Internet of Things

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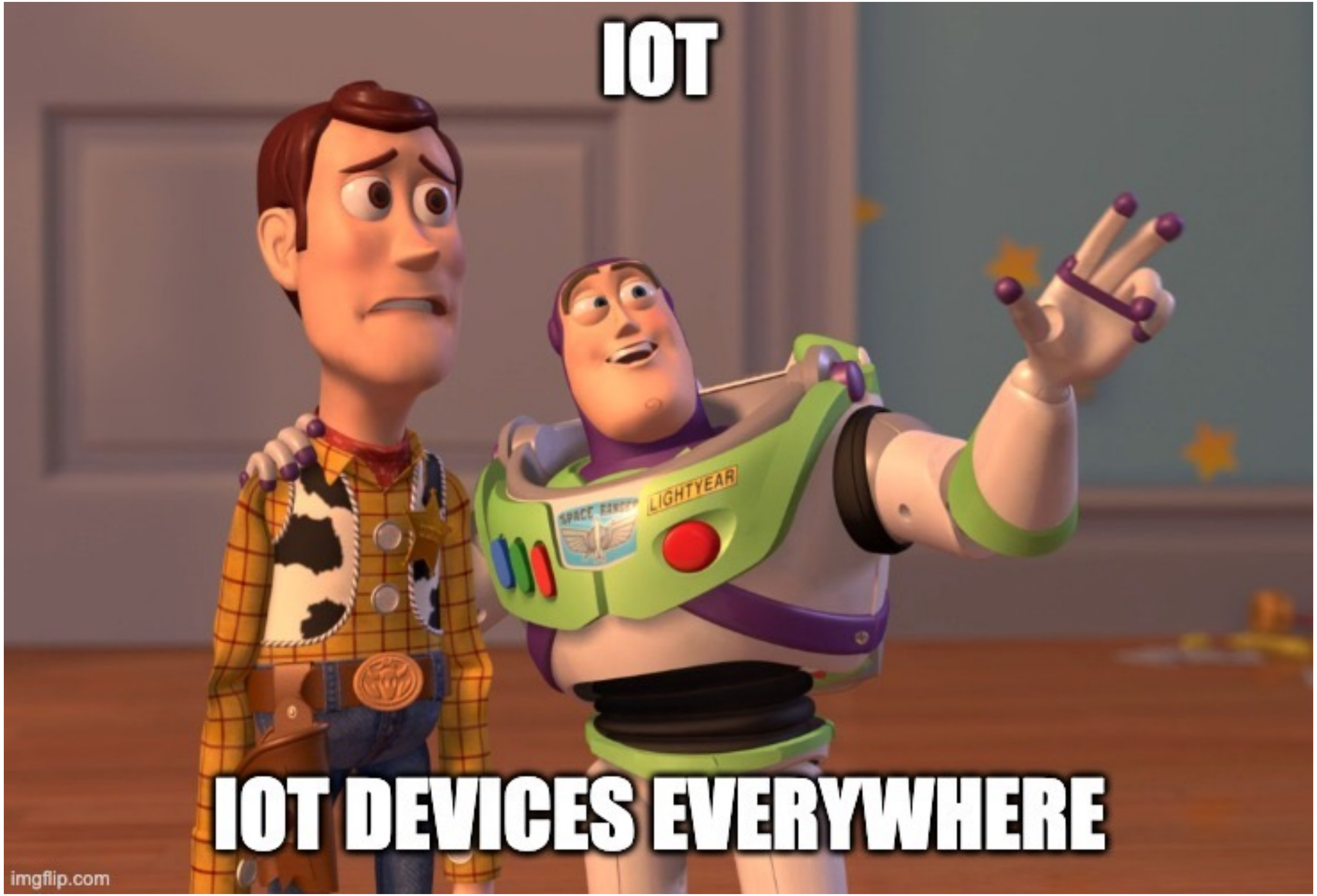

IOT
IOT DEVICES EVERYWHERE
imgflip.com

About me

Dan Ștefan Tudose

- Associate Professor @ UPB
- Ph.D. in IoT & Wireless Sensor Networks
- Research & teaching:
  - Computer architecture, hardware/software interaction
  - Embedded and Pervasive Computing
  - Wireless Sensor Networks
  - Low Power Computing Architectures, Energy Harvesting
  - Fault tolerance

