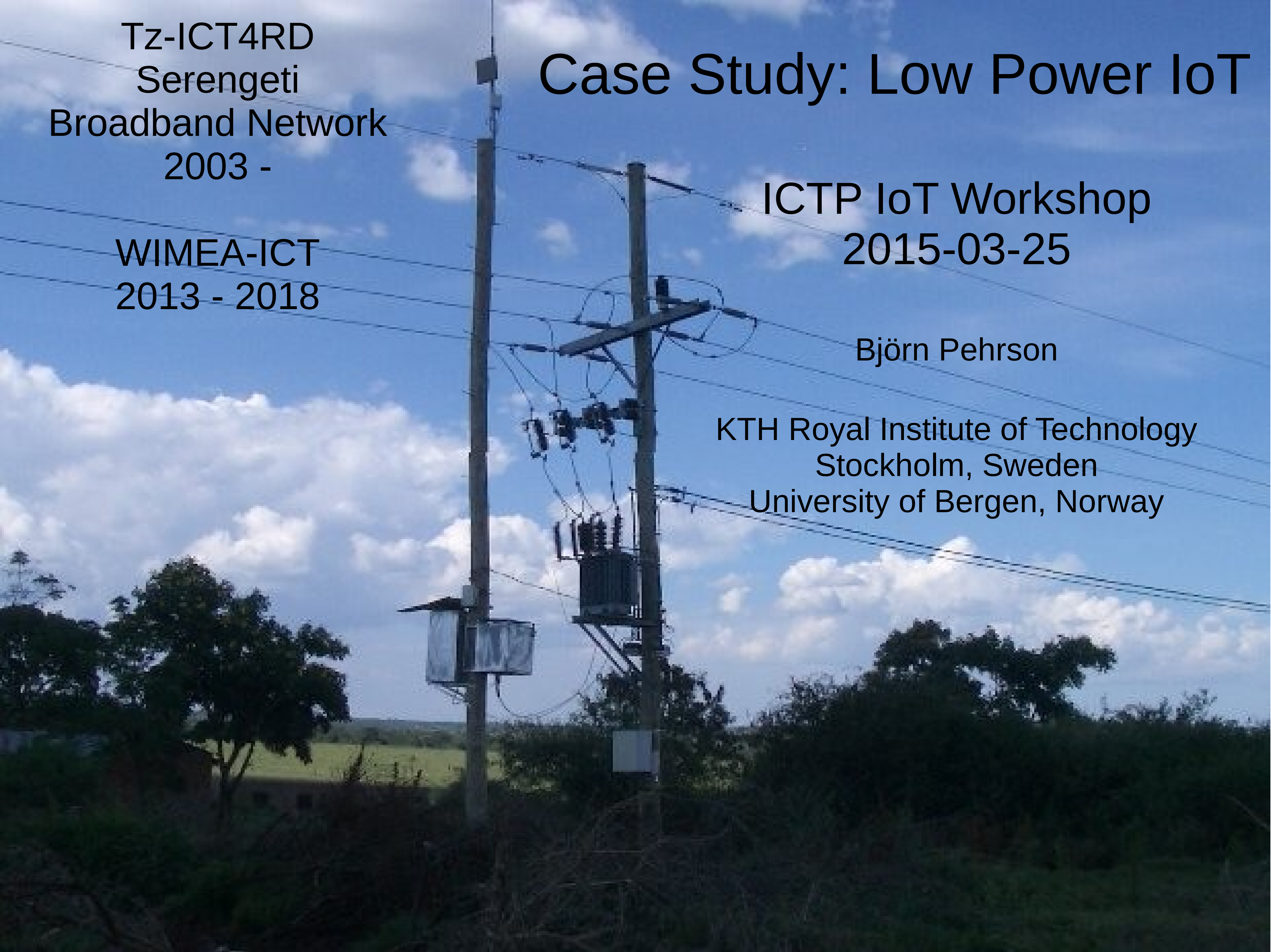

Case Study: Low Power IoT

Tz-ICT4RD
Serengeti
Broadband Network
2003 -

WIMEA-ICT
2013 - 2018

ICTP IoT Workshop
2015-03-25

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Stockholm, Sweden
University of Bergen, Norway

Weather Information Management in East Africa

WIMEA-ICT

Environment Monitoring

Uganda, Tanzania, South Sudan

- R&D Components on
  - Digitizing legacy data
  - Weather research and forecasting (wrf)
  - Automation and densification of the observation station network
  - Dissemination of data to end-users

