Design and development of embedded systems for the Internet of Things (IoT)

Fabio Angeletti
Fabrizio Gattuso

SAPIENZA
UNIVERSITÀ DI ROMA

W • SENSE
INTEGRATED CABLELESS SOLUTIONS

Who we are

Fabio Angeletti

angeletti@diag.uniroma1.it

Fabrizio Gattuso

gattuso@di.uniroma1.it

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Wsense

Wsense is a spin-off of Sapienza University of Rome and has been founded in 2012 by its Director **Prof. Chiara Petrioli**.

Our company has a strong and experienced R&D team specialized in monitoring and communication systems with pioneering patented solutions in the Internet of Underwater Things (IoUT) and Terrestrial IoT such as artwork transport, microclimate monitoring and structural monitoring.

Class informations

The course is scheduled every Tuesday.

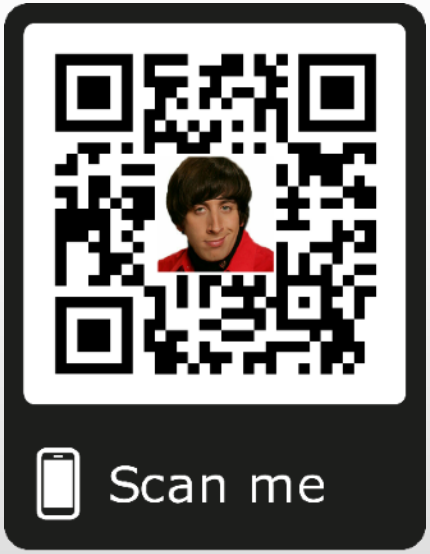
From 14:30 to 17:30/18:00 at Colossus Lab.

The lessons start on 6th March and will end on 29th May.

Lessons are composed by a mix of practical and theoretical sessions, usually the practical one is on the second half of the lesson.

Class informations (2)

It is important to highlight that the page here (again, scan the QRC) will be constantly updated.

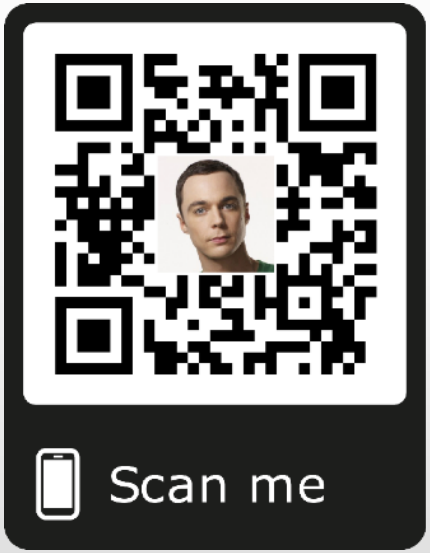


http://twiki.di.uniroma1.it/twiki/view/IOT/

Class informations (3)

To pass the Subsidiary Formative Activity (Attività Formativa Complementare), **you have to present and discuss a project in front of the class.**

If you haven't done yet, please subscribe the google group (scan the QRC).



Syllabus

- What is the IoT?
- STMicroelectronics presentation
- Hardware and bus communications
  - SPI / I2C
  - RS232
  - GPIO
- C in a nutshell
- Sensors
- Hardware platforms

Syllabus (2)

- Operating Systems (FreeRTOS, TinyOS)
- Wireless Communications
  - 802.15.14/ZigBee
  - Wifi/Bluetooth
  - SigFox
  - LoRa
- Energy Power Management
- Security
- Web Communication (REST, MQTT, CoAP)

Syllabus (3)

- Real time web visualization and data analysis
- Cloud Systems for the IoT
- Real Systems Examples
  - SafeArt Project
  - Internet of Underwater Things
  - Other projects

Introduction to the Internet of Things (IoT)

What is IoT?

Electronics and connectivity are getting cheaper.

This favored the rise of a plethora of internet-connected devices.

Smart devices

Smart devices are becoming more present in our lives.

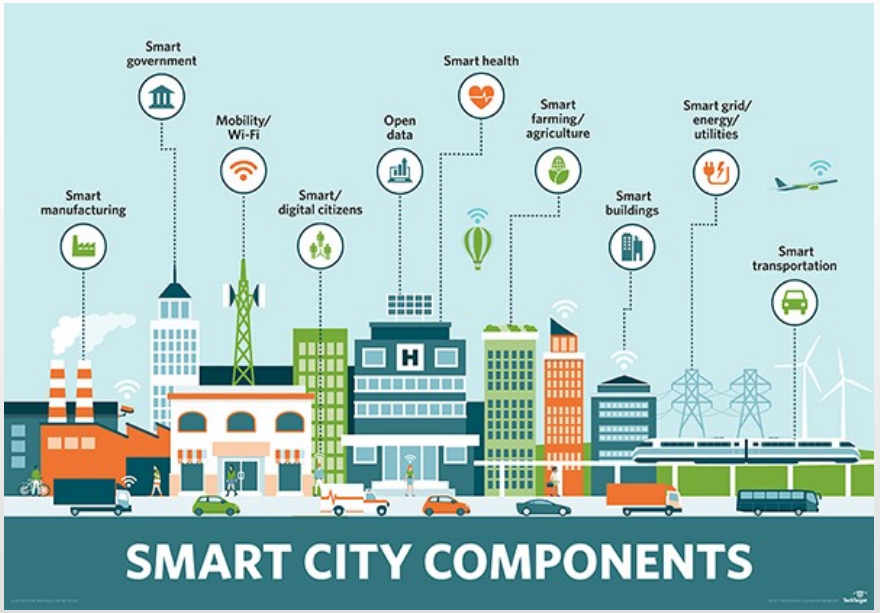
- Smart TVs
- Smart appliances
- Smart home systems

