Selection of Battery and Charging Algorithm to Extend Battery Life and Cycle Life

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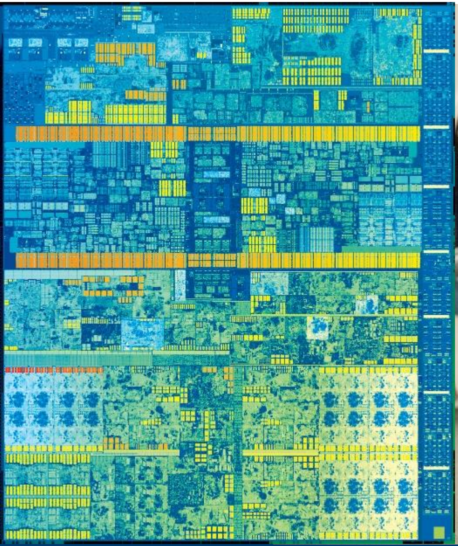
NCCAVS, 2/21/2019

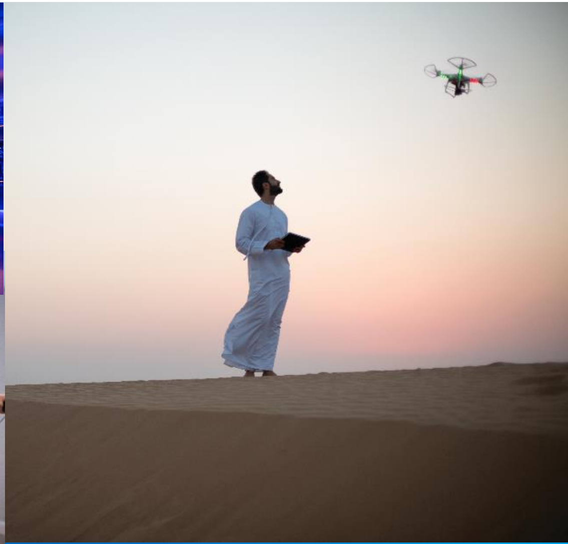
DISCLAIMER

Accelerating Product Focus

- CPU, PC
- Datacenter and Internet of Things







More Devices with Batteries

<u>Consideration in selection (example)</u>

- Rechargeable
  or non-rechargeable?
- Chemistry? (Li, NiMH, Alkaline, etc…)
- Cost + Longevity
  = Cost of Ownership

Example of Batteries for CE/IOT

	Rechargeable		Non-Rechargeable	
	Li-ion	**NiMH**	**Li Coin cell**	**Alkaline**
Energy density	Baseline (700+Wh/l)	½ of Li-ion	Higher	Low (250~500Wh/l)
Nominal voltage	~3.8V	1.2V	3V	1.5V
Cycles	Several hundreds to thousands	Several hundreds to thousands	n/a	n/a
Self-discharge	0.3-1.2%/month	~3%/month	<0.1%/month	~0.2%/month
Cost (online volume price)	~$0.2 /Wh (*18650) + protection + charger	<$1.0/Wh (*AA) + charger	~$0.2/Wh (*CR2032)	<$0.1/Wh (*AA)

* Data varies by manufacturer, model, size, temperature, etc...

- Li-based or rechargeable battery for high-power device
- Non Li-based or non-rechargeable battery for low-power device.
- How about "Normally low-power but sometimes high-power device"?

Impedance Knows…

- Battery voltage drops under current because of impedance.
- Battery impedance increases as discharge continues.
  R = R(Ohmic) + R(Polarization)
- System shuts down when dropped voltage hits system shutdown voltage.
- It's a key to understand what is impedance/IR drop under pulse and continuous discharge.

