Carat: Collaborative Energy Diagnosis on Mobile Devices



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U of Helsinki

Mobile is Hot

- ... sometimes, literally:



ASK LIFEHACKER

Why Is My Cellphone Burning a Hole in My Pocket?

Dear Lifehacker,
I'm loving my new smartphone, but sometimes it gets really hot in my pocket—like surface-of-the-sun hot. Is there something wrong with it? Why does it get so hot, and how can I make it stop?

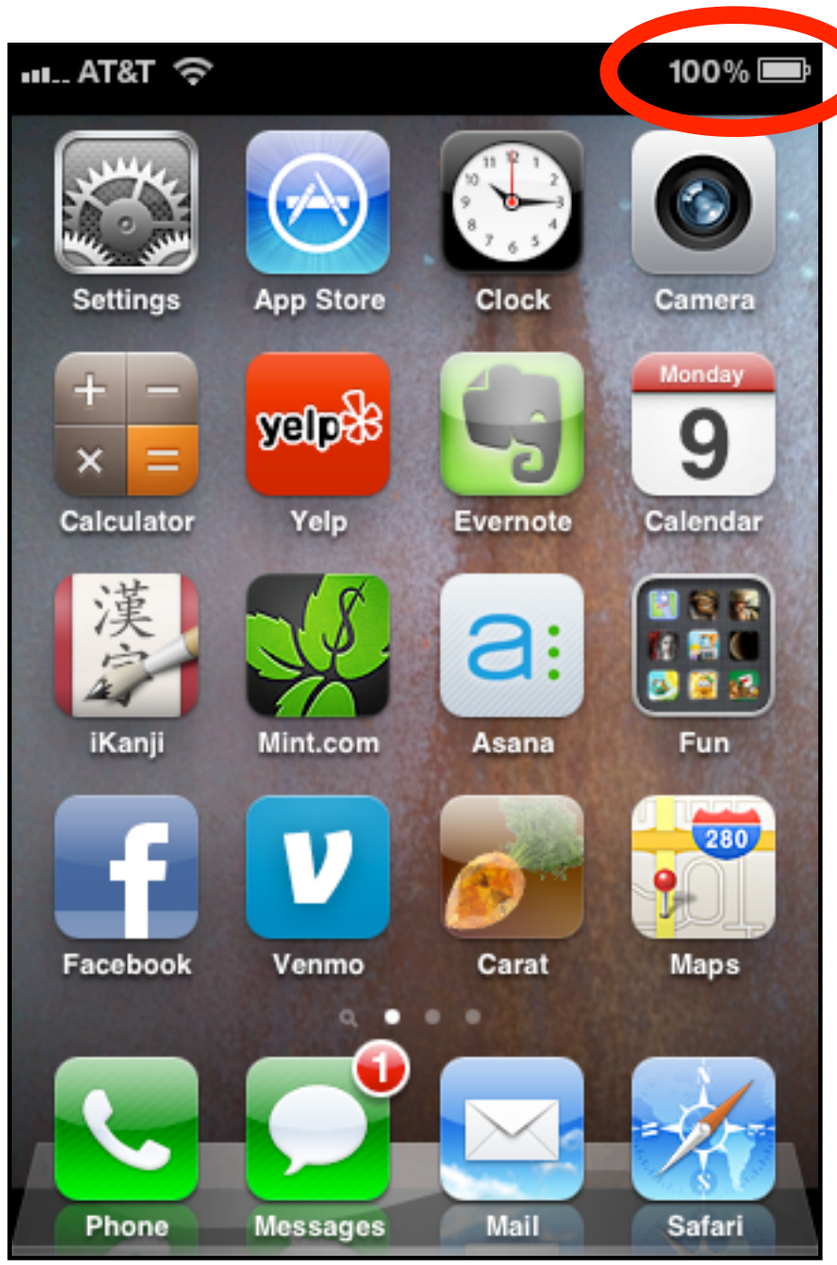
Sincerely,
Fearing Firey Phones

Photo remixed from an original by Shutterstock.

A Day in the Life



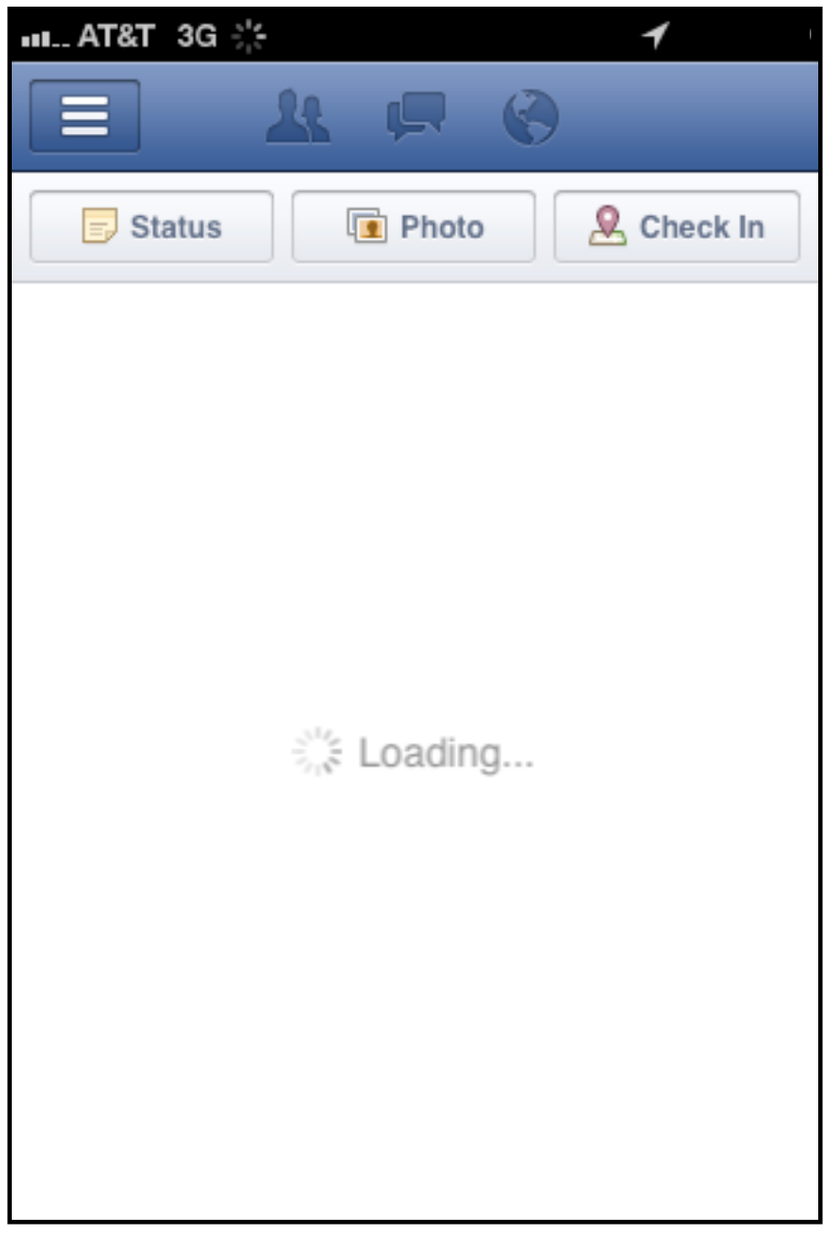
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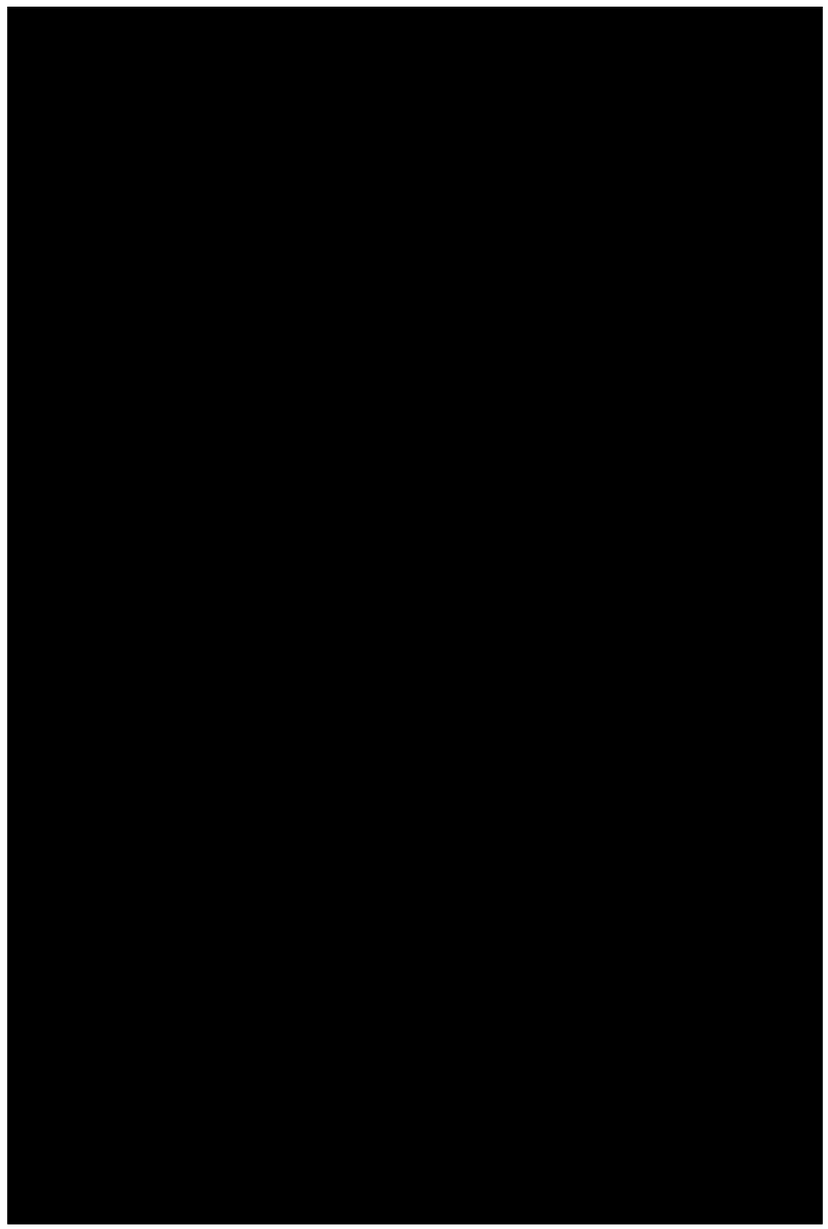
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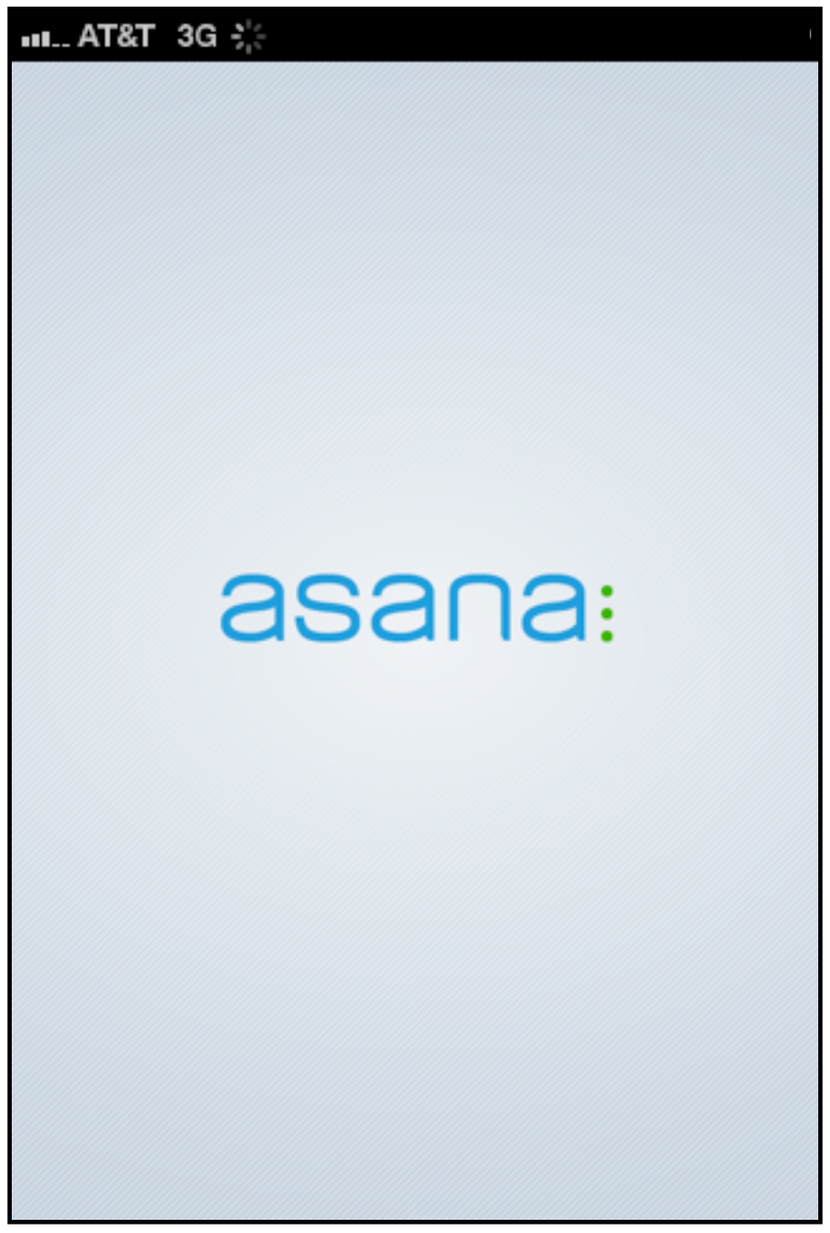
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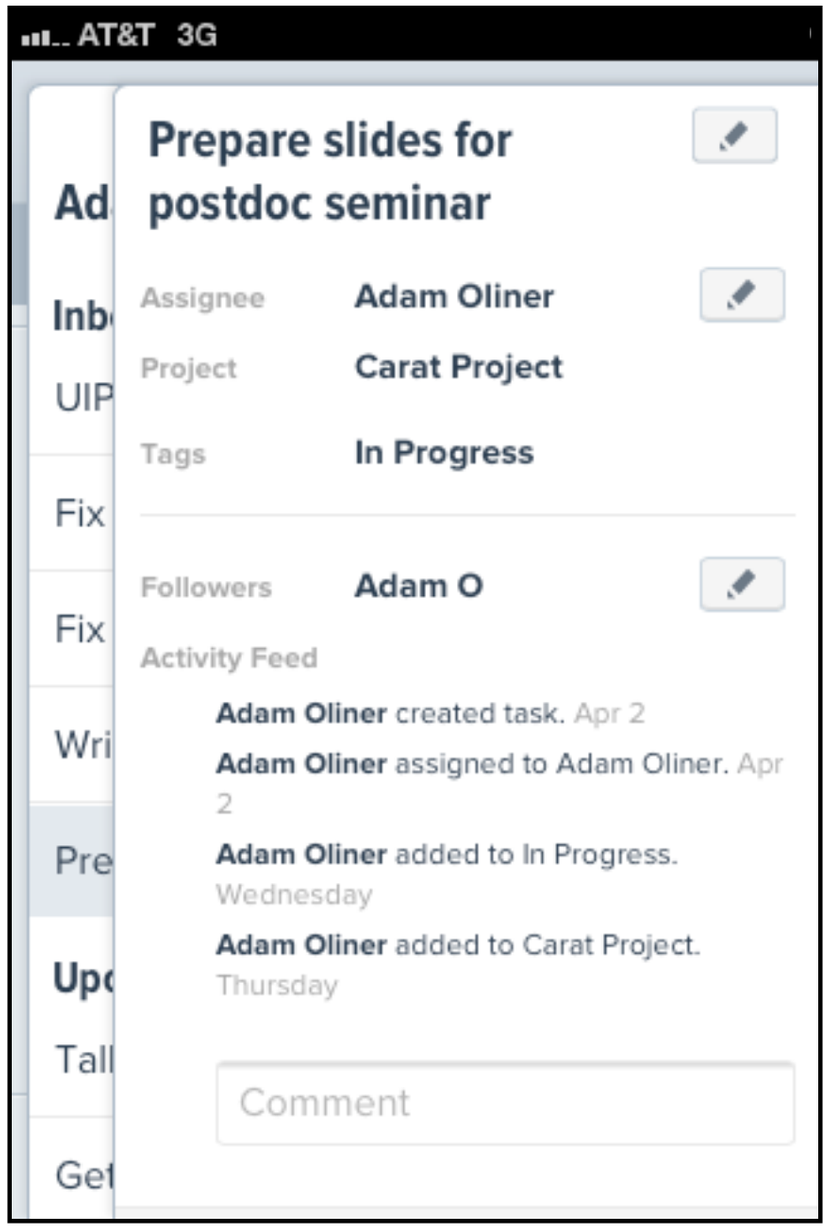
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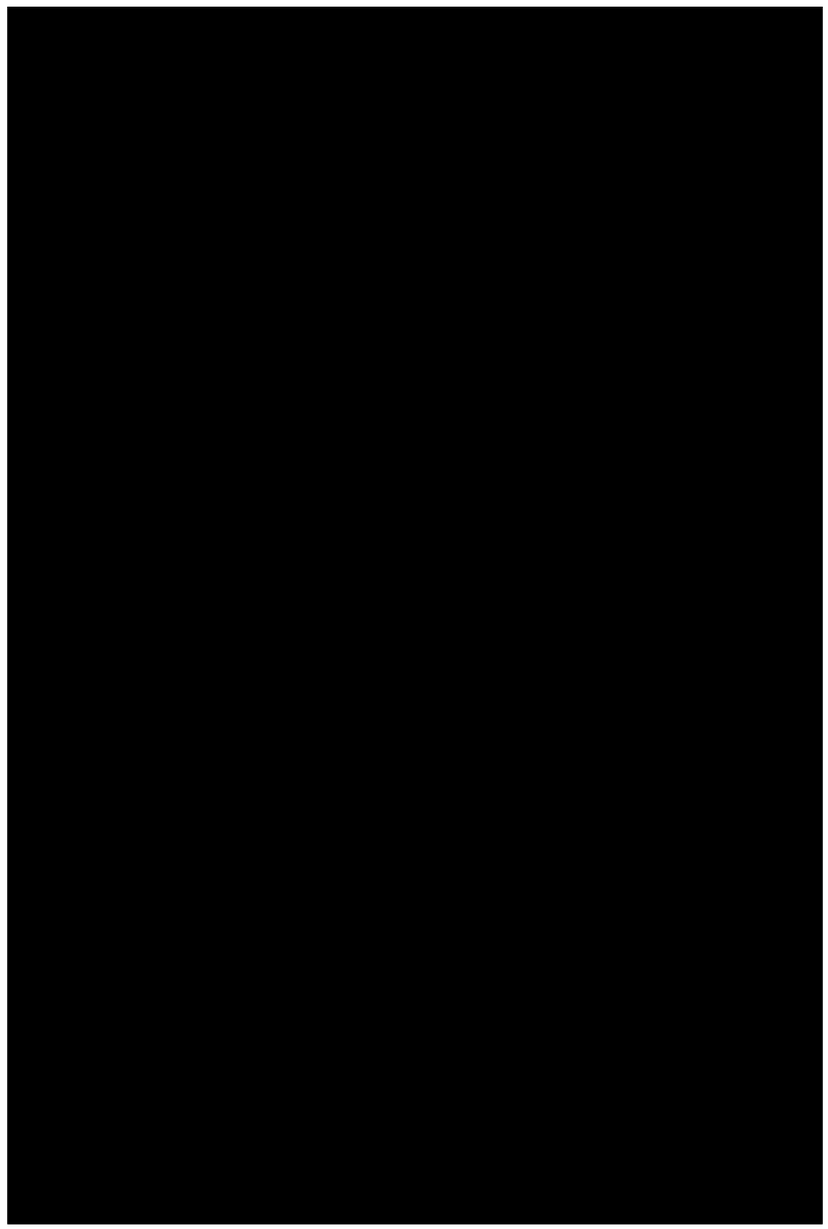
A Day in the Life



A Day in the Life



A Day in the Life



A Day in the Life



Users' Questions

- ***Why*** is my battery draining?
- Is that ***normal***?
- What can I ***do*** about it?



Today

1. Carat
2. Sampling to Diagnosis
3. Dealing with Uncertainty
4. Implementation
5. Deployment



1. Carat

Prior Approaches

- Ad hoc
  - e.g., no-sleep bug
  - Intrusive
  - Generic
    - “Kill *all* background apps”
    - “Dim the screen”

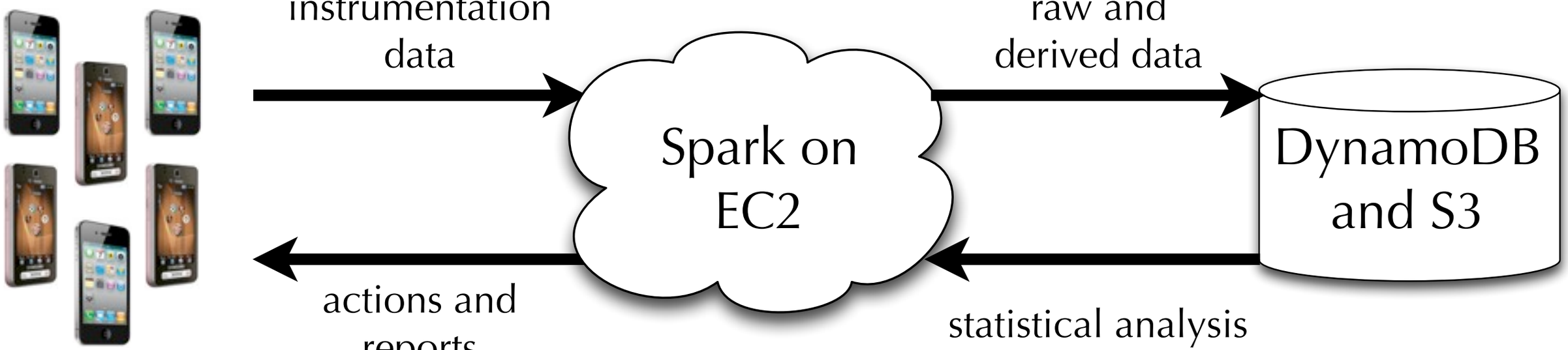


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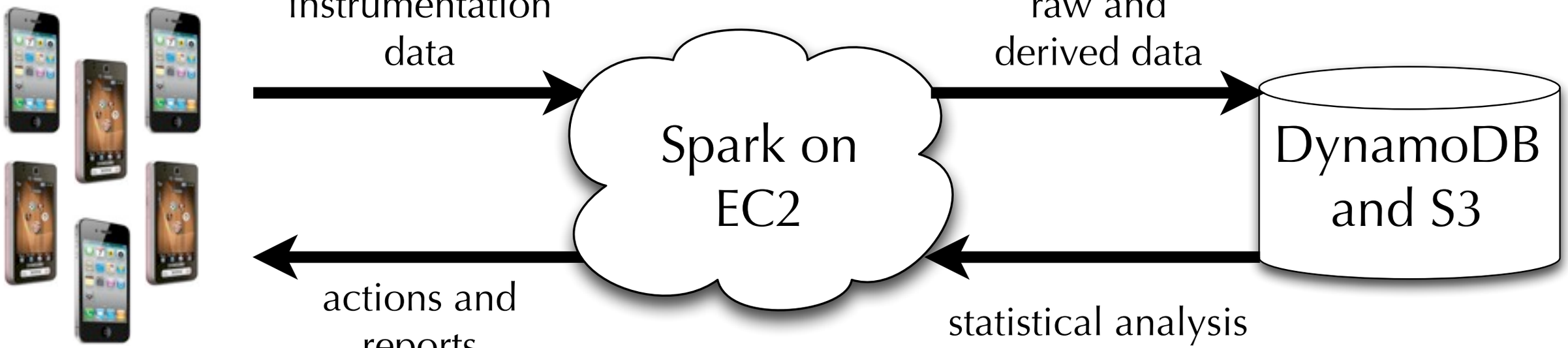


the crowd | ***the cloud*** | ***big data***



Our Approach

the crowd | ***the cloud*** | ***big data***



First collaborative approach for diagnosing energy problems.

Why Collaborative?

- Enables diagnosis
  - Nearly impossible on a single device
    - Normal? Trigger? Severity? Frequency?
- Distribute instrumentation overhead
- Compensate for biases and uncertainty



Design Goals

- Most invasive method that works on both Android and iOS
- Eligible for Apple's App Store
- Investigate how far we can take diagnosis

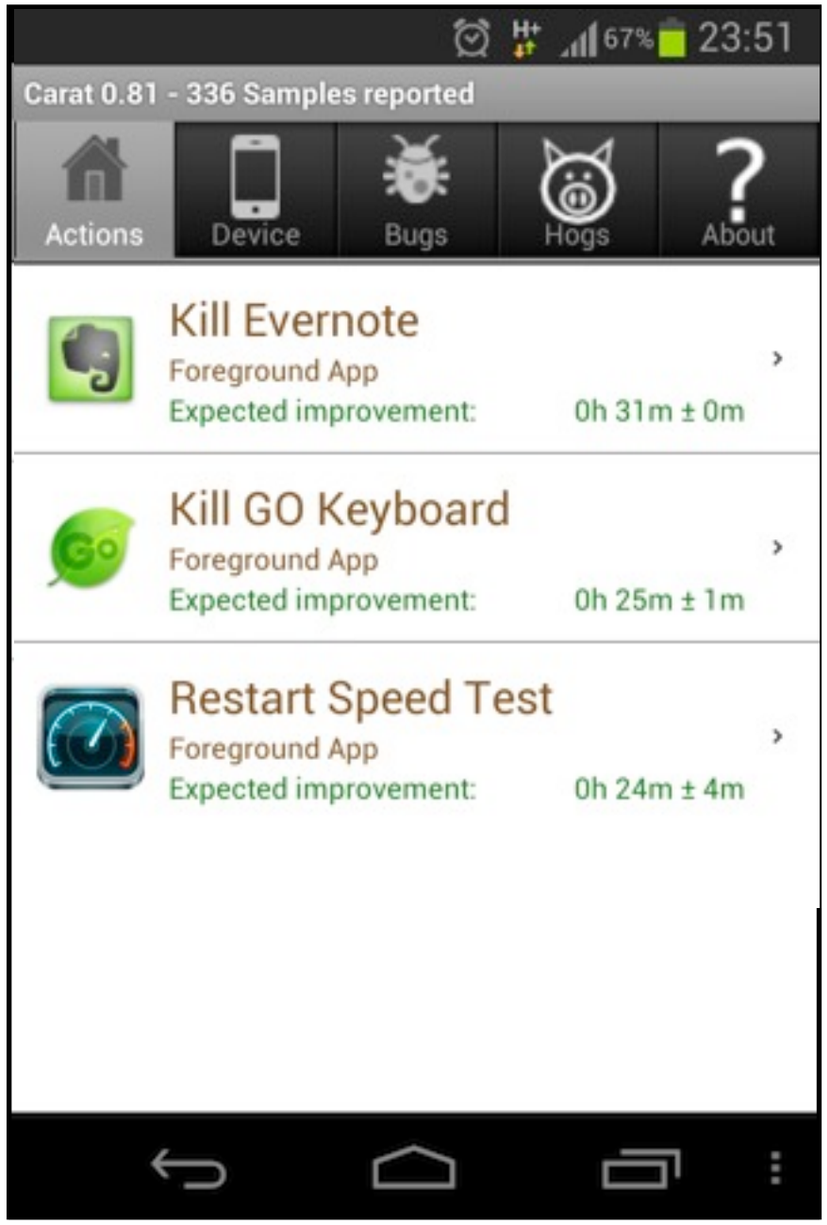


Carat

- Mobile app for iOS and Android
- Personalized energy debugging
  - What is misbehaving
  - Whether that is normal
  - What you can do about it
  - How much it will help






67% 23:51
Carat 0.81 - 336 Samples reported
Actions
Device
Bugs
Hogs
About
Kill Evernote
Foreground App
Expected improvement: 0h 31m ± 0m
Kill GO Keyboard
Foreground App
Expected improvement: 0h 25m ± 1m
Restart Speed Test
Foreground App
Expected improvement: 0h 24m ± 4m


AT&T
2:14 PM
80%
Energy Hogs
Neocom
Battery Impact: 31m 44s ± 25m 56s
iCupid2
Battery Impact: 9m 59s ± 1m 51s
Skype
(Updated 1m 47s ago)
Hide Apps
Show Hidden Apps
Actions
My Device
Hog Report
Bug Report
About


No SIM
10.59
Your Current J-Score:
91
(Updated 17s ago)
Active Battery Life:
15h 56m 17s
Carat ID:
C070E75C-AE97-4B24-AF3A-5E7CF2479745
OS version:
6.0.1
device model:
iPhone 4S
running apps:
View Process List
memory used:
memory active:
Actions
My Device
Hog Report
Bug Report
About



Carat

Operating Instructions

- Install Carat on your iOS/Android device
- Open daily+ for about a week
- Perform the actions it suggests
- Open occasionally for new actions



