





# Green Mining and the Perils of Mining Energy Profiles

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<http://softwareprocess.es/>

with

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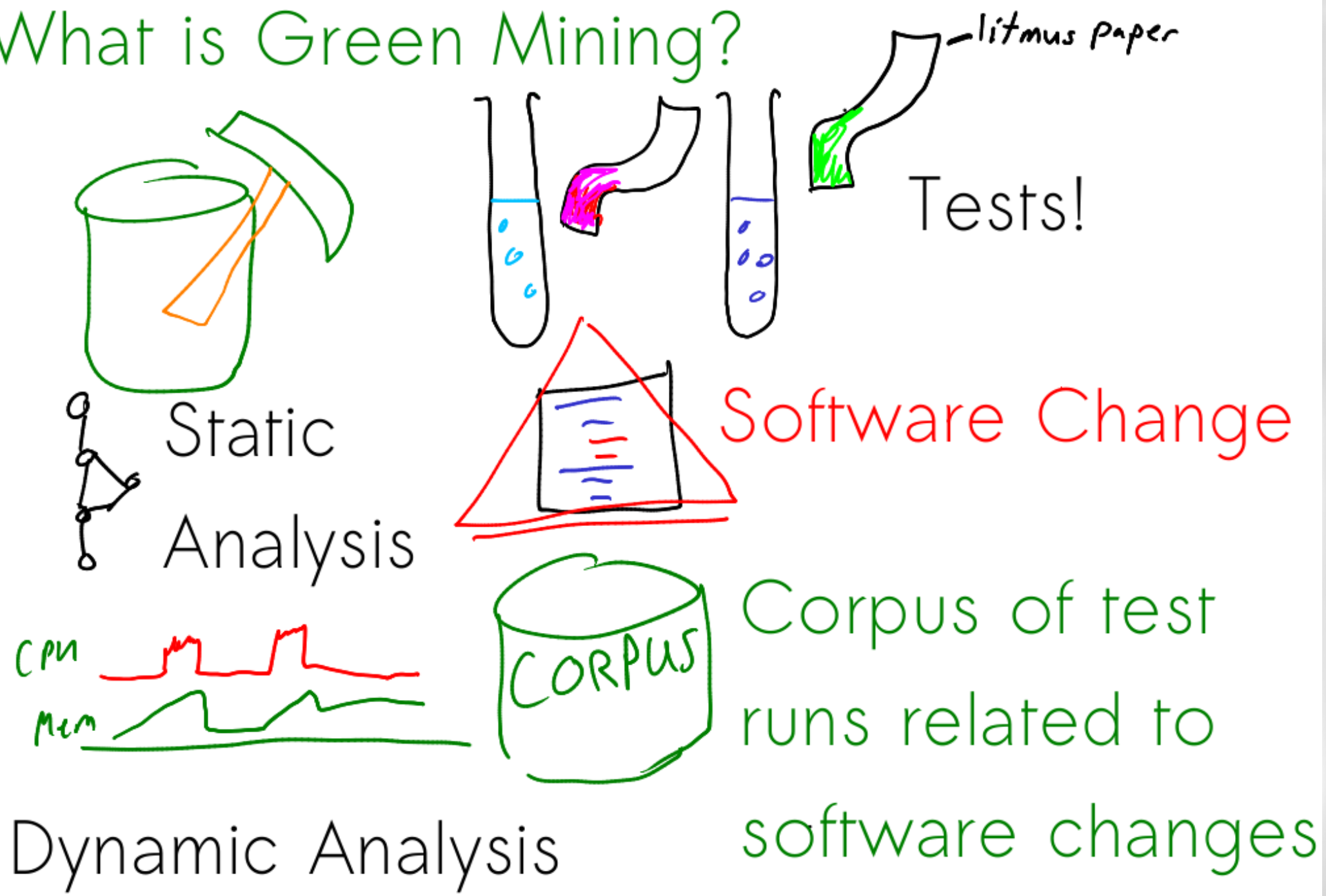
Kent Rasmussen\*, Joshua Campbell\*, Alex

Wilson\*, Jed Barlow\*, Stephen Romansky\*, w/

Eleni Stroulia, Bram Adams, Ahmed Hassan,

Daniel German

# What is Green Mining?

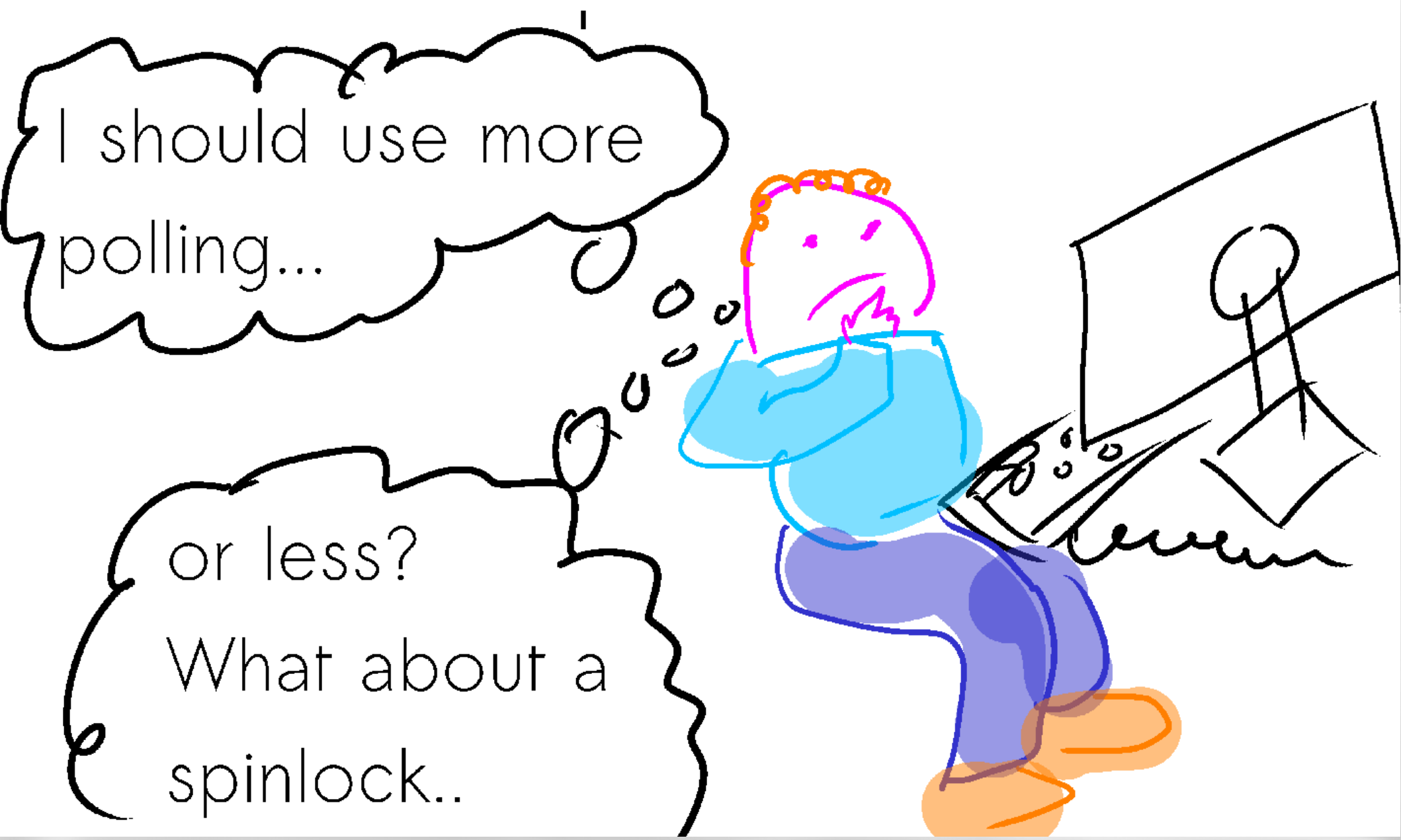


# Green Mining's Goal

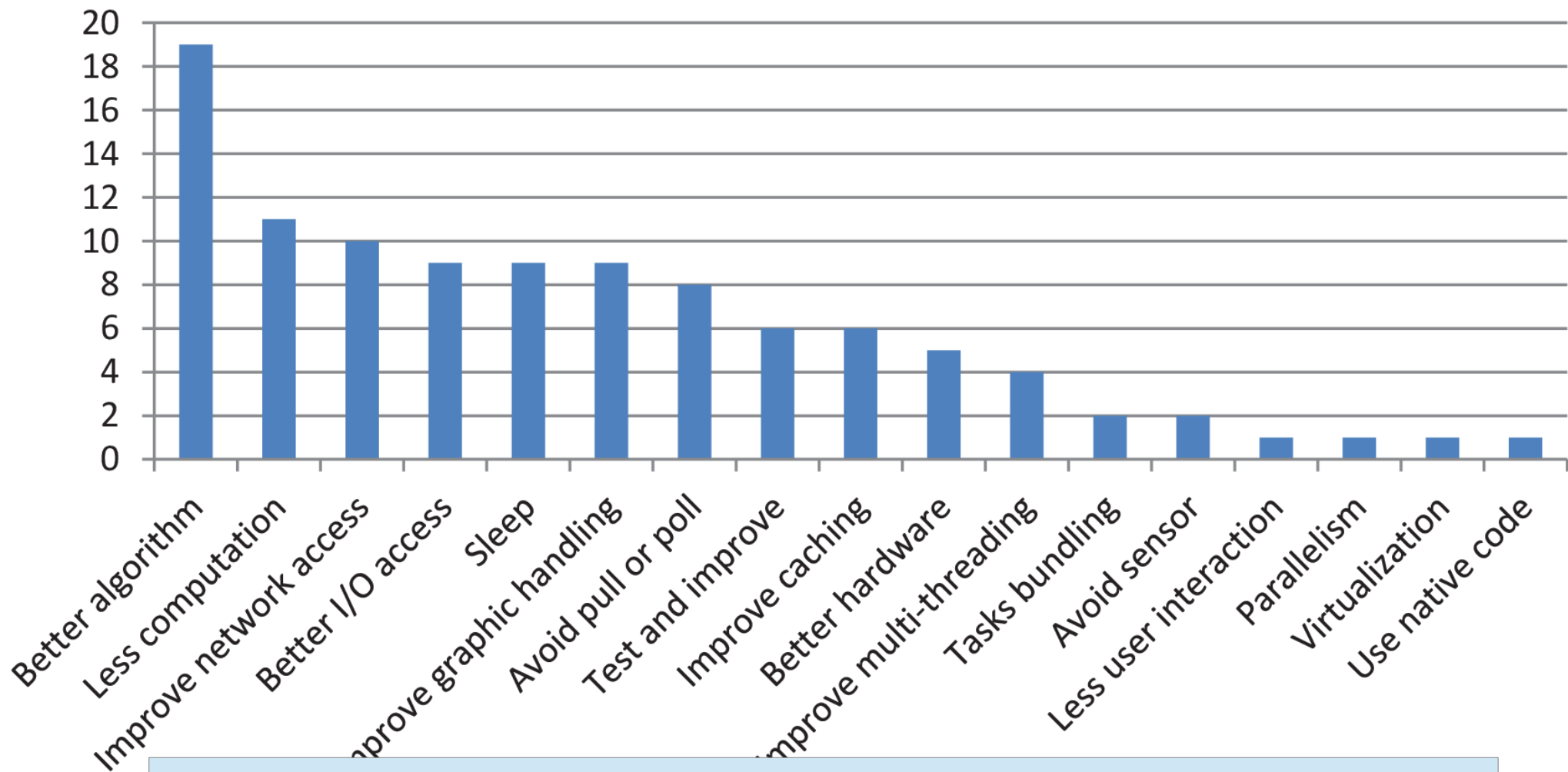


To reason about the  
**energy** consumption  
of source code changes  
based on a corpus of  
power regression tests.

# Programmers are responsible for Software Power Use!



# Energy Efficiency Improvement



*In general, programmers lack knowledge about software energy consumption, but they are more knowledgeable about software energy consumption on mobile devices than on desktop computers.*



Android,  
Flip that buffer!

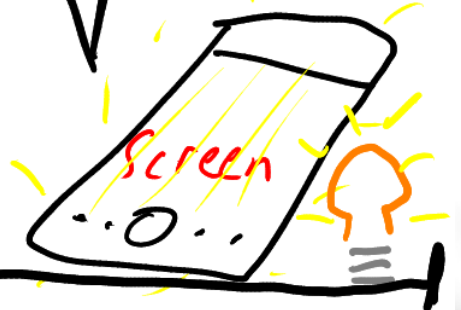


Screen,  
Show this buffer  
instead!