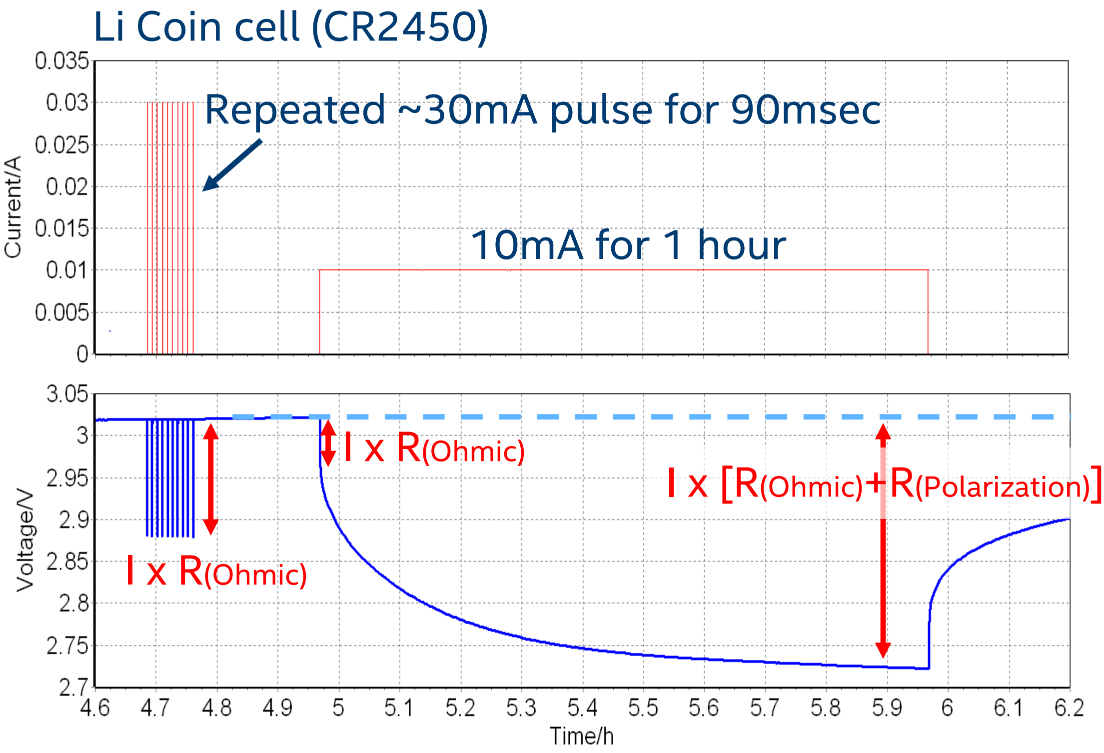
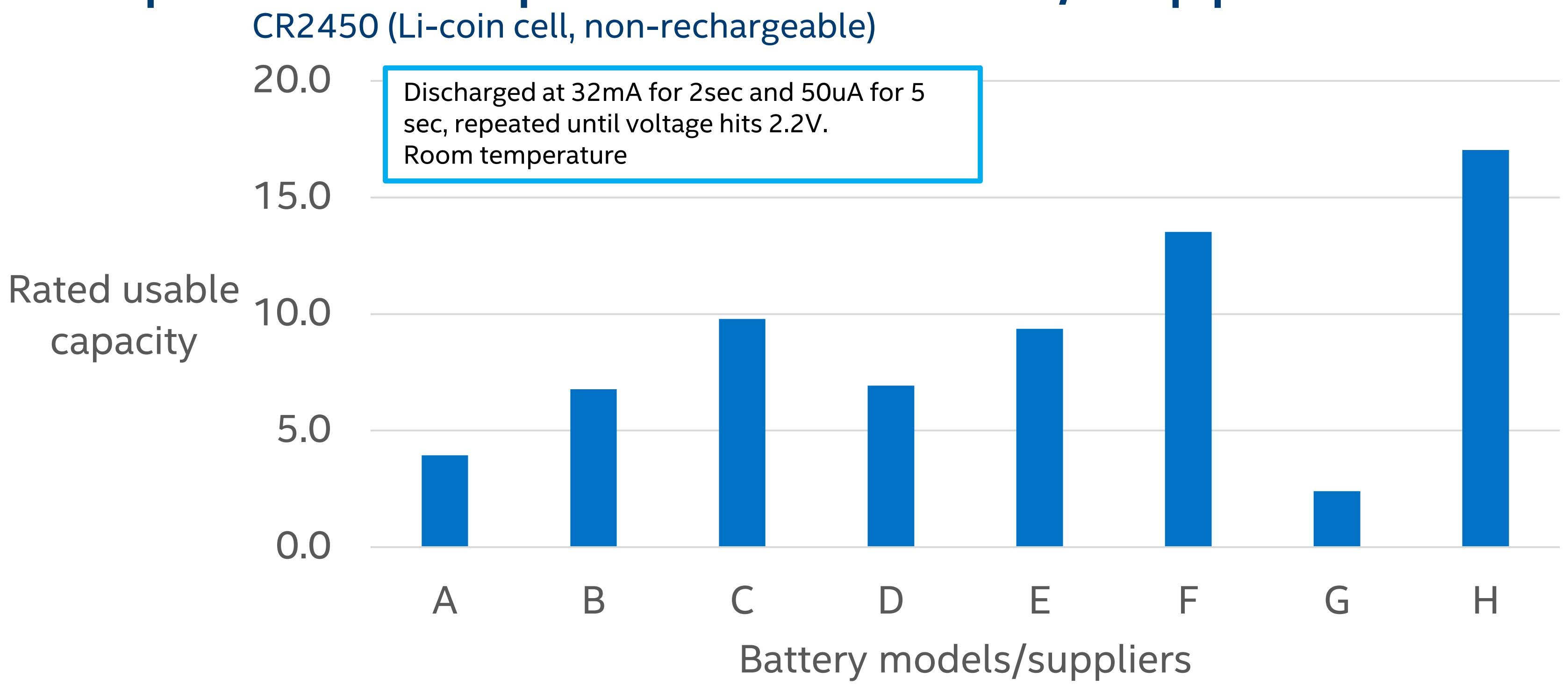