Building and home automation

From enhancing security to reducing energy and maintenance costs, IoT technologies offer a wide range of innovative solutions for monitoring and control of intelligent buildings and smart homes.

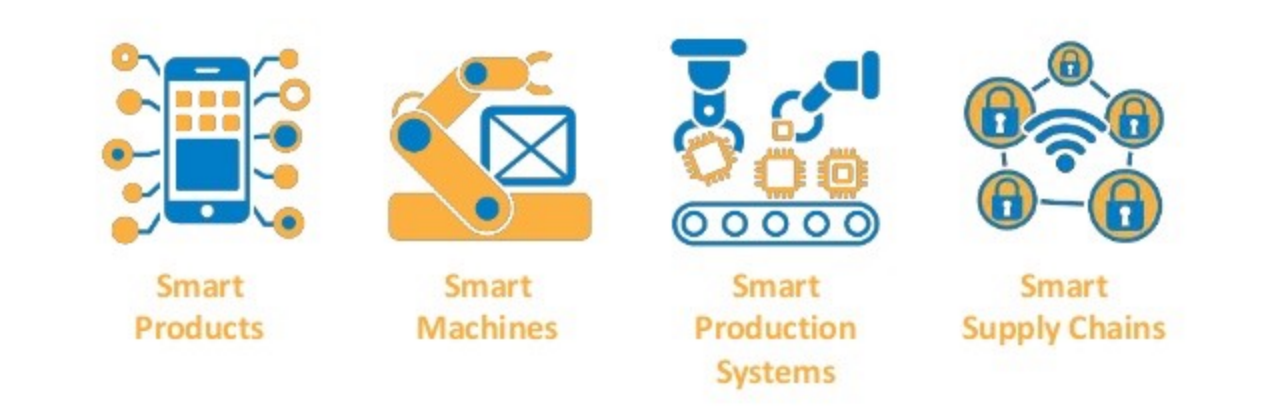
Smart cities

IoT technologies can help reducing energy consumption and maintenance costs in cities. Moreover they can provide useful data.



Smart Manufacturing

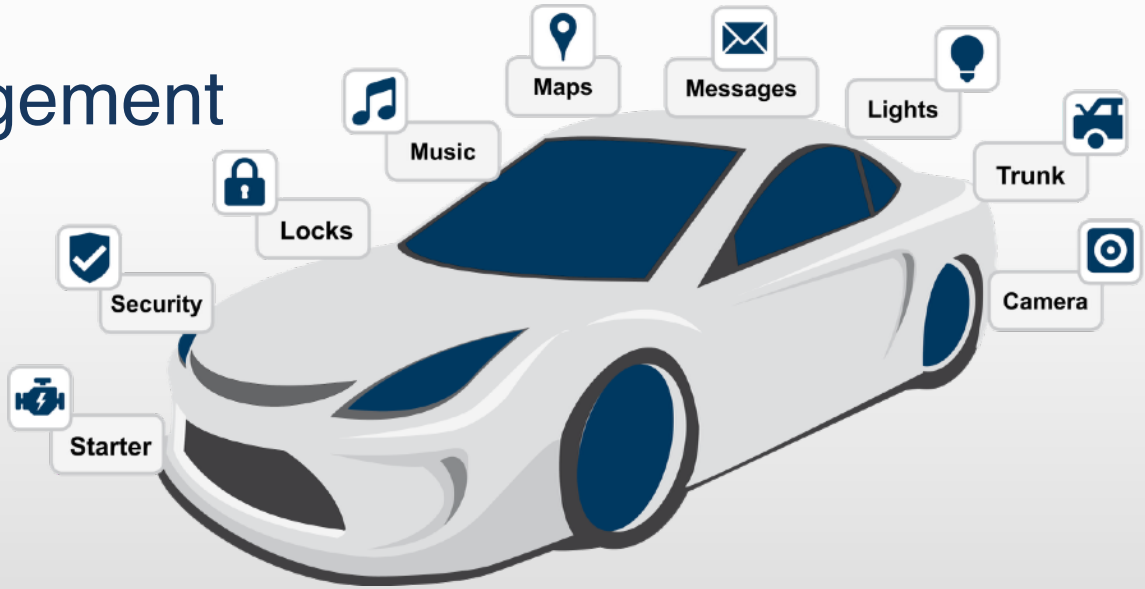
From robotics to communication, from monitoring of the production process to the PLC controller. IoT is deeply used within smart manufacturing.



