Evaluation and Extension of ns-3 Battery Framework

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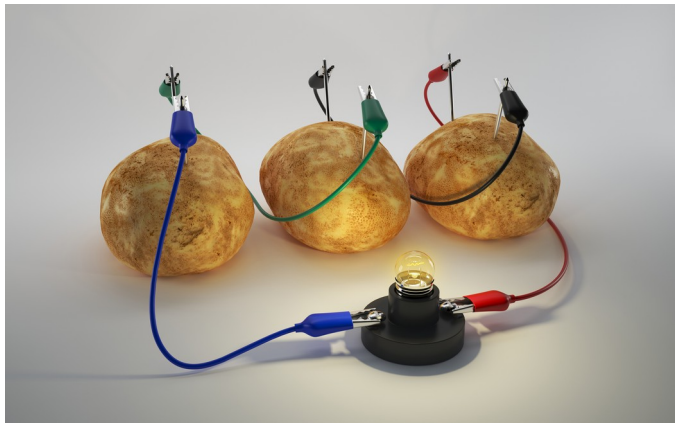
Motivations

- Having an *EnergySource* model that is



  - Simple to use as battery
  - Flexible
  - Open source
  - Designed for ns-3:

    - Radio energy consumption
    - Network energy balancing algorithms
    - UAV flying plans
    - Energy efficient routing protocols

Difficulties

In reality, batteries are complicated beasts:

- Do not discharge linearly
- Different batteries have different outputs.
- Same batteries have different outputs.
- Performance dependent on multiple factors (Age, temperature, cycles, discharge current)

Background

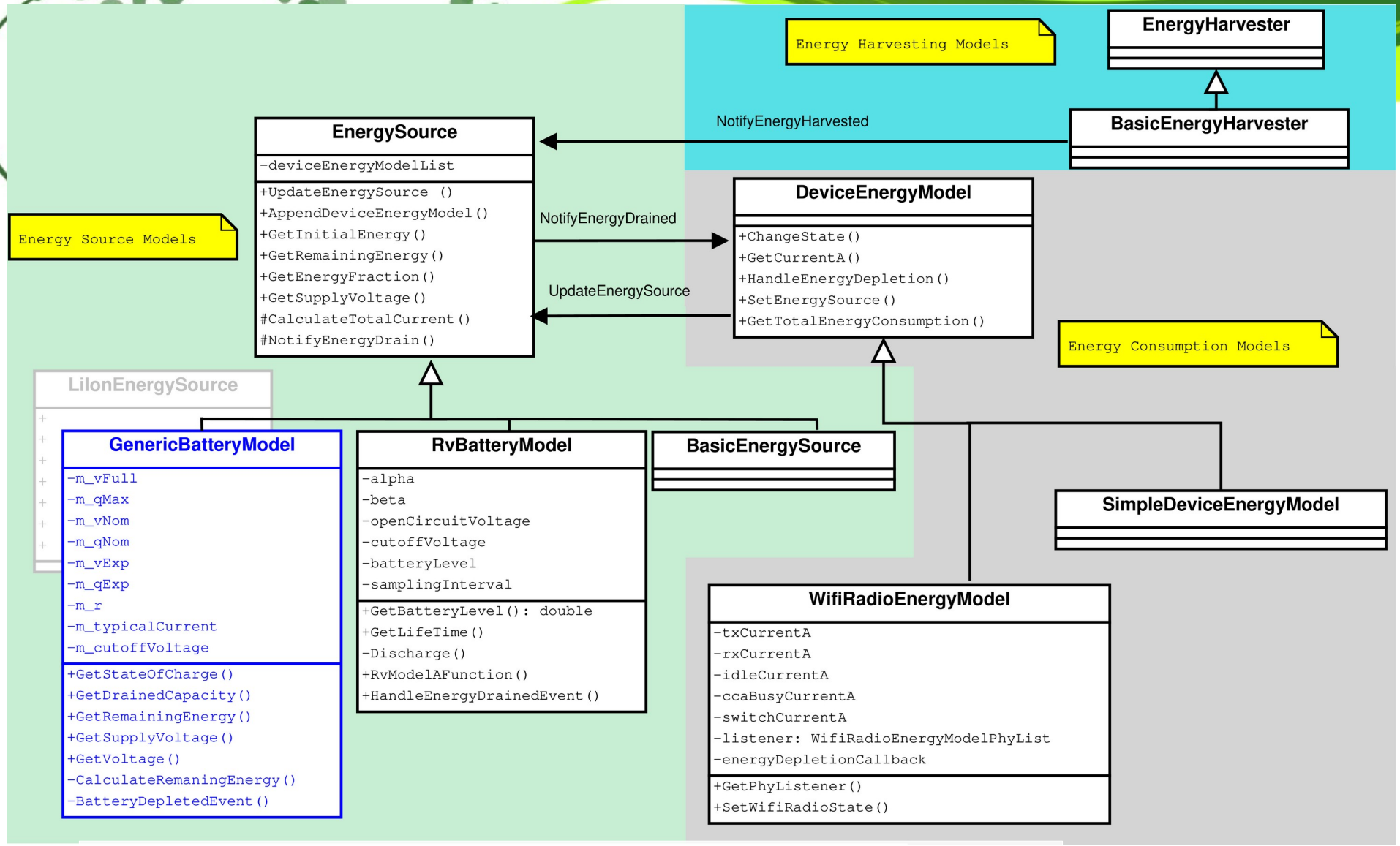
Ns-3 energy framework is mainly formed by 3 elements:

