Beyond operational efficiency: Nontraditional efforts for carbon-efficient computing

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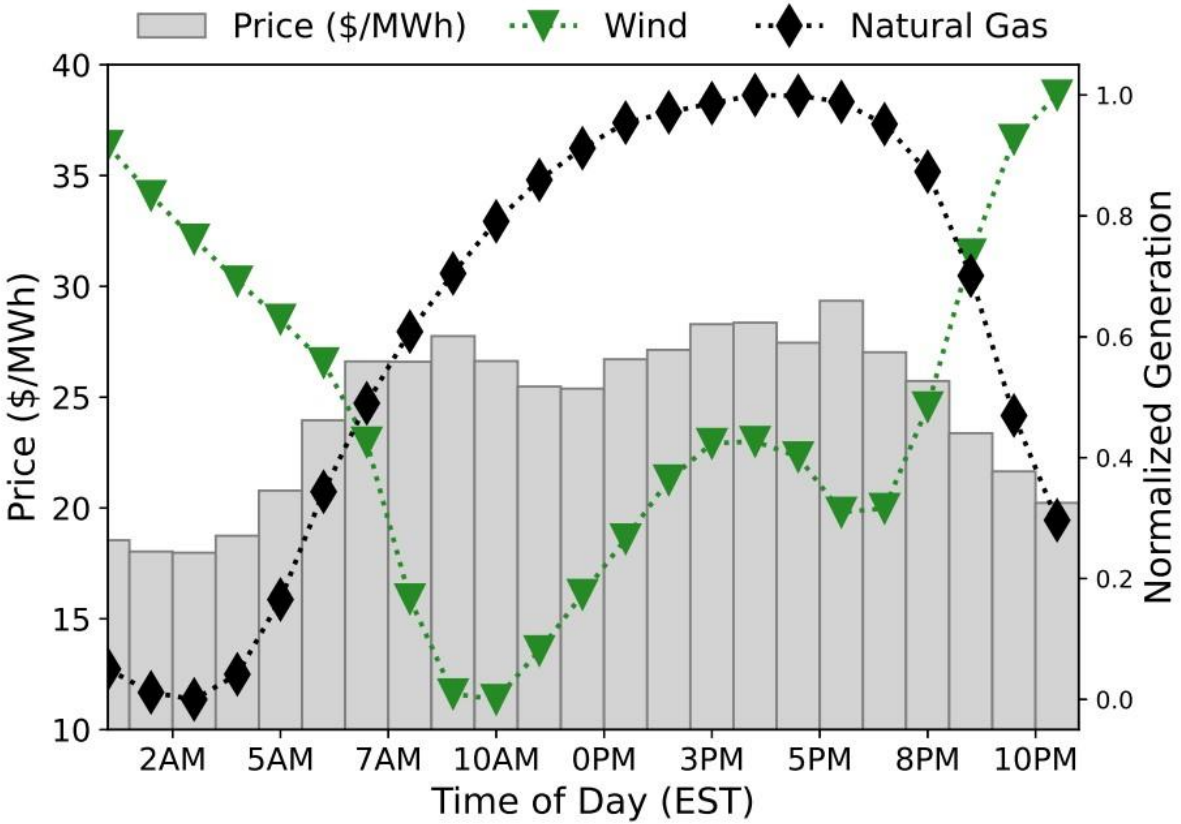
Part 1

