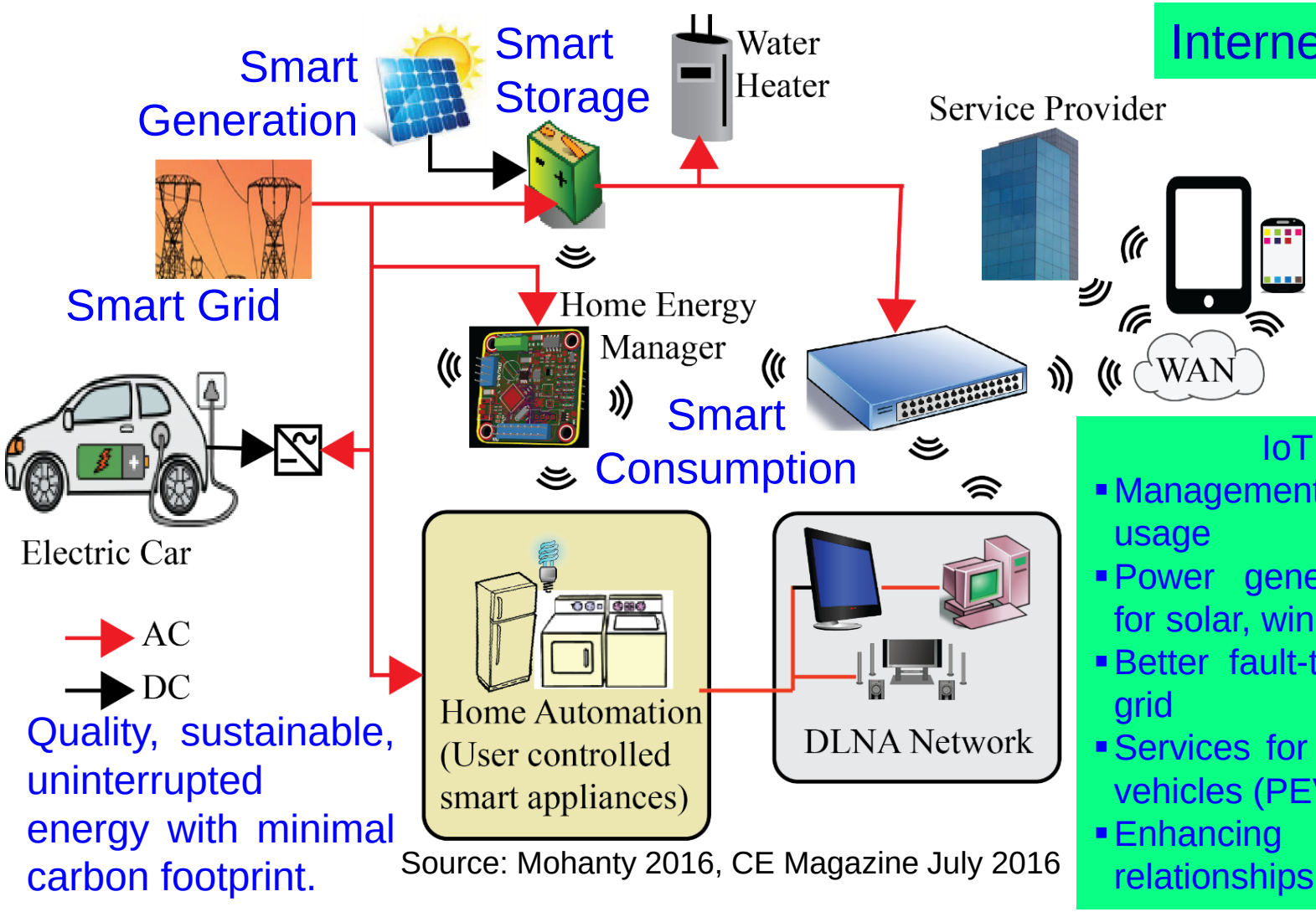
# RelBat: A Reliable Battery System Towards the Realization of Sustainable Electronics

O. C. Okpokwasili[1], S. P. Mohanty[2], E. Kougianos[3] and V. P. Yanambaka[4]
NanoSystem Design Laboratory (NSDL, http://nsdl.cse.unt.edu)
University of North Texas, Denton, TX 76203, USA.[1,2,3]
Email: oco0003@unt.edu[1], saraju.mohanty@unt.edu[2],
elias.kougianos@unt.edu[3], vy0017@unt.edu[14]

# Outline of the talk

- Background
- Novel Contributions
- Proposed Architecture
- Implementation
- Results
- Conclusions and Future Research

# Smart Energy




Quality, sustainable, uninterrupted energy with minimal carbon footprint.

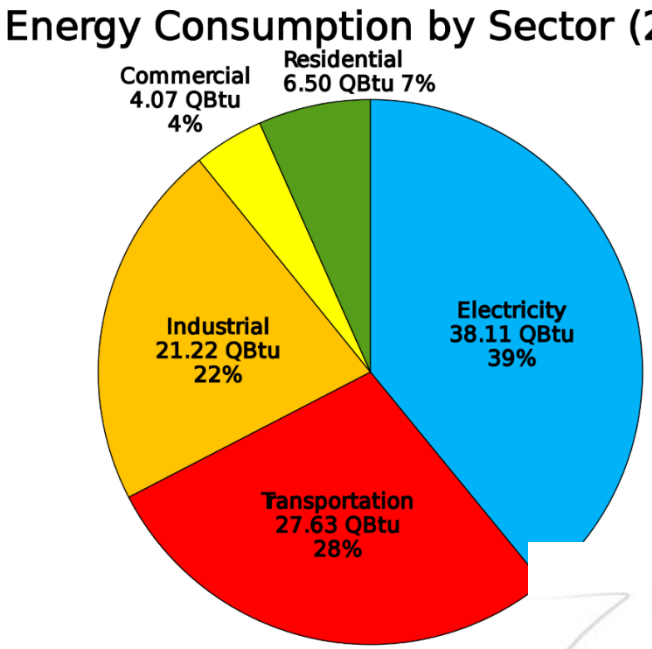
Source: Mohanty 2016, CE Magazine July 2016

