



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

Naoki Matsumura (Senior Staff Engineer, Intel Corporation)  
NCCAUS, 2/21/2019

# DISCLAIMER

No license (express or implied, by estoppel or otherwise) to any intellectual property rights is granted by this document.

This document contains information on products, services and/or processes in development. All information provided here is subject to change without notice. Contact your Intel representative to obtain the latest forecast, schedule, specifications and roadmaps.

The products and services described may contain defects or errors known as errata which may cause deviations from published specifications. Current characterized errata are available on request.

You may not use or facilitate the use of this document in connection with any infringement or other legal analysis concerning Intel products described herein. You agree to grant Intel a non-exclusive, royalty-free license to any patent claim thereafter drafted which includes subject matter disclosed herein.

**Forecasts:** Any forecasts of requirements for goods and services are provided for discussion purposes only. Intel will have no liability to make any purchase pursuant to forecasts. Any cost or expense you incur to respond to requests for information or in reliance on any forecast will be at your own risk and expense.

**Business Forecast:** Statements in this document that refer to Intel's plans and expectations for the quarter, the year, and the future, are forward-looking statements that involve a number of risks and uncertainties. A detailed discussion of the factors that could affect Intel's results and plans is included in Intel's SEC filings, including the annual report on Form 10-K.

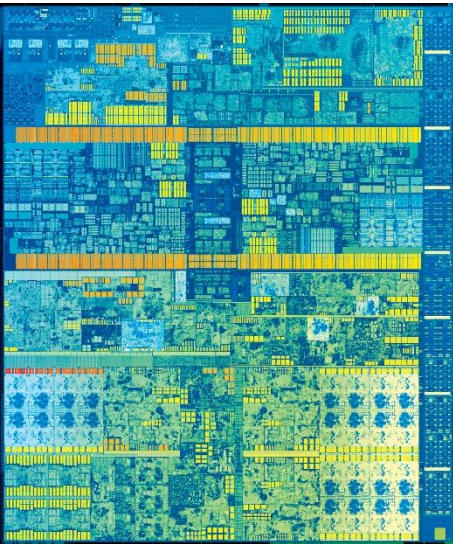
Copies of documents which have an order number and are referenced in this document may be obtained by calling 1-800-548-4725 or by visiting [www.intel.com/design/literature.htm](http://www.intel.com/design/literature.htm).

Intel, the Intel logo, {List the Intel trademarks in your document} are trademarks of Intel Corporation in the U.S. and/or other countries.

\*Other names and brands may be claimed as the property of others © 2016 Intel Corporation.

# Accelerating Product Focus

- CPU, PC
- Datacenter and Internet of Things



# More Devices with Batteries

## Consideration in selection (example)

- 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)	1/2 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.  
 $R = R(\text{Ohmic}) + R(\text{Polarization})$
- 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.