Fig. Voltage reaction under various current

Impedance Depends on Models/Suppliers…



- Even with same chemistry, usable capacity is very different by models/suppliers because of impedance difference.
- For battery selection, it's important to understand its impedance for usage.

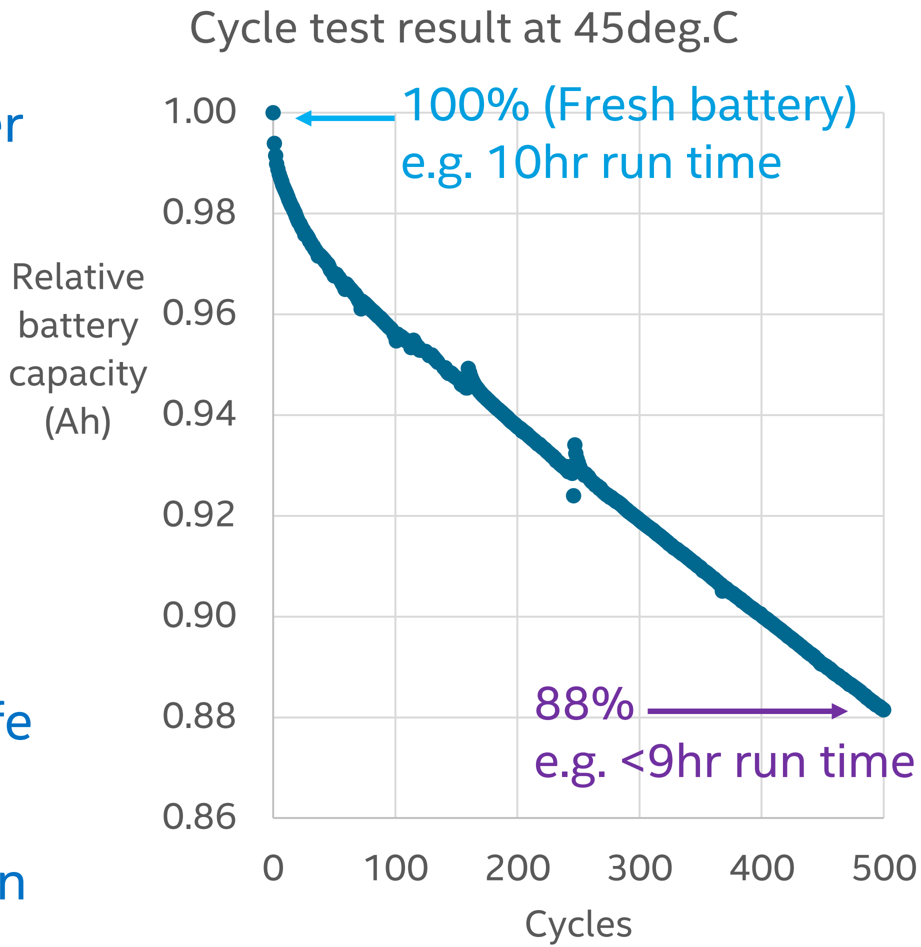
Longevity

- Expectations:
  - Longer battery life for rechargeable/non-rechargeable battery
  - Longer cycle life for rechargeable battery
- Less battery replacement = Lower Cost of Ownership

  (e.g. Li-ion rechargeable battery)
  PC: 500~1000 cycles
  IOT: more
- Solution:
  - New battery chemistry
  - **Smart charging algorithm**

Cycle Life Degradation

- Full-charge-capacity is decreased after repeating charge and discharge.
- Degradation is accelerated at
  - Higher temperature
  - Full charge (higher charge level)
  - Too fast charge/discharge current
  - etc…
- Mixing these factors degrades cycle life even worse.
- What can we do for cycle life extension to reduce Cost of Ownership?

