



PHILIPS

Innovation Services

Connected Systems
& IoT

Low Power Design in Connected Devices

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Connectivity Center of Expertise

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Integral part of innovation organization of Philips



*Effective January 1, 2019, the reporting segment Diagnosis & Treatment comprises two clusters: Precision Diagnosis and Image-Guided Therapy.

Building on our key areas of expertise



Johan Sunter

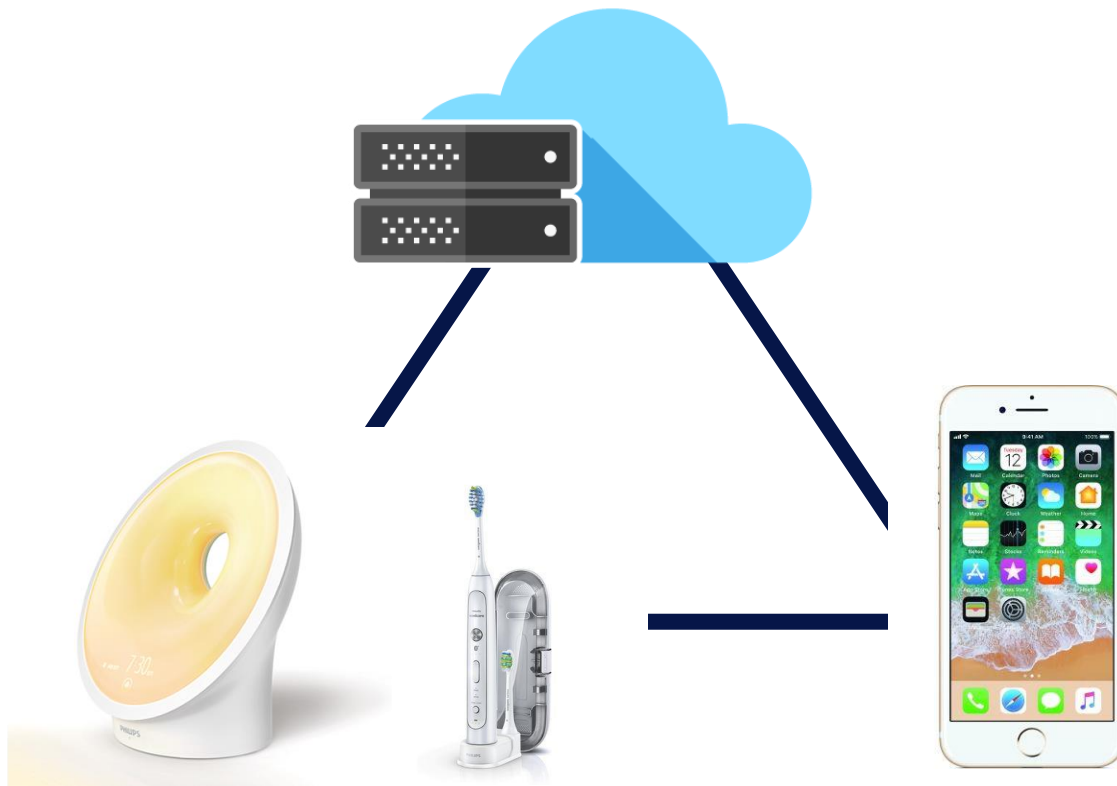


- Connectivity Architect at Connectivity Center of Expertise
- Platform for connected propositions within Philips
 - end-2-end tested, integrated, delivered as a whole
- Wi-Fi, BLE, and cellular
- Mains and battery powered
- Medical and non-medical
- Most have to deal with (low) power requirements at some point

Connected products



Typical Connected Proposition





Low power is not a goal

but a result of business demands and use cases

- Mains powered
 - Regulatory based power requirements
 - EU regulation No 801/2013
 - “Since January 2017 networked standby devices must not consume more than 3 to 12 Watts depending on the product.”
 - Different between networked and non-networked appliances
- Battery powered
 - Usage time
 - “must be able to use shaver for two weeks without recharging”
 - Life time



Architectural options

- Batteries
- System architecture
- Connectivity technology
- Software architecture

Batteries



- Limited capacity
 - Rechargeable or not?
- Life time
 - how long before battery breaks down?
- Usage time
 - how long can it be used before recharging / replacement?
- Shelf time
 - how long can it be idle before it breaks down?

