How to turbo charge the Internet of Things with Ultra Capacitors and Energy Harvesting

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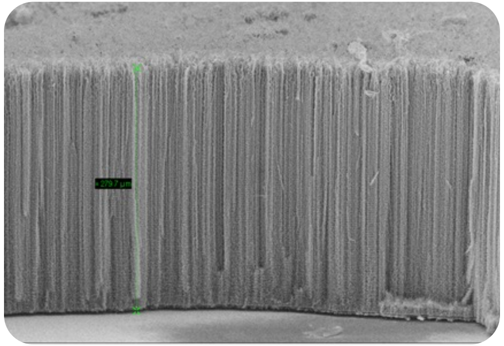
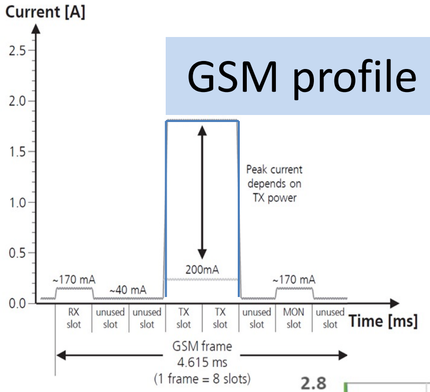
Ultracapacitors electrode technology based on vertically aligned carbon nanotubes (VACNT)

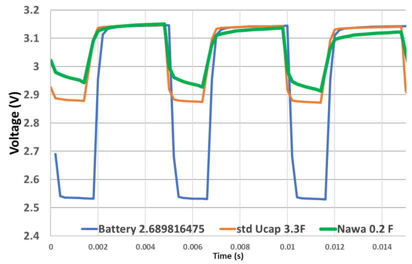
- All VACNT based
- Vertically aligned conductive path
- High ion/electron conductive carbon
- Excellent peak power performance
- Eco-Friendly, no chemicals, non-toxic
- 100% re-cyclable
- Operational life-time equal or larger than device life-time
- No replacement required
- No performance degradation over life- time, predictable performance
- Can be used combined with battery and EH

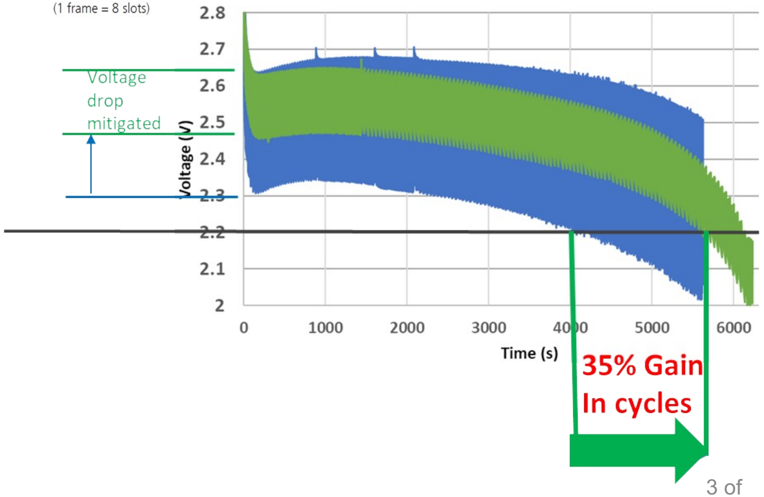


GSM tracking device / accelerated life time test

- 3V operated device
- Standby 40-170mA
- During transmission up to 2A peak
- Voltage drop during transmission
- Cut-off voltage shuts down system
- Use of Ultra-Capacitors mitigates voltage drop and pre-mature shutdown
- Result is 35% gain in operational life time