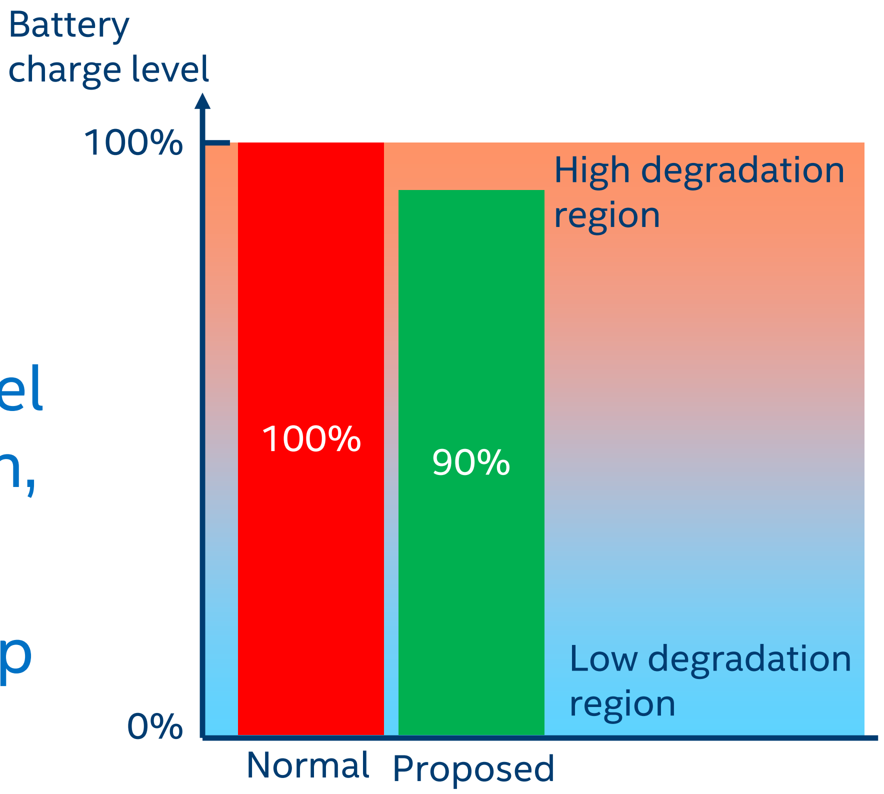


Solution

“Adaptive Charging Algorithm”

