GLOBAL IoT SUMMIT

1st Workshop on Internet of Energy Neutral Things

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Design and energy optimization of a multifunctional IoT solution for connected bikes

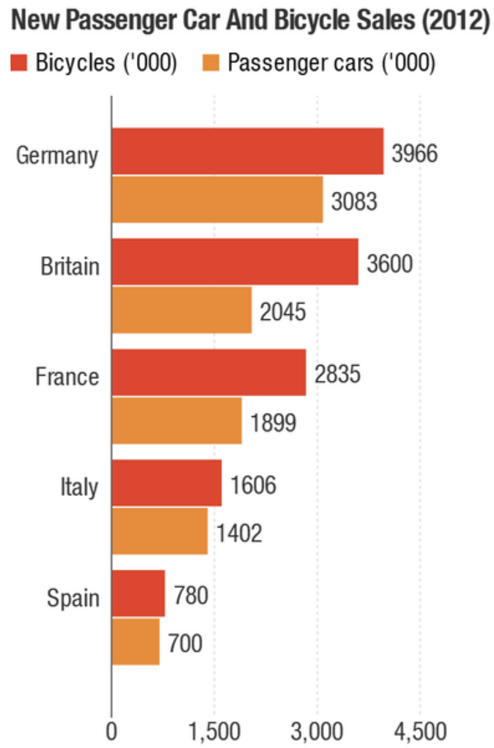
Ivan Minakov, Roberto Passerone and Maurizio Rossi

