Mobile and Ubiquitous Computing
2022/2023
MEIC/METI

Energy Issues in Mobile and Ubiquitous Computing

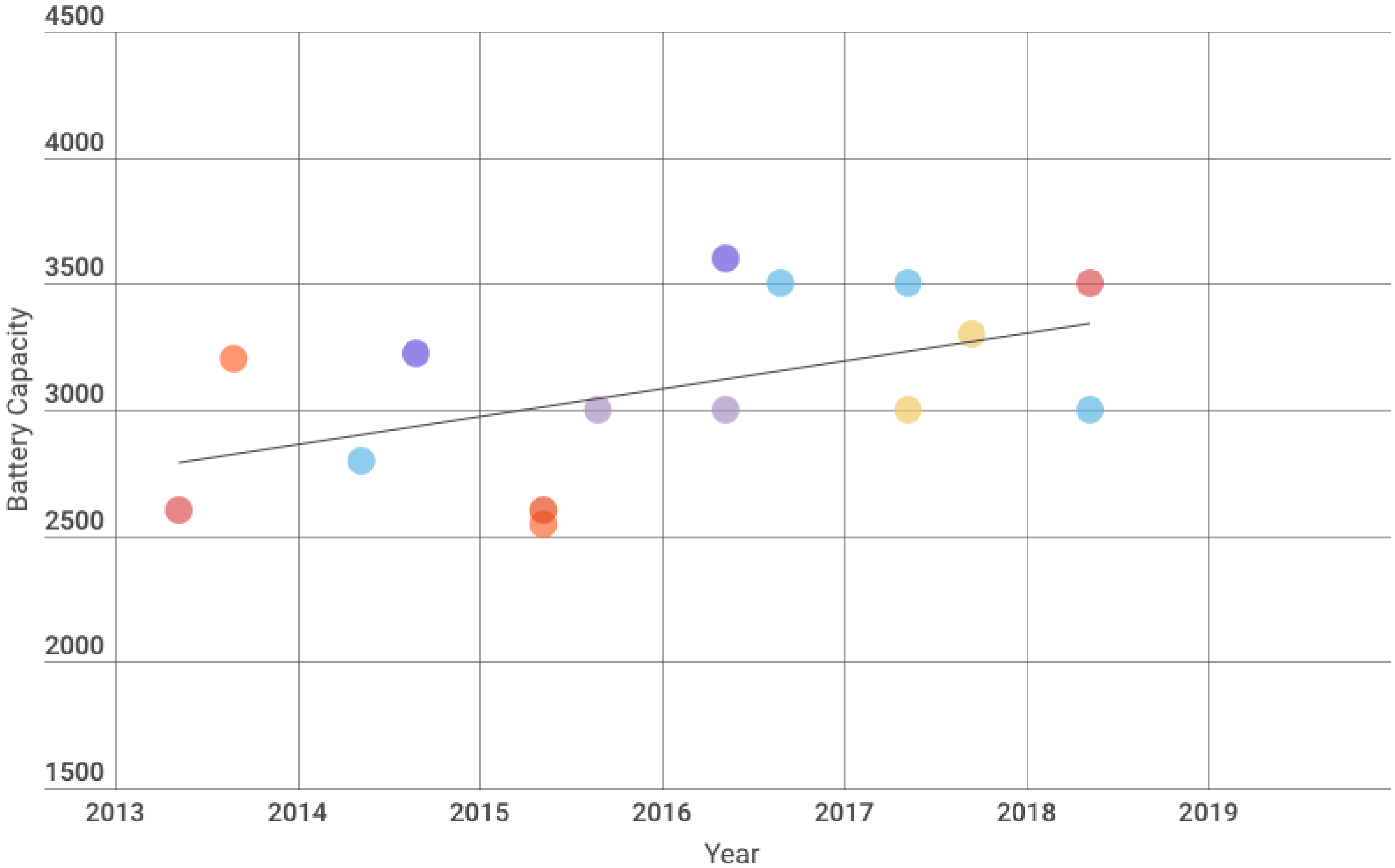
Context

- What is the problem? Matching:
  - Batteries
  - Devices
  - Applications
  - User:
    - App usage
    - Charging behaviour