Automotive

The IoT is breaking fresh ground for car manufacturers by introducing entirely new layers to the traditional concept of a car.

- Engine management
- Infotainment
- EV charging



Wearables

Wearable devices include a highly increasing field, from watches, to weights, from fitness bands to hats. **Mind the energy consumption!**

- Fitness
- Location and tracking
- AR
- Entertainment

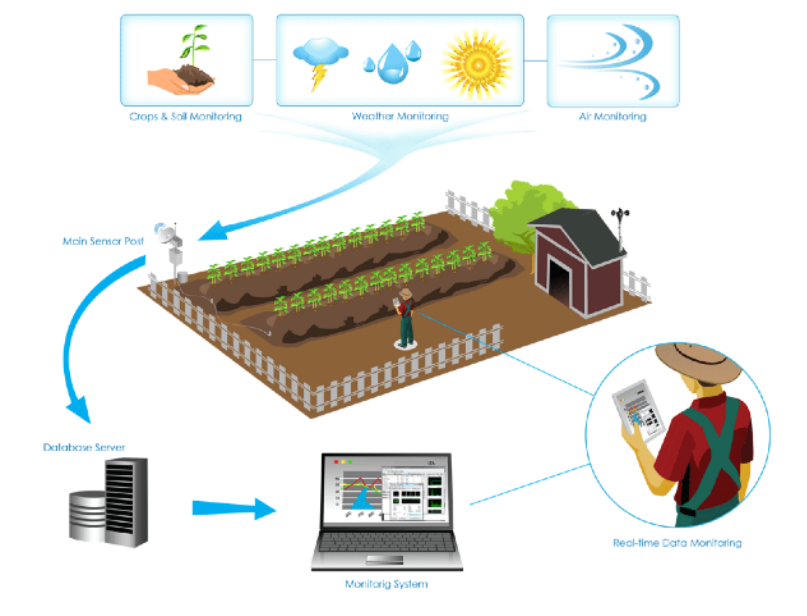
Healthcare

There is currently an ongoing revolution in the field of healthcare thanks to the advancements in IoT solutions and technologies. The eHealth field is now more flourish than ever.

- Telemedicine
- Remote monitoring
- Medicine assumption control

Precision agriculture

Enhancing production and reducing costs are the main use cases in this application field. Also assets monitoring is of central interest.

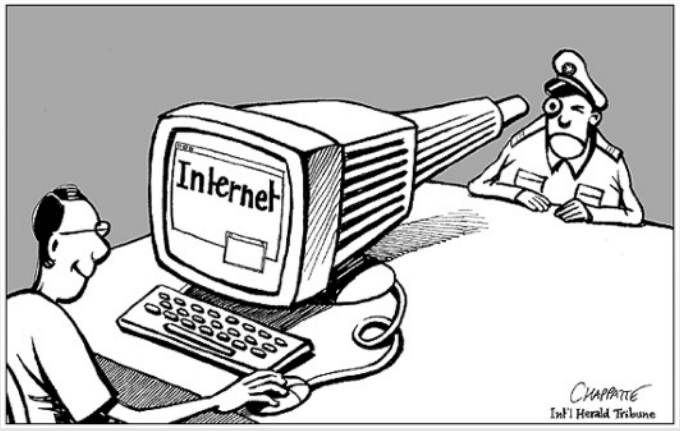


Issues with IoT

- Privacy breaching
- Tampering
- Data flow, from end nodes to servers
- Amount of data produced
- Data management
- Power requirements
- Safety
- Security

Privacy and tampering

Privacy and data tampering are of most interested in the integration of the IoT with the blockchain.



Data flow

The vast majority of smart devices download their date to the cloud (private or public). This generates a huge amount of data flow

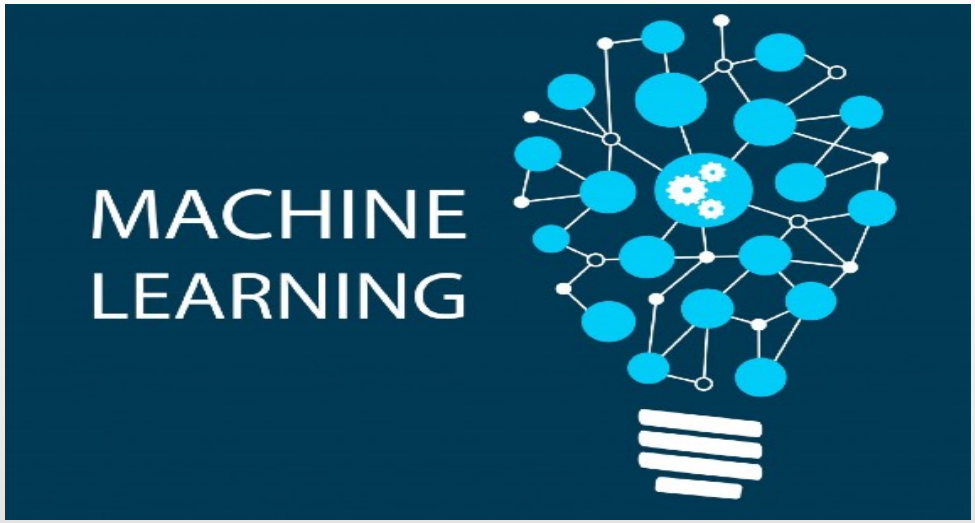
Data domain

As long as the data leaves our perimeter, we must trust someone to be sure that our data remains private.