University of Trento, Italy

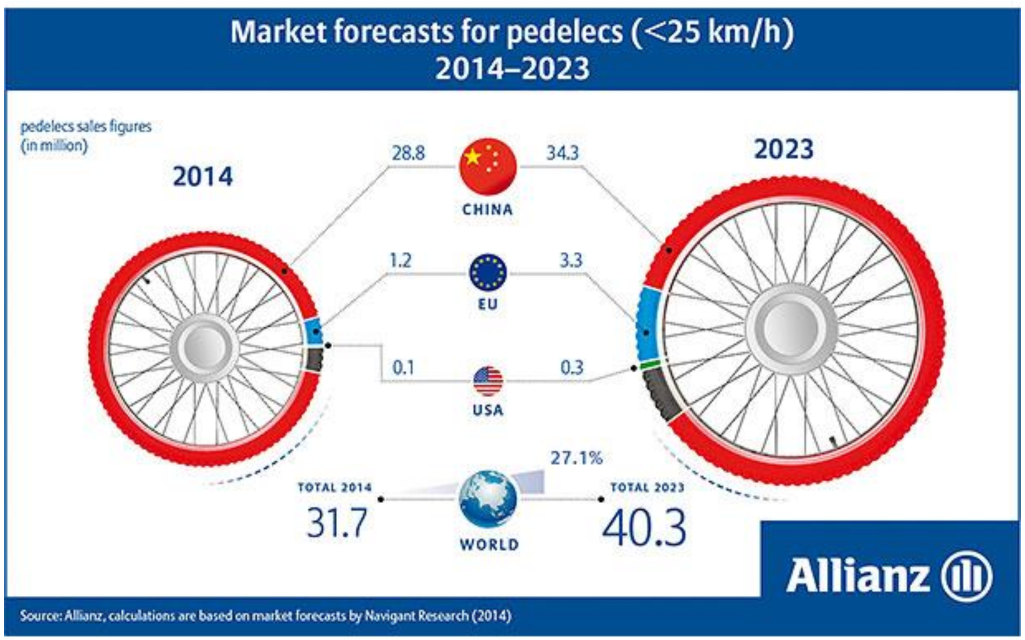
maurizio.rossi@unitn.it

Motivation

Electro mobility market trend



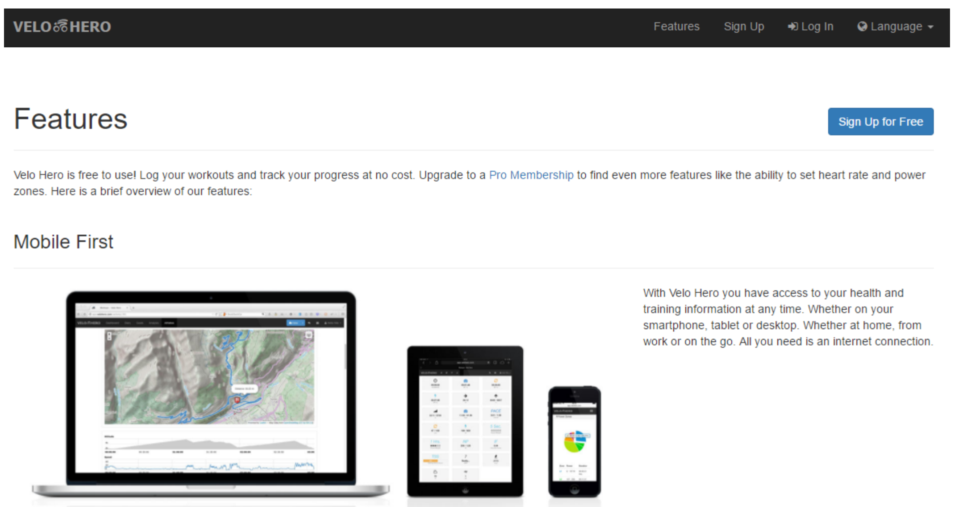
source: npr.og



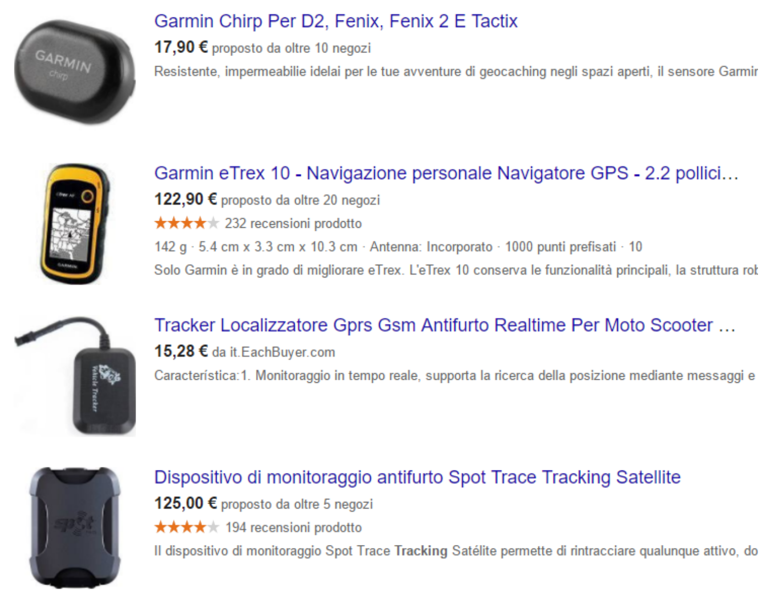
source: Allianz.com

Motivation

Many bike tracking and cycling analysis tools hit the market in the last years



Cloud-based fitness tracking
https://www.velohero.com/

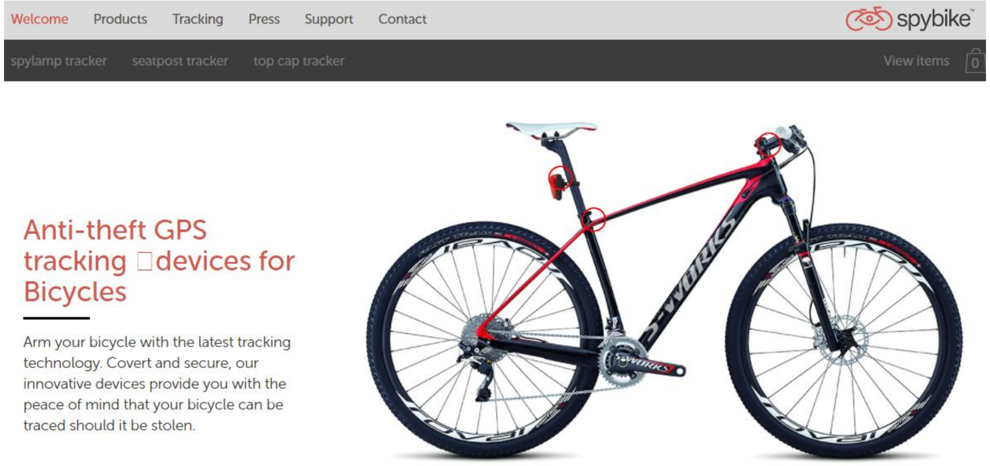


"Wearable" GPS trackers
source google shopping

Motivation

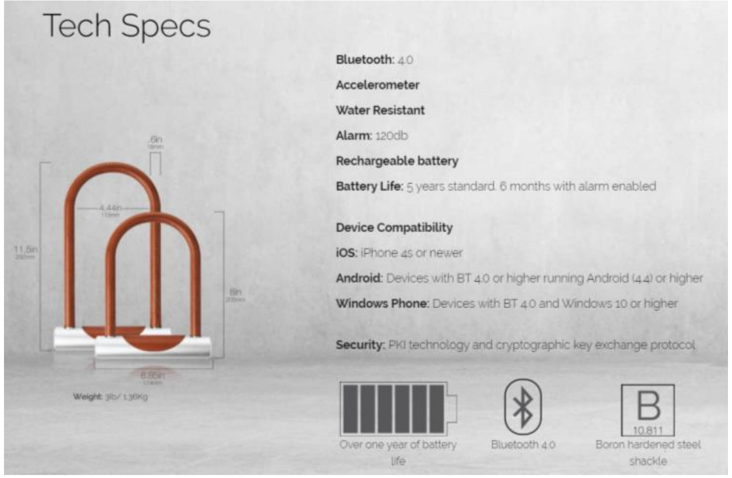
Bike security systems

http://www.spybike.com/



http://bitlock.co/

https://noke.com/pages/ulock



Motivation

However Millions of bicycles are stolen every year

- **Stress**
- **Personal monetary losses**
- **Market losses (≈150M only in Italy)**

We seek a compromise between security, reliability, portability, efficiency, ease of installation/customization…