Device Size, Battery Size

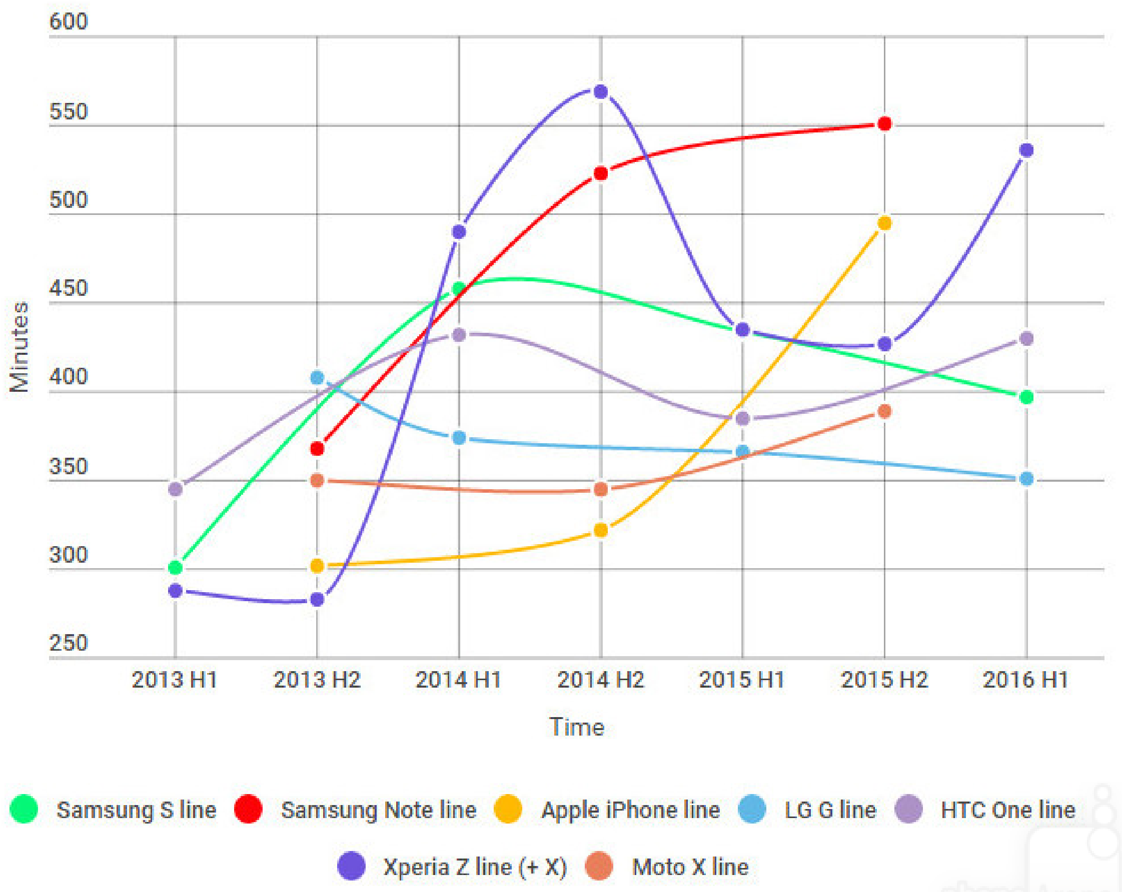
- Over the years mobile devices have become more **powerful**, more fully **featured**, and more essential.
- Resulting:
  - More sensors
  - Faster CPUs
  - Batteries than have grown but not kept up.

Progress in Batteries is Slow



- Example: Capacity on Samsung phones

Progress in Batteries is Slow



- Battery life numbers are mixed too.