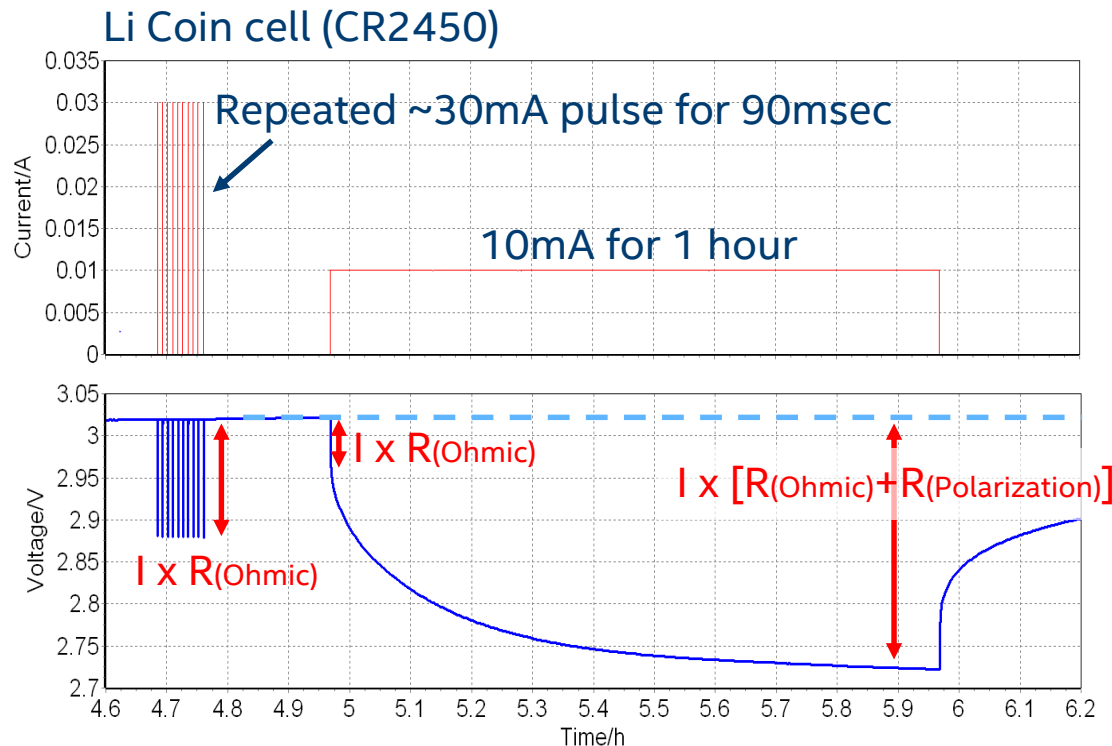
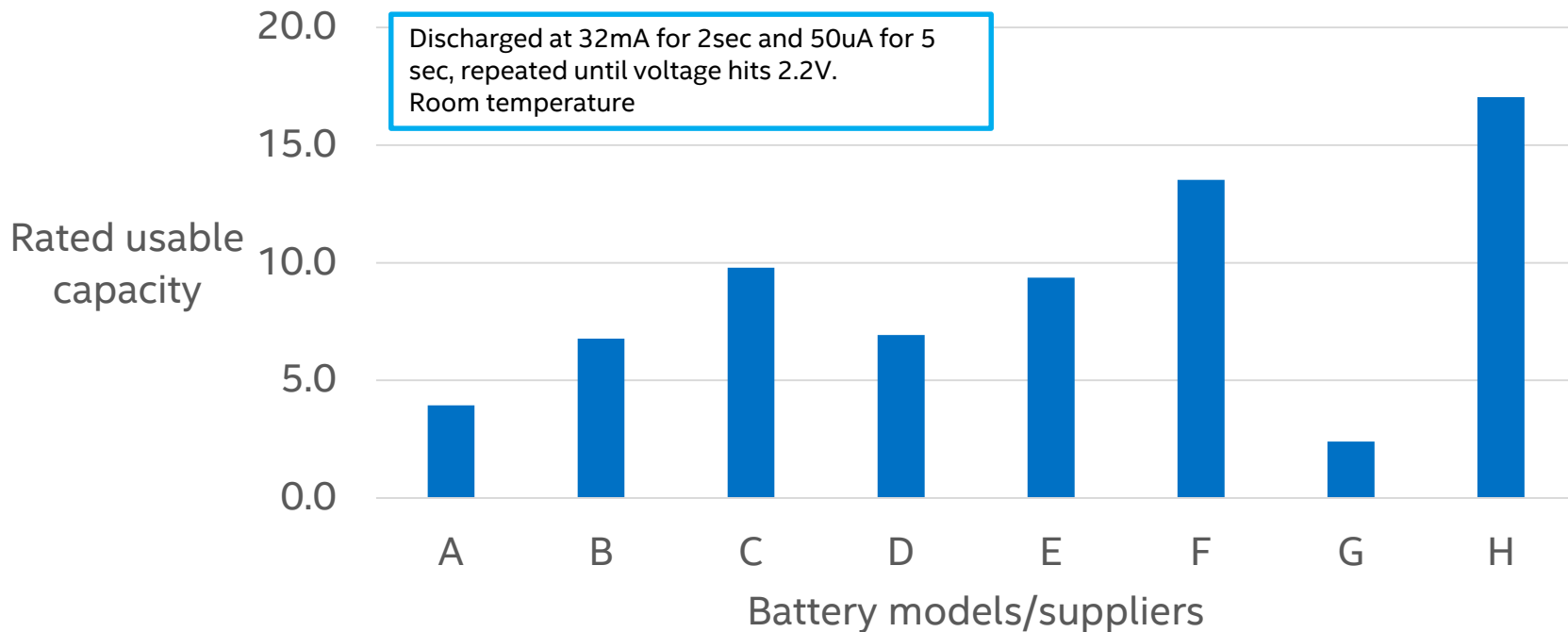


Fig. Voltage reaction under various current

# Impedance Depends on Models/Suppliers...

CR2450 (Li-coin cell, non-rechargeable)



