

Software Defined Batteries

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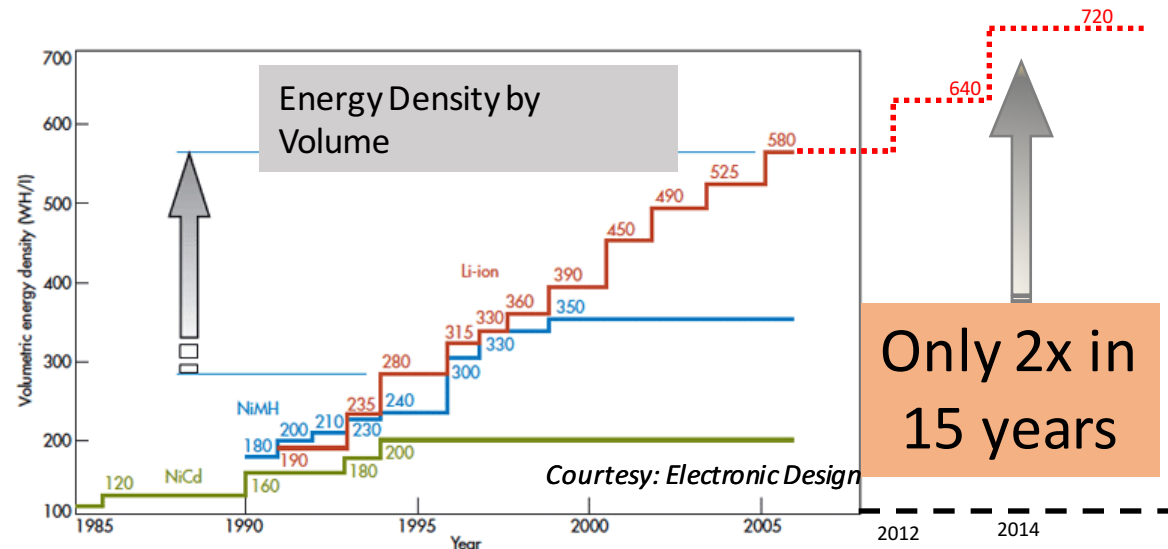
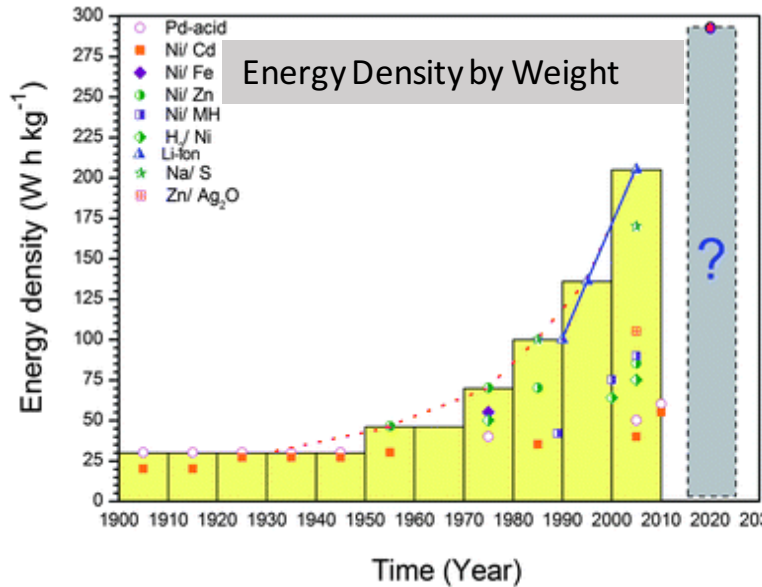


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Evolution of Phones vs. Batteries



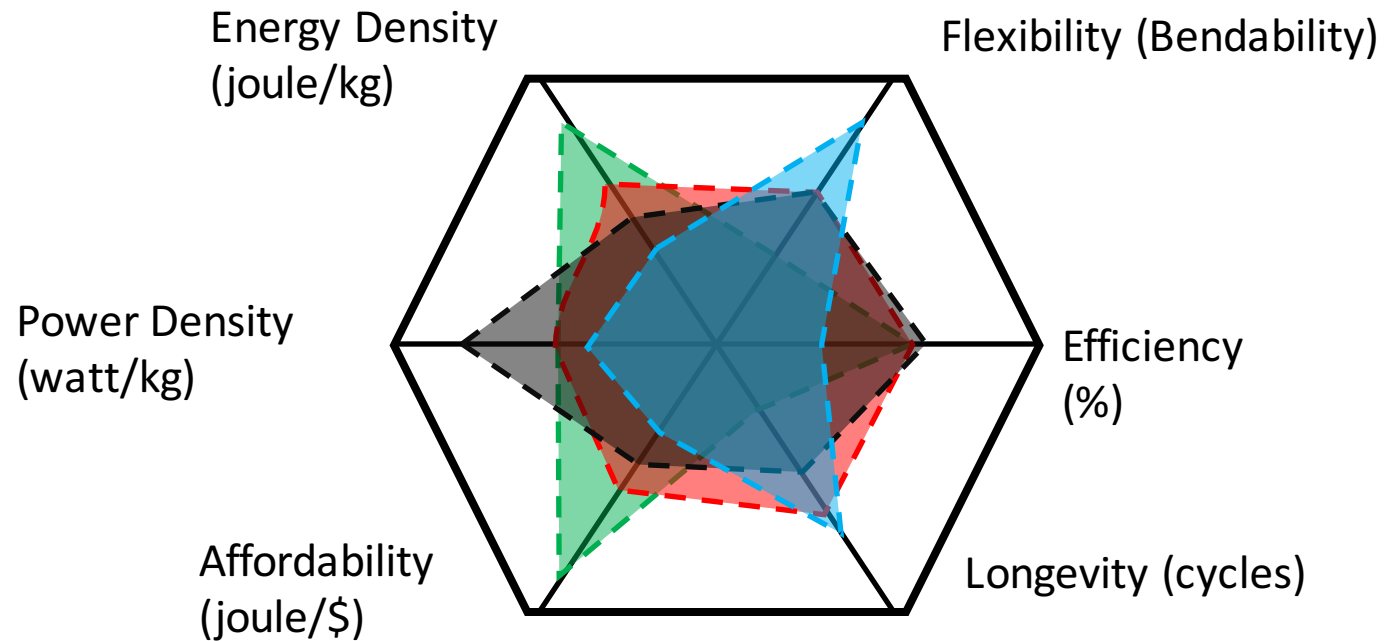
Multi-core processors, LTE, Wi-Fi, larger displays, sensors, ...



Only 2x in 15 years

New battery technologies

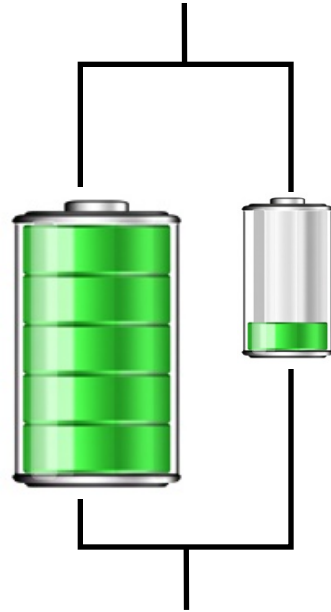
Traditional Li-ion battery vs. emerging battery technologies
Fast-charging batteries: Charge in five minutes
Flexible batteries: Maximize capacity



Problem: Every battery has its benefits and drawbacks

Key insight: Combine batteries of different chemistries

How to connect them?



