Power Measurement & Attribution systems in GNOME

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- GSoC 2018 student with GNOME
- Worked on implementing the power panel in GNOME-Usage
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Section 1

Overview
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
Understanding desktop-user concern

猜想 I have been using my computer for barely 30 minutes. Why is the battery already at 50%?
Understanding desktop-user concern

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- Why are the fans blasting at full speed, *I am just browsing the internet!*
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- Why is the battery at 87% when it was fully charged last night?
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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

**Figure:** GNOME-Usage Mockup, Credits - Allan Day
Understanding developer use-cases

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- **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
Understanding Enterprise concerns

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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.)
Limitations of the battery

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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
How can power attribution fix these problems?

"You cannot improve what you cannot measure."

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Linux solution still awaited despite maximum server deployment.
Section 4

Challenges
Hardware is hard

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Hardware is hard

กระบวนการคอมพิวเตอร์อาจทำงานที่ความเร็ว 3 GHz ขึ้นไป ภายใน 1 วินาที มีจำนวนของเหตุการณ์ที่เกิดขึ้นมากกว่าล้าน

ชีวมนุษย์อาจทำงานที่ความเร็ว 1 Hz กลับกัน

การคิดถึงความผิดพลาดของส่วนตัวของโปรแกรมและอุปกรณ์ทางการเงิน รวมถึงการวัดความซับซ้อนของข้อมูลสำหรับวินาทีของมนุษย์เป็นพื้นฐานที่ยาก!
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- 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
- GPU: thousands of cores + high-bandwidth memories
- I/O Peripherals: USB devices are polled every 5 ms
- Display: Backlight can brighten/darken your day
- Network 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

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- **ACPI / RAPL / Manufacturer data-sheets = Conflicting data sources. How to align and make sense?**
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- ACPI / RAPL / Manufacturer data-sheets = Conflicting data sources. How to align and make sense?
- OEMs: Collect data from devices running your software
Section 5

Case Studies
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- 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.*

![Battery usage by app](image)
Task Manager Front-end

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

Figure: Observation: No absolute numbers are presented, only relative terms such as Low usage, Very High usage etc.
How Does Energy Estimation Engine Work?

Figure: Source link: Microsoft presentation to hardware vendors
Back-end

Power profiles: Windows has separate power profiles for individual hardware devices like network, disks etc. Further, profiles specialize for Laptops, Tablets, Phones devices etc.
Power Measurement & Attribution systems in GNOME

Back-end

 Exists in Windows

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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.

Figure: Statistics recorded by Windows E3
macOS statistics

![Activity Monitor](image)

**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
Data collection- Huge variation in each device, billions of devices, order of magnitude differences in same configurations - 
Data needed to make models!
Back-end

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- Develop power models for each device: Gaussian distributions?
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- Can also be interpreted as a variant of the Multi-armed Bandit Problem
Data Collection?

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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

Figure: GNOME-Usage Mockup, Credits - Allan Day
Section 7

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

Please reach out for questions via:
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