Battery technology



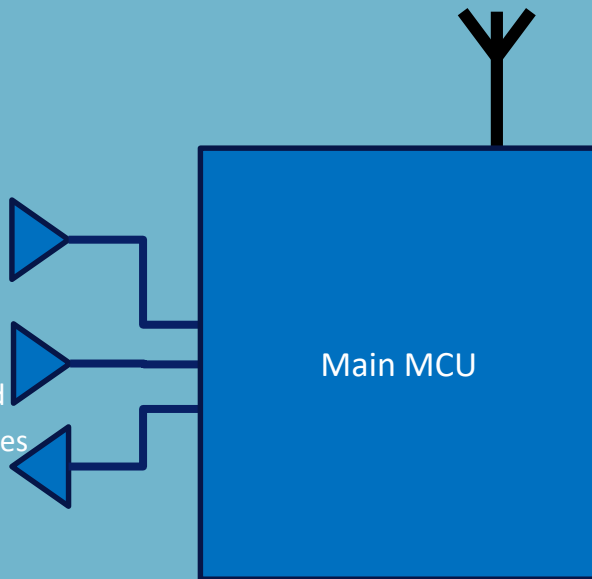
- Choice of technology
 - Li-ion leads to safety issues
- Battery management / modeling
 - Extreme temperatures reduce charge acceptance
 - Charging at low temperatures causes Li-plating
 - Charging at high temperatures degrades cathode
- Monitoring / predicting battery life-time
- Peak power requirements
 - The Energy Cell is made for maximum capacity - long runtime at low C-Rate
 - The Power Cell is for optimal high load (current) capabilities



System Architecture

unified

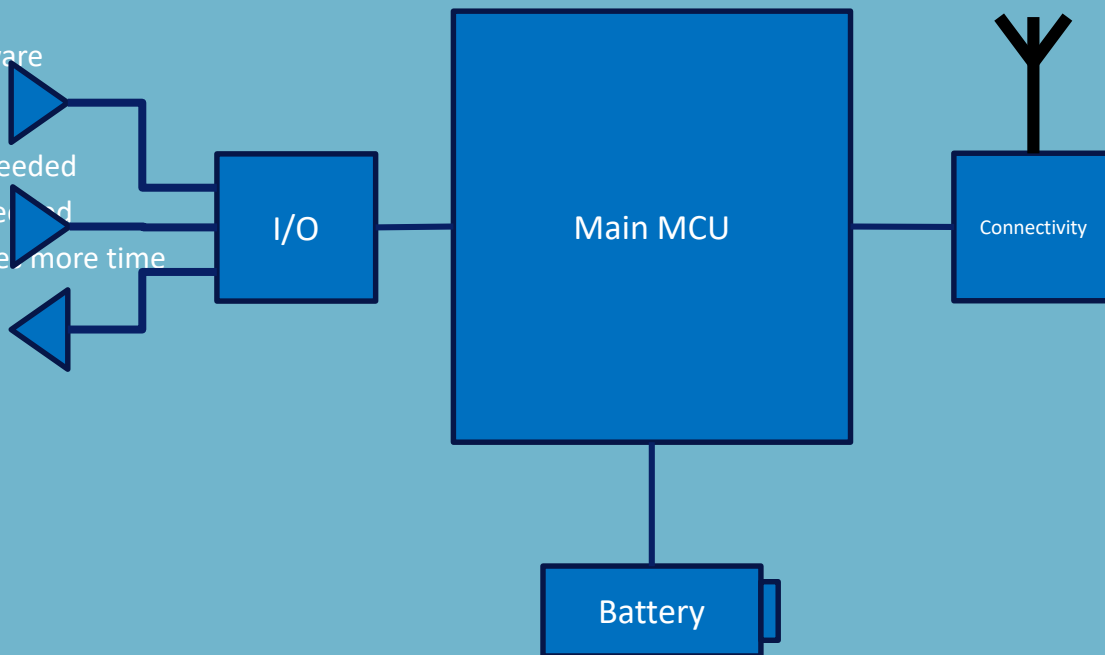
- Pros
 - smaller size
 - less complex layout
- Cons
 - more complex firmware
 - power modes knowledge needed
 - switching connectivity stack modes