Challenge

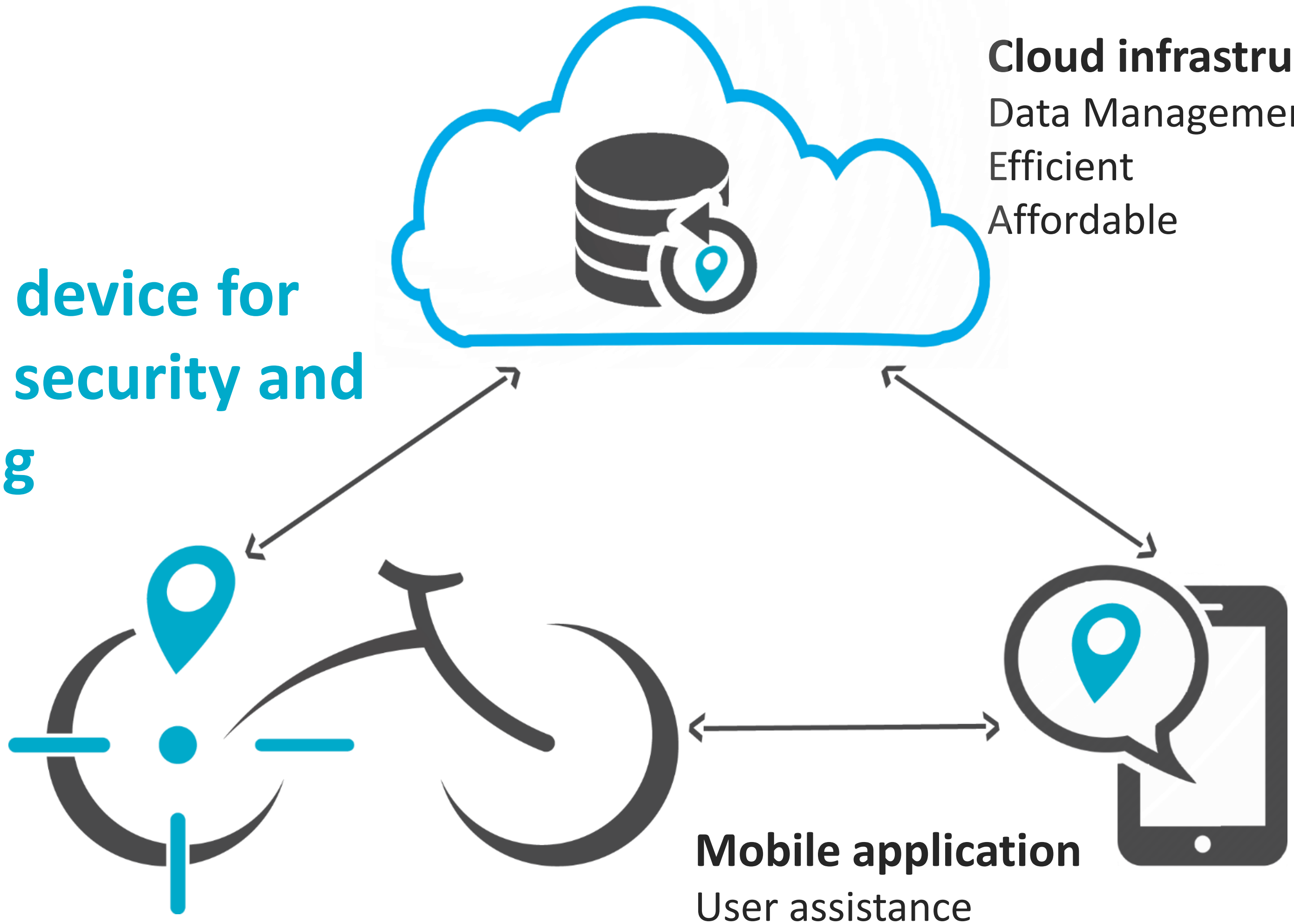
Cloud infrastructure
Data Management
Efficient
Affordable

Electronic device for enhanced security and monitoring

Invisible

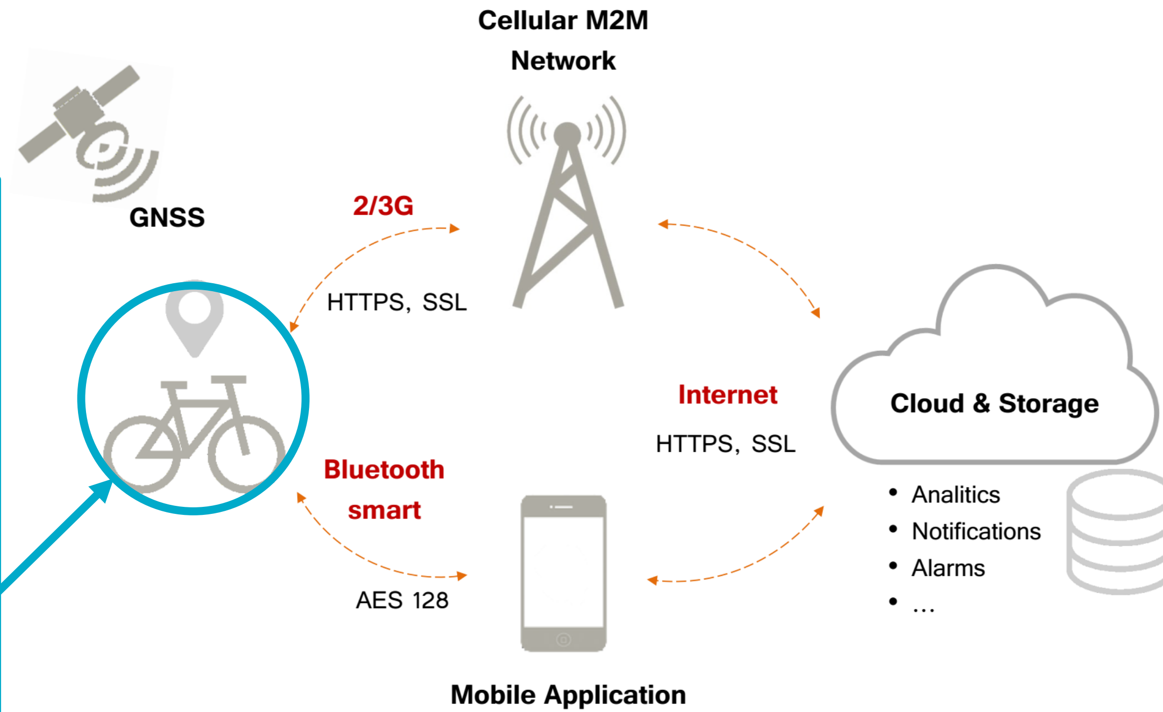
Charge-less

Effective



Mobile application
User assistance
Parking recommendations
Legal retrieval assistance