- 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

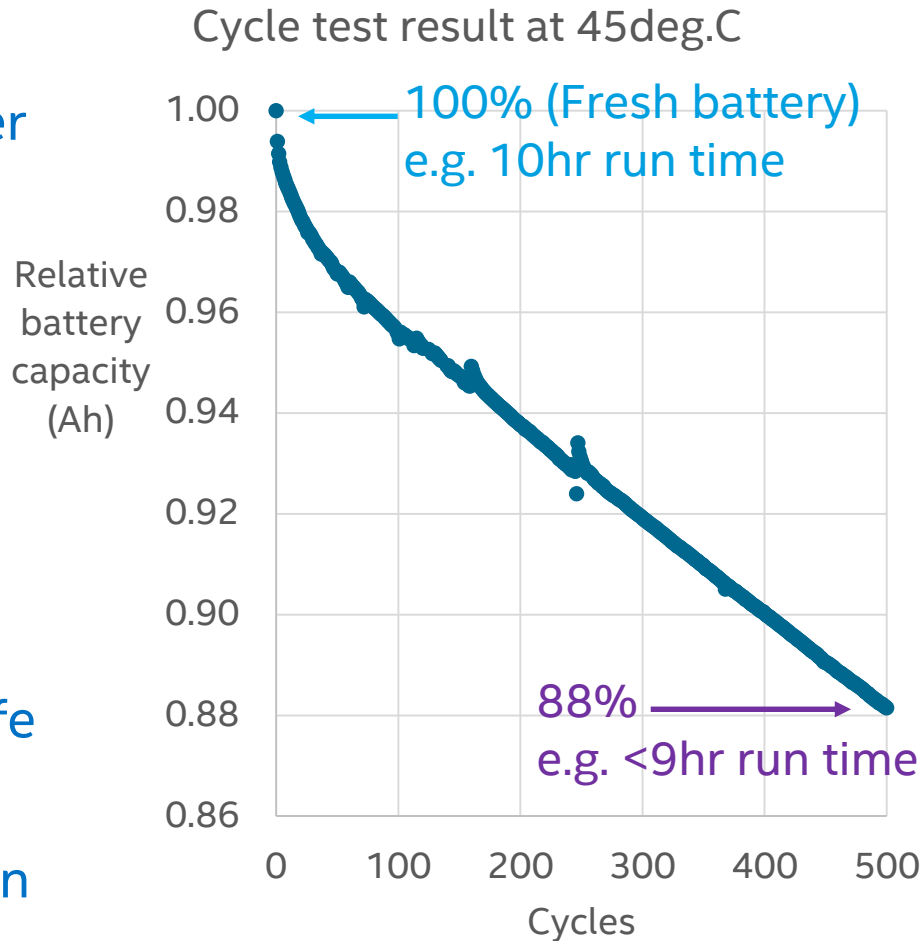
IOT: more

- 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?