- Start-ups, Fitbit, Google

Industrial Revolutions

1st

1760s

Steam engine
Mechanization

2nd

1870s

Electricity
Mass production

3rd

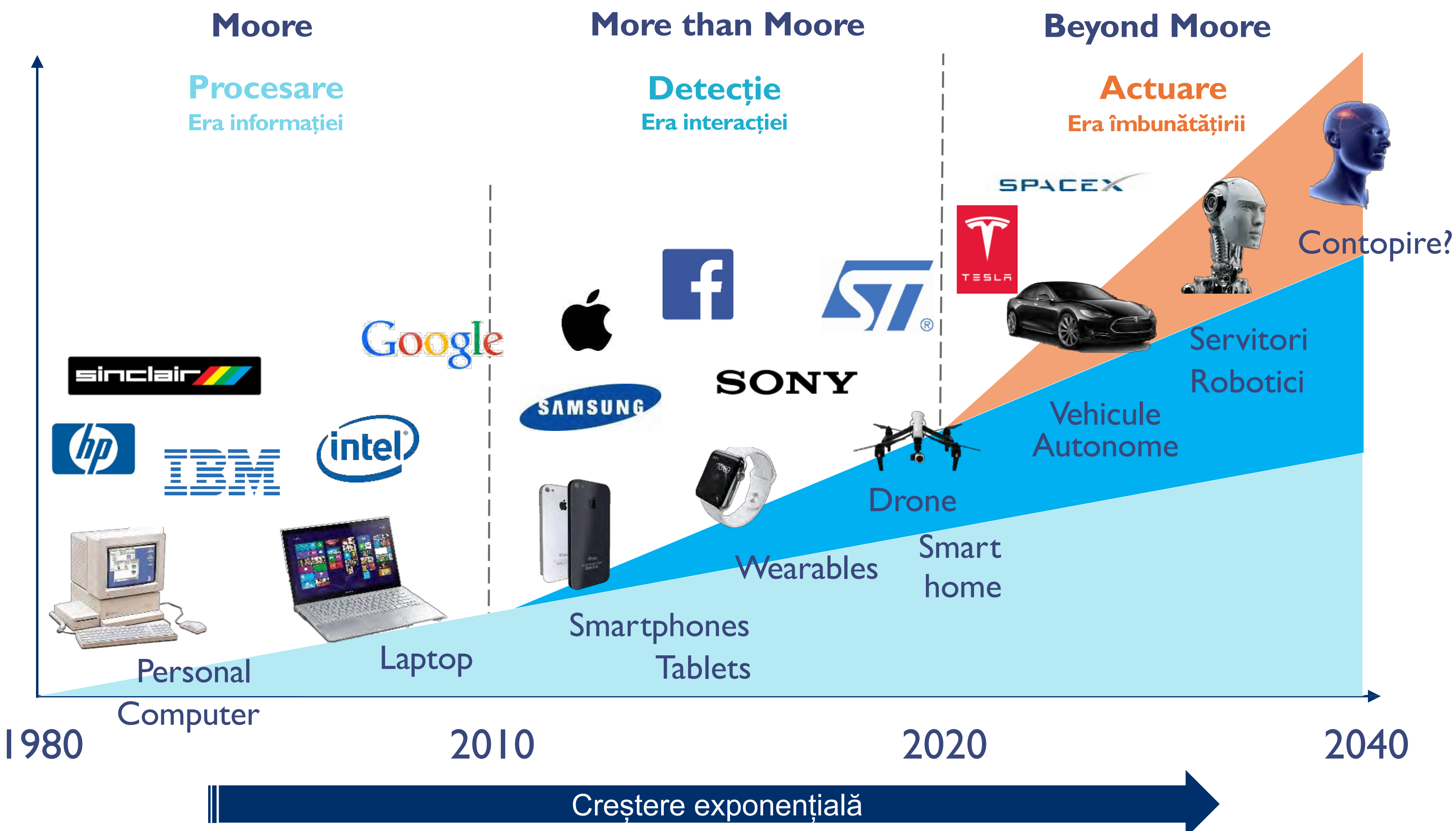
1960s

Computers
Automation
Internet

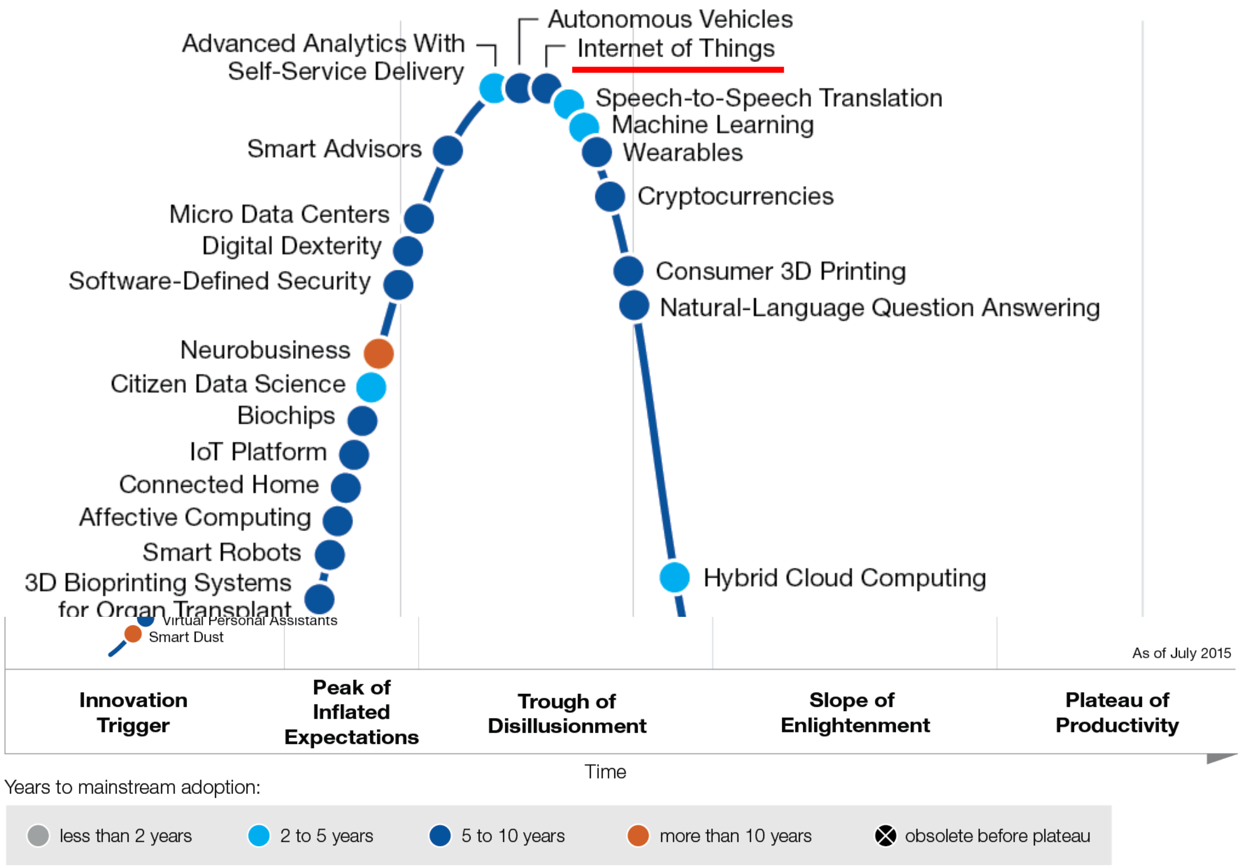
4th

NOW

Hyper-
connectivity


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

Emerging Technology Hype Cycle



gartner.com/SmarterWithGartner

Characteristics

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

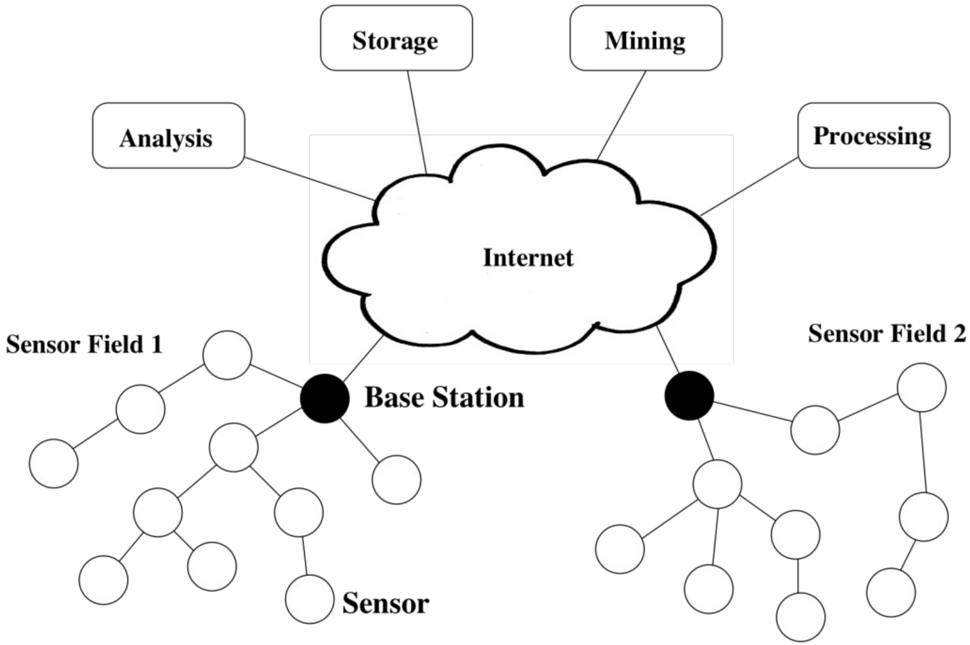
A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network, often communicate data associated with users and their environments.

IoT Features

- Dynamic, self-adaptation
- Auto-configuration
- Interoperable communication protocols
- Unique identifier
- Integrated into a larger network

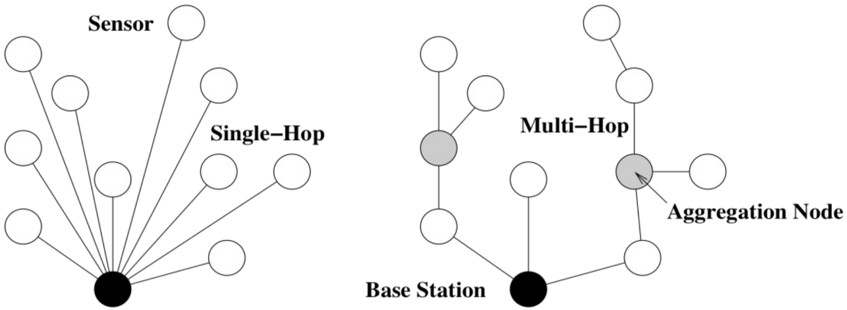
Architecture

- Multiple sensors (sometimes hundreds or thousands) form a network in order to monitor complex or large physical environments
- The collected information is transmitted wirelessly to a base station (BS), which then propagates it to other devices for storage, analysis and processing.



Single-Hop versus Multi-Hop

- Star topology: Each sensor communicates directly (single-hop) with the base station
  - May require high transmission power and may be unfeasible over a wide area Mesh topology
- The sensors act as forwarders for other nodes (multi-hop)
  - It can reduce energy consumption and increase the coverage
  - The routing issue arises



A 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)
  - Conceptul de “motes”: noduri senzoriale extrem de mici
- Berkeley Wireless Research Center (BWRC)
  - PicoRadio project (2000)
- MIT
  - µAMPS (micro-Adaptive Multidomain Power-aware Sensors) (2005)

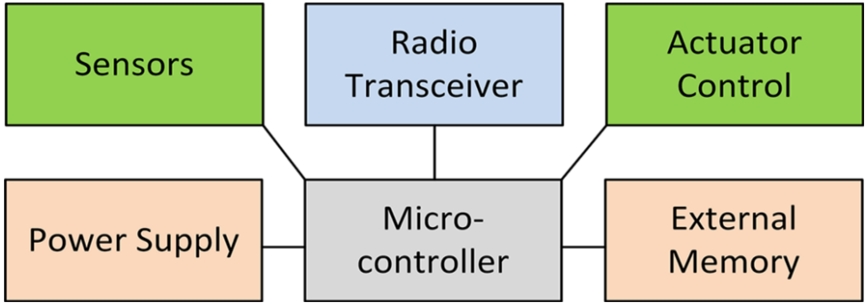
What is a Mote?