Need identical chemistries
with similar voltage curves

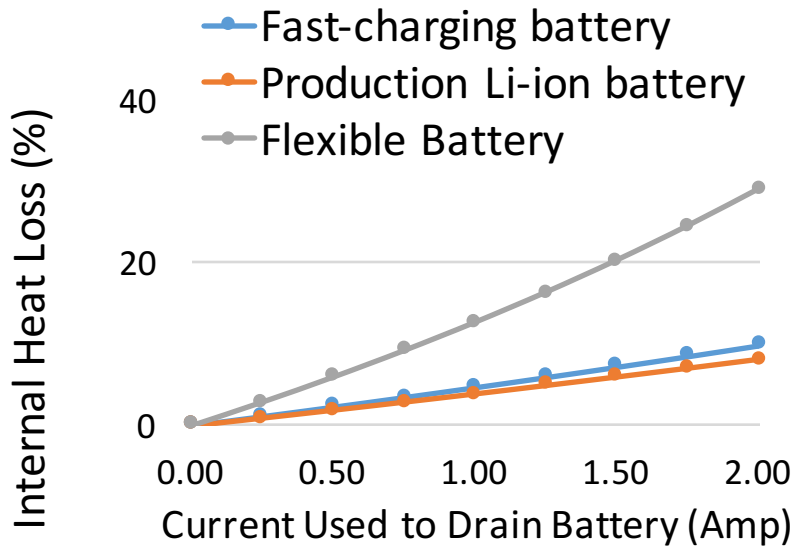
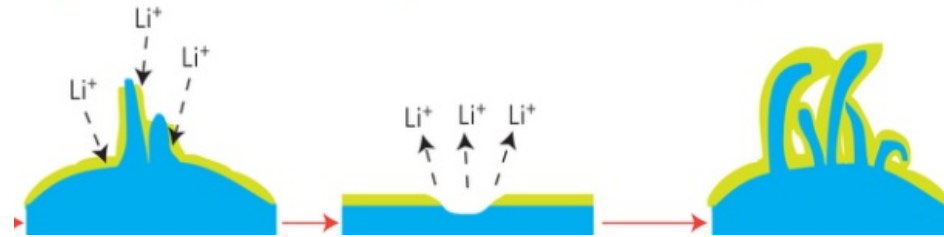
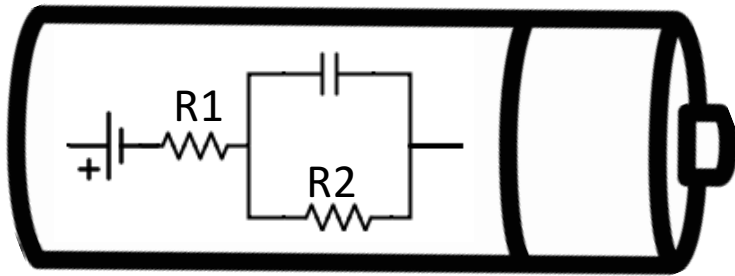


Need similar capacities

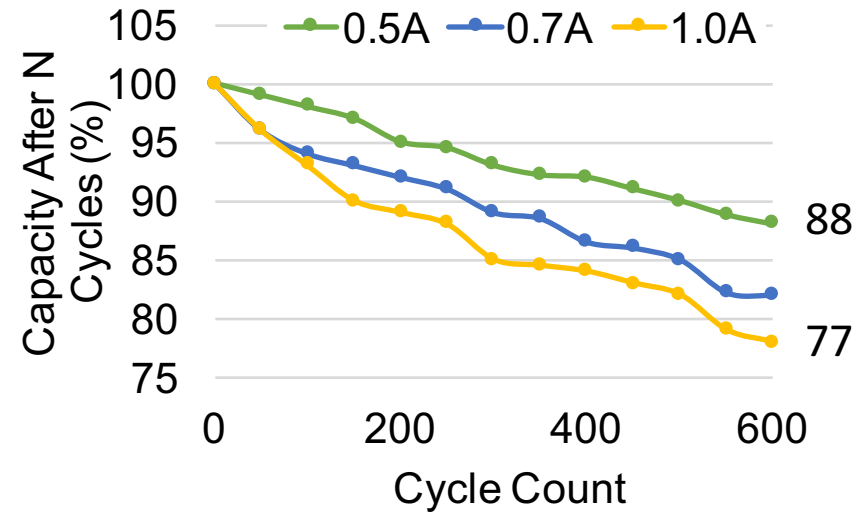
Need for fine grained control of power in/out of each battery

Fine grained power control

Power determines loss and longevity.

