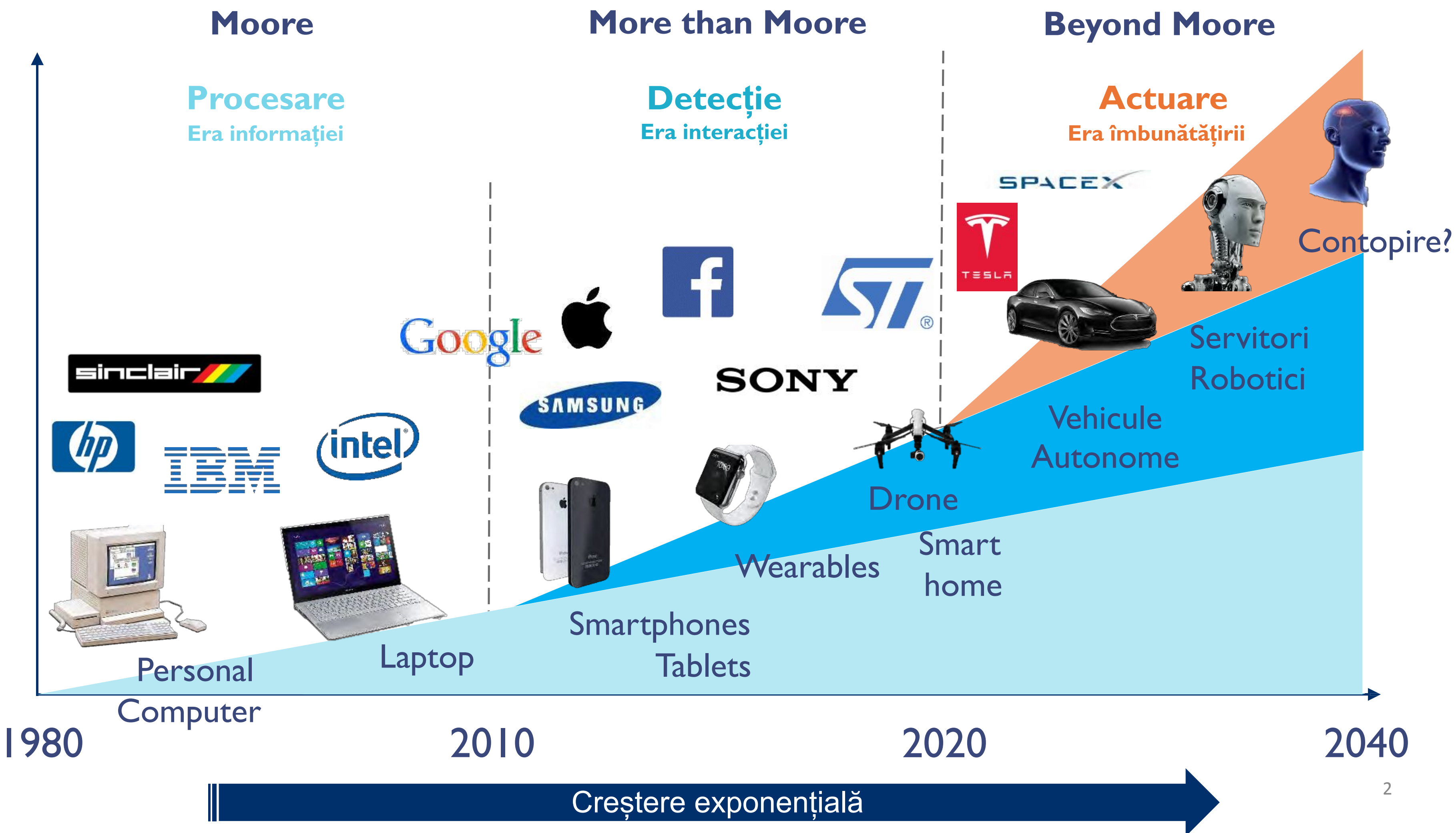
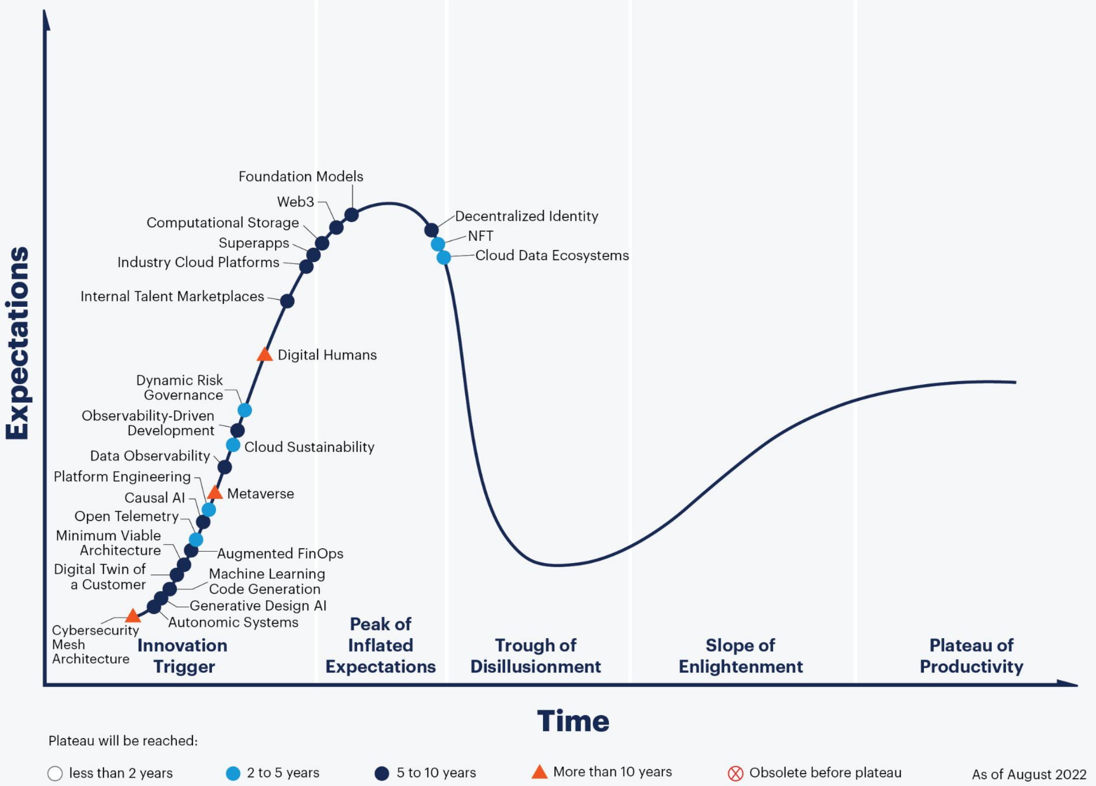
Internet of Things