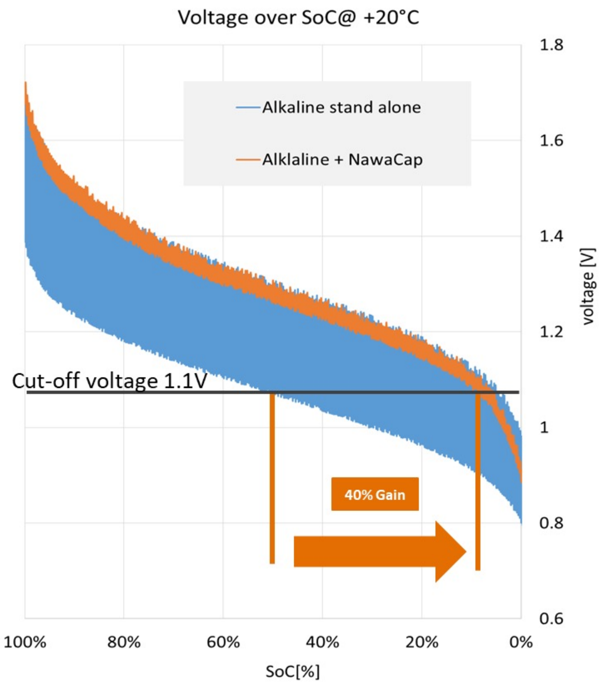






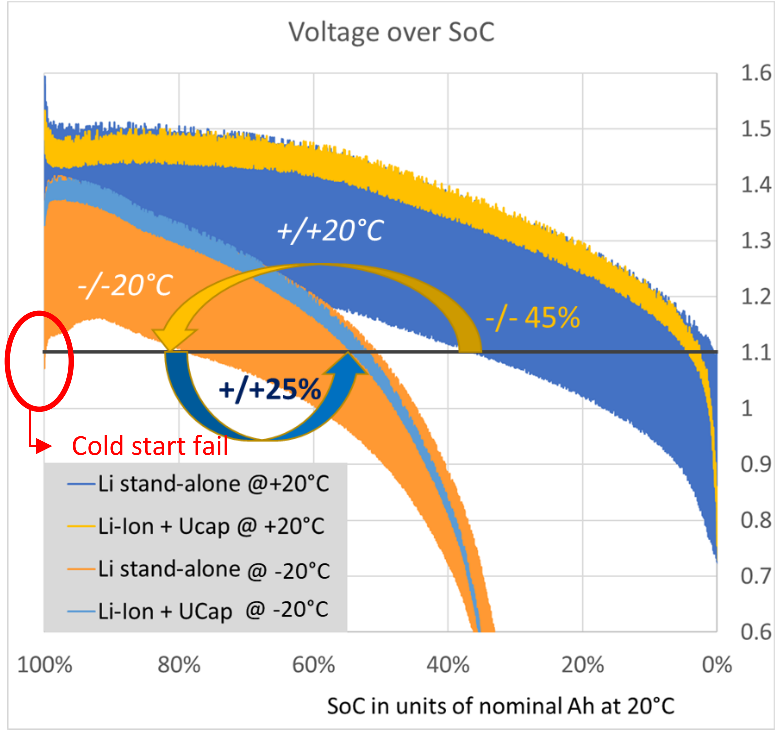
Enable Alkaline as alternative for Lithium

- AA Alkaline battery,1.5V
- Alkaline in many cases not feasible due to linear degrading voltage platform over operational life time
- Ucap “flattens” voltage platform
- Enhances usable energy with 40%

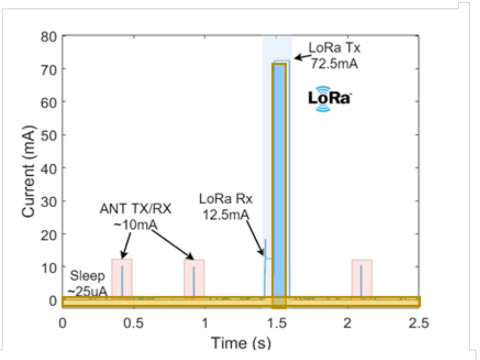


Performance enhancement at extreme temperatures

- At low temperatures
  - Cold start troublesome
  - the cut-of Voltage is reached at a SOC of 80%
- Only 20% usable energy in the battery
- Ucap support more than doubles usable energy at cold conditions (SOC 55%)
- More reliable performance