System Infrastructure

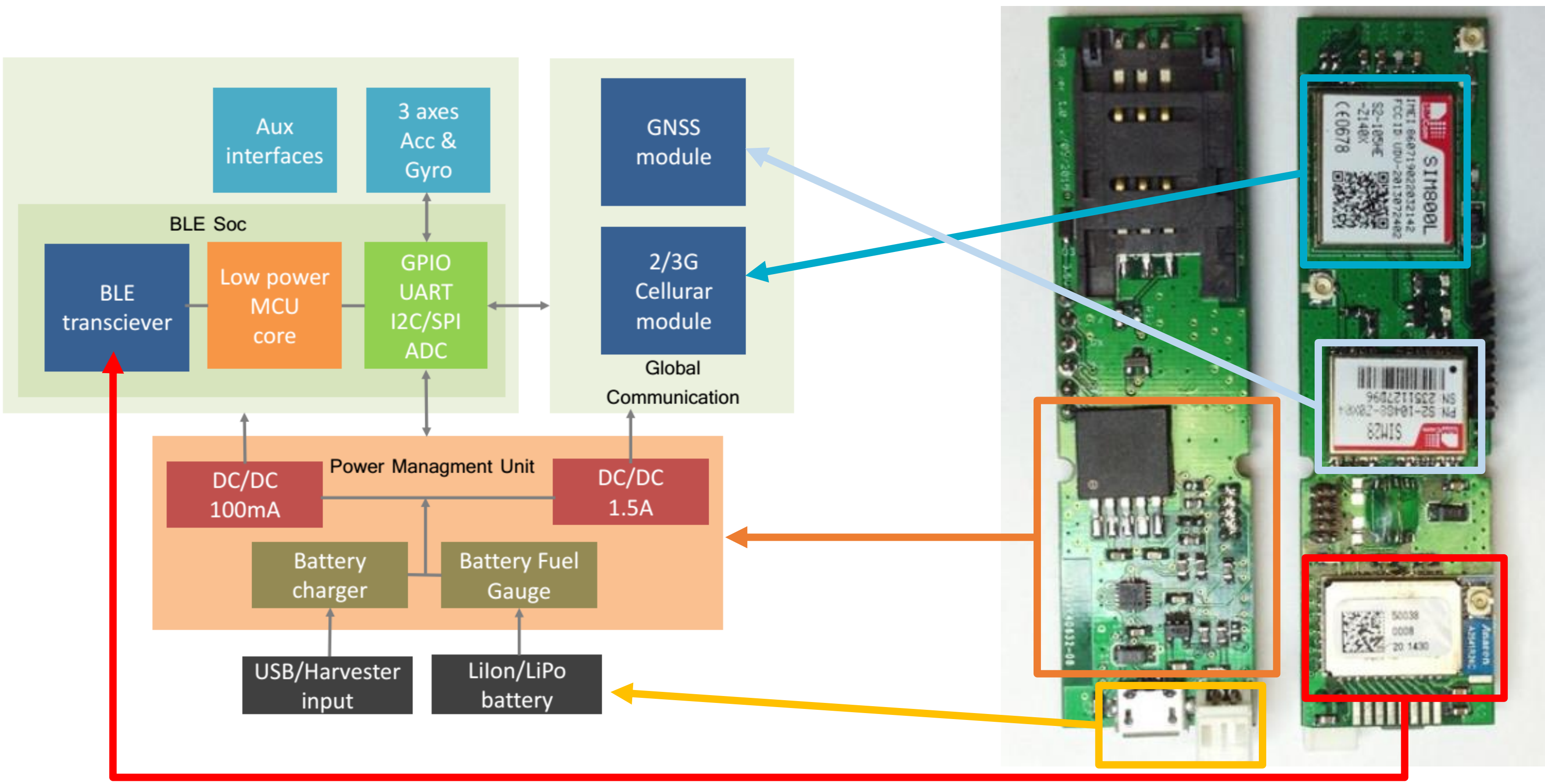


Embedded IoT system -> Core of Infrastructure

Retrieves and communicates data to cloud with heterogeneous interfaces

Hidden in bikes' frame

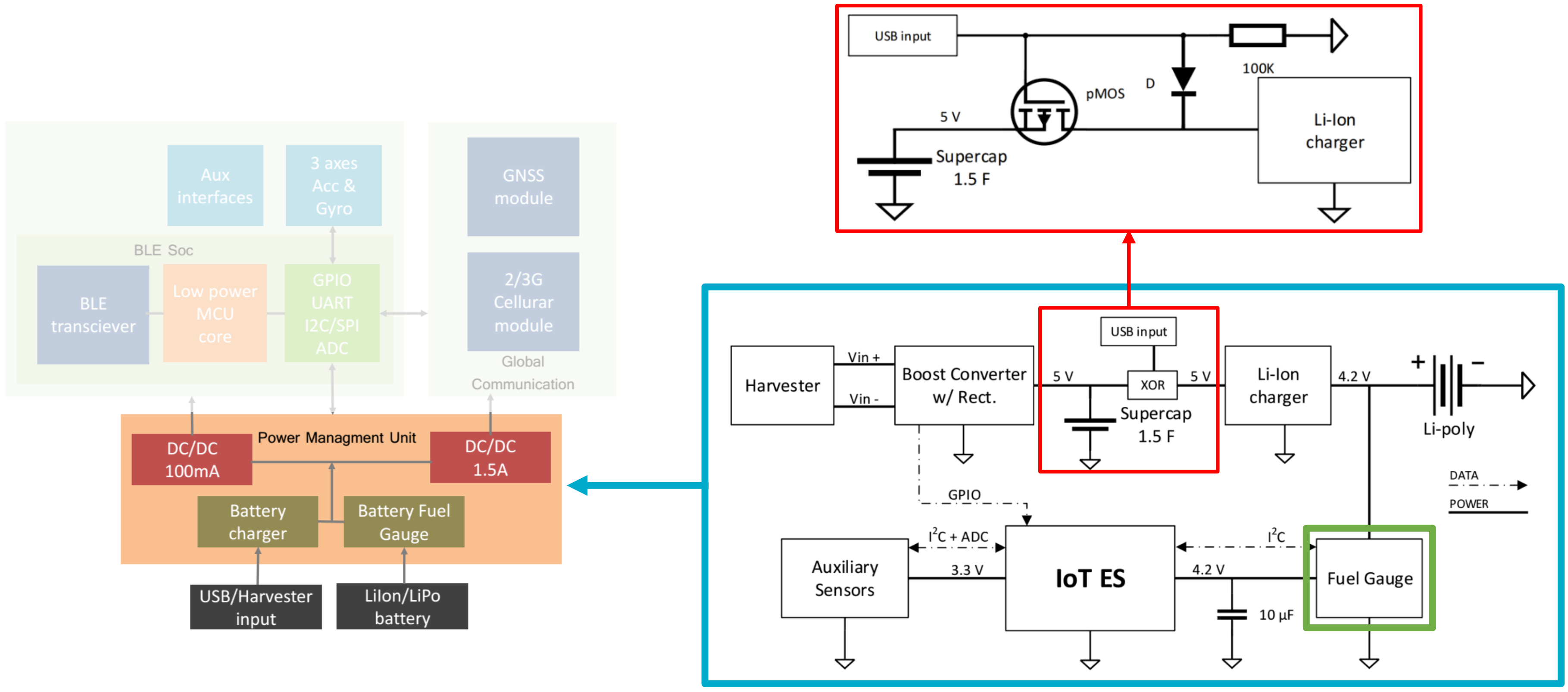
Embedded IoT System



HW Optimized for energy efficiency

Low-power BLE SoC as main MCU controlling sensors and communication peripherals