## Internet of Energy

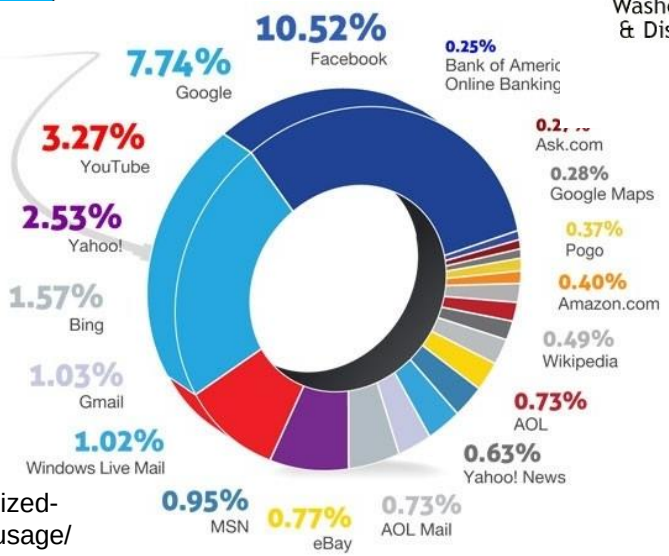
IoT Role:

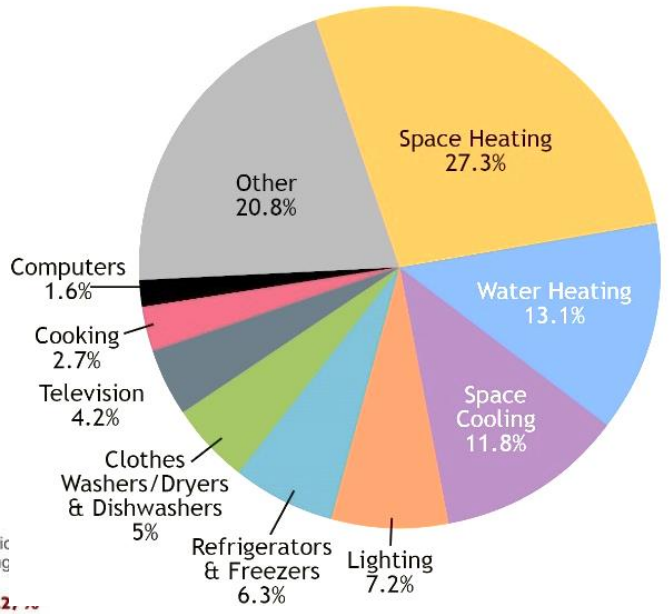
- Management of energy usage
- Power generation dispatch for solar, wind, etc.
- Better fault-tolerance of the grid
- Services for plug-in electric vehicles (PEV)
- Enhancing consumer relationships

# Energy Consumption




Data Center Power Usage

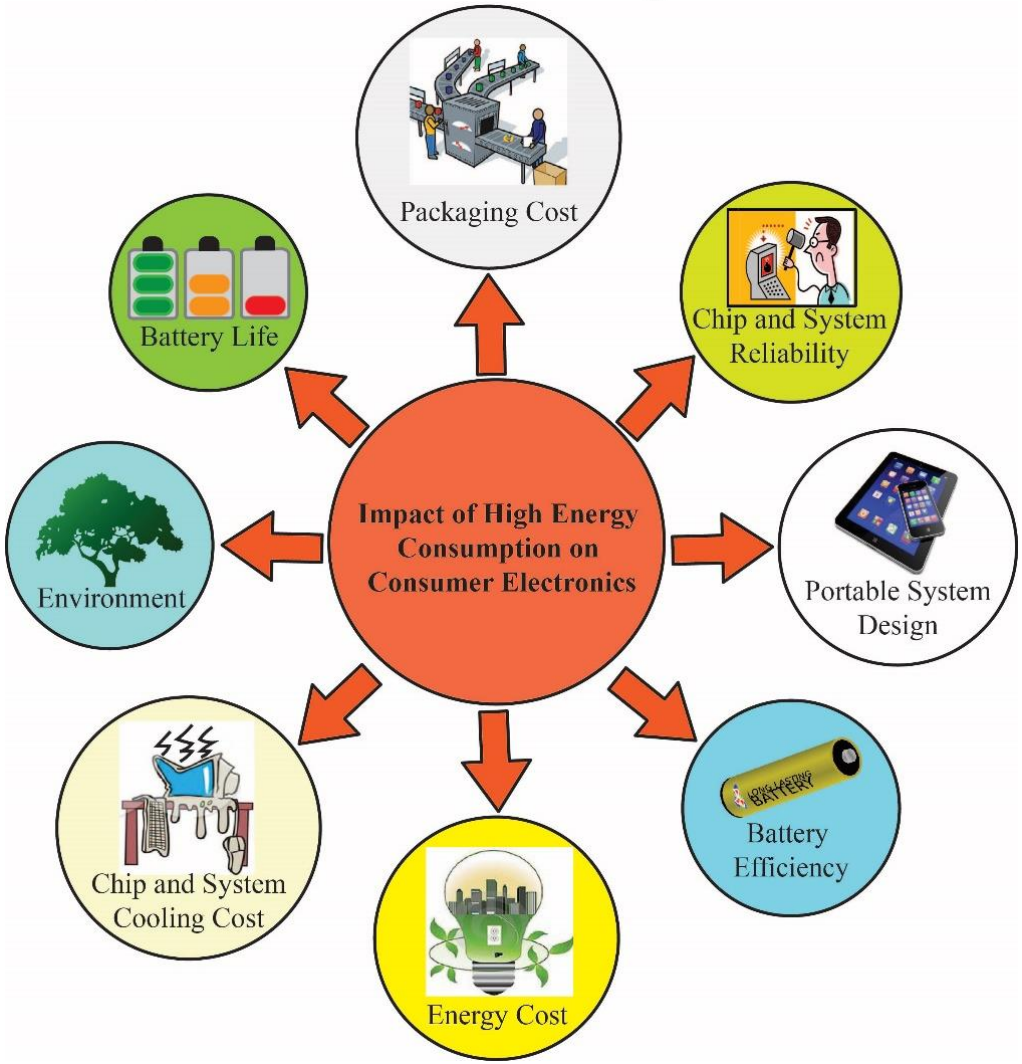



Individual Level: Imagine how often we charge our portable CE!