Machine learning

What is this data used for?

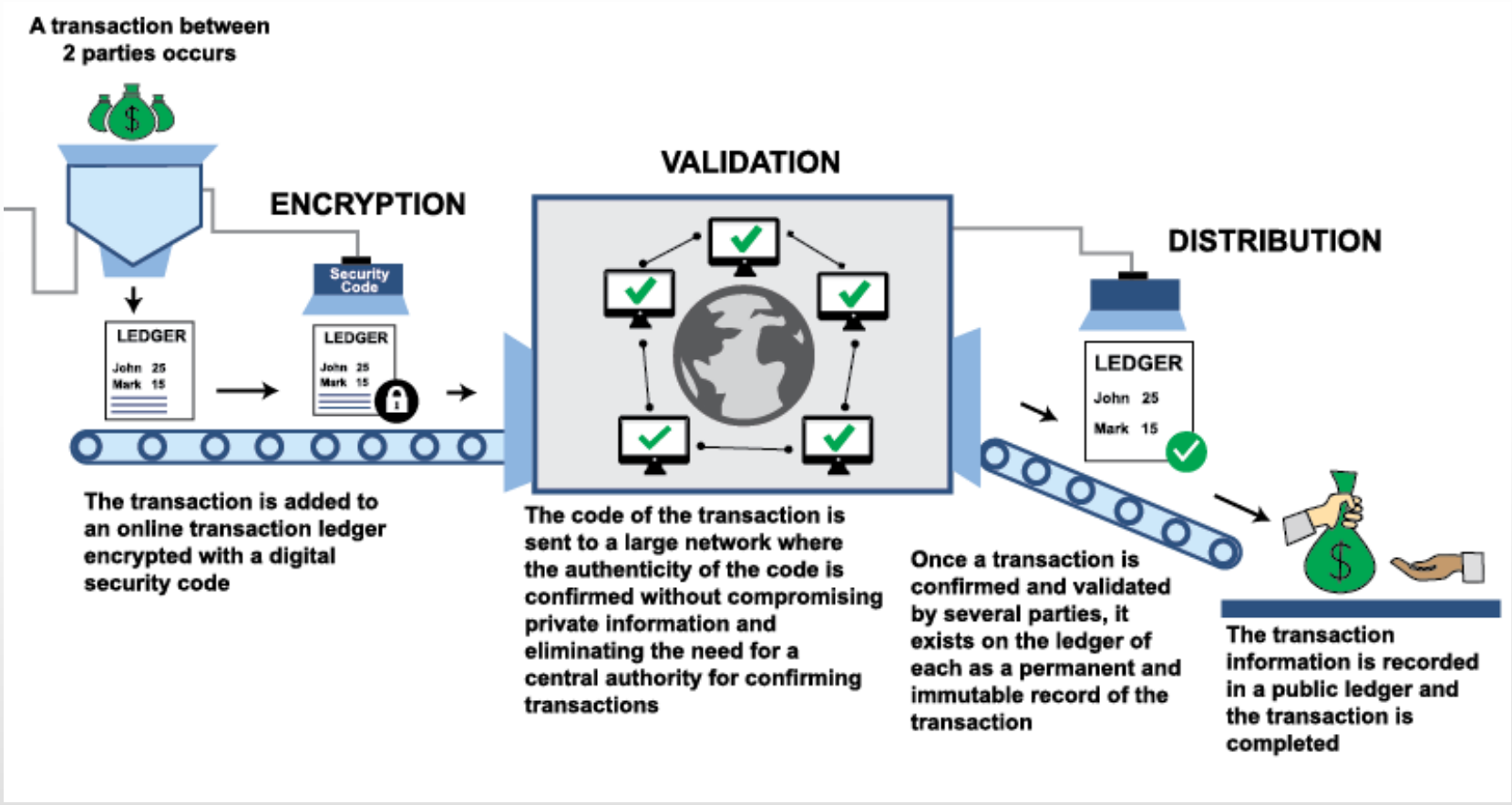
Machine Learning
Profiling
Data Mining
Statistics
…