Privacy Concerns

- Opt-in EULA, prior to installation
- Nothing personally identifying
- Sampled data shown within the app



Open Source

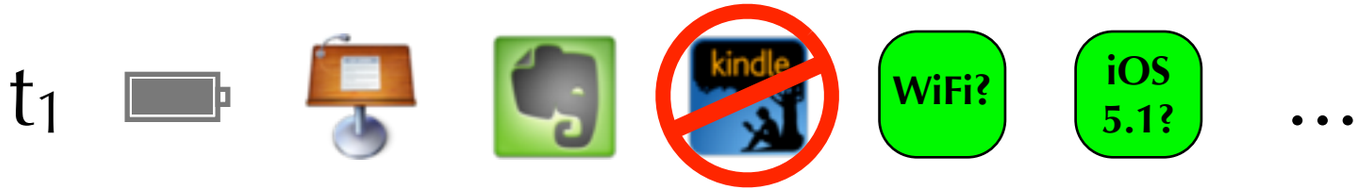
- Both apps are on github
- FreeBSD license
- Analysis code is proprietary

`carat.cs.berkeley.edu`



2. Sampling to Diagnosis





Carat Sampling





Carat Sampling





Carat Sampling





Carat Sampling



Computing Rates



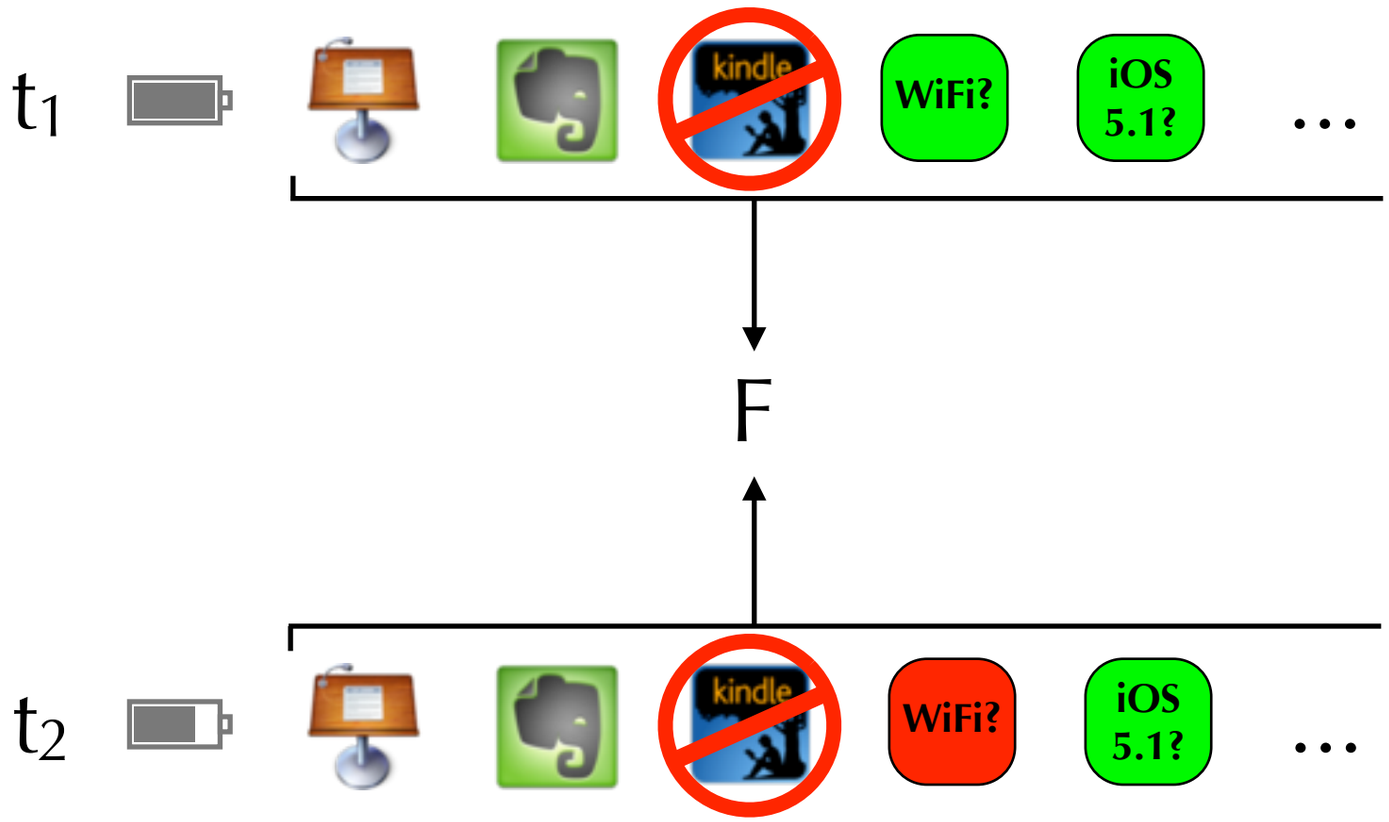
Δt

Computing Rates



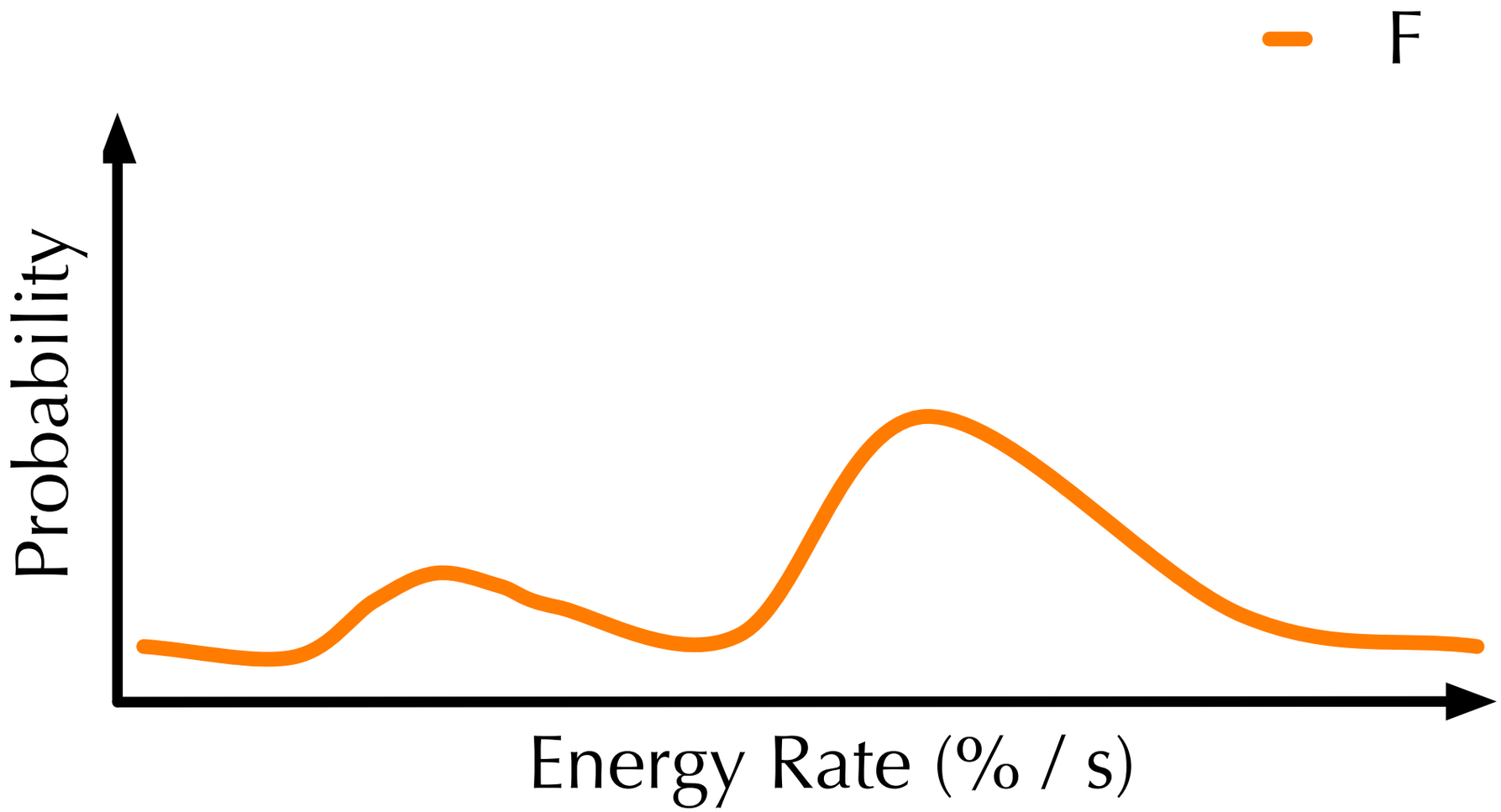
$$\frac{\Delta\%}{\Delta t} = \text{discharge rate (\%/s)}$$

Computing Rates

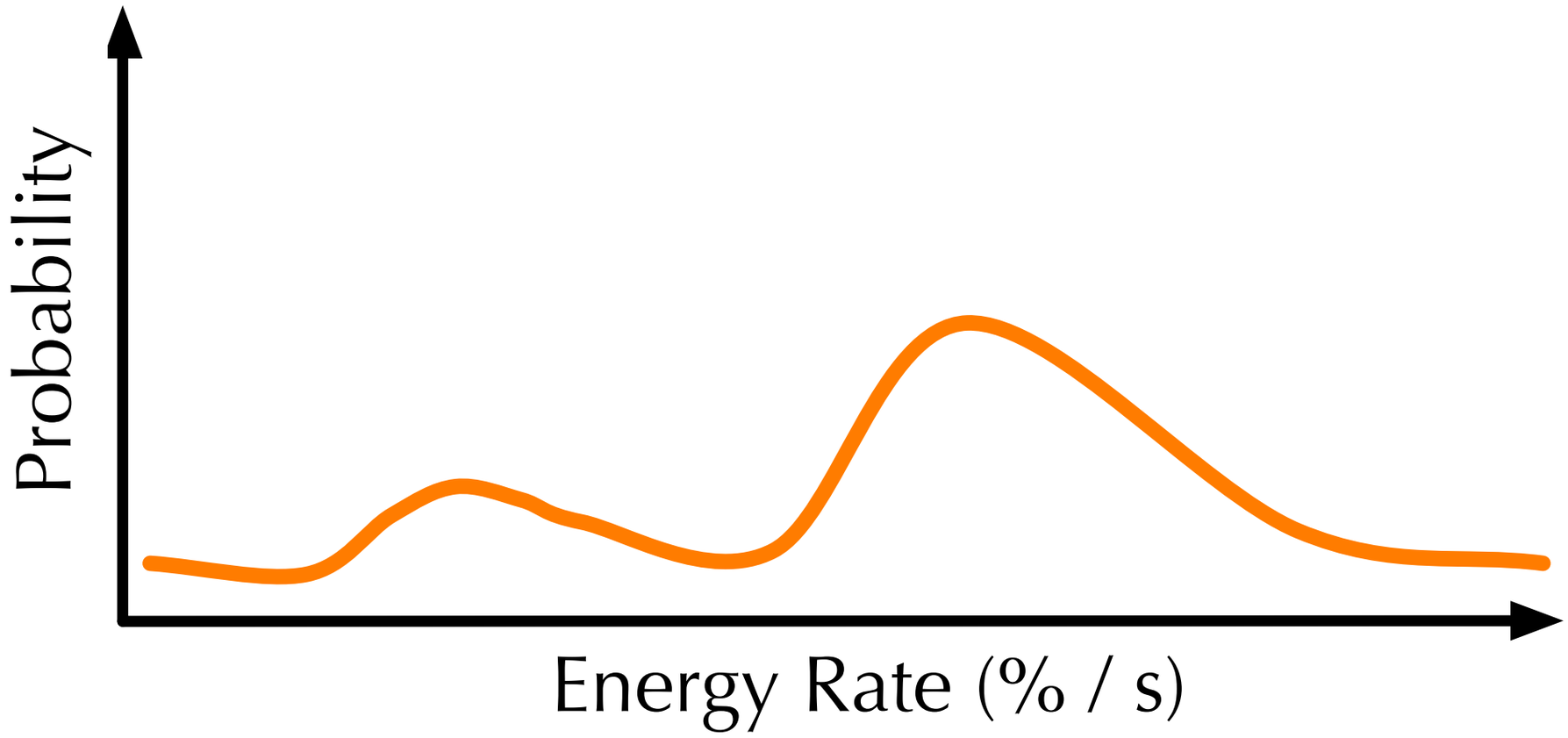


$$\frac{\Delta\%}{\Delta t} = \text{discharge rate (\%/s)} \mid F$$

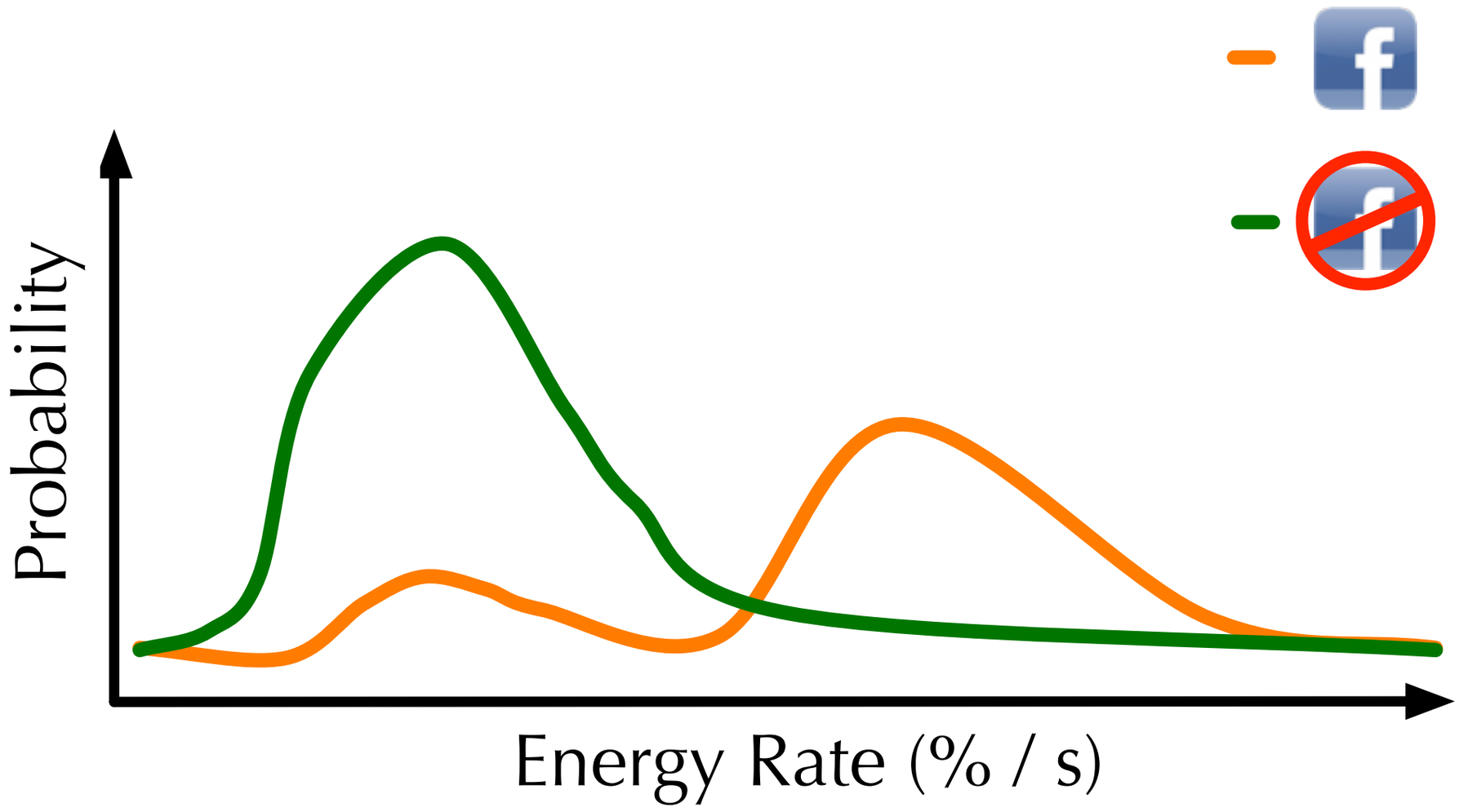
Computing Rates



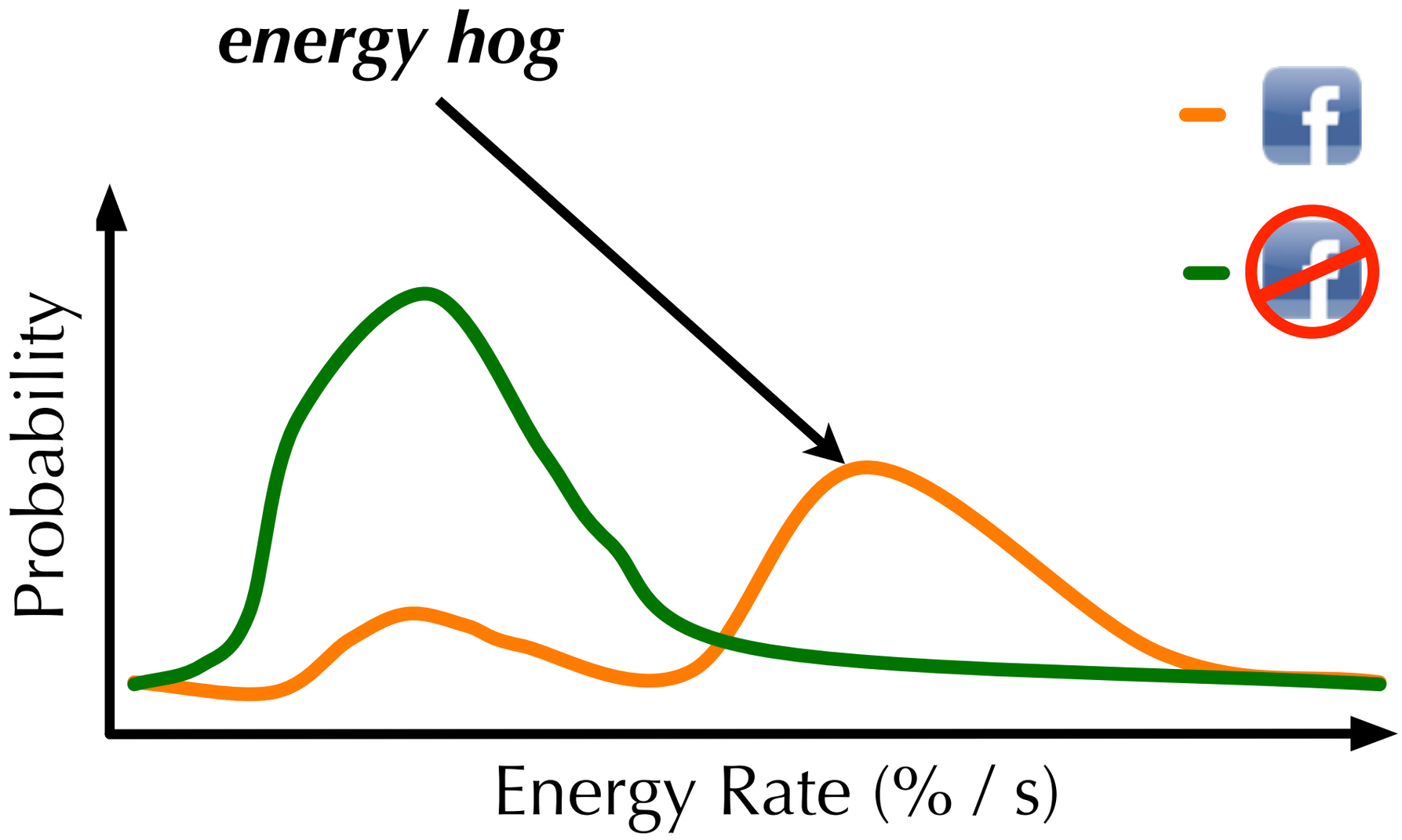
Energy Anomalies



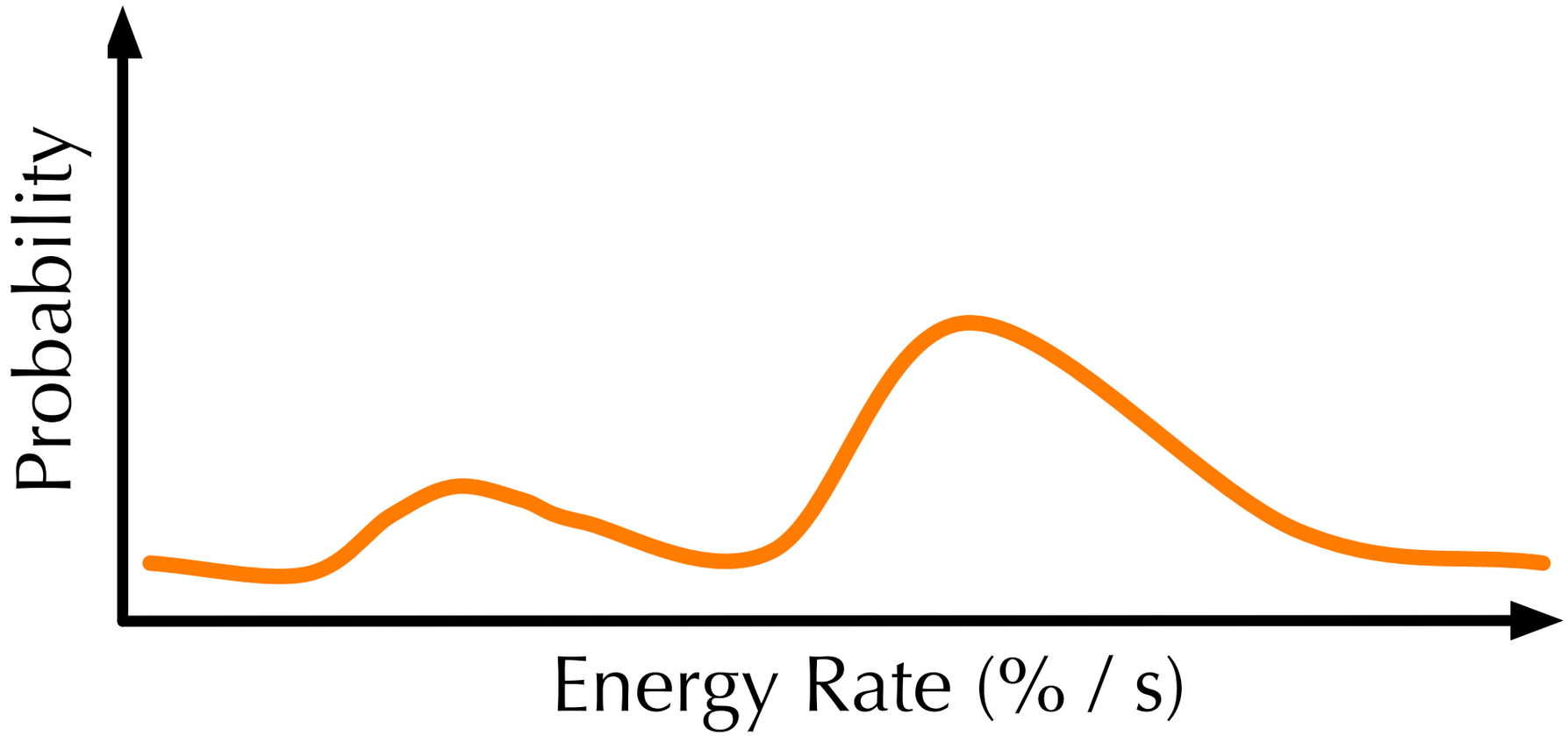
Energy Anomalies



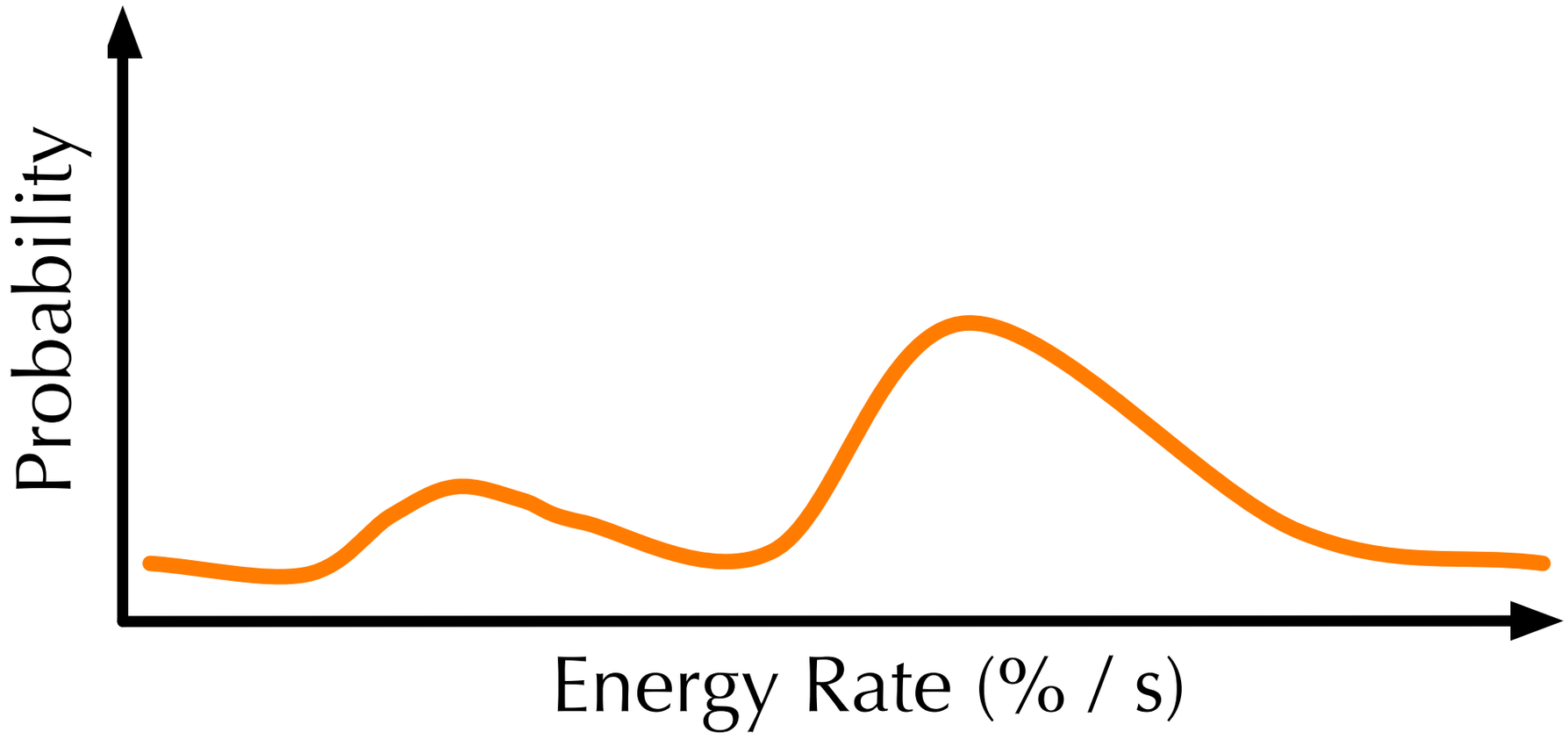
Energy Anomalies



Energy Anomalies



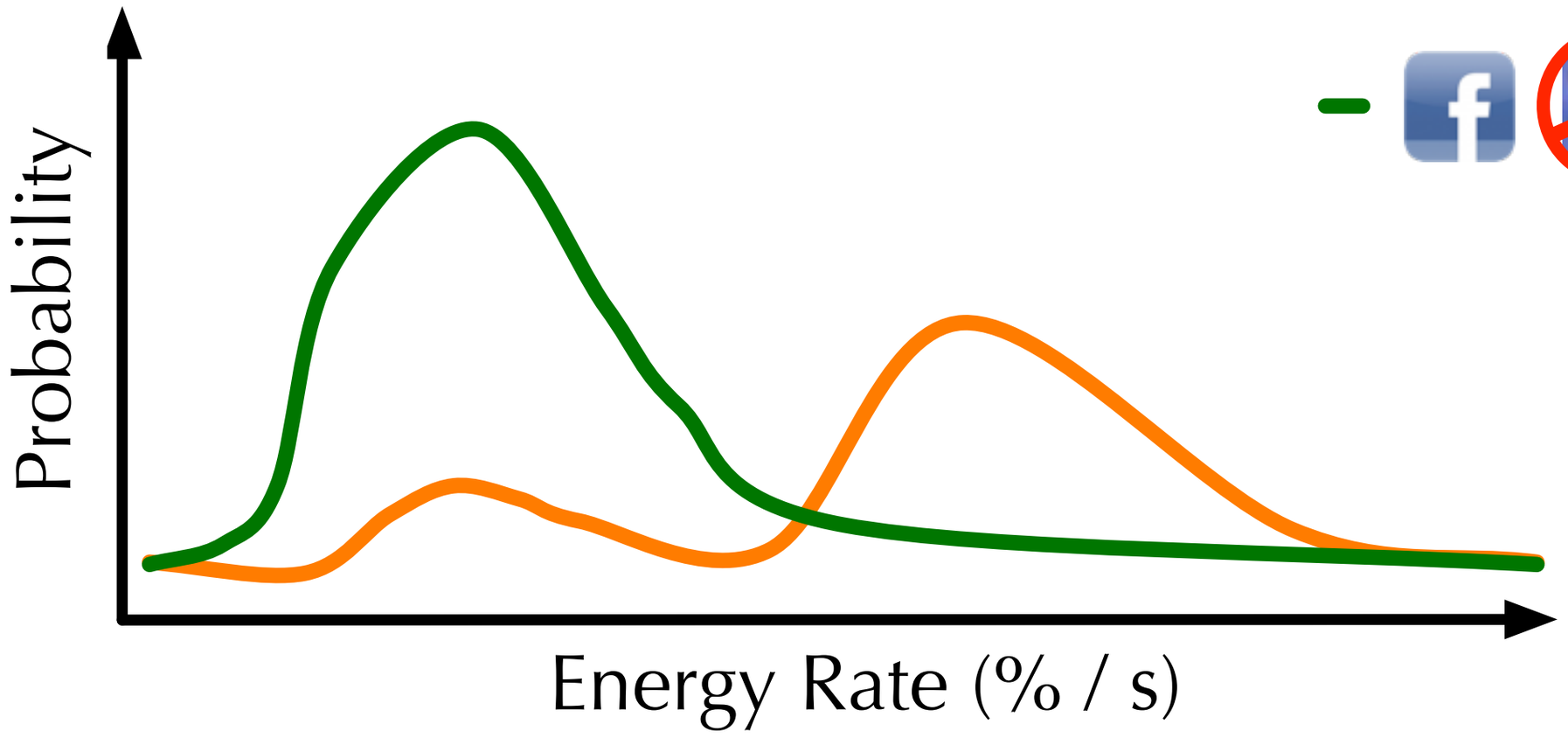
Energy Anomalies



Without the crowd, there is no way to know whether this use is normal.