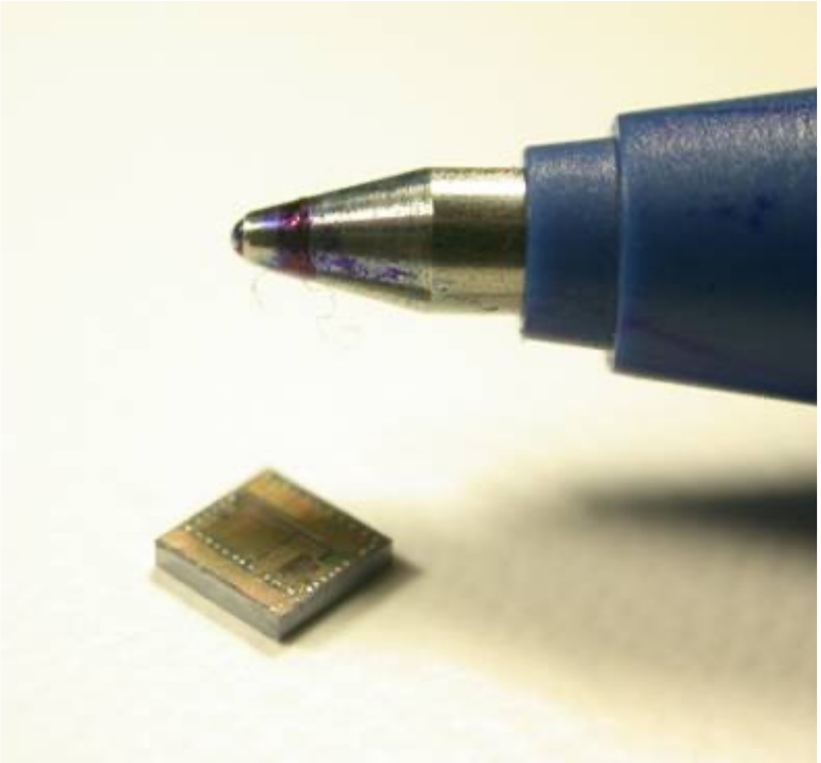
- **mote** *noun [C] LITERARY*
  something, especially a bit of dust, that is so small it is almost impossible to see
  ---Cambridge Advanced Learner's Dictionary
  http://dictionary.cambridge.org/define.asp?key=52014&dict=CALD

UC Berkeley hardware platform evolution

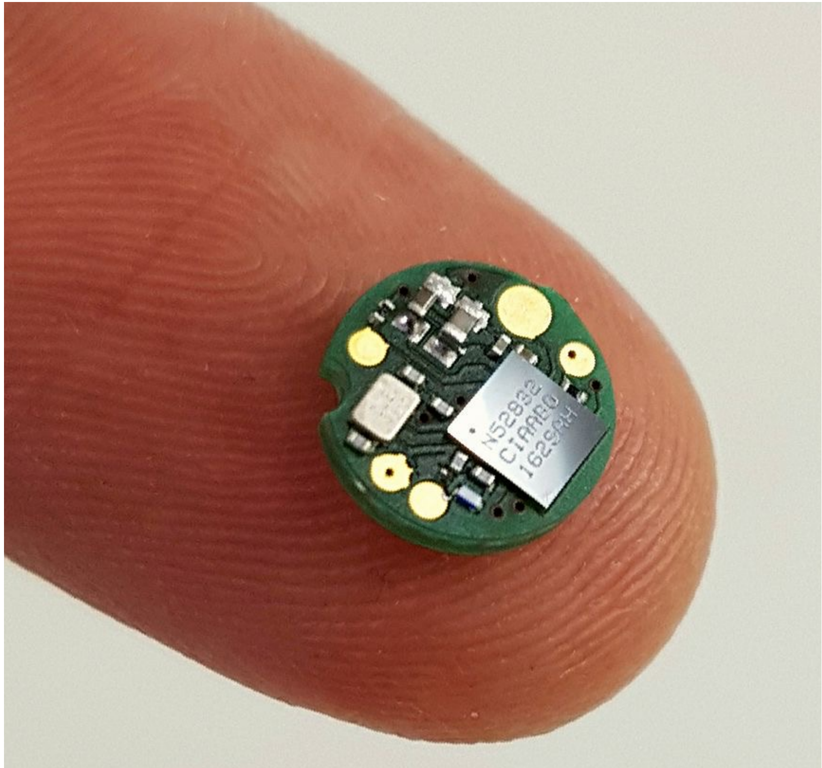
Node components

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



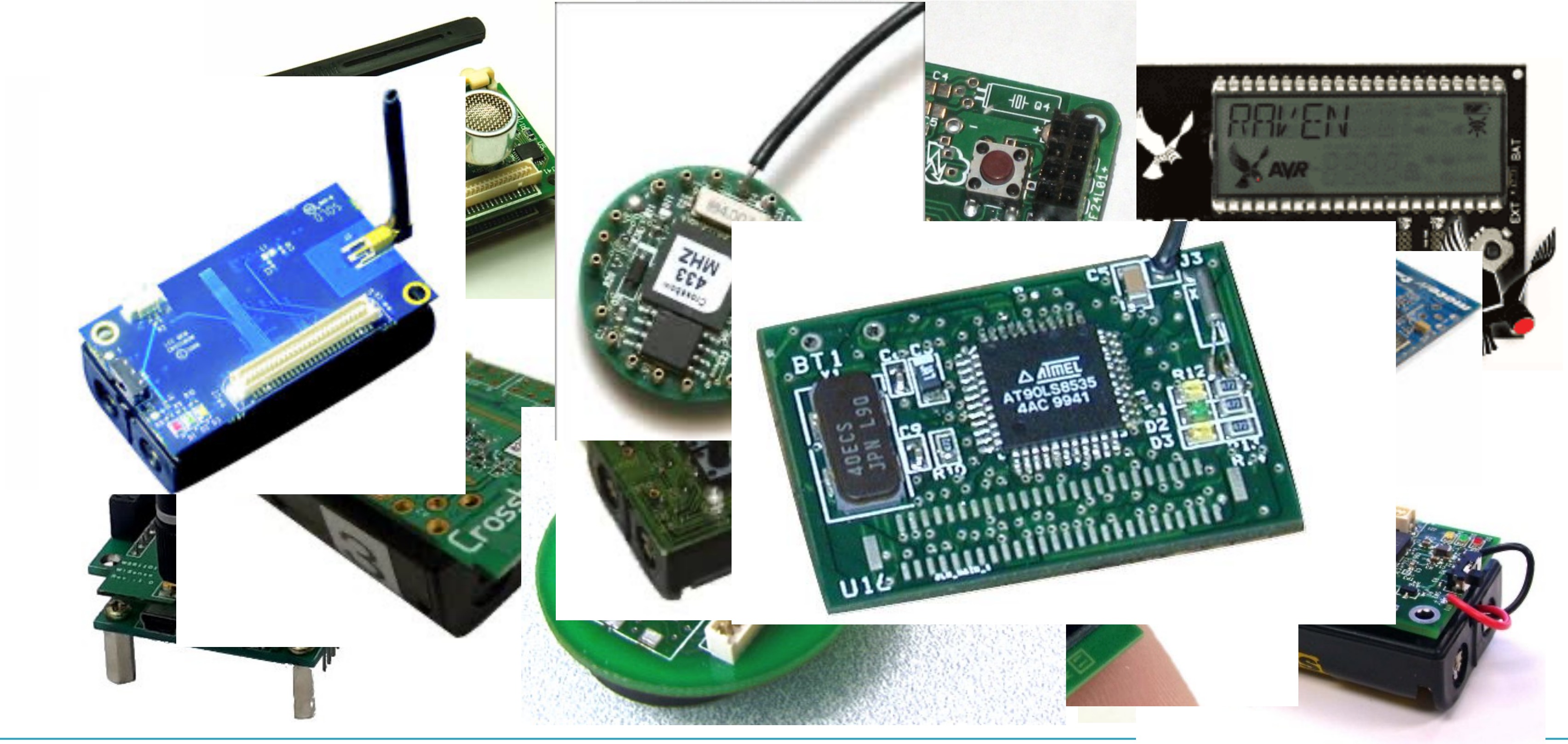


Berkeley Spec (cca. 2000)



UPB Microsal (cca. 2010)