Blockchain

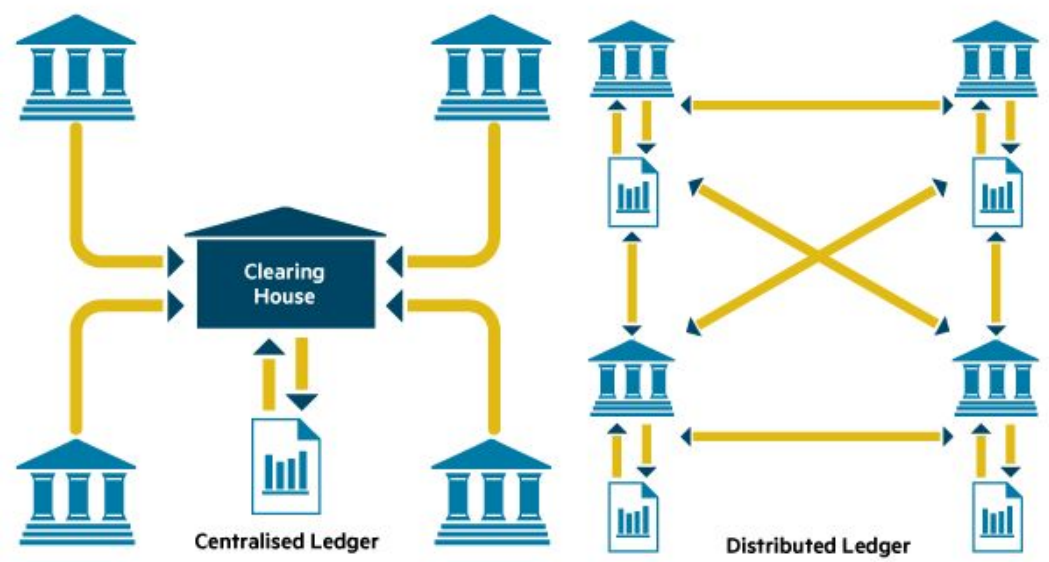
A reliable and very secure database, composed by a multitude of nodes. It is distributed (to all or a vast majority of its users).

How blockchain works



Distributed ledger

The distributed ledger is the core of the blockchain technology. It guarantees that as long as 50% + 1 of all the nodes are well behaving, the database is secure.

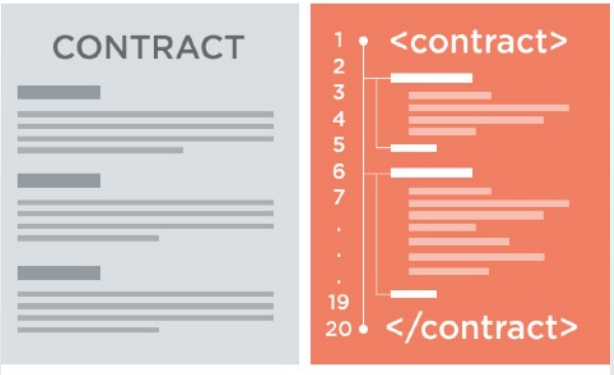


BitCoin and Ethereum

The two most used implementation of the blockchain are bitcoin and ethereum. Each one has specific advantages.

Smart contracts

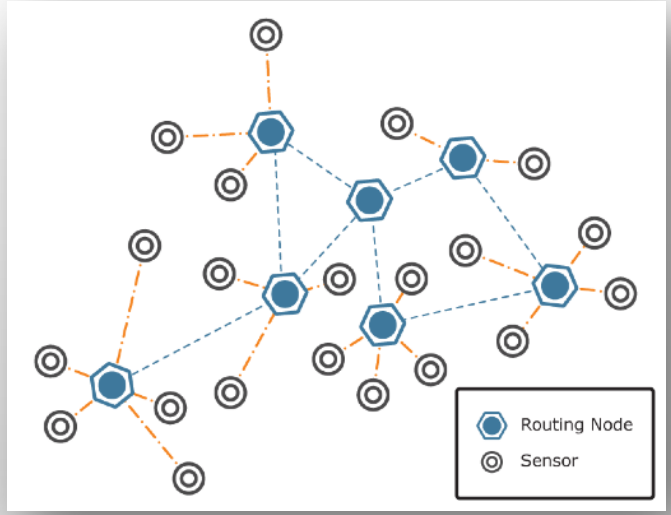
Smart contracts are computer protocols that facilitate, verify, or enforce the negotiation or performance of a contract, or that make a contractual clause unnecessary.



WSN

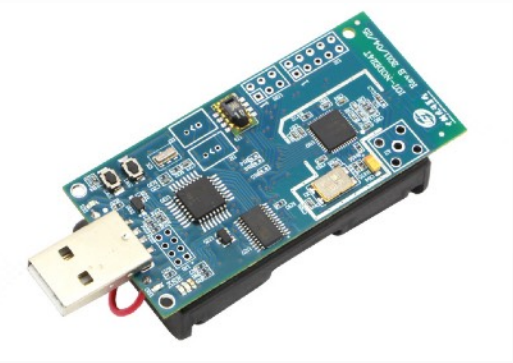
A WSN is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions.

- Limited computational resources
- Sensing
- Limited energy resources
- Autonomous network
- Scalability
- Mobility