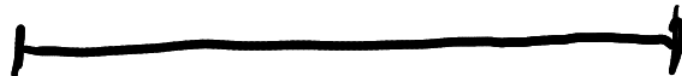


Android

The new buffer is  
brighter, I'll use  
more backlight

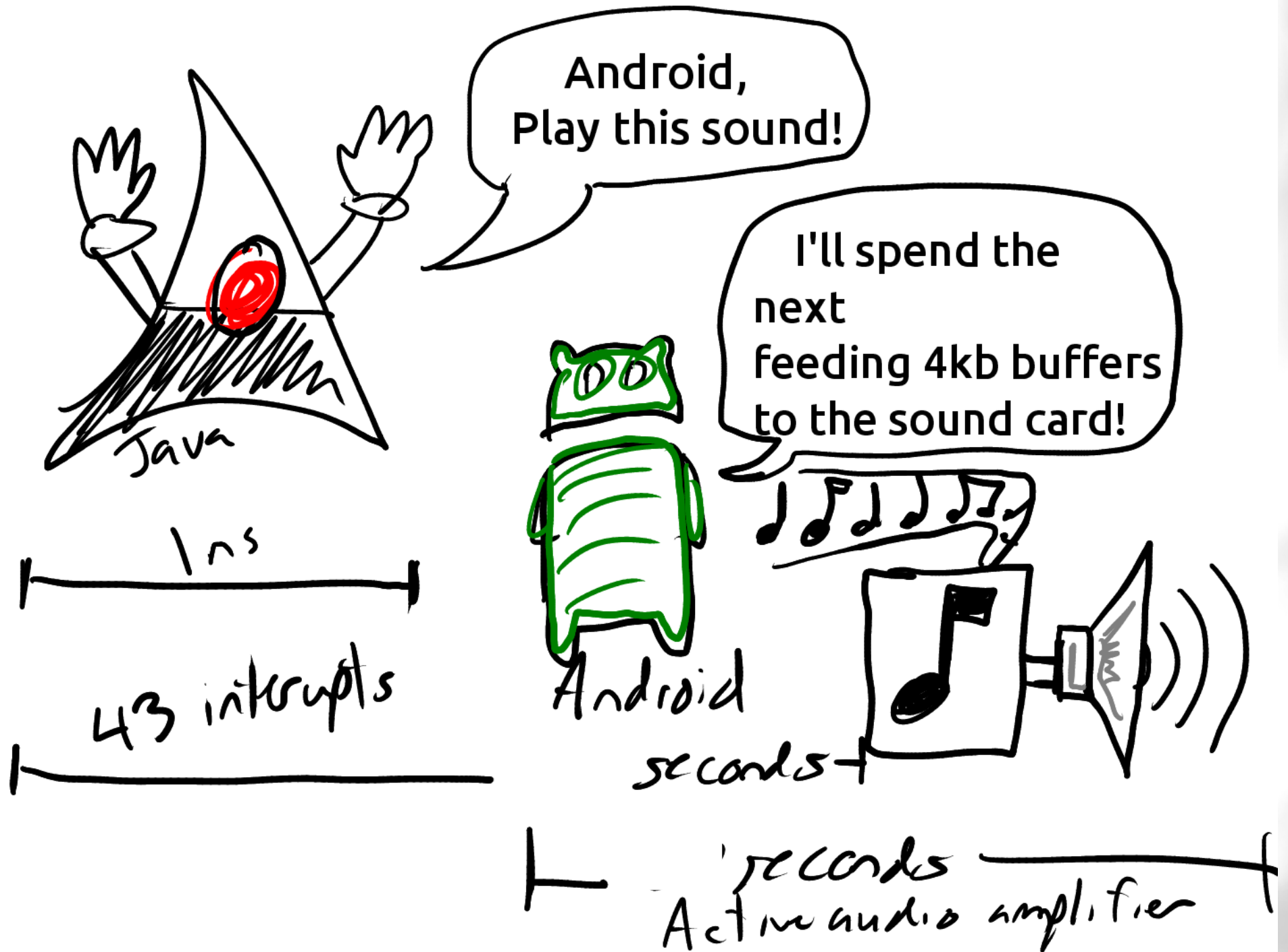


how `MOV [bufferloc], EAX`  
turns into an expensive  
operation

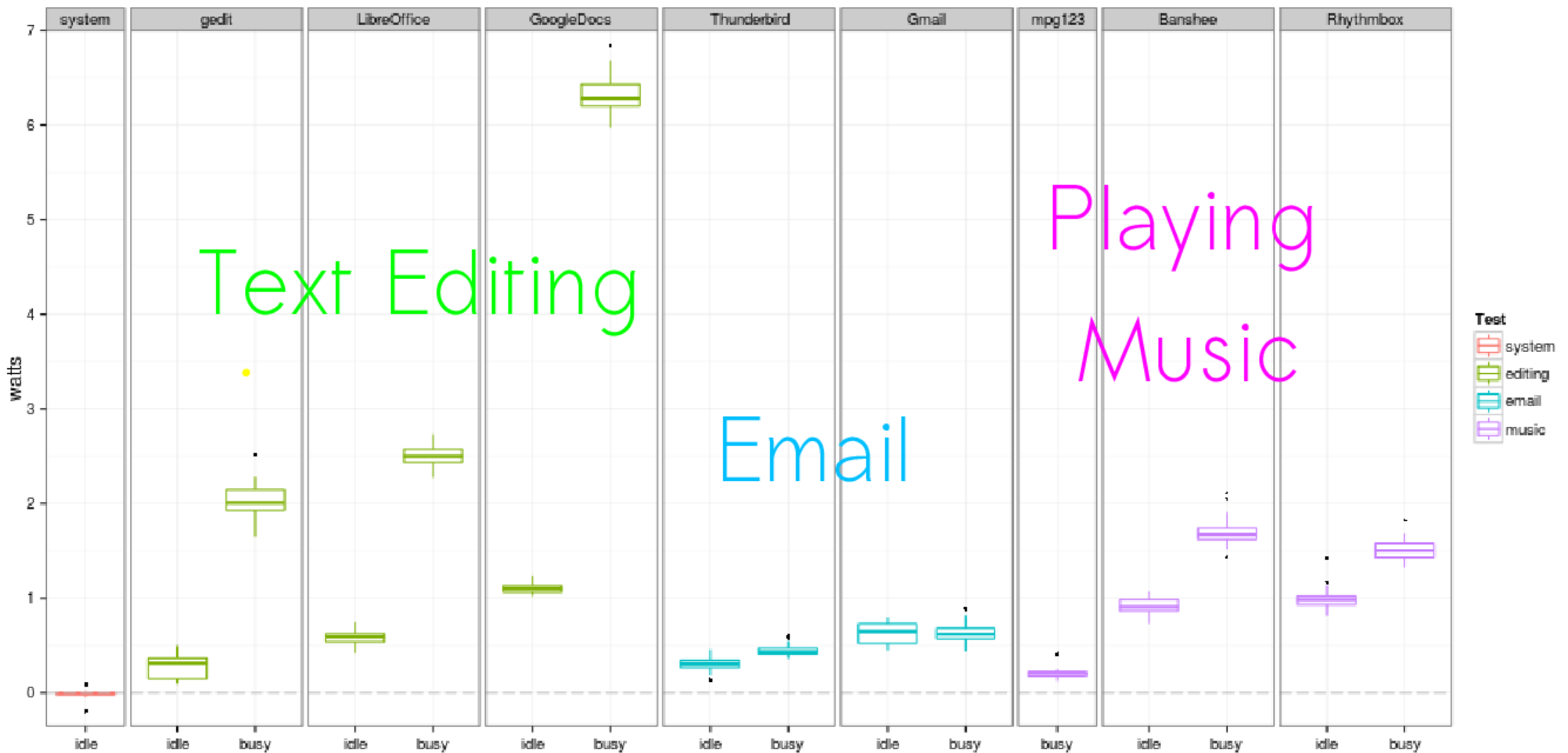






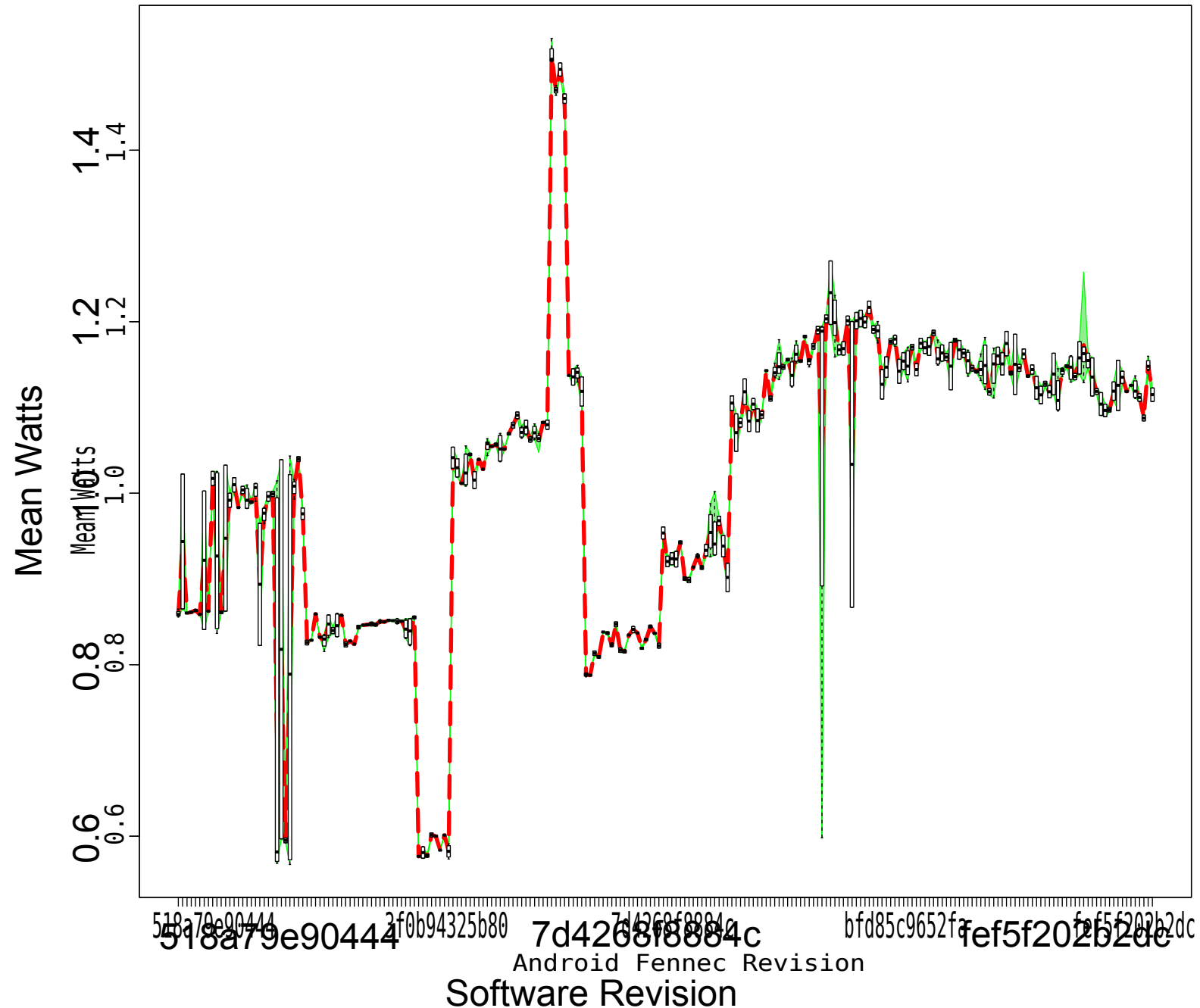


# Energy Profile of Single Versions

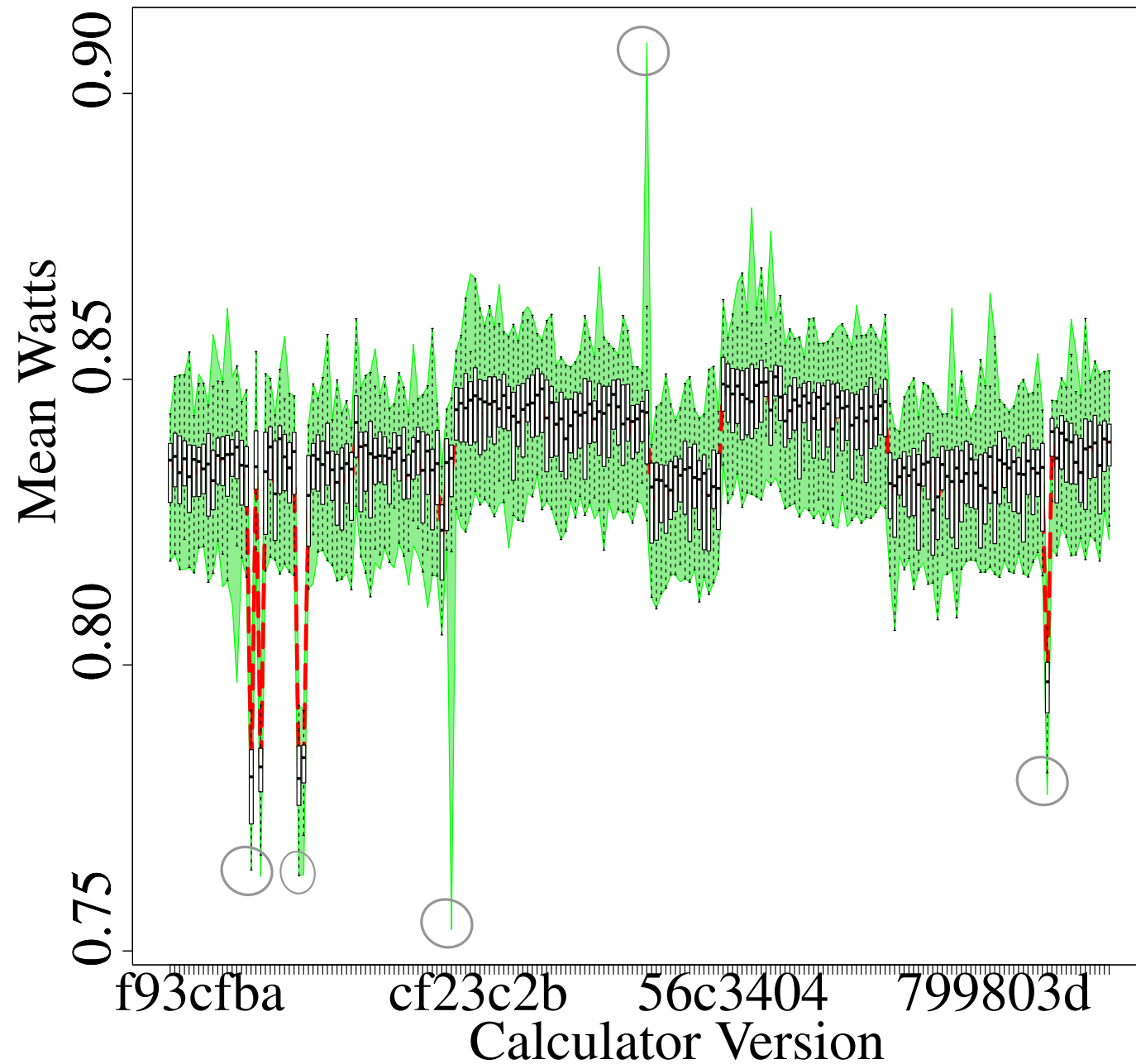


Chenlei Zhang and Daniel German

# Android Firefox Energy Profile

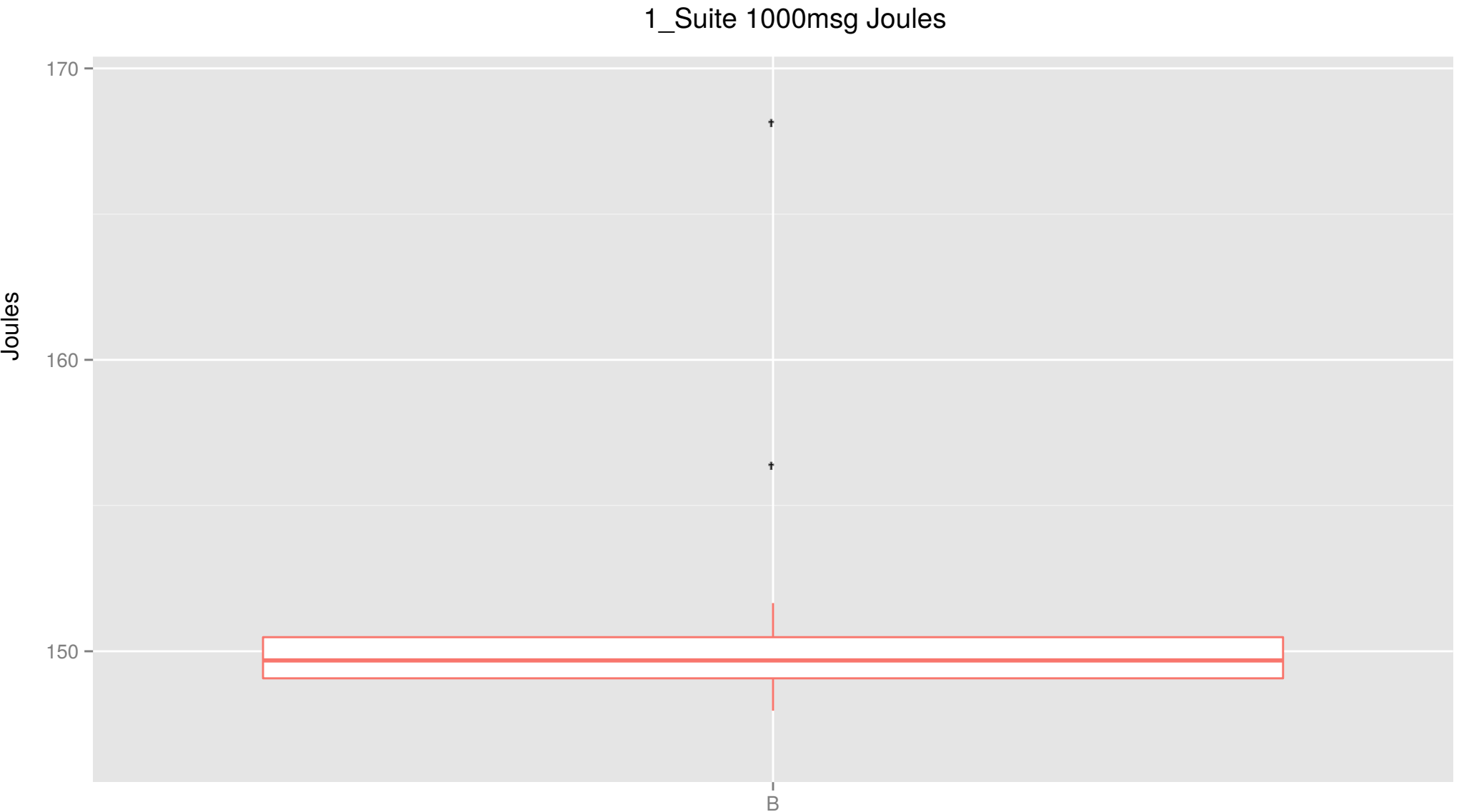


# Android Calculator Energy Profile

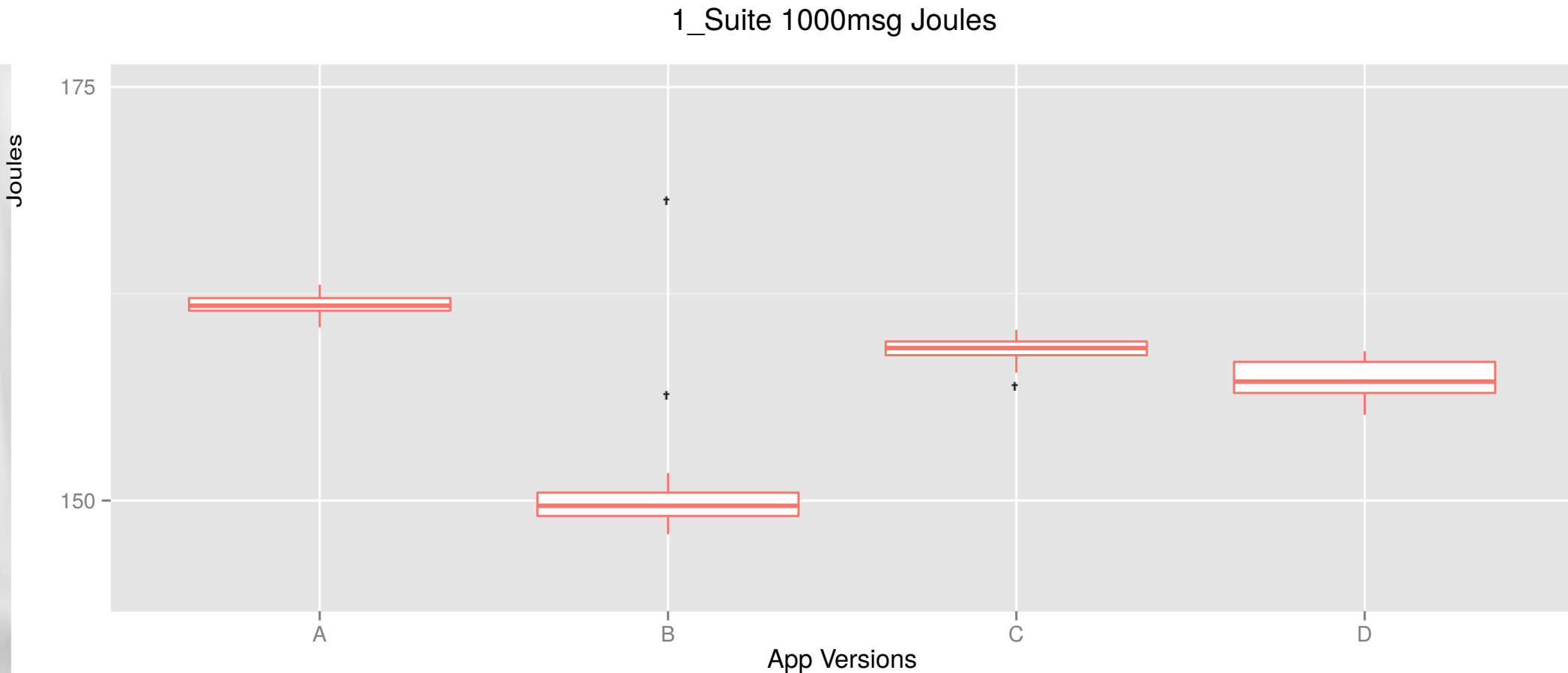




# Energy Profile: Same test, Same Device



# Energy Profile: Different device, different response





A large pile of electronic resistors is shown on a light-colored wooden surface. The resistors are cylindrical with a white body and four colored bands: two red bands, one orange band, and one silver band. They are all oriented in various directions, creating a chaotic scene. The silver band on each resistor represents a manufacturing error tolerance.