Progress in Batteries is Slow

	mAh	Resolution
iPhone 7	1,960	750 x 1334
iPhone 8	1,821	750 x 1334
iPhone 7 plus	2,900	1080 x 1920
iPhone 8 plus	2,691	1080 x 1920
iPhone X	2,716	1125 x 2436
Pixel 2	2,700	1080 x 1920
Pixel	2,770	1080 x 1920
Pixel 2XL	3,520	1440 x 2880
Pixel XL	3,450	1440 x 2560
LG V30	3,300	1440 x 2880
LG V20	3,200	1440 x 2560
Galaxy Note 8	3,300	1440 x 2960
Galaxy Note 7	3,500	1440 x 2560

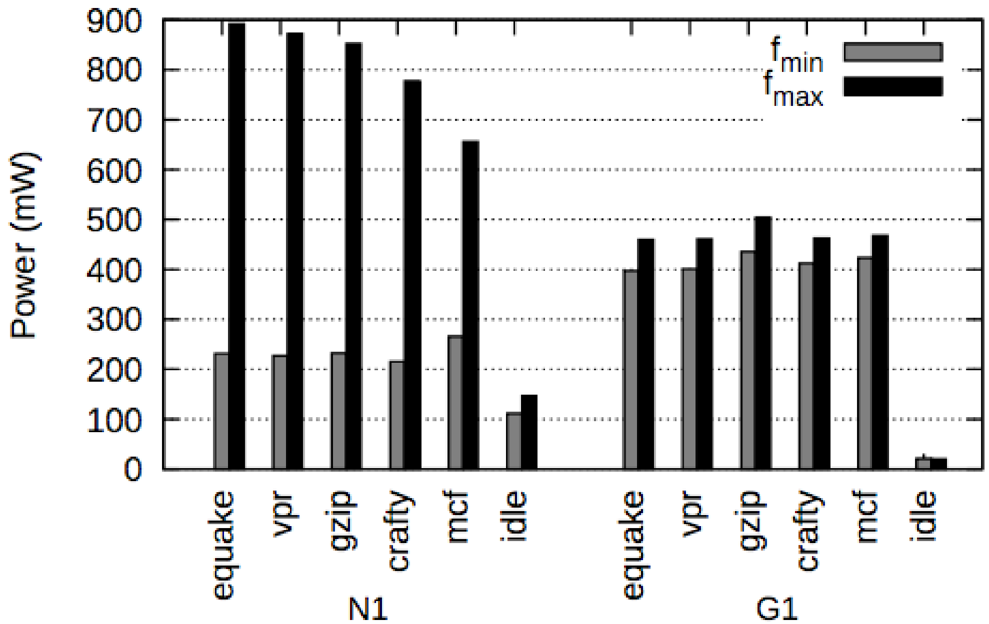
- Battery size and screens go hand in hand: screens create **volume (+)** and **power demand (-).**

Where is Power spent?

- Mobile devices are often power constrained.
- E.g. most smartphones can easily exhaust their batteries.
- Understanding power consumption in mobile devices is important to make choices.