Source: https://www.engadget.com/2011/04/26/visualized-ring-around-the-world-of-data-center-power-usage/

# Impact of High Energy Consumption

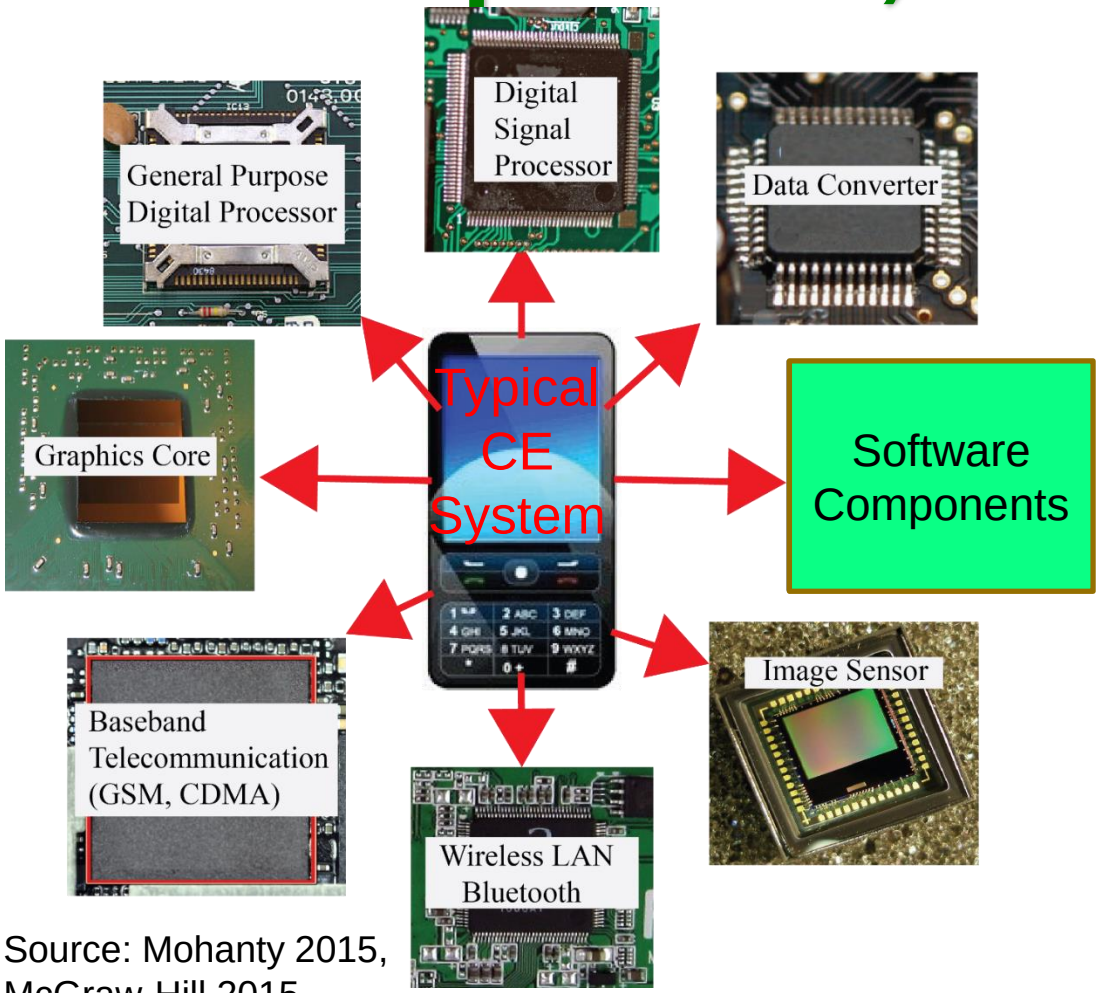



Source: Mohanty 2015, McGraw-Hill 2015

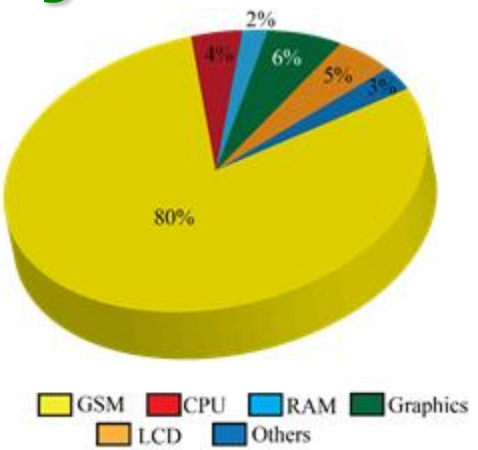

- Great idea: Smartwatch functioning like a smartphone.
- Big Problem: Battery life of one time charging is only 1 day.

Source: Mohanty 2013, CARE 2013 Keynote

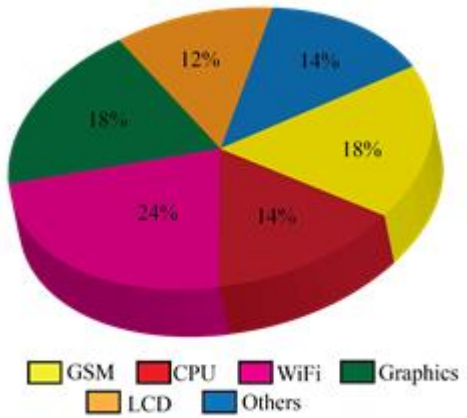
# Energy Consumption of Sensors, Components, and Systems