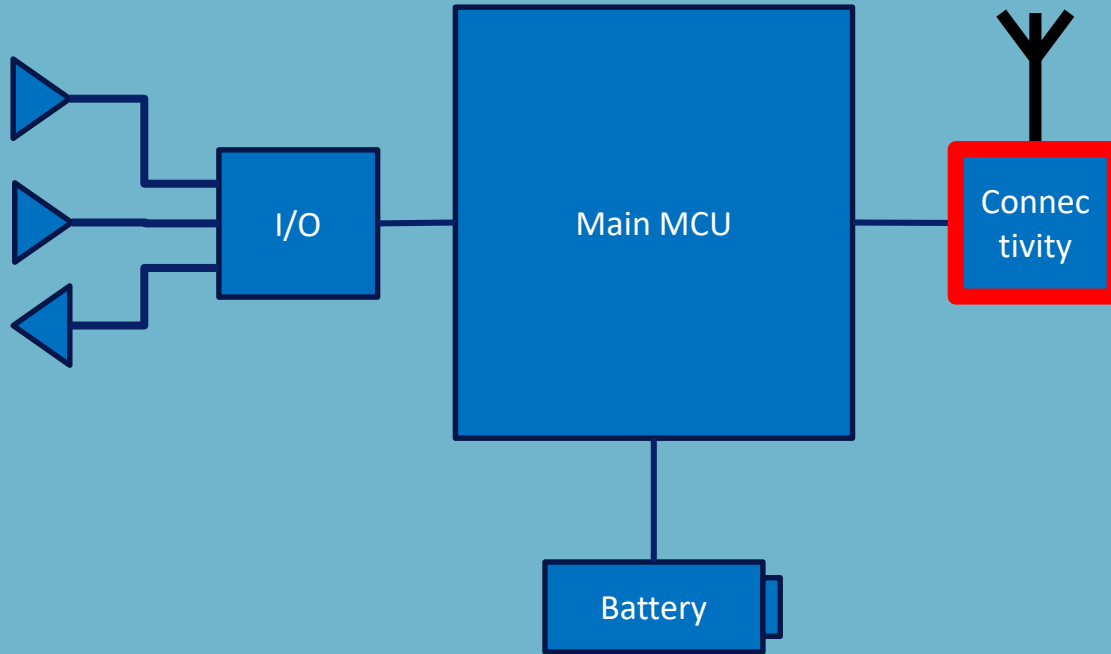
System Architecture

split

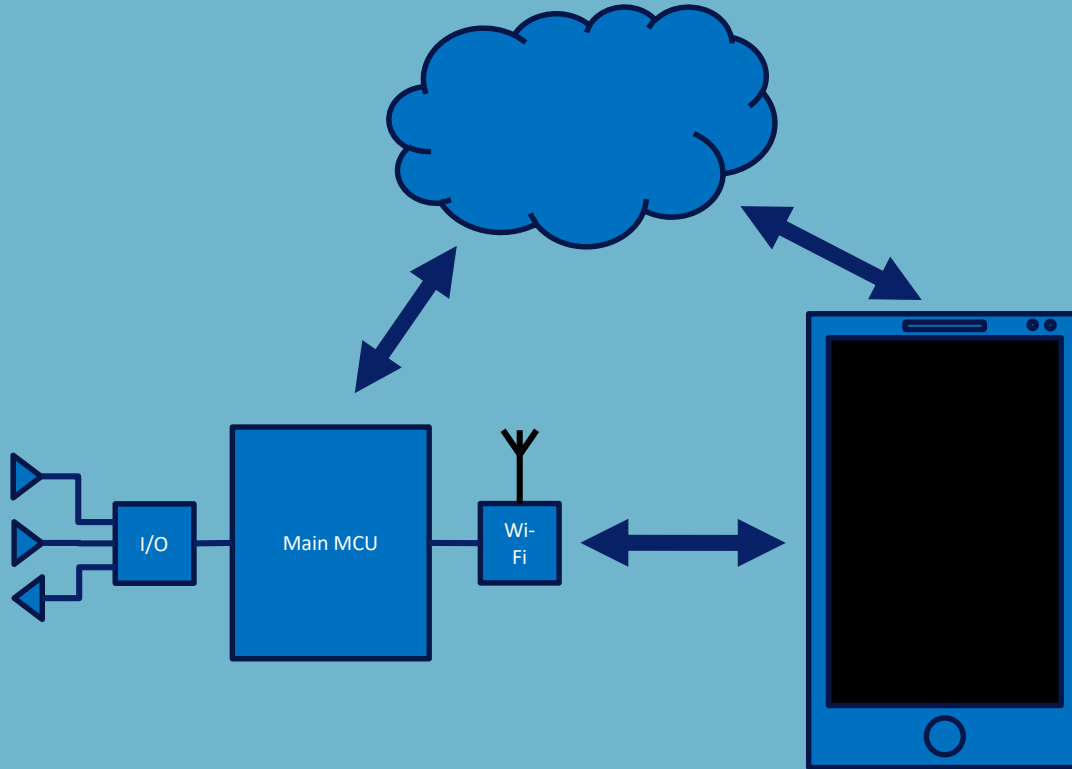
- Pros
 - simpler software
- Cons
 - more room needed
 - integration needed
 - switching takes more time