CPU

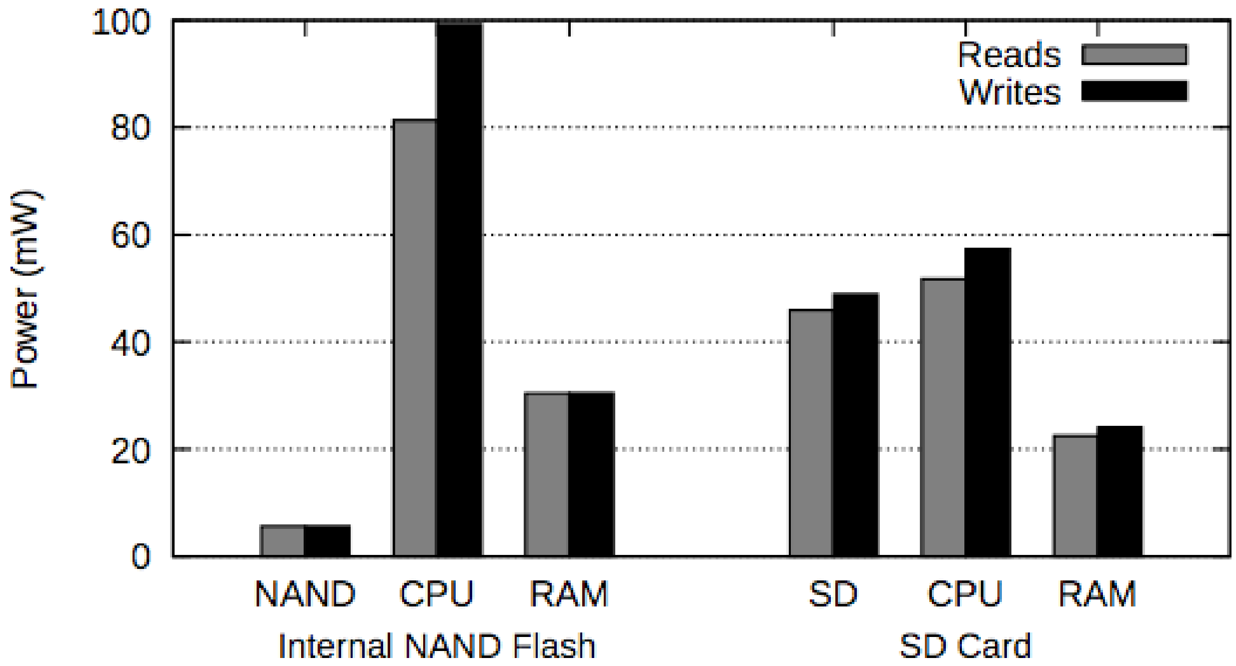
- Highly variable as a power drain.
- Throttling:
  - Doesn't always work.
  - Can be annoying.
  - Is rarely user controlled.



- Adaptive fidelity can be succesful both for CPU and network card power drain reduction.

Storage

- Power costs in access to persistent storage is small
- Circa 20% RAM access with the remaining 80% split between CPU and persistent memory.



Network

- Networking can be a significant source of power consumption, especially because it also triggers CPU activity.
- GSM module: ~800 mW
- WiFi module: ~700 mW
- However, WiFi consumes less power for the same bandwidth.

Other Peripherals

- Screen: Display power consumption in common smartphones is around 6-8 hours at full brightness (e.g. 1000 mW for 10000 mWh@3.7V battery)
- Other common sensors: power varies but tends to be smaller.
- GPS: 150 mW