Information batteries

Storing opportunity power with speculative execution

Motivation

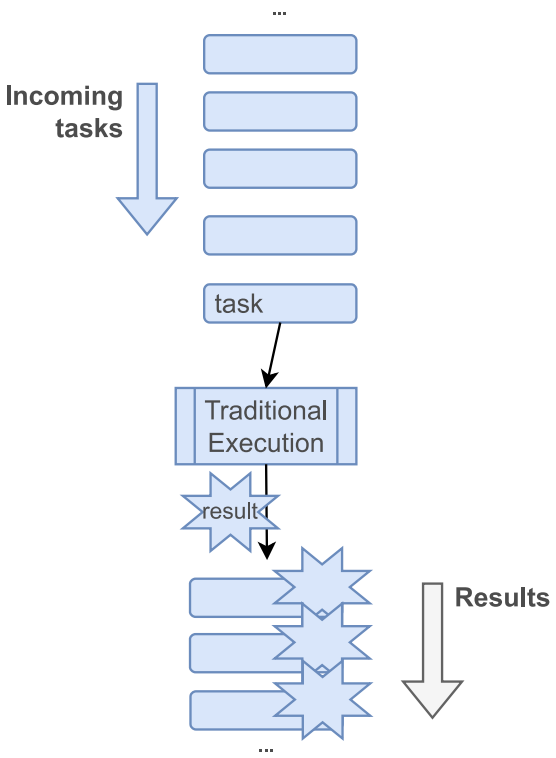


Demand and renewable energy production tend to be **out of phase**.

Opportunity power is renewable energy that is curtailed (thrown out) or sold at a negative price due to this disconnect.

Main idea: Pre-compute speculatively during periods of opportunity power.

System design



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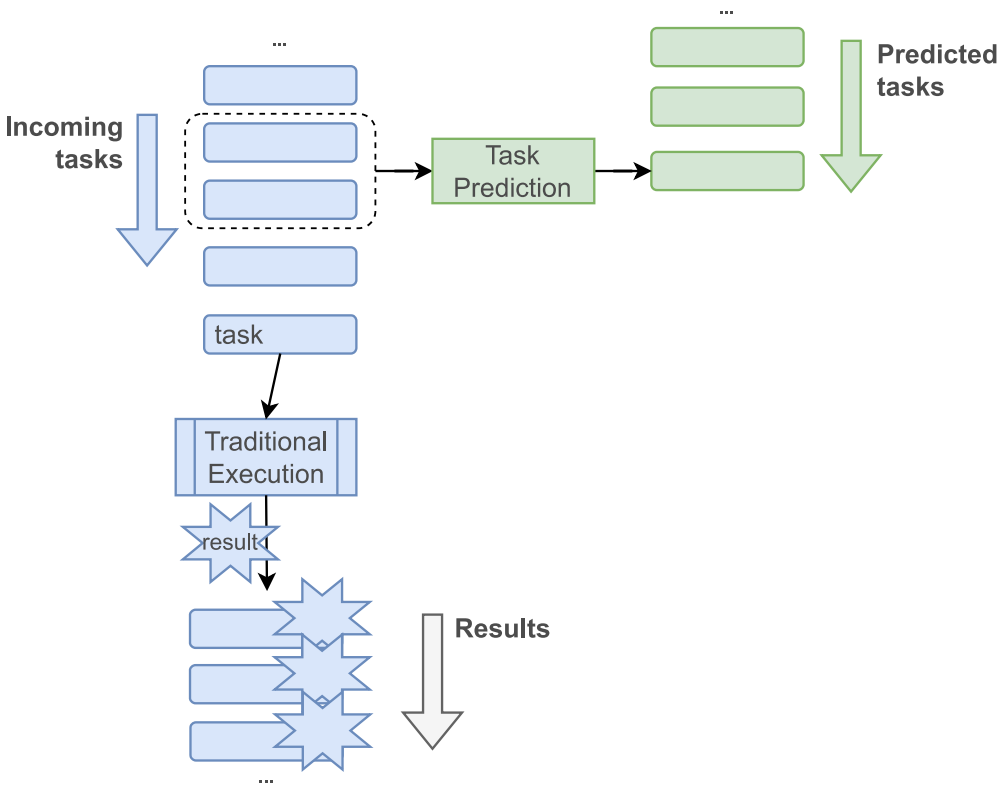