Errors

That silver  
band is the  
manufacturing  
error tolerance



A pile of electronic components, including resistors and wires, on a wooden surface. The resistors are cylindrical with colored bands (red, orange, yellow, green, blue, brown). The wires are thin and blue. The background is a light-colored wooden surface with a visible grain.

# Errors

Multiple instances of the  
same model of phone  
will produce different measurements  
due to error tolerances in  
Manufacturing!

This implies a need for normalization  
and repeated tests!







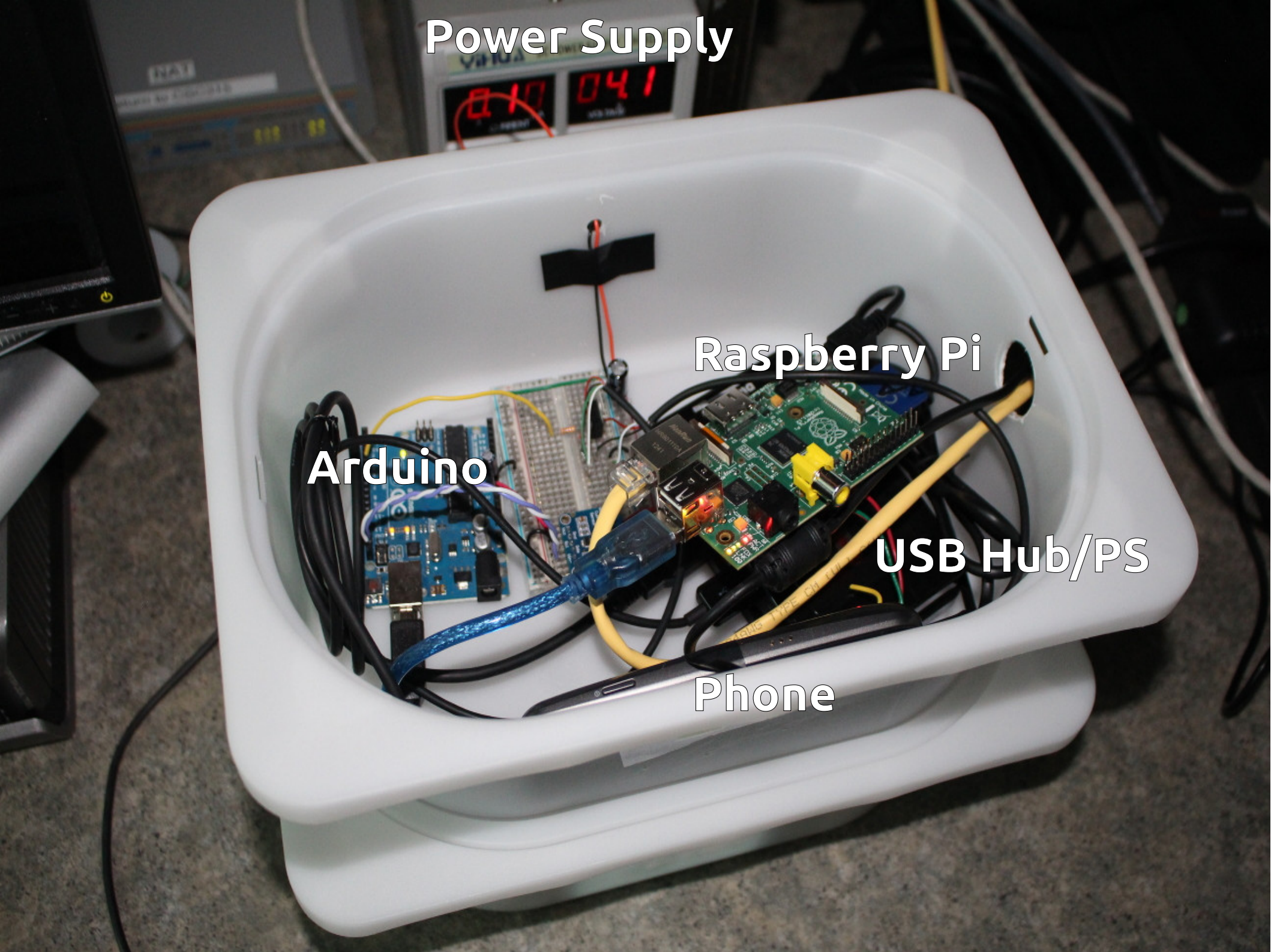
Power Supply

Raspberry Pi

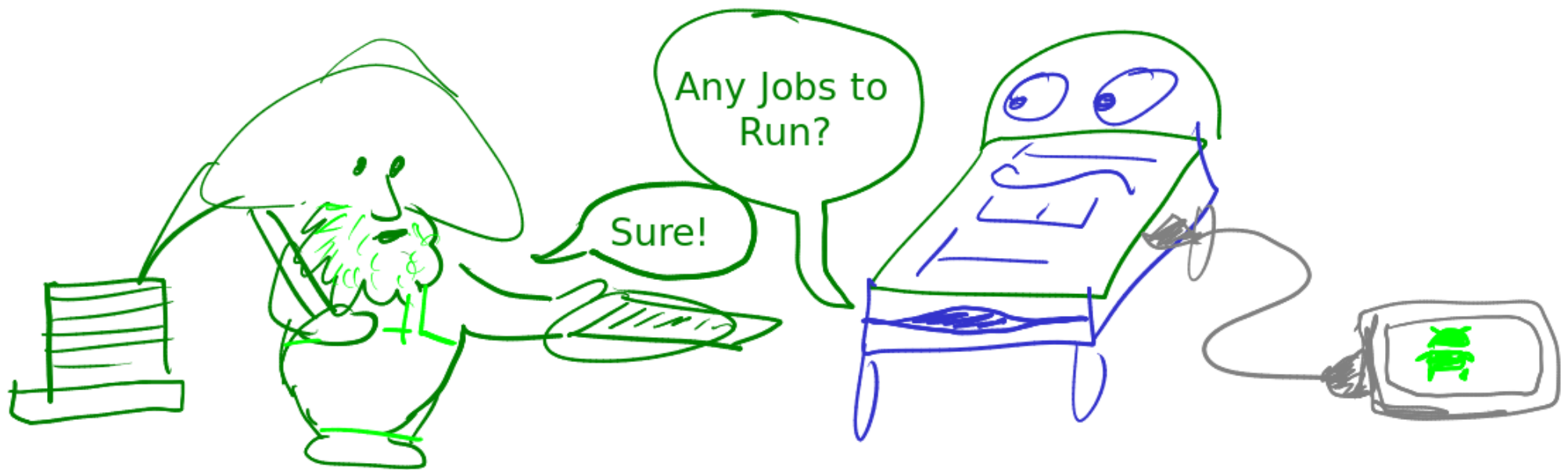
Arduino

USB Hub/PS

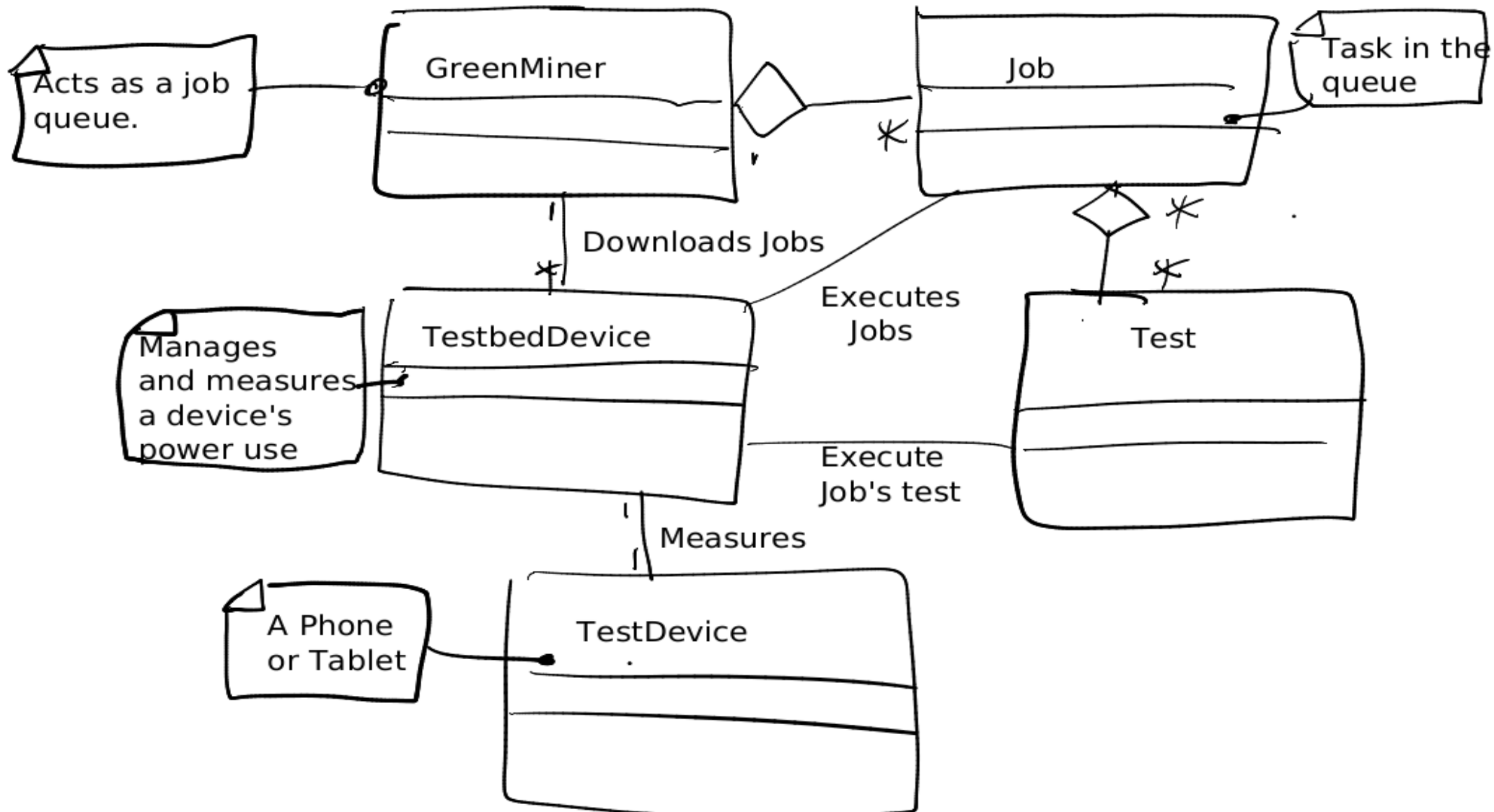
Phone



# Elaborate Job Queue

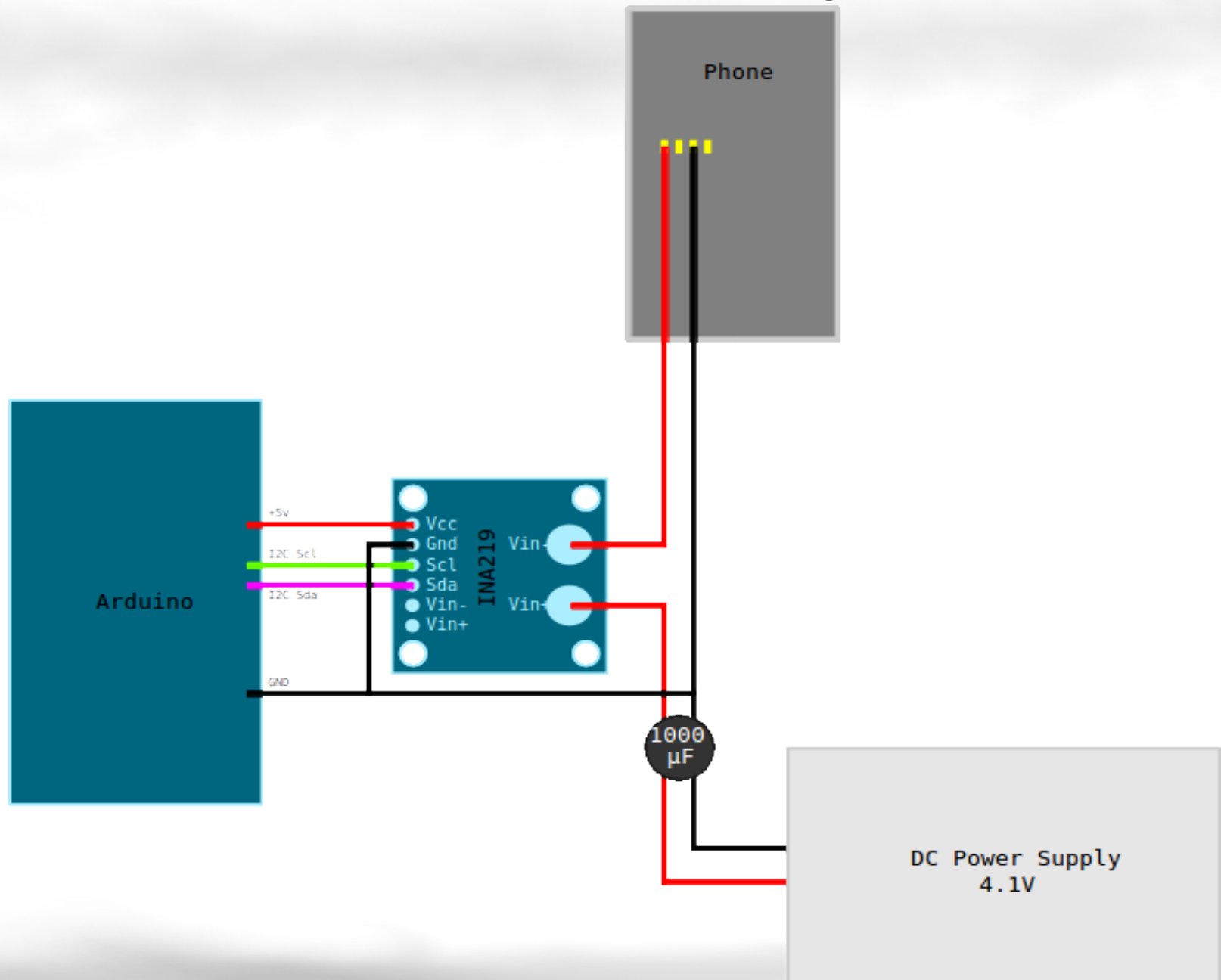


# How does it work?

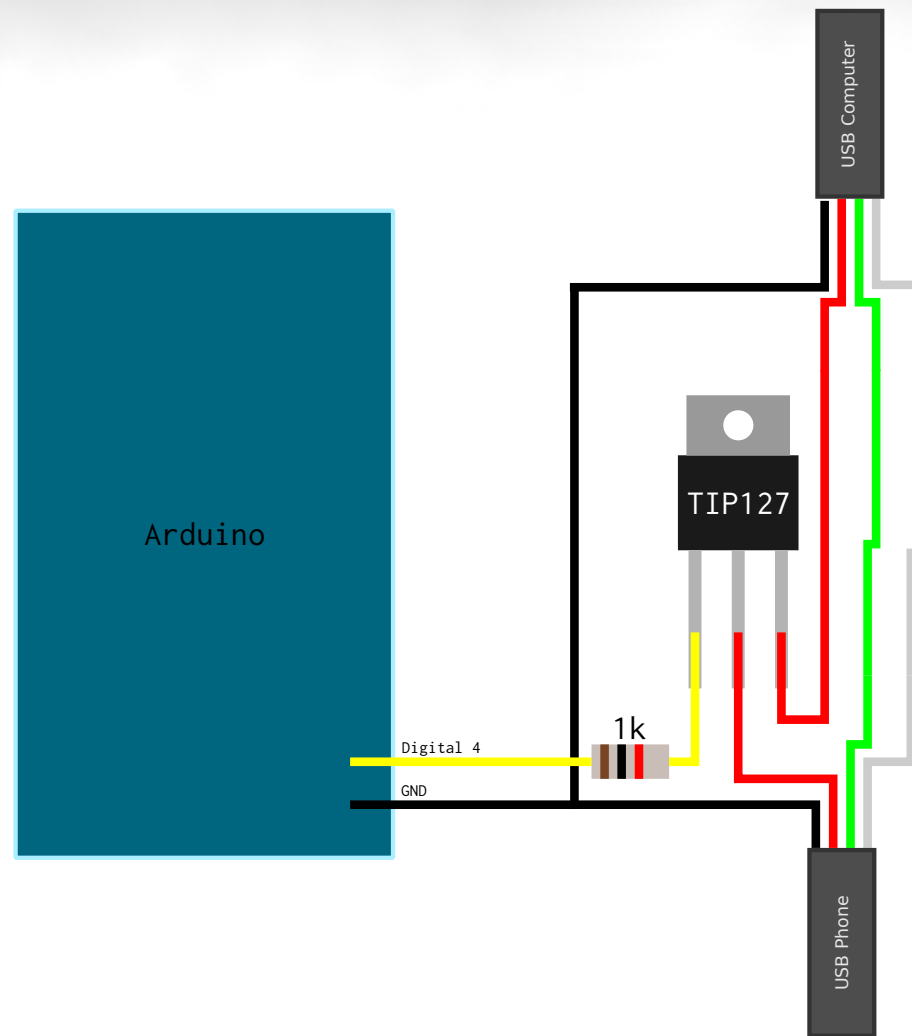




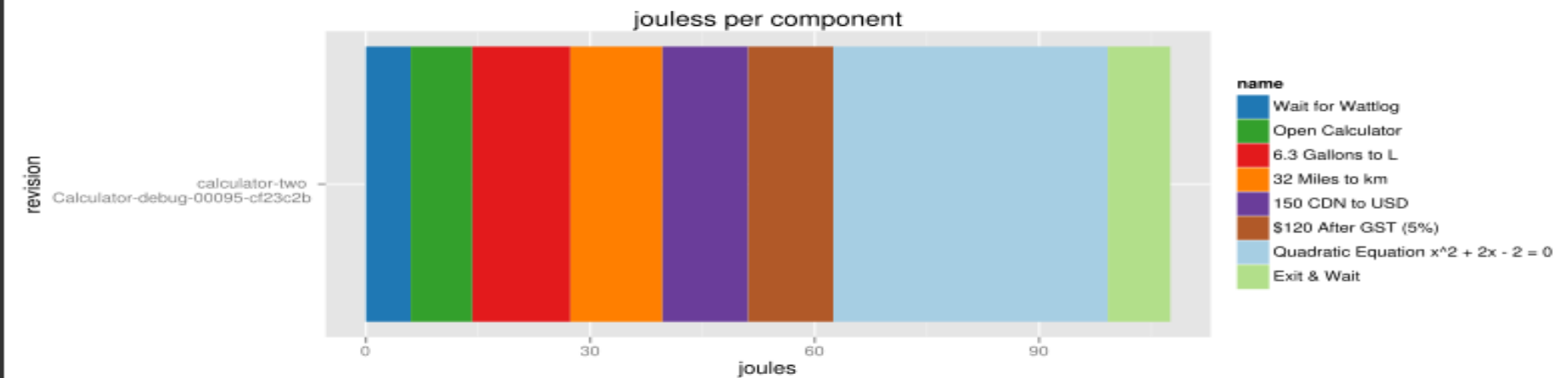
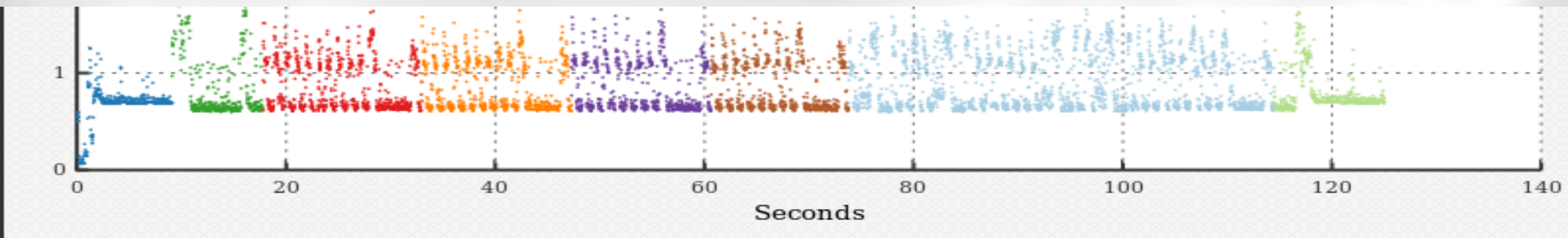
# Fake the Battery



# Control the USB Connection



# Timeseries graph and Component Breakdown

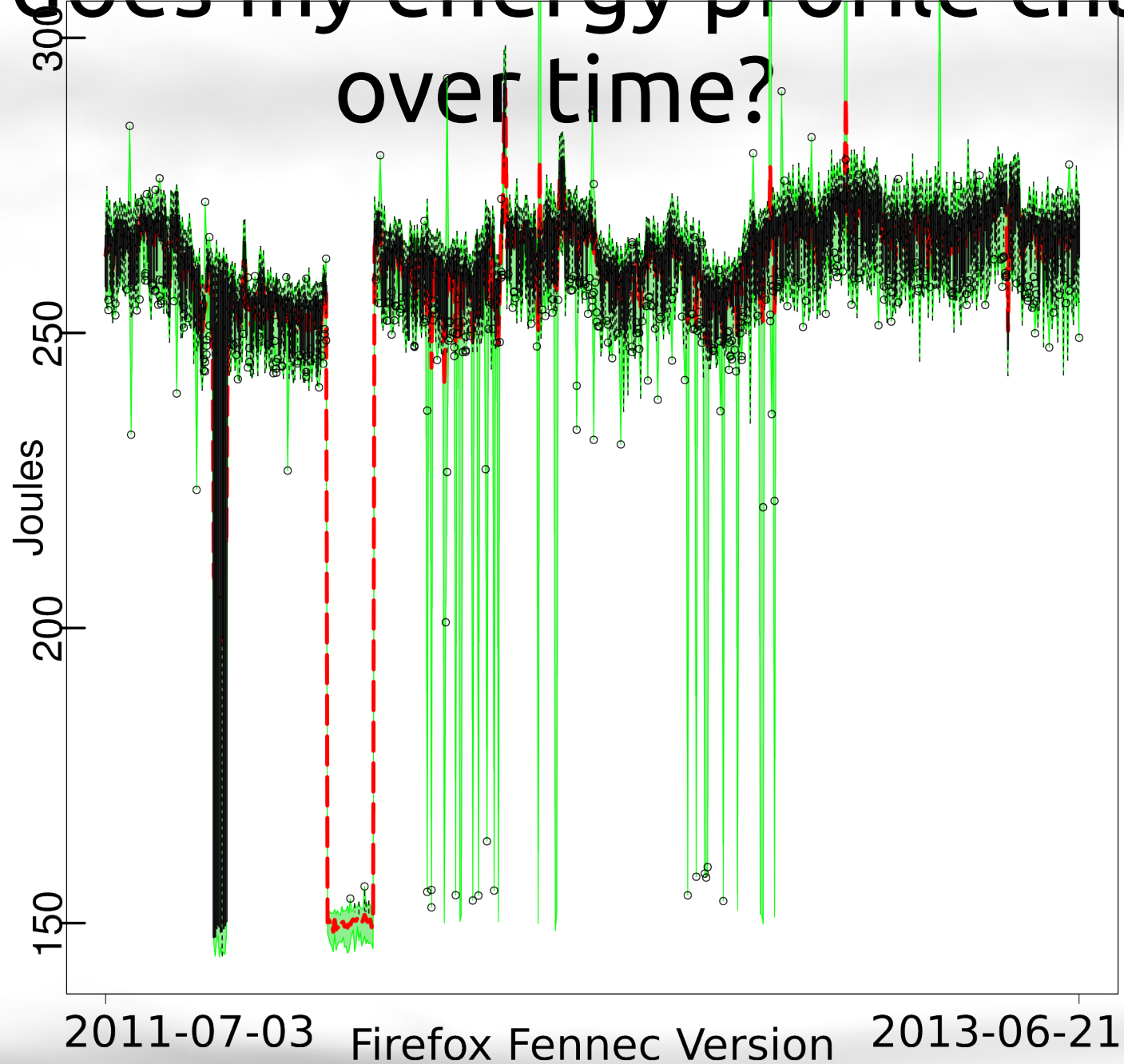


- Wait for Wattlog
- Open Calculator
- 6.3 Gallons to L
- 32 Miles to km
- 150 CDN to USD
- \$120 After GST (5%)
- Quadratic Equation  $x^2 + 2x - 2 = 0$
- Exit & Wait

Power Consumption for Test: 107.53J  
Average Power Use (Entire Test): 0.860W  
Maximum Power Consumption: 2.705W at 9.610s  
Minimum Power Consumption: -0.215W at 0.019s

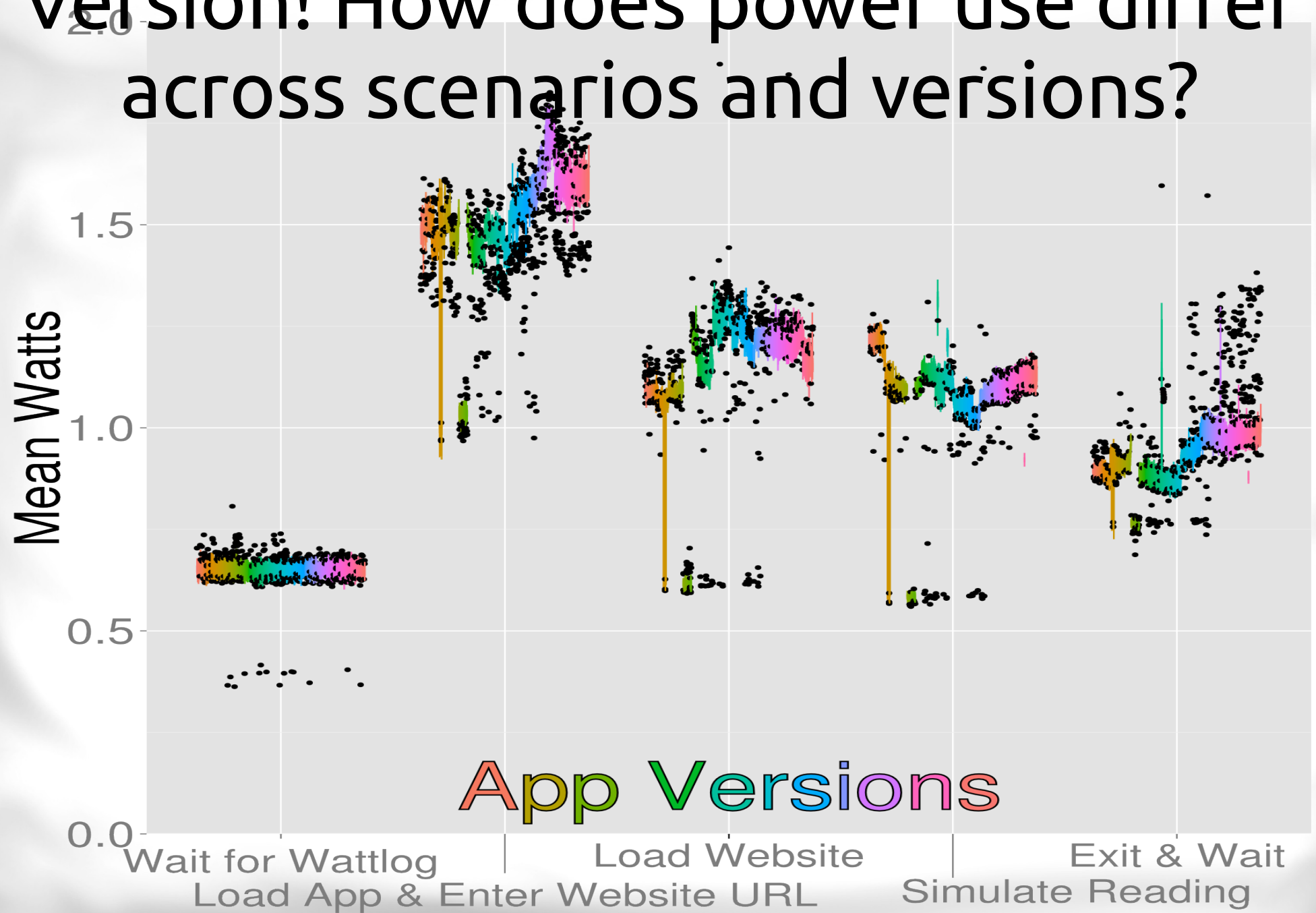
# Aggregate Plotting

How does my energy profile change over time?





# Aggregate by Component and Version! How does power use differ across scenarios and versions?



# Green Miner

Activities Firefox Web Browser Fri 10:08

greenminer test results - Mozilla Firefox

File Edit View History Bookmarks Tools Help

greenminer test results