Approaches to meet the power supply challenge

1. Design of power-lean loads
2. Adequate storage
3. Selection of Adequate sources and backup sources

Experiences from field tests mainly in the

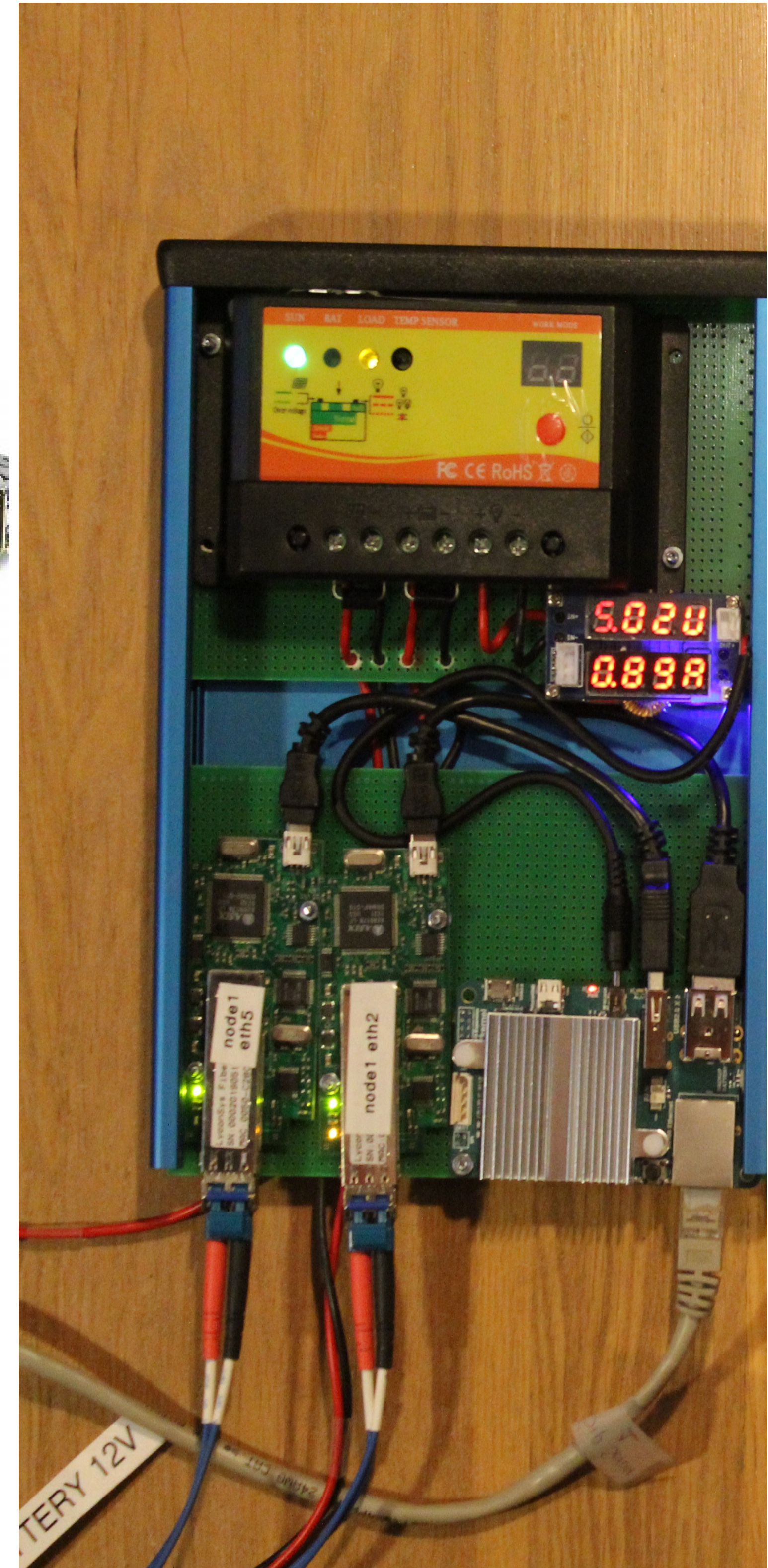
- Serengeti Broadband Network (www.ict4rd.ne.tz)
- WIMEA-ICT project (wimea-ict.gfi.uib.no)
- AMPRnet Sweden (www.se.ampr.org)