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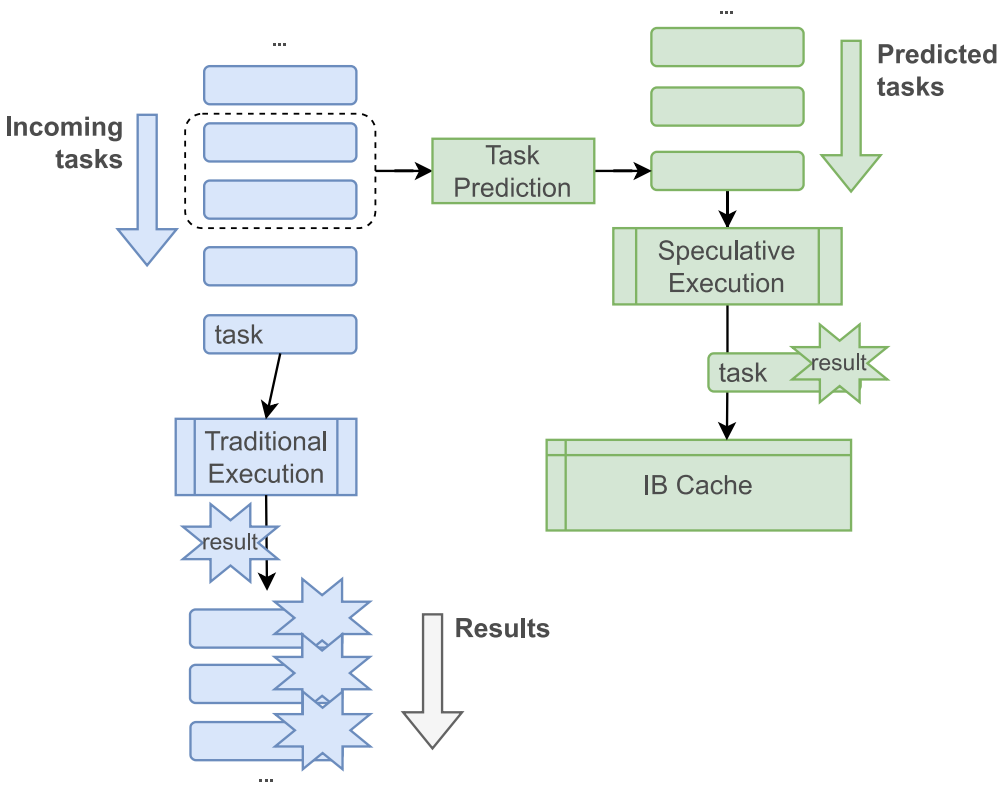