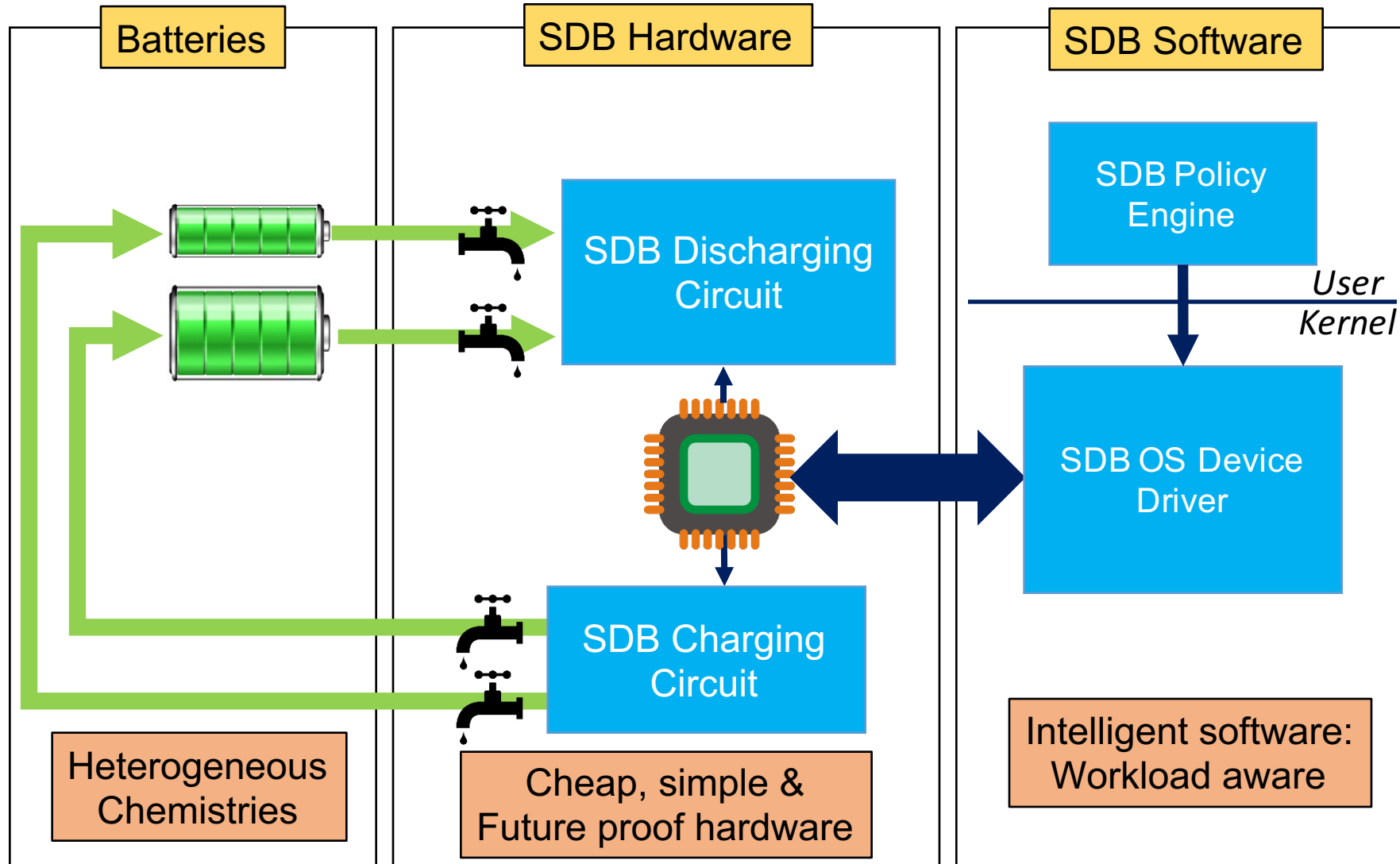


Loss (efficiency) vs Power



Longevity vs Power

Software Defined Batteries



SDB Battery



SDB Hardware

Goals:

1. Accurate & efficient power flow control (in & out)
2. Minimal silicon changes, low cost, small form-factor

Discharging:

Fine-grained load sharing across batteries

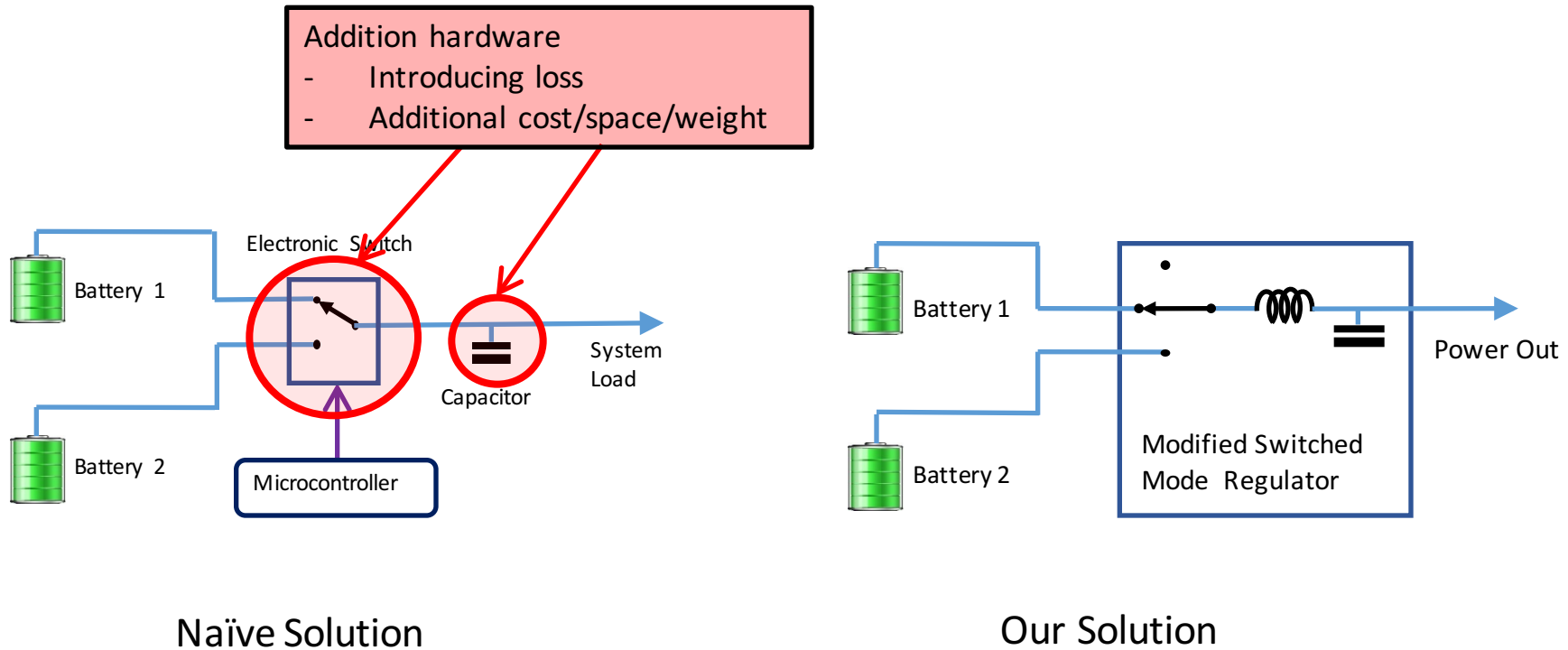
Charging:

Change charge current, charge one battery from another

SDB Hardware - Discharging

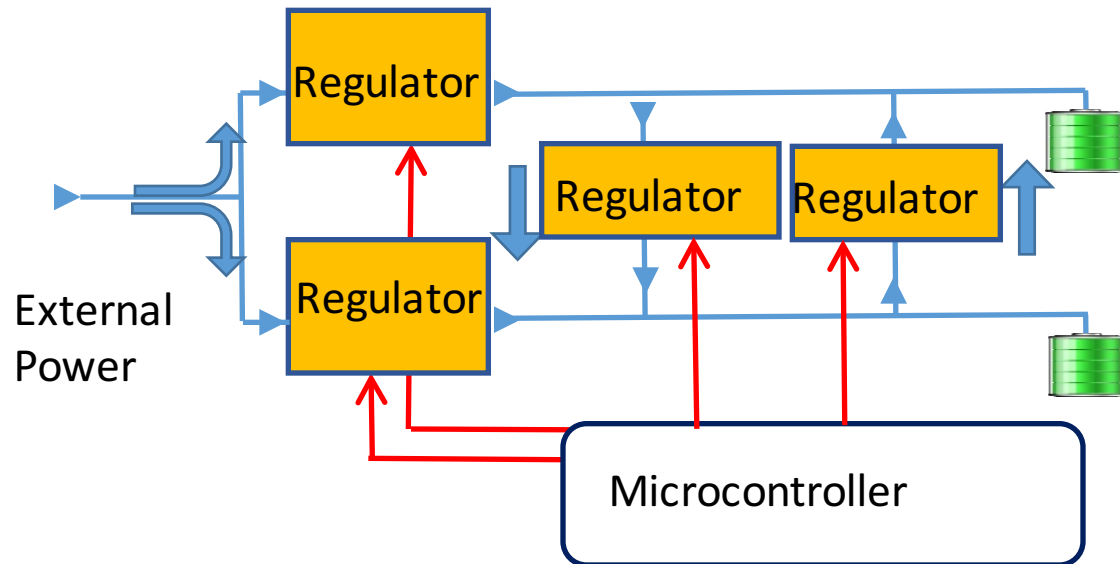
How is fine-grained load-sharing achieved?