Lecture 2 - Wireless Sensor Networks


Moore
More than Moore
Beyond Moore
Procesare
Era informației
Detecție
Era interacției
Actuare
Era îmbunătățirii
Contopire?
Servitori
Robotici
Vehicule
Autonome
Drone
Smart
home
Wearables
Smartphones
Tablets
Laptop
Personal
Computer
1980
2010
2020
2040
Creștere exponențială

Hype Cycle for Emerging Tech, 2022



gartner.com

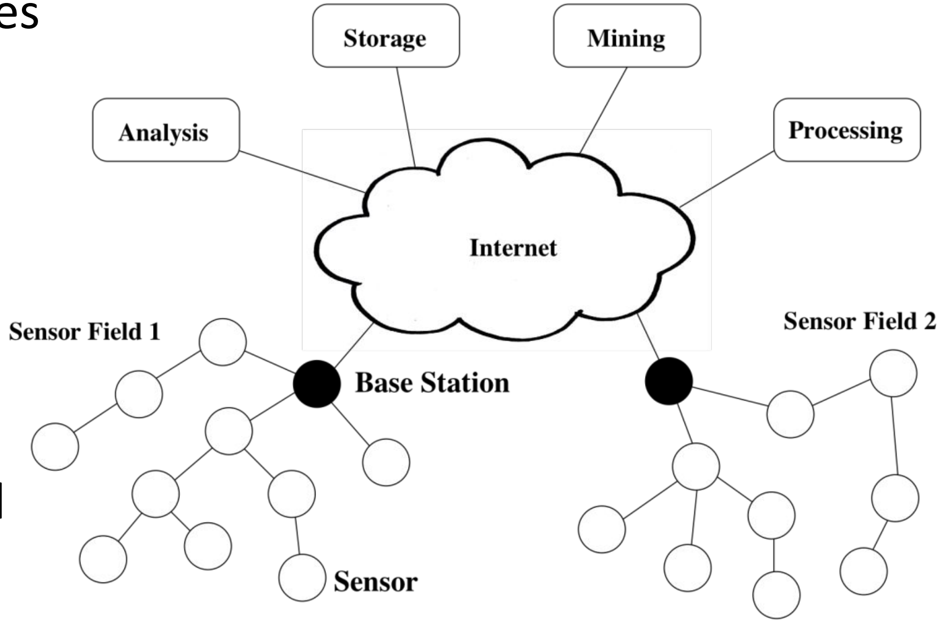
Gartner

Source: Gartner

Wireless Sensor Networks

Wireless Sensor Networks

- Hundreds/thousands of sensors nodes
- Monitor environment parameters
- Gateway/base station
  - Receive data from nodes
  - Send commands to nodes
- Storage, analysis, processing in cloud

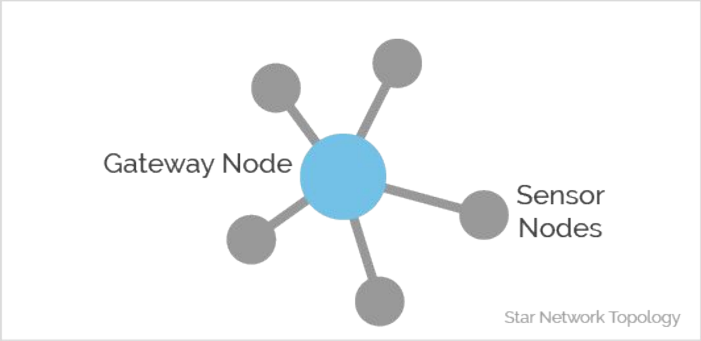


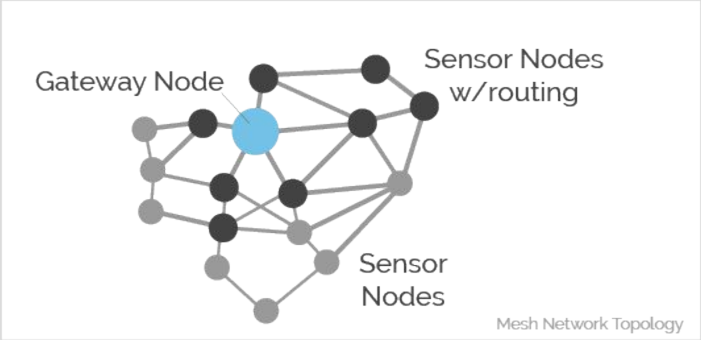
Characteristics

- Small size
- Low bandwidth (10s-100s kbps)
- Star and mesh topology
- Low power, battery operated
- Low cost
- Ad-hoc network
- Unreliable wireless medium

Single-Hop versus Multi-Hop

- Star topology (single-hop)
  - Sensors communicates directly with the GW
  - May need a high transmission power
  - May not be feasible to cover a wide area
- Mesh topology (multi-hop)
  - Sensors act as forwarders for other nodes
  - This may reduce the energy consumption
  - May increase coverage
  - Routing protocol





Source: https://www.lprsiot.com/networks/

Brief History

- DARPA:
  - Distributed Sensor Nets Workshop (1978)
  - Distributed Sensor Networks (DSN) program (early 1980s)
  - Sensor Information Technology (SensIT) program
- UCLA and Rockwell Science Center
  - Wireless Integrated Network Sensors (WINS)
  - Low Power Wireless Integrated Microsensor (LWIM) (1996)
- UC-Berkeley
  - Smart Dust project (1999)
  - The concept of **mote**
- Berkeley Wireless Research Center (BWRC)
  - PicoRadio project (2000)
- MIT
  - µAMPS (micro-Adaptive Multidomain Power-aware Sensors) (2005)

Sensor Nodes

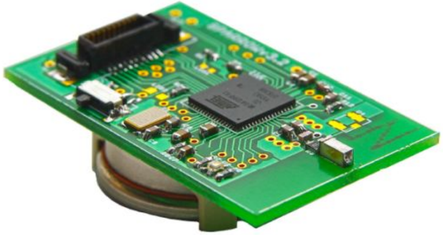
What is a Mote?

- **mote** *noun [C] LITERARY*
  something, especially a bit of dust, that is so small it is almost impossible to see
  ---Cambridge Advanced Learner's Dictionary