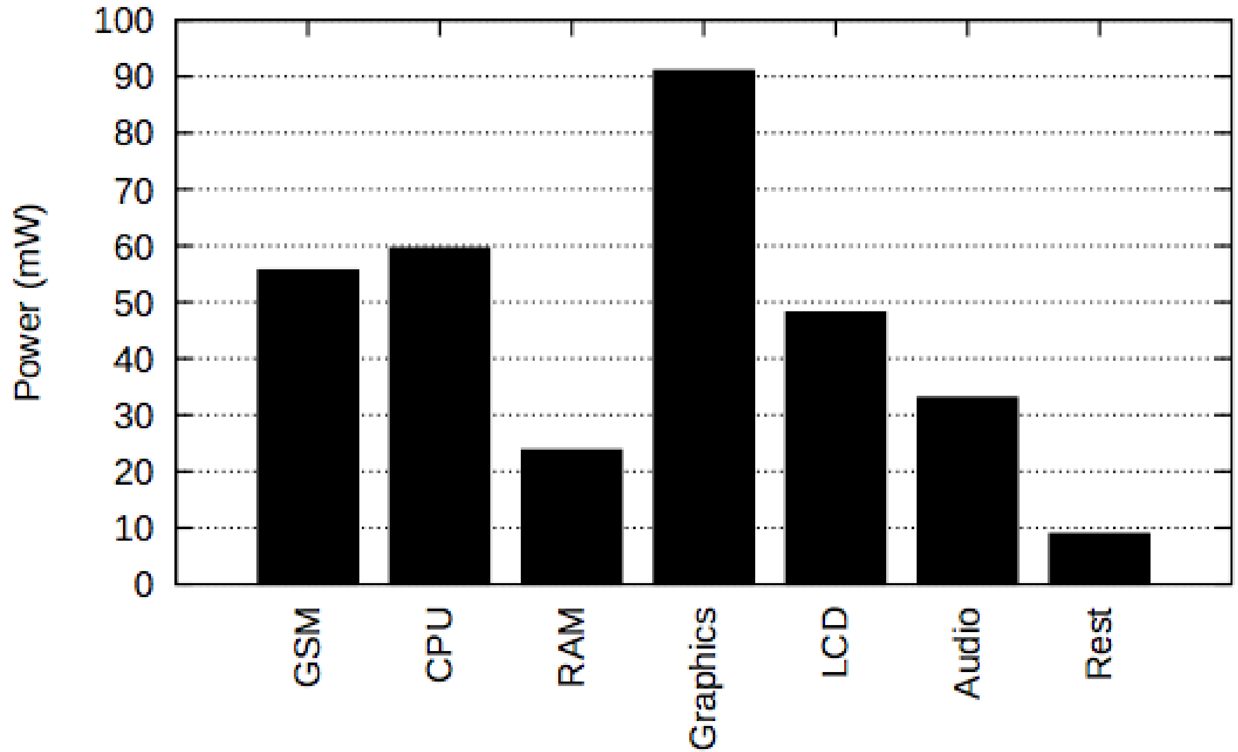
Optimizing Location Sensing

- Mobile applications are more and more location-aware.
- The need for constant location and constant GPS use can be minimized by:
  - **Combining multiple sensors** to reduce the energy consumption while minimising the error, e.g. rare GPS samples + accelerometer.
  - Rely on **probabilistic models** of users' location to infer future locations. (CPU mostly use less power than radio…)
  - Use **heuristics** to adapt the sampling rate, e.g. sampling more when the user is moving or cancelling sampling in areas known not to have GPS coverage.