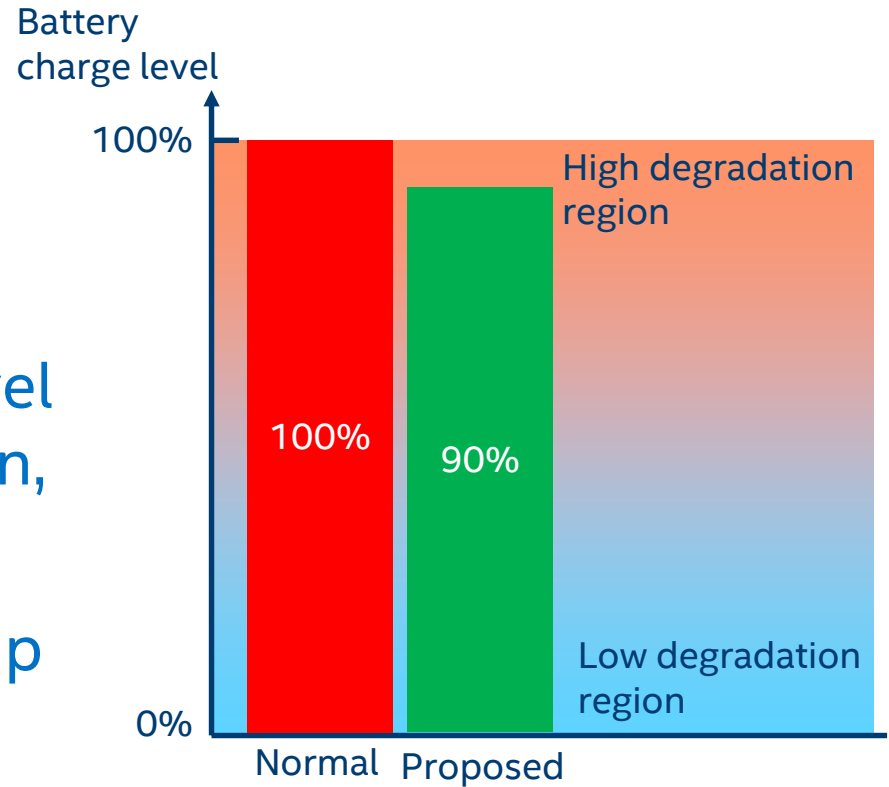


# Solution

## “Adaptive Charging Algorithm”

# Adaptive Charging by Scheduling Application

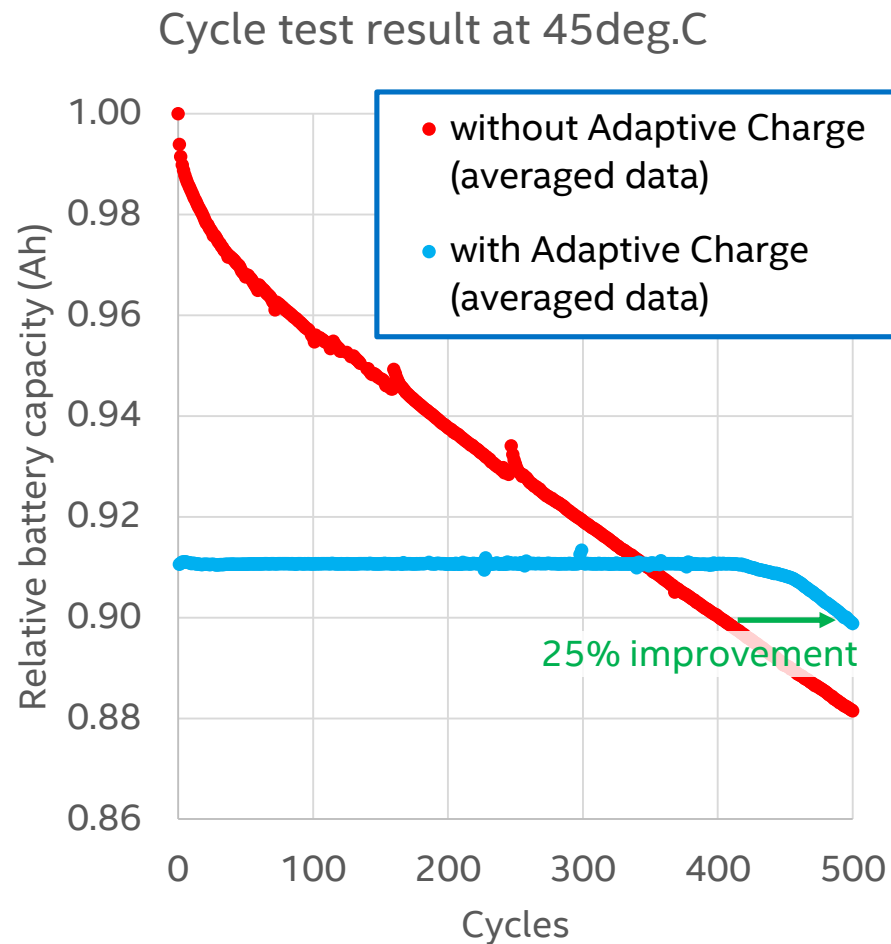
- Charge battery as needed by “scheduling application”.
- This avoids higher charge level which gives more degradation, extending longevity.
- This lowers Cost of Ownership as it requires less battery replacement.



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

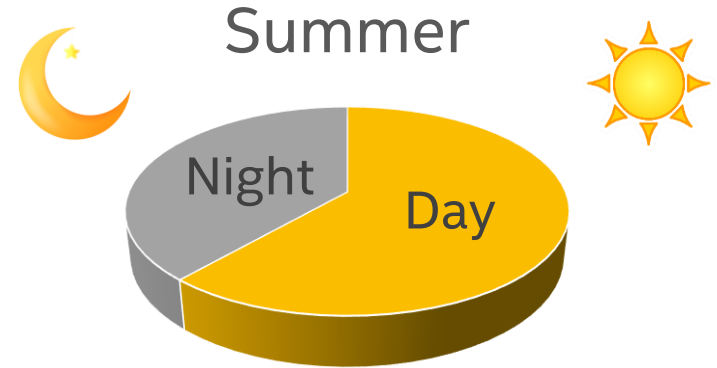
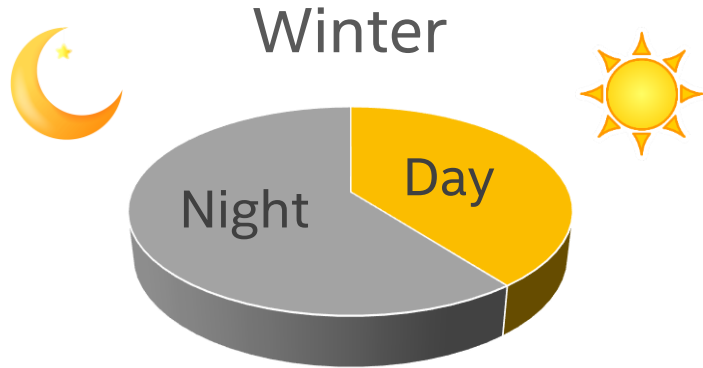
# Adaptive Charging by Scheduling Application

- Example: If a device needs 90%, charge to  $90+\alpha\%$ .
- 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](mailto:naoki.matsumura@intel.com)