- Energy Source models (batteries, capacitors)
- Energy Consumption models (Radio transceivers, sensors, UAV)
- Energy Harvesting models (Solar panels, chargers)

<u>Ns-3's current EnergySource models:</u>

- Rakhmatov battery model (RV model) – Sidharth Nabar, He Wu (2010)
- Basic energy source model – Sidharth Nabar, He Wu (2010)
- Lion energy source model – Andrea Sacco (2010)

Ns-3 Energy Framework



Proposed energy source model: *GenericBatteryModel*

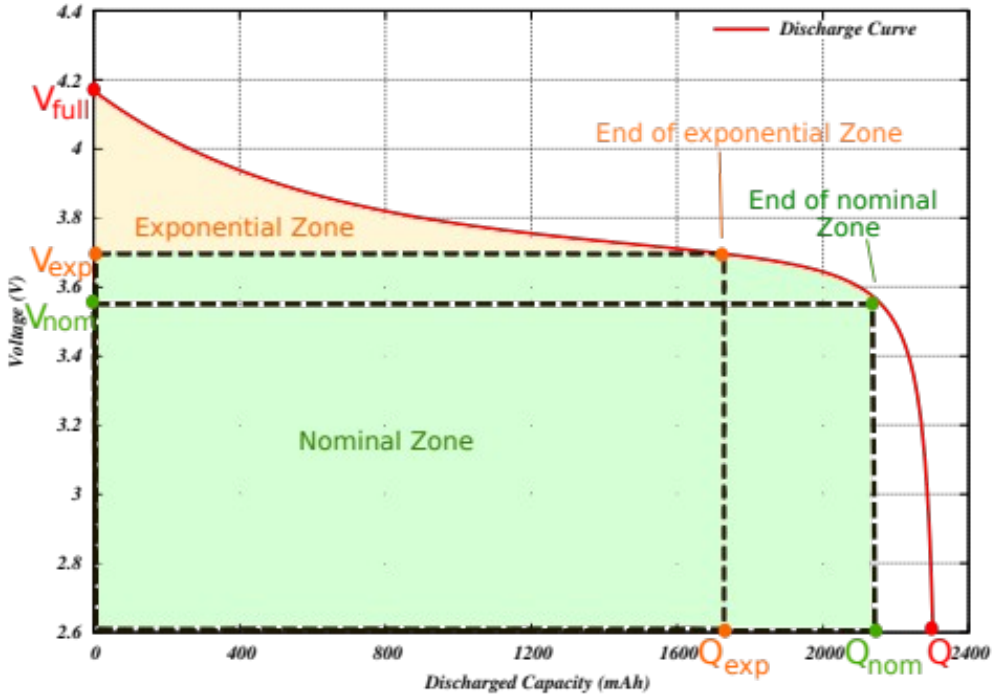
Proposed Generic Battery Model

- Replaces Andrea Sacco's LiIonEnergySource

- Based on the latest Tremblay's battery model.

- Requires visual identification of points in manufacturers datasheets's discharge curves.