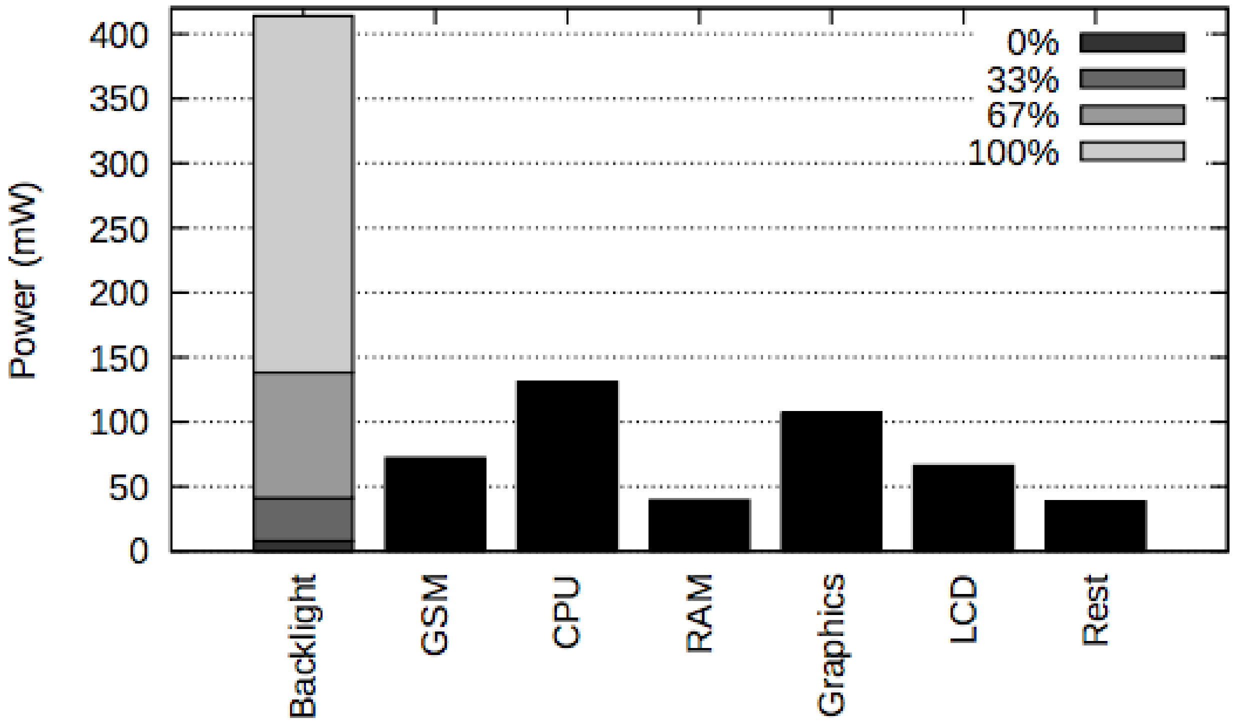
Sources of Power Consumption

- How do they aggregate?
- What are typical application profiles?