Dedicated DC converters for energy hungry sub-systems

Power Management Unit

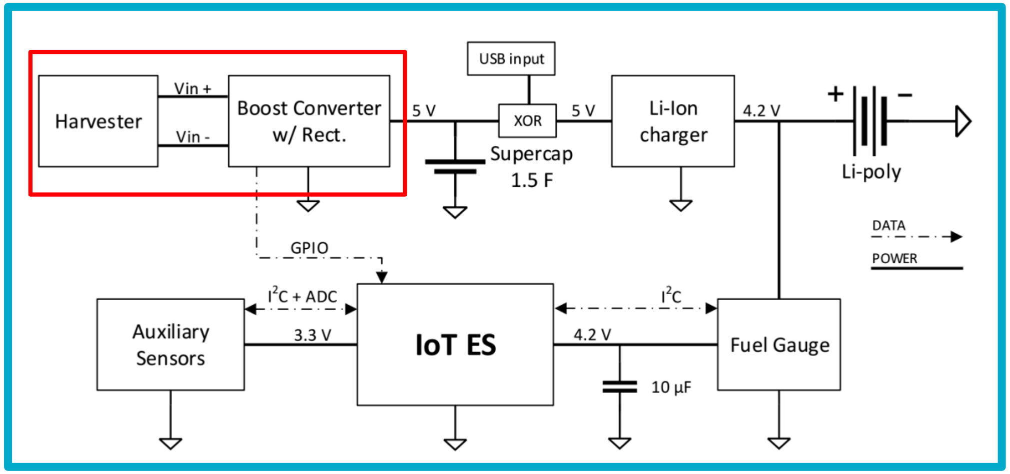


Multi-source Power Supply and Management

Automatic switching between USB and Harvesting + Supercapacitors by means of HW XOR

Fuel Gauge -> precise battery charge/discharge/state control

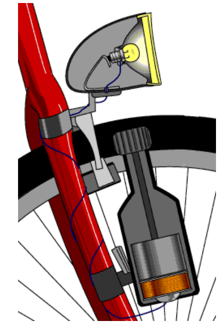
Energy Harvesting Configuration and Tests