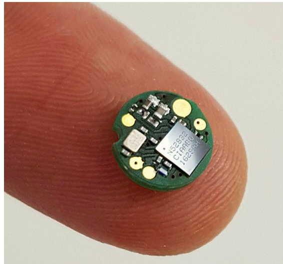
UC Berkeley hardware platform evolution

Examples of Sensor Nodes

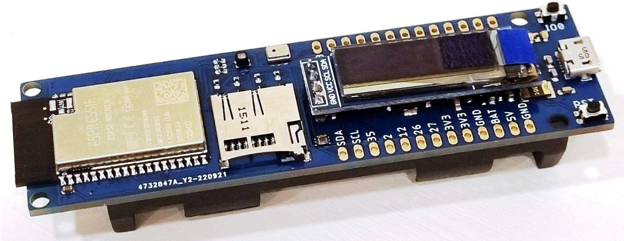
MicaZ, Mica2, Mica2 Dot
UC Berkeley



Sparrow
UPB



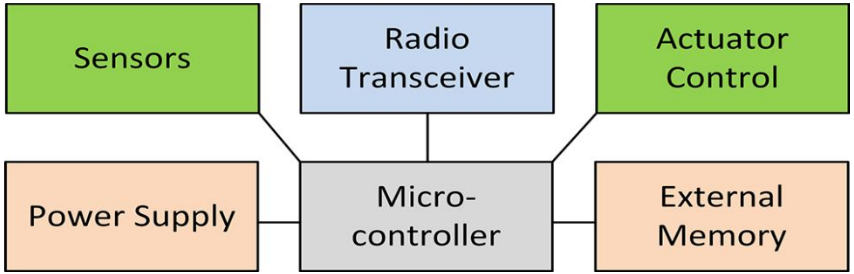
Microsal
UPB



ESP32 Sparrow
UPB

Sensor Node Components

- Low-power processor
  - Limited computing power
- Memory
  - Limited capacity
- Radio
  - Low-power
  - Low data rate
  - Limited range
- Sensors
  - Scalar: temperature, light etc.
  - Image sensors, microphones etc.
- Actuators
- Power supply



Network Communication

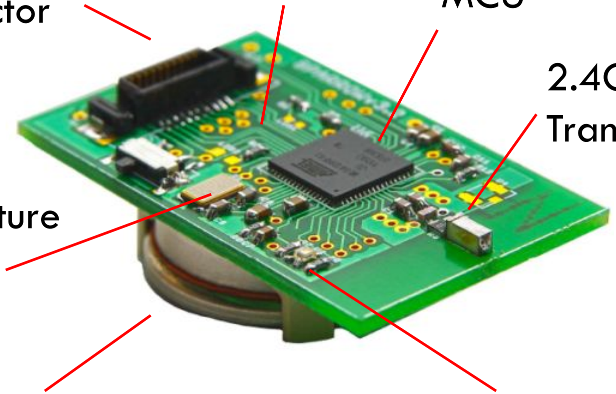
- Low data rate because of energy constraints
- **IEEE 802.15.4** standard
  - Designed for WSN networks
  - Short-range communication
  - Low data rate
  - Low power consumption
  - Widespread use in academic IoT or commercial solutions
- **IEEE 802.11** standard (Wi-Fi)
  - The most common for wireless communication
  - Used frequently in current IoT networks

Network Communication

- Networking is a key component (protocol stacks)
- Addressing schemes (IPv4, IPv6)
- Data transmission (802.15.4, WiFi, BLE, LoRa, LTE, 5G, etc.)
- Transfer rate (Kbps, Mbps, Gbps)
- Application layer (CoAP, MQTT, HTTP etc.)

WSN Applications

Example: Sparrow Nodes



Works with IEEE 802.15.4

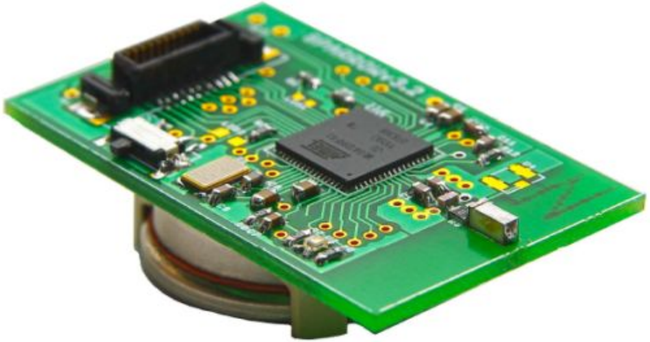
256kbps transfer speed

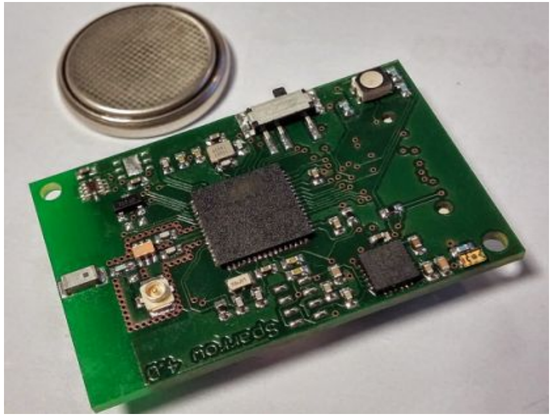
Specs:

16MHz	4.77MHz
8KB RAM	16-256KB RAM
128KB Flash	160KB Floppies
~ $10	~ $6,000
50mW, 36uW (sleep)	~ 64W
7g, 50x30x5mm	12kg, 500x140x400mm

WSN @ UPB

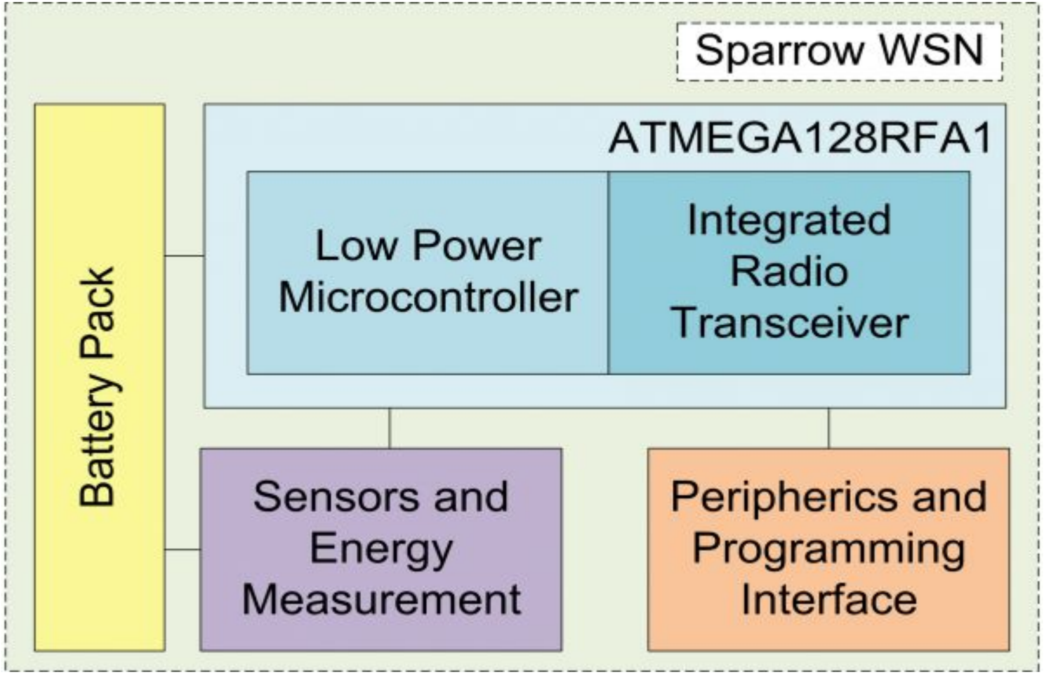
- Sparrow - designed for energy harvesting
- Low-power (13mA Run-Time, 6uA Sleep)
- May run many OSes and protocol stacks
- Arduino compatible
- Autonomy measured in years