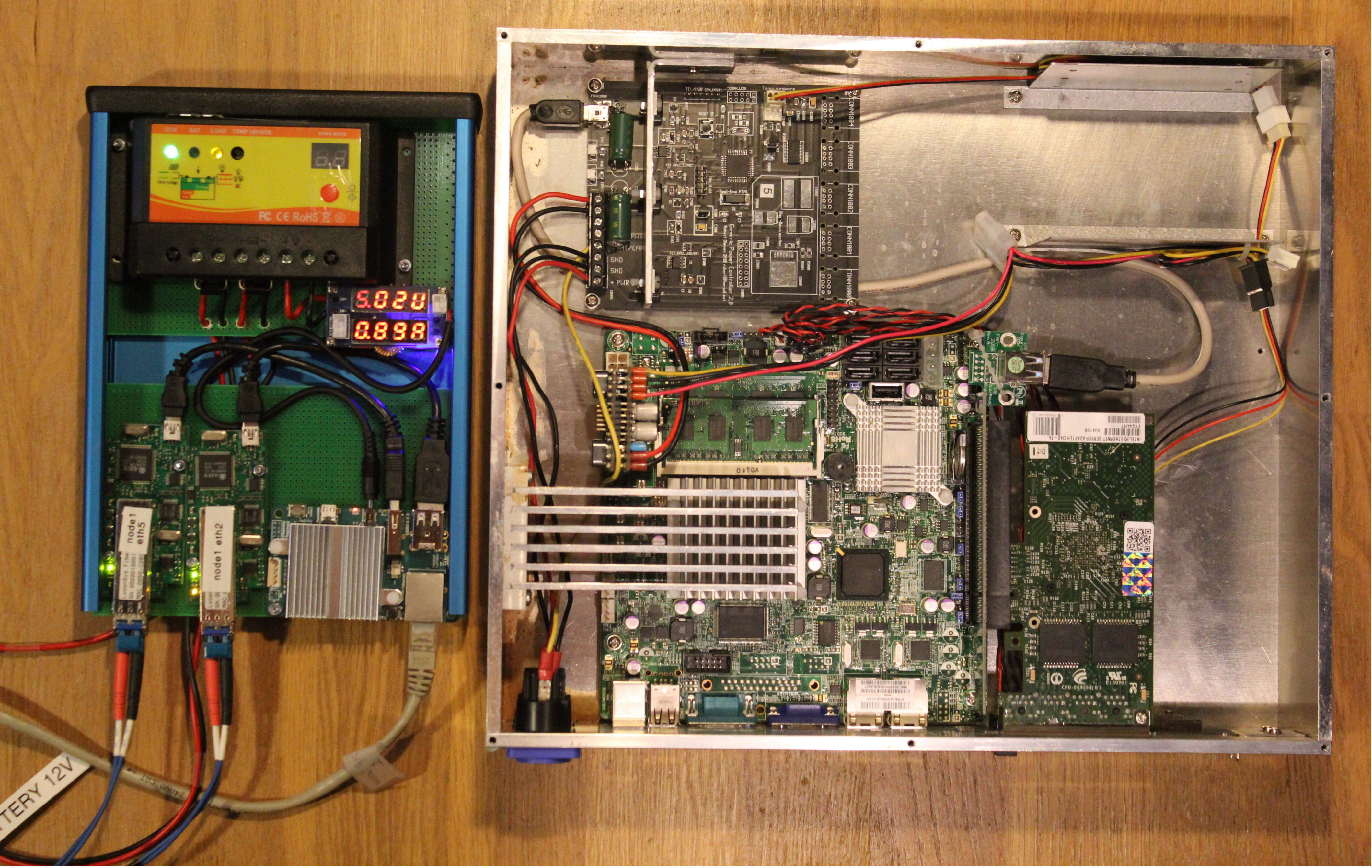
Crowd-sourcing environment data

#1: Power-lean loads

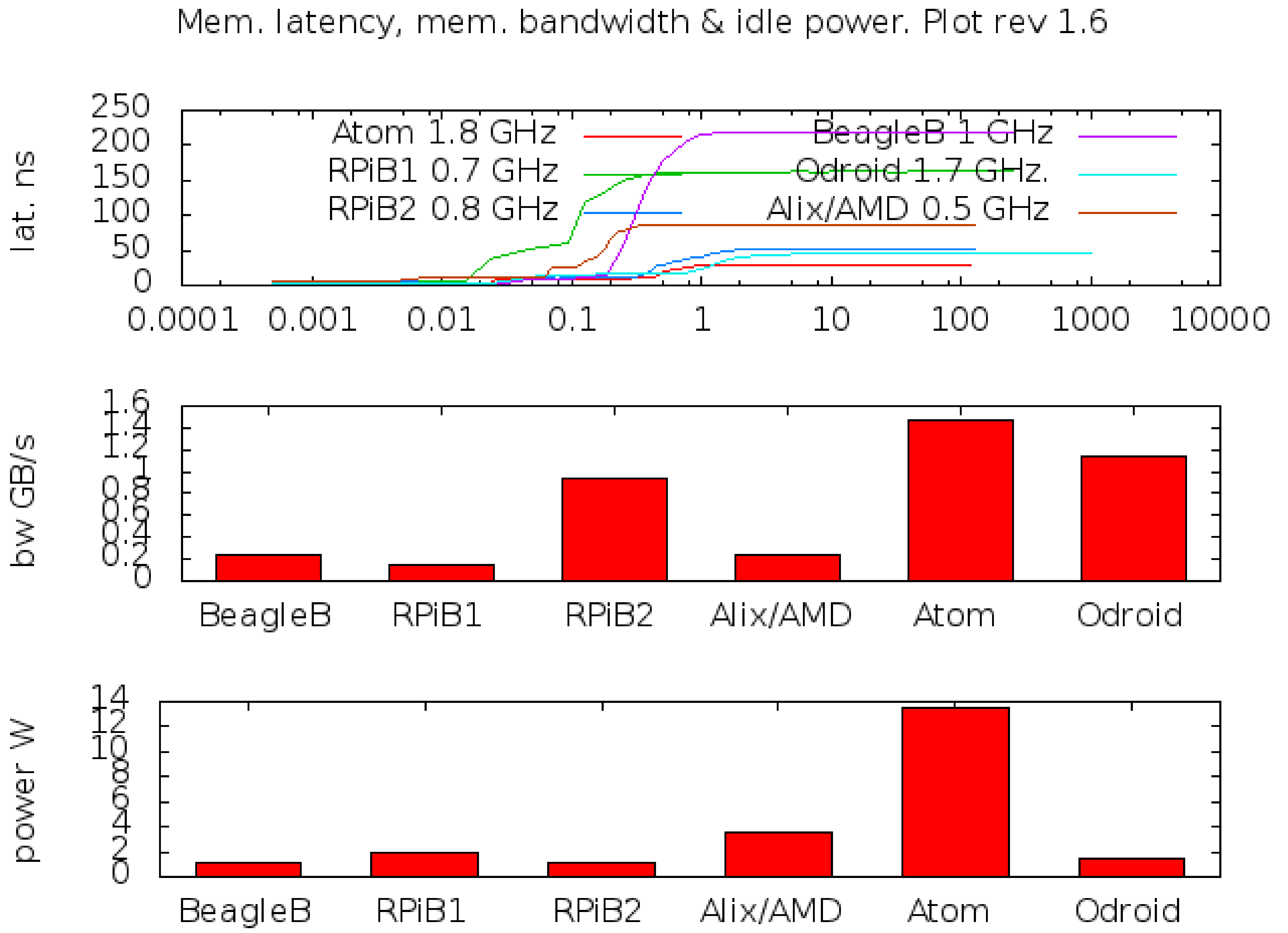
gateway and mote

- CPU/MCU
- Motherboard/Mote
- Network interfaces/modems
- Sensor interfaces
- Sensors
- The PSU itself





Serengeti Broadband Network core routers with optical fibre transceivers
- Generation 2 (right) Atom based, GE 2 RJ45, 4SFP ~20w.
- Generation 3 (left) Odroid U3 based, FE, 1 RJ45, 2 SFP ~ 5W

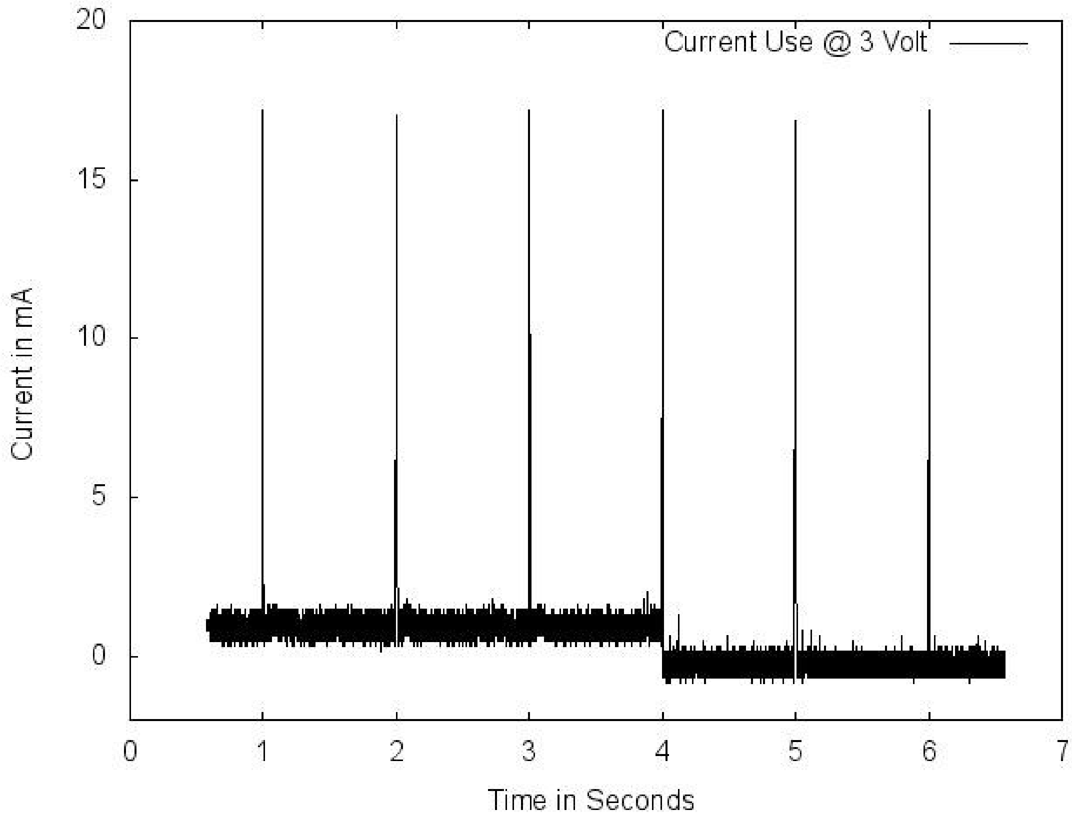

Mem. latency, mem. bandwidth & idle power. Plot rev 1.6
lat. ns
Atom 1.8 GHz
RPiB1 0.7 GHz
RPiB2 0.8 GHz
BeagleB 1 GHz
Odroid 1.7 GHz.
Alix/AMD 0.5 GHz
0.0001
0.001
0.01
0.1
1
10
100
1000
10000
bw GB/s
BeagleB
RPiB1
RPiB2
Alix/AMD
Atom
Odroid
power W
BeagleB
RPiB1
RPiB2
Alix/AMD
Atom
Odroid

