# The **GIADE** Conference

Power Measurement & Attribution systems in GNOME

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Virtual Conference

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#### whoami

- Researcher in computer architecture and systems at ETH Zurich (with Prof. Onur Mutlu)
- GSoC 2018 student with GNOME
- Worked on implementing the power panel in GNOME-Usage
- CMentors: Felipe Borges, Christian Kellner

# Section 1

Overview

Power Measurement & Attribution systems in GNOME

- Defining the Problem Statement
  - Non-commercial users and developer impact
  - Enterprise user impact
  - How Power attribution solves these problems?
- Case Study: Windows Energy Estimation Engine (E3)
- Case Study: MAC OS Energy Impact
- Proposed System Architecture
- **&** Bringing it all together; *GNOME-Usage*
- 🐮 Brainstorming

# Section 2

#### **Problem Statement**

Power Measurement & Attribution systems in GNOME

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- Why is the battery at 87% when it was fully charged last night?
- Why is a process consuming much more energy than the amount of value I am deriving from it?

#### Premise



Dashed line in the graph indicates when the device was suspended or turned off and the data has been extrapolited.

#### Figure: GNOME-Usage Mockup, Credits - Allan Day

Power Measurement & Attribution systems in GNOME

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- How do I quantify the power impact of my code?
- Power attribution data gives developers the ability to see how and where the power is being consumed.
- For example, a compute-intensive application should not be dominated by data movement costs which would show up DRAM energy!
- This also allows system administrators stronger control and easier ways to detect misbehaving applications

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- Power attribution enables data-centers to monitor high energy-cost applications, and improve application scheduling across clusters for optimizing energy efficiency
- Theoretically, enterprise IT administrators could create scripts to collect periodic logs to analyze energy usage data from devices, and improve workload allocation across devices (RNNs for server-class CPUs, CNNs for GPUs, cloud apps etc.)

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- Current battery technologies have been stagnant w.r.t charge capacity and density improvements.
- Power envelopes have emerged as the major constraint for any consumer-facing system = mobile devices, laptops, tablets, etc.

### Section 3

#### Why Power attribution

Power Measurement & Attribution systems in GNOME

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- Windows, MAC OS, Android have closed the gap
- ¿ Linux solution still awaited despite maximum server deployment

#### Section 4

Challenges

Power Measurement & Attribution systems in GNOME

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- Hardware chips do not measure/expose individual wattage information
- Reliable values available include Processor wattage (post Nehalem) and available battery charge (via ACPI/UPower)

#### Hardware devices

- CPU: Cores vs Clock, P-states vs C-states
- ℭ GPU: thousands of cores + high-bandwidth memories
- ℭ I/O Peripherals: USB devices are polled every 5 ms
- Display: Backlight can brighten/darken your day
- Vetwork Adaptors: Ethernet, WiFi pings
- Disk: HDD writes are cached for bulk ops
- RAM: Till 2016, Macs could only use maximum 16 GB RAM due to DDR3 power requirements (Reference)

#### Ideal solution

*Cell intermine time spent on CPU, I/O and Memory. Multiply by nominal power for these components.* 

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- *Constant of the components of*
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- ACPI / RAPL / Manufacturer data-sheets = Conflicting data sources. How to align and make sense?
- CEMs: Collect data from devices running your software

## Section 5

#### Case Studies

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- Wicrosoft also claims that they prioritize data from devices with dedicated chips while developing the software-based power models.
- Few PCs in the market have such dedicated chips: According to reports, 99% of current devices in market lack current and voltage monitors.

# E3 front-end: Battery usage

This breakdown can be observed via the Settings app in Windows. The interesting observation here is that they do not report hardware device attribution, rather only for processes.

Settings	-		×
Battery usage by app			
Time: 24 Hours ∨			
Showing: Apps with usage $\checkmark$			
Mail and Calendar Managed by Windows		9%	
S Skype Preview Managed by Windows		8%	
Cortana Managed by Windows		6%	
Microsoft OneDrive		4%	
Skype for Business		3%	

## Task Manager Front-end

The Task Manager shows per-process power impact, for short-term (first column) and over long term (second column).