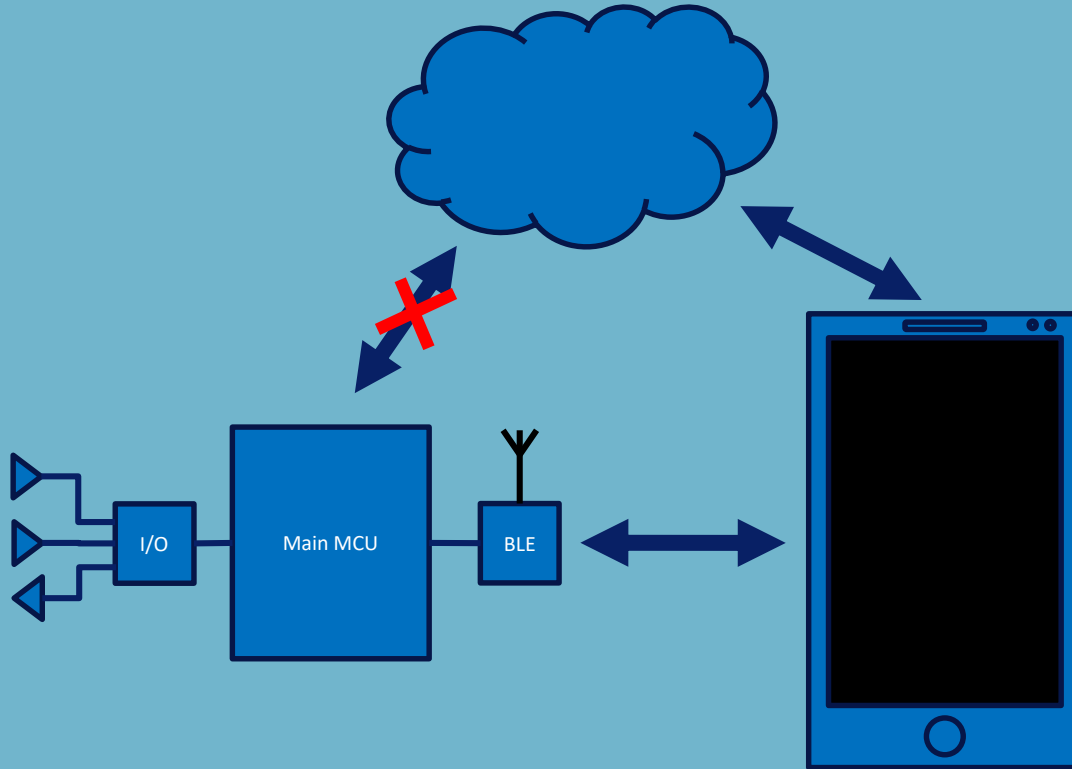
Software Architecture



Connected Proposition

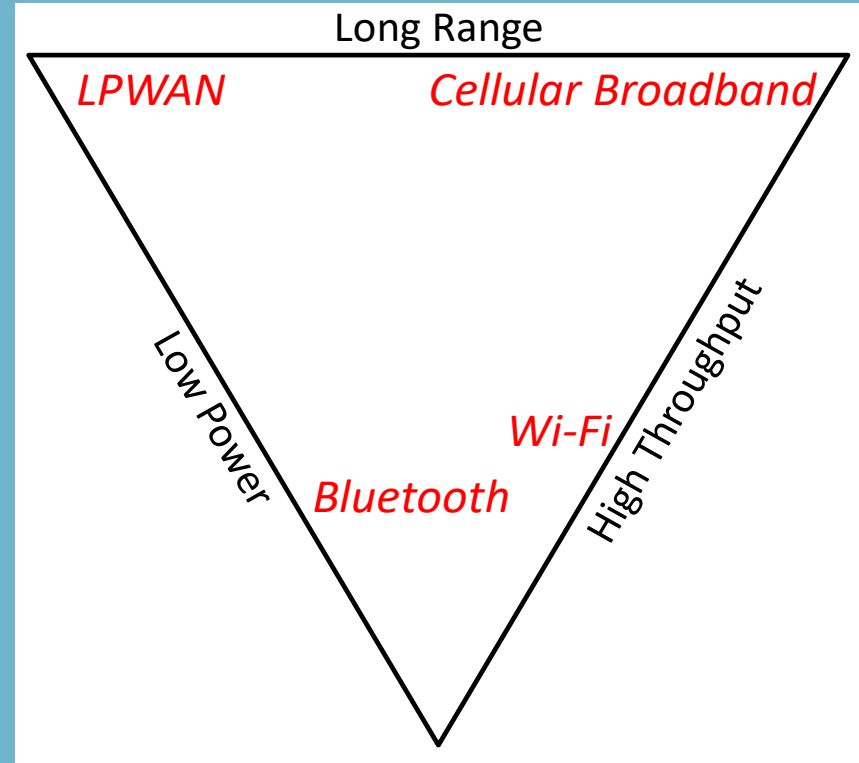


Connected Proposition

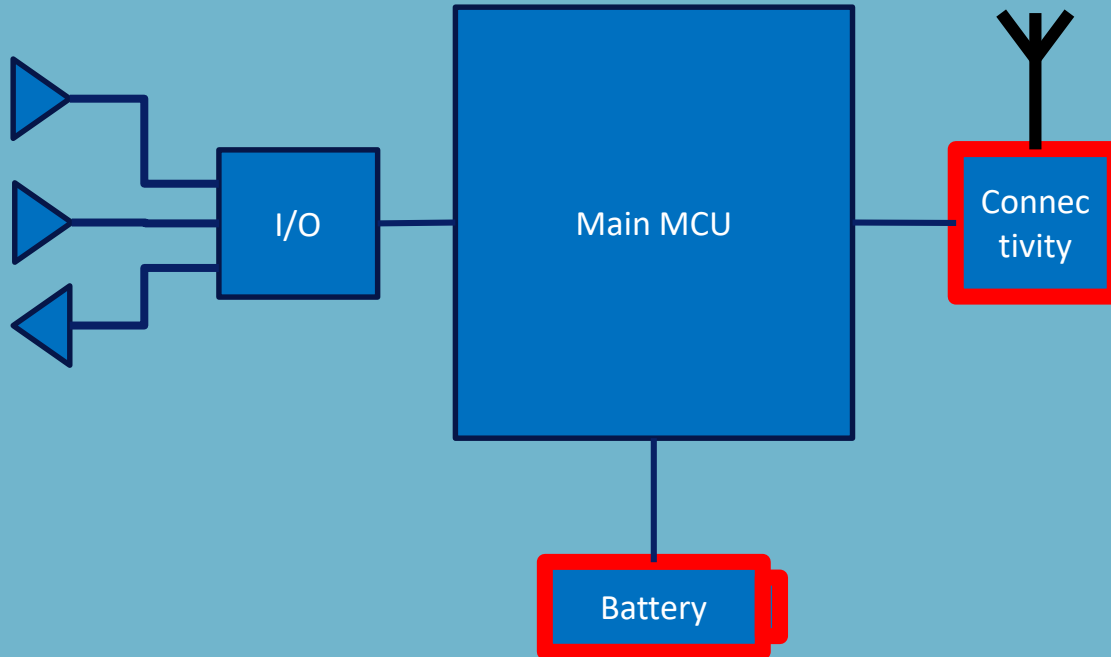


Connectivity standards

- NB-IoT / LTE-M
 - power safe mode
 - extended discontinuous reception
- LoRa
 - years on button cells
- BLE
 - designed for low power
 - connection intervals
 - advertisement times
- Wi-Fi
 - beacon timing
 - sensitivity -> antenna design
 - signal strength