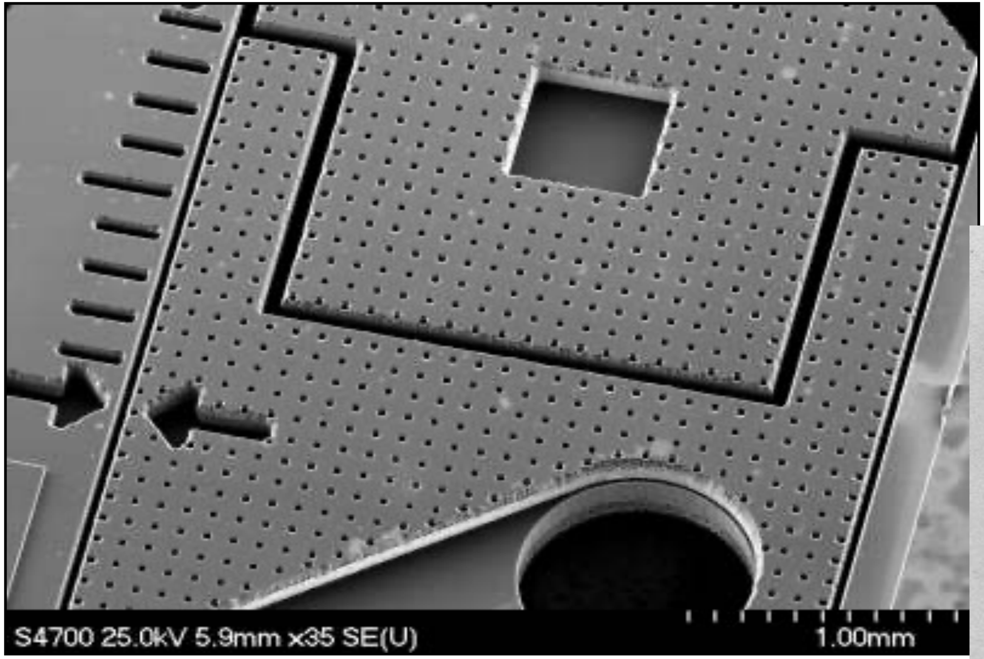
...and many more

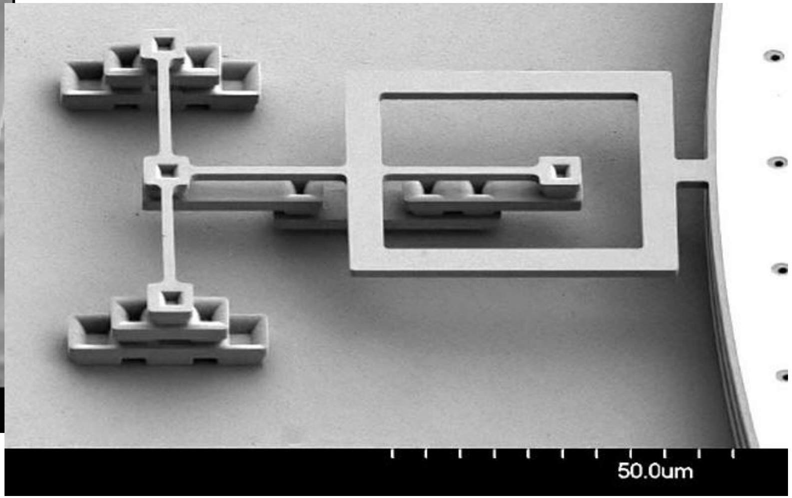


How did we get here?

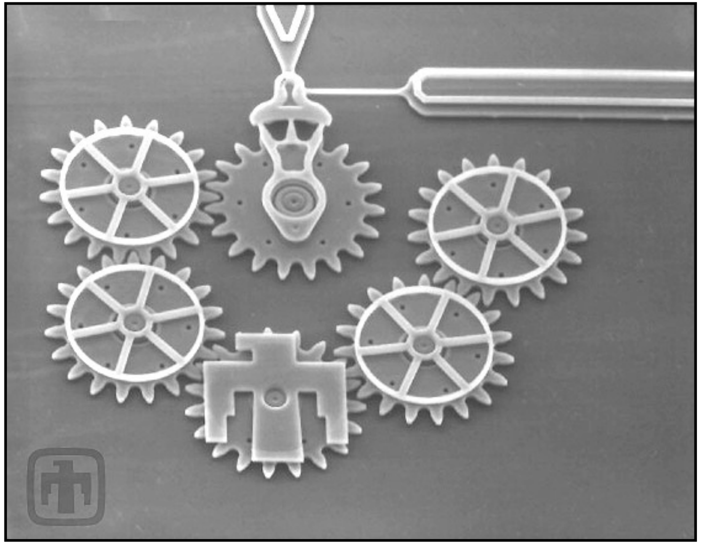
- Development of wireless technology
  - MEMS, VLSI
  - Bandwidth explosion
  - Cultural and legislative changes
- Wireless devices are everywhere and people are increasingly receptive to new applications
  - The concept of network (not only data) is a basic one in our society
  - Open source
- Computer Science
  - Network theory, operating systems
  - Cheap and universally available compilers

Micro-Electro-Mechanical-Systems (MEMS)

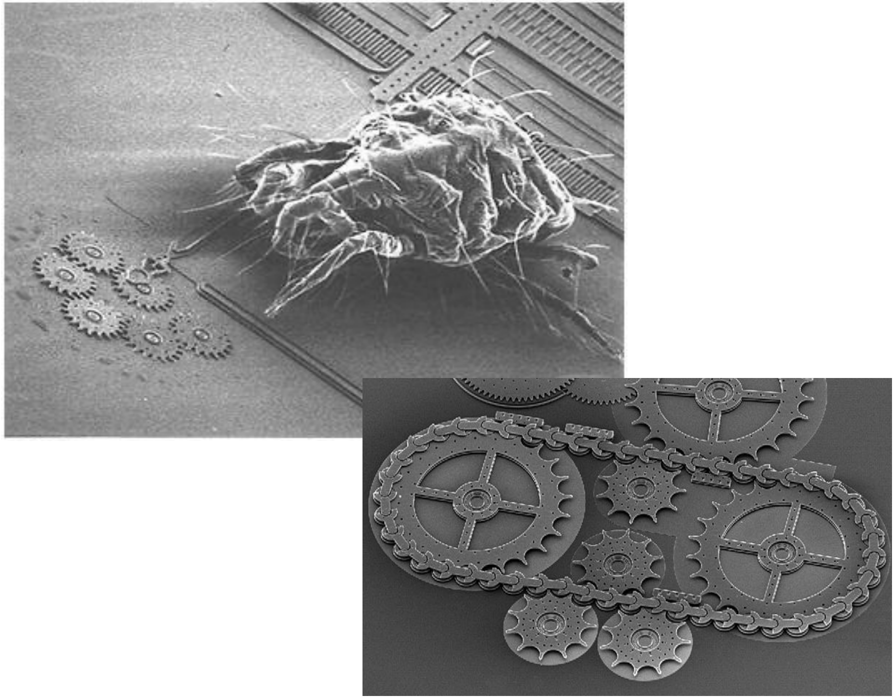




Micro-Electro-Mechanical-Systems (MEMS)

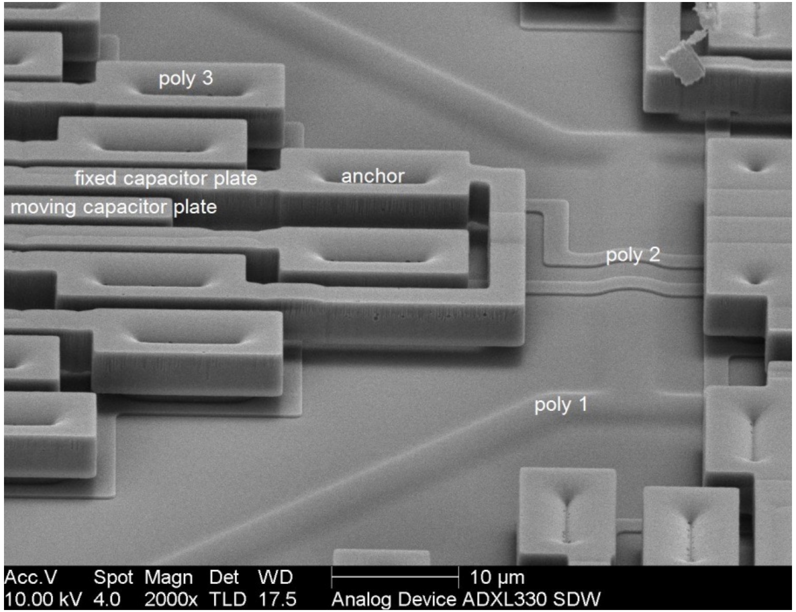


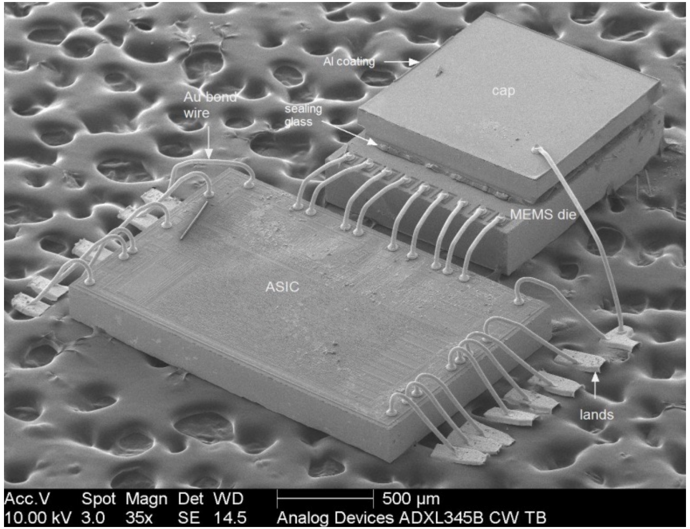
~ 1mm



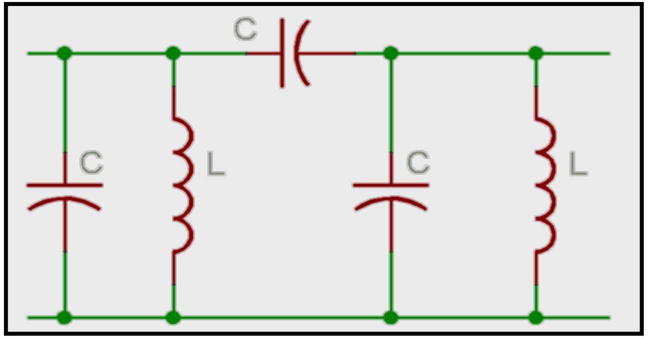
MEMS sensors

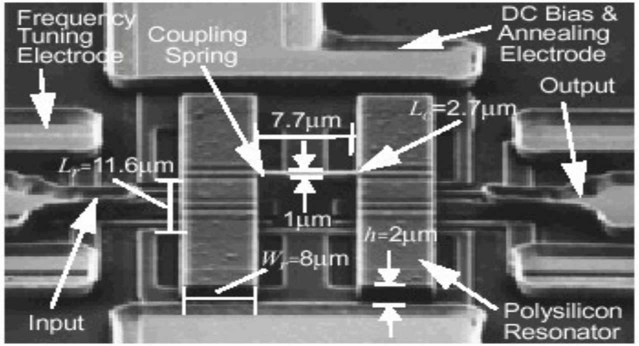
Accelerometers, gyroscopes, magnetometers, microphones, speakers etc.