-Support 4 batteries chemistries: LiIon, NiCd, NiMh, Lead Acid



Tremblay's model parameter identification

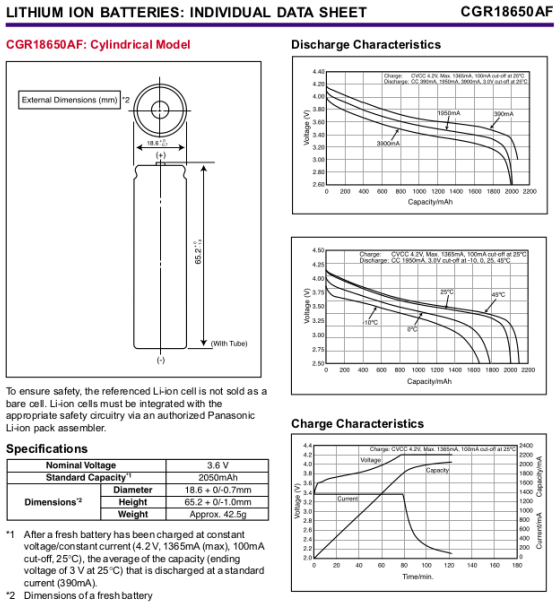
Vfull,Q, Vexp, Qexp, Vnom,Qnom
R, i_typical, cutoff voltage

Obtaining Discharge Curves

1

2

3



LITHIUM ION BATTERIES: INDIVIDUAL DATA SHEET CGR18650AF

CGR18650AF: Cylindrical Model

External Dimensions (mm) *2

(With Tube)

To ensure safety, the referenced Li-ion cell is not sold as a bare cell. Li-ion cells must be integrated with the appropriate safety circuitry via an authorized Panasonic Li-ion pack assembler.

Specifications

Nominal Voltage		3.6 V
Standard Capacity*1		2050mAh
Dimensions*2	Diameter	18.6 + 0/-0.7mm
	Height	65.2 + 0/-1.0mm
	Weight	Approx. 42.5g

*1 After a fresh battery has been charged at constant voltage/constant current (4.2V, 1365mA (max), 100mA cut-off, 25°C), the average of the capacity (ending voltage of 3 V at 25°C) that is discharged at a standard current (390mA).