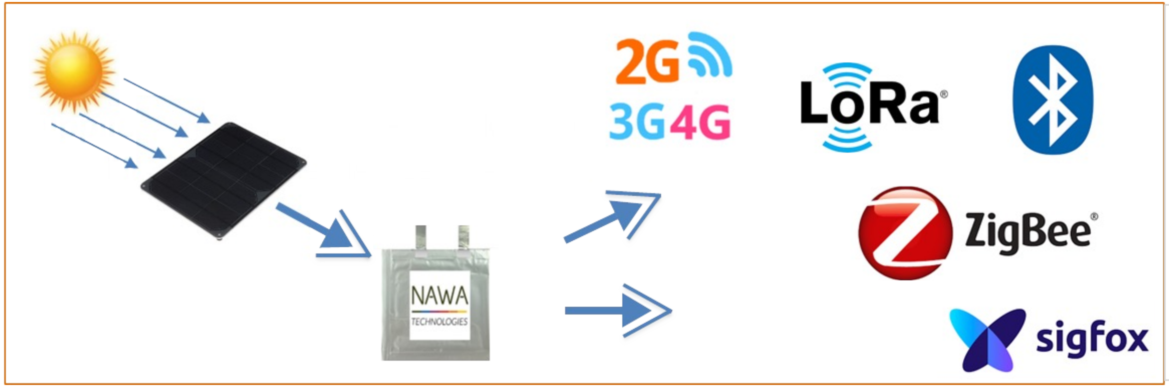
Energy Harvesting with UCap

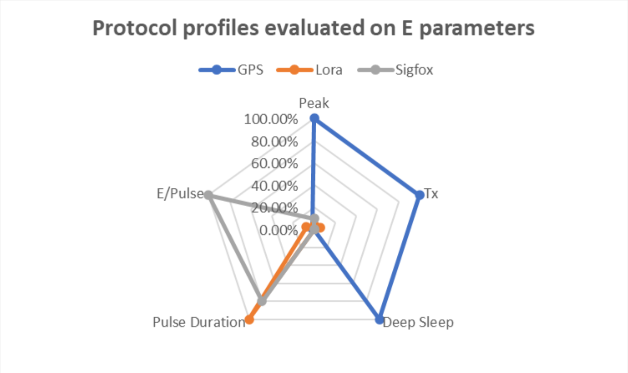


NAWACap – High Power – High Current

- Charged by Solar cell during standby
- Peak transmission by Ucap
- Ucap re-charged between intervals

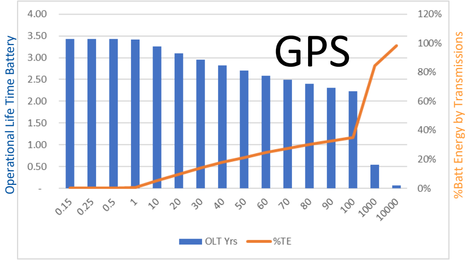
Solar Cell – Deep Sleep – Low Current

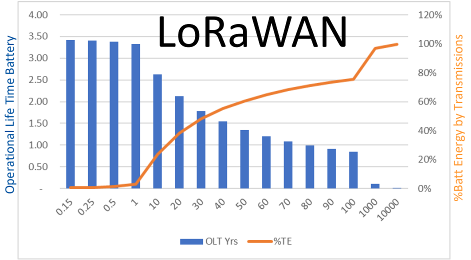


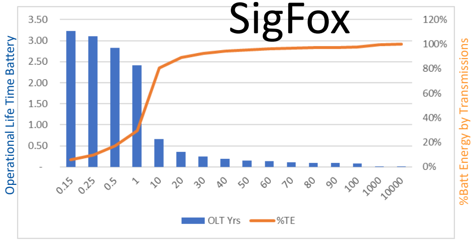


When to use Energy Harvesting

- Battery Operational Life Time strongly determined by #Transmissions / day
- At high level transmissions/day, >90% of battery energy is used for transmissions
- Batter better solution
- At low occurrence level (<10 Tr/day), BOLT determined by standby / deepsleep
- BOLT hardly affected by transmissions
- In this region EH (Solar) with Ucap better solution