https://pizza.cs.ualberta.ca/gm/index.py

Google

GreenMiner Test Results Add Tests Graphing

**Test Results**

This colour is what happens  
When you don't specify UI  
Look and feel requirements.

Search

Prev	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	
67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126							
127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153							
154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180							
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207							
208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234							
235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261							
262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288							
289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315							
316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342							

https://pizza.cs.ualberta.ca/gm/index.py?q=&sort=d&start=10700

ABE X

[MSR 2014]

# Per Component Breakdown

Partition	Time	Joules	Average	Maximum	Minimum
Wait for Wattlog	9.08s	5.99J	0.659W	1.260W at 1.218s	-0.215W at 0.019s
Open Calculator	8.70s	8.23J	0.946W	2.705W at 9.610s	0.601W at 14.732s
6.3 Gallons to L	15.18s	13.12J	0.864W	1.638W at 28.346s	0.606W at 18.593s
32 Miles to km	14.33s	12.30J	0.859W	1.645W at 42.333s	0.607W at 47.201s
150 CDN to USD	13.34s	11.47J	0.860W	1.655W at 55.831s	0.608W at 60.579s
\$120 After GST (5%)	13.16s	11.37J	0.864W	1.564W at 64.794s	0.610W at 62.529s
Quadratic Equation $x^2 + 2x - 2 = 0$	40.68s	36.71J	0.902W	1.693W at 106.599s	0.598W at 76.831s
Exit & Wait	10.55s	8.36J	0.792W	1.761W at 116.764s	0.612W at 116.251s

Info	Description
Power Source	Power Supply
Current Sense	ina219

Statistic	Before	After
Battery Charge	86	86
Battery Health	2	2
Battery Temperature	33°C	33°C
Airplane Mode	On	