Adaptive Charging by Scheduling Application

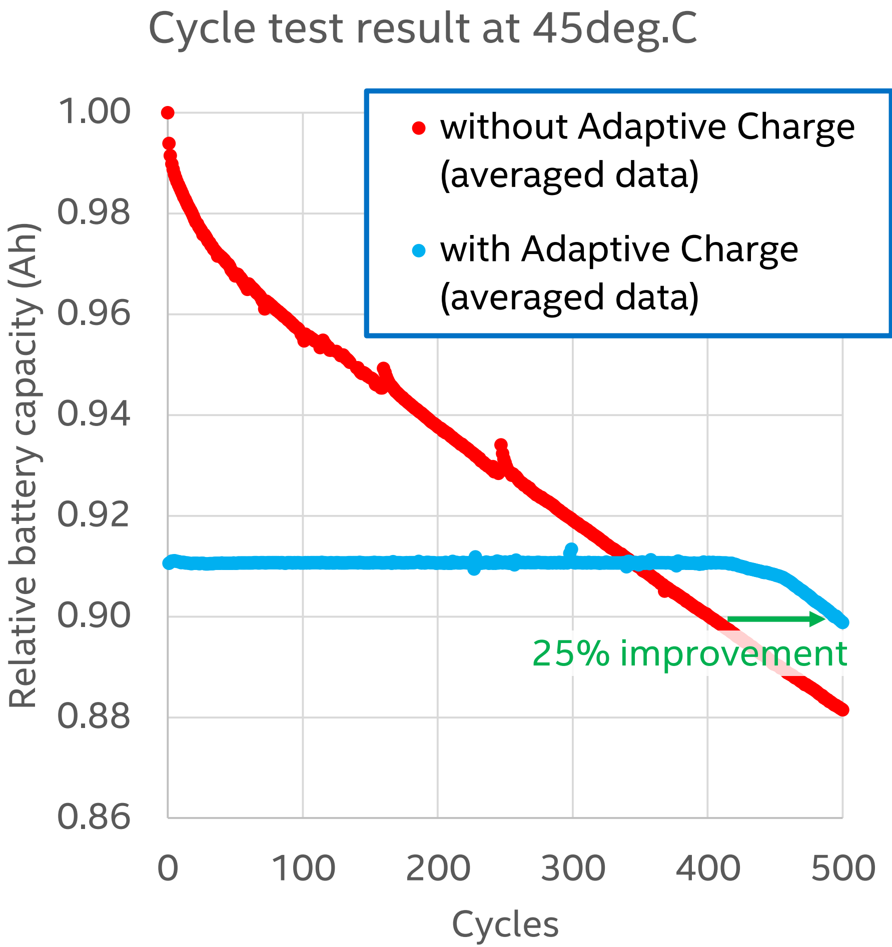
- Charge battery as needed by “scheduling application”.
- This avoids higher charge level which gives more degradation, extending longevity.
- This lowers Cost of Ownership as it requires less battery replacement.



(U.S. Patent 9041356, 8232774, 7852045)

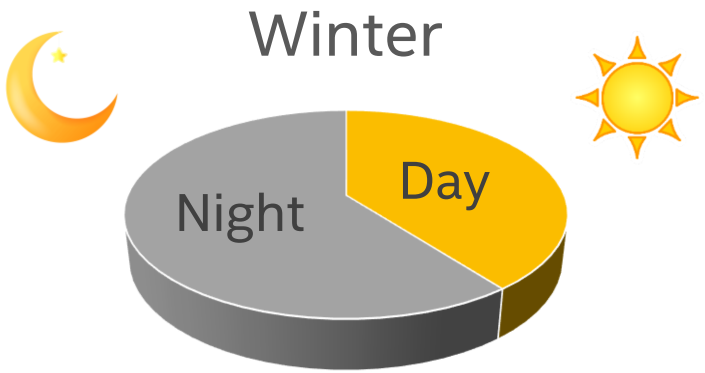
Adaptive Charging by Scheduling Application

- Example: If a device needs 90%, charge to 90+α%.
- 25% cycle life improvement.
- Lower charge level,
  Better cycle life.
- Application:
  Autonomous driving, Cleaning robot, Sensors, etc...

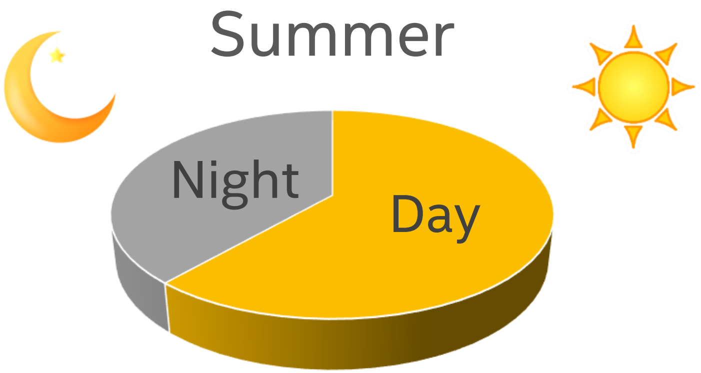


Situational Charging

IOT devices may operate with a battery charged by solar cell.



Full charge is needed in winter.



Full charge is NOT needed in summer.

Avoiding full charge by situations (season, usage, etc...) extends battery cycle life.

Conclusion

- Understanding impedance by usage is important to know usable battery capacity.
- Longer cycle life is expected for CE/IOT devices to reduce Cost of Ownership.
- Extension of battery cycle life (longevity) is possible by “Adaptive Charging Algorithm”.

- If you are interested in implementation, please contact us. naoki.matsumura@intel.com intel®