Kinetic Energy Harvesters

(i) Bottle Dynamo

(ii – iii) Contactless single-/double-coil transformers

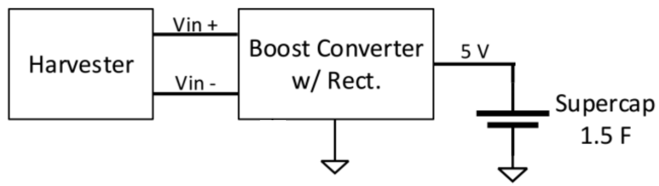


Energy Transformers

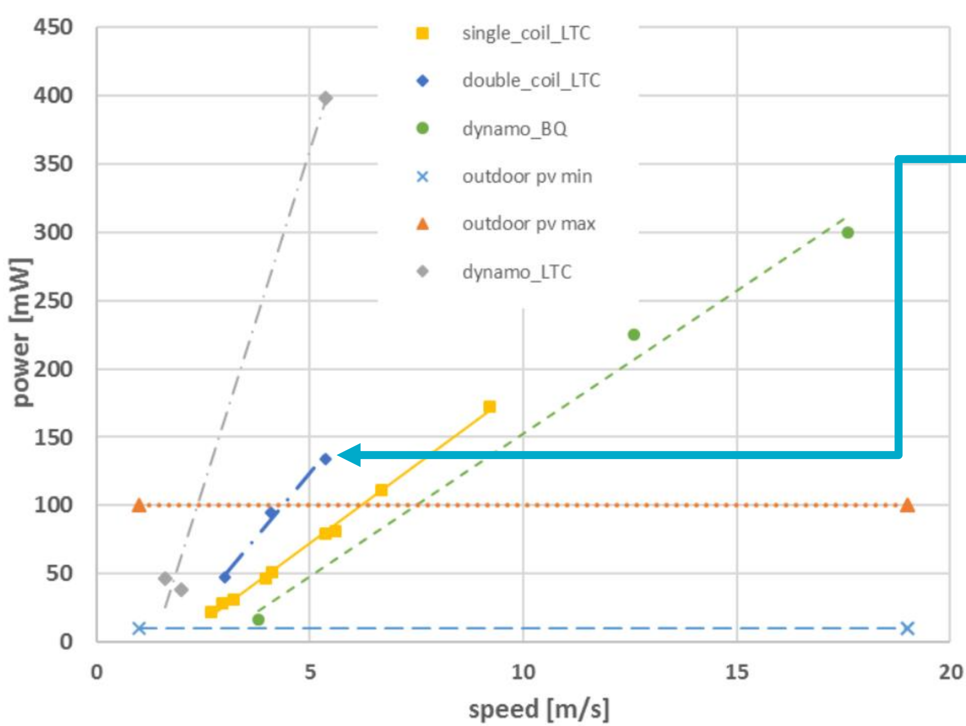
(i) TI BQ-25570

(ii) Linear LTC-3588-1

Energy Harvesting Performance



Experimental Data



Results

Solar PV panel as reference

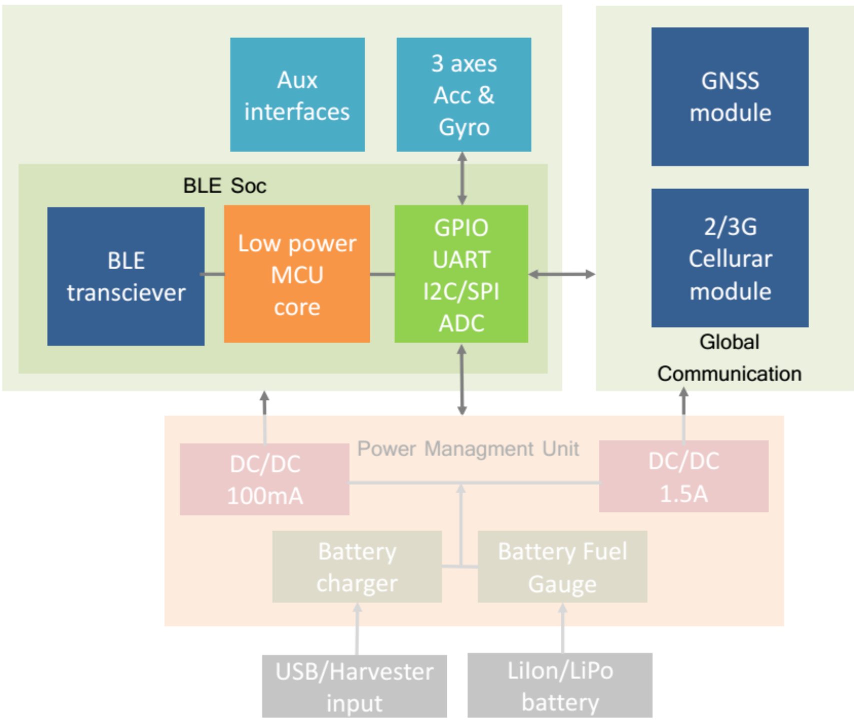
(i) Dynamo + LTC can sustain very large electronic loads

DRAWBACK – can't be hidden

(ii) Double inductive coil can provide more than 125 mW at 5 m/s travelling speed

(iii) LTC3588-1 with internal rectifier outperforms in efficiency BQ + external diode bridge solution

SW Optimization



Component	Current Consumption	Power Consumption
BLE SoC		
Tx/Rx peak	14/12 mA	29.4/25 mW
BLE connection	100μA	210μW
Sleep	8μA	16μW
IMU sensors		
Active 100Hz	20μA	42μW
Off	2μA	4μW
Cellular 2G		
Tx/Rx peak	120 - 1000mA	450 - 3700mW
Active	13mA	50mW
Idle	1.1mA	4mW
GNSS		
Tracking mode	14mA	52mW
Idle	20μA	74μW
PMU		
Active	150μA	560μW
Idle	10μA	38μW

Security and Fitness Tracking Tasks have different performance requirements

- Reliability and long lasting autonomy
- High resolution spatial data, one day of autonomy

Power Consumption characterization of *any sub-system* is crucial to optimize performance focusing efforts on power hungry components

SW Optimization – Adaptive Tracking

Algorithm 1: Time based tracking algorithm

```
Input: currentTime, lastSamplingInstant, targetTime
while Forever do
    updateCurrentTime();
    elapsedTime = currentTime - lastSamplingInstant;
    if elapsedTime == targetTime then
        lastSamplingInstant = currentTime;
        samplePositionWithGNSS();
        storePositionInLocationsBuffer();
    end
    if getLocationsBufferState() == FULL then
        sendLocationsBufferWithGPRS();
        clearLocationsBuffer();
    end
    waitInLowPowerState(seconds);
end
```