- By switching between batteries at a high-frequency
- By spending configurable amount of time on each battery



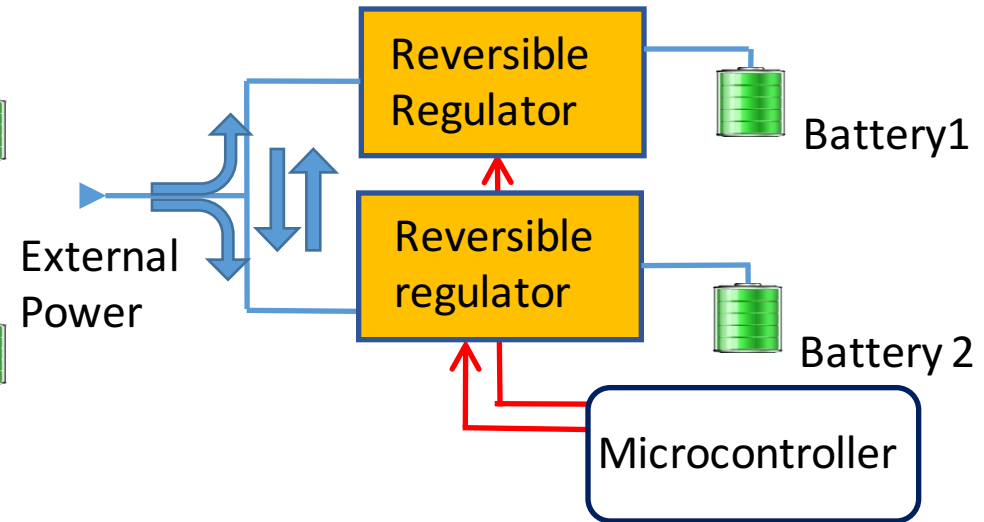
SDB Hardware - Charging

N^2 Regulators!



Naïve Solution

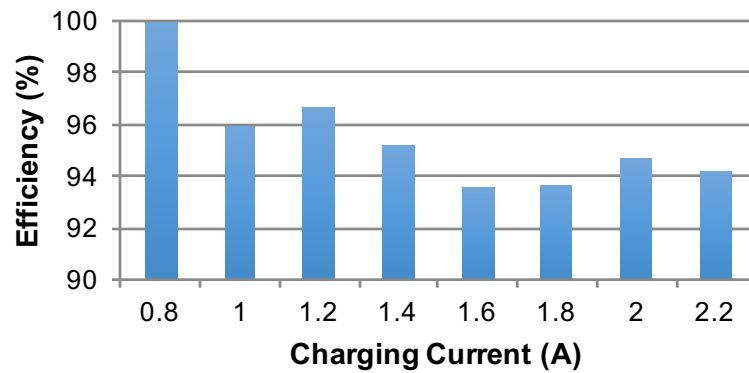
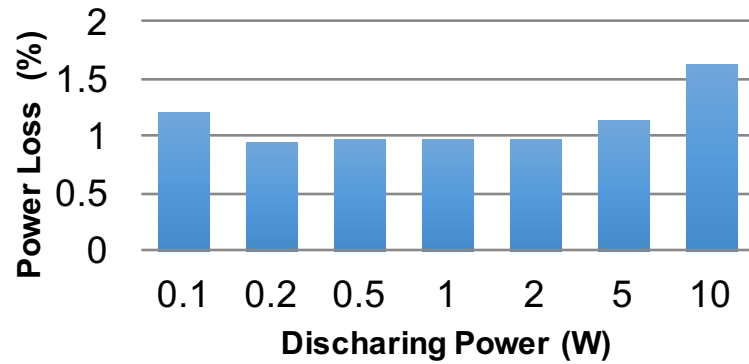
N Regulators using reversible regulator



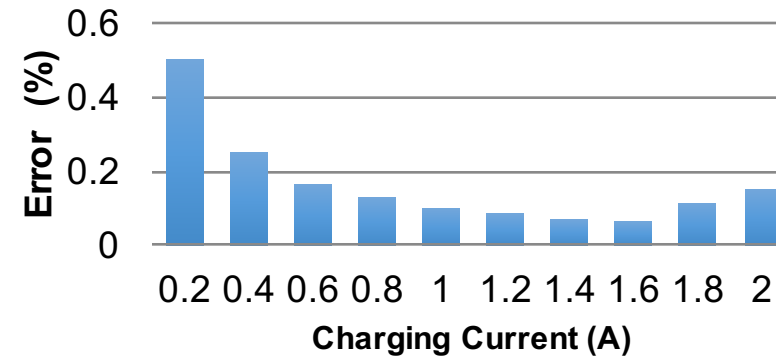
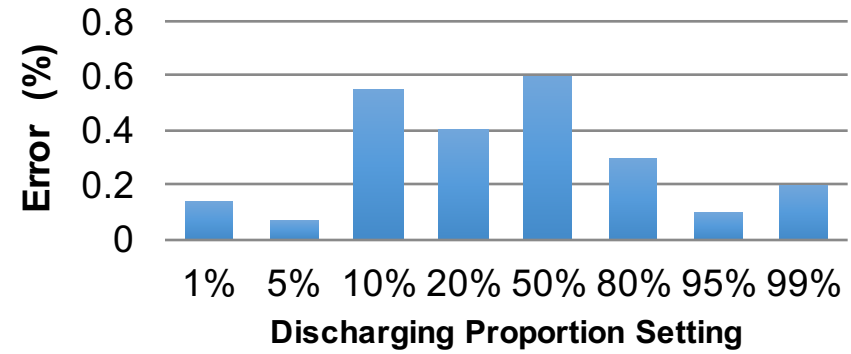
Our Solution