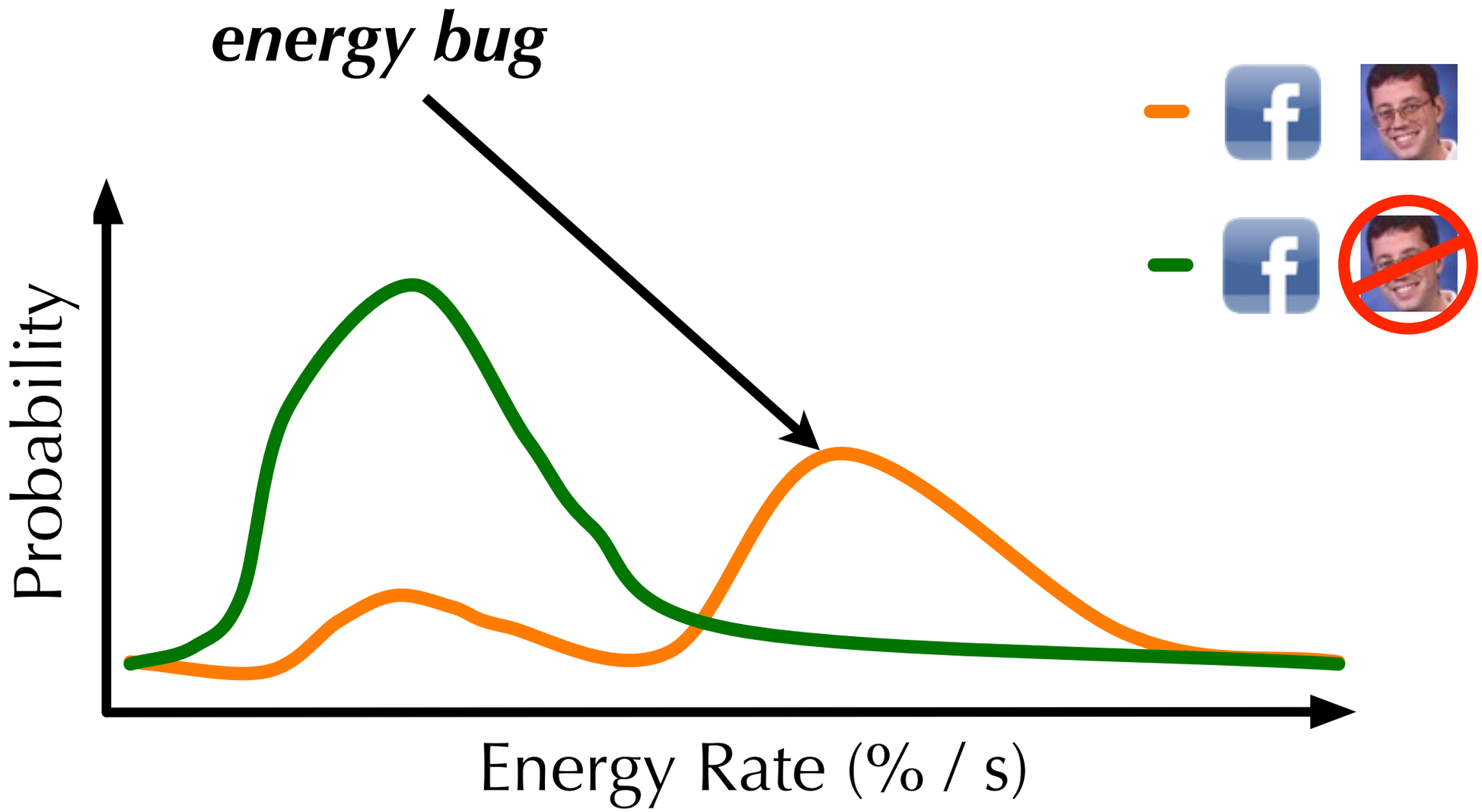
(Given  is not a Hog.)





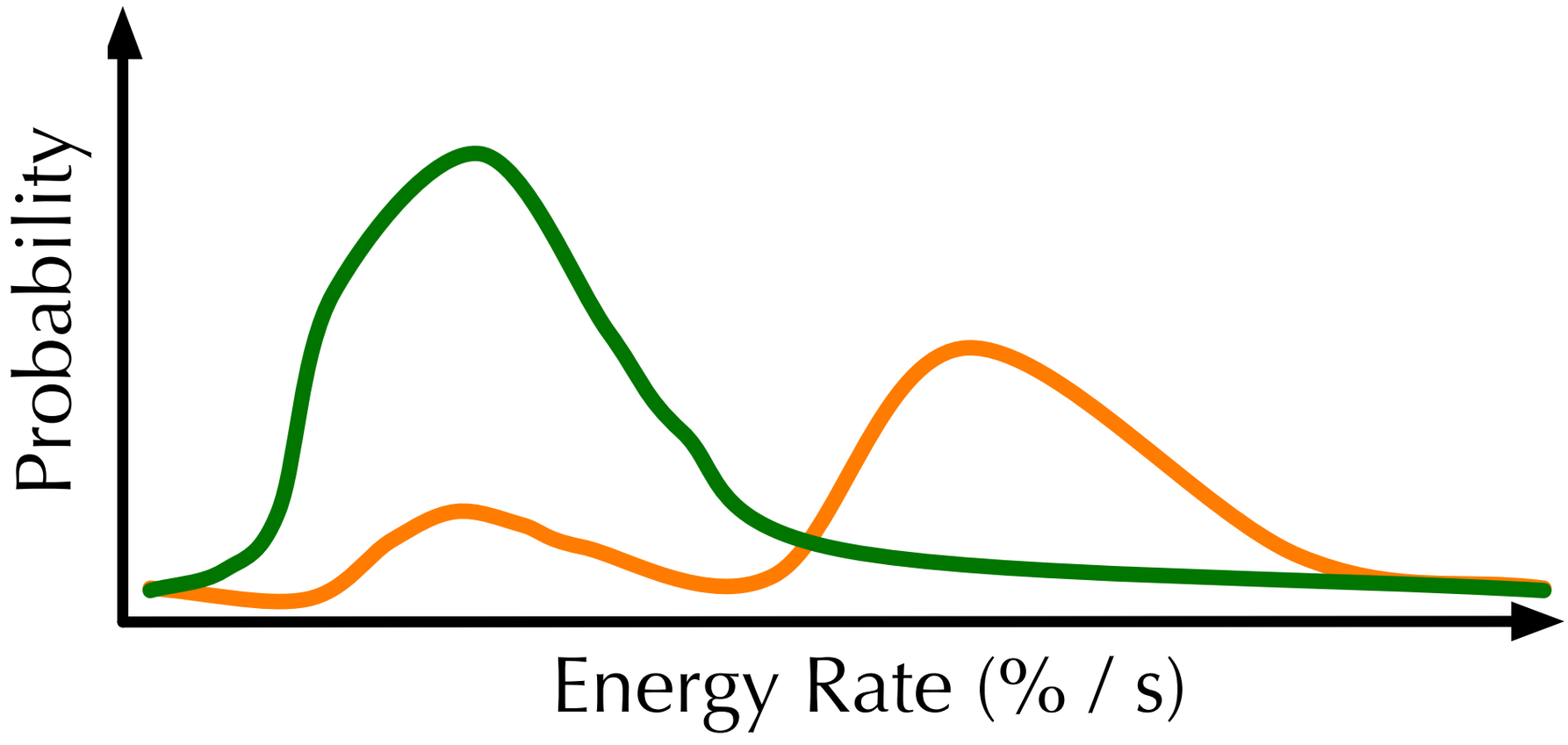
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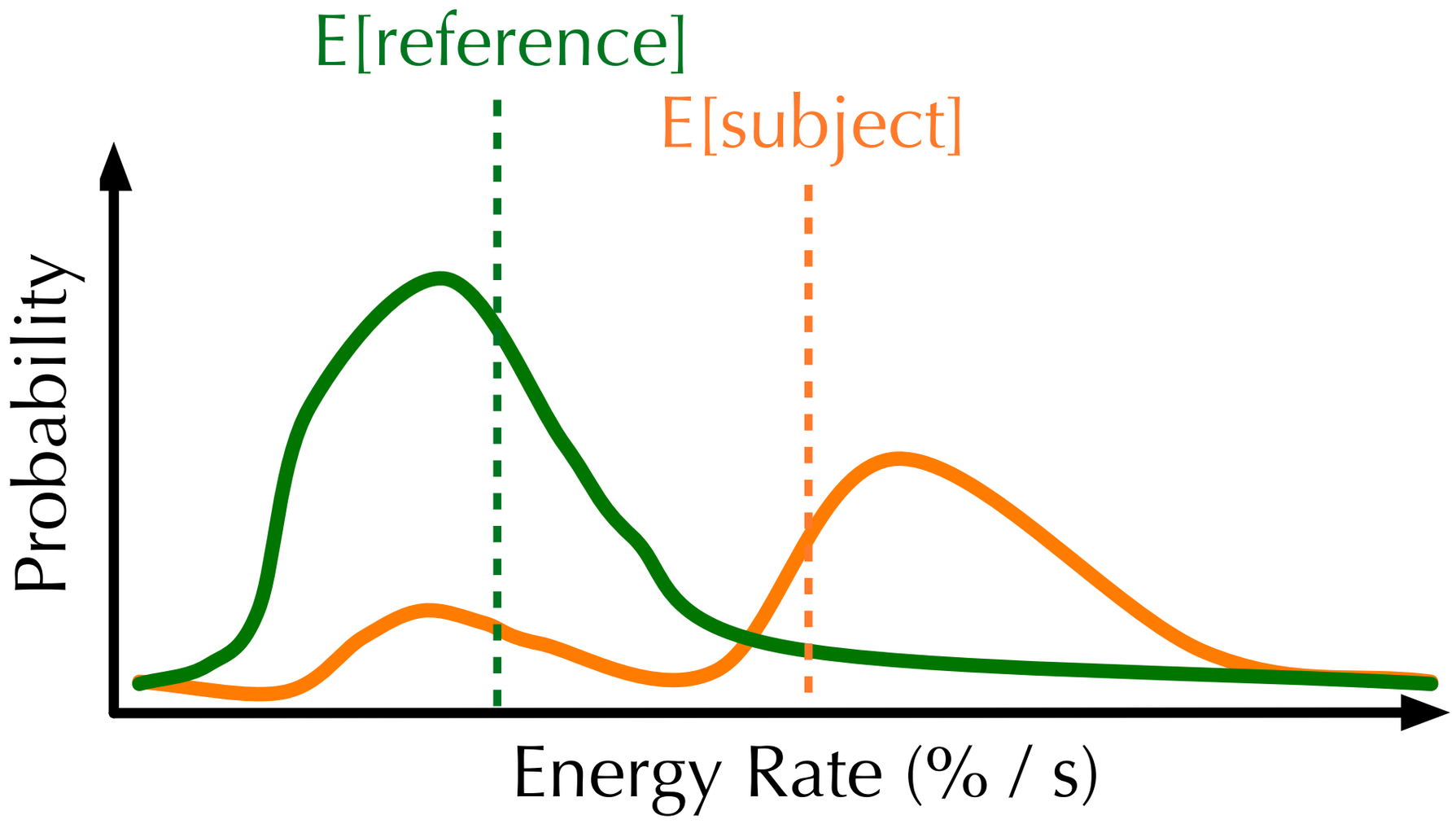


Energy Anomalies

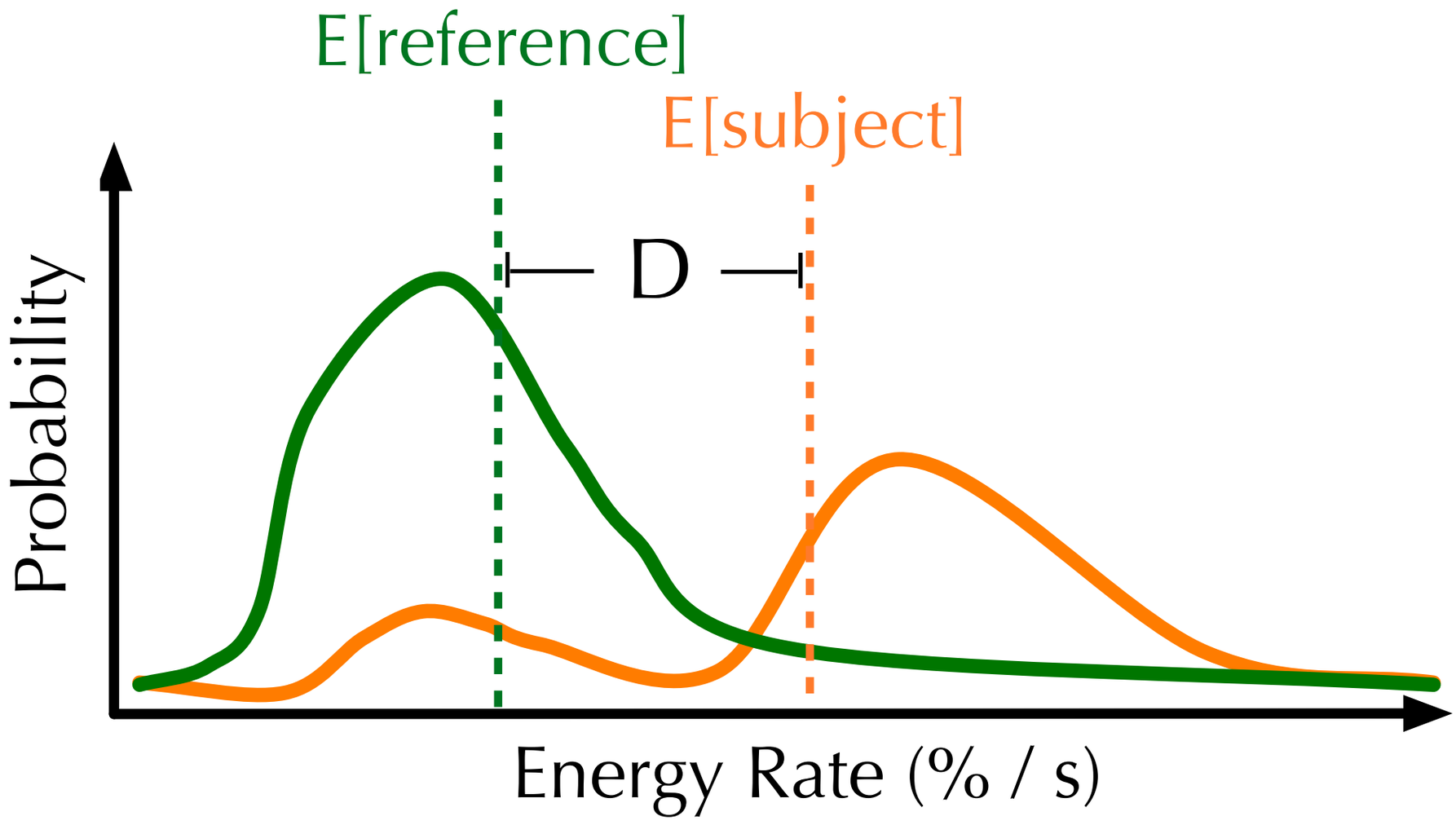
Original Distribution



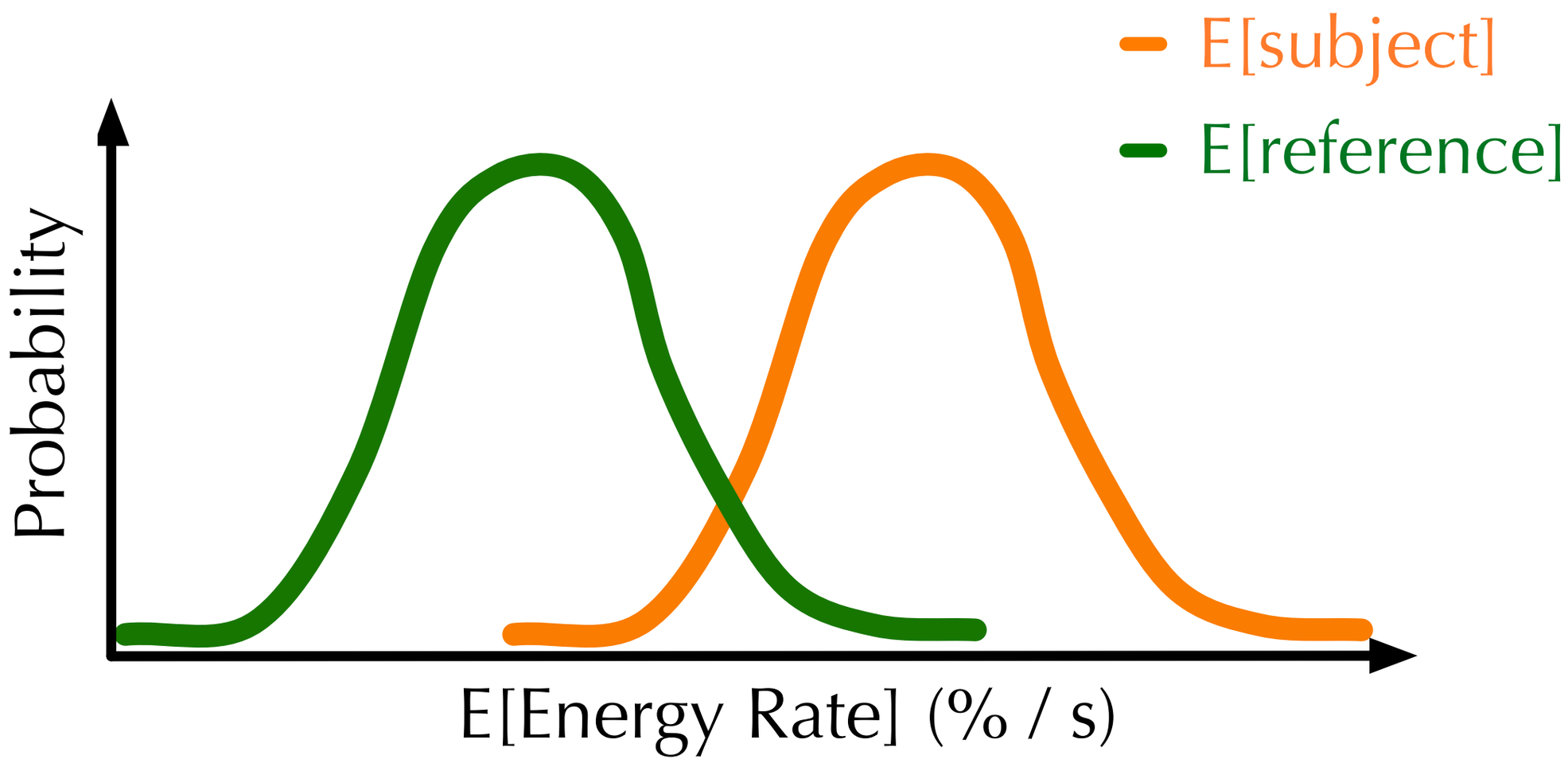
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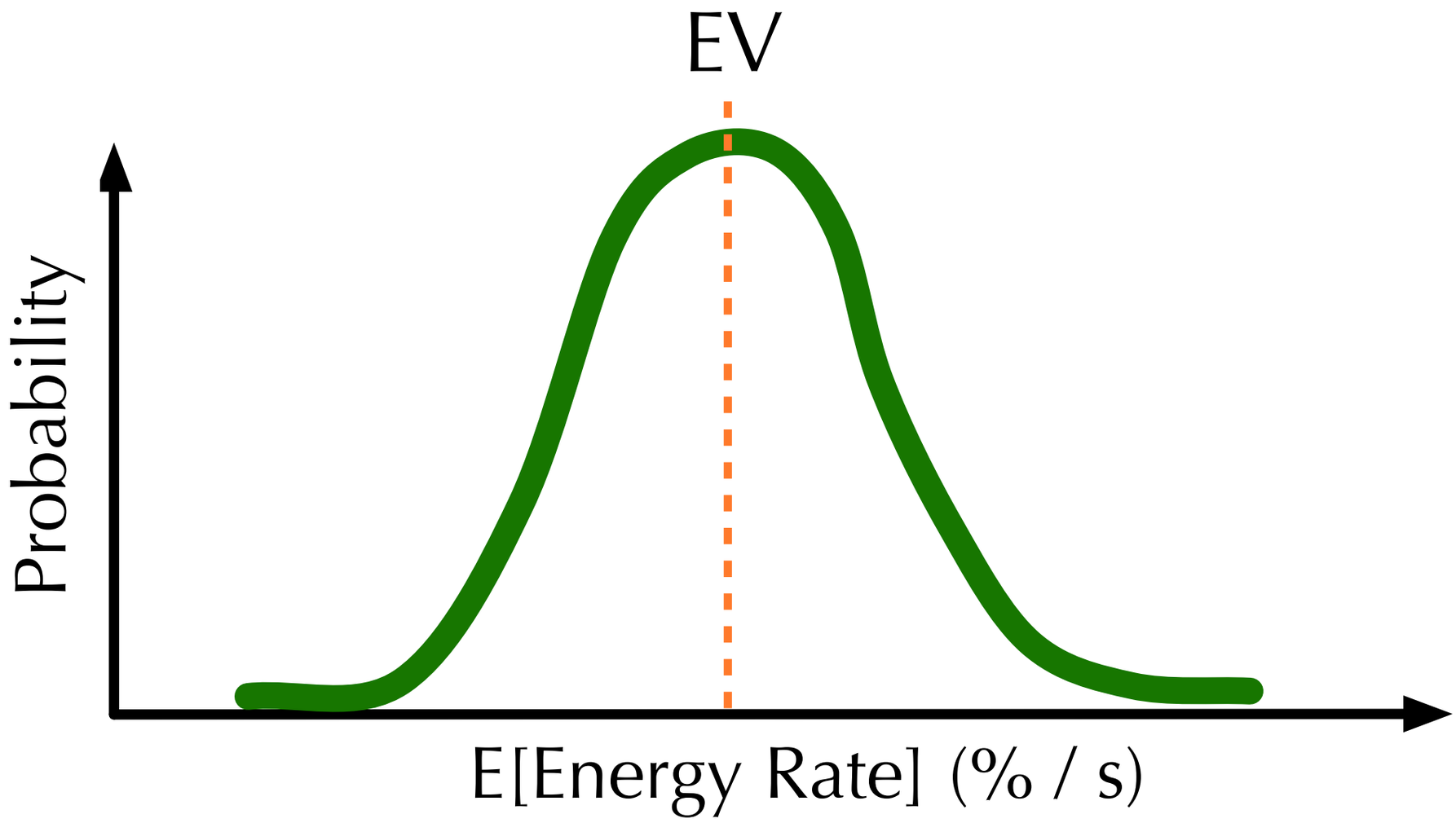
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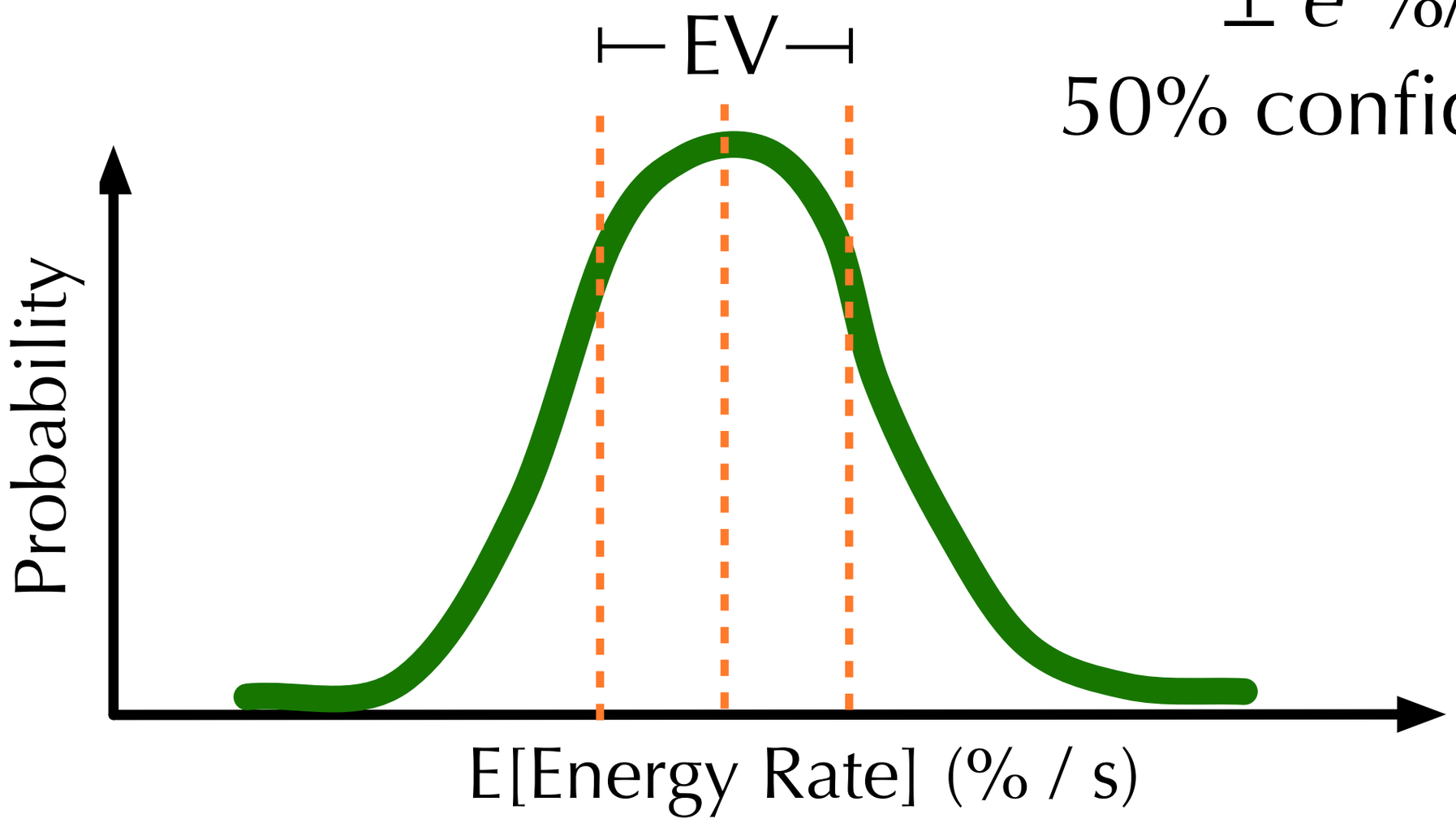
Mean Distribution