# Sometimes we need to debug the tests with some context

\$120 After GST (5%)	13.16s	11.37J	0.864W	1.564W at 64.794s	0.610W at 62.529s
Quadratic Equation $x^2 + 2x - 2 = 0$	40.68s	36.71J	0.902W	1.693W at 106.599s	0.598W at 76.831s
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Info	Description
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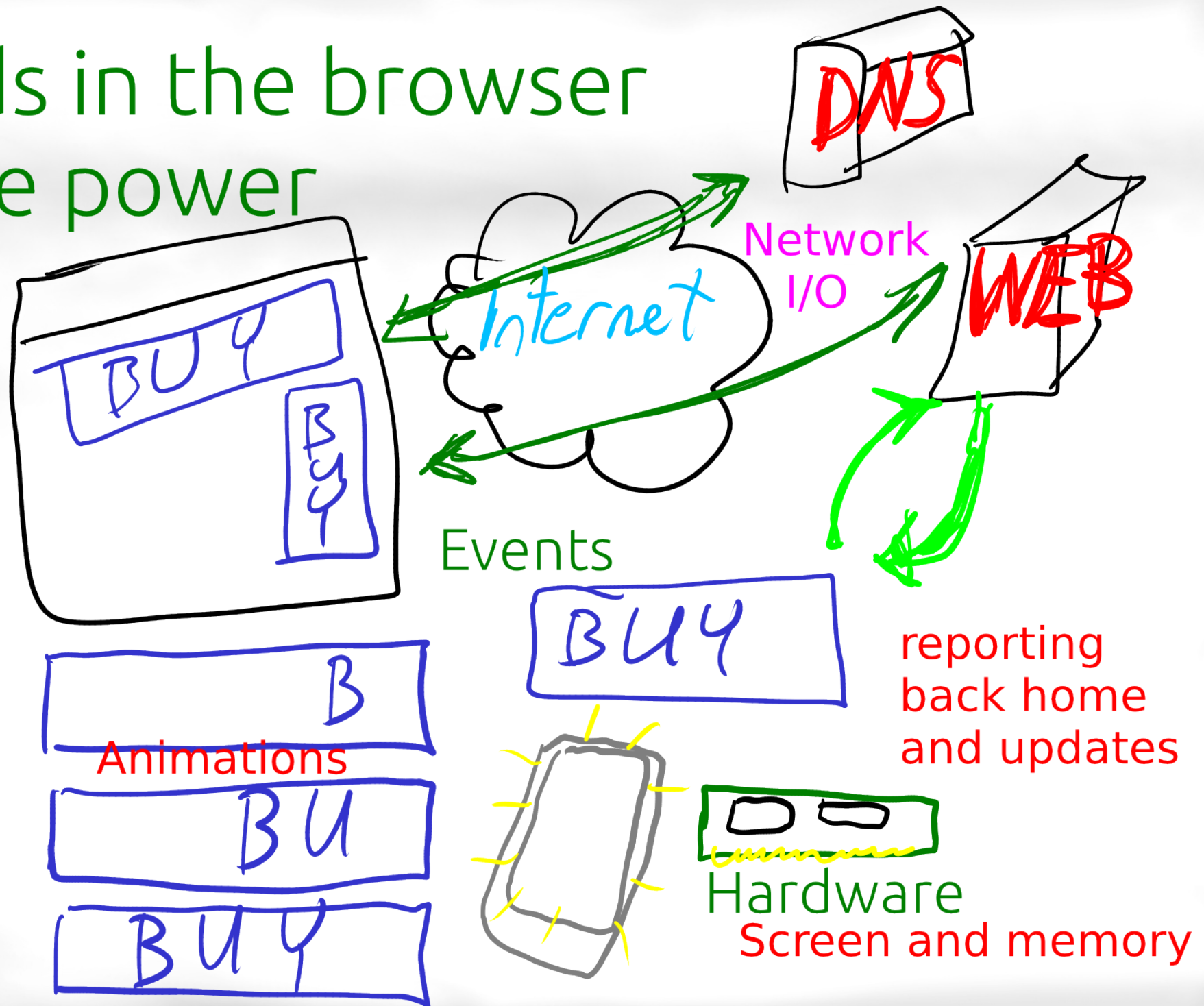
Statistic	Before	After
Battery Charge	86	86
Battery Health	2	2
Battery Temperature	33°C	33°C
Airplane Mode	On	
Wireless	1	
	SERL-EMPLAB	SERL-EMPLAB
	BSSID: 60:a4:4c:66:33:f7	BSSID: 60:a4:4c:66:33:f7
	MAC: a0:0b:ba:cf:25:61	MAC: a0:0b:ba:cf:25:61
	Supplicant state: COMPLETED	Supplicant state: COMPLETED
	RSSI: -47	RSSI: -45
	Link speed: 5	Link speed: 5
Bluetooth	Net ID: 0	Net ID: 0
	Metered hint: false	Metered hint: false
Bluetooth	Off	
Screen Auto Brightness	Disabled	
Screen Brightness	120/255	
Screen Timeout	30s	
Haptic Feedback	Disabled	
OS Version	4.2.2	

# Green Miner is an enabler

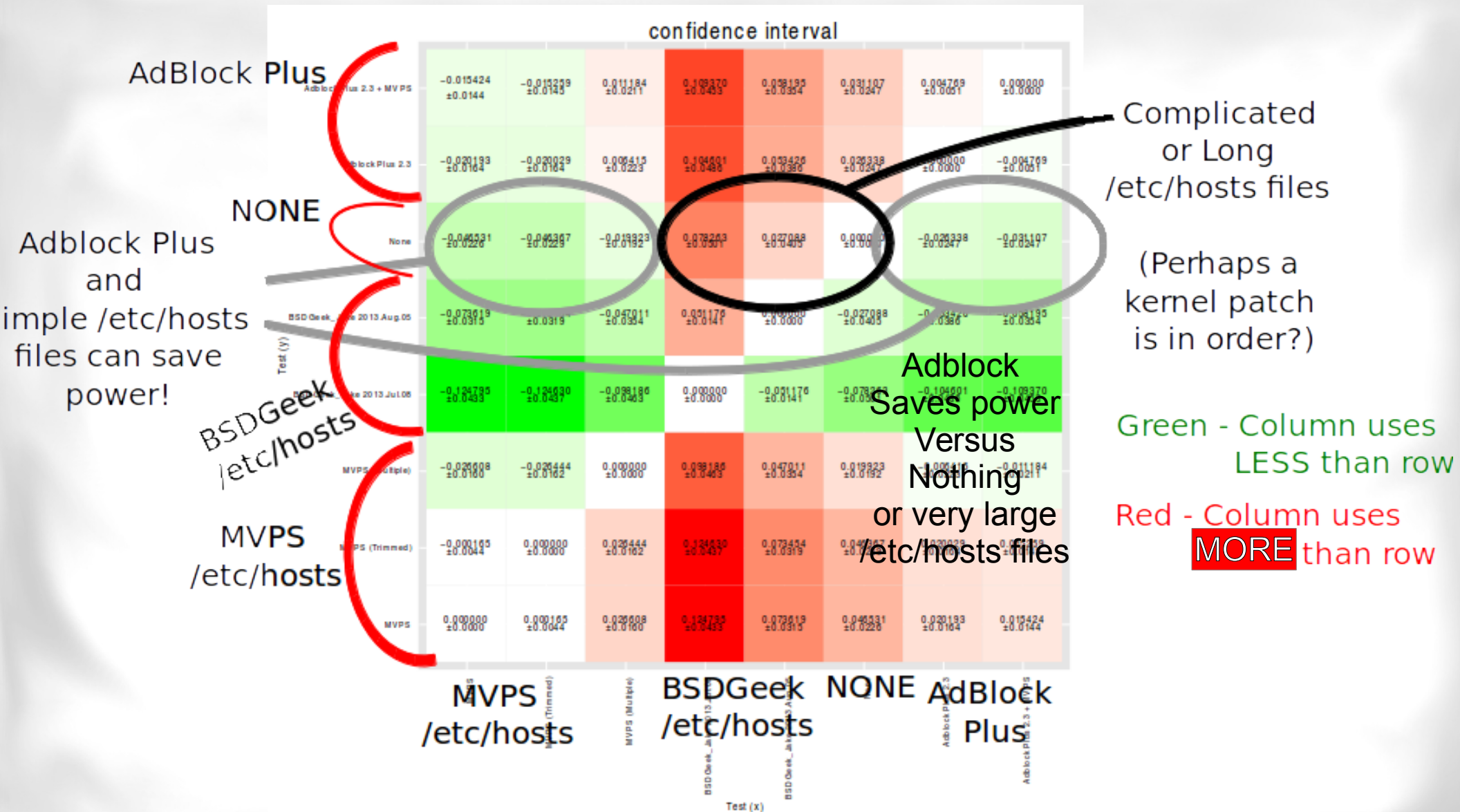
- Continuous Integration and Testing for Energy Regressions
- Repeatable, logged, measureable framework.
- Enables asking of questions and repeating experiments.
- Some examples to follow



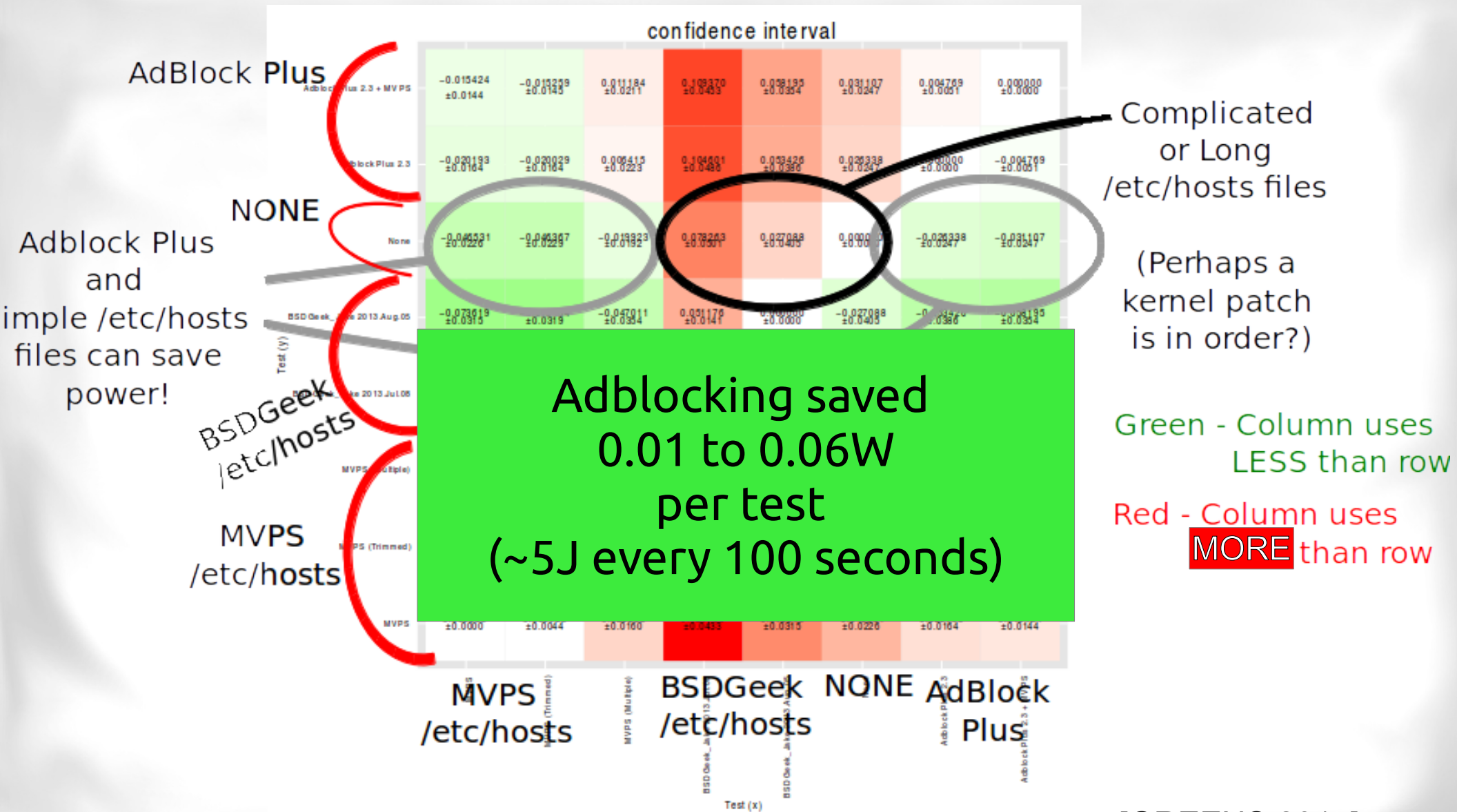
# Ads in the browser use power



# Does Adblocking Save Power?



# Does Adblocking Save Power?





# Which UI Theme would use More Power?

**White on Black  
UI Theme**

**Black on White  
UI Theme**

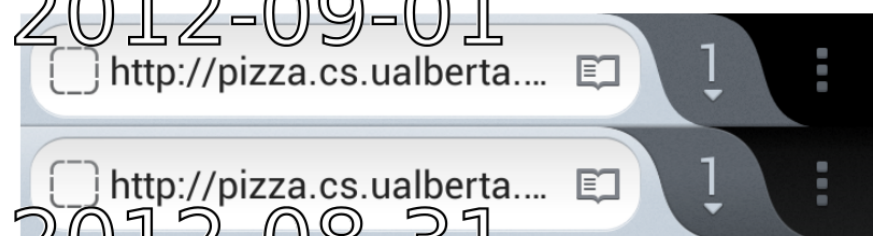
# Black Text on White Screenshot Significant Changes