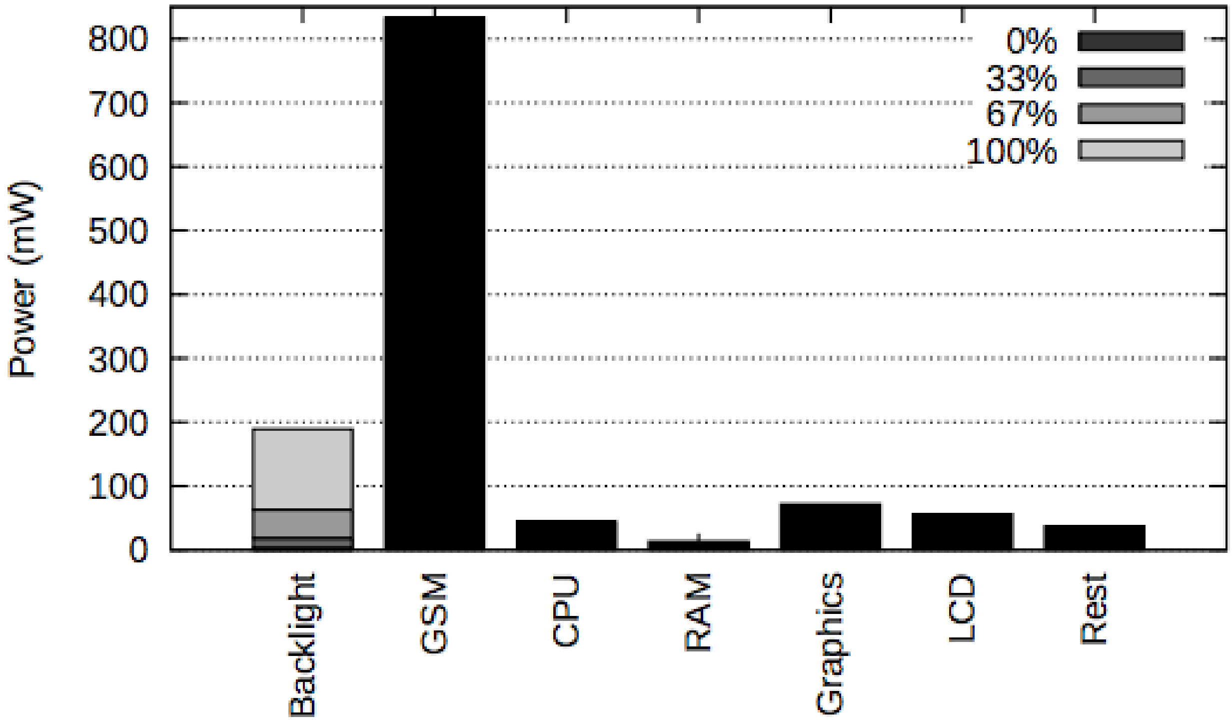
Power profile examples: audio playback



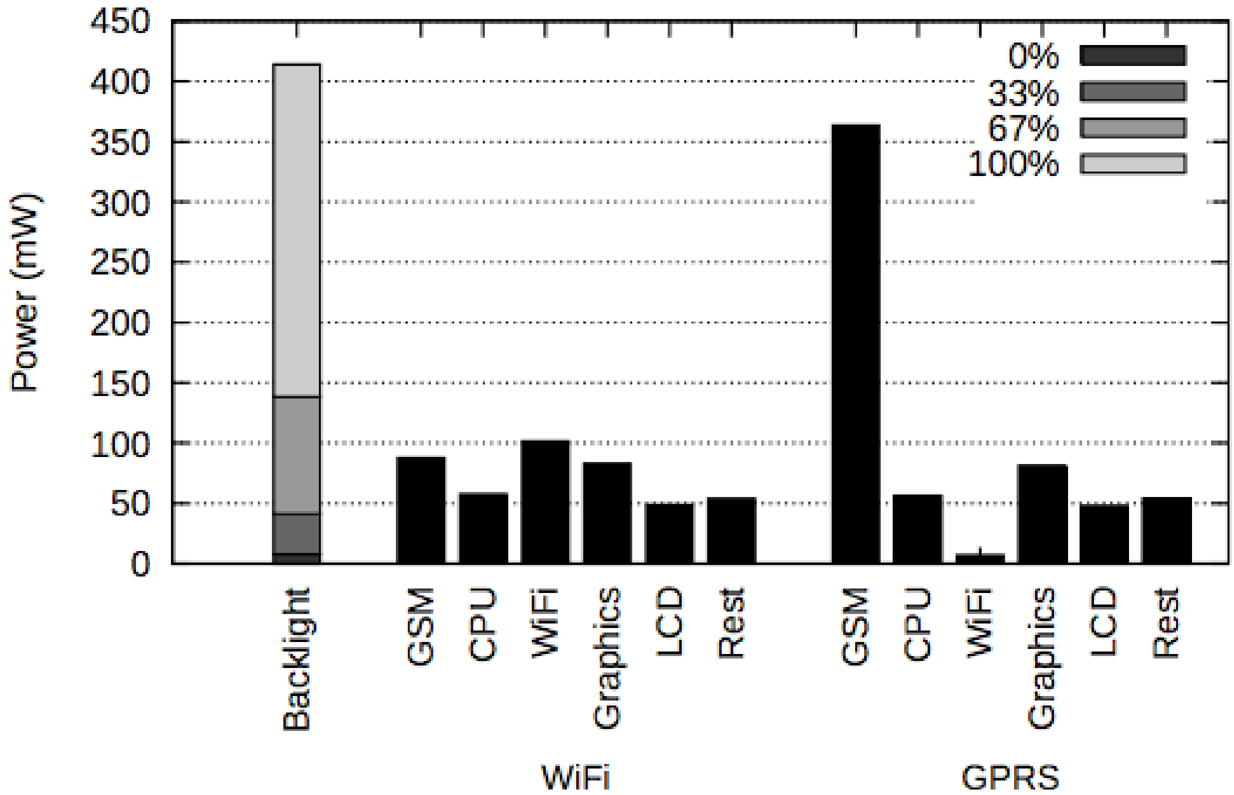
Power profile examples: video playback



Power profile examples: phone call



Power profile examples: email



How to adjust for power optimization

- Efficient power management in mobile platforms is a complex and challenging research problem:
  - due to the multitude of possible hardware configuration options and power states.
  - and the interdependencies between computing, sensing and networking resources caused by applications.

Understanding Users

- **Energy aware operating systems:**
- Who should be responsible for energy management: Applications or operating system? Probably both.
- At the OS level, the main idea is to reduce energy consumption by unifying resource and energy management and by using collaboration between applications and operating system.
- A key part of energy-efficient resources and energy management is having a good understanding of how resources are demanded by users and applications in the system.