Error and Confidence

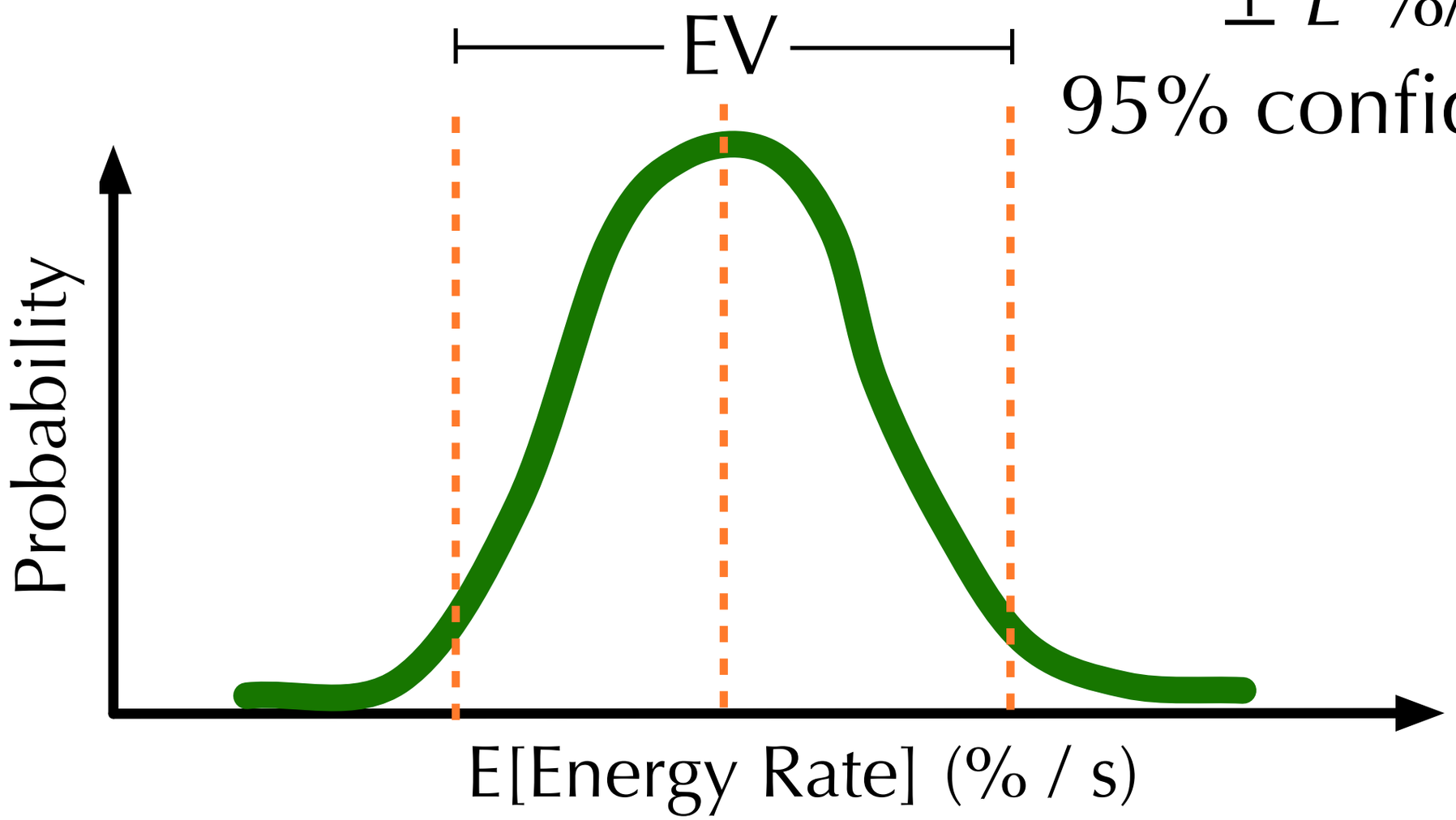


Error and Confidence



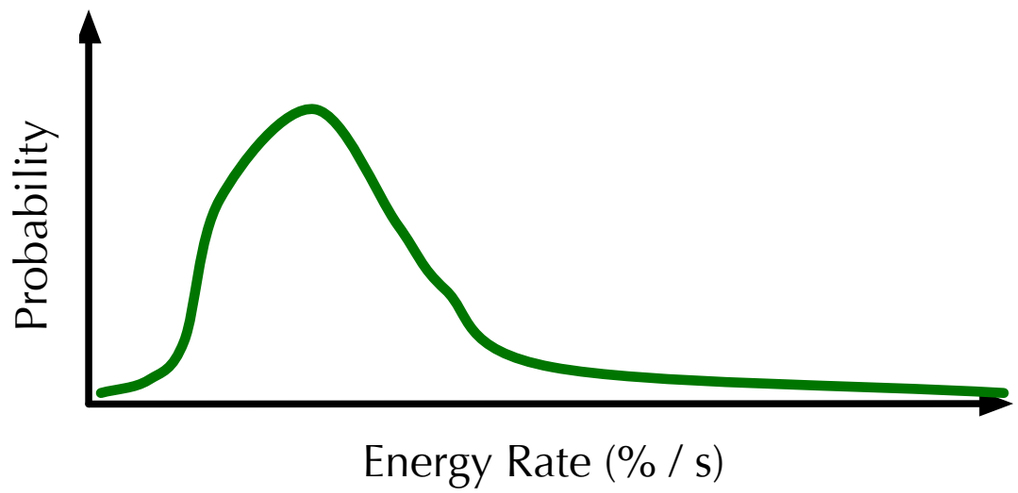
± e %/s
50% confidence

Error and Confidence

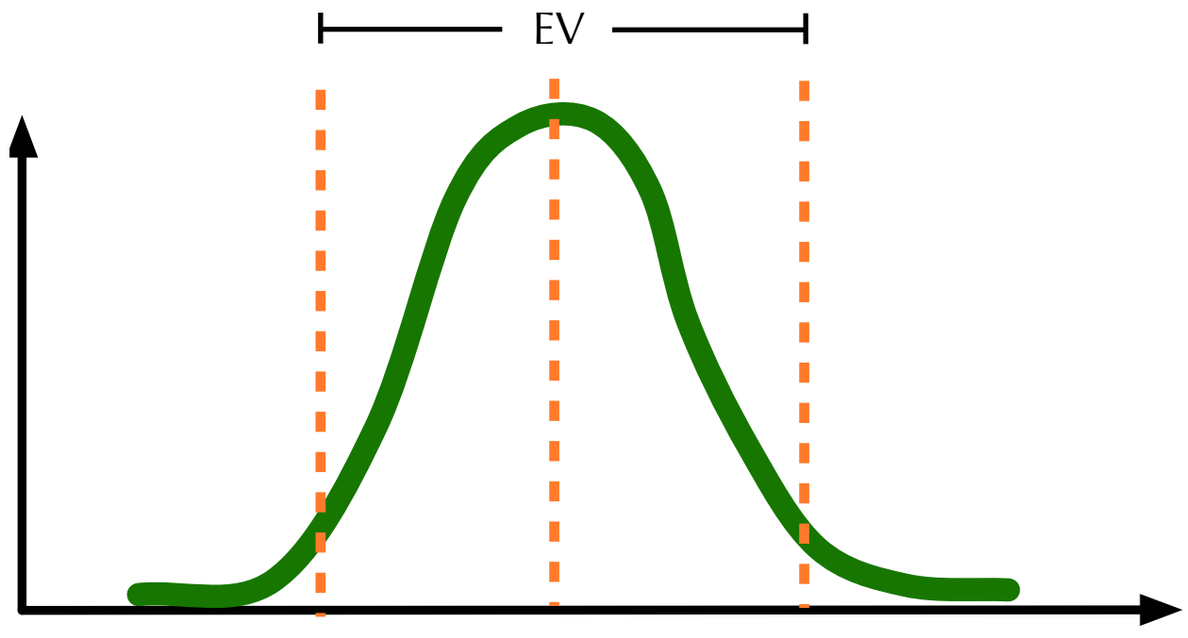


± *E* %/s
95% confidence

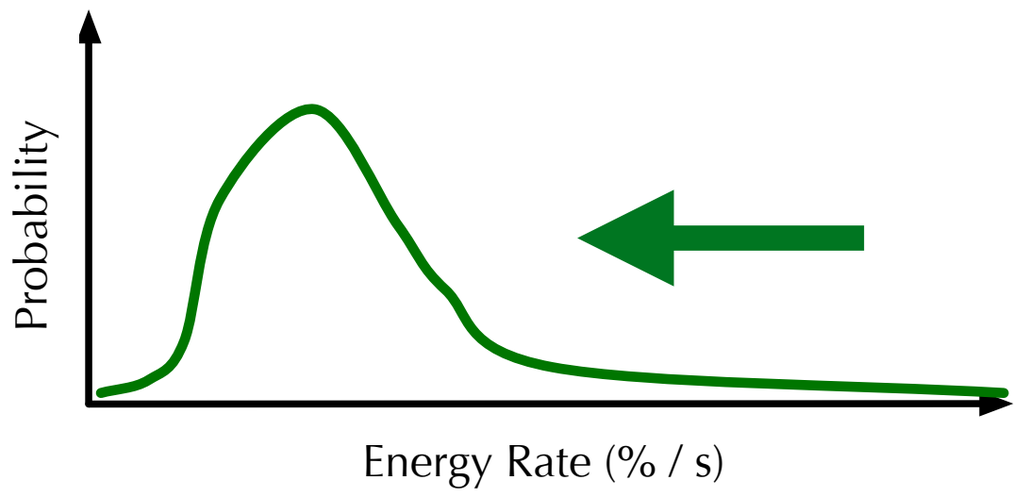
Confidence Factors



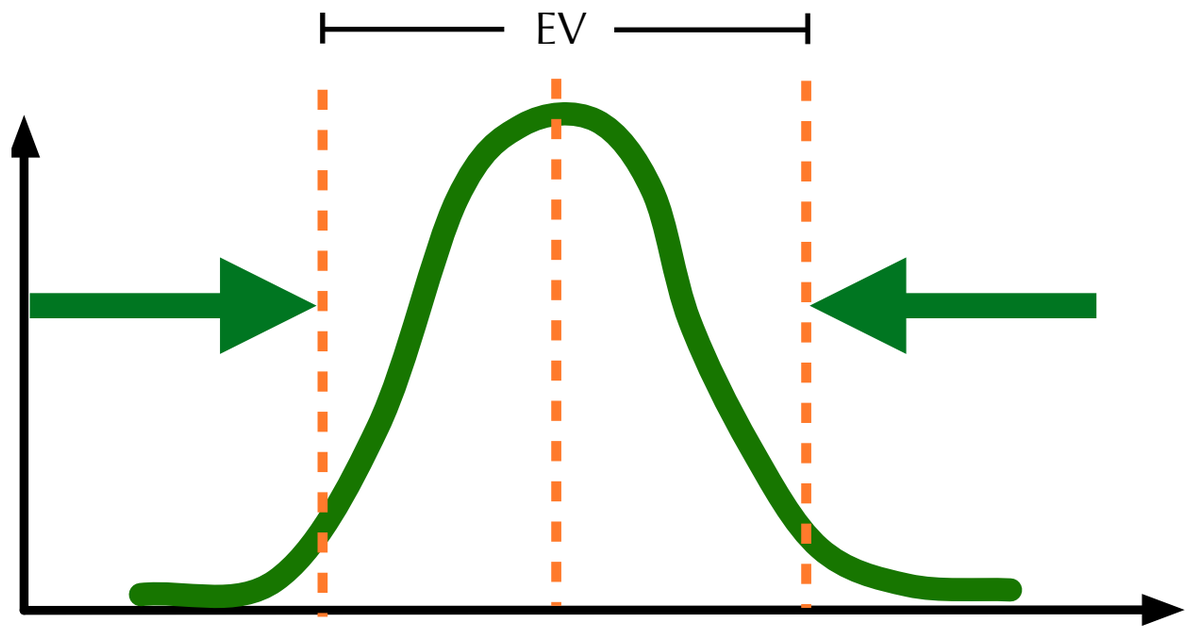




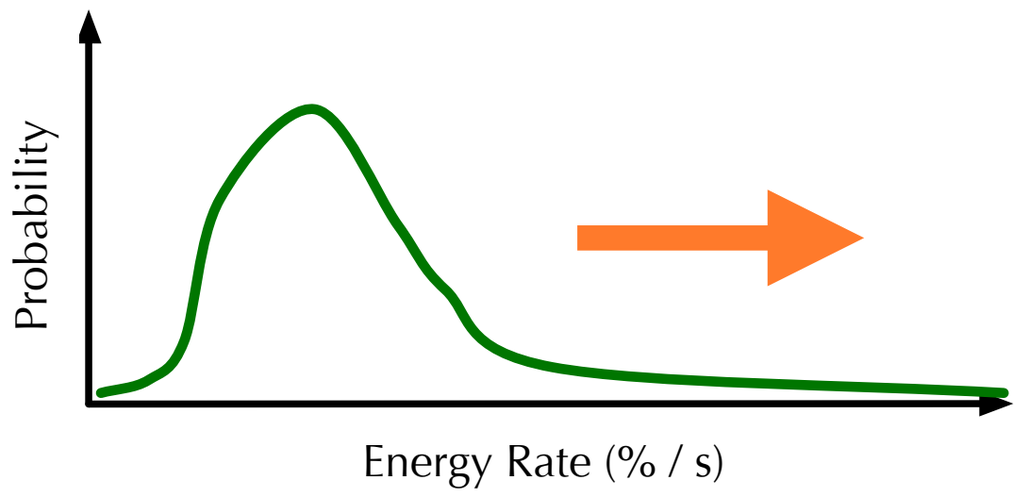
Confidence Factors



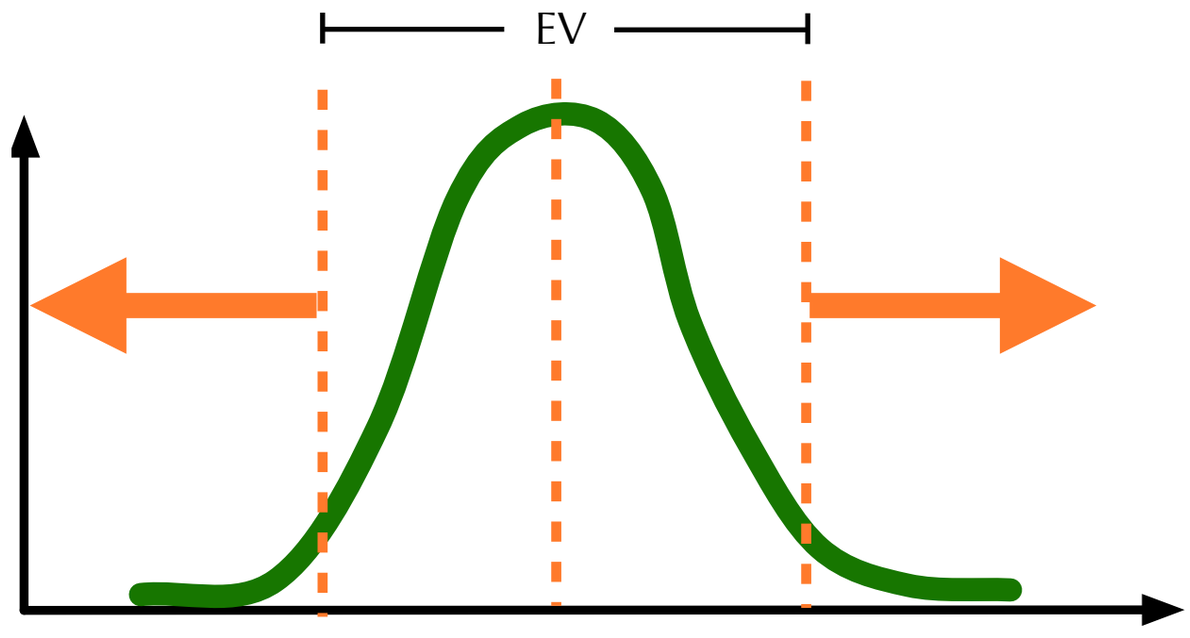




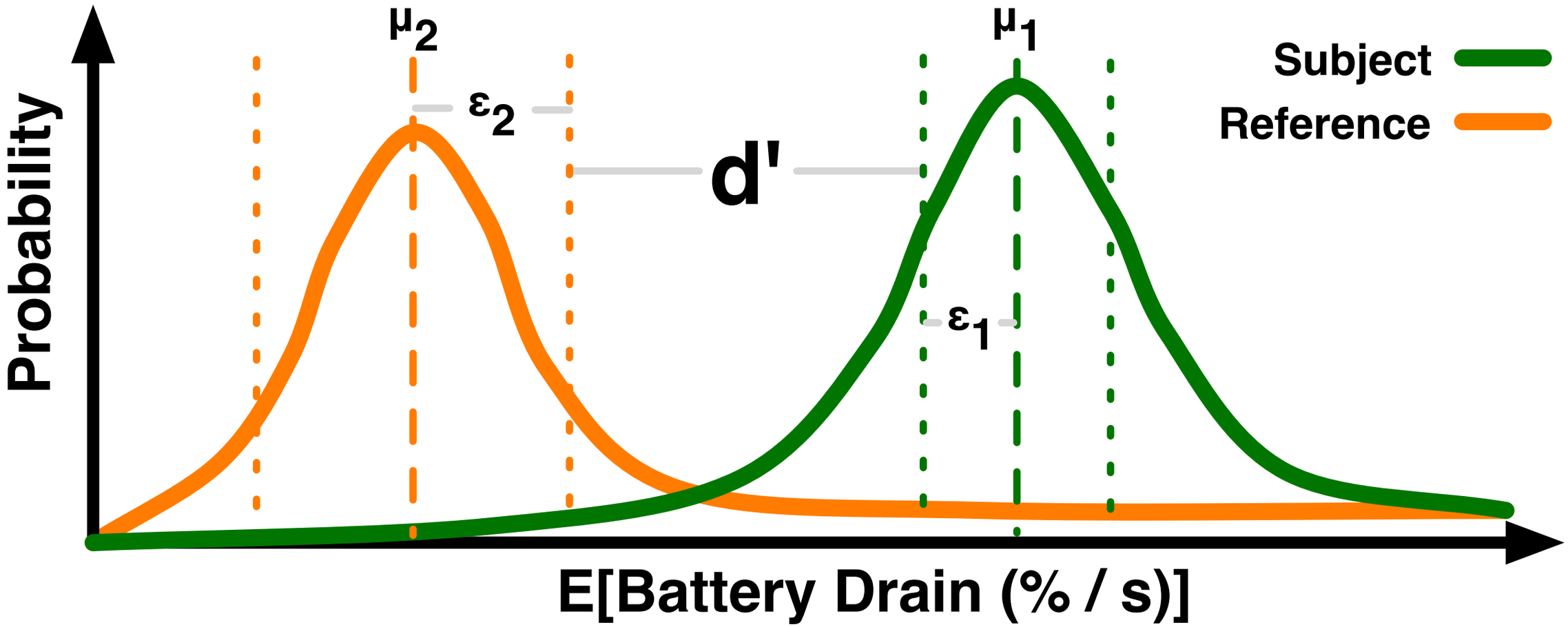
Confidence Factors



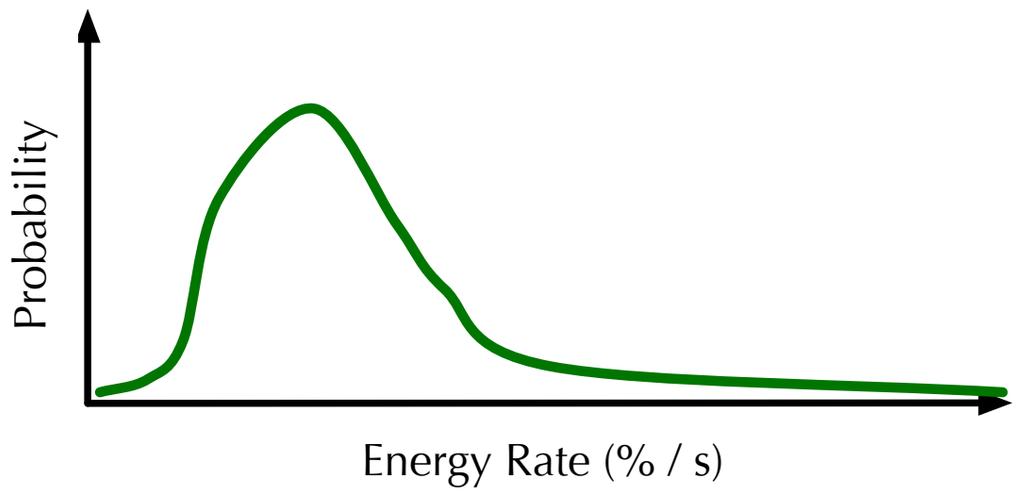




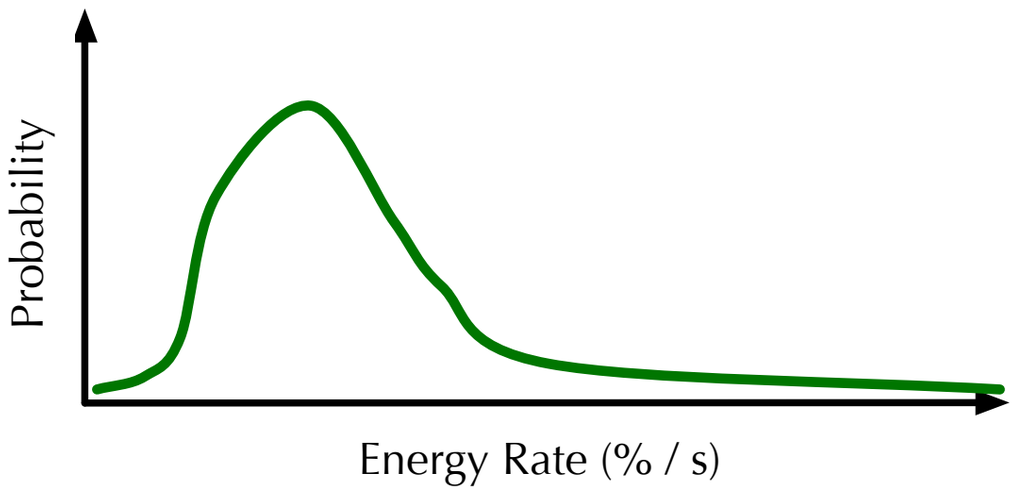
"Significant"



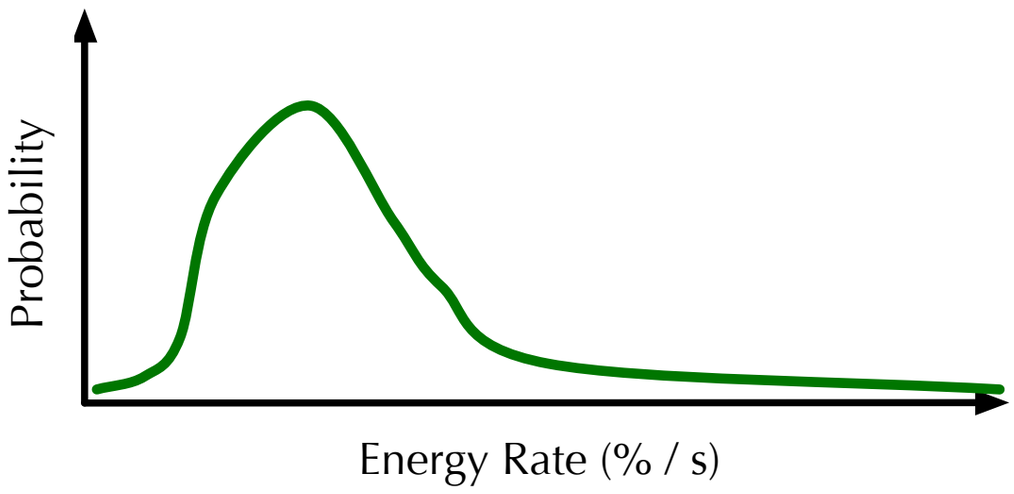
Classification



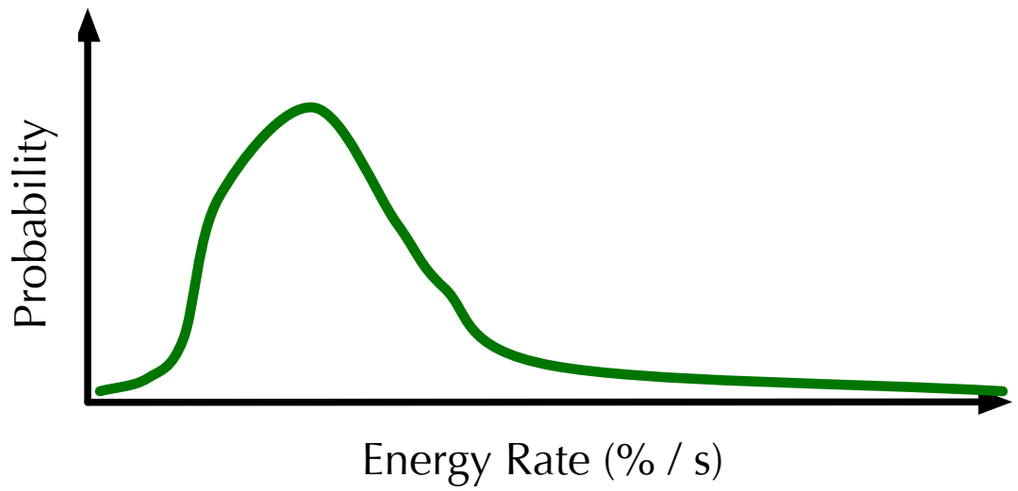
not-F

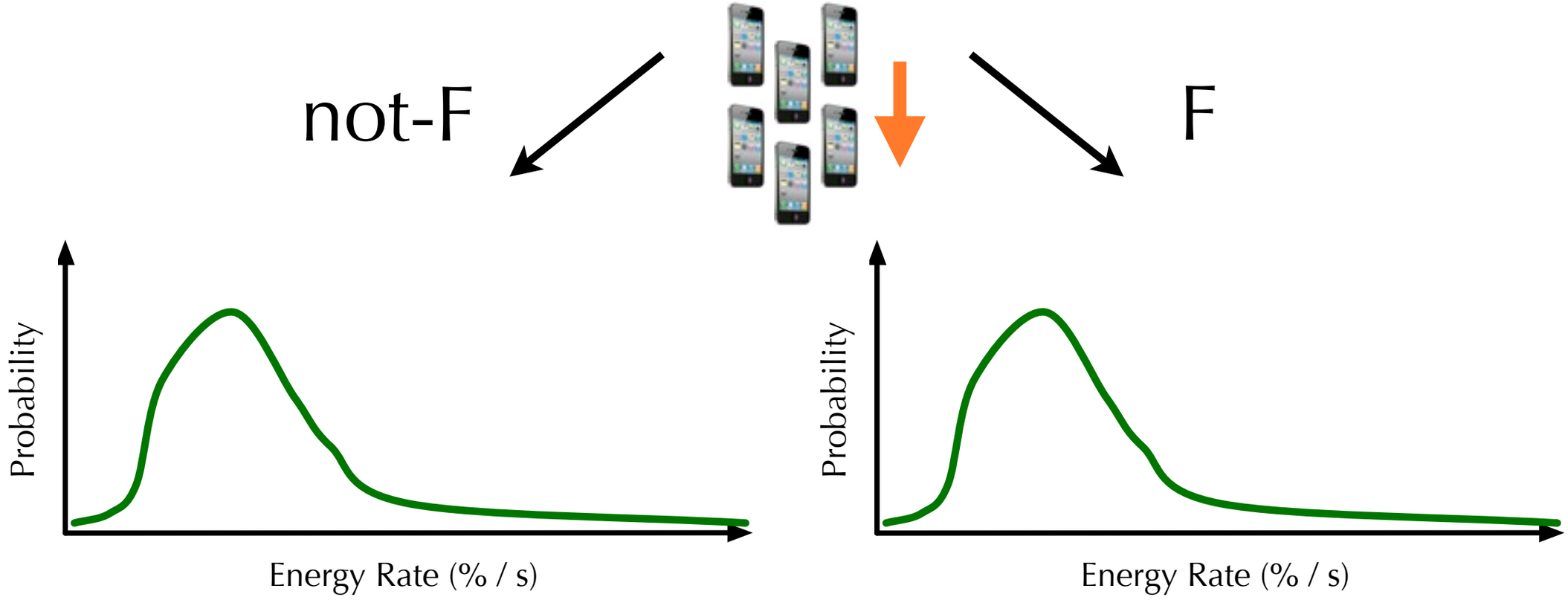


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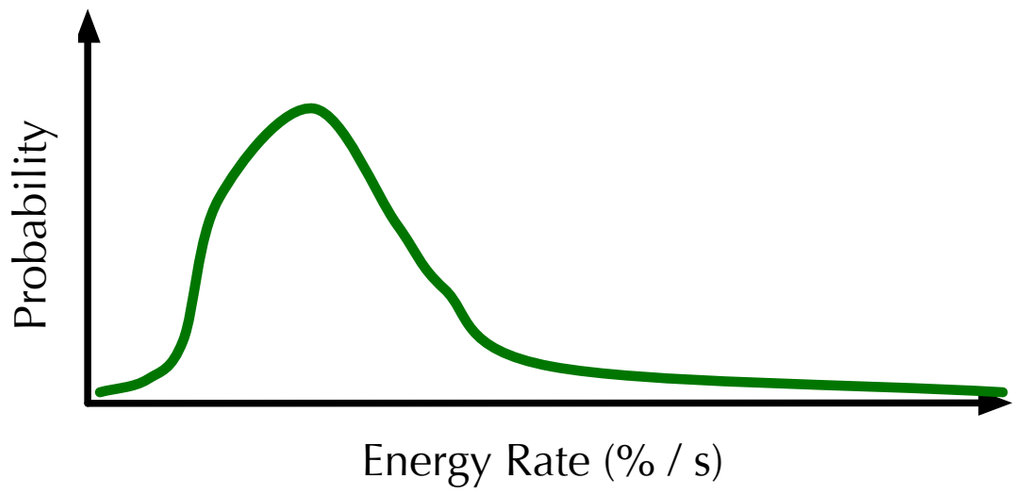