2012-12-14



2012-12-13

2012-09-01



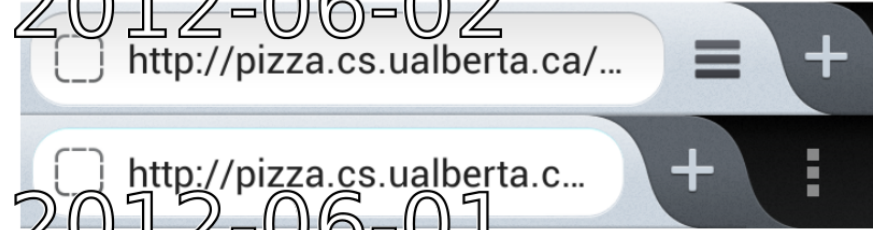
2012-08-31

2012-07-11

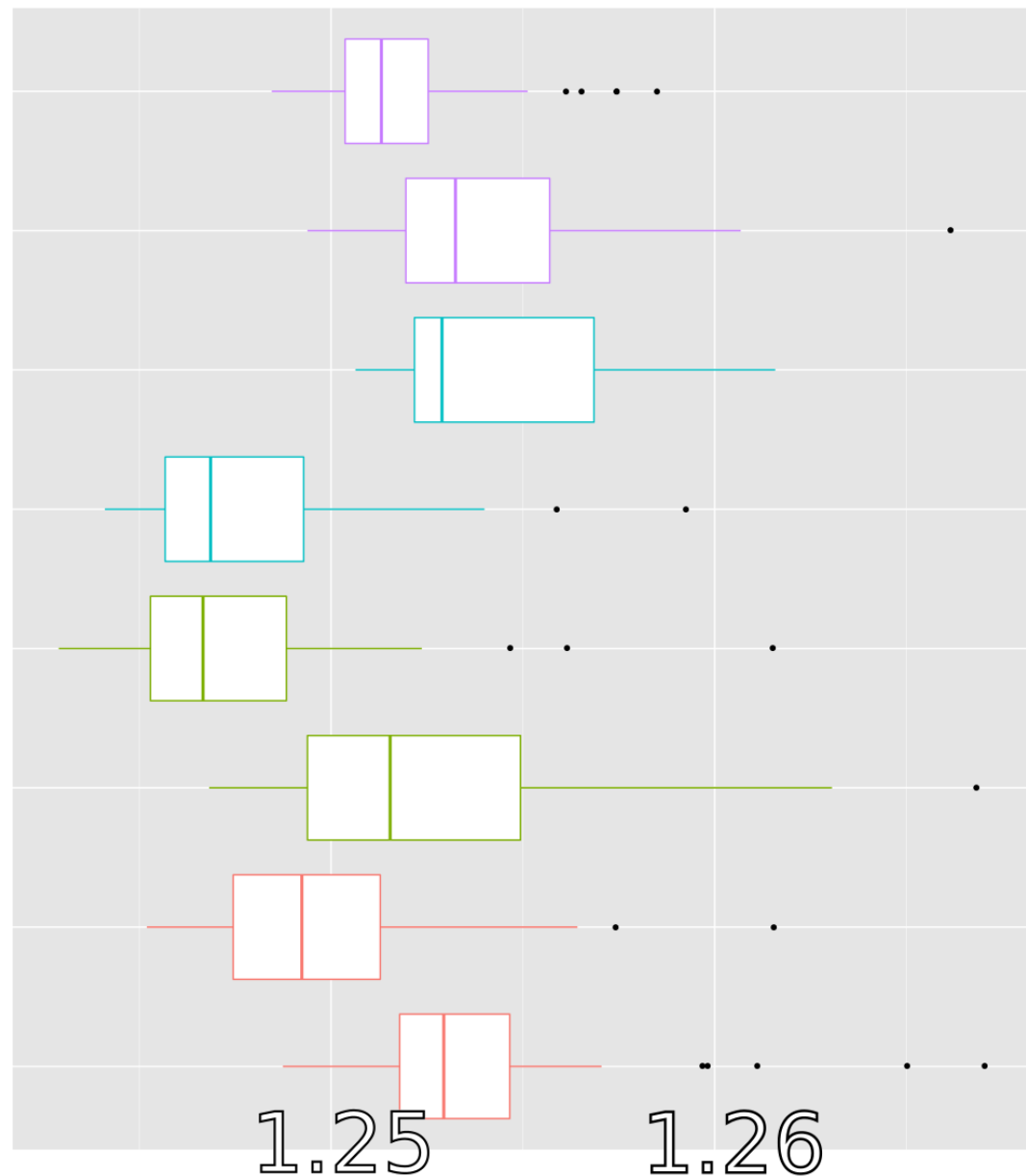


2012-07-10

2012-06-02

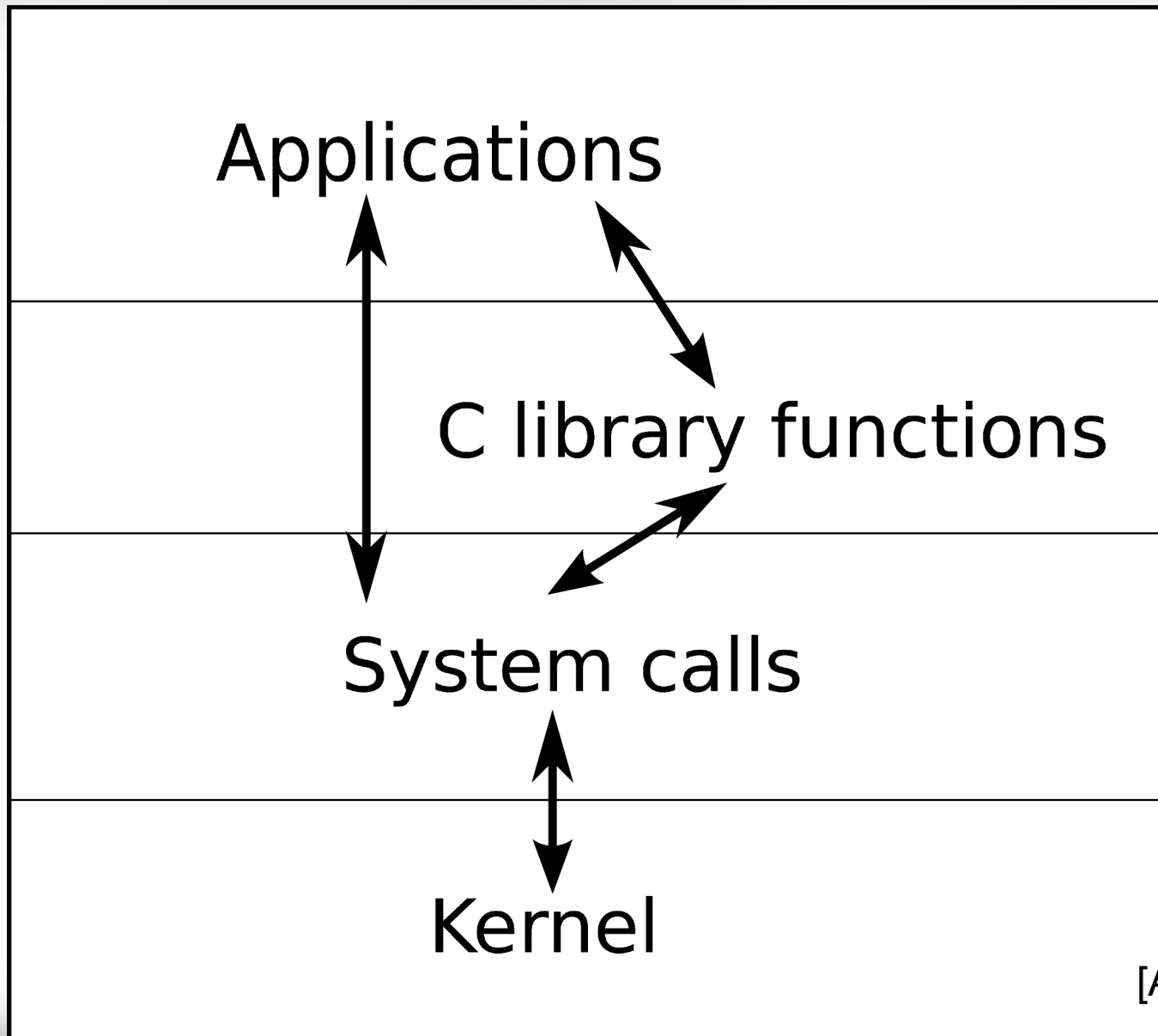


2012-06-01



Mean Power Consumption (watts)

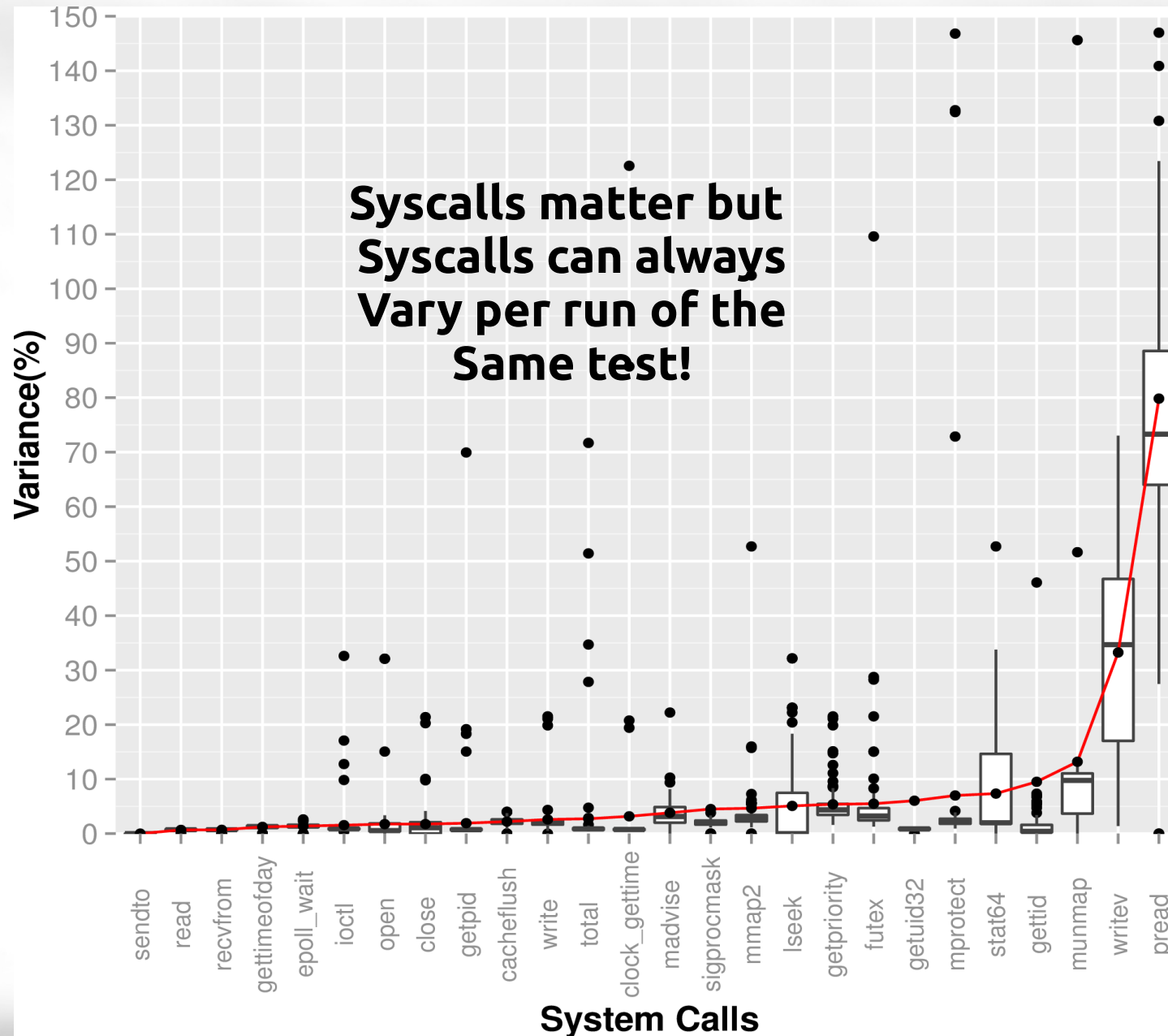
# What Causes Software Power Use?



[Aggarwal et al.]

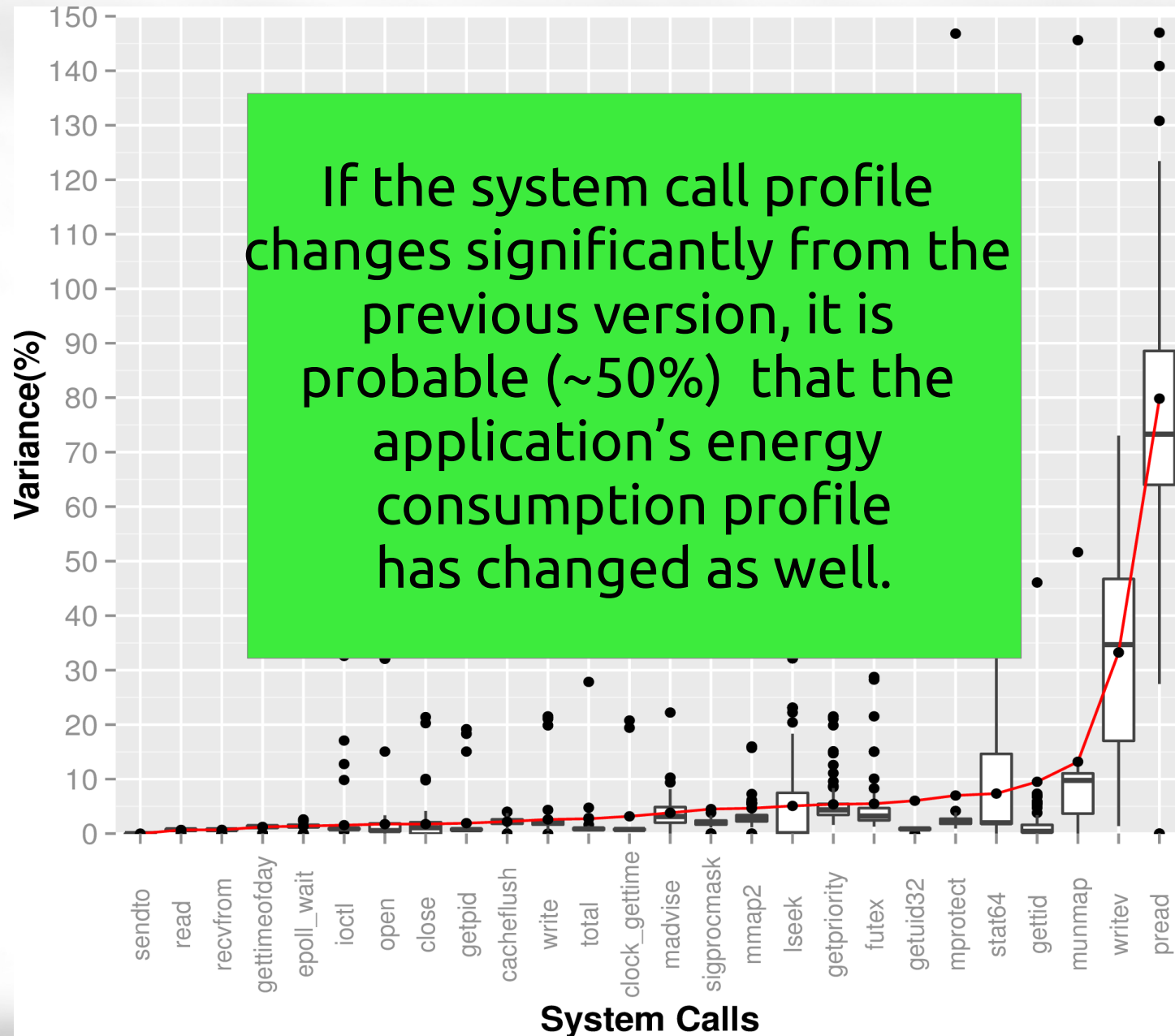


# What causes Software Power Use?



[Aggarwal et al.]

# What causes Software Power Use?



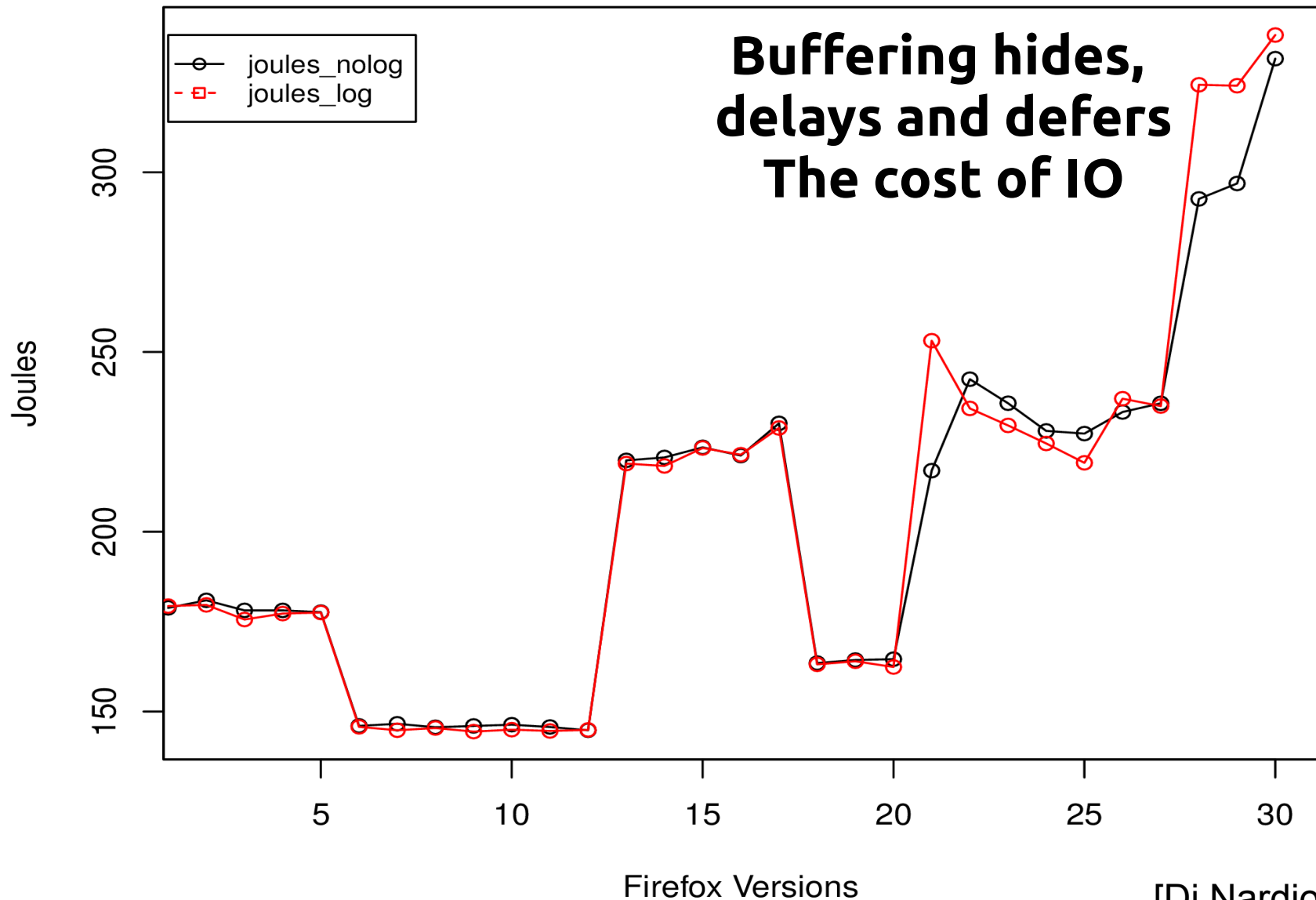
# What causes Software Power Use?

- Rule of thumb model:  
If a cumulative count of a syscall changes significantly between versions there's a good chance of a significant change in power use and energy consumption!