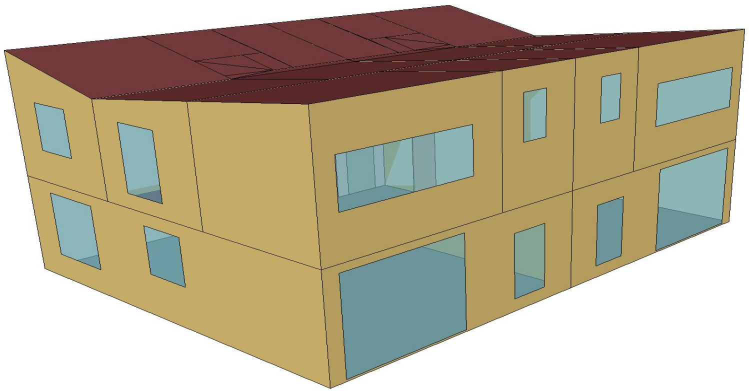


Technical specs

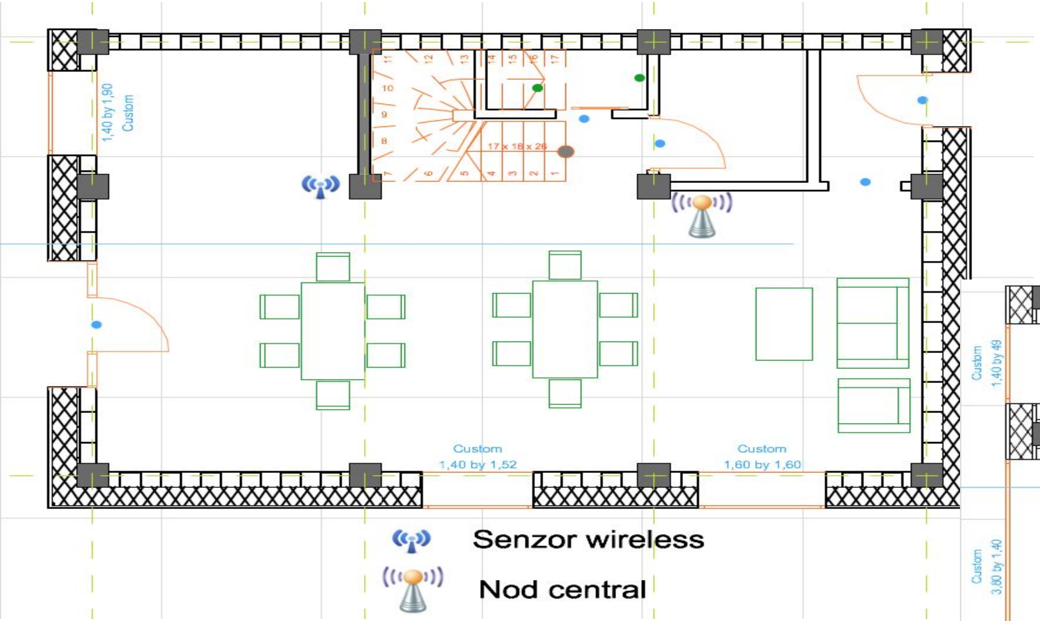
	Range
Humidity	Meas. interval: 0 … 100 % Meas. error: ± 2% RH
Luminosity	Meas. interval: 0...100000lux Visible & IR UV index
Temperature	Meas. Interval: -40 … 100˚C Meas. error: ±0.5˚C