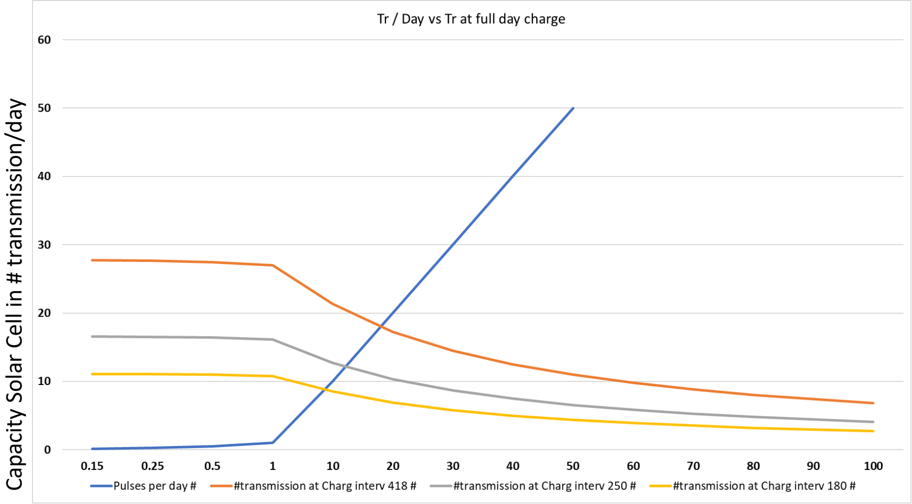






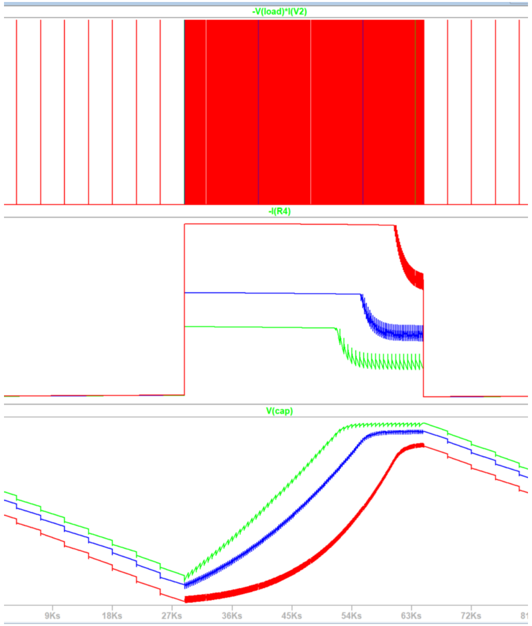
How to optimize configuration

- Example LoRaWan
- Reviewing three different EH solar cells with output power (Indoor)
  - 480µW #28 Tr/day
  - 250µW #16 Tr/day
  - 180µW #11 Tr/day
- In the range of 1-20 transmissions per day the solar panel / Ucap can optimized
- In case >20 transmissions/day, support of energy storage desired
- Output power matches transmission energy
- Ucap size mainly determined by E-Transmission