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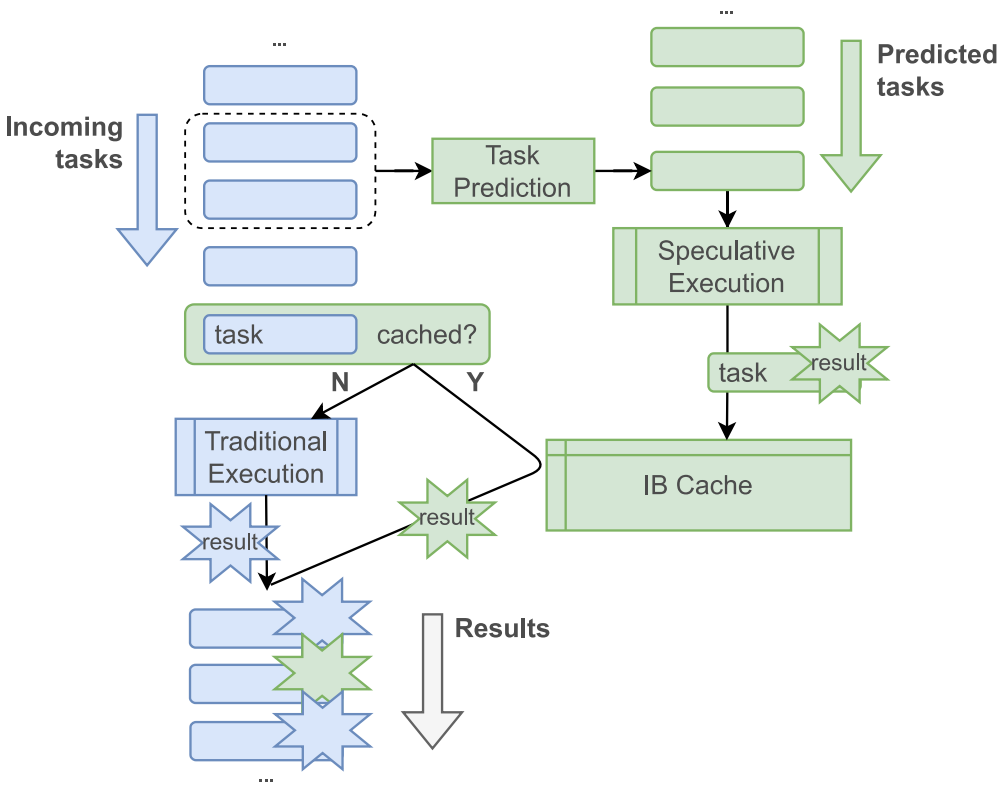
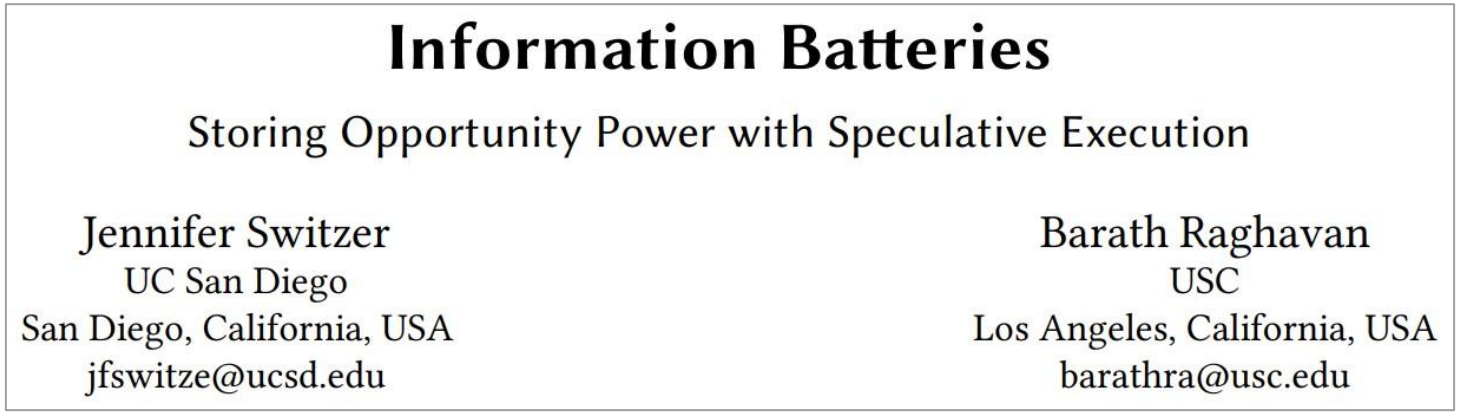


Insights from simulation

- Accurate price prediction is essential.
- Cache latency must be small compared to task runtime.
- Savings can be had even with imperfect task prediction (e.g. 30% accuracy).