Source: Mohanty 2015, McGraw-Hill 2015




During GSM Communications




During WiFi Communications

# Safety of Electronics


One 787 Battery: 12 Cells / 32 V DC

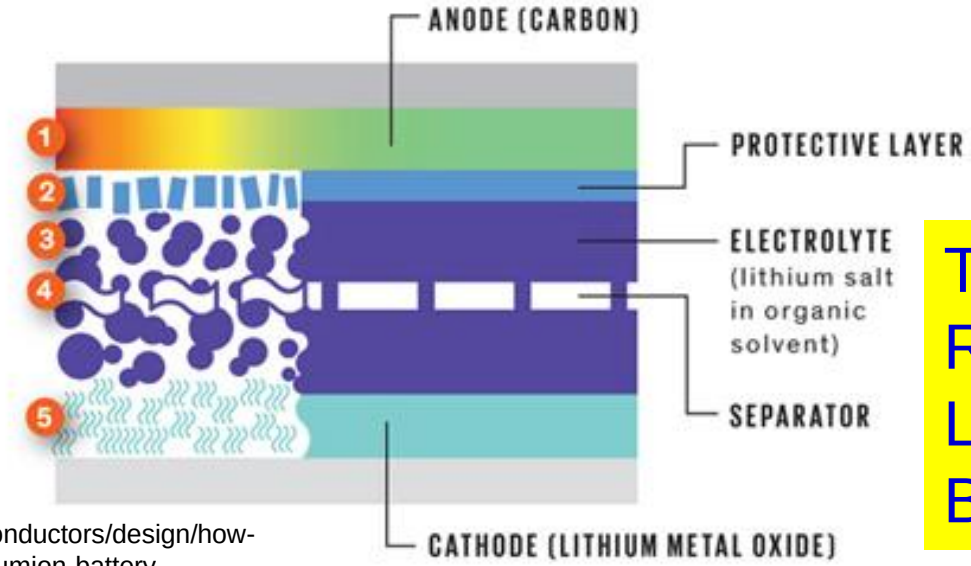
Source: http://www.newairplane.com

- Boeing 787's across the globe were grounded.

# Safety of Electronics

Smartphone Battery

1. Heating starts.
2. Protective layer breaks down.
3. Electrolyte breaks down into flammable gases.
4. Separator melts, possibly causing a short circuit.
5. Cathode breaks down, generating oxygen.

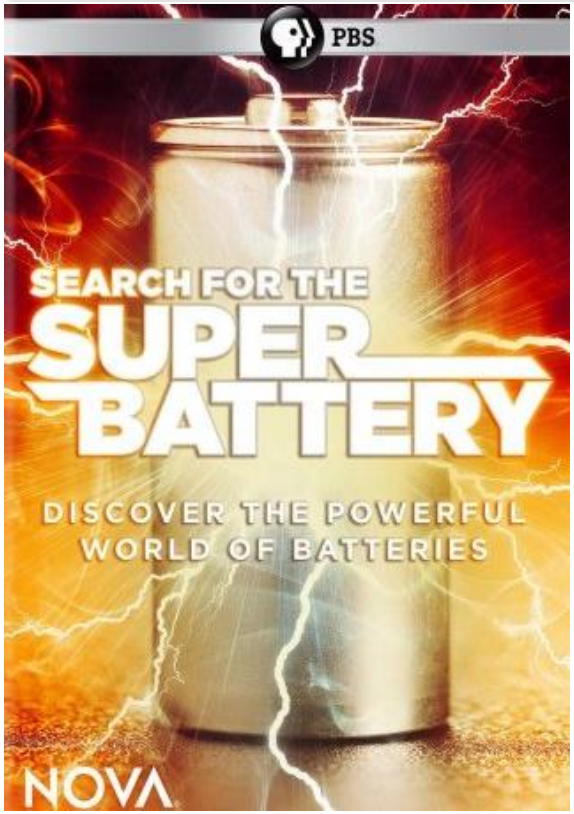



Source: http://spectrum.ieee.org/semiconductors/design/how-to-build-a-safer-more-energydense-lithiumion-battery

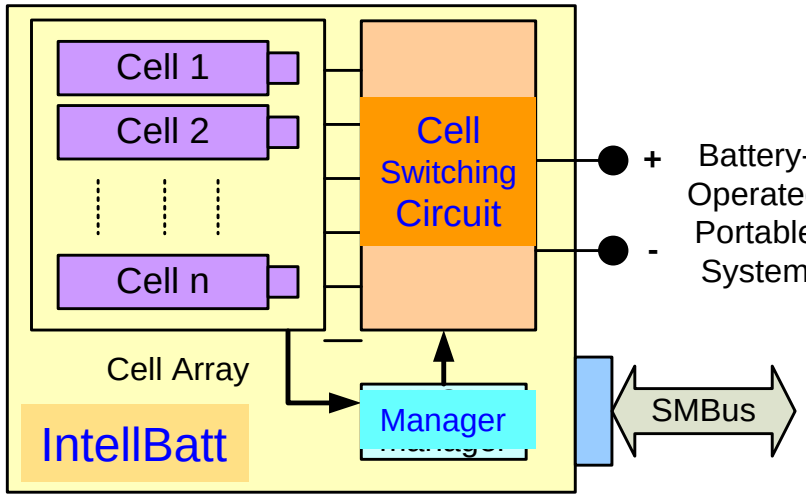
Thermal Runaway in a Lithium-Ion Battery

# Energy Storage - High Capacity and Efficiency Needed

| Battery | Conversion Efficiency |
|---|---|
| Li-ion | 80% - 90% |
| Lead-Acid | 50% - 92% |
| NiMH | 66% |