Connectivity & power



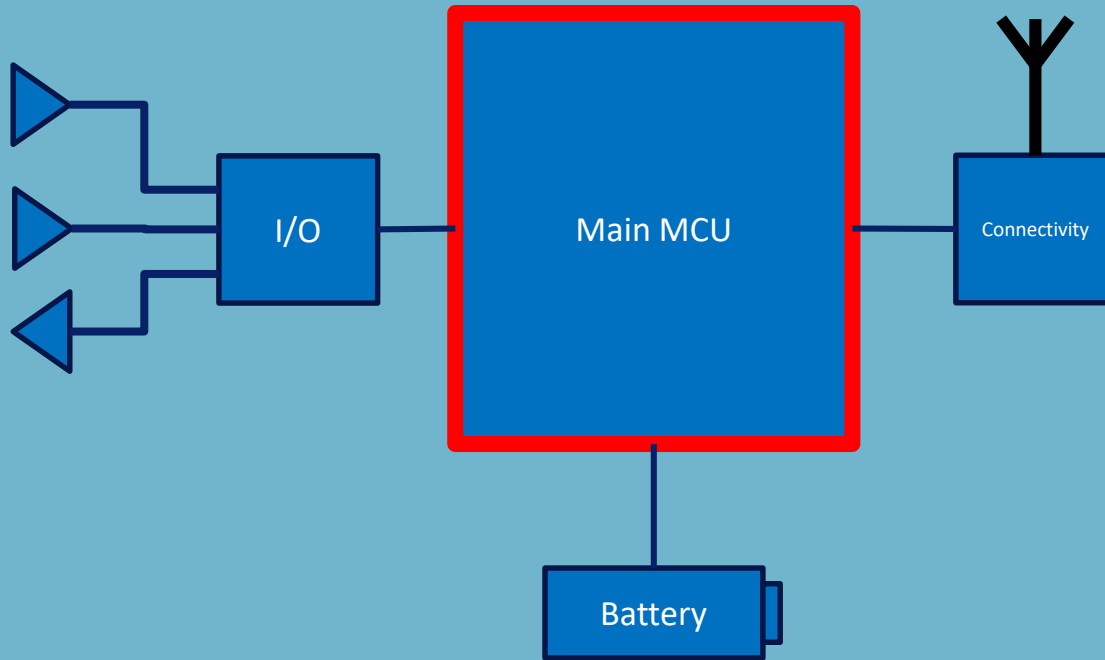
Example LTE-M Battery Calculation

Remote Environmental Sensor w/ Alarm (450 mAh battery)

Transmission Interval	Operating Mode	Estimated Battery Life
5 minutes	Toggle On / Off	25 hours
5 minutes	PSM	14 days
5 minutes	eDRX (10 s latency)	12.3 days
1 hour	PSM	110 days
1 hour	eDRX (3 min latency)	67 days
4 hours	PSM	205 days
12 hours	PSM	277 days
1 day	PSM	304 days