Energy and CPU resources

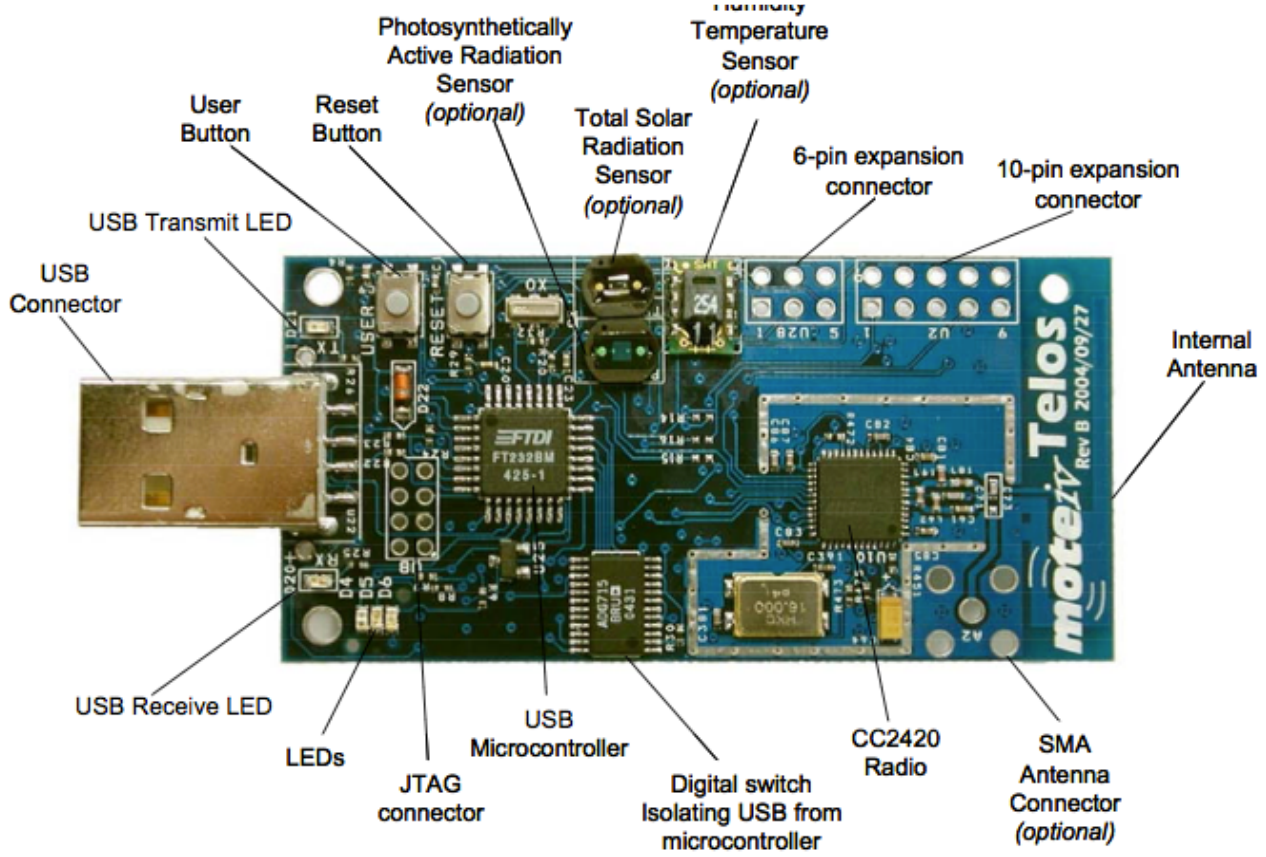
- TelosB
  - 8 MHz TI MSP430 MCU with 10kB RAM
  - 1MB external flash for data logging
  - IEEE 802.15.4 compliant RF transceiver
  - Sensors: light, temperature and humidity



- MagonodeB
  - 16 MHz ATmega256 MCU with 32kB RAM
  - 2 MB external flash for data logging
  - IEEE 802.15.4 compliant RF transceiver
  - Sensors: temperature and humidity

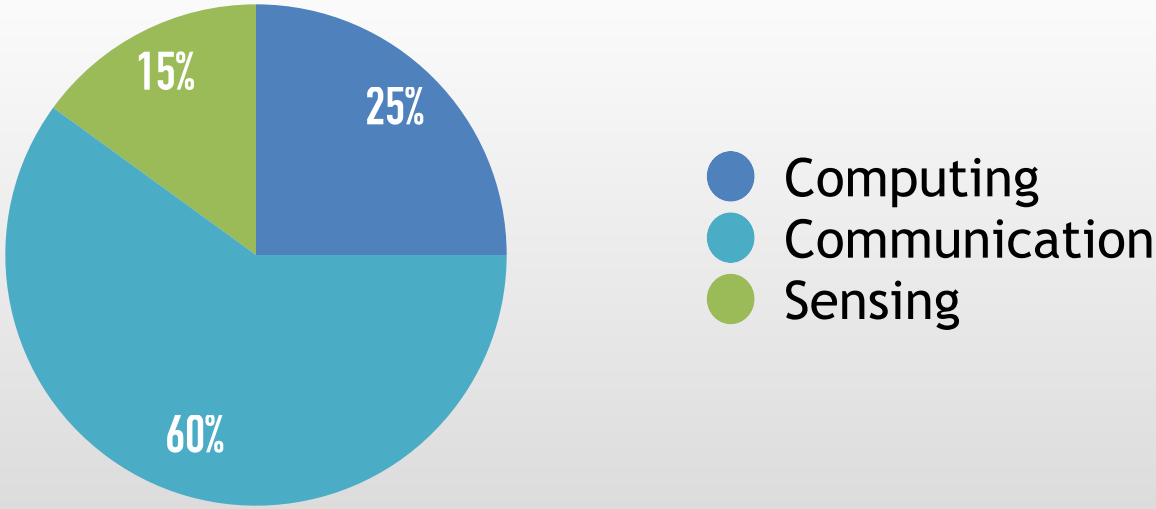
Powered by 2xAA batteries, can last for years!