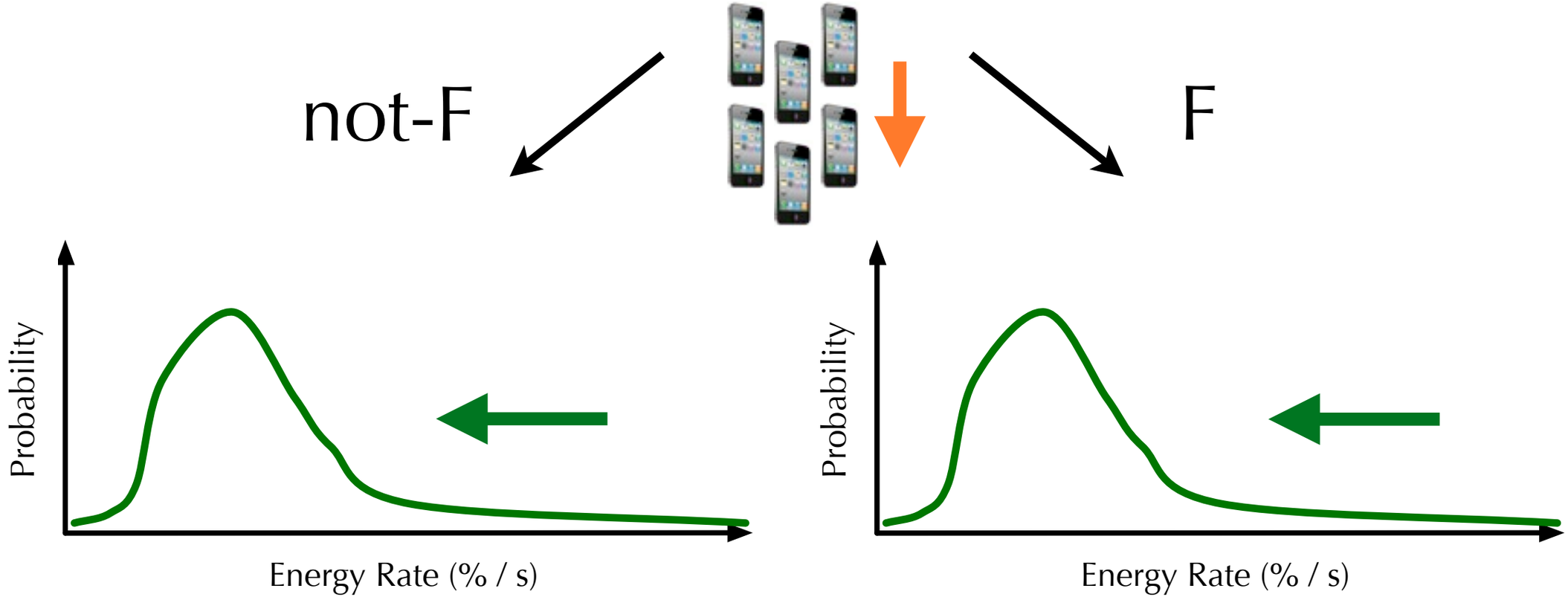
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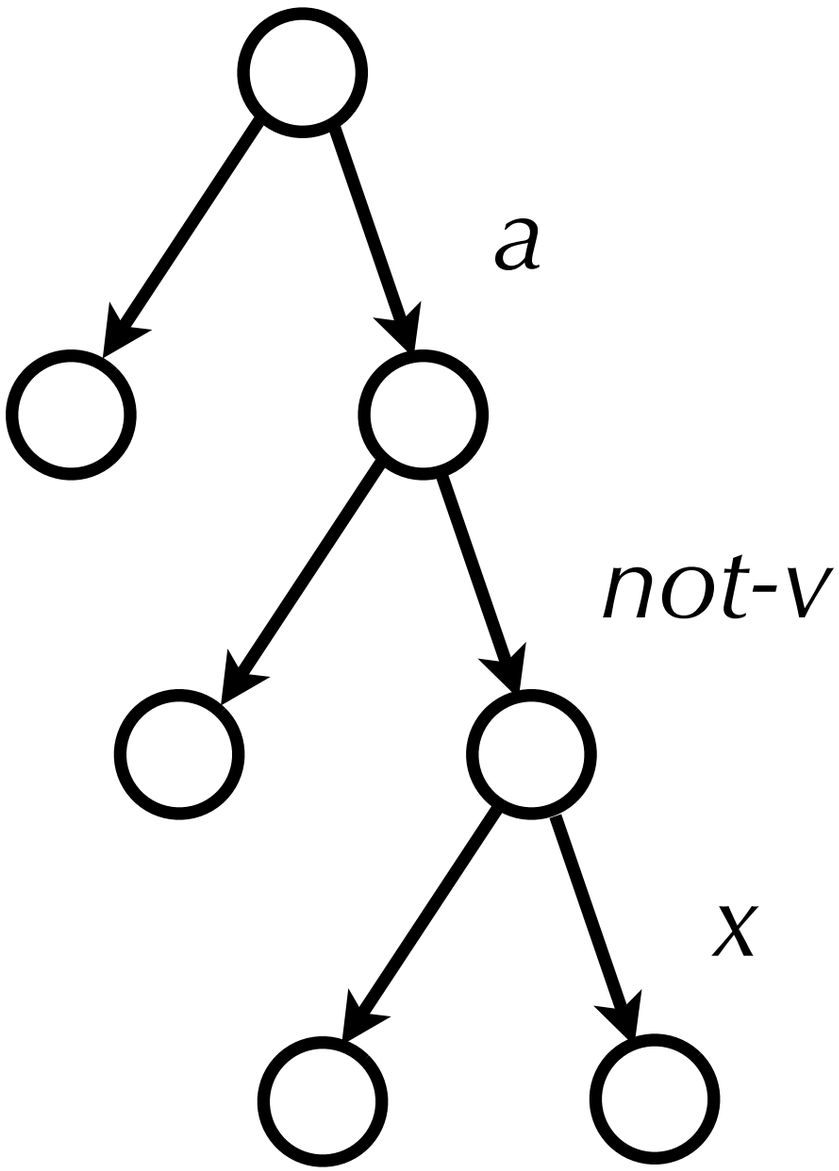


Classification

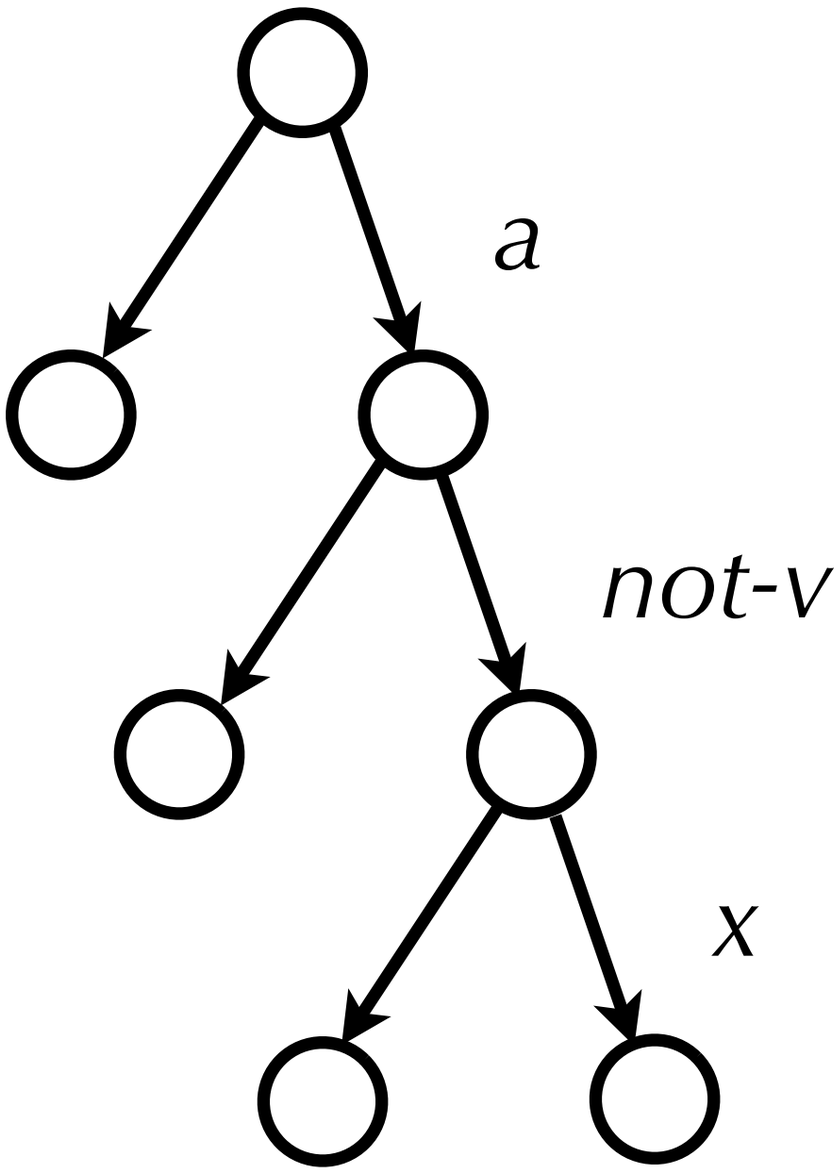




Diagnosis



Diagnosis



"Killing app *a* will give *x*±*e* of battery life (95% confidence), as would upgrading the OS to version *v*."

3. Dealing with Uncertainty

Trigger	Measured %	Actual %
BatteryLevelChanged	x	x
else	x	(x-5, x]

Measurement Uncertainty

Trigger	Measured %	Actual %
BatteryLevelChanged	x	x
else	x	(x-5, x]



85% → 85%

Measurement Uncertainty

Trigger	Measured %	Actual %
BatteryLevelChanged	x	x
else	x	(x-5, x]

- 85% → 85%
- 85% → (80%,85%]

Measurement Uncertainty

Trigger	Measured %	Actual %
BatteryLevelChanged	x	x
else	x	(x-5, x]



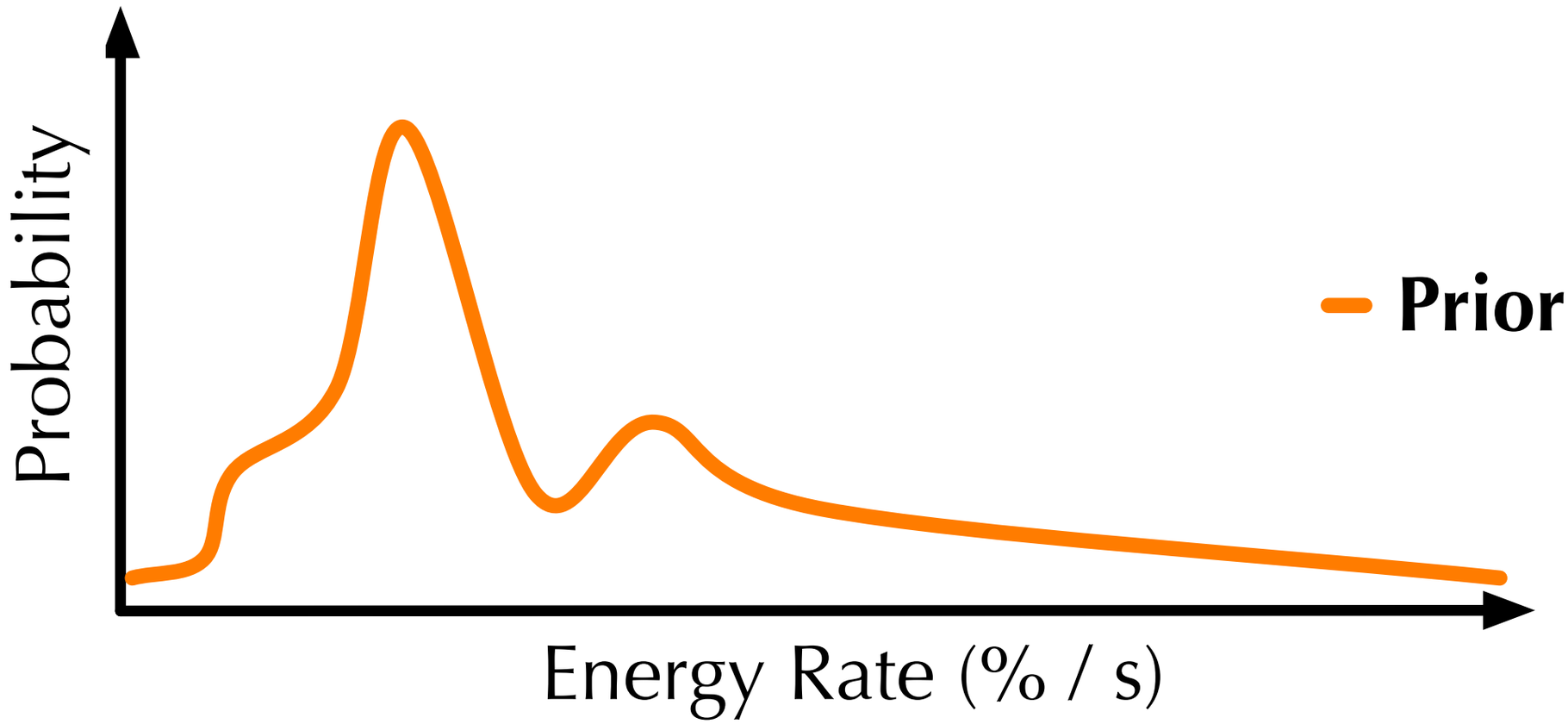
85% → 85%

Prior

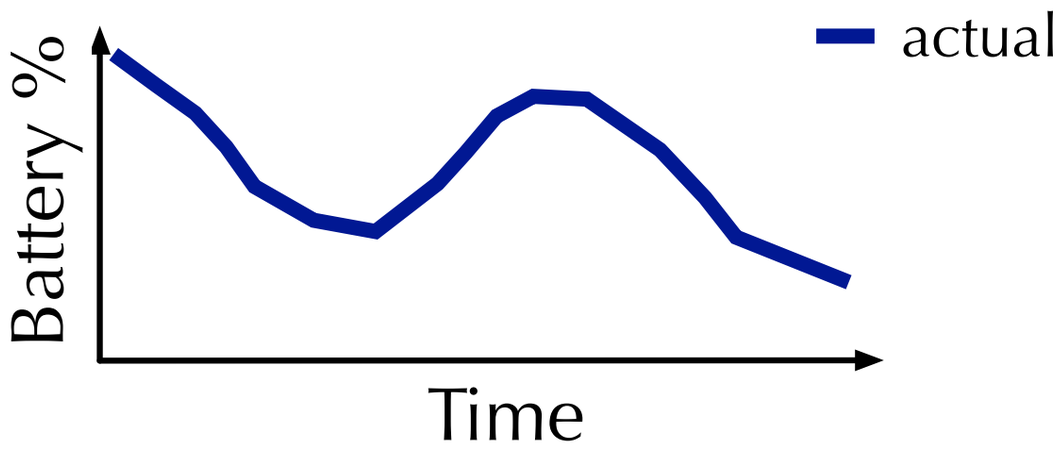


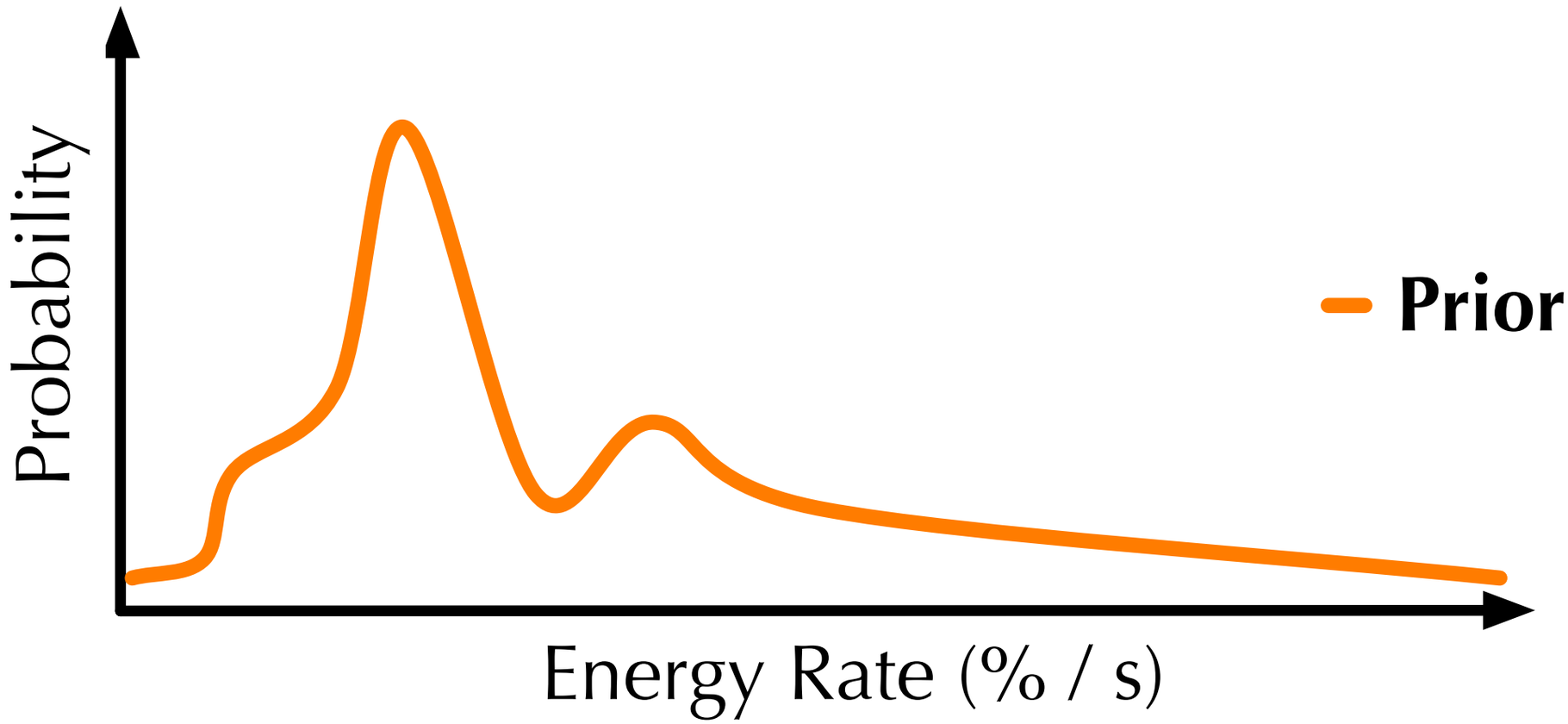
85% → (80%,85%]