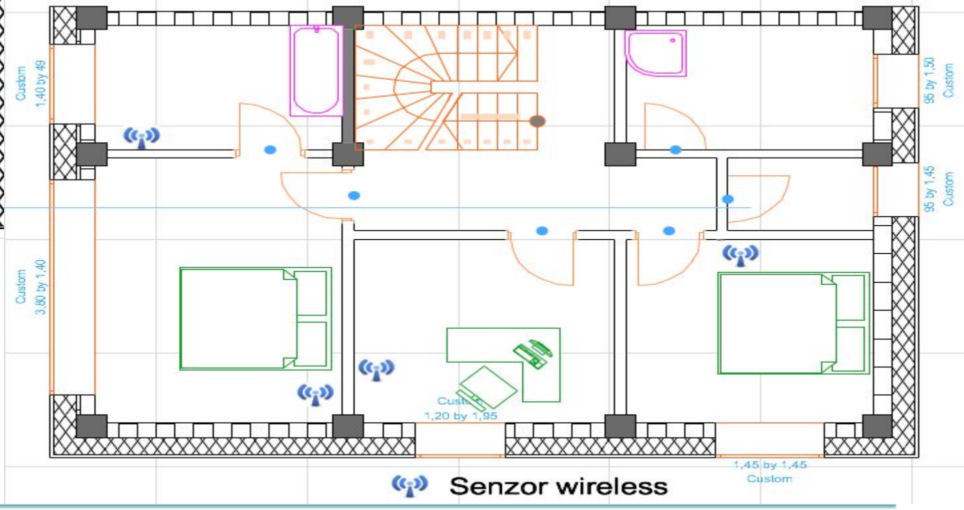


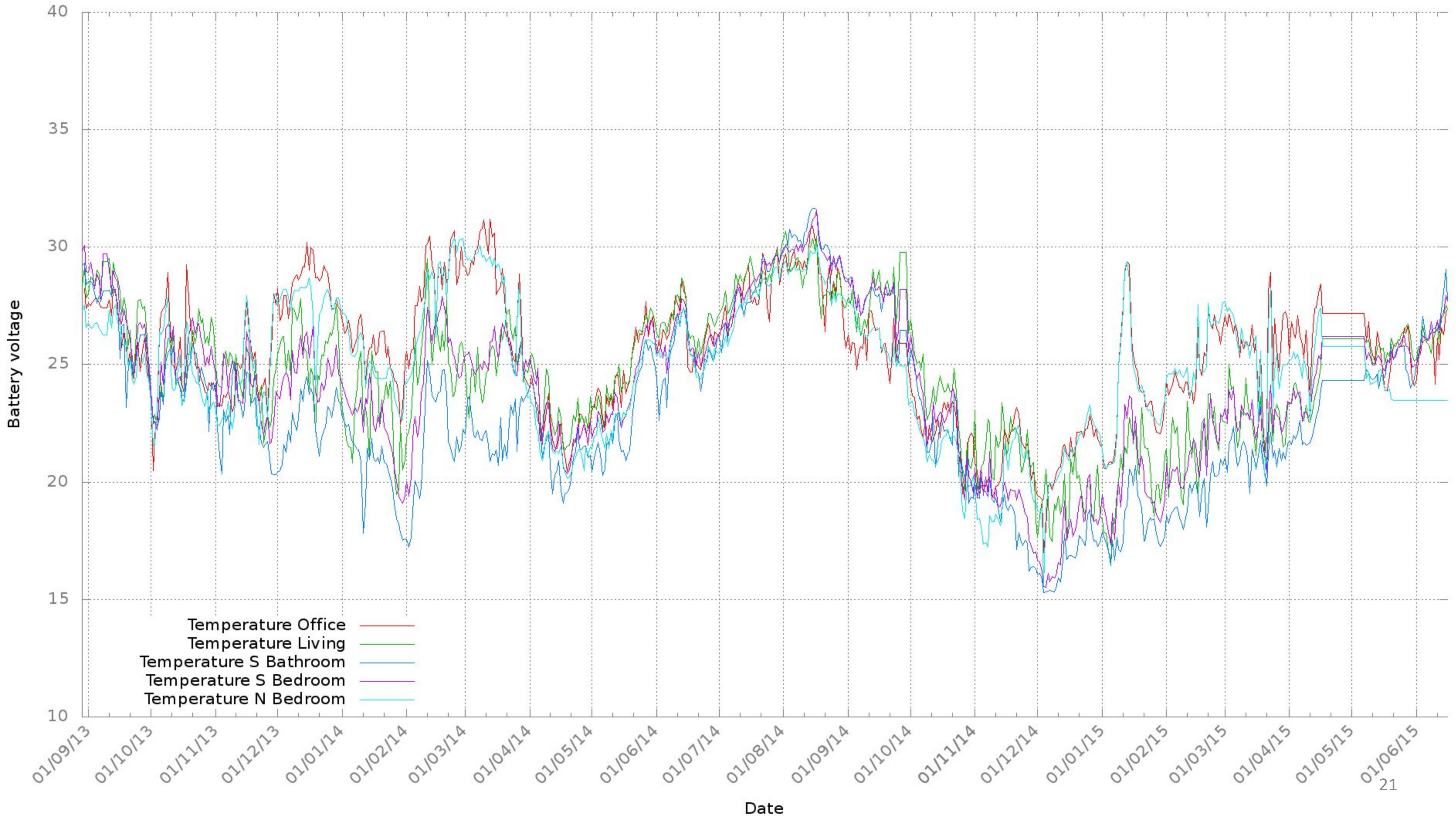
Deployment: Off-grid building



Floor plan


1,40 by 1,90
Custom
17 x 18 x 26
Custom
1,40 by 1,52
Custom
1,60 by 1,60
Senzor wireless
Nod central

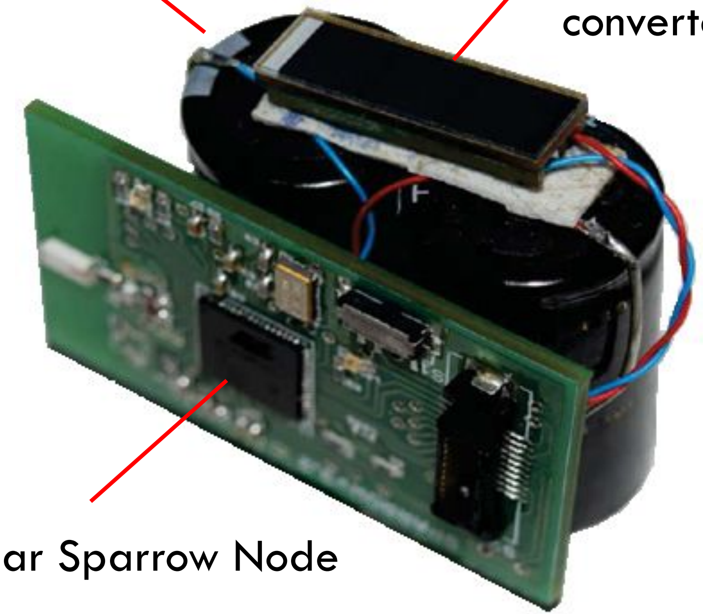

Custom
1,40 by 49
Custom
3,80 by 1,40
95 by 1,50
Custom
95 by 1,45
Custom
1,20 by 1,95
1,45 by 1,45
Custom
Senzor wireless



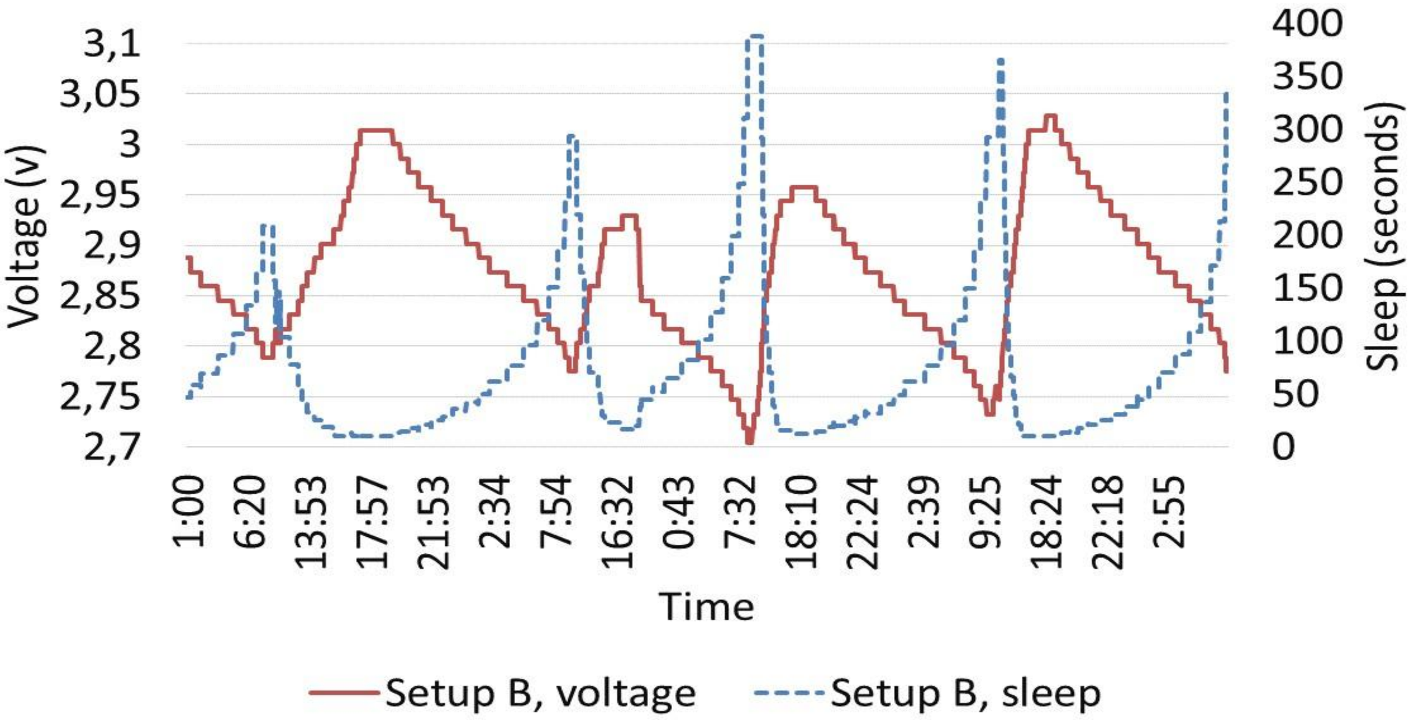
40
35
30
25
20
15
10
Battery voltage
Temperature Office
Temperature Living
Temperature S Bathroom
Temperature S Bedroom
Temperature N Bedroom
01/09/13
01/10/13
01/11/13
01/12/13
01/01/14
01/02/14
01/03/14
01/04/14
01/05/14
01/06/14
01/07/14
01/08/14
01/09/14
01/10/14
01/11/14
01/12/14
01/01/15
01/02/15
01/03/15
01/04/15
01/05/15
01/06/15
Date