SDB Hardware - Evaluation

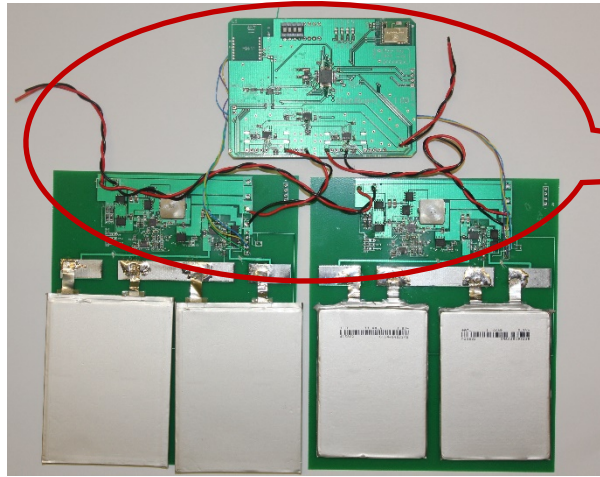
Efficiency



Accuracy



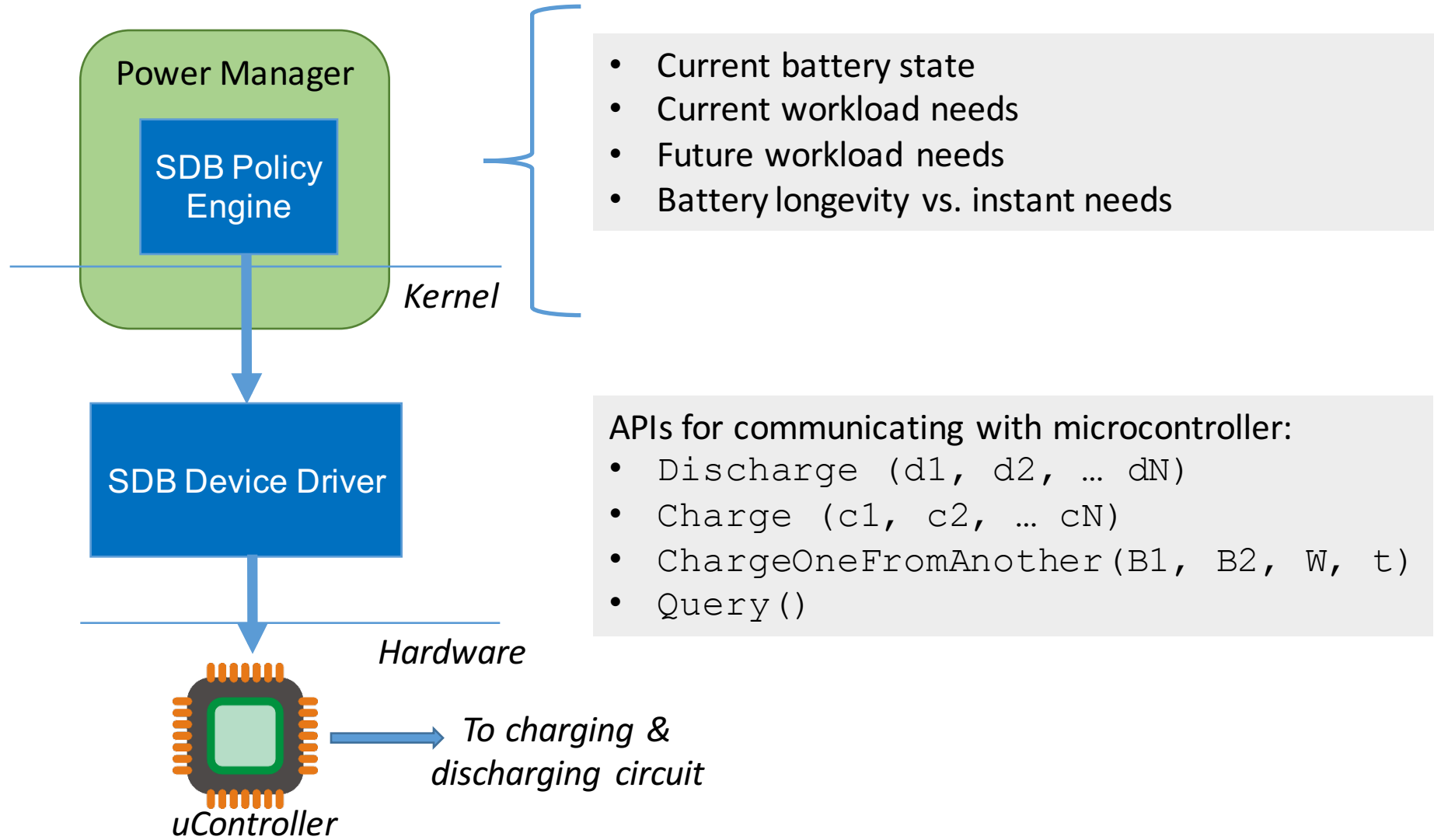
SDB Hardware Cost



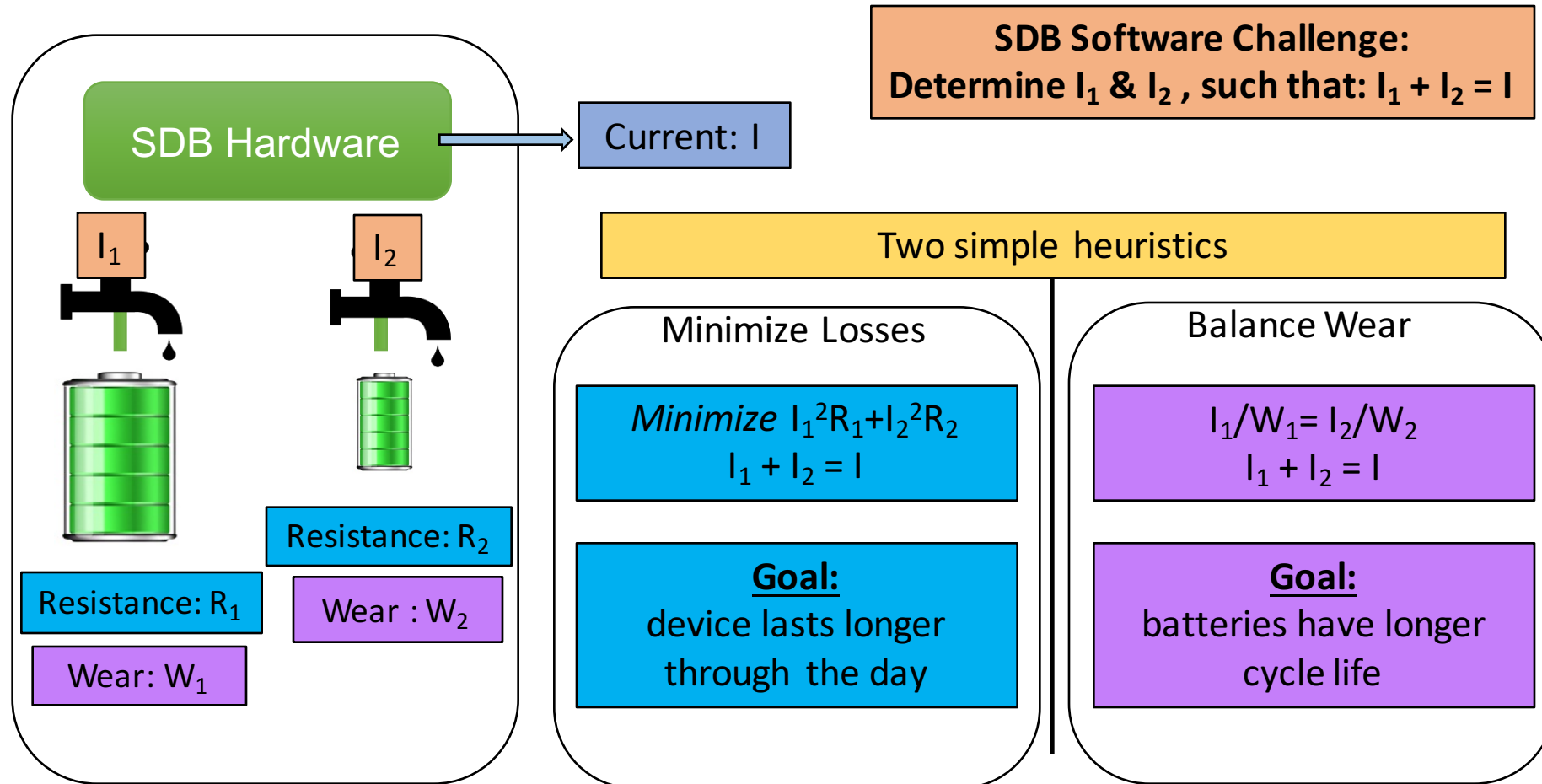
Power Management Circuit
(PMIC)

- Switching/sharing → integrated into existing PMIC
- Negligible extra silicon → tens of cents per IC
- No new chips → no additional weight or volume