Measurement Uncertainty

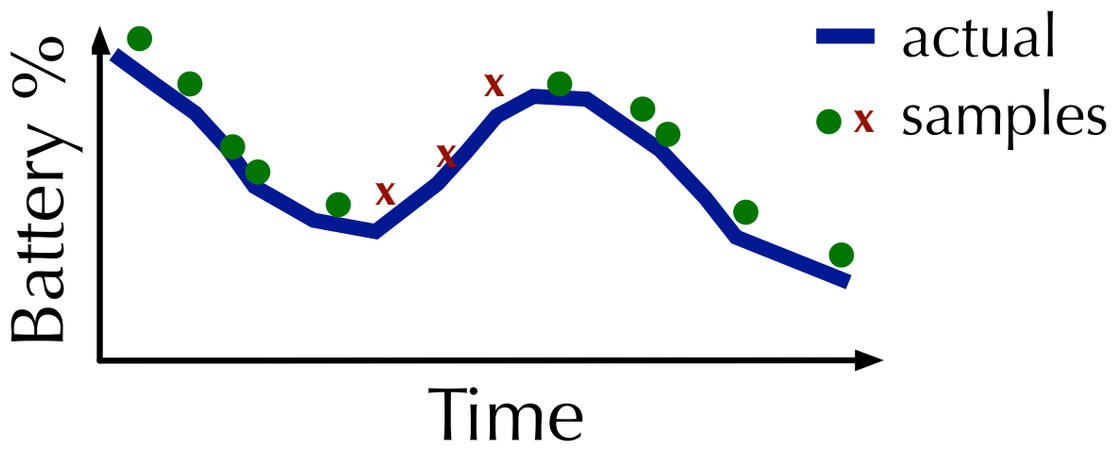


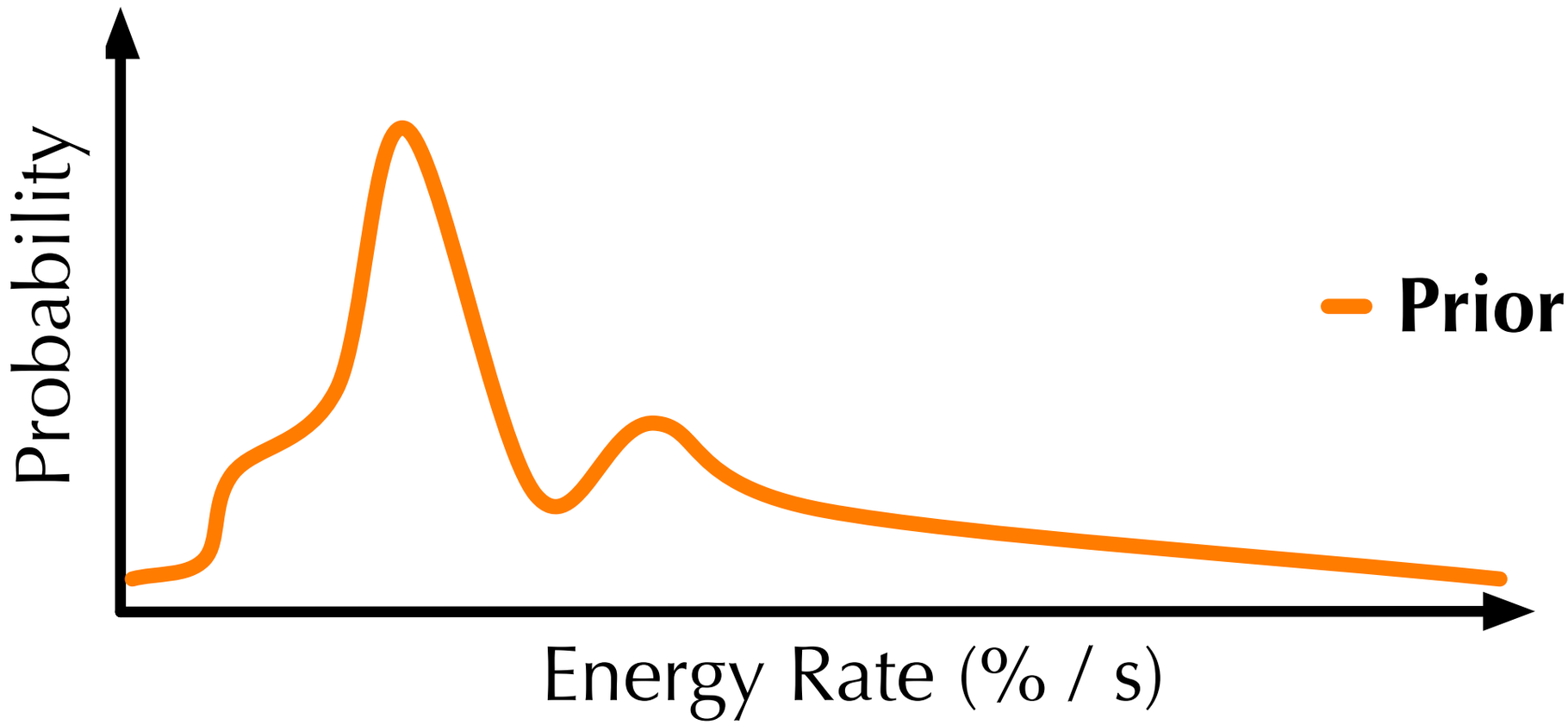
Measurement Uncertainty



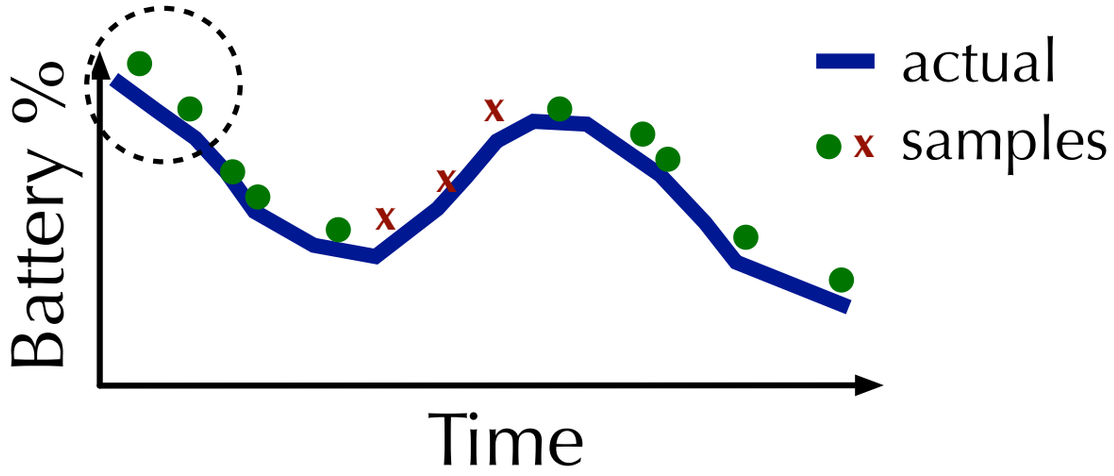


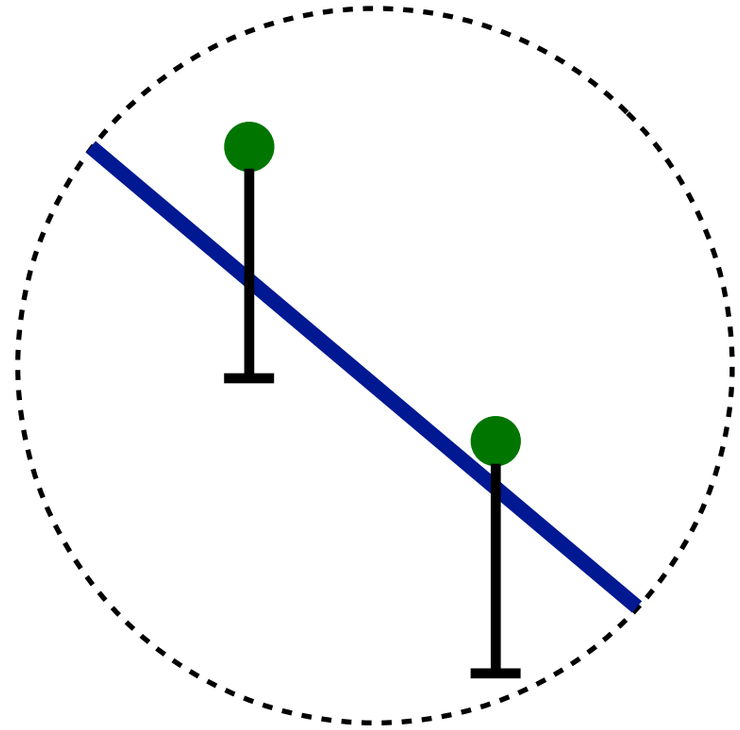
Measurement Uncertainty

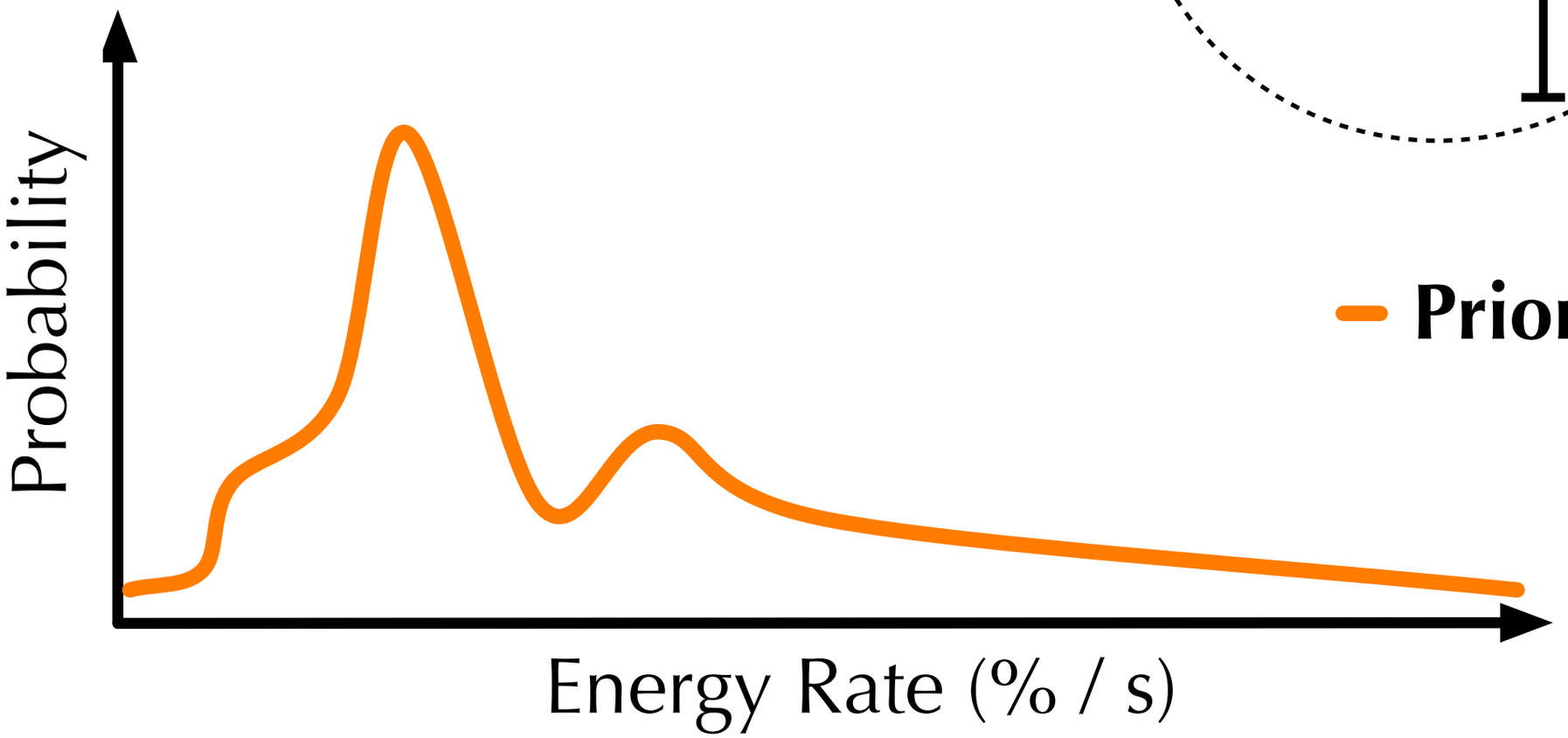




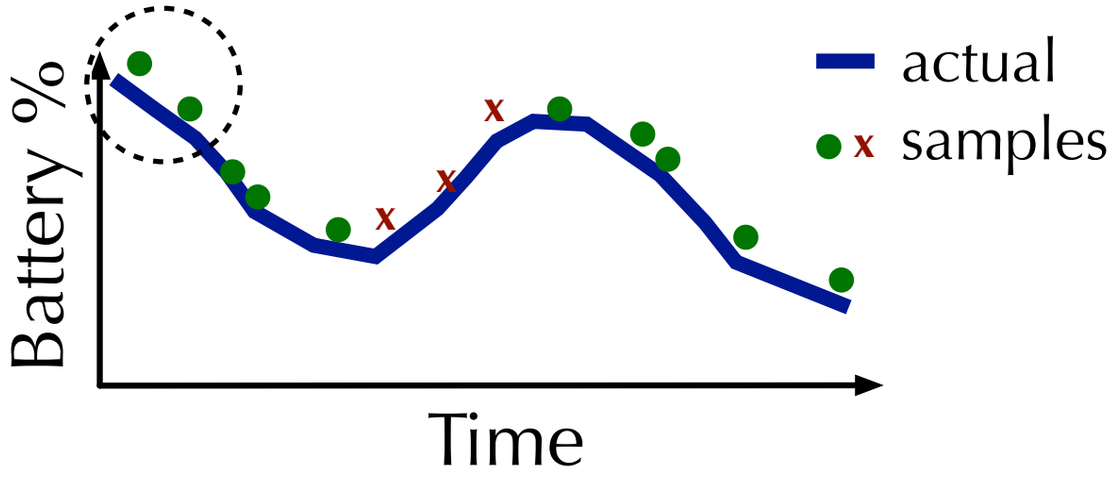
Measurement Uncertainty

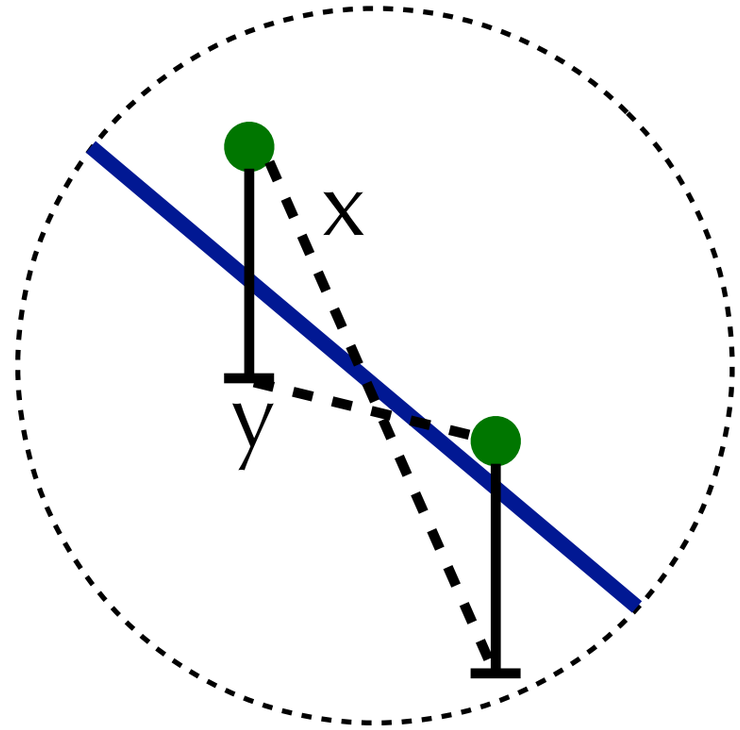


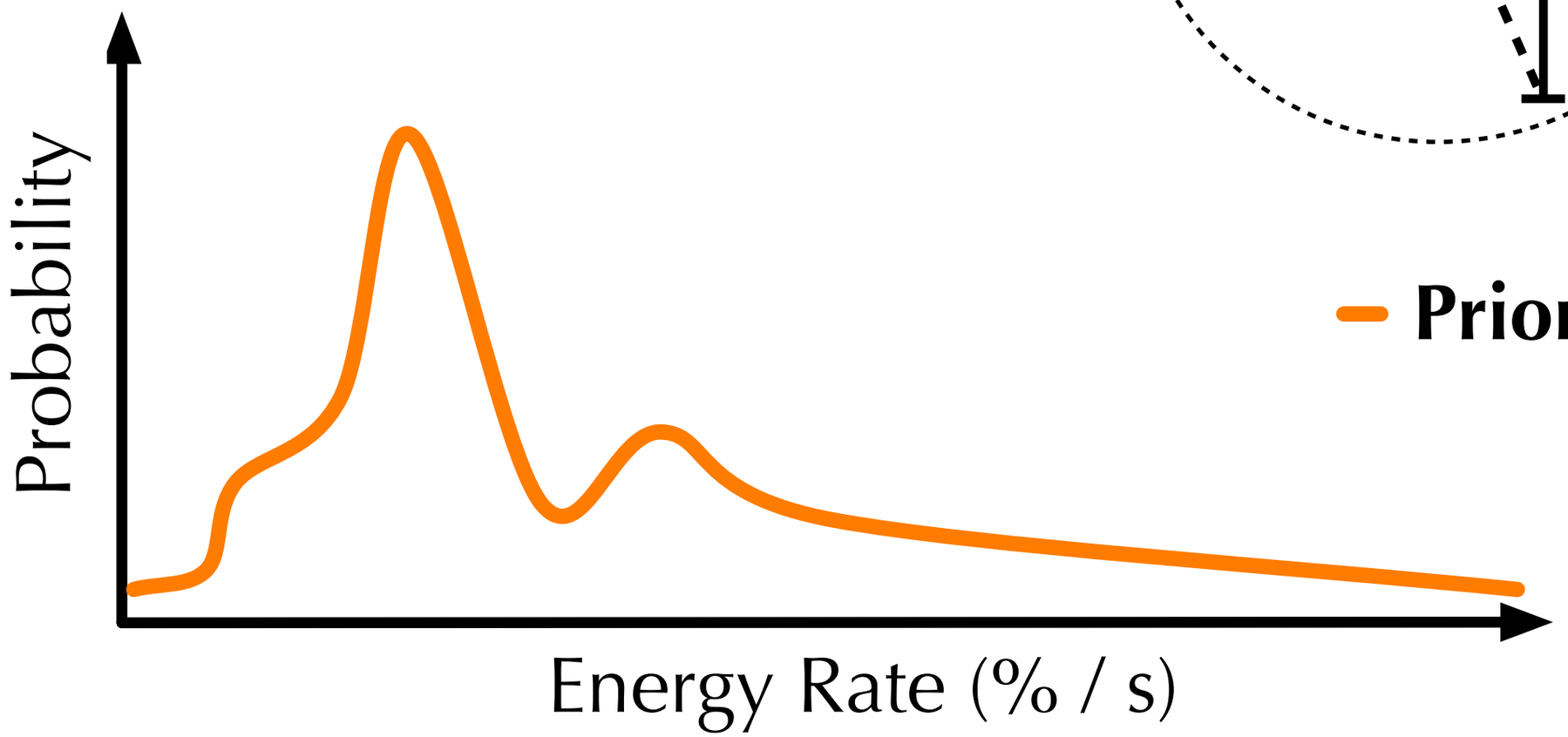




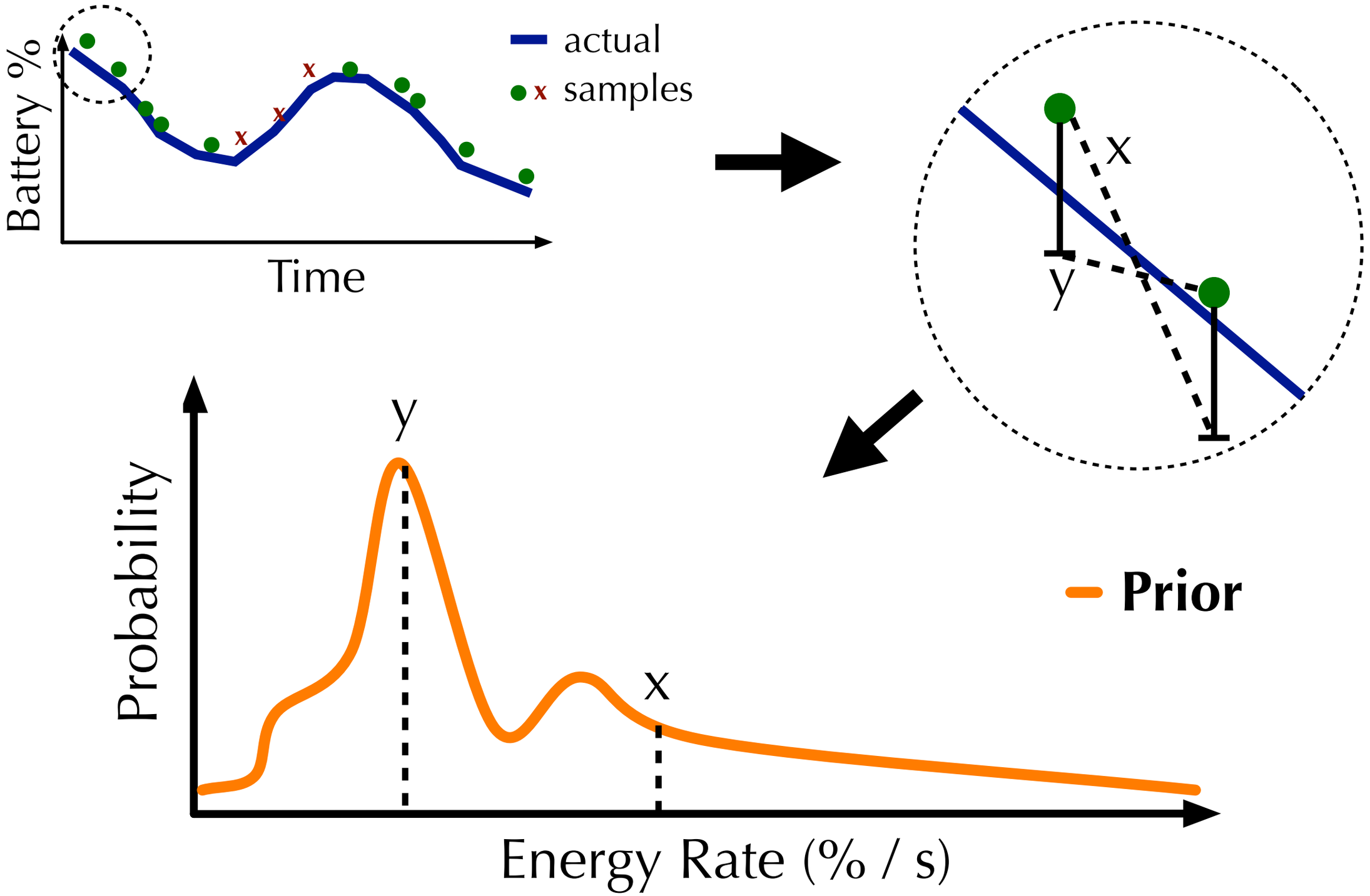
Measurement Uncertainty







Measurement Uncertainty

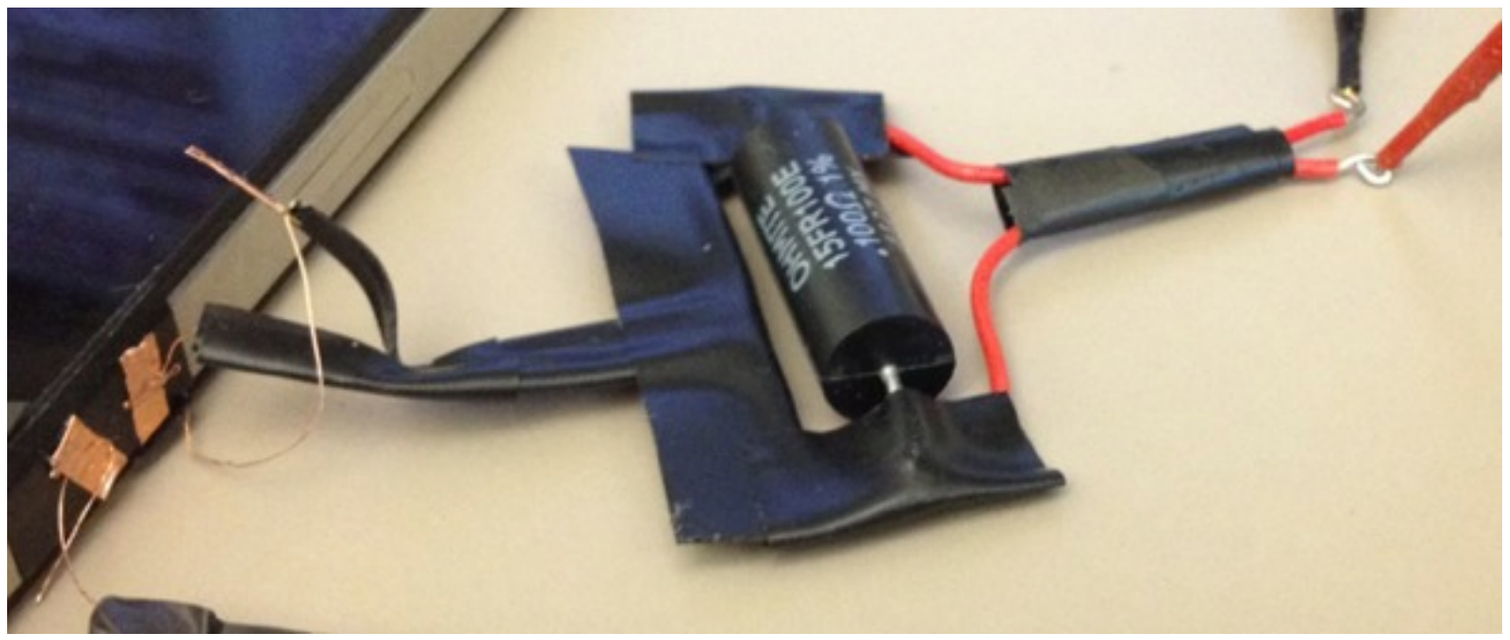


Measurement Uncertainty

Ground Truth

- Does sampling match reality?
- What does sampling cost?



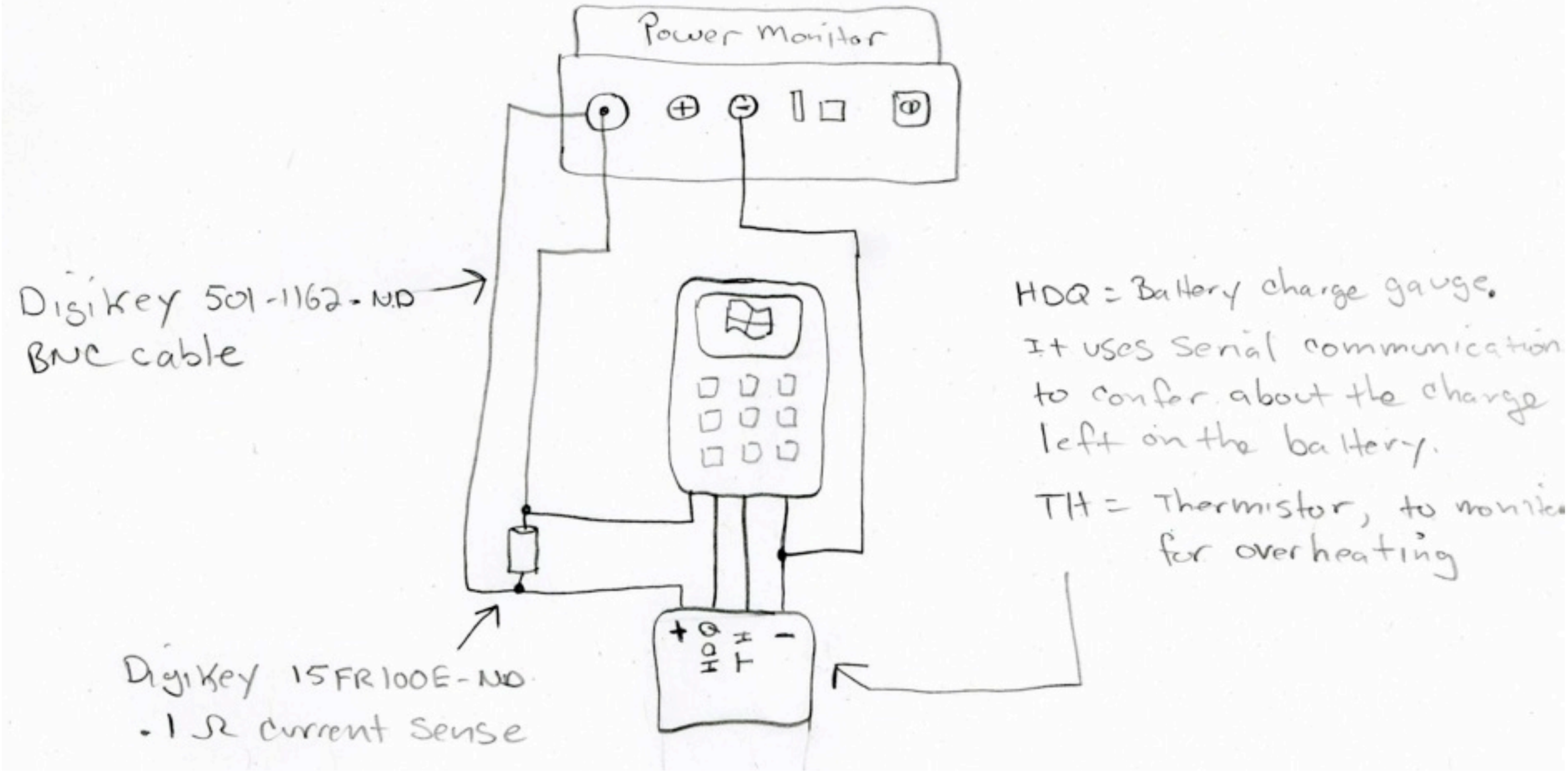


Ground Truth

- iPhone 4S + Monsoon Power Monitor
- Galaxy Tab 2 10.1 + Leyden Energy
- Usage scripts



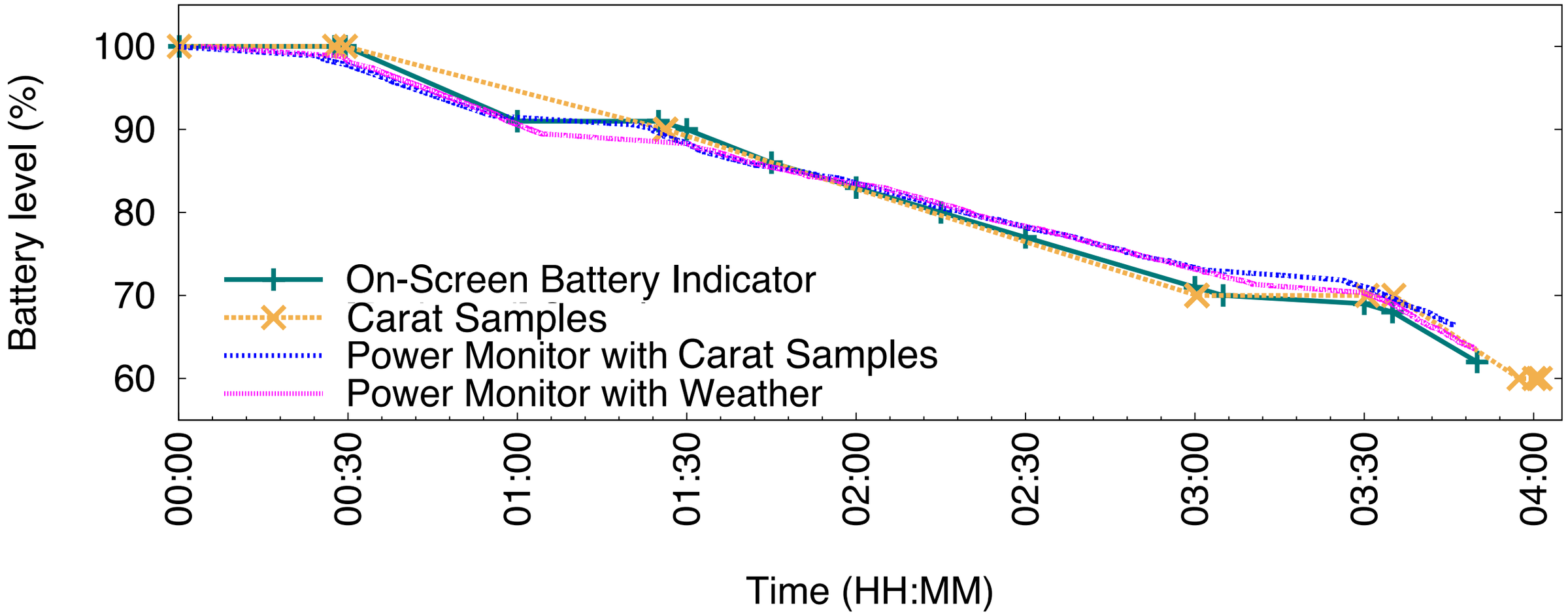
Measuring Power Consumption from Battery



Customer Service

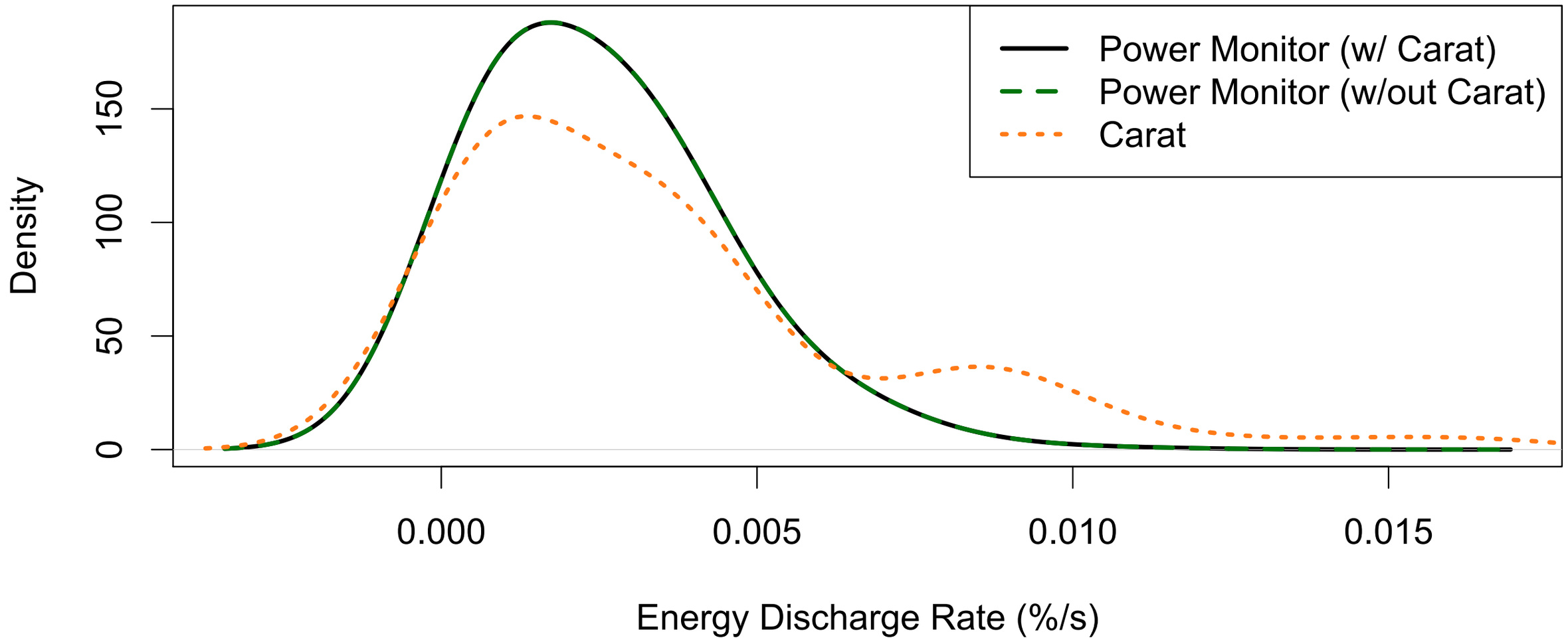
Ground Truth

- Battery indicator agrees with the monitor



Ground Truth

- Good accuracy with low overhead



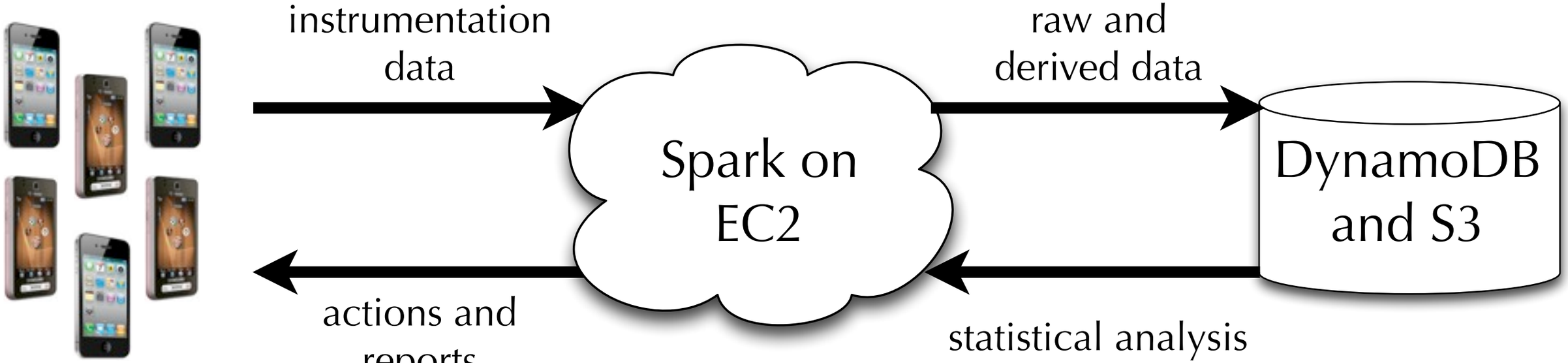
Ground Truth

- Discharge rate estimation
  - Android: 0.00015 %/sec
  - iOS: 0.00088 %/sec
- Overhead
  - 3.5% of the battery less than Weather
  - Less than experimental imprecision