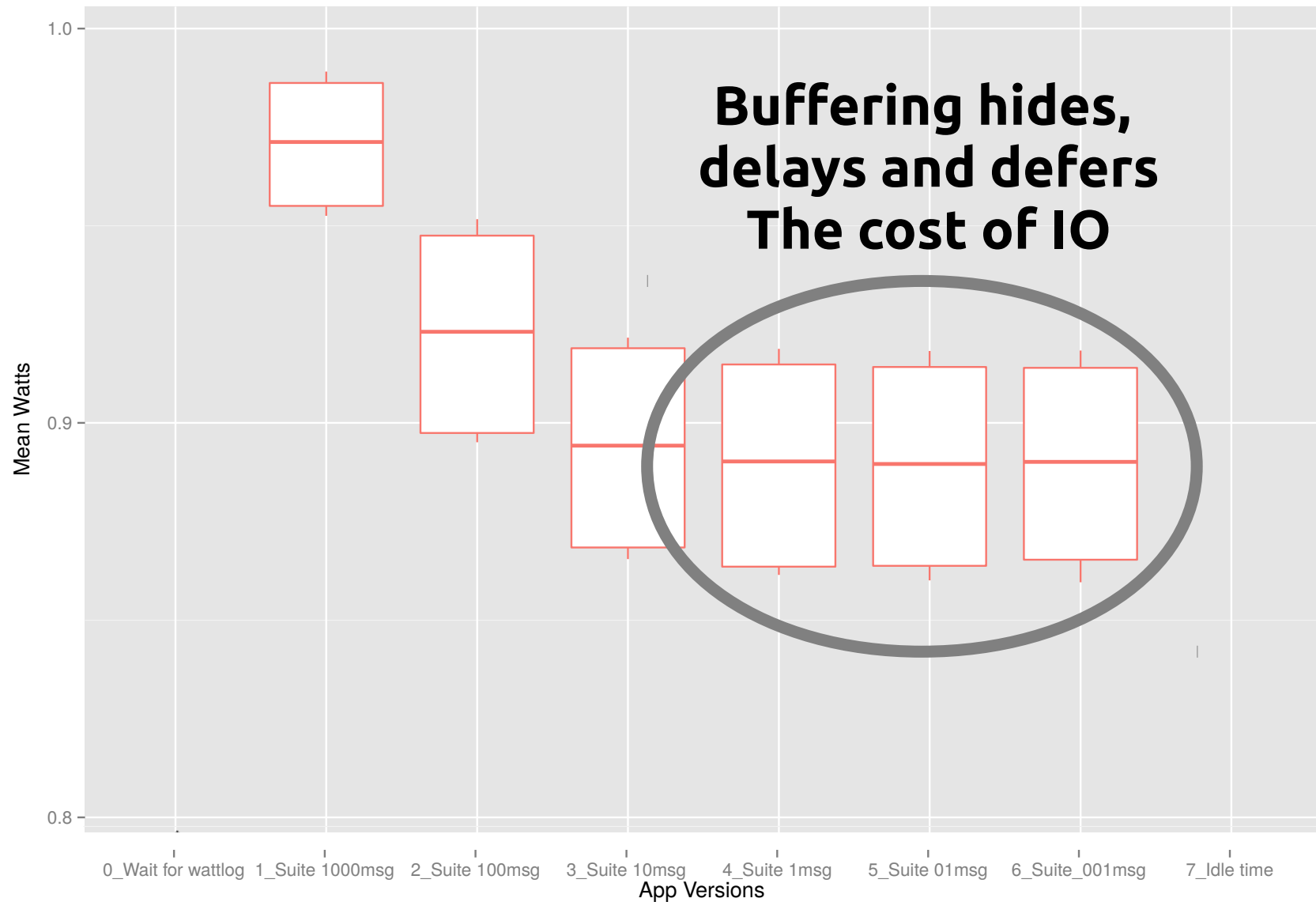
Calculator application			
	Precision	Recall	Specificity
sendto	0	0	0.89
stat64	<b>1.00</b>	0.55	0.98
cacheflush	0.34	<b>0.91</b>	<b>0.98</b>
Sum of calls	0.35	0.72	0.96
Coin flip	0.11	0.50	0.50
Firefox application			
	Precision	Recall	Specificity
fcntl64	0.04	0.10	0.94
ioctl	<b>0.26</b>	0.50	<b>0.96</b>
lstat64	0.08	<b>0.60</b>	0.95
Sum of calls	0.18	0.60	0.97
Coin flip	0.06	0.50	0.50



# Does logging matter?



# Does logging matter?

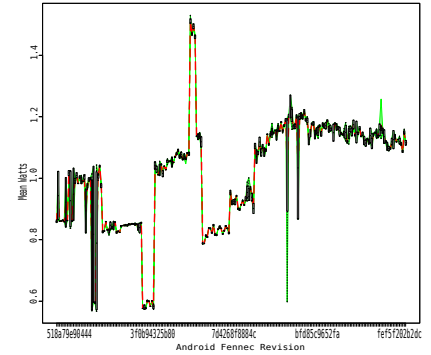


# Methodological Bottleneck

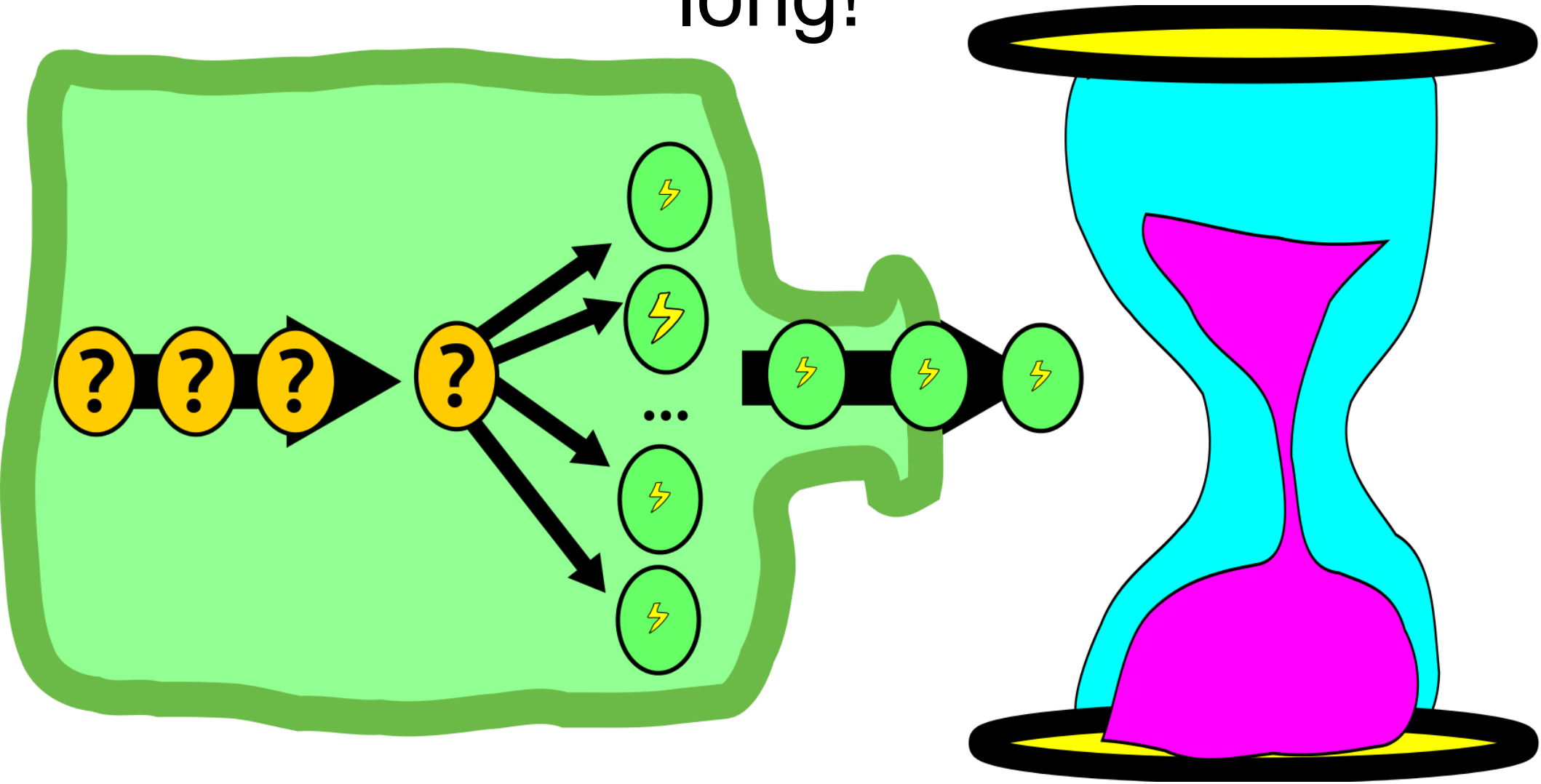
Applied  
Exhaustively  
to all revisions



Revisions are  
measured  
multiple times  
for stability

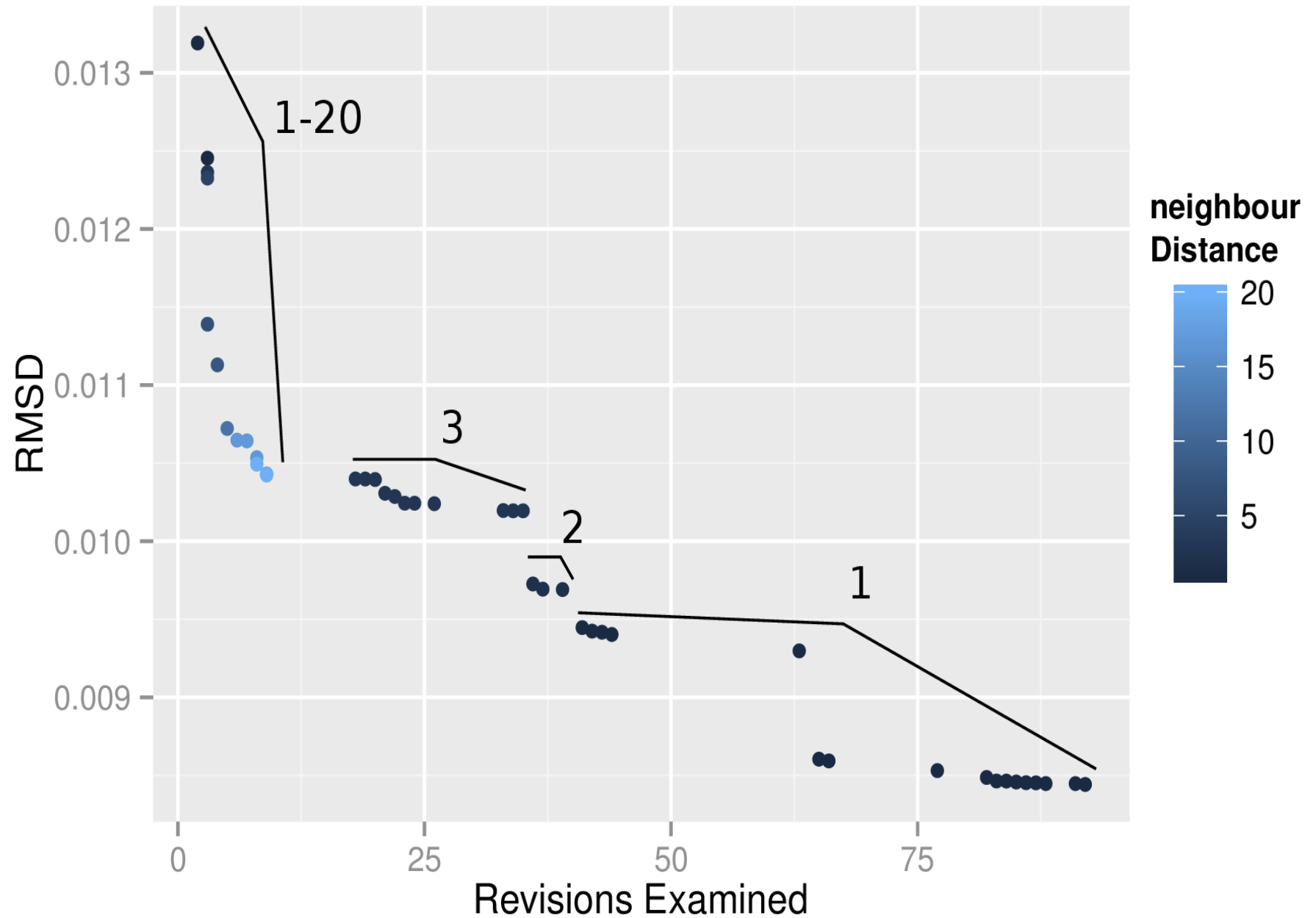


# The Research Hurdle: Measuring every revision takes too long!

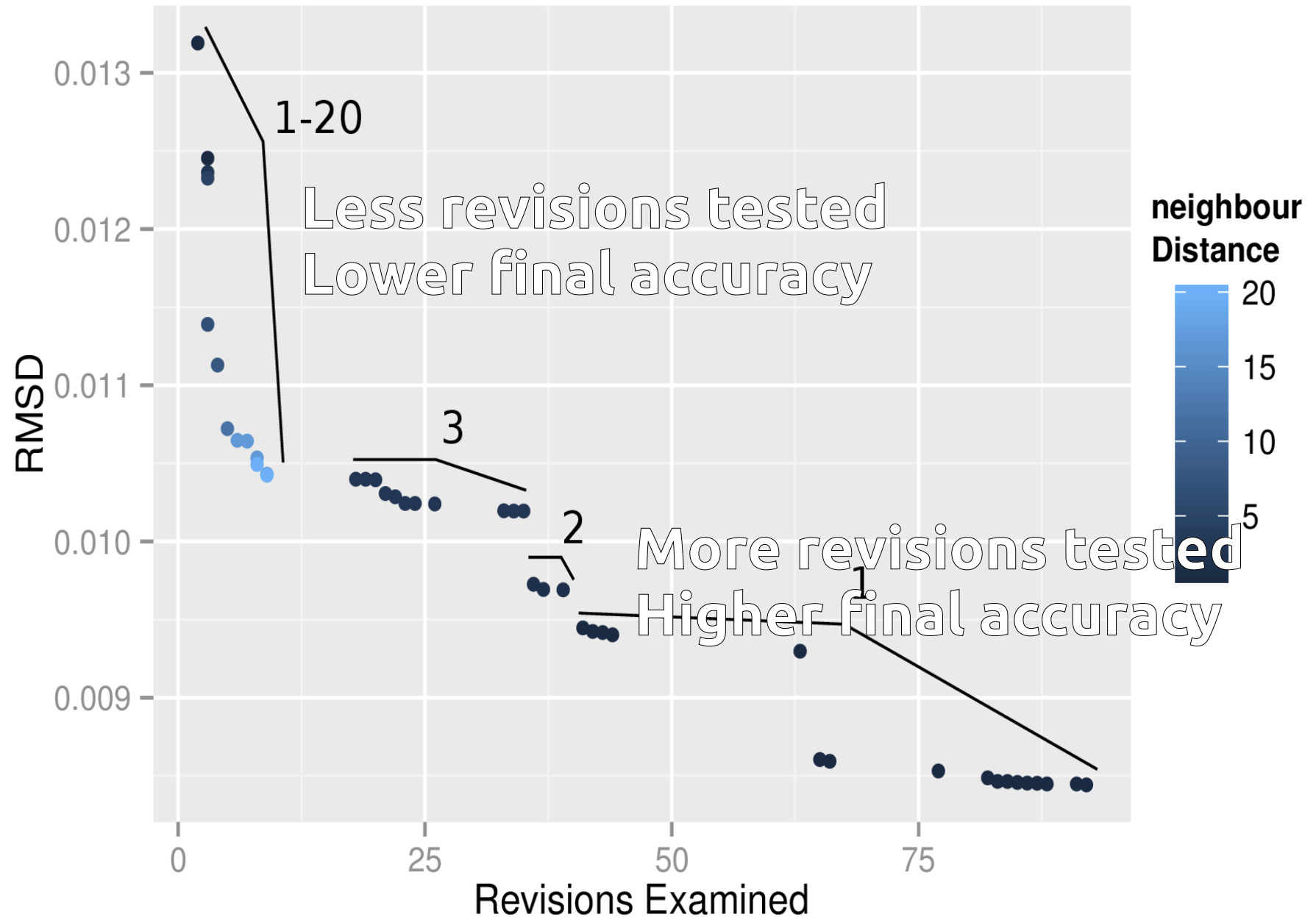




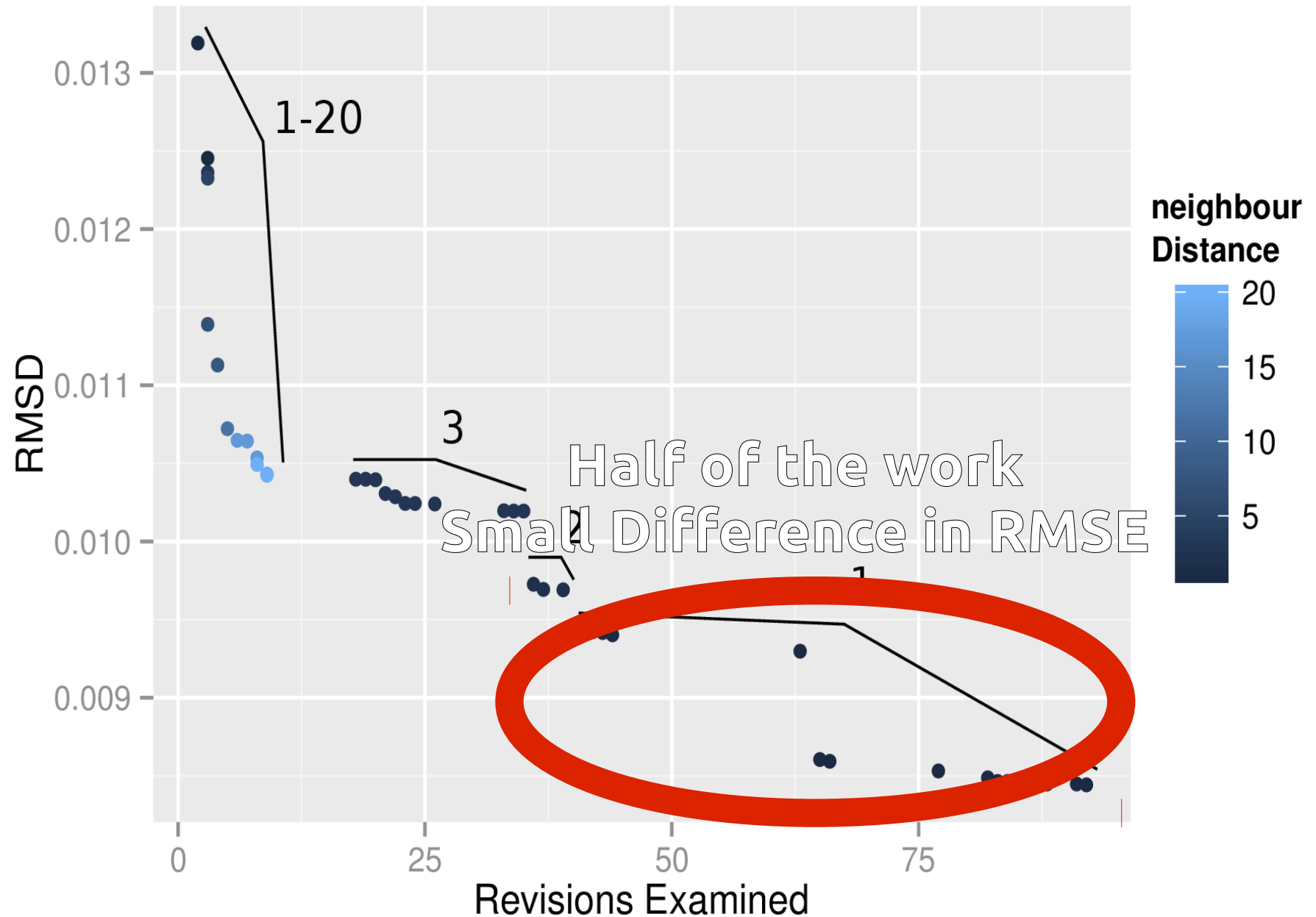
# Pareto frontier: Most cost effective approximations per time spent