SDB Software

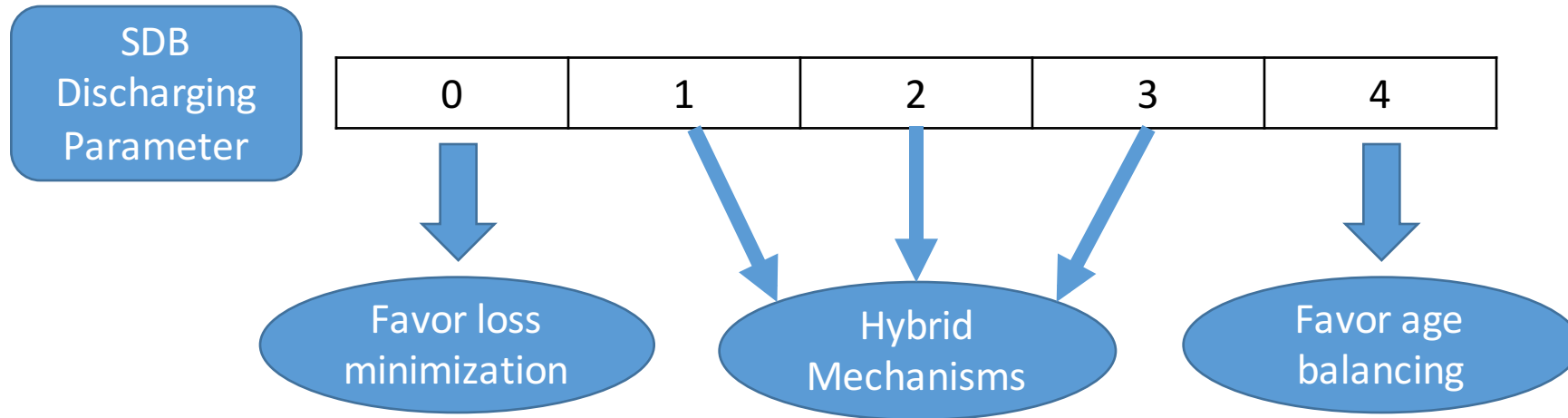


SDB Algorithms: For Discharge



SDB API: Meet User's Needs

Simple parameter to capture user's need



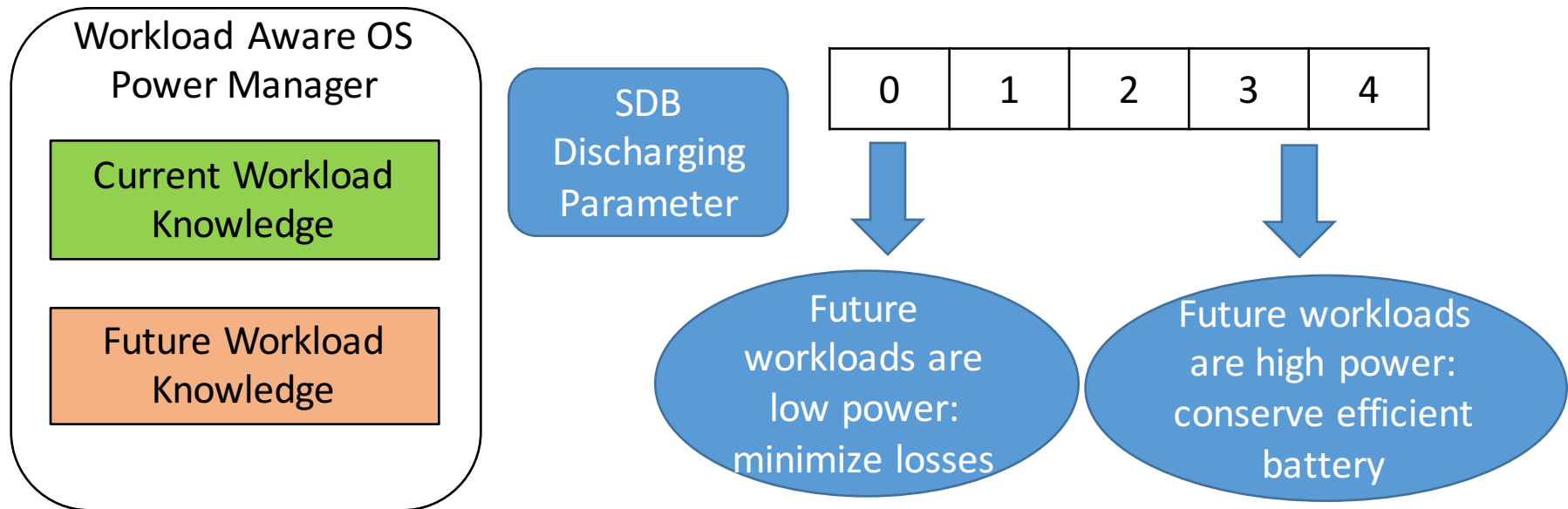
Policy engine picks algorithm based on selected parameter

SDB API: Meet User's Future Needs

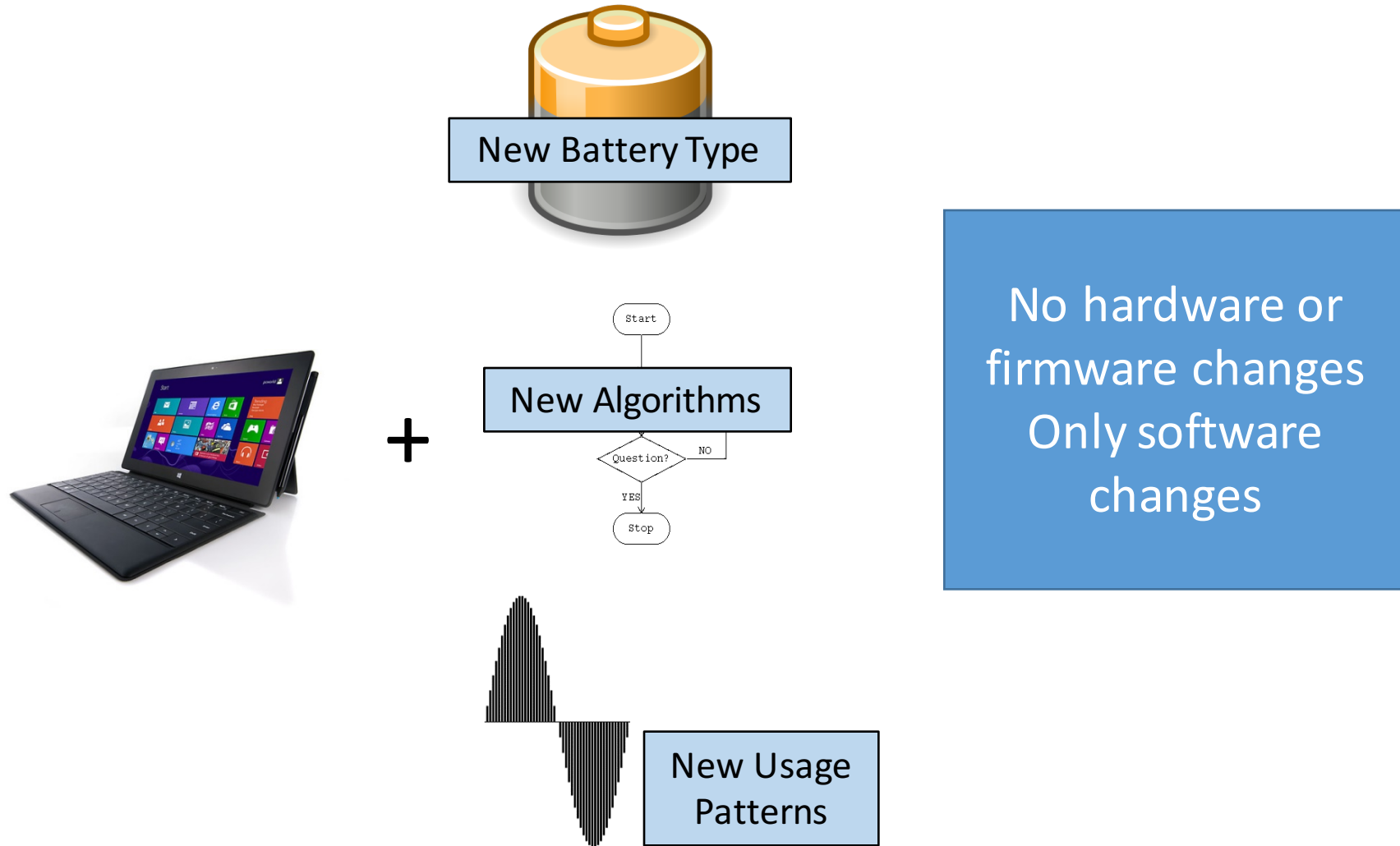
Instantaneous optimal may not be global optimal