4. Implementation

the crowd | ***the cloud*** | ***big data***



Carat Infrastructure

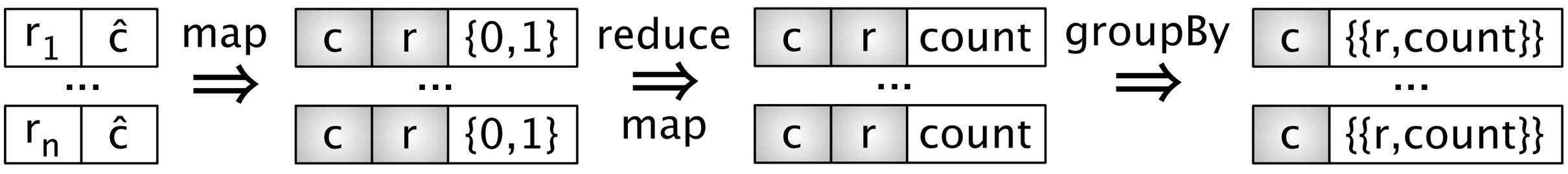
Spark

- Cluster computing framework
- Resilient Distributed Datasets (RDDs)
  - Read-only in-memory data structures
  - Parallel operations (e.g., reduce)
- Iterative or interactive workloads

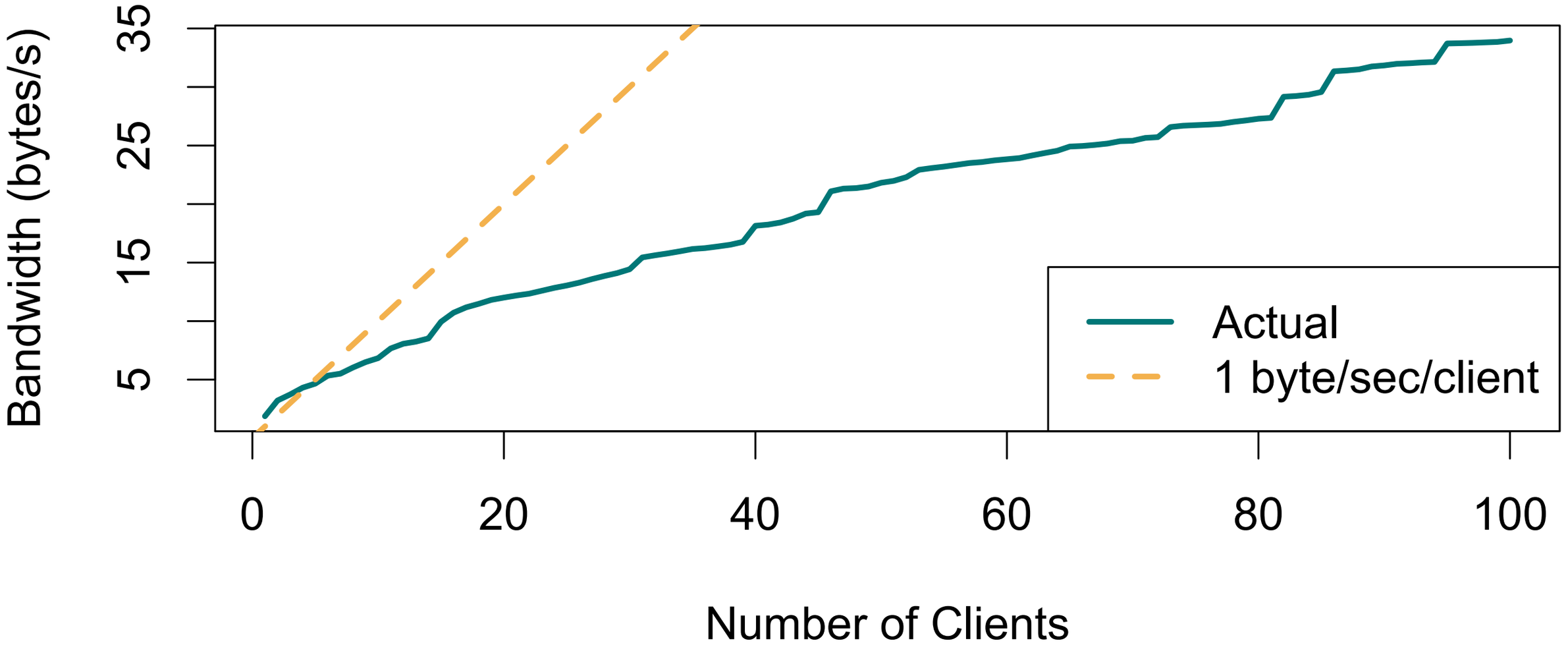


Rates to Distributions

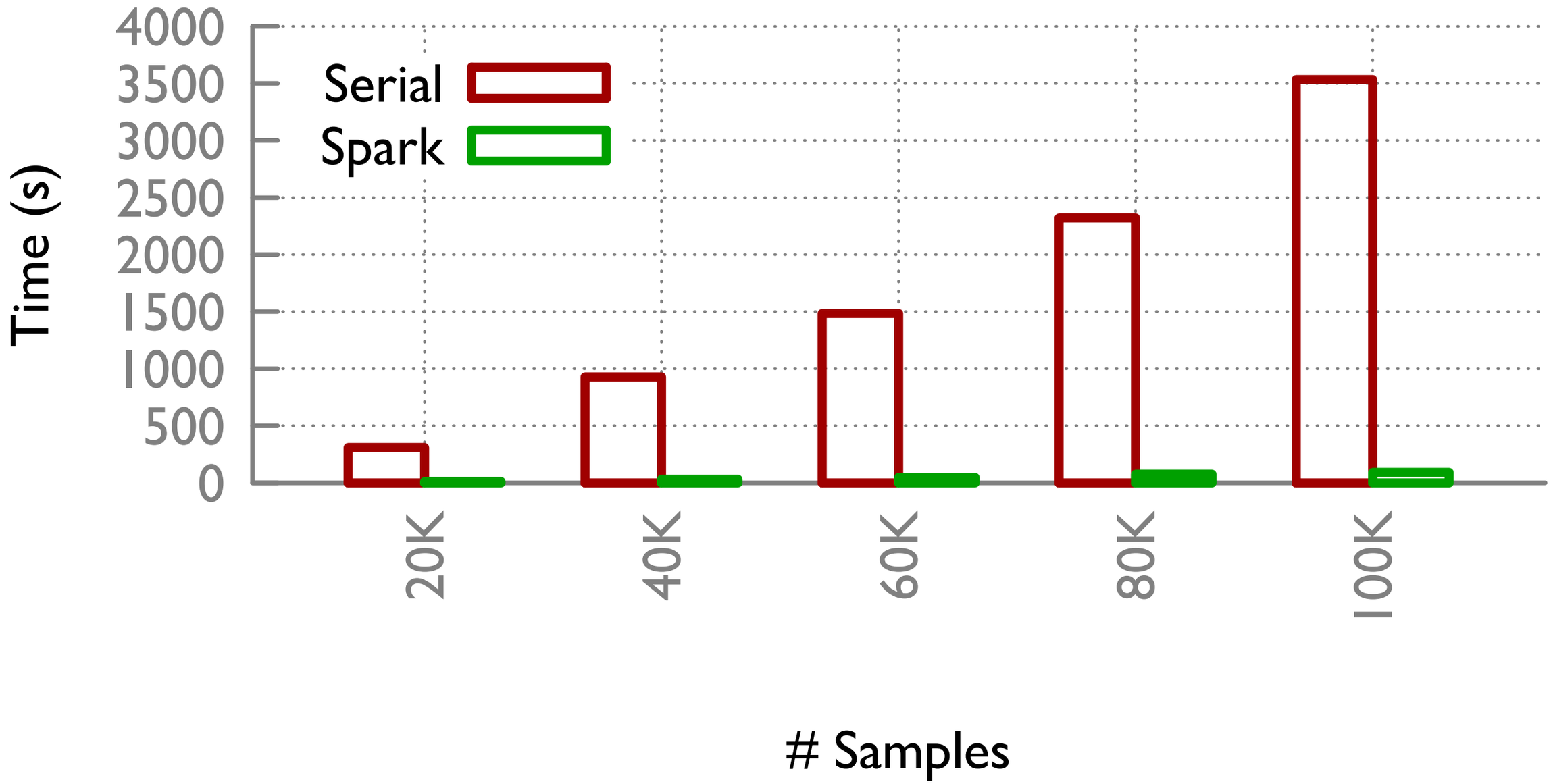
- Rate RDDs from sample pairs
- Compute conditional distributions
- Leverage Spark parallelism



Server Traffic



Parallelization



5. Deployment

Initial Deployment

- TestFlight over-the-air beta
- 100 sign-ups (Apple's max)
- 75 installs
- Collected 10,000+ samples



Initial Results

- Found 35 apps exhibiting energy bugs
  - e.g., Facebook, Kindle, Flipboard
    - Corroborated with forum posts, news articles, and data correlations
- Injected three bugs in Wikipedia
  - Detected all of them



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...





171

t By 'o Kill

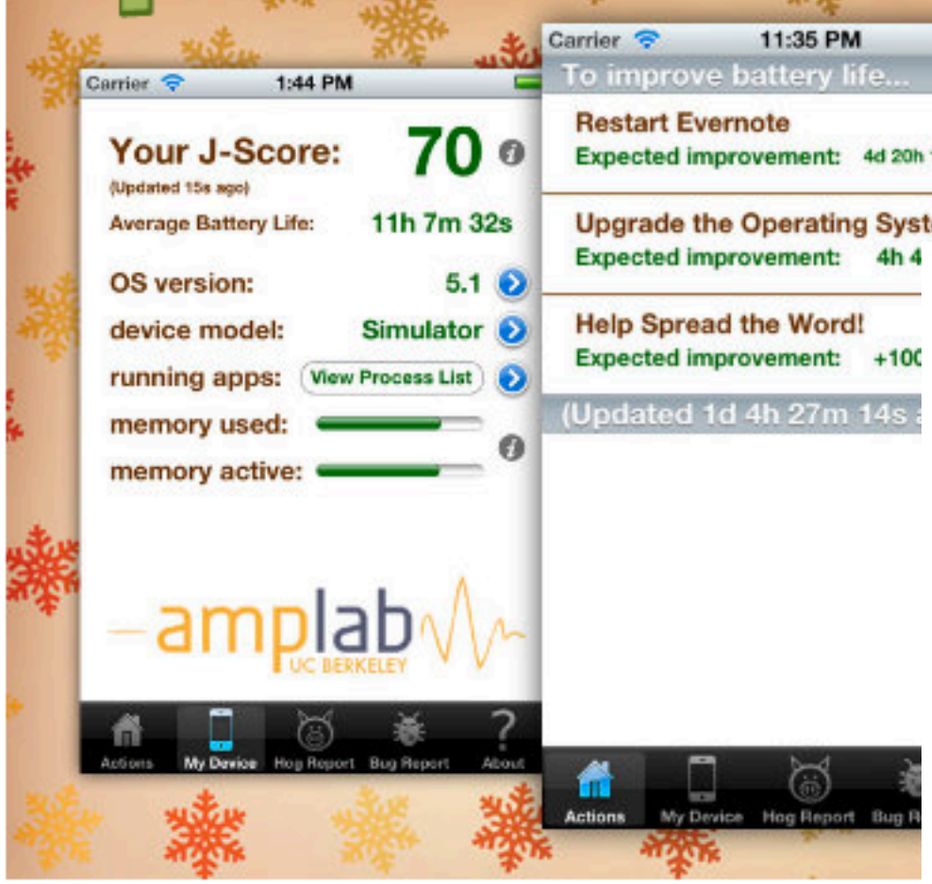
36 Comments

Life Improvement: 1 hour
ırn from **Carat**, an
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171

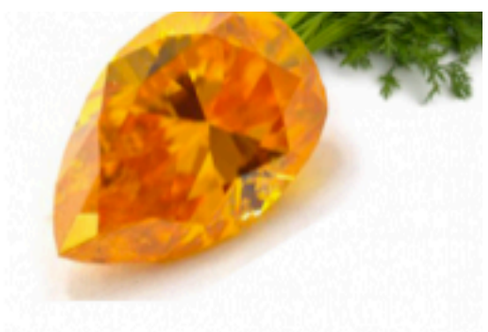
t
By
'o Kill

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

ANDROID | JUNE 14, 2012 | BY: MICHAEL SANTO

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2 Tweet
0 +1
1
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Get Tech Gear alerts!
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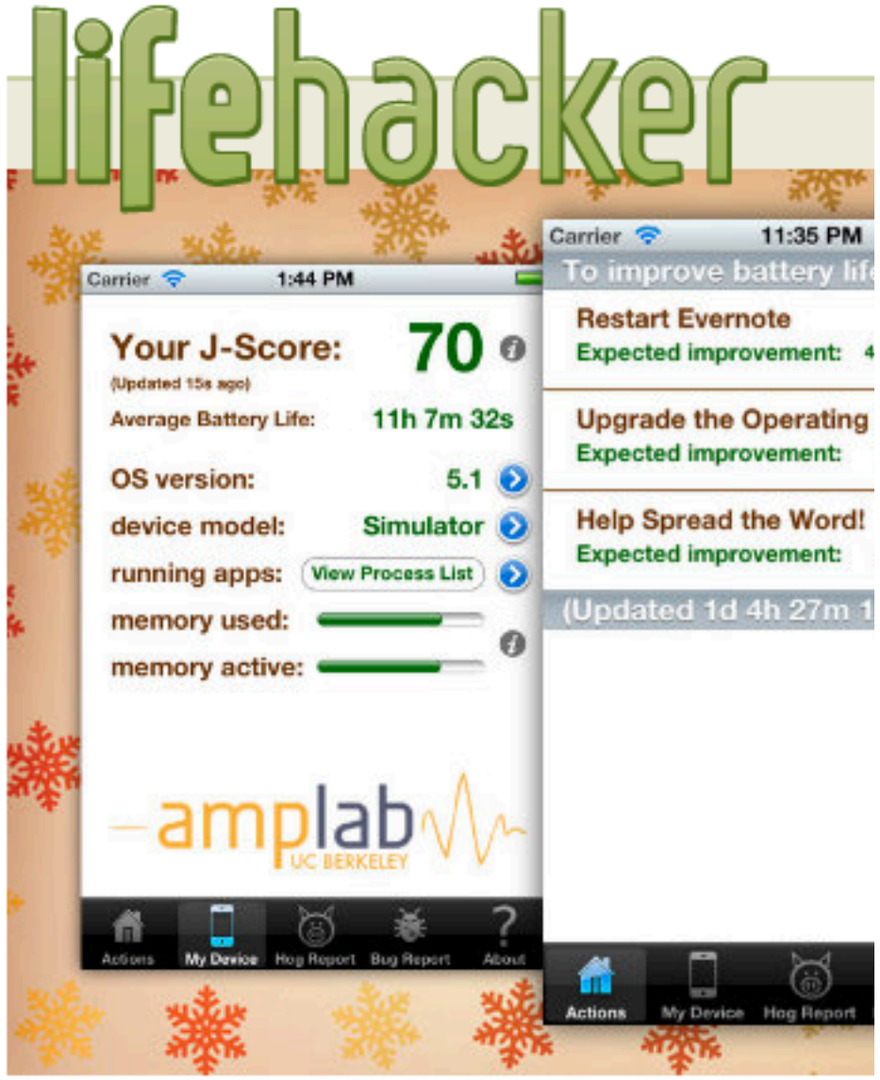


Su



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)

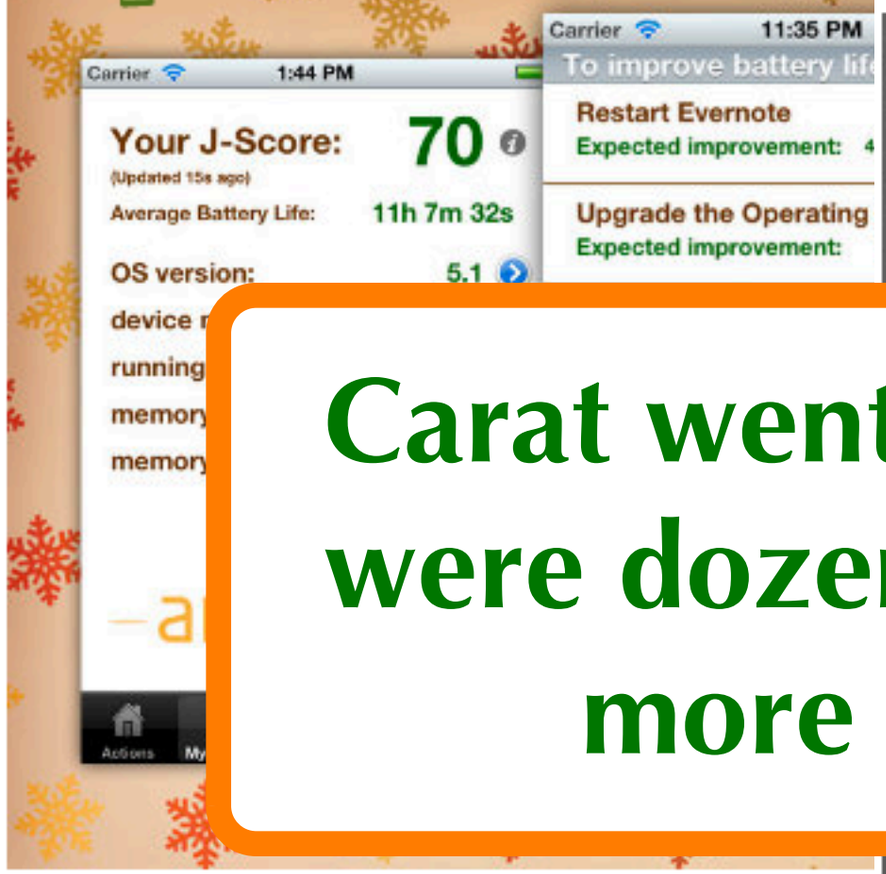
Follow @the_pc_doc

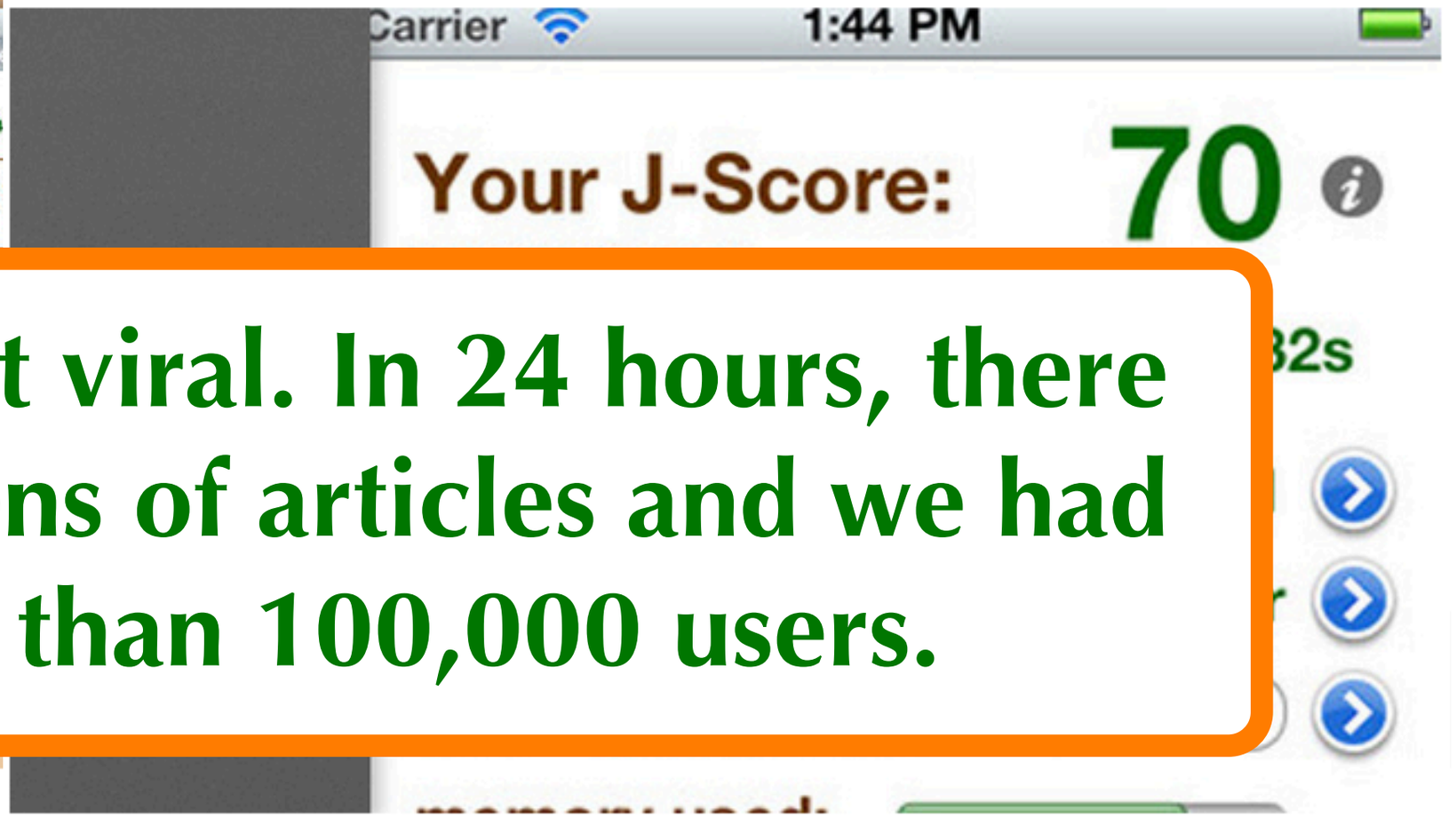


lifehacker

Carat: Extend Your Phone's Battery Life

LESLIE HORN JUNE 19, 2012 2:00 PM





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

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



Carat Today

- 450,000+ devices
  - 60% iOS
  - 40% Android
- Tens of millions of samples



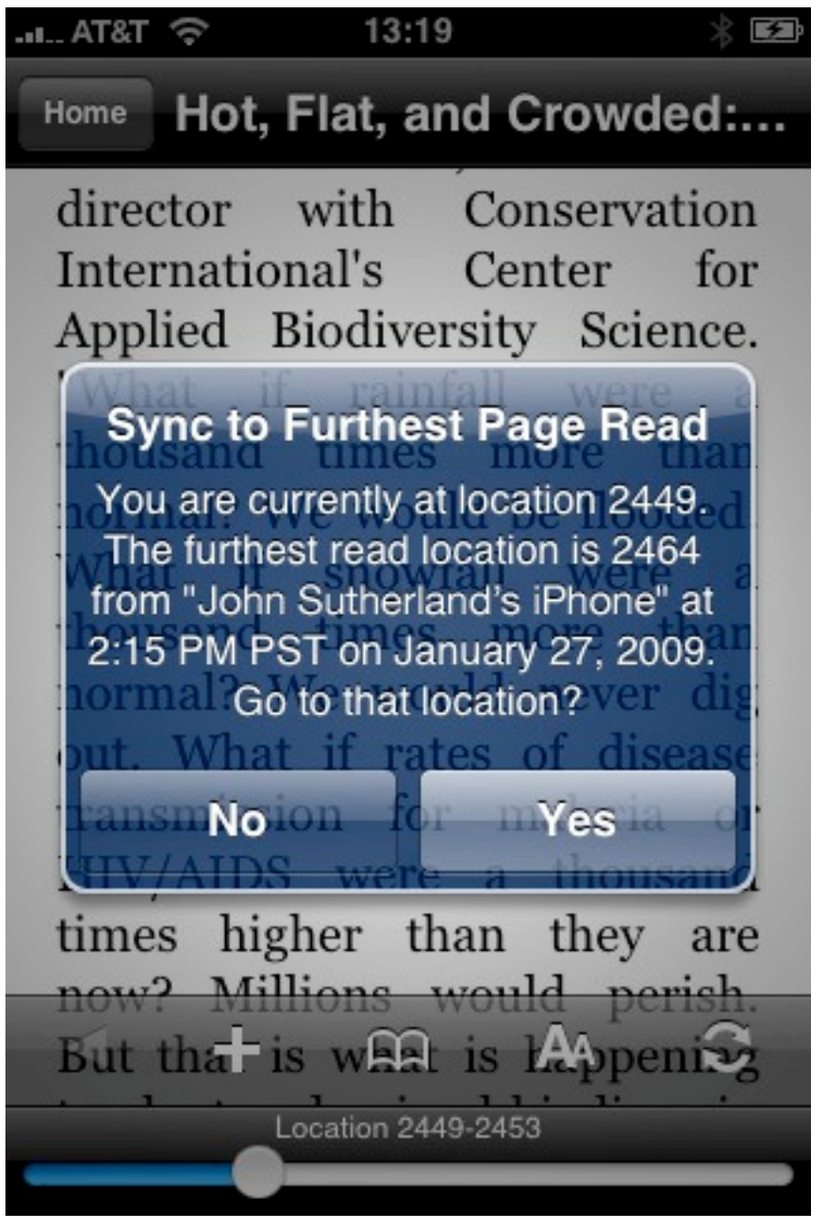
Energy Anomalies

- Hogs
  - 11,256 hogs (9.4%)
    - e.g., Pandora and Skype
- Bugs
  - 483,354 buggy instances (5.3%)
  - e.g., Kindle, Facebook, and YouTube

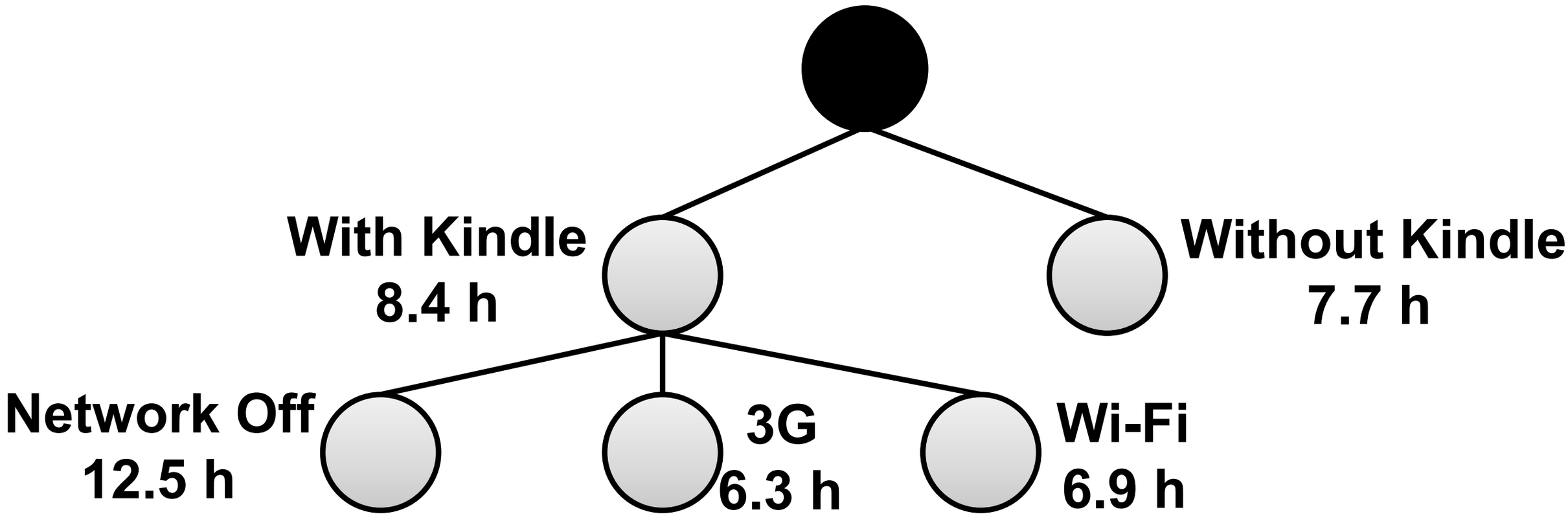


Kindle Bug (iOS)

- E-book reader
- Bug on 3.9% of clients
  - Forum: WhisperSync
  - Confirmed by our data
  - Turn on WiFi
    → 36m improvement