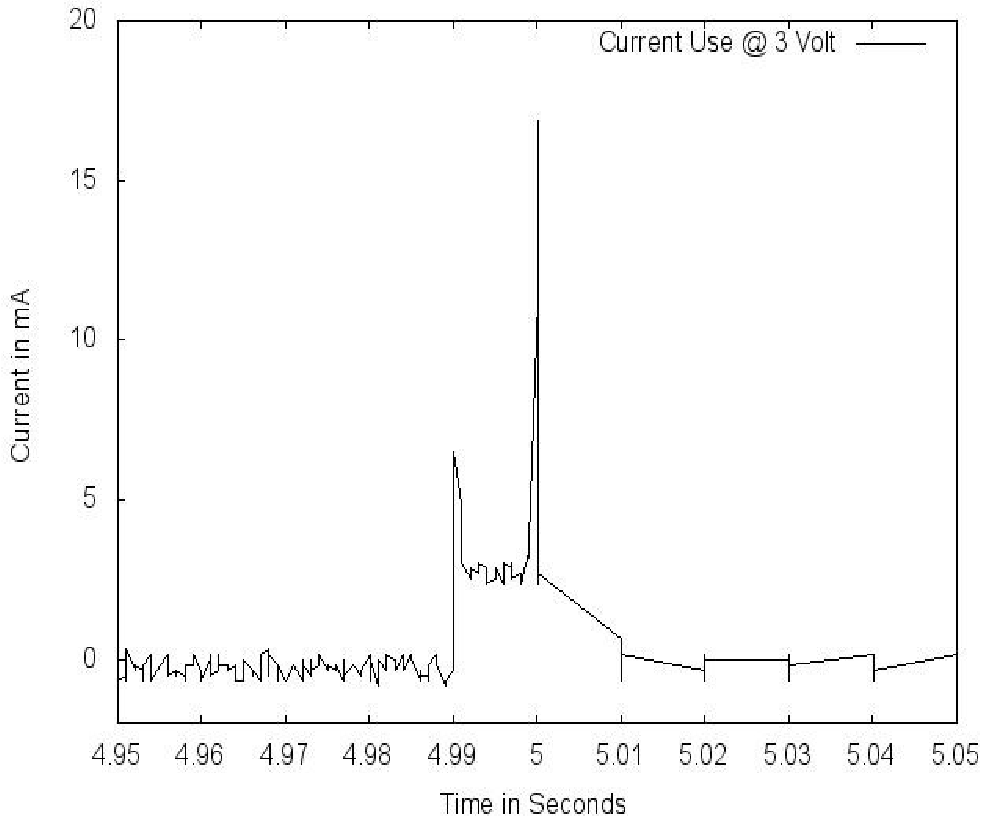
Radio-Sensors mote

http://www.radio-sensors.com/

- ATMega128RF integrates MCU 802.15.4 transceiver and ADC 1.8-3.6V operating voltage 250nA@25C in deep sleep
- Analog and pulse inputs with feed
- DS18B20 and Ambient light sensors on board
- Daughter cards with other sensors
- Connectors to SPI, I2c, ow-buses
- CinikiOS-based software

Mote load current





Periodic broadcast of Contiki RIME packet intervals with ATMega128RF IEEE 802.15.4 output at 3dBm:

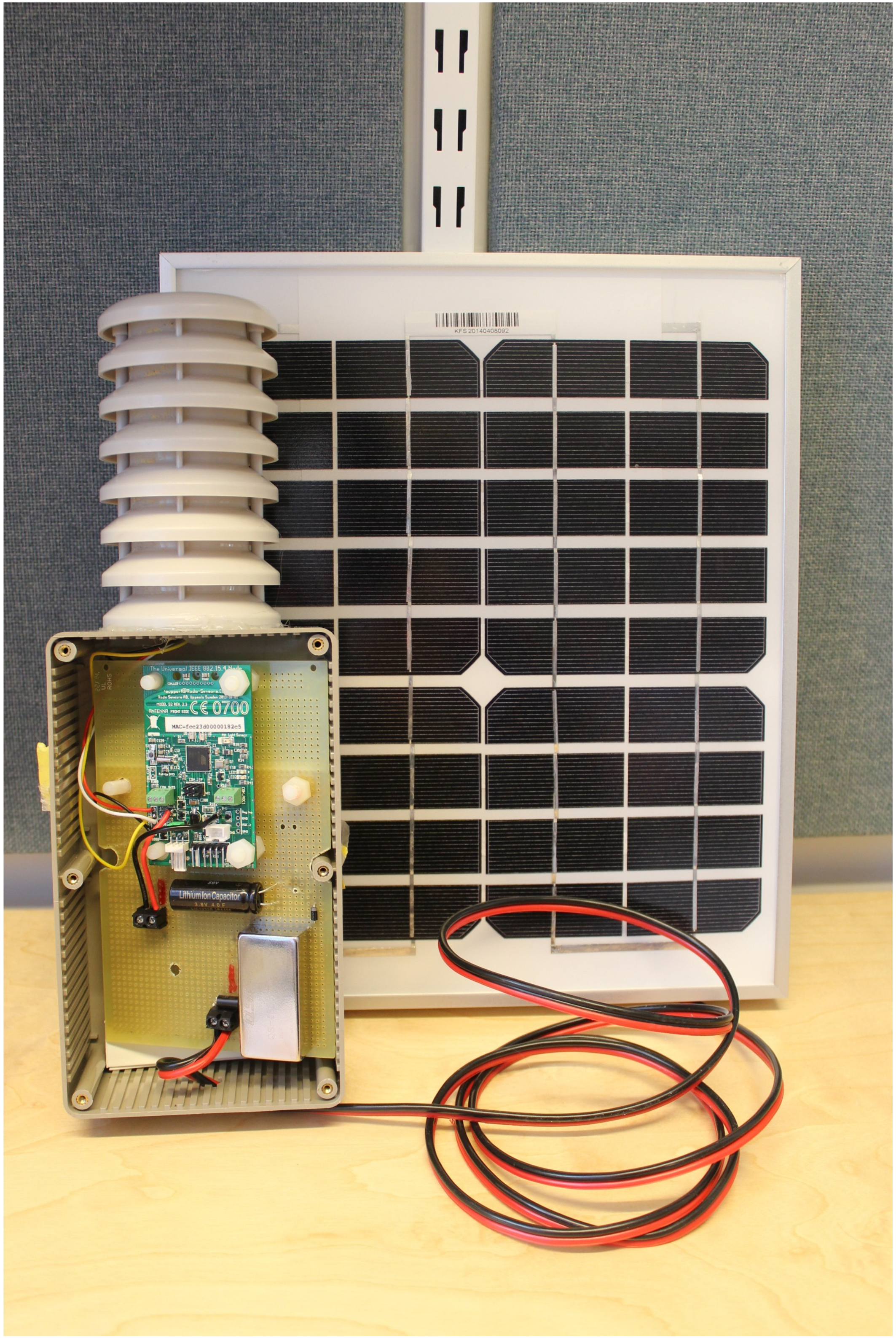
Left: Using MCU sleep mode IDLE first 4s and then PWR-SAVE
Right: Close-up of one of the transmissions in sleep mode PWR-SAVE