1 day	Toggle On / Off	160 days



Software Architecture

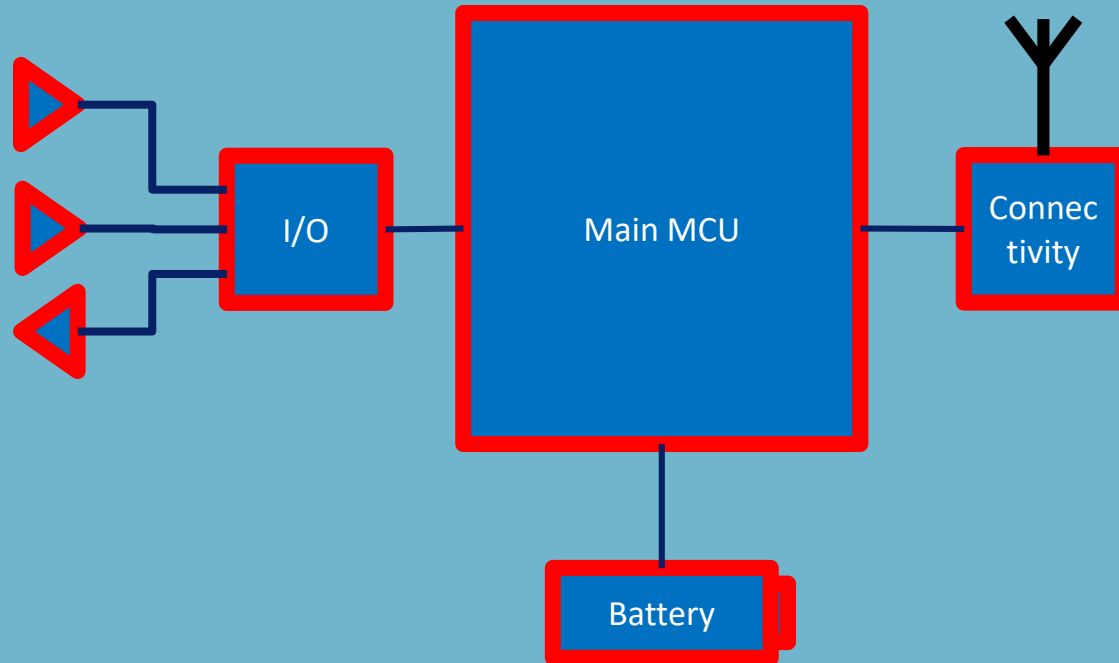




Software Architecture

- Algorithm efficiency
 - Power (design for limited power)
 - Time (design for speed)
 - Resources (limited resources)
 - Reduced quality
- Avoid busy waiting
 - No polling
 - No super loops
 - Super loops with delays are suspect
- Monitor end-user experience
 - startup times
 - response times
 - switching times