Please see the paper for more details



Information Batteries

Storing Opportunity Power with Speculative Execution

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Part 2

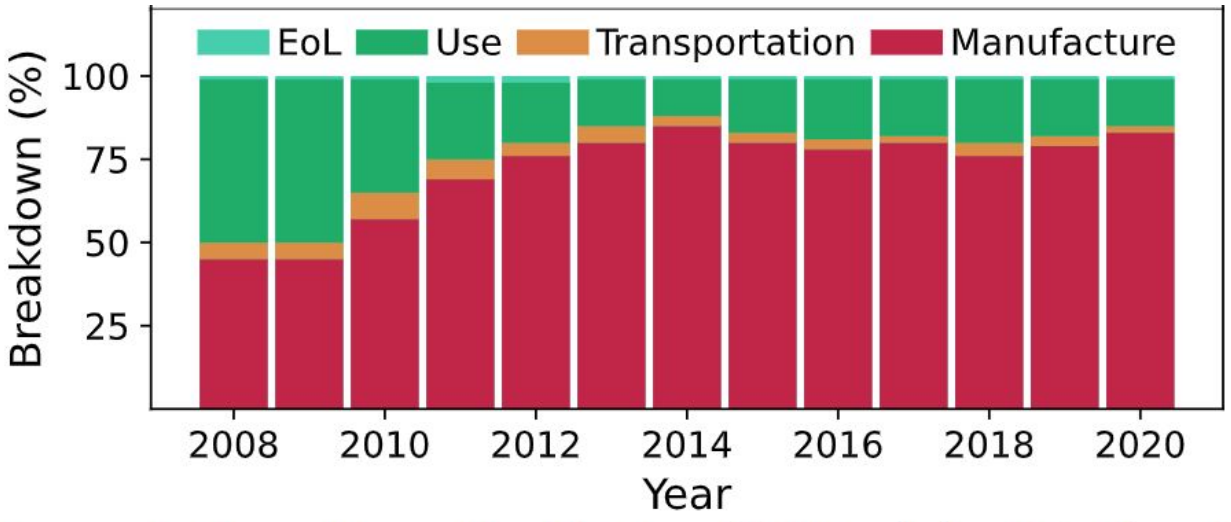
Junkyard datacenters

Carbon-efficient computing systems from old phones

How many smartphones have you had in your life?

Most of these phones were still functional!

Short lifetimes + low power = Majority of carbon emissions from manufacturing.



Example from Apple.

The result: Reducing carbon intensity requires extending lifetimes.

Takeaway 6: *Given the energy-efficiency improvements from software and hardware innovation over the last decade, amortizing the manufacturing carbon output requires continuously operating mobile devices for three years—beyond their typical lifetime.*

Gupta et al. “Chasing Carbon: The Elusive Environmental Footprint of Computing” HPCA ‘21.

If we want CO_2 manufacture = CO_2 use, we need to double lifespans

Problem: Lifetime extension is hard.

Consumers want new phones.

Refurbishing market is limited.

Recycling is hard, and only recovers raw materials.

Idea: Lifetime extension through *repurposing*.

What else can a smartphone be?

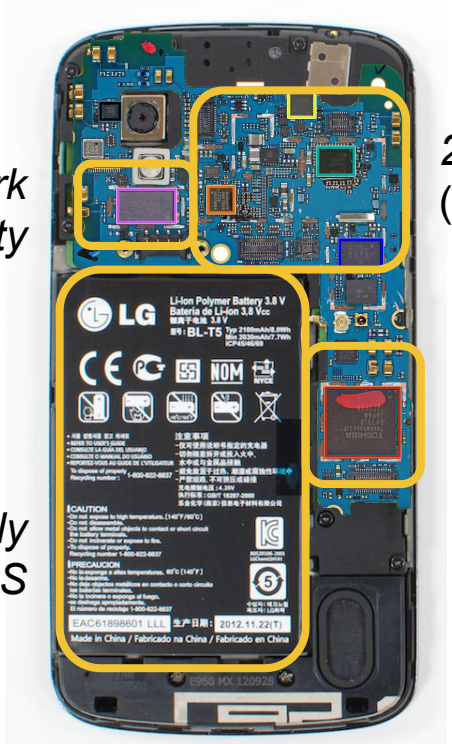
A baby monitor?
A parking meter?
A wildlife monitor?
A datacenter?

=

?