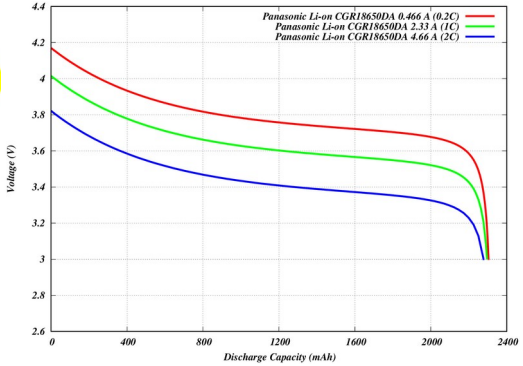
*2 Dimensions of a fresh battery

Discharge Characteristics

Charge Characteristics

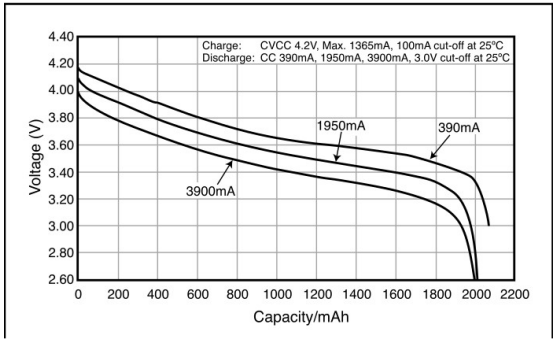
Panasonic JANUARY 2007

Battery Datasheet

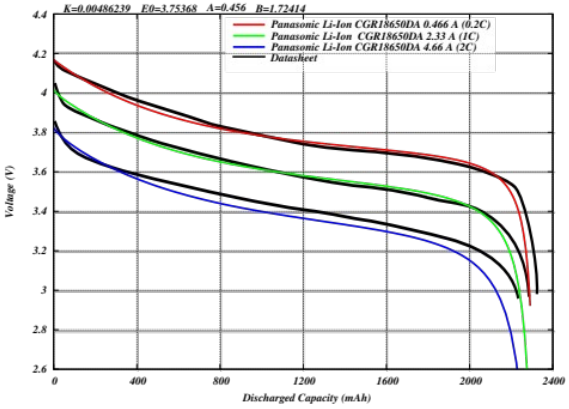


Ns-3 generated Gnuplot

+



Datasheet discarge curves



Generic Battery model in ns-3

```
Ptr<Node> node;
Ptr<GenericBatteryModel> batteryModel;
Ptr<SimpleDeviceEnergyModel> devicesEnergyModel;

node = CreateObject<Node>();
devicesEnergyModel = CreateObject<SimpleDeviceEnergyModel>();
batteryModel = CreateObject<GenericBatteryModel>();

batteryModel->SetAttribute("FullVoltage", DoubleValue(1.39)); // Qfull
batteryModel->SetAttribute("MaxCapacity", DoubleValue(7.0)); // Q

batteryModel->SetAttribute("NominalVoltage", DoubleValue(1.18)); // Vnom
batteryModel->SetAttribute("NominalCapacity", DoubleValue(6.25)); // QNom

batteryModel->SetAttribute("ExponentialVoltage", DoubleValue(1.28)); // Vexp
batteryModel->SetAttribute("ExponentialCapacity", DoubleValue(1.3)); // Qexp

batteryModel->SetAttribute("InternalResistance", DoubleValue(0.0046)); // R
batteryModel->SetAttribute("TypicalDischargeCurrent", DoubleValue(1.3)); // i typical
batteryModel->SetAttribute("CutoffVoltage", DoubleValue(1.0)); // End of charge.
batteryModel->SetAttribute("BatteryType", EnumValue(NIMH_NICD)); // Battery type

devicesEnergyModel->SetEnergySource(batteryModel);
batteryModel->AppendDeviceEnergyModel(devicesEnergyModel);
devicesEnergyModel->SetNode(node);
```

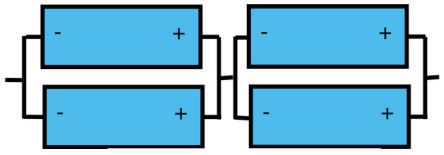
Generic Battery model in ns-3

Easy configuration using helpers:

```
Ptr<Node> node;
GenericBatteryModelHelper batteryHelper;
batteryHelper.Install(node,PANASONIC_HHR650D_NIMH);
```

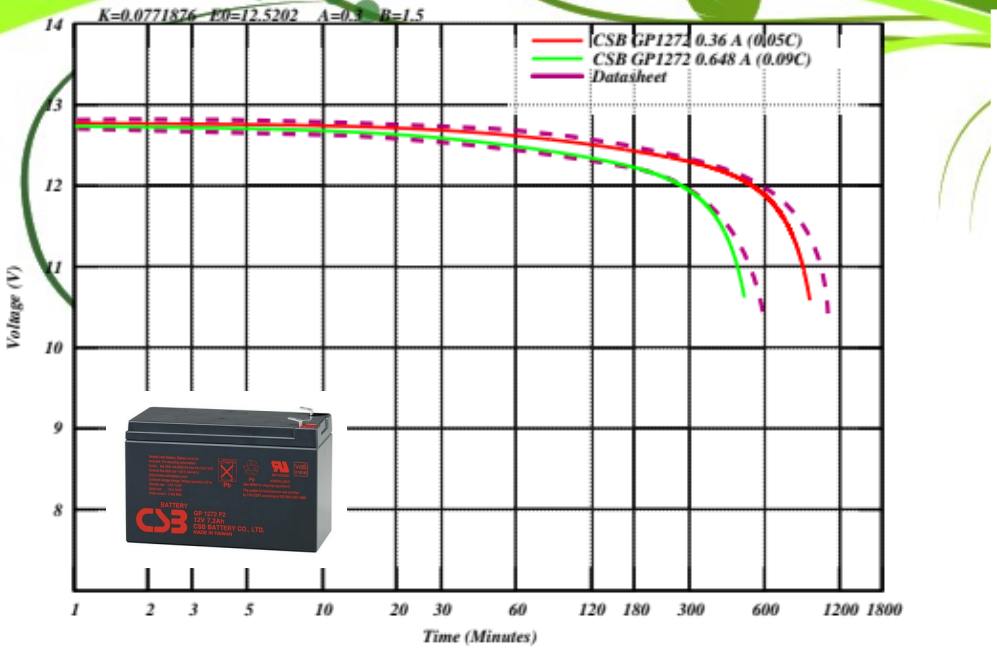
Support for battery cell packs:

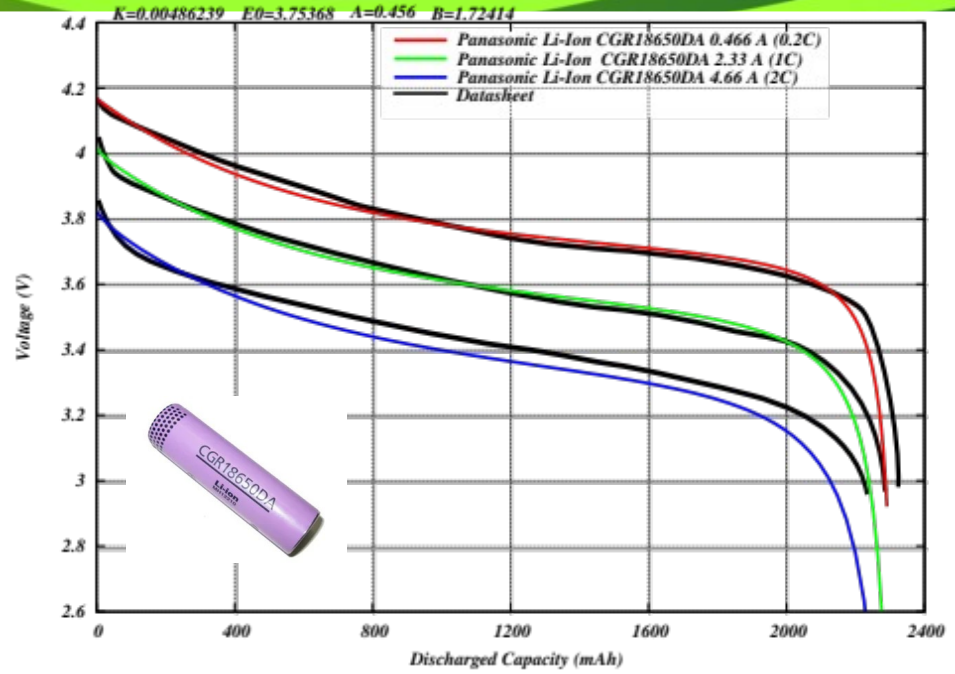
```
EnergySourceContainer energySourceContainer =
batteryHelper.Install(nodeContainer,
                      PANASONIC_CGR18650DA_LION);
// Series | parallel
batteryHelper.SetCellPack(energySourceContainer, 2, 2);
```