Conclusion

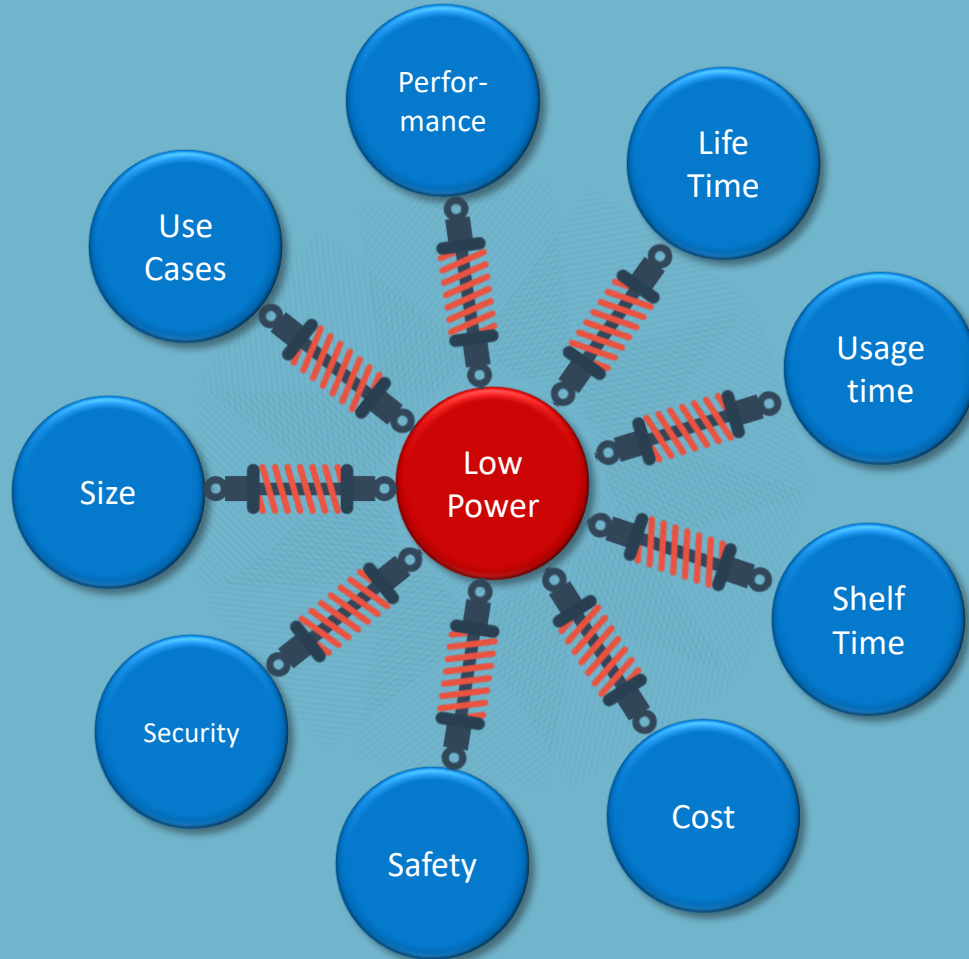


Conclusion



- Battery technology
 - safety, cost, use cases, connectivity technology
- System architecture
 - complexity, cost, size, use cases, performance
- Connectivity technology
 - power usage, bandwidth, use cases
- Software architecture
 - power usage, complexity, safety, performance

Conclusion





Further observations

- It is *never* only about low-power
- Before optimizing power usage for a certain aspect
 - Challenge business requirements
 - should it really work for 2 weeks without re-charging?
 - why should the battery life-time be longer than the expected end-user lifetime?
 - Consider use cases
 - a small change here may make a lot of difference
- Model it, monitor it, track it
- Create automated tests
 - implies rather specific requirements for the test setup
 - but it pays off..