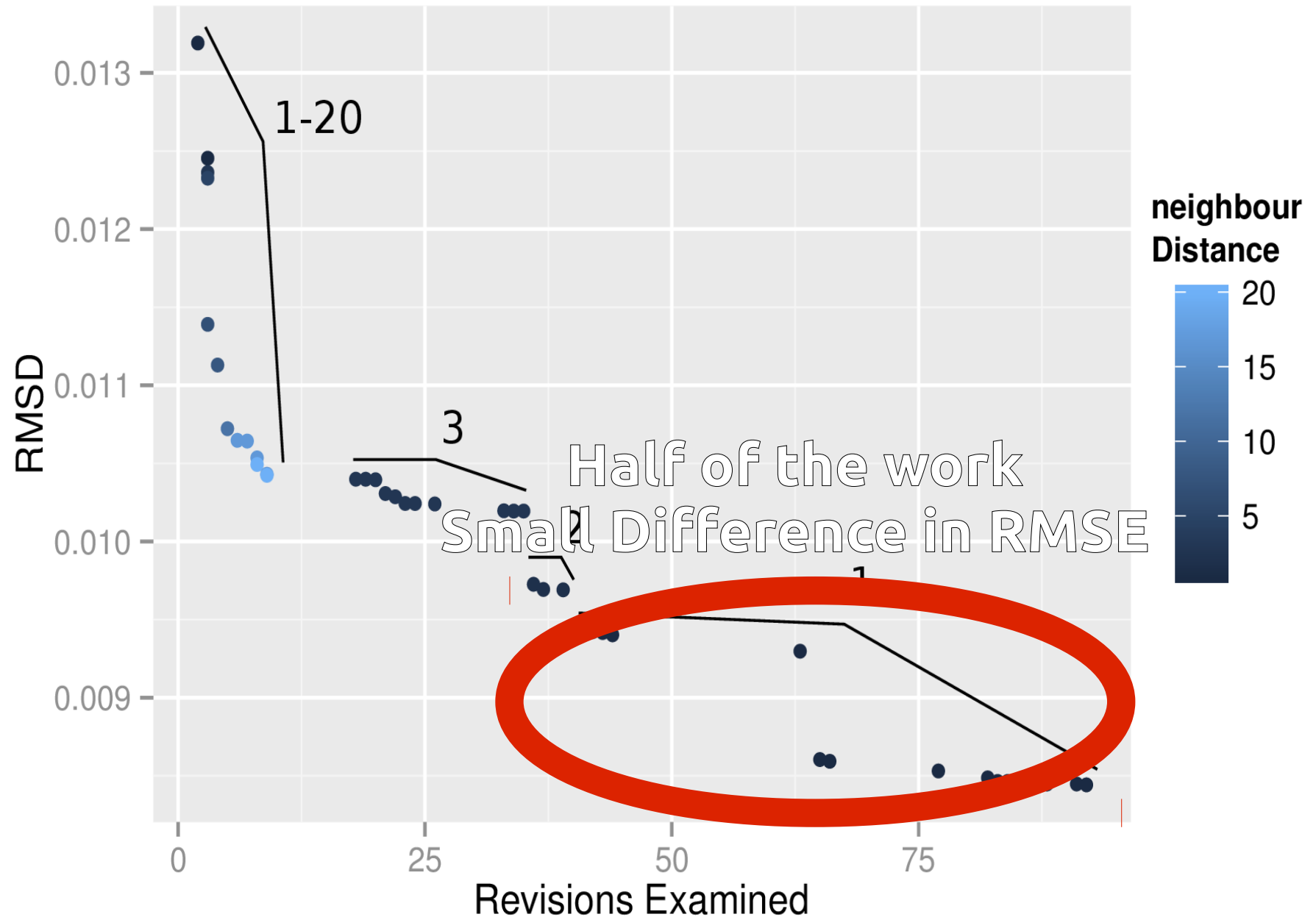
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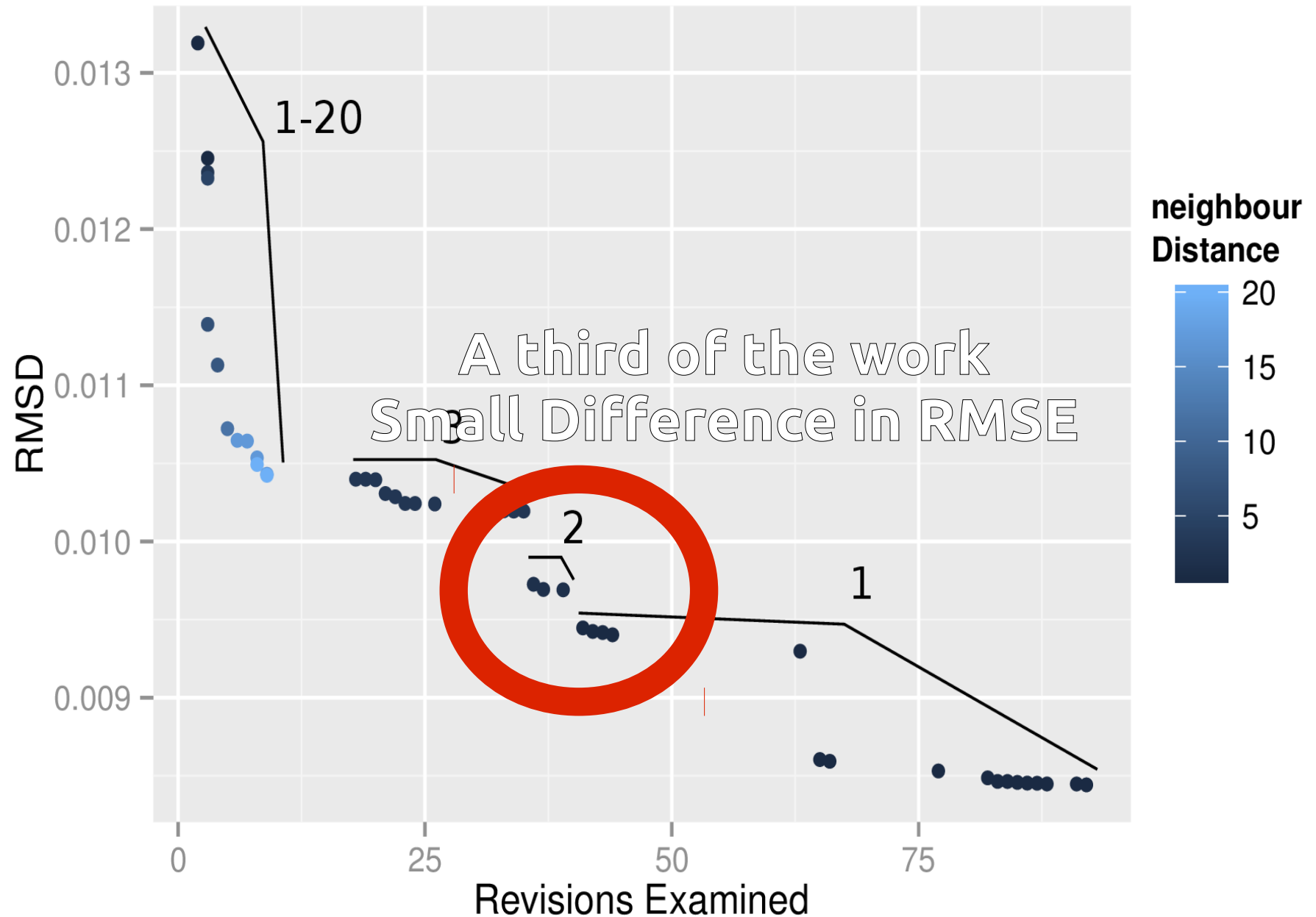


# Pareto frontier: Most cost effective approximations per time spent

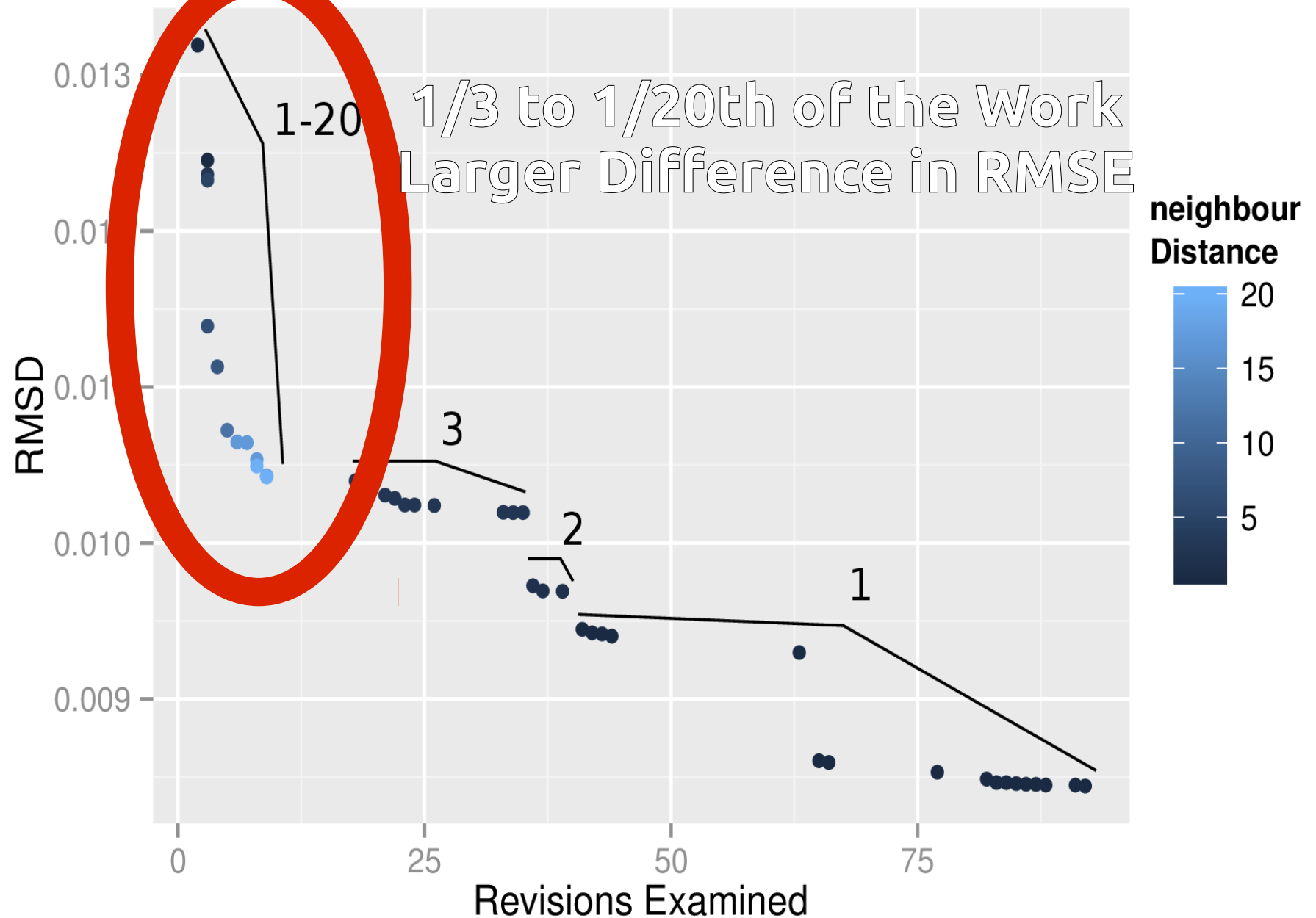




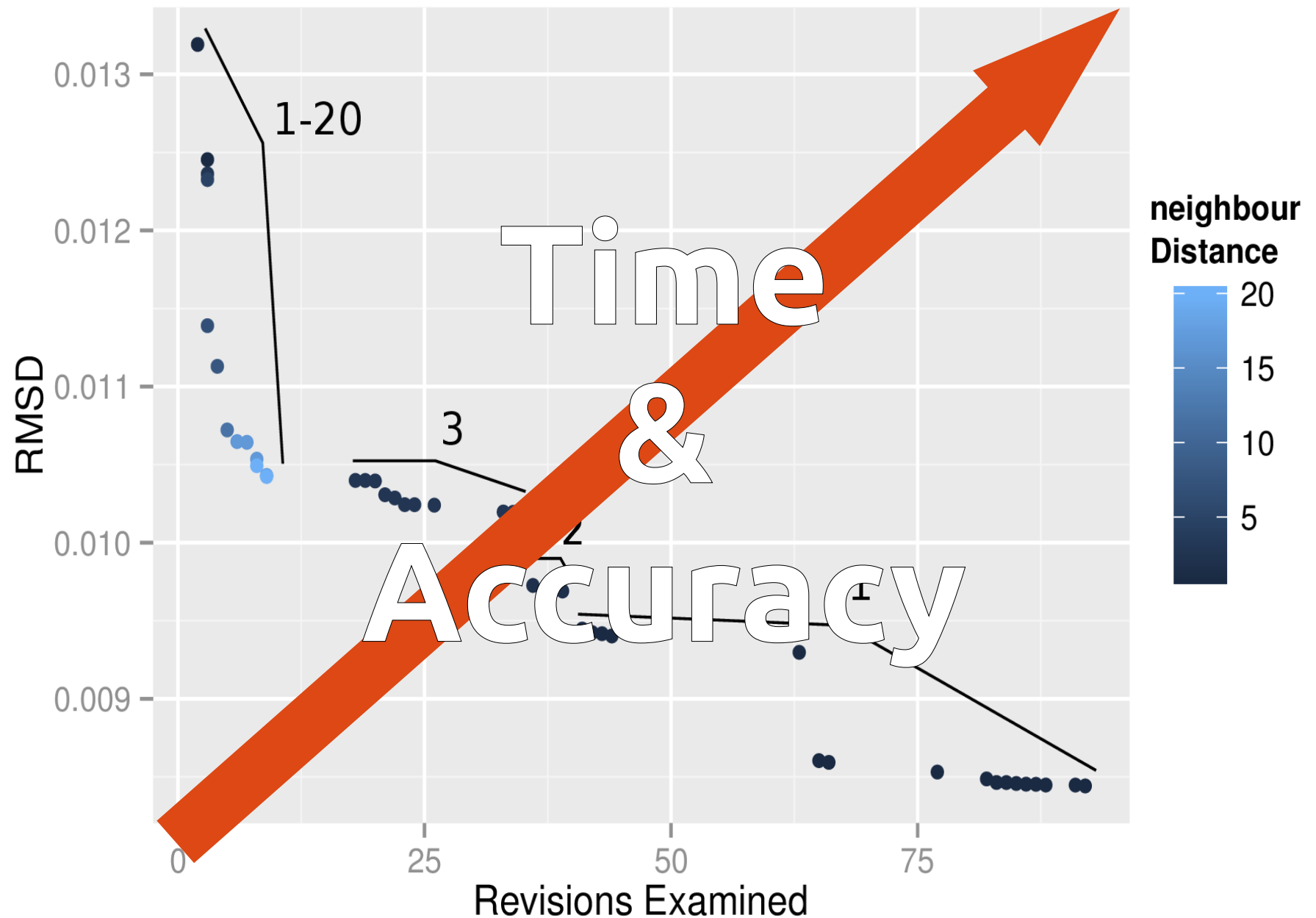
# Pareto frontier: Most cost effective approximations per time spent



# Pareto frontier: Most cost effective approximations per time spent



# Pareto frontier: Most cost effective approximations per time spent



# Green Mining Needs You



Got a question  
about power?

Looking for  
collaborators.

Green Miner is  
usable remotely.



# Conclusions

1 measurement is not enough

Energy profiles change

Measurement Granularity

Software evolves, and forks,  
-- it's not always now.

<http://greenmining.softwareprocess.es/>

Green Miner is available  
For collaboration!