Energy-Independent Indoor WSN

- Employs energy harvesting
- Miniature Solar Panel
- Ultra low-power DC/DC
- Super-capacitor storage
- Dynamic duty-cycling using energy estimation algorithms
- Achieves total energy independence in outdoor & indoor scenarios

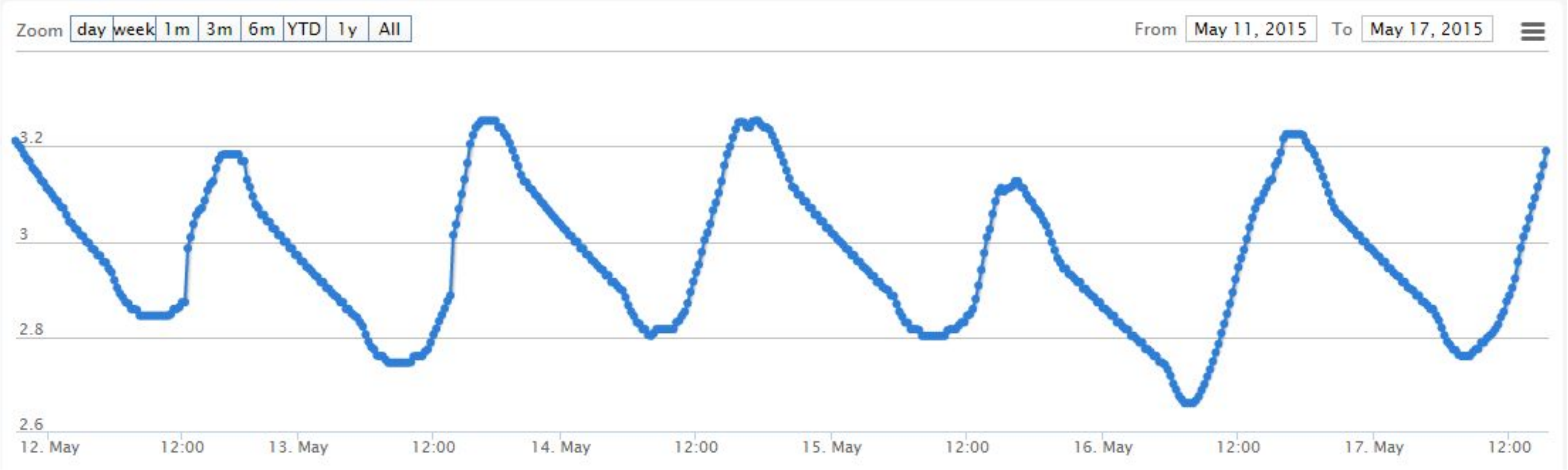


Results



3,1
3,05
3
2,95
2,9
2,85
2,8
2,75
2,7
Voltage (v)
400
350
300
250
200
150
100
50
0
Sleep (seconds)
1:00
6:20
13:53
17:57
21:53
2:34
7:54
16:32
0:43
7:32
18:10
22:24
2:39
9:25
18:24
22:18
2:55
Time
Setup B, voltage
Setup B, sleep

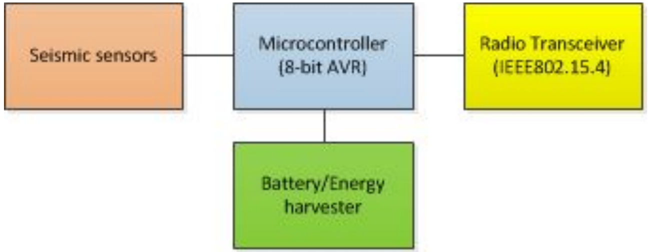
Results

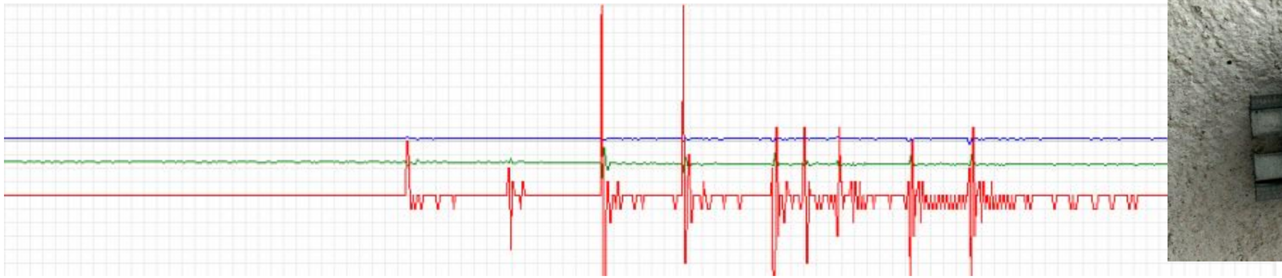


Zoom
day
week
1m
3m
6m
YTD
1y
All
From
May 11, 2015
To
May 17, 2015
3.2
3
2.8
2.6
12. May
12:00
13. May
12:00
14. May
12:00
15. May
12:00
16. May
12:00
17. May
12:00