Intelligent Battery




Mohanty 2010: IEEE Computer, March 2010.
Mohanty 2018: ICCE 2018

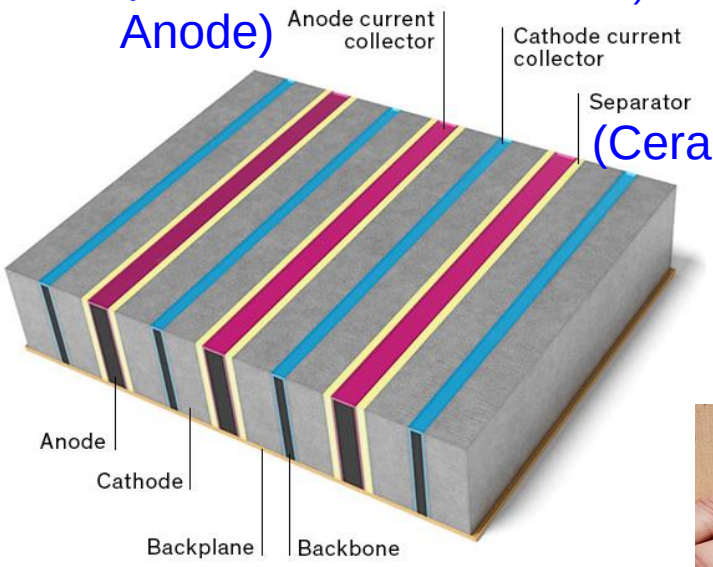

Lithium Polymer Battery


Supercapacitor

# Energy Storage - High Capacity and Safer Needed

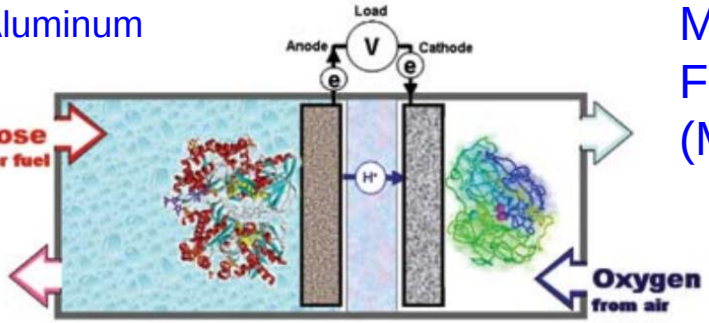
(Silicon Anode)

(Lithium Nickel Cobalt Aluminum Oxide - NCA) Cathode





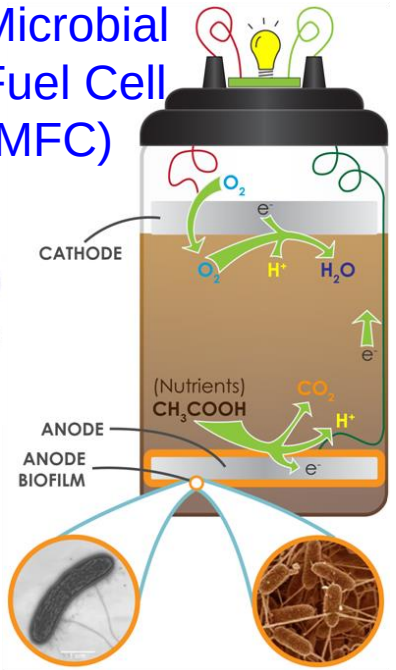
Source: http://spectrum.ieee.org/semiconductors/design/how-to-build-a-safer-more-energydense-lithiumion-battery

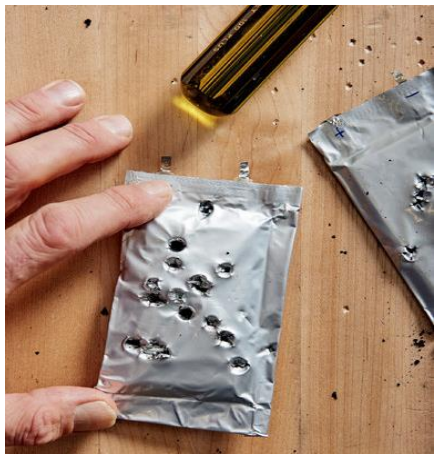



Source: https://www.electrochem.org/dl/interface/sum/sum07/su07_p28_31.pdf

Enzymatic Biofuel Cell

Microbial Fuel Cell (MFC)

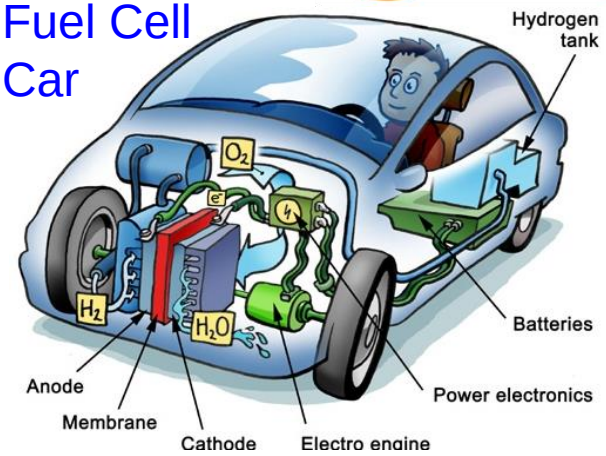


Solid Polymer Lithium Metal Battery

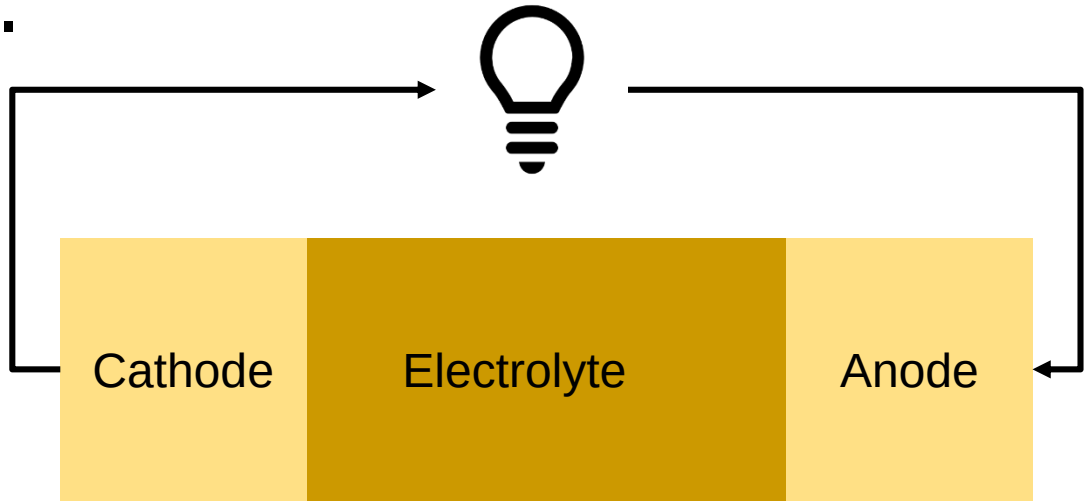
Source: https://www.nytimes.com/2016/12/11/technology/designing-a-safer-battery-for-smartphones-that-wont-catch-fire.html