What's in a phone

1. Network connectivity

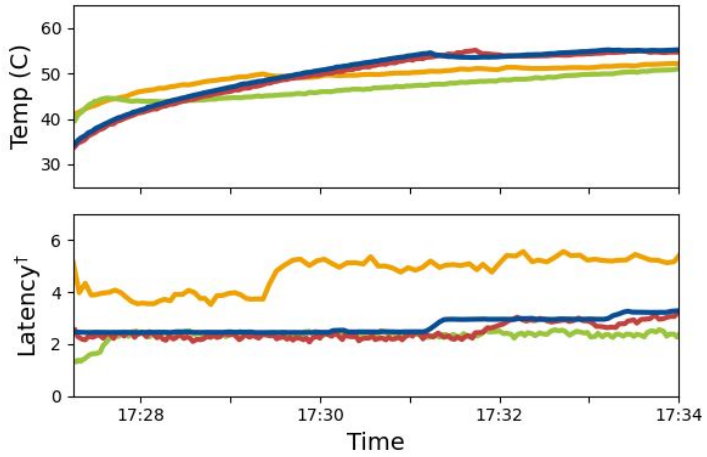


2. Processors (CPU & GPU)

3. Power supply & UPS

4. Storage

5. Thermal throttling

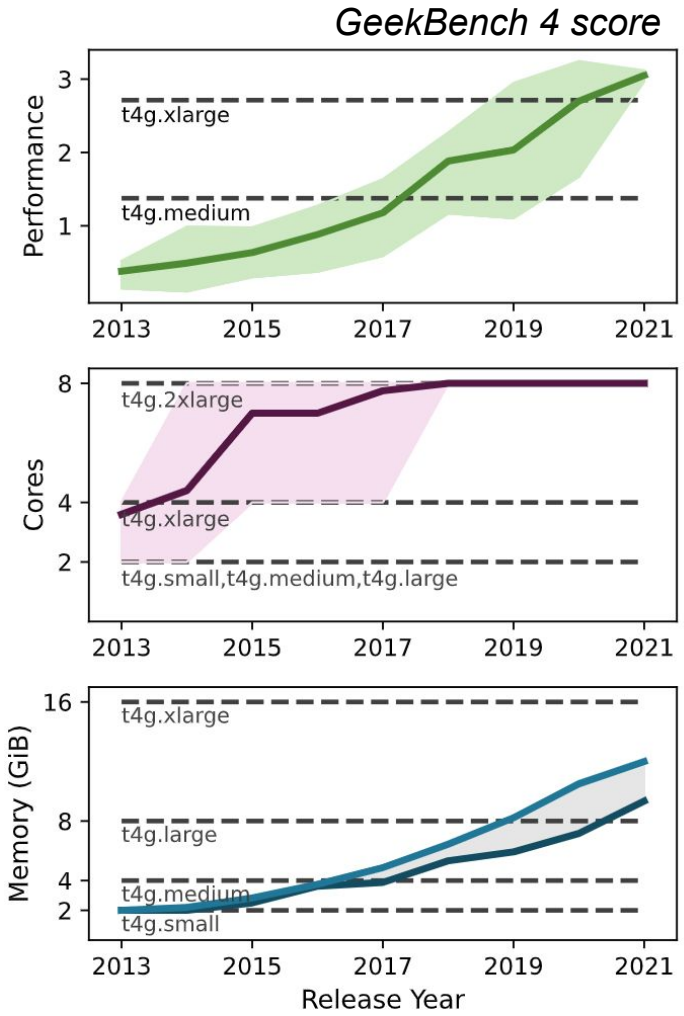


What's in a phone

Smaller-scale machines are popular for cloud applications.

Dotted lines show AWS' current-day "burstable cloud" offerings.

Curves represent the average from the most popular 5 smartphones released each year.



What's *not* in a phone (Challenges)

Challenge 1. Smartphones aren't meant for continuous operation.

– They expect human input & may stall without it
– Performance saturates over time
– Battery is not designed for continuous use

What's *not* in a phone (Challenges)

Challenge 1. **Smartphones aren't meant for continuous operation.**

Challenge 2. They still can't compete with a server.

	SGEMM	**PDF Rendering**	**Dijkstra**
PowerEdge Server	2,170 Gflops	3,140 Mpixels/sec	80.2 MTE/sec
Nexus 5	16.8 Gflops	85.8 Mpixels/sec	3.31 MTE/sec
Slowdown	*130x*	*37x*	*24x*

Goal: Build a server from old smartphones that is *carbon-efficient* despite these challenges.