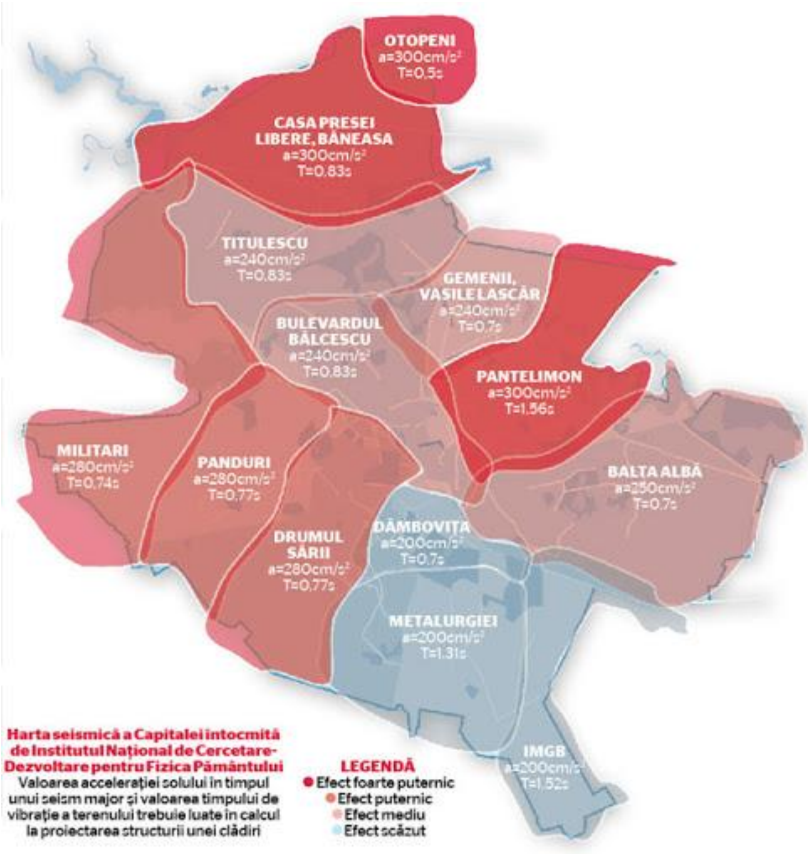
Seismic Building Monitoring

- The interaction between seismic waves and building structures are not well defined or easy to model
- Existing seismic monitoring networks can't detect structural deformation in buildings



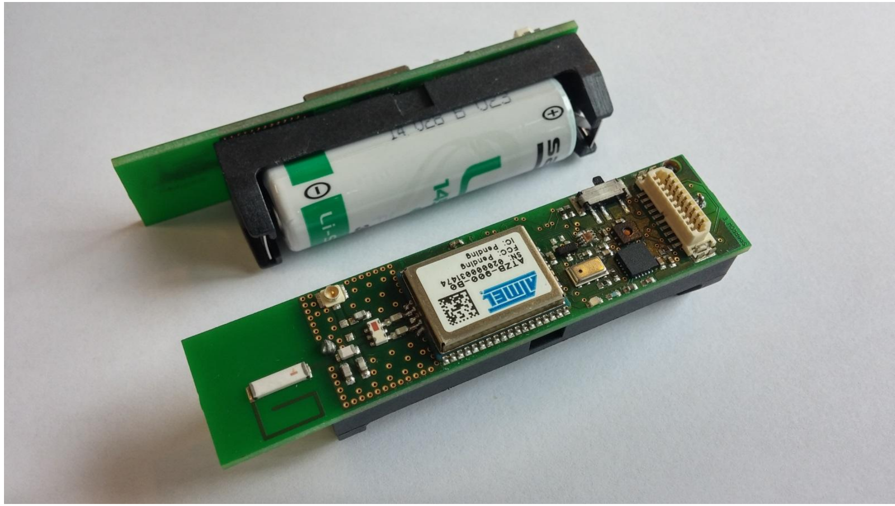


Seismic Building Monitoring

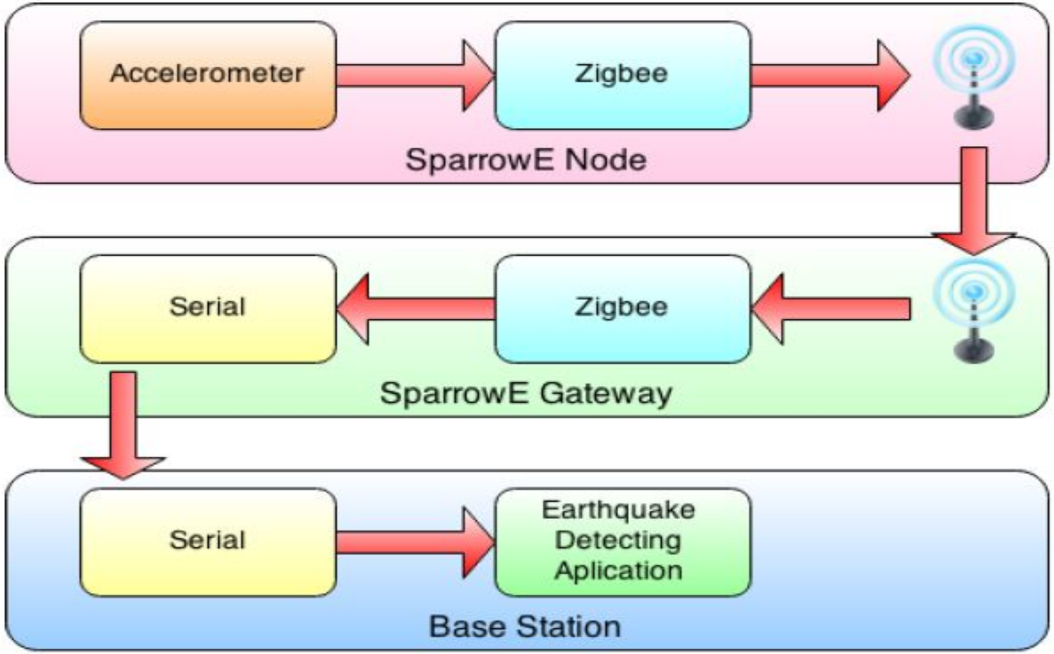


Platform Design

- Sparrow nodes
- Attached to the outside of buildings walls, on different floors
- Monitor vibrations
  - High-precision accelerometer
- Very high energy availability
  - Large battery
  - Autonomy of at least one year



Communication

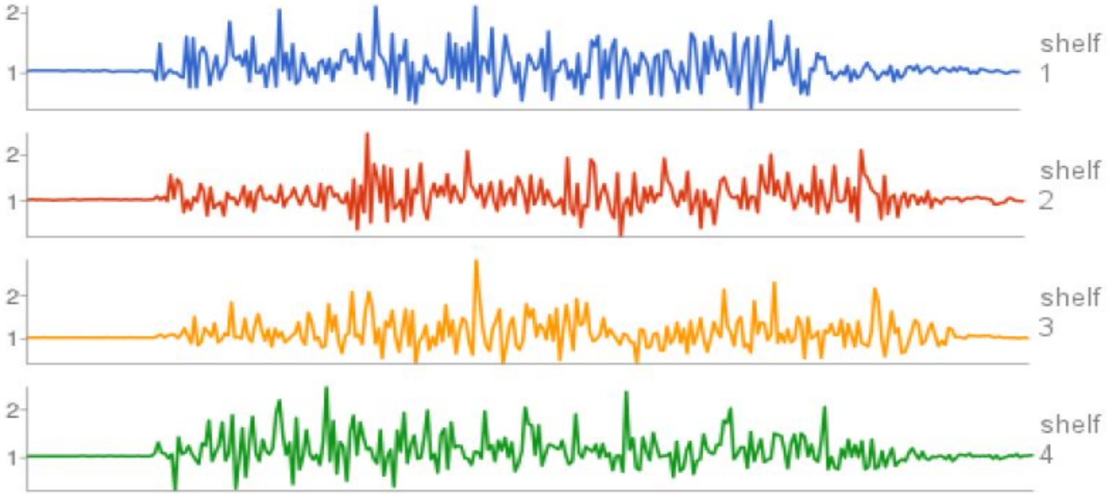


Experimental Setup

- Seismic shake table
  - slide and vibrate in two axes
  - simulated the resistance structure of a building using a metallic structure
- At each level - a sensor node