Fuel Cell Car



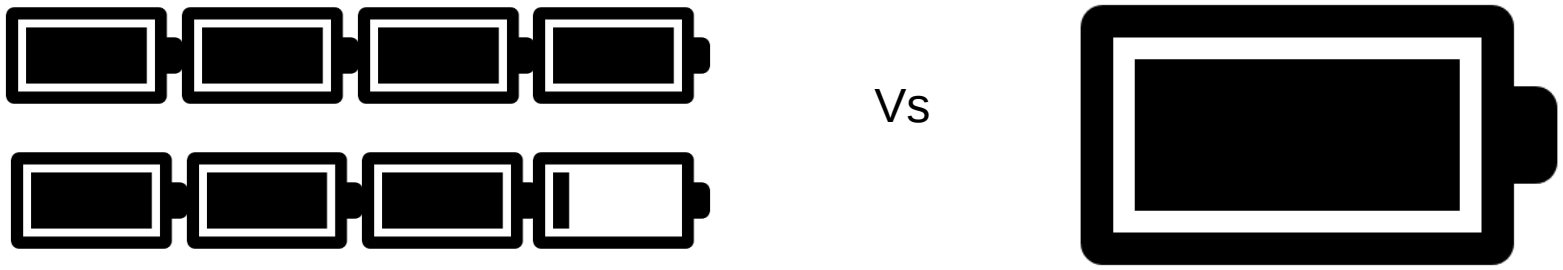
# Lithium-Ion Battery

- Understanding of how lithium-ion battery works
- High capacity vs. collection of low capacity batteries.



# Lithium-Ion Battery

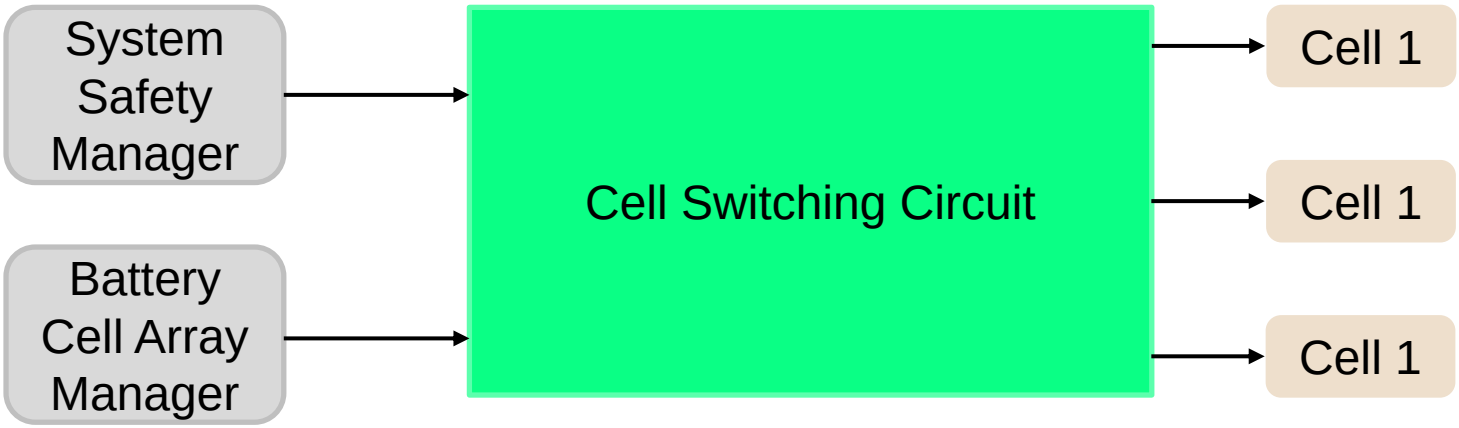
- Advantages of maintaining several lower capacity battery cells, vs. one very high capacity cell.



# Novel Contributions

- Intelligent batter management.
- Smart utilization of available energy in cells.
- Ability to replenish energy while using another cell (Future direction).

# Proposed RelBat Architecture



# Cell Selector Algorithm

**Algorithm 1** Proposed Cell Selector Algorithm.

**Data:** Input = Load Current(I), Voltage/State of Charge(V)
Output = g1, g2, and g3

**Result:** Assign threshold for I and V to g1, g2 and g3

initialization **while** *I and/or V(SoC) equals and/or less than(assigned threshold)* **do**

    g1, g2, and g3 equals 0 (gate opens) **if** *not* **then**
        go to next section current section becomes this one
    **else**
        g1, g2, and g3 equals 1 (gate closed)
    **end**

**end**

# Cell disconnect Algorithm

**Algorithm 2** Proposed Cell Disconnect Algorithm.

**Data:** Input = Voltage/State of Charge(V) Output = c1, c2, and c3

**Result:** Assign threshold for V to c1, c2 and c3

initialization **while** *V(SoC) equals and/or less than(assigned threshold)* **do**

    c1, c2, and c3 equals 0 (gate opens) **if** *not* **then**

        go to next section current section becomes this one

    **else**

        c1, c2, and 3 equals 1 (gate closed)

    **end**

**end**

# Design of RelBat

- Components of System:
  - Collection of battery cells.
  - Battery Cell Array manager.
  - System Safety Manager.

# Design of RelBat

- Cells are connected to a switching circuit which is mapped to the cells, in series and parallel combination.
- Its purpose is to transfer the load from one cell to another dependent on situation at that time.
- The situation is determined by the algorithm.