Quantifying Carbon

We define a new metric: Computational Carbon Intensity (CCI)

$$\text{CCI} = \frac{\text{Carbon}}{\text{Computational work done}}$$

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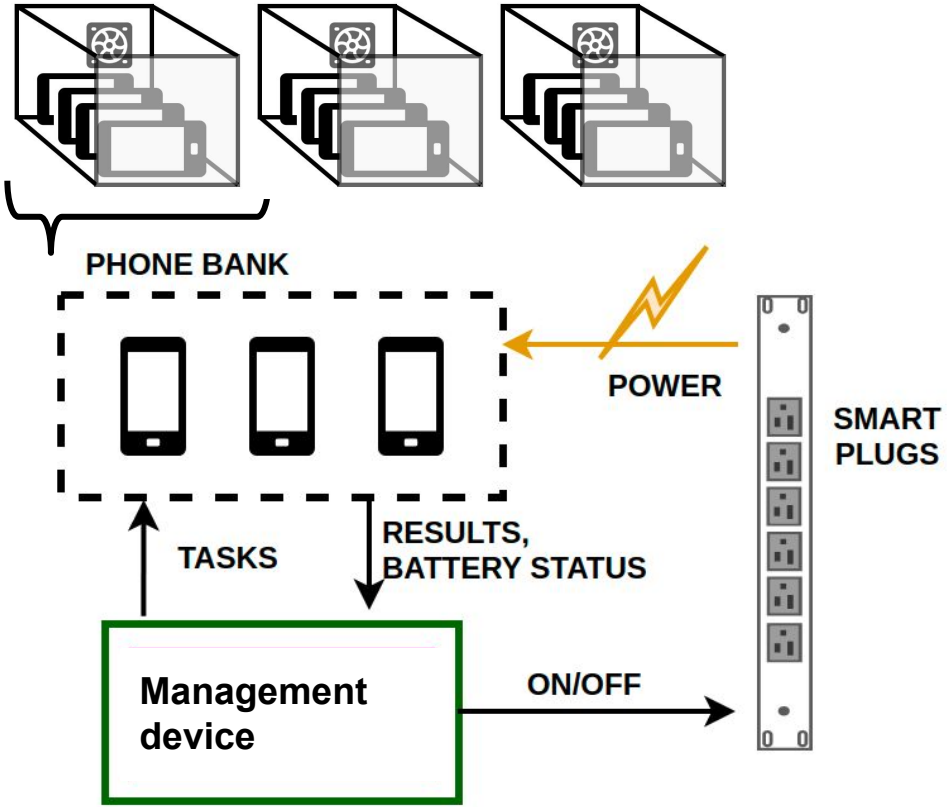
Definitions might vary depending on application

Challenge 1: Continuous Operation

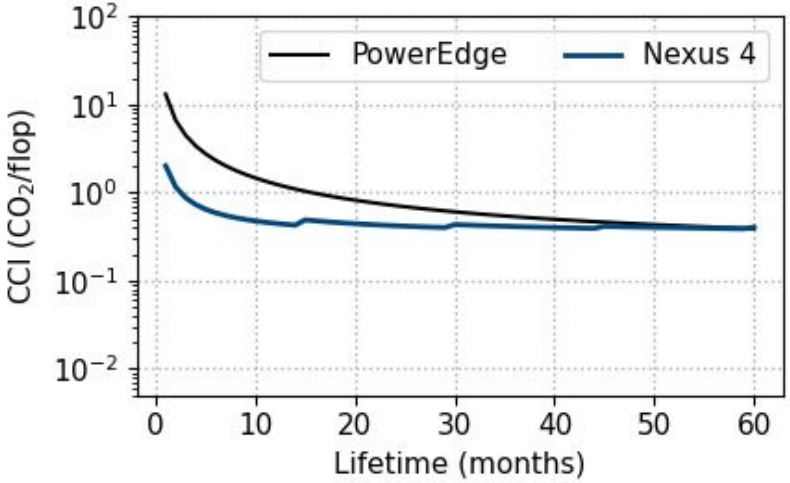


Proposal: Phones in a box.