Results

- Seismic waves on each floor
- Behavior is completely different depending on the distance from the base



Microsal – Salivary Pacemaker

- Neuro-electrostimulator for the salivary glands
- Measured the level of salivary pH and humidity in the oral cavity
- Stimulate the salivary glands to produce more saliva
- Treatment of xerostomia
- Miniaturized dental implant incorporated in a dental crown

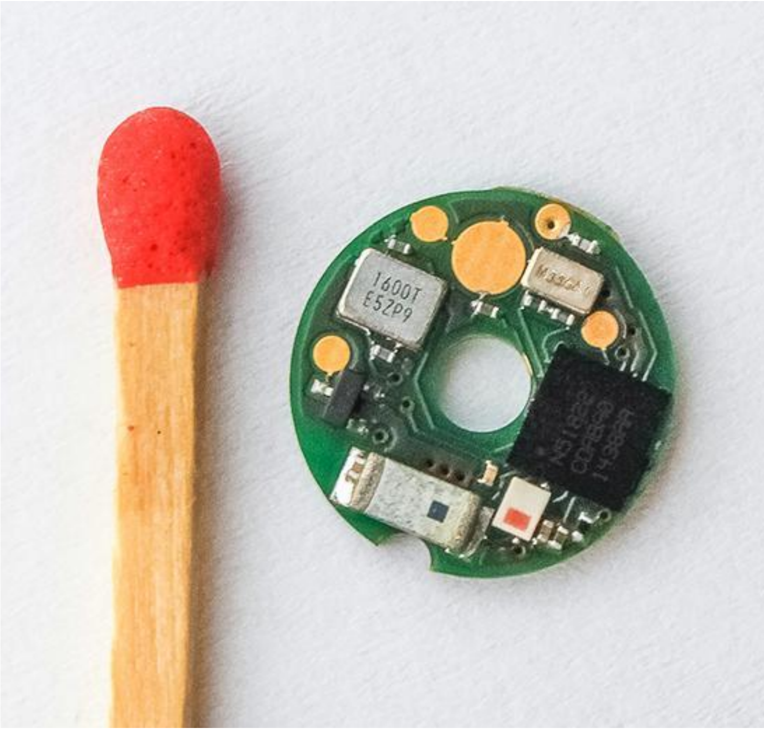
Microsal – Salivary Pacemaker

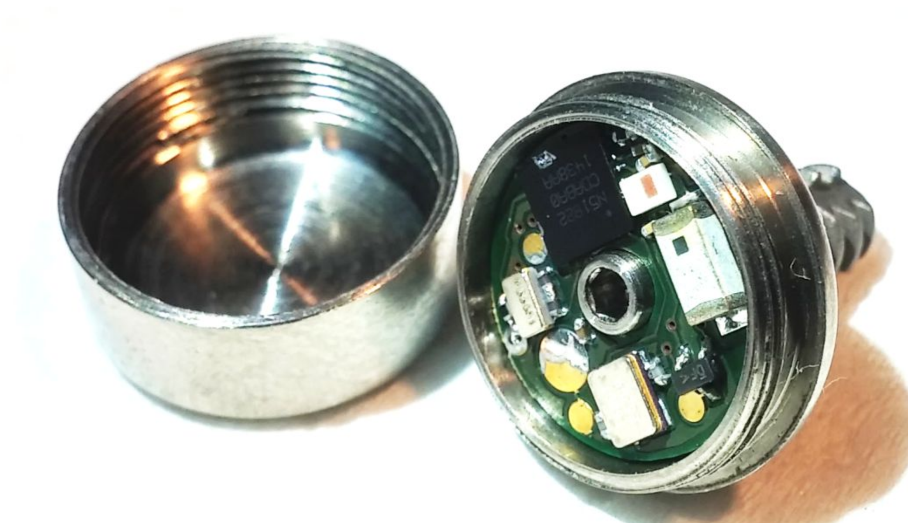
- Connectivity to a tablet through BLE
  - See logged data
  - Set parameters
- Data send and stored in Cloud

Microsal – Salivary Pacemaker

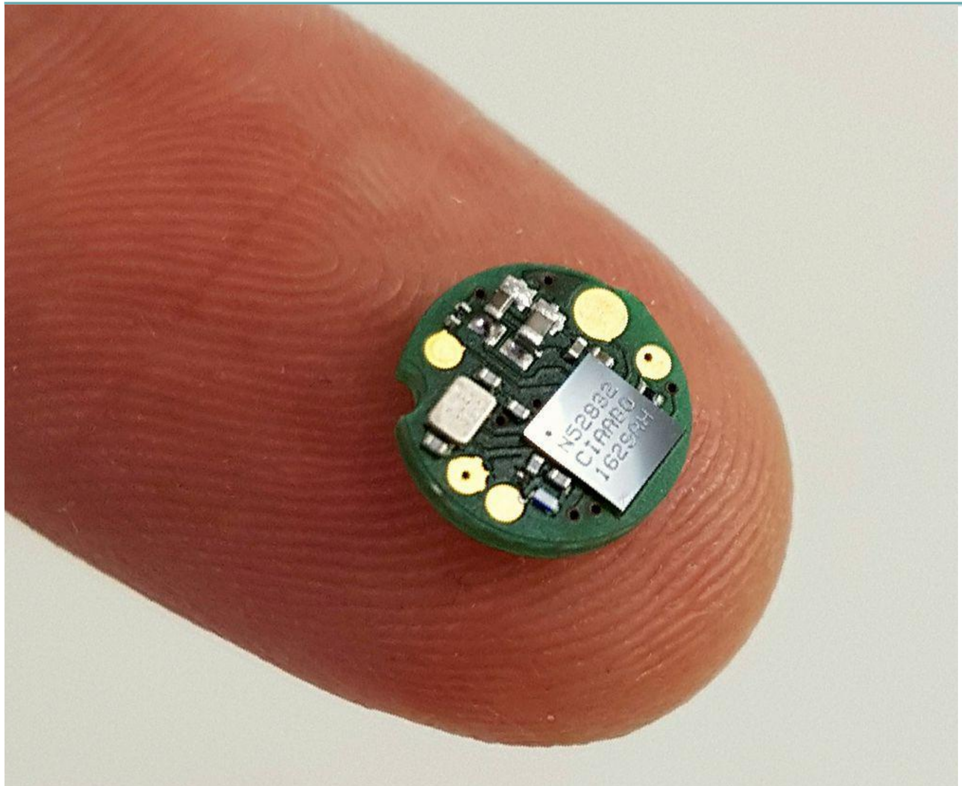
IoT
Sensor Node Crunch

Embedded Systems Laboratory





Microsal – Salivary Pacemaker



Keywords

- Wireless Sensor Networks
- Sensor node
- Mote
- Single-hop
- Multi-hop
- Sparrow