Kindle Diagnosis



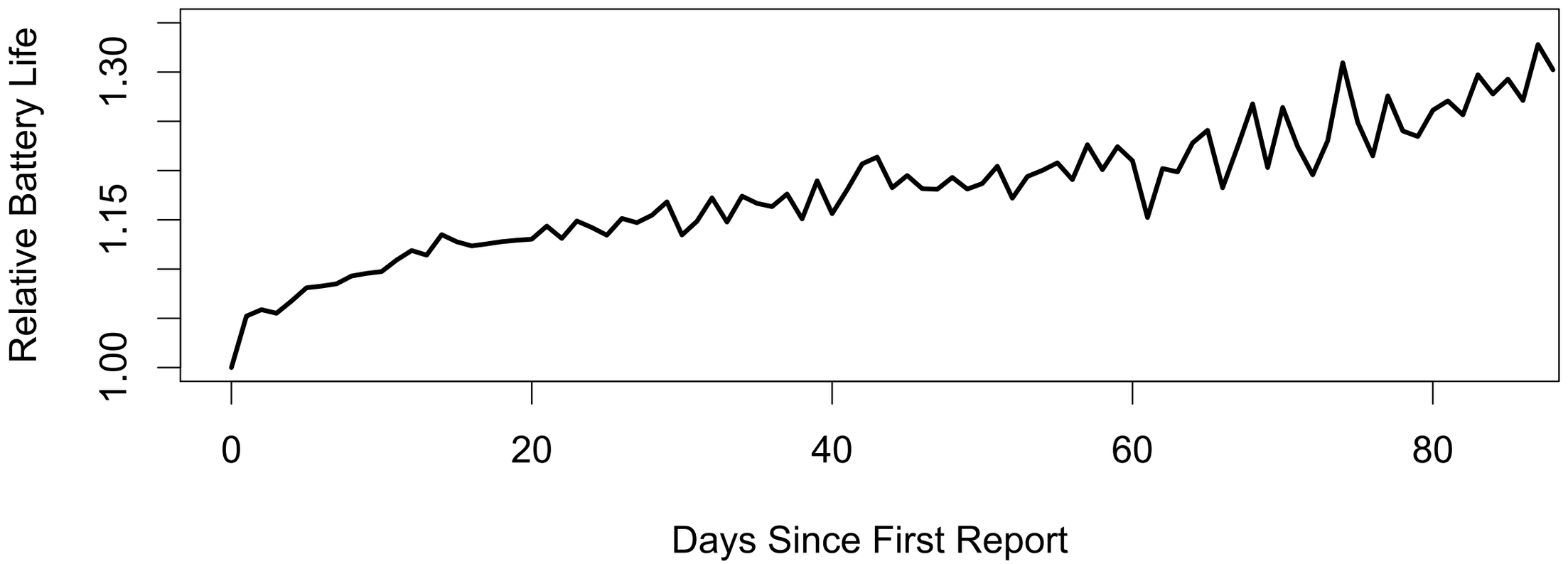
Twitter Bug (Android)

- Microblogging app
- Bug on 14.9% of clients
- MCAD implicates OS
- WiFi also helps
- Upgrade to ICS 4.0.4
  → 94m improvement



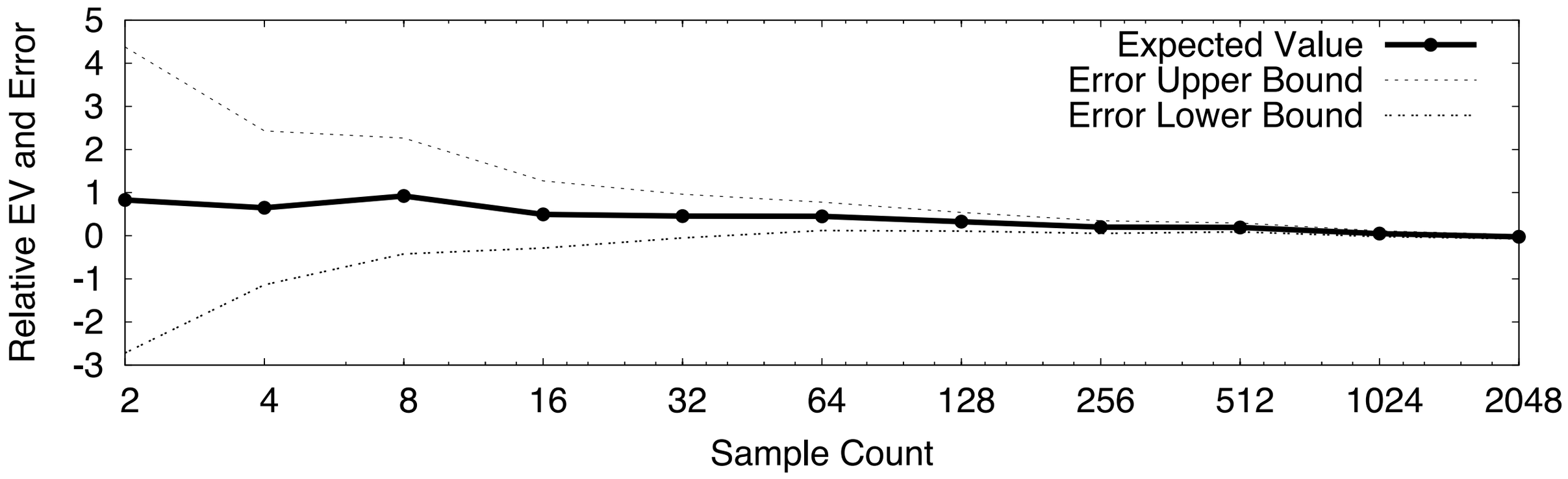
Battery Life

- +10% after 10 days
- +30% after 90+ days



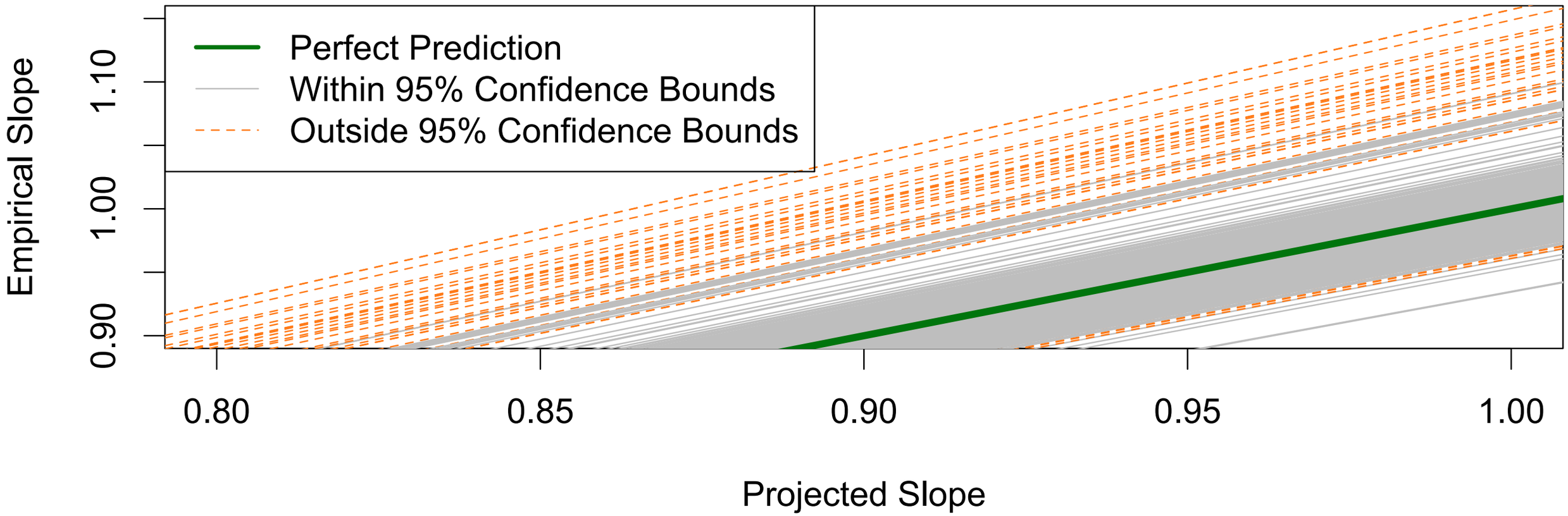
Error Convergence

- Error bounds converge in practice



Prediction Accuracy

- 95.4% within confidence bounds

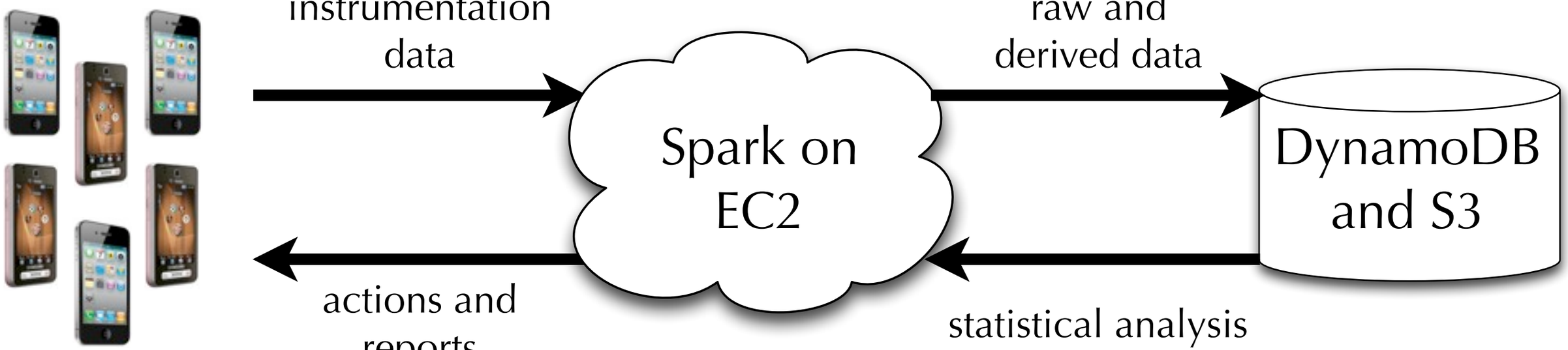


Positive Feedback

- “Carat has given me control of my phone in a way I never had before. Thank you! :-D”
- “In closing, I just want to say thank you & keep up the great work w/carat. It has to be one favorite apps on my Droid.”
- “I’ve been measuring my battery with and without its recommendations for the past month, and I’m getting about 32-48 extra minutes of battery life from my phone”
- “just wanted to tell you that I love your app - in fact, it’s the only one that I keep running all the time on my iPhone 5.”
- “I absolutely love the app. Very, very useful.”
- “I love this app. Very very very useful.”



the crowd | ***the cloud*** | ***big data***



Our Approach

the crowd | ***the cloud*** | ***big data***



The Google Model

the crowd | ***the cloud*** | ***big data***



The Google Model

the crowd | ***the cloud*** | ***big data***

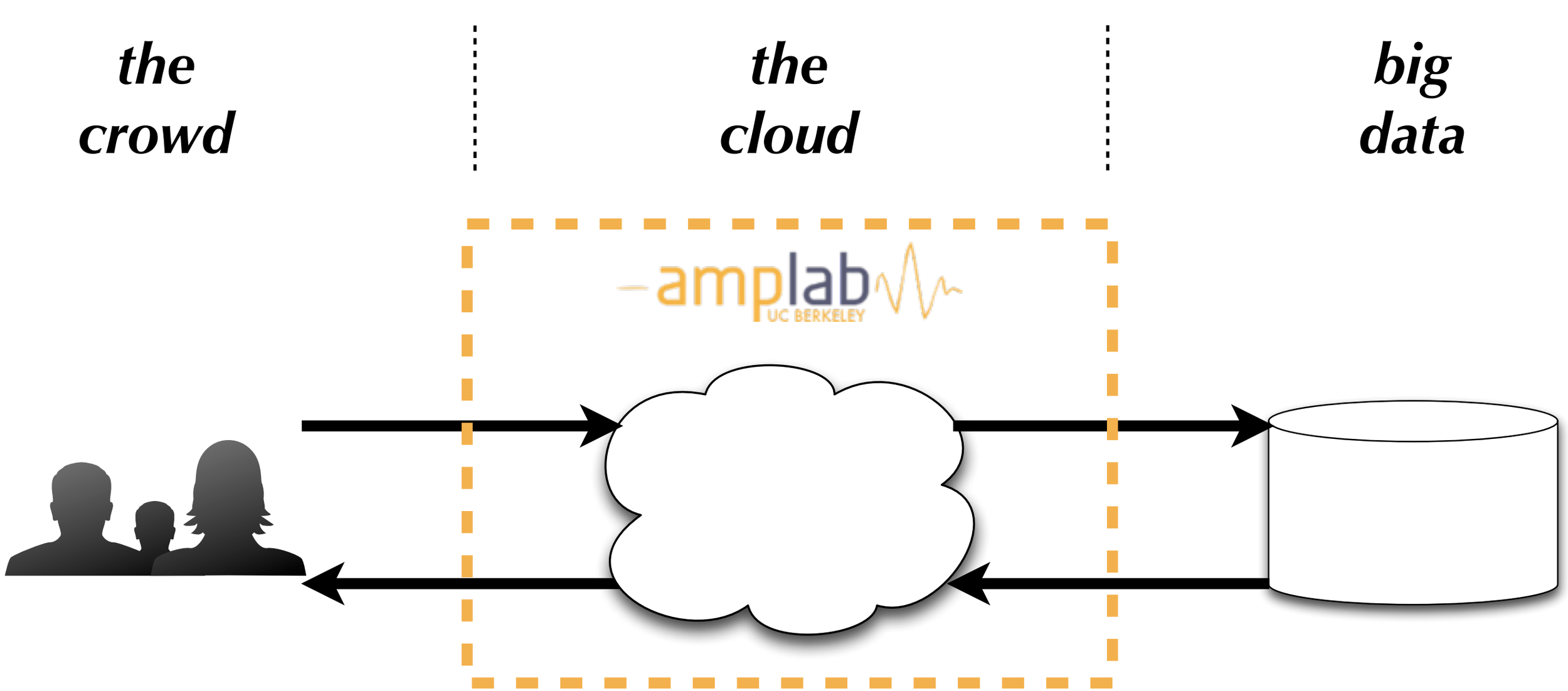


The Facebook Model

the crowd | ***the cloud*** | ***big data***

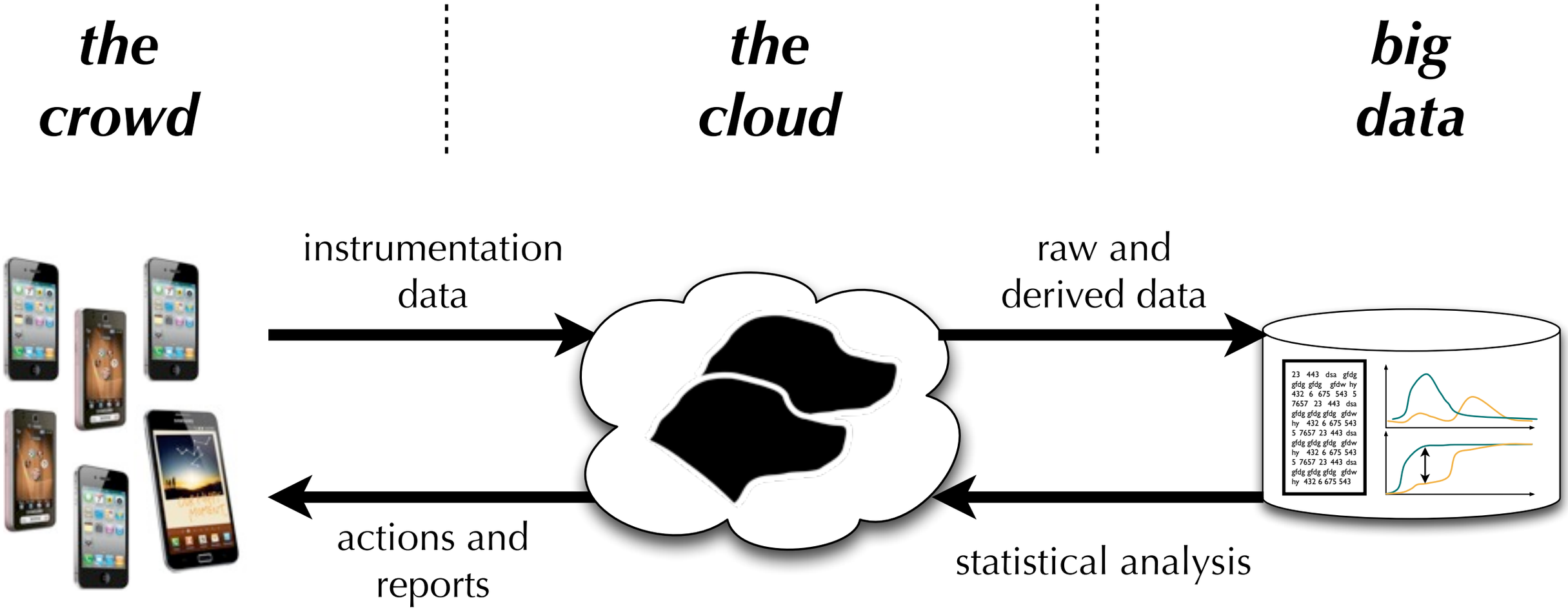


The Facebook Model

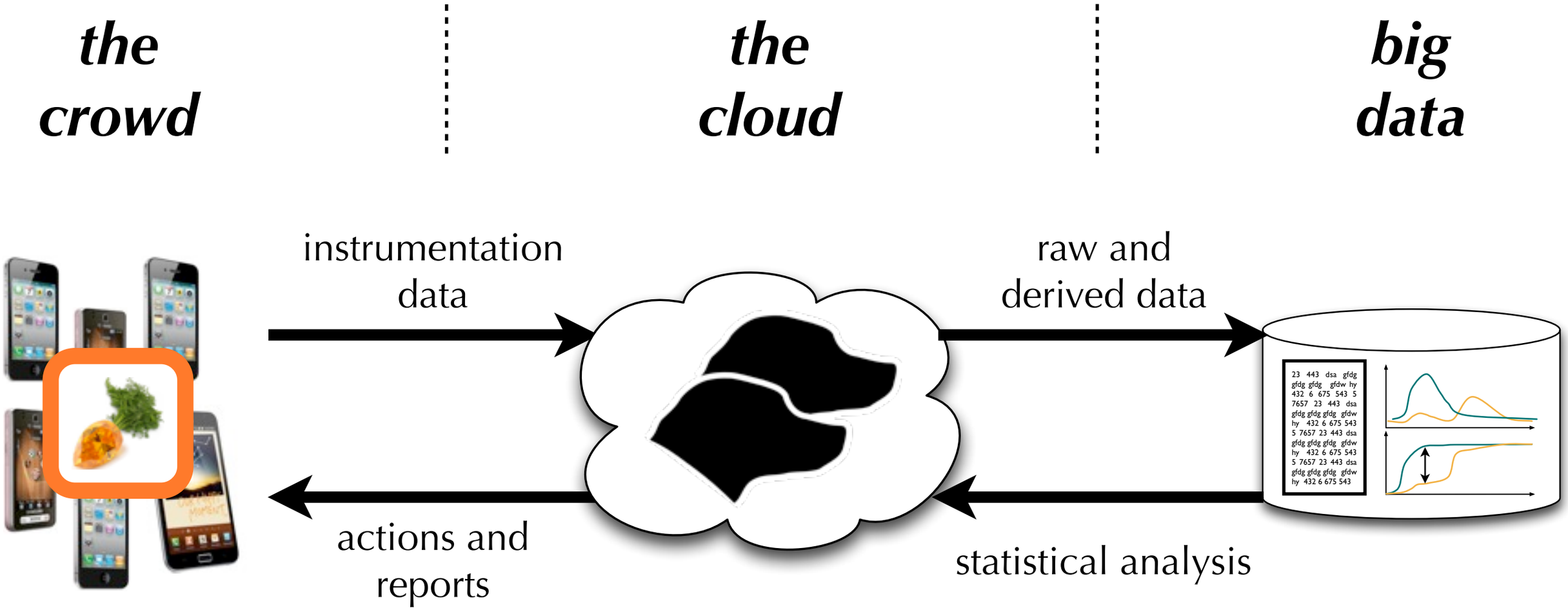


To define and build the layer between the crowd and big data. This layer extracts data and computation *from* the crowd, and extracts value from big data *for* the crowd.

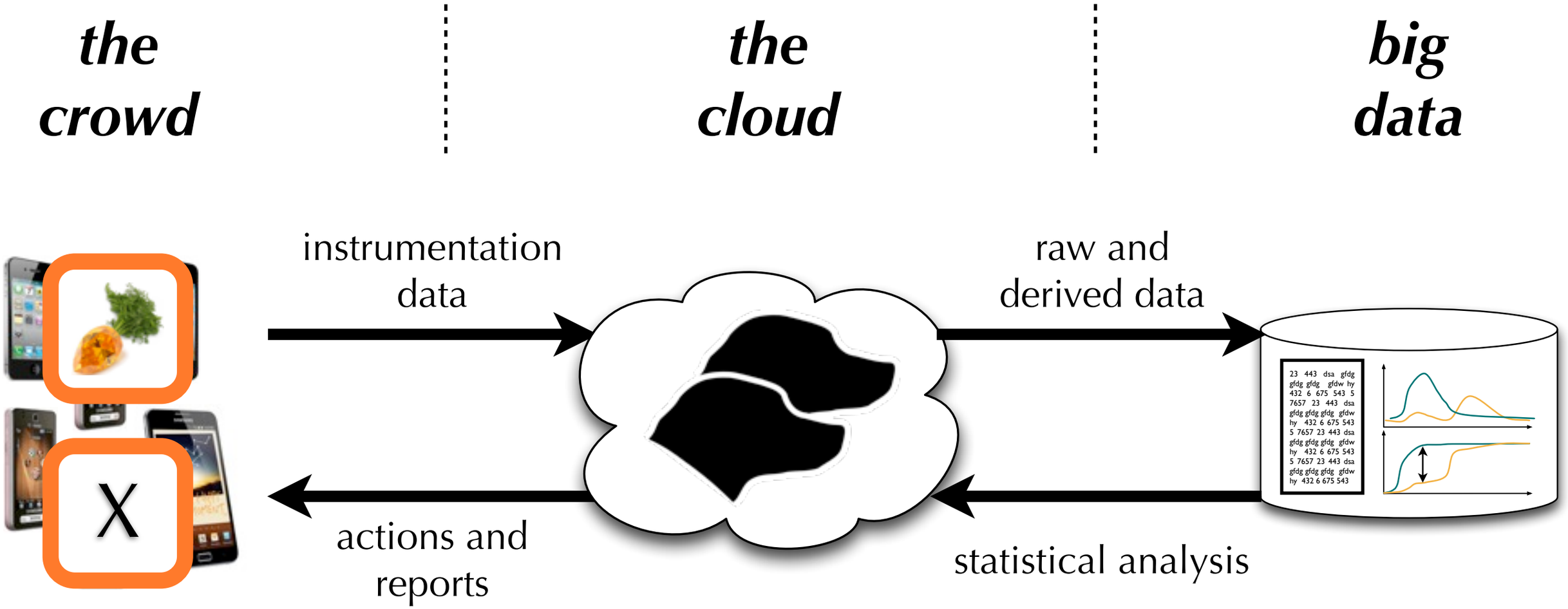
AMP Lab Vision


the crowd
the cloud
big data
instrumentation data
raw and derived data
actions and reports
statistical analysis
23 443 dsa gfdg gfdg gfdg gfdw hy 432 6 675 543 5 7657 23 443 dsa gfdg gfdg gfdg gfdw hy 432 6 675 543 5 7657 23 443 dsa gfdg gfdg gfdg gfdw hy 432 6 675 543 5 7657 23 443 dsa gfdg gfdg gfdg gfdw hy 432 6 675 543

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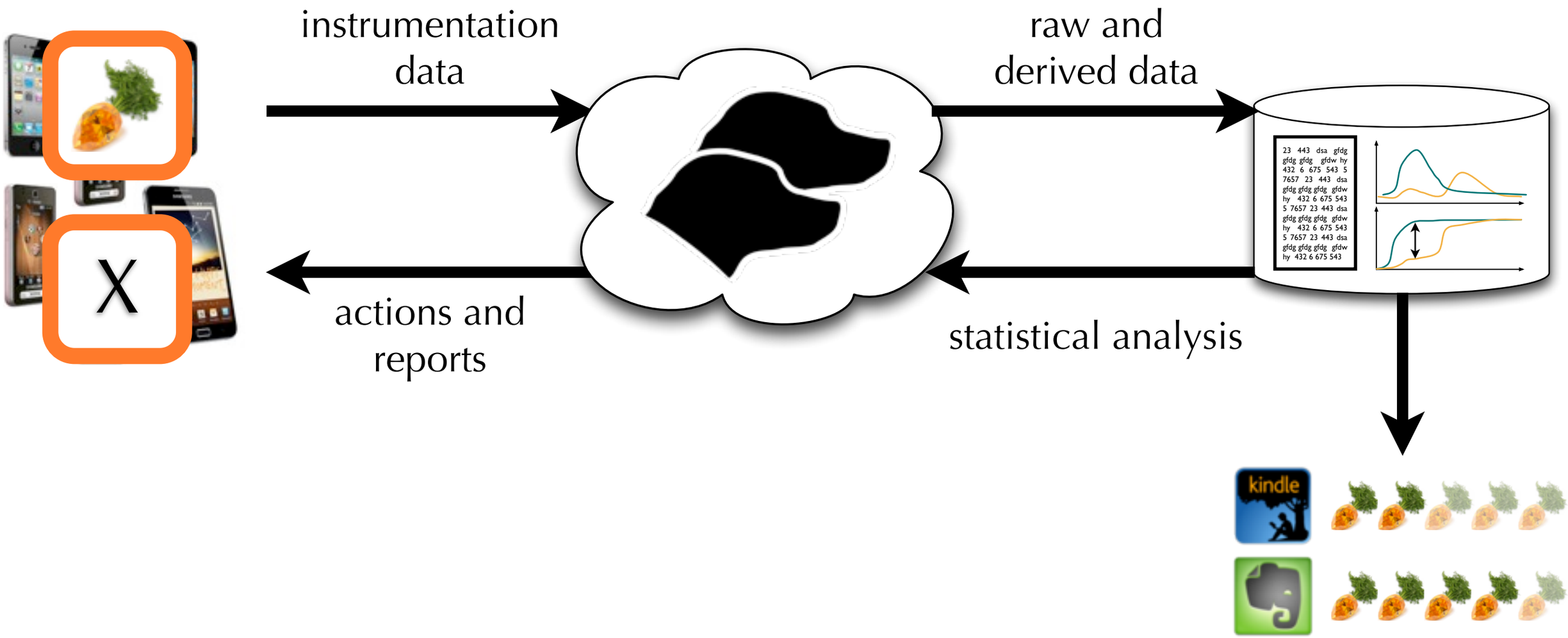

the crowd
the cloud
big data
instrumentation data
raw and derived data
actions and reports
statistical analysis

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the crowd
the cloud
big data
instrumentation data
raw and derived data
actions and reports
statistical analysis
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the crowd | ***the cloud*** | ***big data***



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the crowd | ***the cloud*** | ***big data***



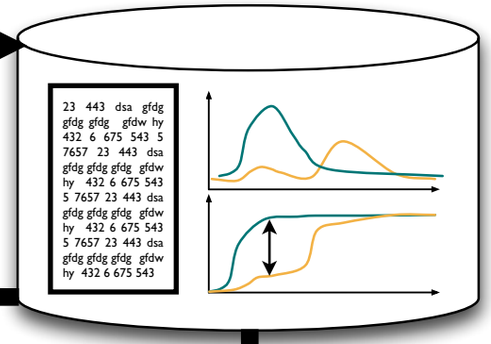


instrumentation data

actions and reports

raw and derived data

statistical analysis





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the crowd | ***the cloud*** | ***big data***

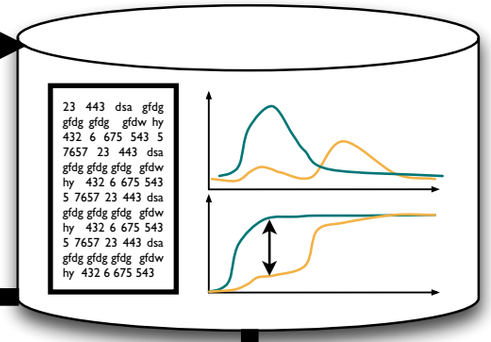


instrumentation data

actions and reports

raw and derived data

statistical analysis









Kuro Labs

the crowd | ***the cloud*** | ***big data***



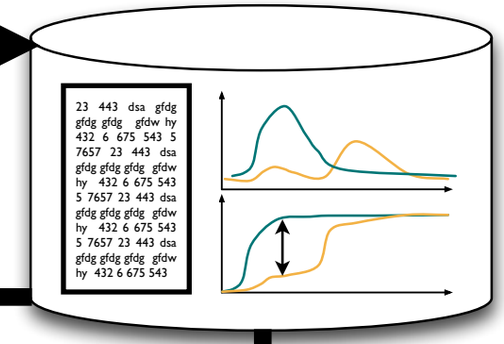


instrumentation data

actions and reports

raw and derived data

statistical analysis





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the crowd | ***the cloud*** | ***big data***

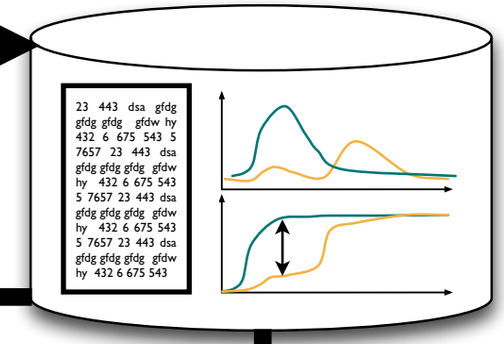


instrumentation data

actions and reports

raw and derived data

statistical analysis



Stats as a Service



Kuro Labs

Next Steps

- API for developers
- New application domains
- Deploy to the crowd; diagnose in the cloud
  - Platform for collaborative diagnosis
  - Statistics as a service

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Fin

You have reached the end of the presentation. Please turn back.