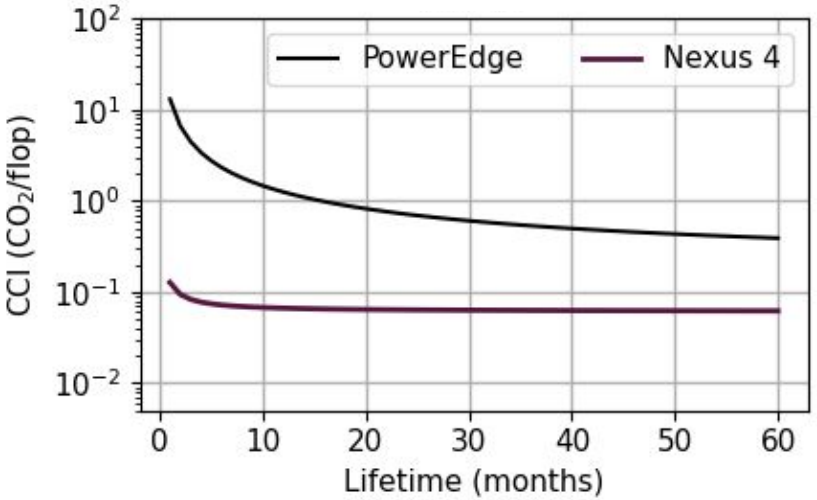
- Redundancy
- Power management
- FaaS-like interface for programmability

Projections

CA Energy Mix



Solar only



This assumes that:

- Batteries are replaced periodically
- Moderate cooling employed
- 80% of devices are computing

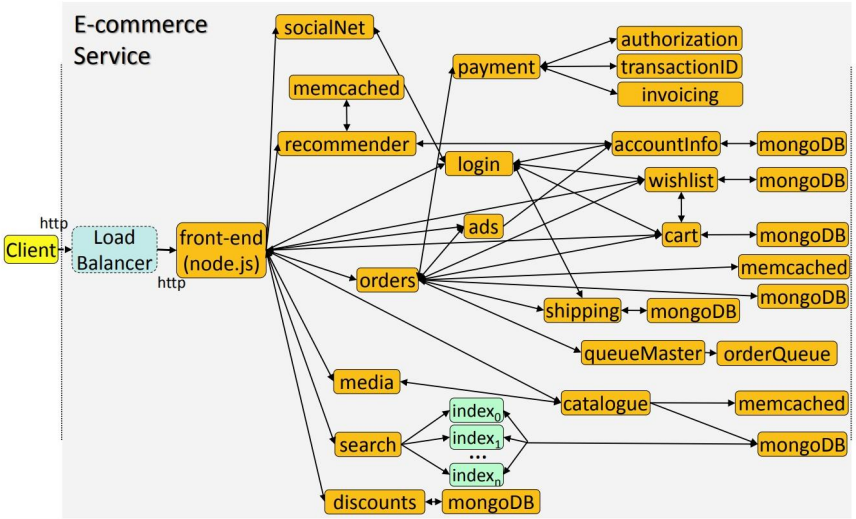
$$CCI = \frac{C_{manufacture} + C_{use}}{\text{Computational work done}}$$

Challenge 2: Per-device Computational Power (WIP)

Q: How can we make a cluster of small devices do large-scale work?

A: Microservices.

Microservices break down large applications into smaller, single-purpose components



Gan, Yu, et al. "An open-source benchmark suite for microservices and their hardware-software implications for cloud & edge systems." *ASPLOS '*19.

Summary

Smartphones are carbon intense to manufacture, and discarded quickly.

They are capable of so much more than what we ask of them!

Let's open up new avenues for reuse, and recover some of the

450 million tonnes = 2 million statues of liberty 

of sunk carbon that we carry around in our pockets.