Algorithm 2: Distance based tracking algorithm

```
Input: speed, lastSamplingD, targetD
while Forever do
    updateDistanceTraveled(speed);
    distanceTraveled = currentDistance -
     lastSamplingD;
    if distanceTraveled == targetD then
        lastSamplingD = currentDistance;
        samplePositionWithGNSS();
        storePositionInLocationsBuffer();
    end
    if getLocationsBufferState() == FULL then
        sendLocationsBufferWithGPRS();
        clearLocationsBuffer();
    end
    waitInLowPowerState(seconds);
end
```

Time-Based Tracking

Periodic sampling of GPS location
Embedded in modern GPS modems
Simple yet effective

Distance-Based Tracking

External sensors to measure speed
Minimal GPS utilization

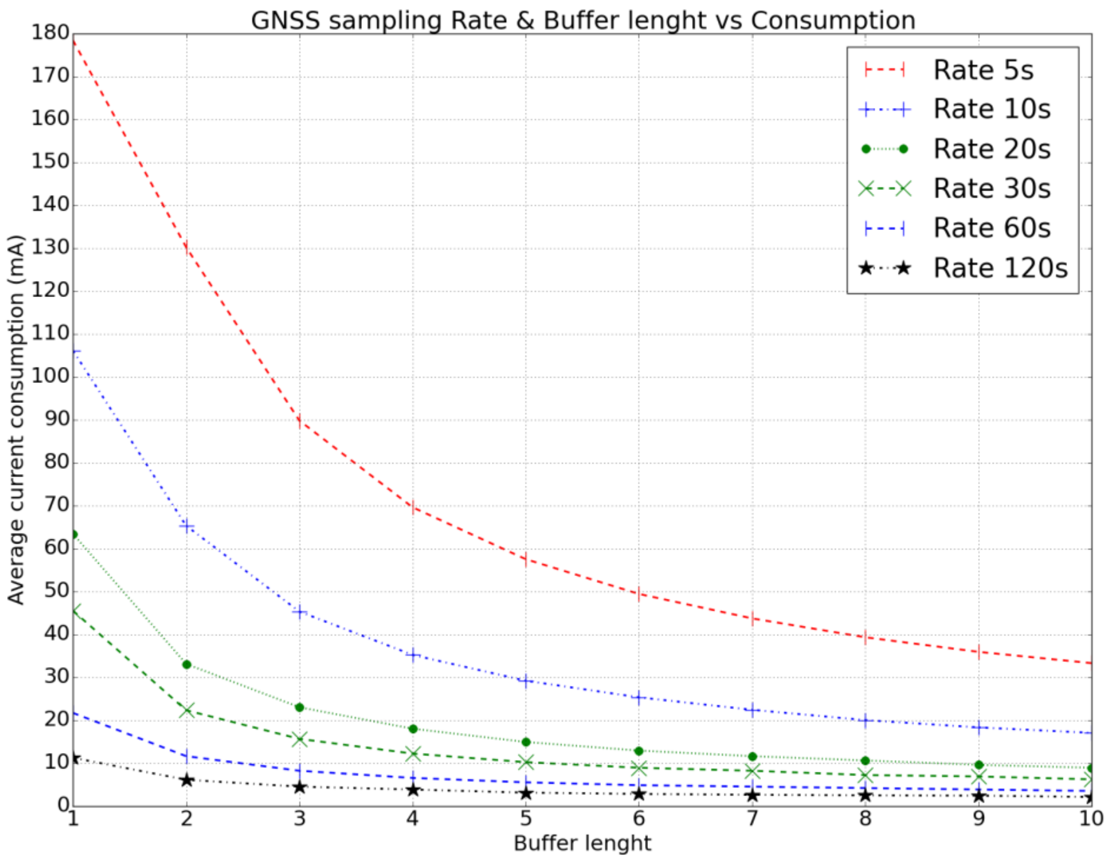
These realize the ***Adaptive Tracking*** -> user selects its preferred tracking mode
-> Cloud post-processing to optimize tracking depending on activity and user habits/preferences

SW Optimization – Power Consumption

Simulated Power Profiles

Power consumption of Time-based tracking as function of GPS sampling rate and buffering (delayed transmission of data to cloud)

Independently from the rate, buffering severely increases performance, reducing current consumption down to 10 mA introducing a delay of 180 seconds, considering 20s rate and a buffer of size 9 packets