# Design of RelBat

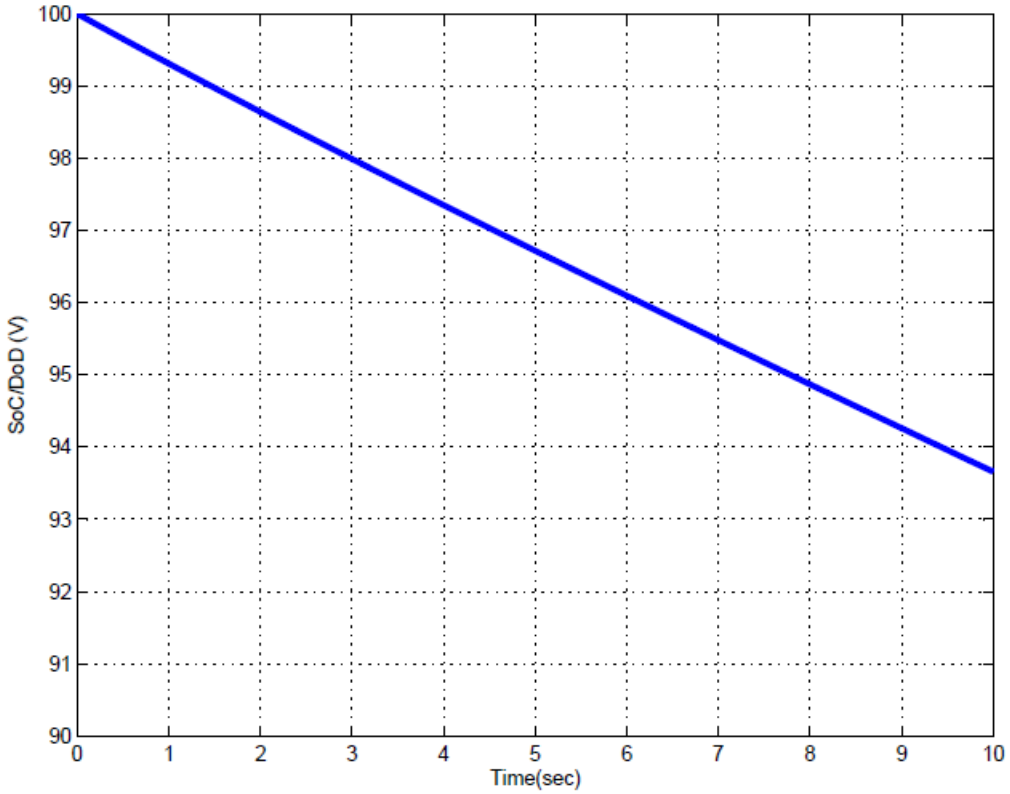
- The algorithm is embedded in both BCAM and SSM.
- The BCAM monitors the situation and environment and acts based on the input.
- The BCAM continues to analyse the situation, gathers the data as input and acts based on coded algorithm.

# Design of RelBat

- The SSM function is to determine if the system is safe to continue operation and if the user of the device is safe based on the situation.