👰 Task M	anager													
File Options View														
Processes	Performance	App histor	y Startup	Users	Details	Services								
	^		8%		69%	0%	0%	- 1	-					
Name		Status	CPU	M	emory	Disk	Network	Power us	Power usage					
Apps (3)	)													
> 💓 Ma	alwarebytes Tra.		0%	1	1.7 MB	0.1 MB/s	0 Mbps	Very low						
> 🧧 Mi	crosoft Edge (8)	)	0%	114	4.0 MB	0 MB/s	0 Mbps	Very low						
> 🙀 Tas	sk Manager		0%	- 1	5.7 MB	0 MB/s 0 Mb		Very low						
Backgro	ound proces.													
			0.001											

Figure: Observation: No absolute numbers are presented, only relative terms such as *Low usage, Very High usage etc.* 

## E3 Architecture

# How Does Energy Estimation Engine Work?

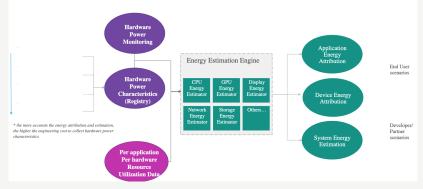


Figure: Source link: Microsoft presentation to hardware vendors

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- The following data columns can be observed in the E3 Service Report (shown below): ScreenOnEnergy, CPUEnergy, SoCEnergy, DisplayEnergy, DiskEnergy, MBBEnergy, NetworkEnergy, EmiEnergy etc.

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For Home boat Populated Fermula Data Radow Vew 2 followed at																						
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Chevor's partition via used printing and pupilines are																						

Figure: Statistics recorded by Windows E3

## macOS statistics

• •		Activit	y Monitor	(Application	s in last 12	2 hours)					
8	8 * -	CPU	Memory	Energy	Disk	Network					
App N	ame	Energy Impact	Avg Ener	gy Impact ~	Арр Nap	Preventing Sle	User				
۵	Firefox	2.9		30.84	No	No	admangl				
▶ 👩	Google Chrome	0.7		5.45			admangl				
► Q	Spotlight	0.0			-						
▶ 📓	Mail	0.0		0.34	Yes		admangl				
2		-									
e (e)					-						
▶ 💽	Finder	0.0		0.09	Yes	No	admangl				
۵	Microsoft PowerPoint	0.0		0.06	Yes		admangl				
<b>S</b>		_			-						
<u></u>	Microsoft Update Assistant	0.0		0.05			admangl				
	Activity Monitor	0.8		0.05	No	No	admangl				
	Notes	0.0		0.02	Yes		admangl				
۱ 🛞	Photos Agent	0.0		0.01							
۹	Time Machine	0.0		0.01	-						
	zOutlookPluginAgent	0		-	No	No	admangl				
	McAfee Reporter	0.0					admangl				
	McAfeeSafariHost	0.0			No	No	admangl				
	Menulet	0.0					admangl				
	ENERGY IMPACT BATTERY (Last 12 hours)										
	ENE						12 mours)				
	Remaining charge: 59%										
			Time ren		2:18						
			Time on	battery:	2:07						

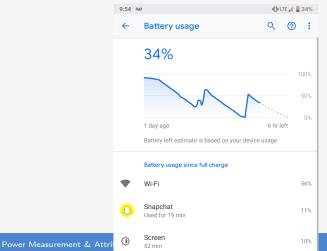
#### Figure: Activity Monitor displays process-relative power impact

## macOS: Energy Impact

- The Energy panel debuted in Activity Monitor approximately 6 years ago
- The panel displays "Energy Impact" of each open app based on a number of factors including CPU usage, network traffic, disk activity, Interrupts and more.
- The higher the number, the more impact an app has on battery power (maximum observed around 780 during stress tests).
- Similar to Windows, MAC OS also attributes power only to processes, not individual hardware devices
- Details are sparse, but I strongly suspect that MAC devices have dedicated chips for power measurement

# Android

Android has stringent power envelopes, and power statistics predate at least v2.3 GingerBread! Interestingly, android **attributes power to both hardware and software**!



## Section 6

## System Architecture

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- *Constructions* Develop power models for each device: *Gaussian distributions*?
- Incorporate these models into a multi-variate regression model with current battery charge as one of the inputs
- Can also be interpreted as a variant of the Multi-armed Bandit Problem

## Data Collection?

There are billions of devices, and tens of billions of ICs inside these devices. The power estimates can range across 2-3 orders of magnitude. How do we develop accurate & reliable power models across this range?

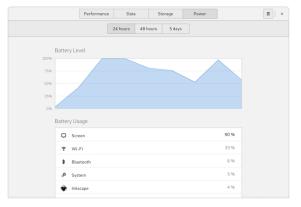
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- Windows performs data mining across ALL devices for developing the power models. These models enable reliable per-component estimates, with constant fine-tuning.
- Privacy concern: Should users share this data? What can be the challenges here? How else can we obtain this data (across billions of devices, millions of ICs and thousands of OEM/IHV)?

## Front-end



Dashed line in the graph indicates when the device was suspended or turned off and the data has been extrapolited.

#### Figure: GNOME-Usage Mockup, Credits - Allan Day

# Section 7

End

#### Questions? Shout-out: Felipe Borges, Christian Kellner (gicmo)

Please reach out for questions via: reach.aditya.here+guadec@gmail.com