TelosB - details



Energy consumption

- **Sensing system**: every sensors, actuators connected to the nodes plus the software handler to retrieve the data
- **Computing system**: part of this system are the core functions: memory, microcontroller and operating system
- **Communication system**: the network operations in order to communicate with the other nodes (MAC, ROUTING, SYNC)



Power consumption - sensors

Sensor Type	Power Consumption
Temperature - Humidity	0.5mW - 5mW
Acceleration	3mW
Pressure	10mW - 15mW
Image	150mW
Gas	500mW - 800mW

We can't sample a sensor as often as we want (especially the most power hungry ones). It's important to find the right compromise between accuracy and energy consumption.

Power consumption - radio

Values from MagonodeB.

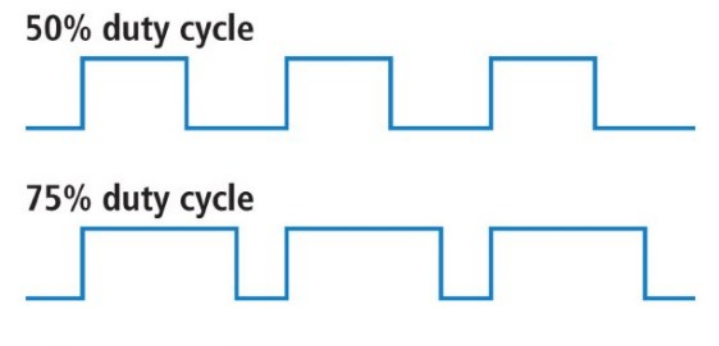
Radio can be in different states.

Radio State	Power Consumption
Sleep	1.1 µA
Idle	4.1 mA
RX	14.5 mA
TX	27.7 mA

- **Transmit and receive**
  - The transceiver is transmitting or receiving a packet
- **Idle**
  - The transceiver is ready to receive but it's not doing anything active. Less energy consuming than TX/RX state.
- **Sleep**
  - In this state the transceiver can't receive any packet because it is in sleep mode. A wake-up time is required to turn on the radio and make it ready. The energy consume is lesser than the other states.

Duty cycle

- ✓ Ready to use with the standard radio
- ✓ State of the art solution with high-level of power energy saving
- ✓ Implemented in most OS
- ✓ Introduces latency in the network
- ✓ Node are not synchronized: long face of idle listening needed