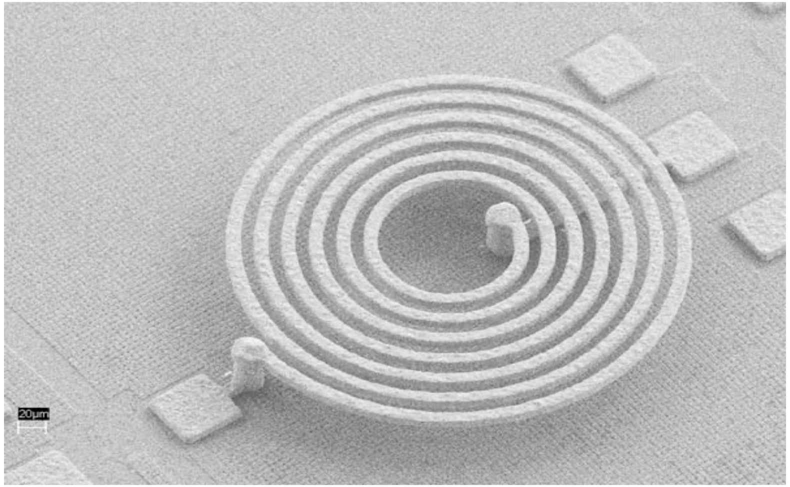


MEMS for RF





Conventional LC filter – Qs aprox. 100-200, takes a lot of space on PCB



MEMS filter: Qs 98,000, REALLY small

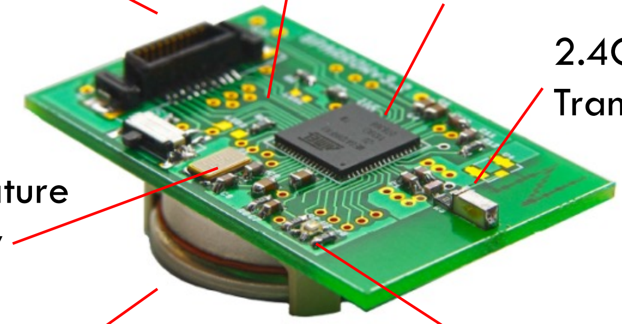
IoT Communication

- Characteristics
  - low data rate (comparable to a dial-up modem)
  - strong energy constraints
- IEEE 802.11 standard
  - The most common for wireless communication
  - Can be found on the first IoT networks, or for nodes without big energy constraints
- IEEE 802.15.4 is a standard for short-range communication, specially designed for WSN networks
  - low data rate
  - low power consumption
  - widespread use in academic IoT or commercial solutions

Some Technical Aspects

- Networking is a key component (different levels)
- Addressing schemes (IPv4 vs. IPv6)
- Data transmission (ZigBee, WiFi, 5G, LTE etc.)
- Transfer rate (Kbps, Mbps, Gbps)
- Medium control (MAC layer and Data Link Layer)
- Cross-geography (CoAP, MQTT etc.)

Example: Sparrow



Works with IEEE 802.15.4

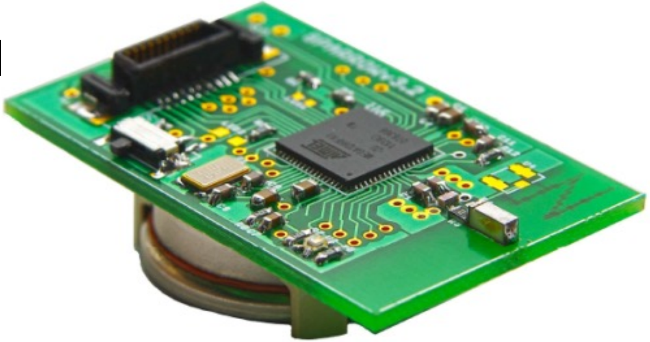
256kbps transfer speed

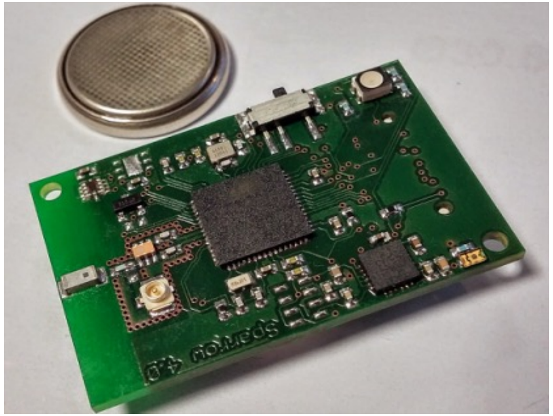
Specs:

Sparrow	Original IBM PC (1981)
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 - Wireless Sensor Network creată special pentru studiul energy harvesting
- Low-power (13mA Run-Time, 6uA Sleep)
- Poate rula o multitudine de sisteme de operare și stive de protocol

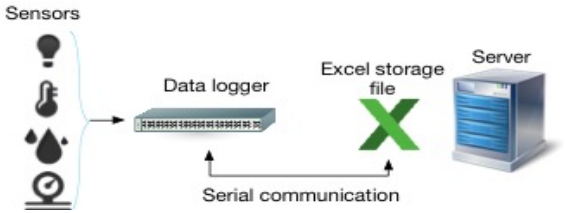


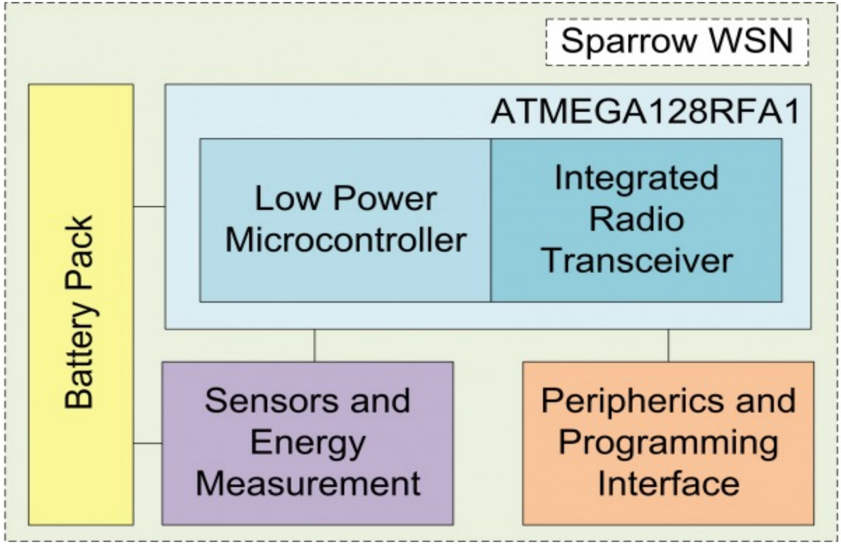


- Arduino compatible!
- Autonomie măsurată în ani de zile (4 years and still going strong)