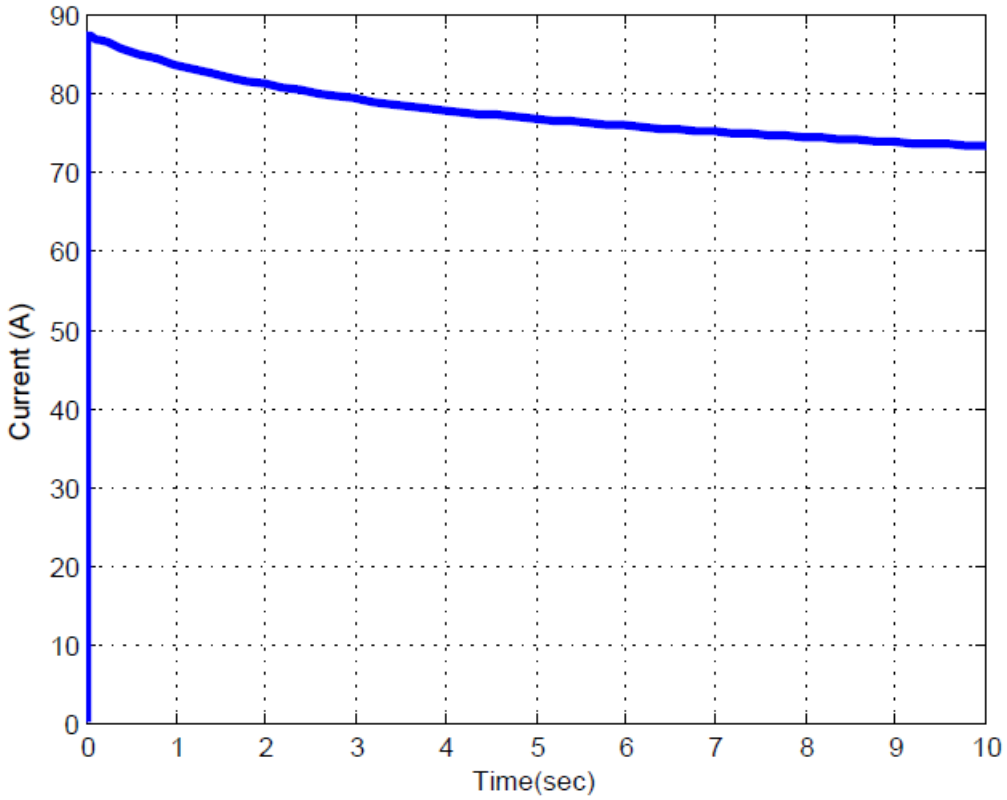
# Results – SoC/DoD

- State of Charge and Depth of discharge

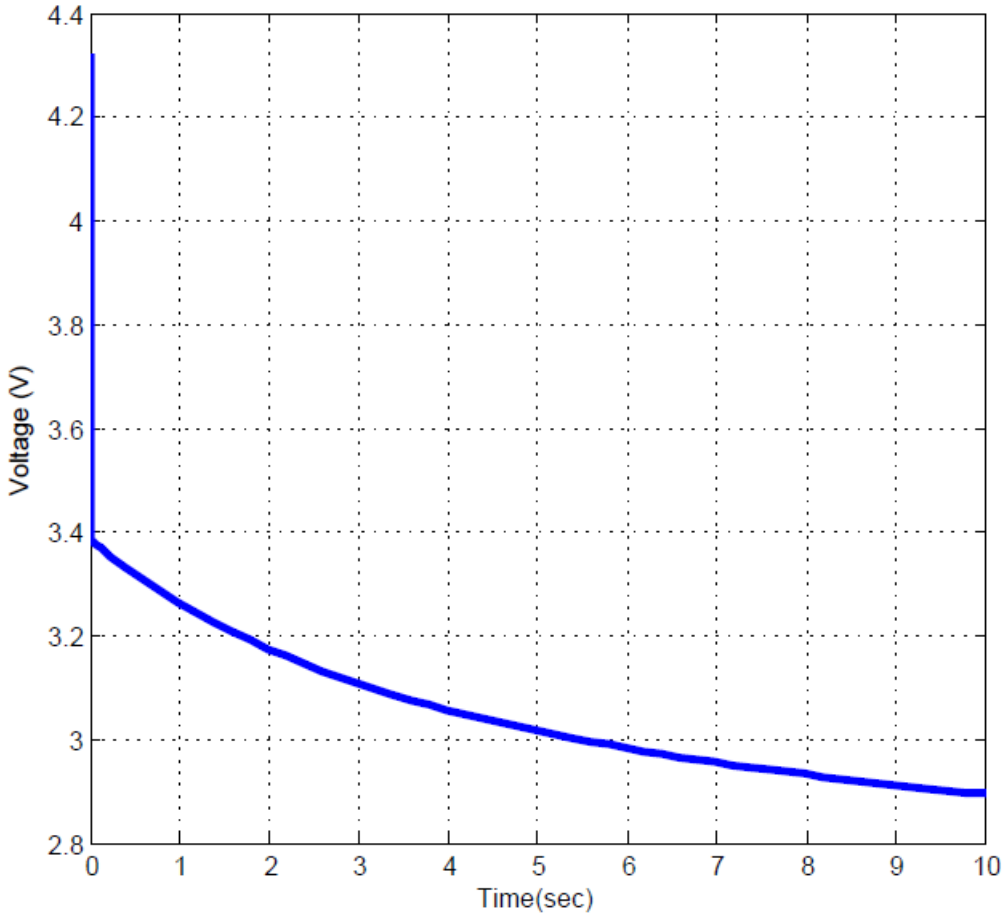


# Results - Current

- Current utilization by load.

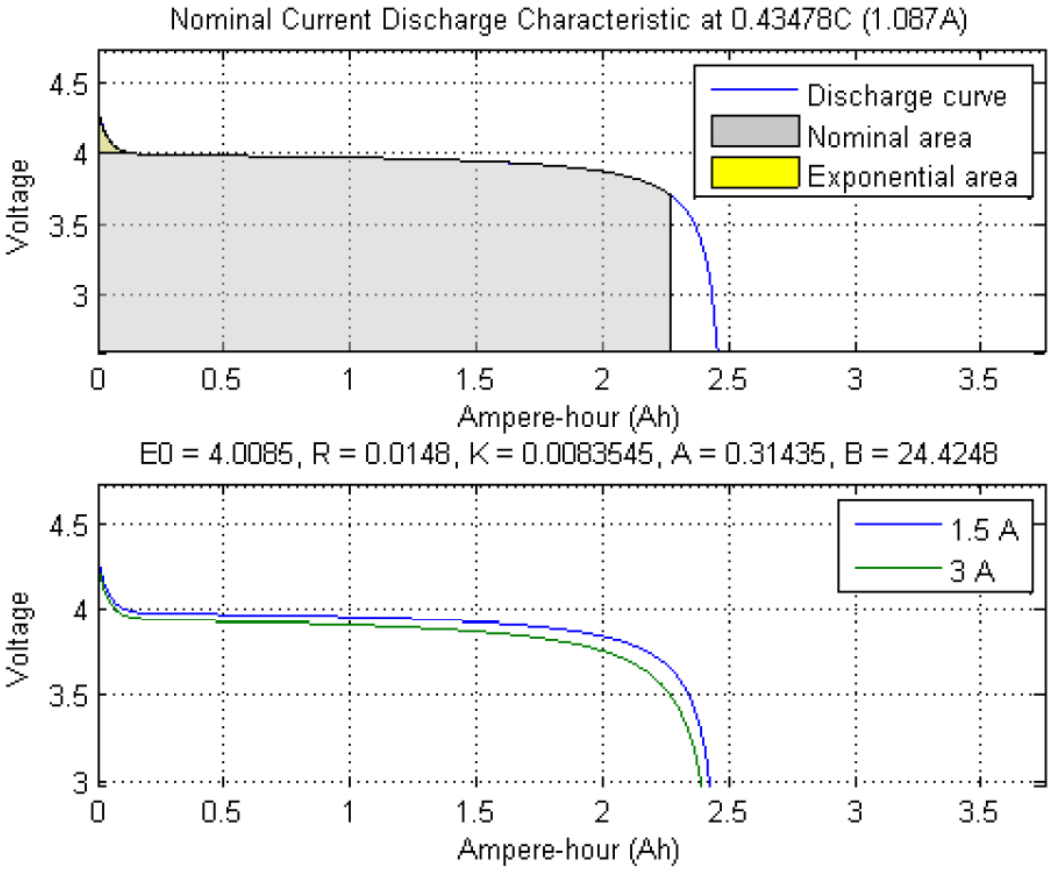


# Results – Voltage Attenuation



# Results

- Lithium-Ion Battery Discharge Characteristic.



# Conclusions and future research

- The proposed practical implementation of this research is in portable and non-portable devices
- Future research will address recharge management.
- The introduction of a solar charging system/panel will be a realistic and smart approach towards the next level of this research.

# Thank You !!!

Slides Available at:

http://www.smohanty.org