OS approach:

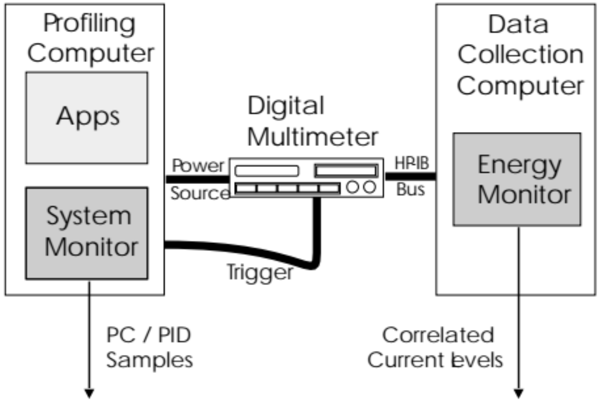
- Several systems adapt operating systems to:
- Disable unnecessary hardware devices.
- Provide fairness between applications using credit systems.
- Use power forecasting to do scheduling.

OS approach: Cinder

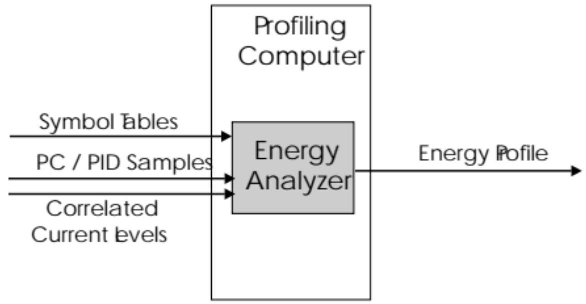
- Cinder [9] is a mobile OS designed on top of the HiStar exokernel that exploits device-level accounting and power modelling.
- Cinder allocates energy to applications using two abstractions called **reserves** (batteries) and **taps** to form a graph of resource consumption.
- When an application consumes a resource, the Cinder kernel reduces the values of the corresponding reserve and its scheduler only allows threads to run if they have enough reserves to run.
- The rate at which the reserves are being consumed is controlled by taps which are defined as special-purpose threads whose only role is to transfer energy between reserves (they support constant and proportional rates).
- Once an application has consumed all its reserves, the kernel prevents its threads performing more actions.

Power Modelling: Powerscope

- Mapping Energy to code procedures
- Powerscope: identifies applications behaving as energy sinks.
- Requires an external power meter and a second computer to reduce any possible interference at the profile stage.
- Uses statistical sampling to collect traces.
- This approach is not scalable since it requires repeating the off-line training for every single hardware configuration and machine.



(a) Data Collection



Powerscope: A tool for profiling the energy usage of mobile applications.Flinn, Jason and Satyanarayanan, Mahadev. Proceedings WMCSA'99. Second IEEE Workshop on Mobile Computing Systems and Applications. 1999.

User Modelling

- User based energy management requires:
- 1) understanding the charging-discharging cycle the users impose on phones.
- 2)Knowing how users interacts with their handsets (and particular resources), and therefore how they demand energy.

Charging Prediction

- There are 3 types of users:
  - opportunistic chargers, light-consumers and night-time chargers.
- EET, a predictive model:
  - Tries to determine the subset of high-level energy characteristics that differentiate users.
  - It is possible to predict the energy level on a mobile handset within 7% error within an hour and within 28% error within 24 hours.

User Behaviour

- Users do typical 20-100 phone use sessions of 10 to 250 s. Sessions are longer at night than during the day.
- User app use is strongly related to location and time of day.
- App category and usage duration is correlated for individual users.

Conclusions

- Smartphones continue to become more powerful.
- The evolution of batteries has been slower.
- Power consumption is mostly dominated by the screen and networking.
- Power usage and charging patterns can be learned and harmonized.
- Any application can contribute to power saving. **Be frugal as a developer!**