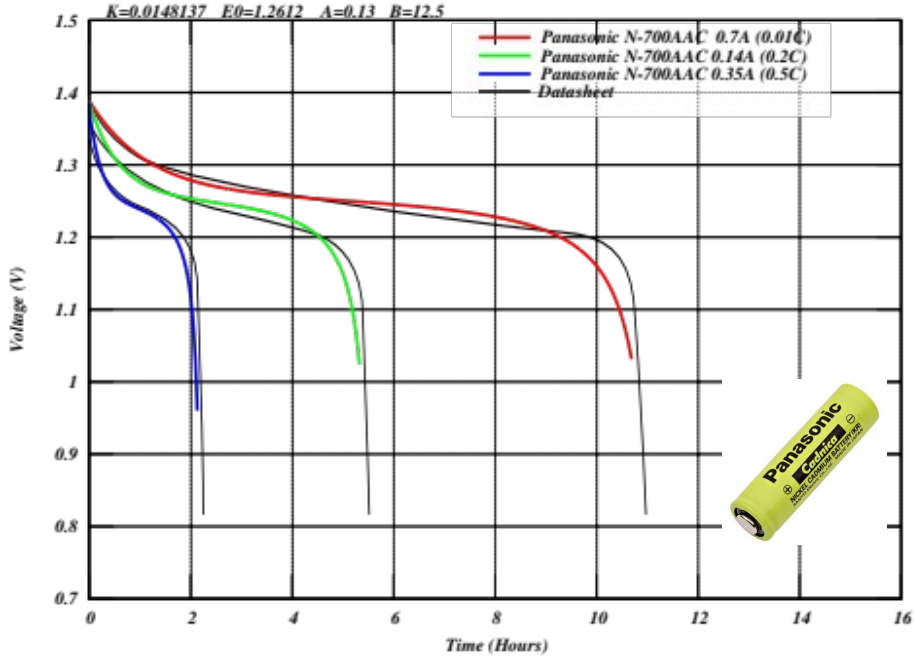


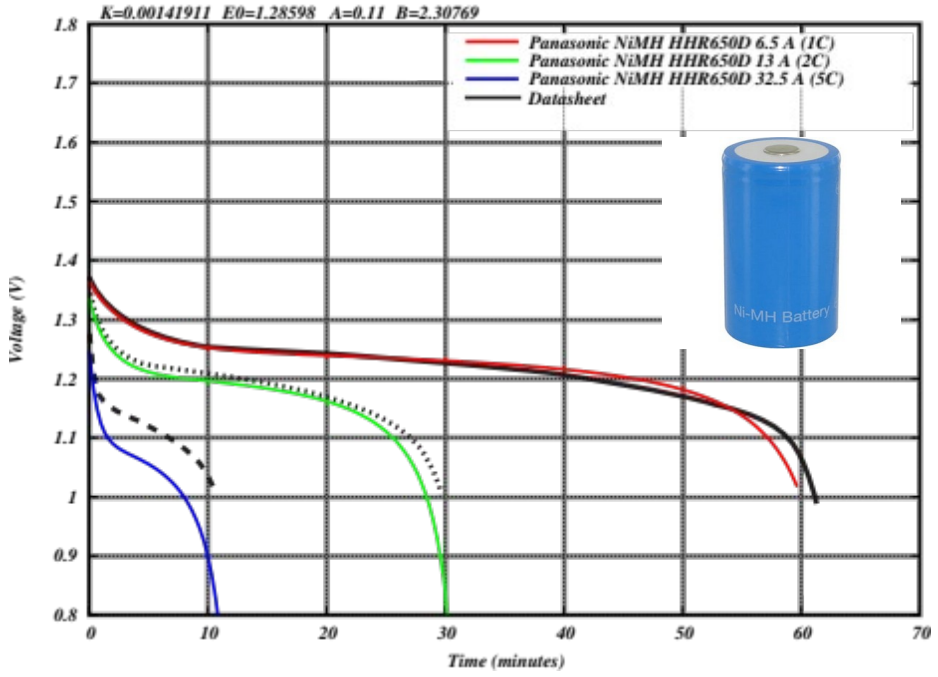
2S | 2P

Evaluation


K=0.0771876 E0=12.5202 A=0.3 B=1.5
CSB GP1272 0.36 A (0.05C)
CSB GP1272 0.648 A (0.09C)
Datasheet
Voltage (V)
Time (Minutes)


K=0.00486239 E0=3.75368 A=0.456 B=1.72414
Panasonic Li-Ion CGR18650DA 0.466 A (0.2C)
Panasonic Li-Ion CGR18650DA 2.33 A (1C)
Panasonic Li-Ion CGR18650DA 4.66 A (2C)
Datasheet
Voltage (V)
Discharged Capacity (mAh)


K=0.0148137 E0=1.2612 A=0.13 B=12.5
Panasonic N-700AAC 0.7A (0.01C)
Panasonic N-700AAC 0.14A (0.2C)
Panasonic N-700AAC 0.35A (0.5C)
Datasheet
Voltage (V)
Time (Hours)


K=0.00141911 E0=1.28598 A=0.11 B=2.30769
Panasonic NiMH HHR650D 6.5 A (1C)
Panasonic NiMH HHR650D 13 A (2C)
Panasonic NiMH HHR650D 32.5 A (5C)
Datasheet
Voltage (V)
Time (minutes)

Limitations and features

- Age, temperature, variable resistance, cycle effects are not considered.

- Battery charge capability is implemented but not tested.

- Further adjustments and testing with energy harvesters and device energy models is required.

- Simple to use.

- Battery presets support.

- Cell pack support.

- Flexible design

- Examples and tests available

src/energy/examples/generic-battery-discharge-example.cc
src/energy/examples/generic-battert-wifiradio-example.cc

Future work

- Battery discharge test using dynamic current draw

- Extend battery presets (e.g. UAV LiPo battery)

- Battery charge tests (use CCCV)

- Lr-wpanEnergyModel support, refactor WifiRadioEnergyModel, refactor HarvesterModel