WIMEA-ICT montoring station prototype
http://wimea-ict.gfi.uib.no

- At each station, a wireless sensor network connecting sensors on different locations to a sink node connected to a gateway
  - 10m node measuring wind and insolation
  - 2m node measuring air temperature and humidity
  - Ground node measuring precipitation, soil tempterature and soil moisture
  - Sink node measuring atmospheric pressure, connected to
  - Gateway with buffering capacity and alternative uplinks

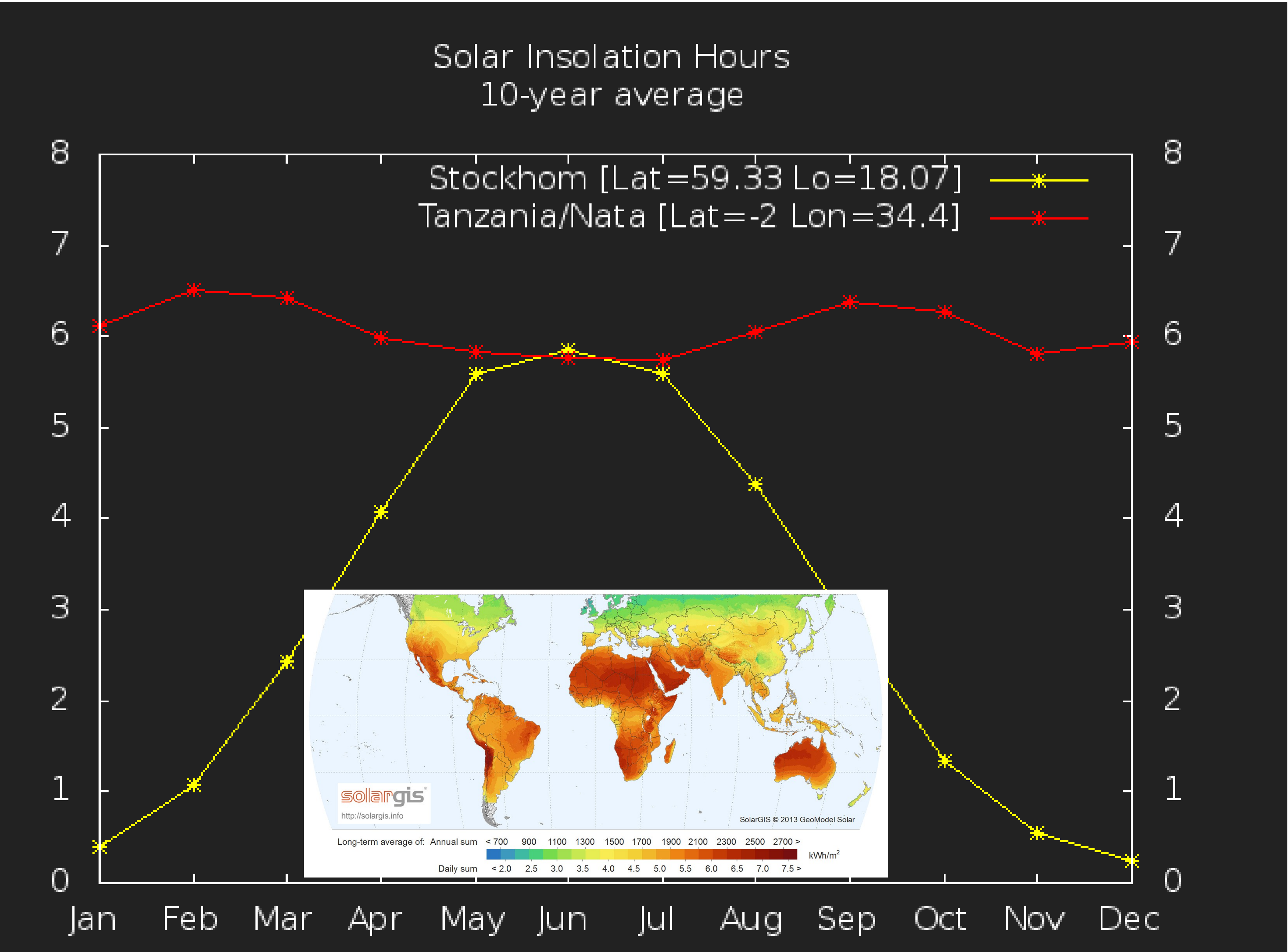
Wimea-ICT 2m node

- Radio-Sensors mote
- SHT25 sensor in ventilated radiation shield
- 40F LIC
- DC-DC converter QSKJ QS-2405CBD-3A
- 2 1N5819 diodes
- 1 TVS diode
- 10W Solar panel