Future workloads determine current policy

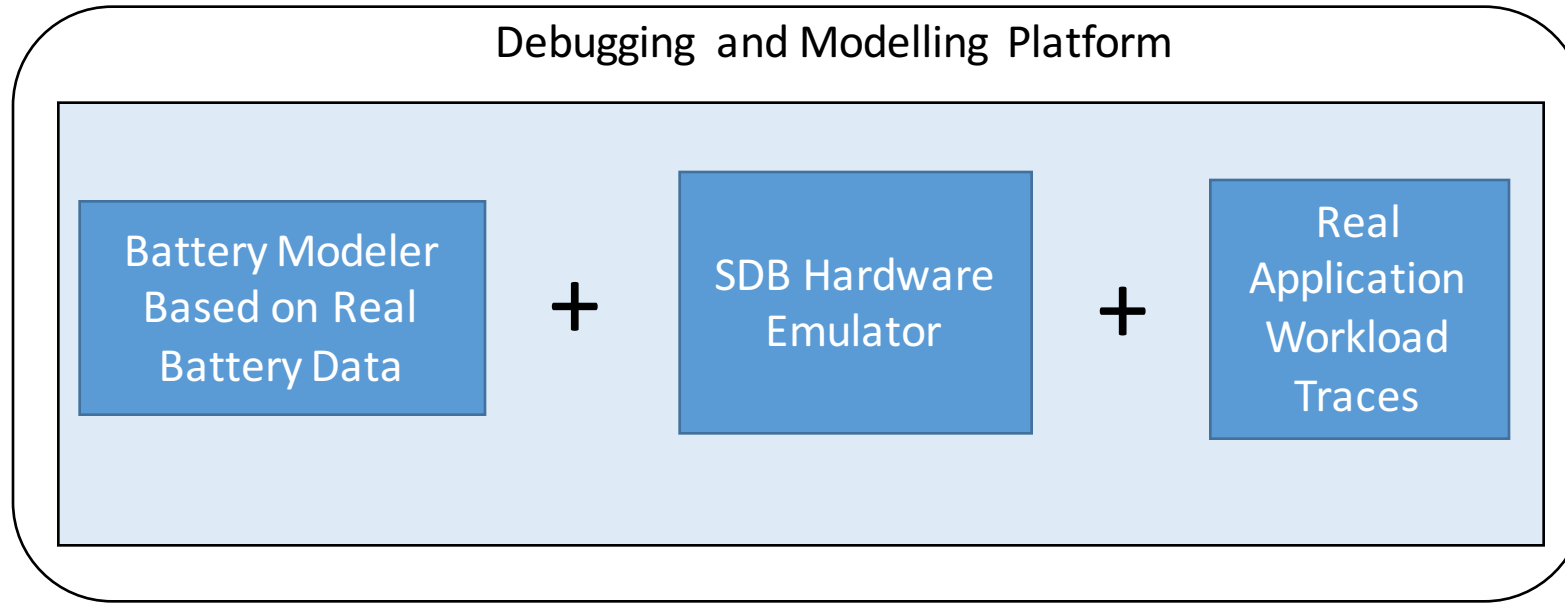
For simplicity, assume user cares only about daily battery life



SDB API: Implications

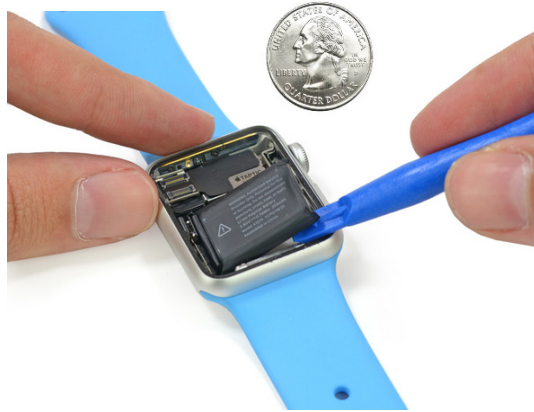


SDB Evaluation

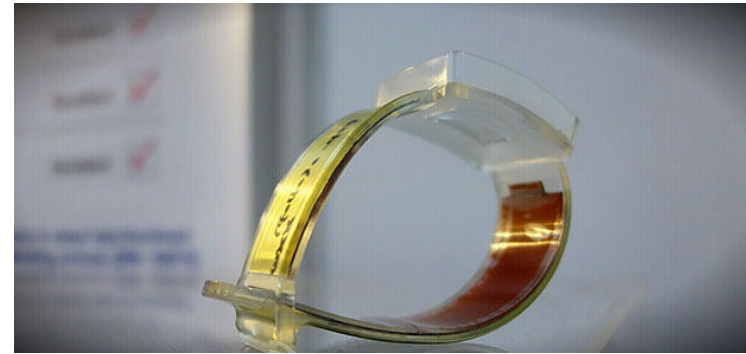


- Fast and easy experimentation for OS developer
- Repeatable experiments
- Does not explode batteries!

