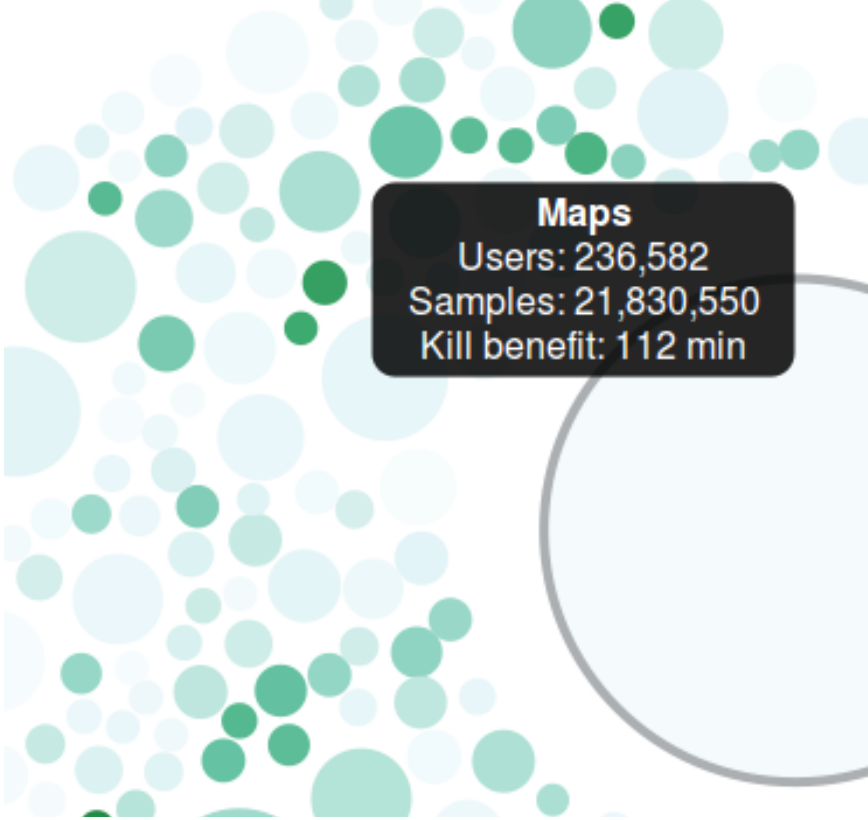
850K users, 250 million data points on energy, applications, system settings

Dataset is growing, more directions to explore

Related Publications

- A. J. Oliner, A. P. Iyer, I. Stoica, E. Lagerspetz, S. Tarkoma. Carat: Collaborative Energy Diagnosis for Mobile Devices. In ACM SenSys 2013.
- A. J. Oliner, A. Iyer, E. Lagerspetz, S. Tarkoma, I. Stoica. Carat: Collaborative energy debugging for mobile devices. In HotDep 2012.
- A. J. Oliner, A. P. Iyer, E. Lagerspetz, I. Stoica, and S. Tarkoma. Carat: Collaborative Energy Bug Detection. Poster and demo at the proceedings of the 9th USENIX Symposium on Networked Systems Design and Implementation (NSDI '12), San Jose, California.
- K. Athukorala, E. Lagerspetz, M von Kügelgen, A. Jylhä, A. J. Oliner, S. Tarkoma, G. Jacucci. How Carat Affects User Behavior: Implications for Mobile Battery Awareness Applications. ACM CHI 2014.
- H.T. T. Truong, E. Lagerspetz, P. Nurmi, A. J. Oliner, S. Tarkoma, N. Asokan, S. Bhattacharya, The Company You Keep: Measuring Mobile Malware Infection Rates and Identifying Inexpensive Predictors of Susceptibility to Infection, Proceedings of WWW 2014.
- E. Lagerspetz, H. Truong, S. Tarkoma, N. Asokan. Mdoctor - A Mobile Malware Prognosis Application. DASec workshop in conjunction with ICDCS 2014.
- E. Peltonen, E. Lagerspetz, P. Nurmi, and S. Tarkoma. Energy Modeling of System Settings: A Crowdsourced Approach, IEEE PerCom '15. **(Best paper award).**
- S. Tarkoma, M. Siekkinen, E. Lagerspetz, Y. Xiao. “Smartphone Energy Consumption: Modelling and Optimization”, August 2014, Cambridge University Press.
- E. Lagerspetz. Collaborative Mobile Energy Awareness. PhD thesis. University of Helsinki. November 2014. (**UH Dissertation Award 2014**).





carat.cs.helsinki.fi/statistics

iPhone

Android

Download the app with the QR codes