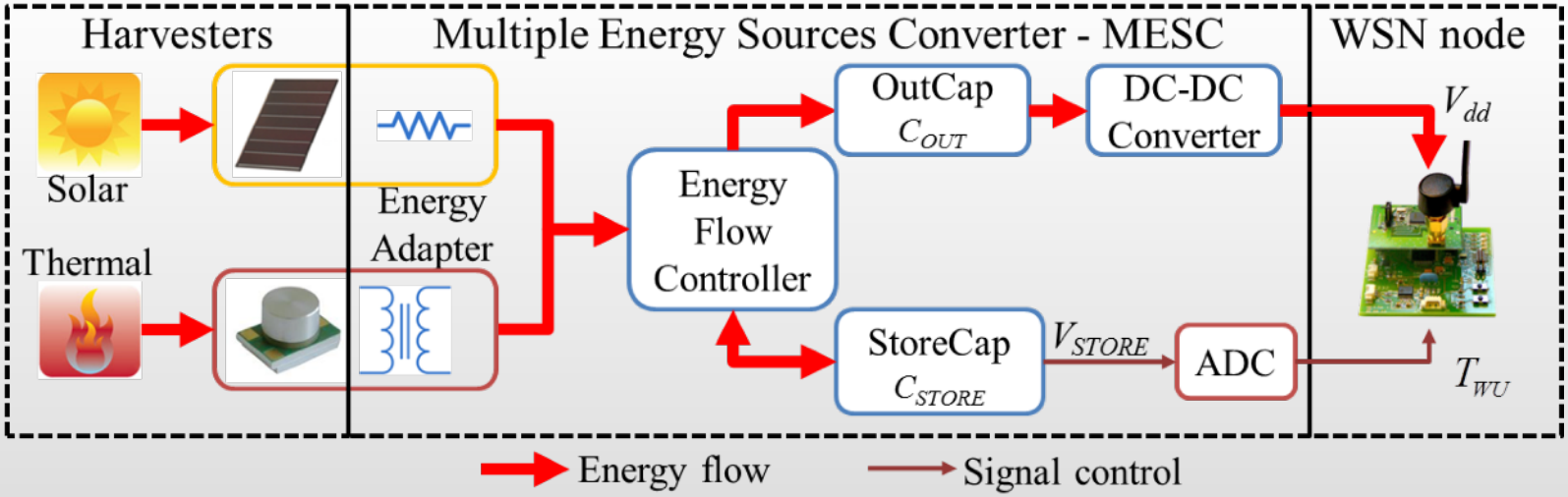


Energy harvesting

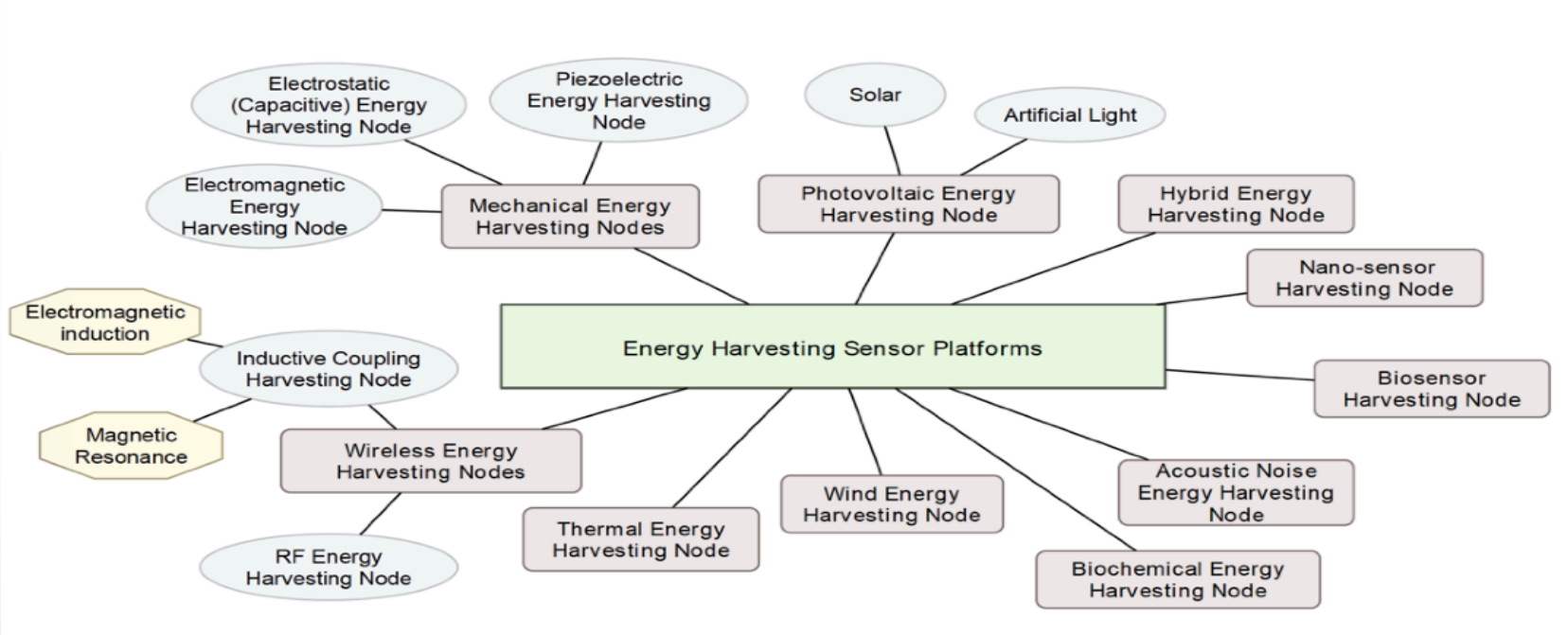
"Energy harvesting is the process by which energy is derived from green external sources, captured and stored for small devices, like those used in wearable electronics and wireless sensor networks."

It's possibile to use one or more external sources to sustain the node life.

The energy is either stored in super capacitors and in secondary rechargeable batteries, or it is immediately used.



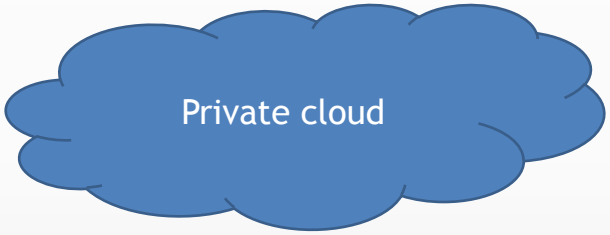
Energy harvesting sources

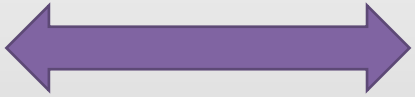


Most of them do not provide enough energy to sustain the node indefinitely. However to most used one is the photovoltaic.

The need of a gateway

Low power devices often cannot access internet directly, thus we should rely on a trusted intermediary, such as a gateway.





For the next lessons

From the third class we will start with practical stuff and the C recap.

Every students should have a laptop otherwise is free to use a computer from the lab (not suggested).

You have to install the **C gnu compiler** and an **editor / IDE for C**.

For windows user is suggested to install Ubuntu from the Windows Store.

For the next lessons (2)

In the middle of the course we will start to develop on **FreeRTOS** with ST Microelectronics hardware.

You have to download:

ATOLLIC TRUESTUDIO

https://atollic.com/truestudio/

Available for **Windows** and **Linux**. **Mac** user can use a virtual machine (**VirtualBox**, **mWare**) or install another operating system on your machine.