Case Study: Flexible Batteries for Wearables



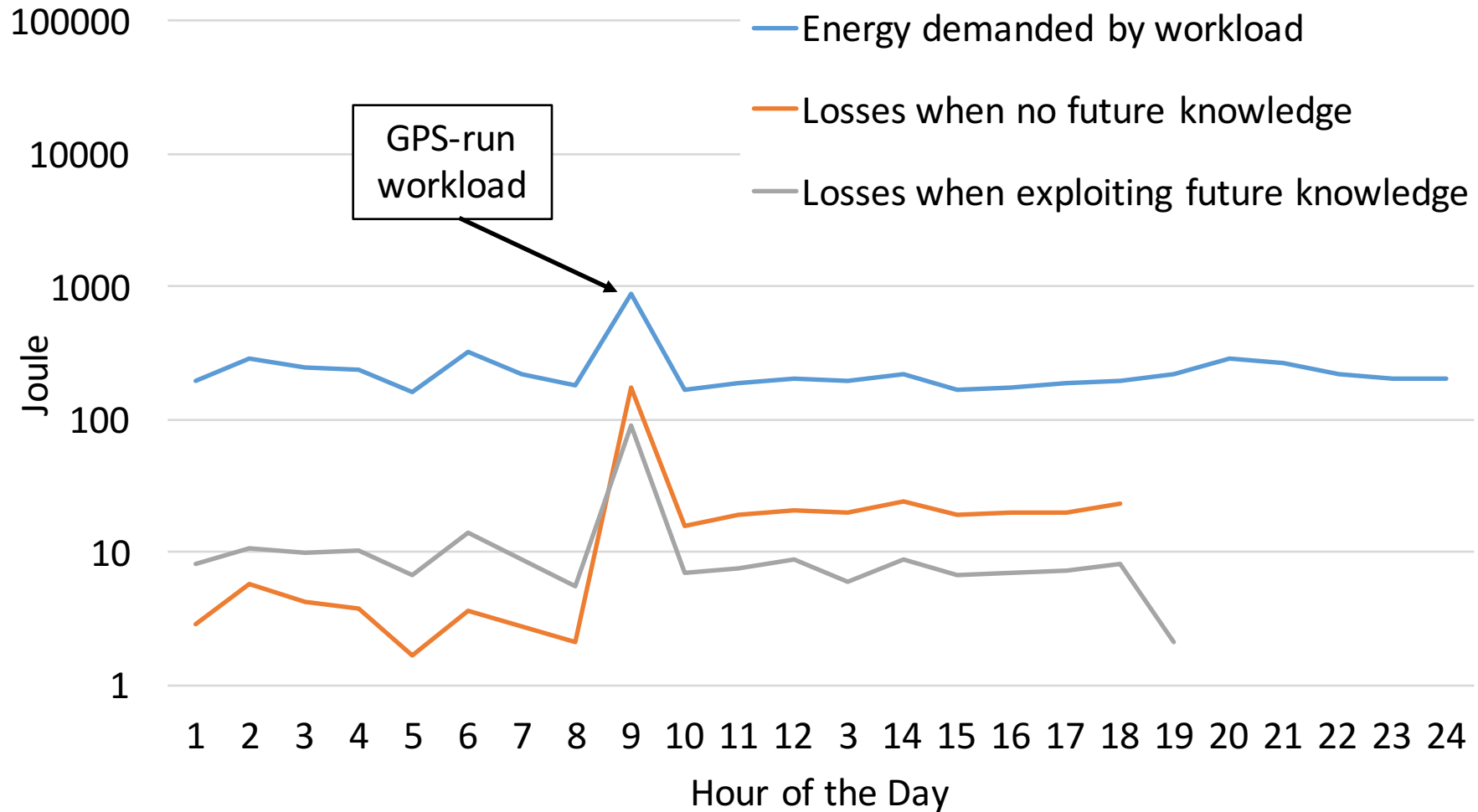
Wearables' batteries are constrained by volume restrictions



Flexible batteries can help augment the capacity without increasing bulk

- Flexible batteries are inefficient
 - They have a rubber-like electrolyte with high resistance
- Use Li-ion battery for high-power scenarios
- Flexible battery for low-power scenarios
- Experiment demonstrates how future workload knowledge helps SDB improve battery life

Case Study: Flexible Batteries for Wearables



Case Study: External Batteries

36 Wh tablet battery



25 Wh keyboard battery



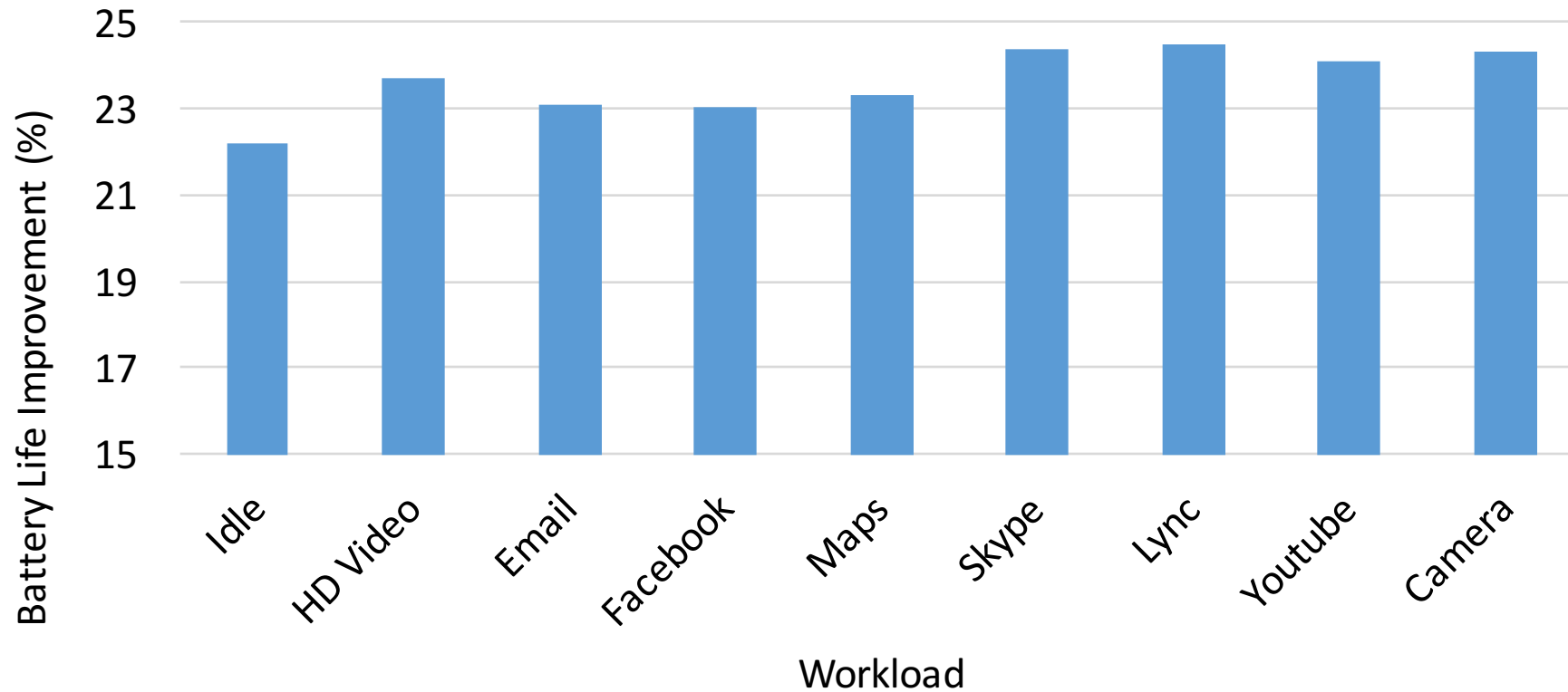
Extra battery in
phone case



Portable battery
packs

- External batteries today charge internal battery
- This is inefficient because of charging losses
- *Idea: Draw power from both using SDB*
- However, need to know how external battery is used
 - If user always plugs it in then draw power from both
 - If user plugs it in only to charge the tablet then charge the internal battery with the external one
- SDB can improve battery life by understanding usage

Case Study: External Batteries for 2-in-1s



SDB v.s. External Battery Charging Internal Battery

Summary & Future Work

- SDB enables battery to be managed by the OS as a resource
 - Power to/from the battery can be adapted based on workload
- Combining different chemistries leads to significant benefits
 - New scenarios, increase capacity, reduced charging times
- Moving ahead:
 - Integration with calendars and smart assistants, e.g. Cortana
 - Improving electrical vehicle range based on incline, temperature, traffic
 - Increasing drone flight time based on wind conditions, flight path

Thank you!