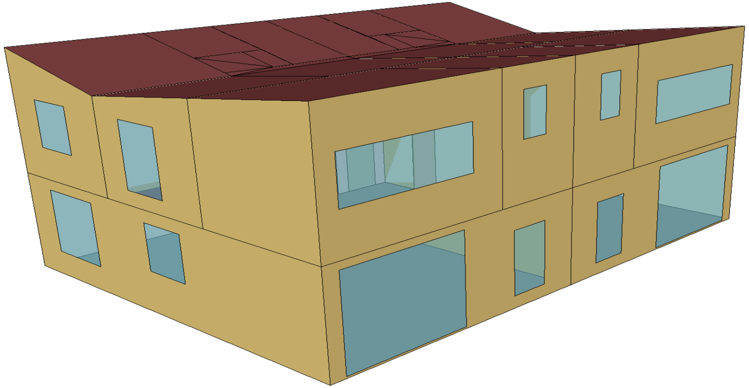
Technical specs

	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

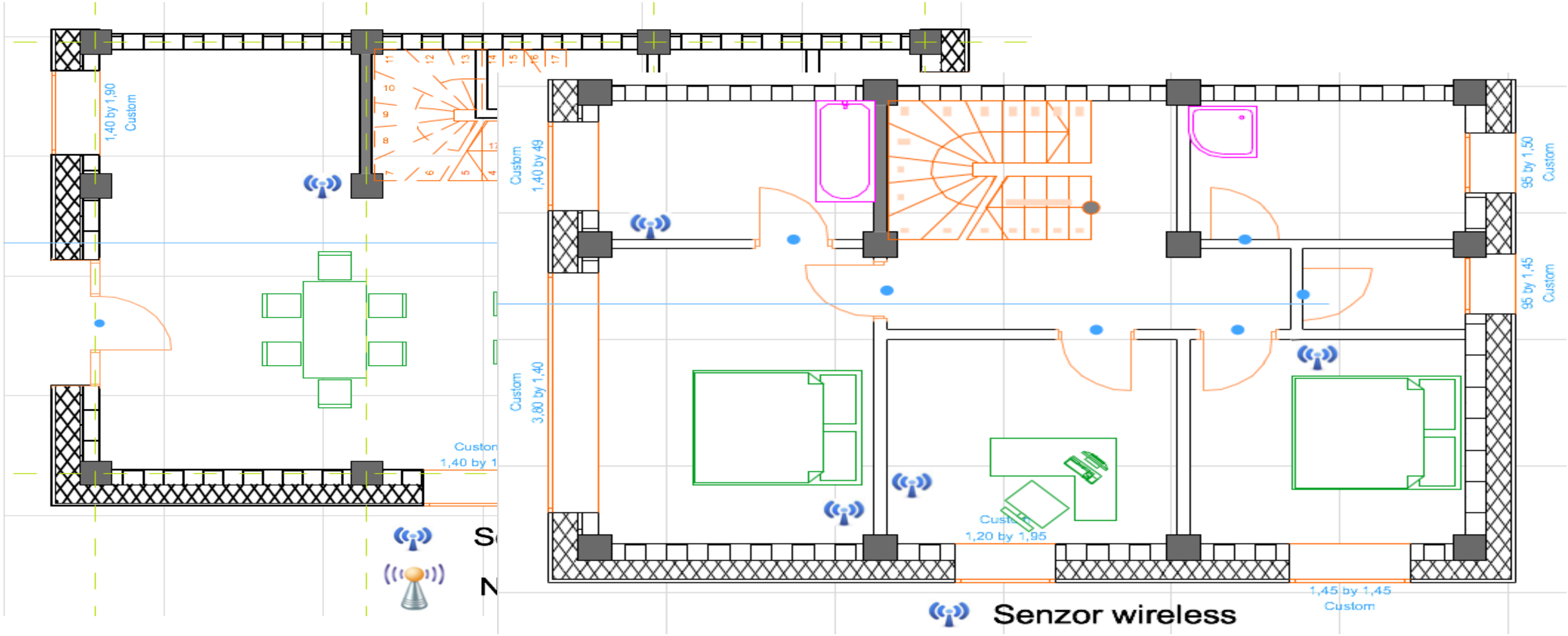


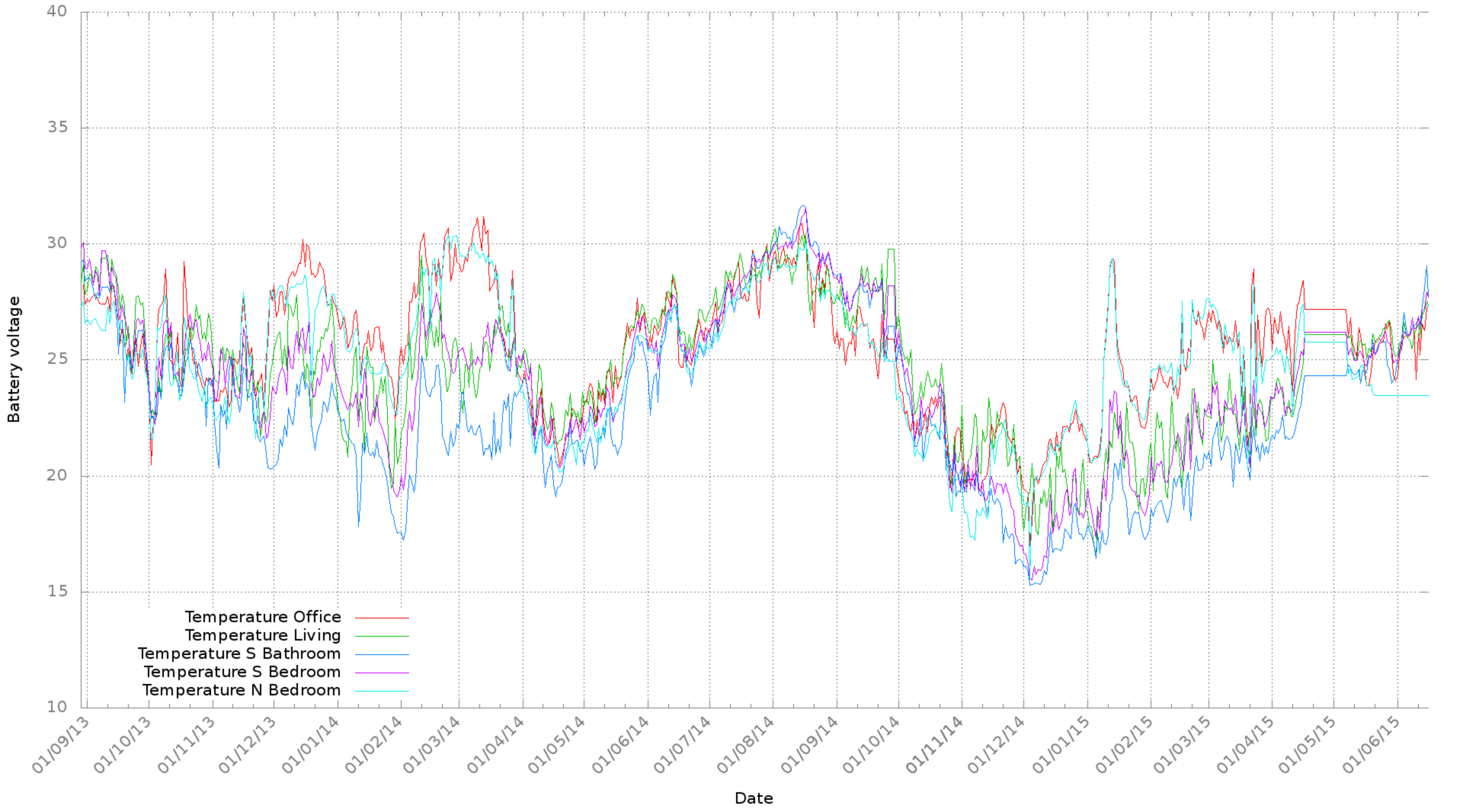


Deployment: Off-grid building



Floor plan


1,40 by 1,90
Custom
Custom
1,40 by 49
95 by 1,50
Custom
95 by 1,45
Custom
Custom
3,80 by 1,40
Custom
1,40 by 1
Custom
1,20 by 1,95
1,45 by 1,45
Custom
Senzor wireless