#2: Adequate sources and backups

- Solar (NASA statistics)
- Wind
- Fuel cells

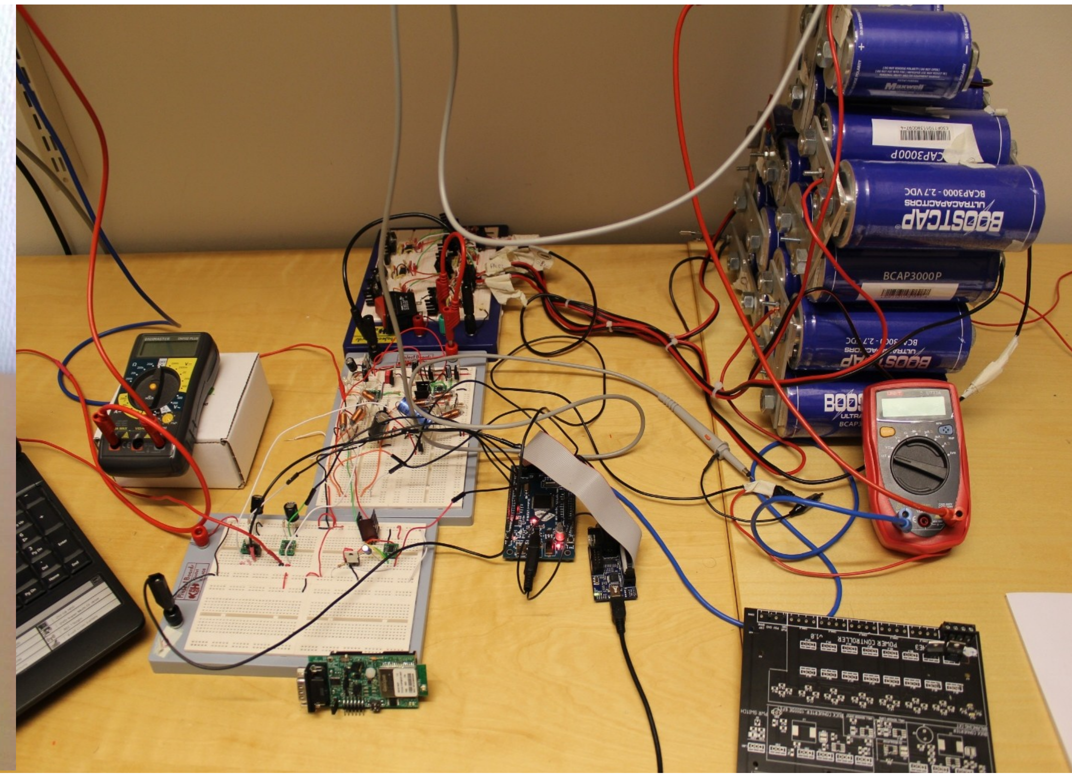

Solar Insolation Hours
10-year average
Stockhom [Lat=59.33 Lo=18.07]
Tanzania/Nata [Lat=-2 Lon=34.4]
0
1
2
3
4
5
6
7
8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
solargis
http://solargis.info
SolarGIS © 2013 GeoModel Solar
Long-term average of: Annual sum < 700 900 1100 1300 1500 1700 1900 2100 2300 2500 2700 >
kWh/m2
Daily sum < 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 >

#3: Storage

- Batteries with chemical cells
  - High internal resistance
  - Heat sensitive
  - Limited number of (deep) cycles
- Batteries with electrostatic cells
  - Electrical Double Layer Capacitors (EDLC) max 2.7V
- Batteries with hybrid cells
  - Lithium Ion Capacitors (LIC) Max 3.8V - min 2.2V
    - What does hybrid mean?