SW Optimization – Battery Autonomy

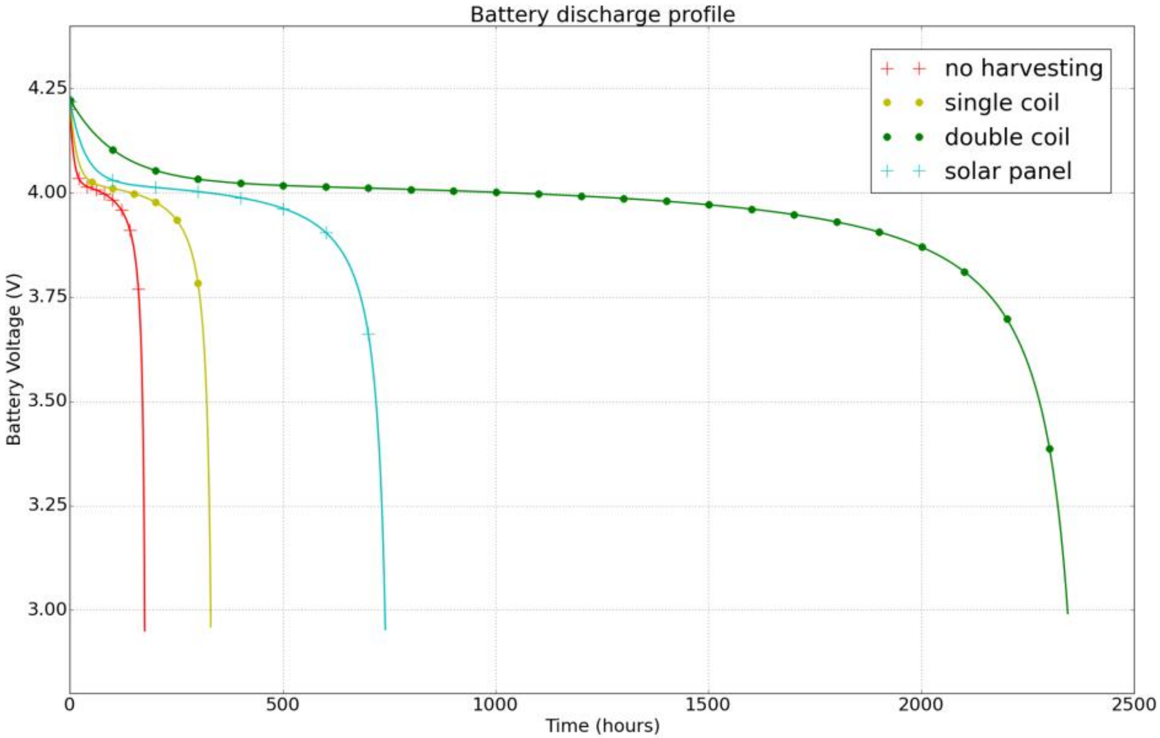
Simulated Battery Discharge

One GNSS sampling per minute
Direct data streaming (cellular)
Constant 10 km/h speed

Theoretically, with harvesting, we expect up to 2400 hours of Autonomy

Reasonably, more than 1000 hours of autonomy are expected in a real scenario

Even more implementing data buffering and adaptive tracking



Conclusion

We presented an Embedded System and IoT based Infrastructure for bicycle tracking and enhanced security

We analysed the HW design of the power management subsystem and presented different energy harvesting solution for extending system autonomy and battery self recharge

We investigated SW improvements for minimization of power consumption of the tracking task and data synchronization with cloud

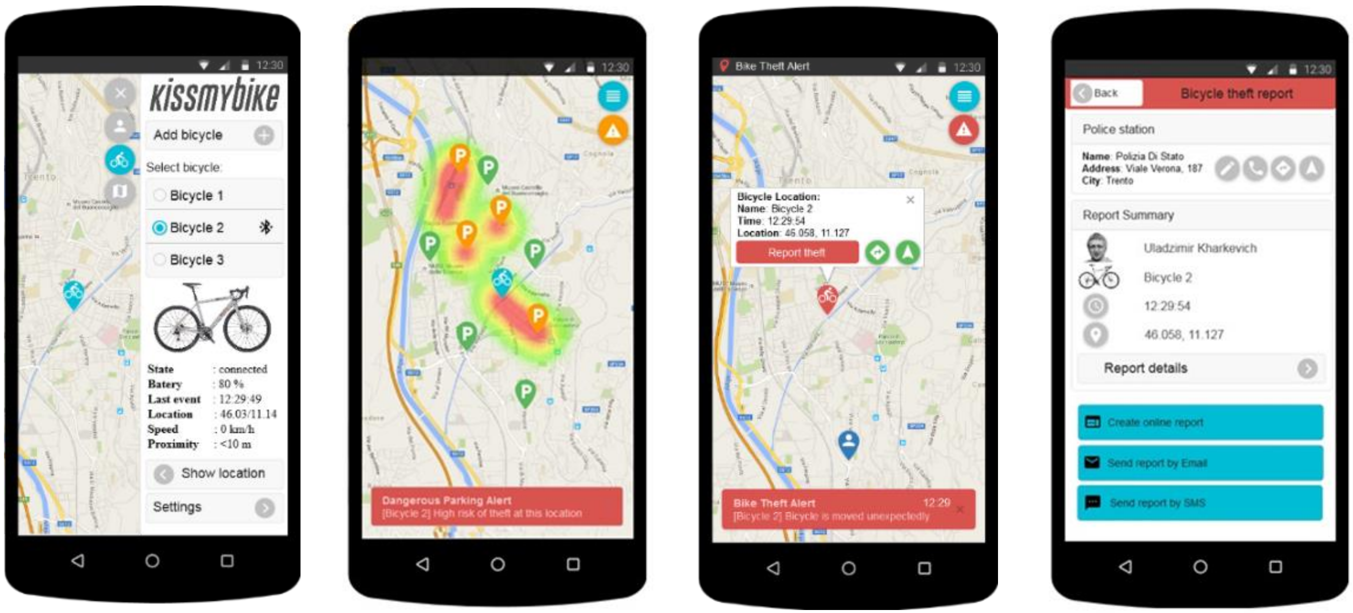
thank you very much for the kind attention

maurizio.rossi@unitn.it

kissmybike

UNIVERSITY
OF TRENTO - Italy
Department of Industrial Engineering

Service



- ✓ **Bicycle identification**
- ✓ **Parking recommendations and security maps**
- ✓ **Tracking service with global coverage**
- ✓ **Legal retrieval assistance**

E-bike installation

Plain seatpost