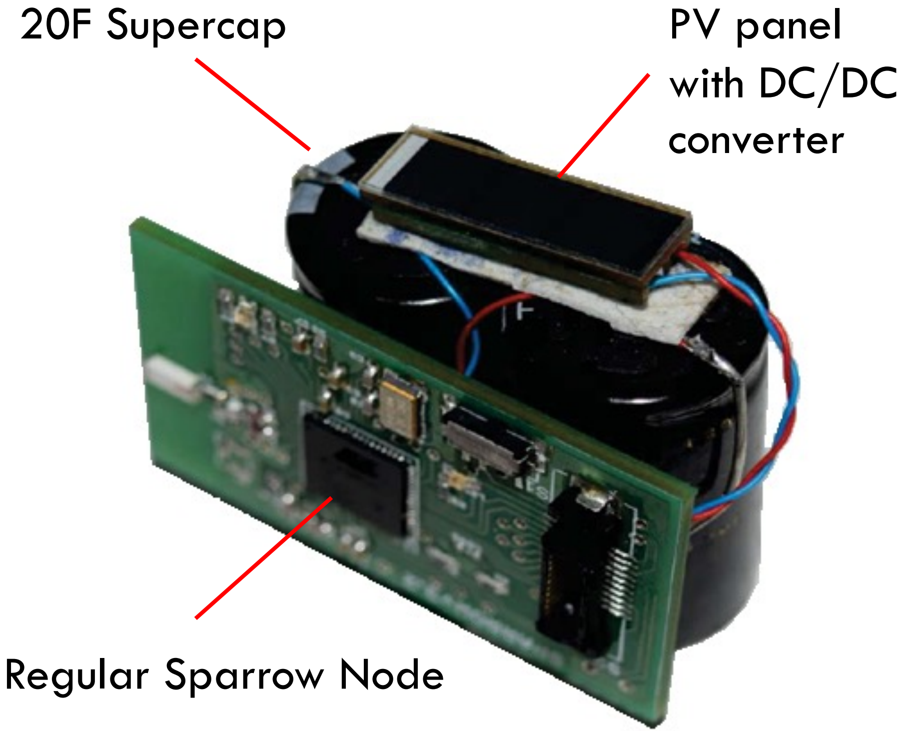


Battery voltage
40
35
30
25
20
15
10
Temperature Office
Temperature Living
Temperature S Bathroom
Temperature S Bedroom
Temperature N Bedroom
01/09/13
01/10/13
01/11/13
01/12/13
01/01/14
01/02/14
01/03/14
01/04/14
01/05/14
01/06/14
01/07/14
01/08/14
01/09/14
01/10/14
01/11/14
01/12/14
01/01/15
01/02/15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

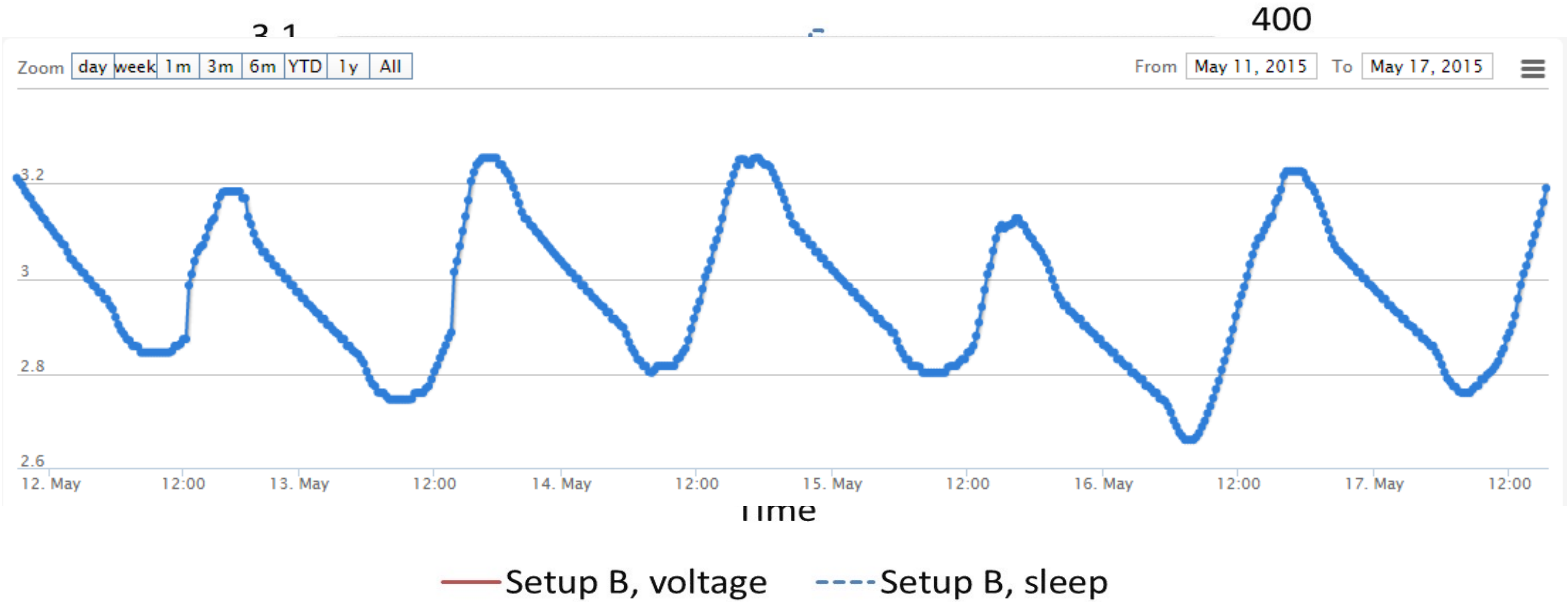
Energy-Independent Indoor WSN

Employs energy harvesting

- Minuature 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



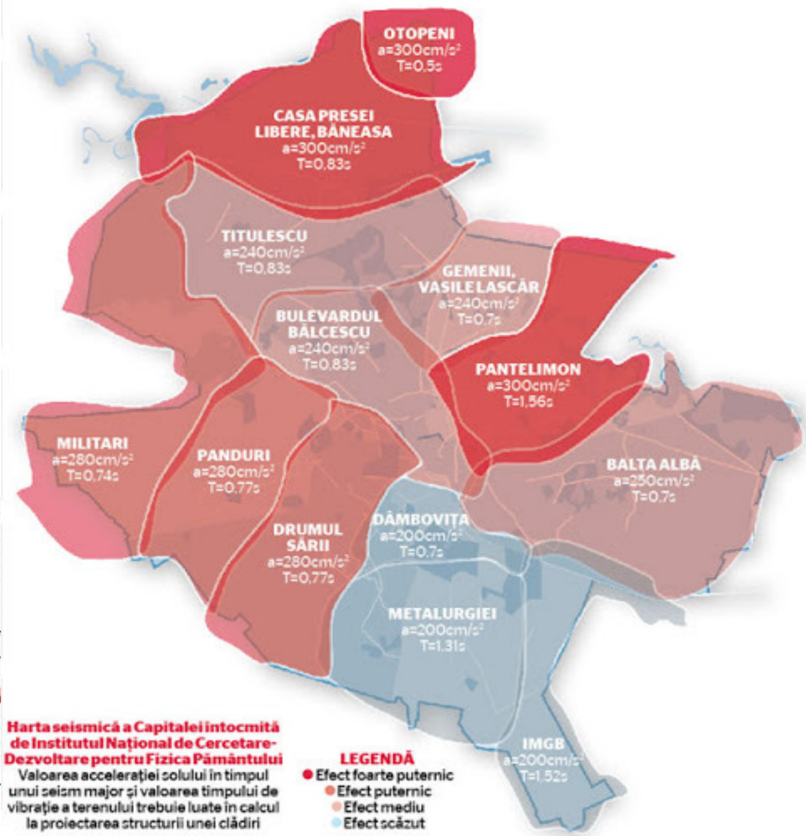
Results



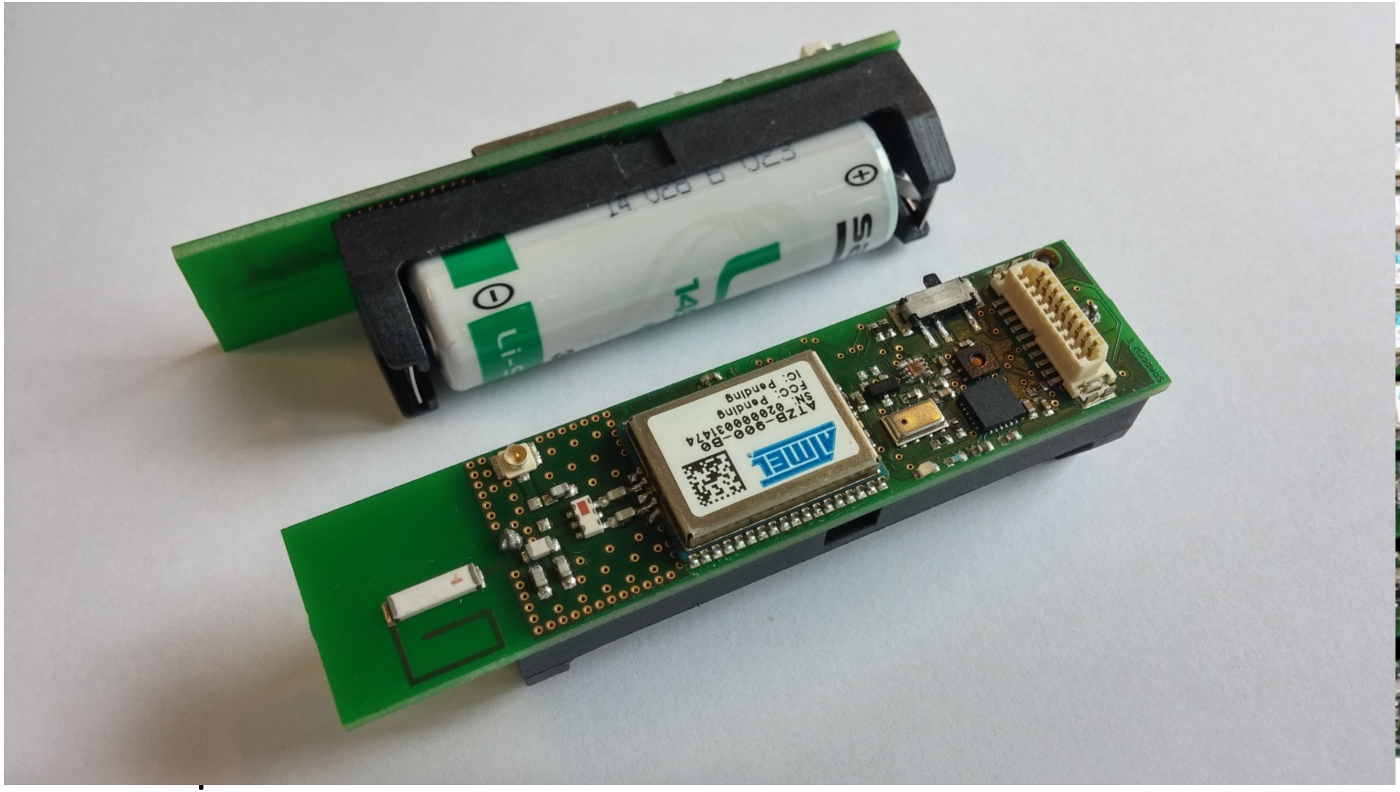
400
Zoom day week 1m 3m 6m YTD 1y All
From May 11, 2015 To May 17, 2015
3.2
3
2.8
2.6
12. May 12:00 13. May 12:00 14. May 12:00 15. May 12:00 16. May 12:00 17. May 12:00
Setup B, voltage
Setup B, sleep