EDLC


BCAP3000P
BOOSTCAP
ULTRACAPACITORS
BCAP3000 - 2.7 VDC

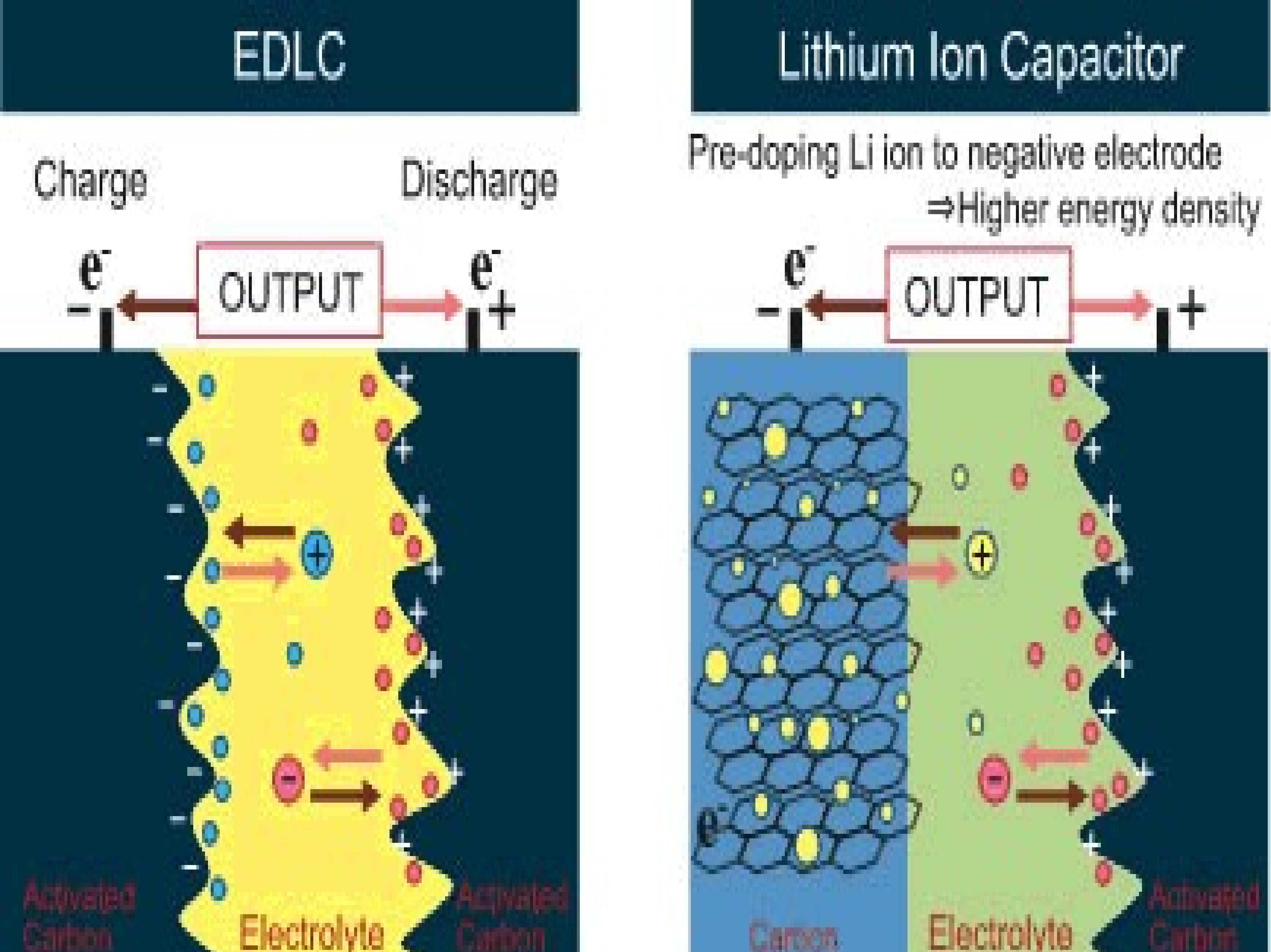

BCAP3000P
BOOSTCAP

Capacitor theory

- Coulombs Law: $Q = C * U$ (1)
  - Q = stored charge (Coulomb or As)
  - C = Capacitance (F)
  - U = Potential between the electrodes (V)
- Deriving (1) gives you $dq/dt = i = C * du/dt$ (2)
- You get the power fed to the capacitor when charging by integrating u*i over time:

$$\int u*i*dt = C*\int u*du = C*U^2/2 \ \ W \qquad (3)$$

- Connecting capacitors in series gives you:
- $1/C = 1/C_1+1/C_2+...1/C_n$ (4)
- If all n capacitors have the same capacitance (C) in series, the total capacitance $C_{tot}= C/n$ (5)



EDLC
Charge
Discharge
OUTPUT
Electrolyte
Lithium Ion Capacitor
Pre-doping Li ion to negative electrode
⇒Higher energy density
OUTPUT
Electrolyte

Varying voltage

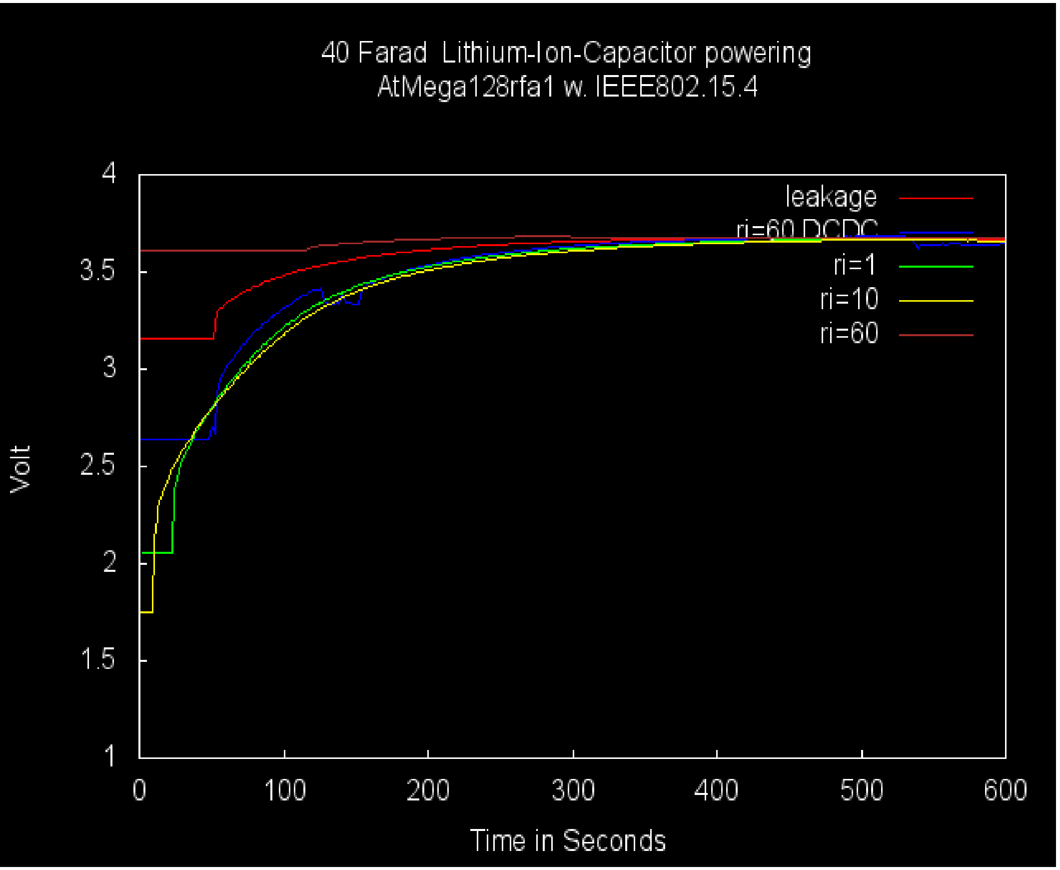
- The capacitor voltage decreases as it is discharged