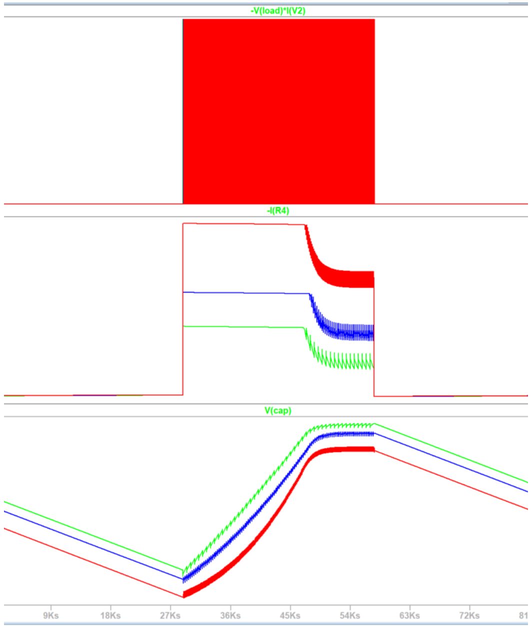


Transmission strategy

Day/night charging/transm.



Day time charging/transm.



Hybrid Usercases

Bulky | Flatter+ Lighter + Smaller | Lithium Free

Side View

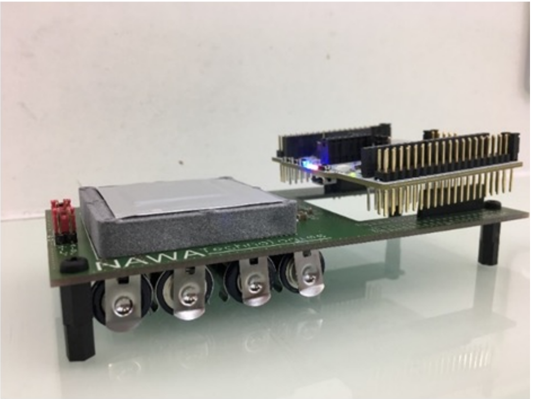
Reference AA Li-Ion Battery | AAA + Ultracap | Coin Cell + Ultracap | Solar Cell + Ultracap | Alkaline + Ultracap

Top View

IoT Usercase with STM32 + Alkaline + In-Building Solar

STM LoRaWAN integrated solution Ucap poweres by:

- Alkaline Battery + Ucap
- solar cell + Ucap



- Device was life demonstrated at the CES 2020 in Las Vegas
- Fully operational with Alkaline battery + Ucap and equal life time as Li-Ion
- Fully operational with Solar cel + Ucap harvesting ambient light

Usercase E-Peas with Ucap + Solar EH with battery as back-up

- Ucap and EH holds-up performance under normal conditions
- Once operating conditions change drastically, battery is used as back-up

Usercase: Post-Crash emergency signal

- 2G/3G
- After main battery fail / detached battery
- One single charge NAWACap - 6 SMS transmissions demonstrated
- Suitable for any emergency alert transmission
- NAWACap can be charged by EH integrated solar cell or battery during operation

Transmission	Voltage	Voltage drop
T1	6.39	Start
T2	5.94	0.45
T3	5.47	0.47
T4	4.97	0.5
T5	4.41	0.56
T6	3.79	0.62
	3.10	cut-off

General considerations

- Factors to take into account when configuring a EH + Ucap combination:
  - Start-up of device
  - Firmware updates
  - Transmission interval
  - Transmission strategy
  - Protocol used
  - Consistency and efficiency Energy Harvesting solution
  - External operational conditions like °C
  - Signal strength and Tr/Tx repetion required for transmission
- EH needs to be configured towards the average energy consumption per day (St.By/Deepsleep/Leakage)
- Ucap configured towards the peak, peak duration and repetition

Conclusions

- Ultracapacitors are an excellent complementary solution for IoT devices with low transmission rates
- Li-Battery free solution perfectly feasible
- With EH + Ucap no need for battery replacement
- Low TCO solution

NAWARACER: A TECHNOLOGY PLATFORM DEMONSTRATOR

NAWA Racer

- First E-bike with integrated Hybrid Batteries
- Lithium battery for high density storage = autonomy
- NAWACap for energy, power and max recuperation
- NAWA seamless battery management system
- Lighter overall mass of energy solution: >150 kg less
- Higher range: 150 km standard - 300 km NAWA urban package
- Composites in frame and wheels