Seismic Building Monitoring

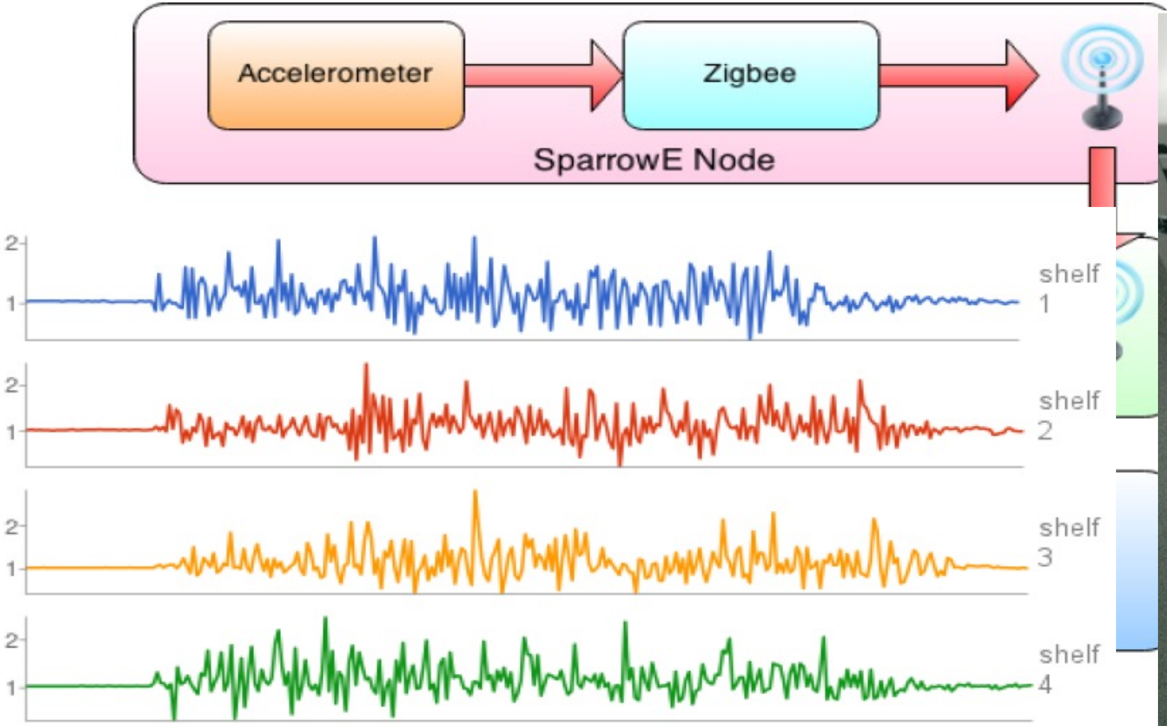
- The interaction between seismic waves and building structures are not well defined or easy to model
- Existing seismic monitoring networks can’t detect structural deformation in buildings



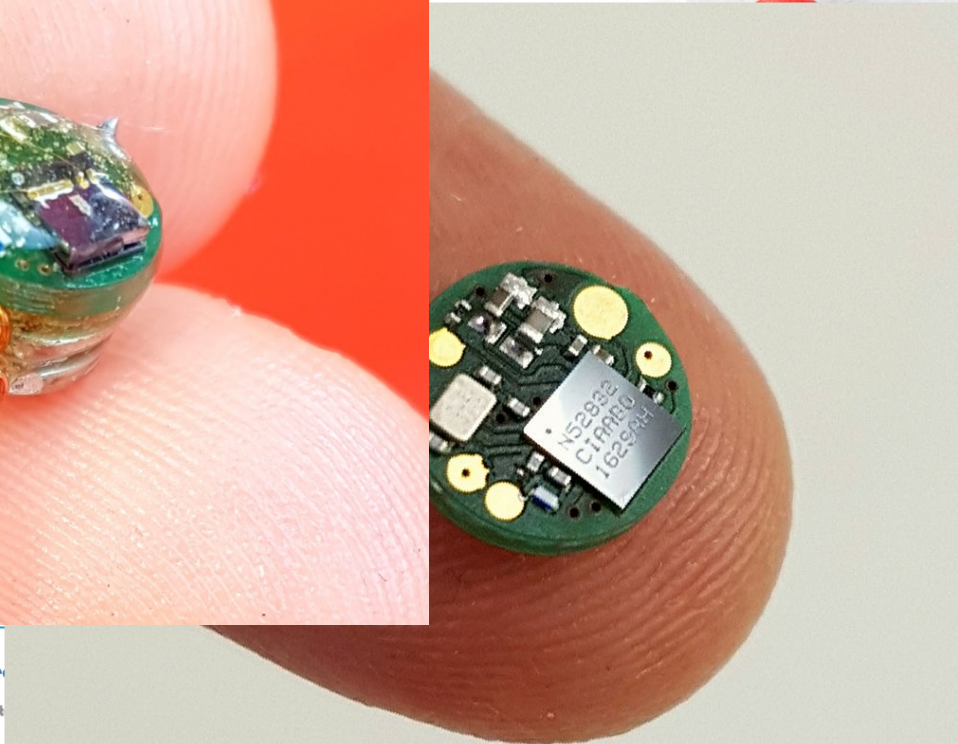
Measurement nodes

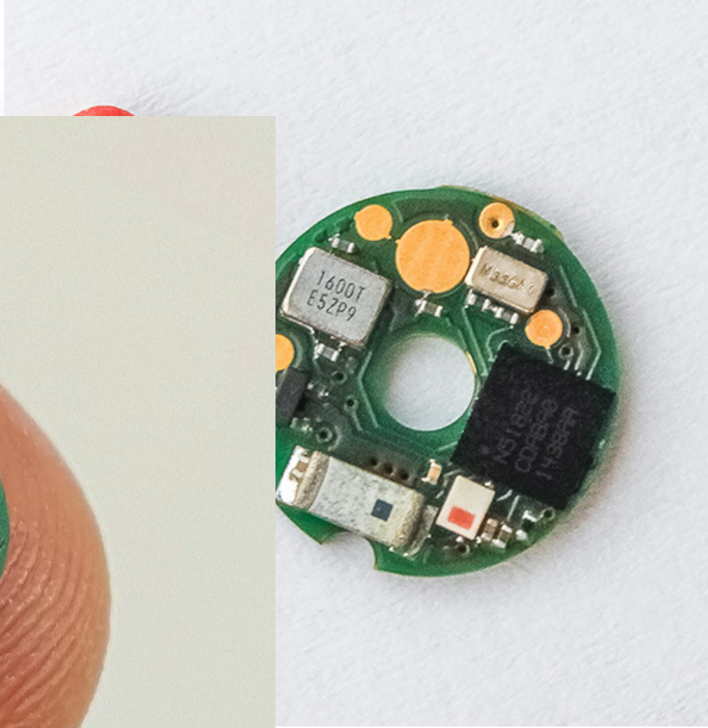


Results


Accelerometer
Zigbee
SparrowE Node
2
1
shelf 1
shelf 2
shelf 3
shelf 4

Microsal – Salivary Pacemaker





Thank you!