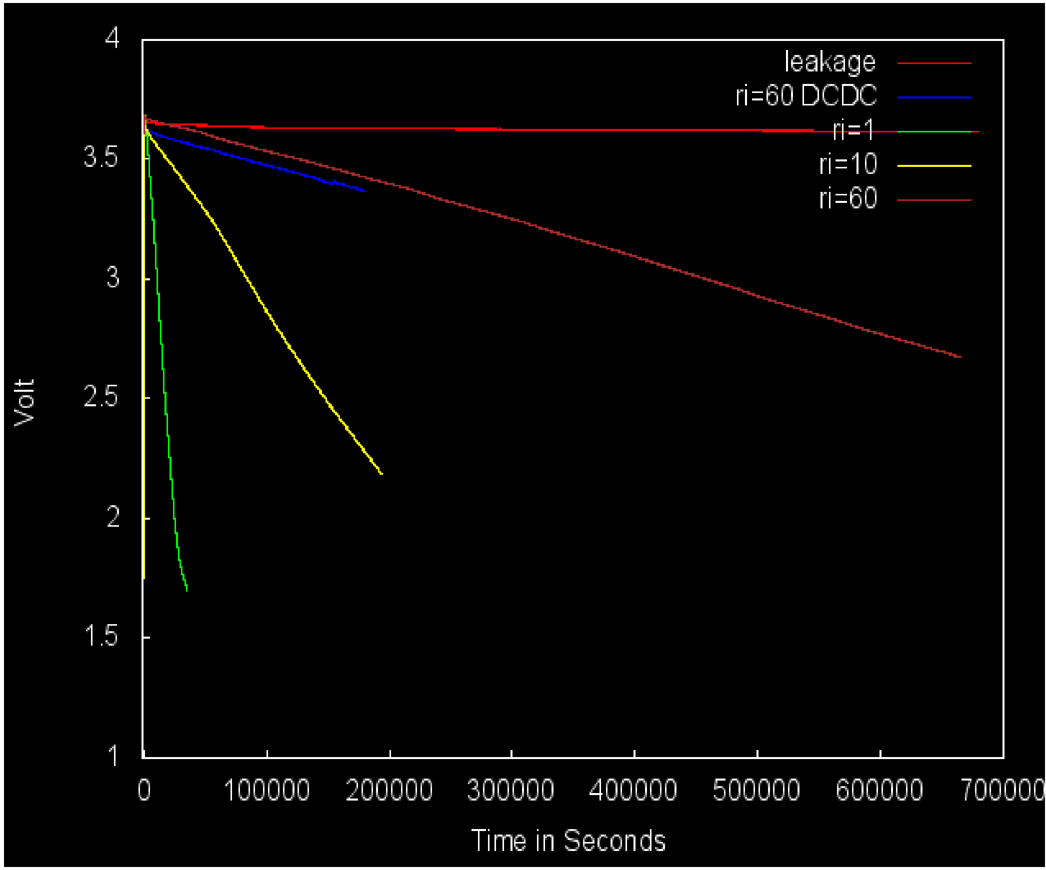
However, the specified intervals for the capacitors and many key loads (MCUs and sensors) overlap!

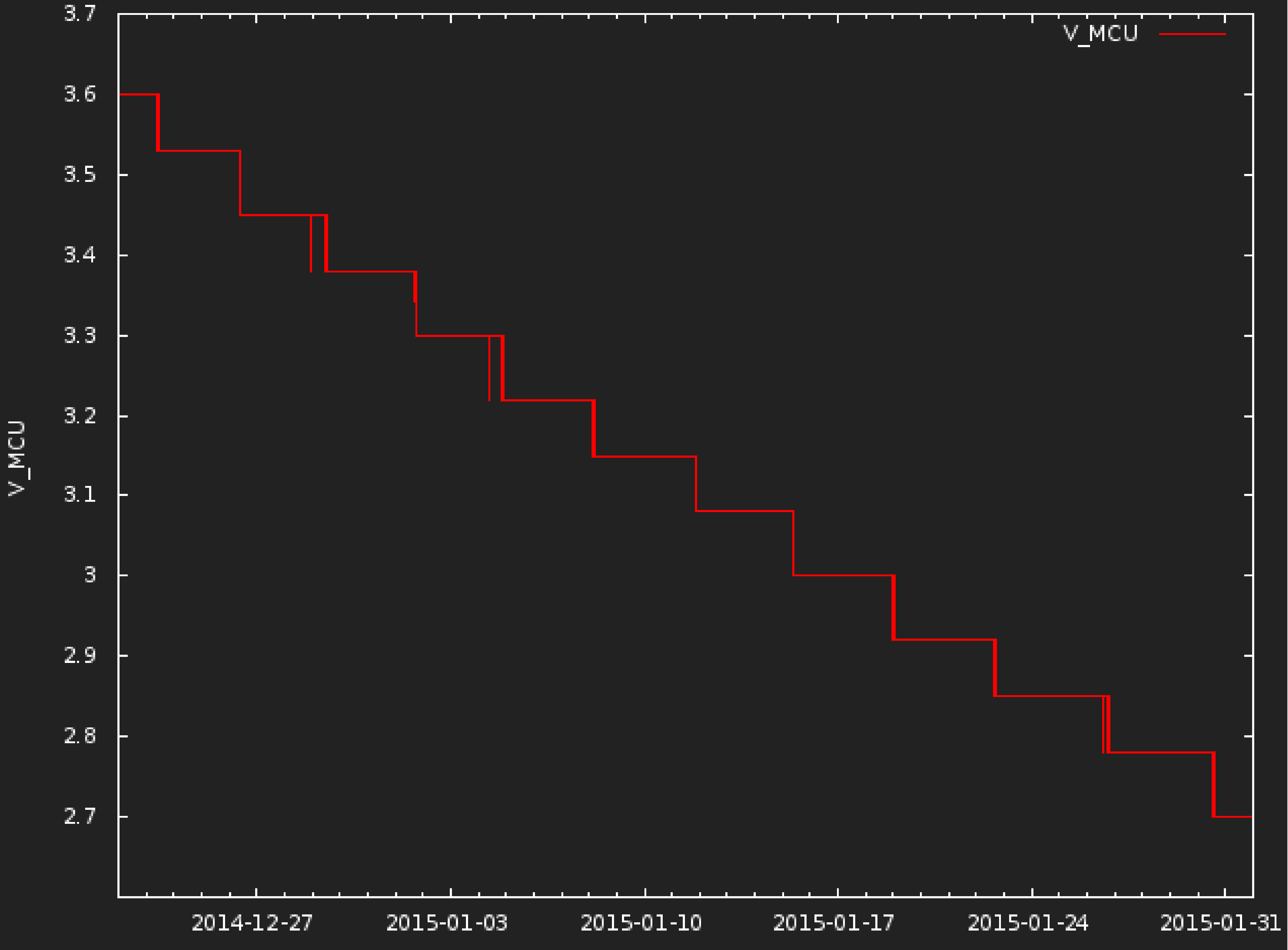
Component	Voltage	Min	Max
EDLC			2.7
LIC		2.2	3.8
Atmega128RF		1.8	3.6
SHT25		2.1	3.6

- And the load current seems constant during discharge
  - mAh is therefore a more adequate measure than Wh
  - A capacitor can store 1000/3600*C*(Umax-Umin) mAh

LIC charge – discharge rates







V_MCU
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
V_MCU
2014-12-27
2015-01-03
2015-01-10
2015-01-17
2015-01-24
2015-01-31

DC-DC converter

- QSKJ QS-2405CBD-3A
- http://www.qskjpower.com


QSKJ
Vin-
DC/DC CONVERTER
Vo-
QS-2405CBD-3A
Vin+
IN:4.5V-35V OUT:1.2-30V 3A
Vo+
MADE IN CHINA
QSKJ
Vin-
DC/DC CONVERTER
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KAMCAP