Alessandro Tocchi

Tutor: Prof. Mauro D'Arco

XXXIII Cycle - III year presentation

IoT for measurements and measurements for IoT

UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

My background

- I received the MSc degree in Electronic Engineering from University of Naples, “Federico II”.

- I have worked within “Measurements Group” of DII-DIETI and with (INFN) National Institute for Nuclear Physics (Naples)

Internet of Things (IoT)

Internet-of-Things is a neologism, which identifies a set of smart things capable of communicating with each other, exchanging and processing the information collected by them, and operating in unison to achieve one or more goals. The term "network connectivity" is often used to refer to such communication capability. 50 Billion of devices will be connected within 2020

The IoT allows all smart things to evolve with respect to the functions that characterize the individual units, making possible innovative applications that improve the quality of life, unimaginable until a few years ago.

Thanks to the IoT, the concepts of Cyber Physical System and Digital Twin become pervasive, according to which objects acquire a virtual soul with a perfect correspondence between the physical world and the digital world.

Internet of Things (IoT)

The technological development of smart sensors, the rapid spread of smart things and the improvement of the performances of communication protocols enable completely new scenarios, even on a large scale, such as Smart City, Smart Agriculture and Smart Factory, which aim at a digitized and intelligent management of very complex systems such as cities, agri-food production and factories for the production of goods and services.

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Outline

- IoT for measurements
  - Why?
  - Proposal
    - Case_study_I:**Integrated Distributed Sensor Network-Based System to Figure out Safety Protocols for Animals under Risk of Fire**
      - Technical details
    - Case_study_II:**IoT-Oriented Technologies for Measurement Networks of Environmental Radiation**
      - Technical details
- Measurements for IoT
  - Why?
  - Proposal
    - **Estimation of Instantaneous Frequency**
      - Chirplet transform(CT) and Warblet transform (WT)
    - **LoRa Signals Classification**
      - Compressive Sampling

IoT for measurements

- One path of research is the upgrading of some old traditional monitoring systems and industrial activity, in terms of adoption of new technologies but also of new approaches, according to Industry 4.0 main concepts and IoT paradigm.

- Cases of study:
  - **Integrated Distributed Sensor Network-Based System to Figure out Safety Protocols for Animals under Risk of Fire**

  - **IoT-Oriented Technologies for Measurement Networks of Environmental Radiation**

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Case study I

- The problem of early detection of fires in forest areas is widely recognized at both national and international level. **FRAC** Program (*Fire Risk Assessment in Campania Region*) presented in 2018 as a project to support Regional Government

- IoT approach to Distributed sensing systems can offer a suitable measurement solution of the relevant parameters involved in fire risk and, hence, in its early detection

IoT for measurements

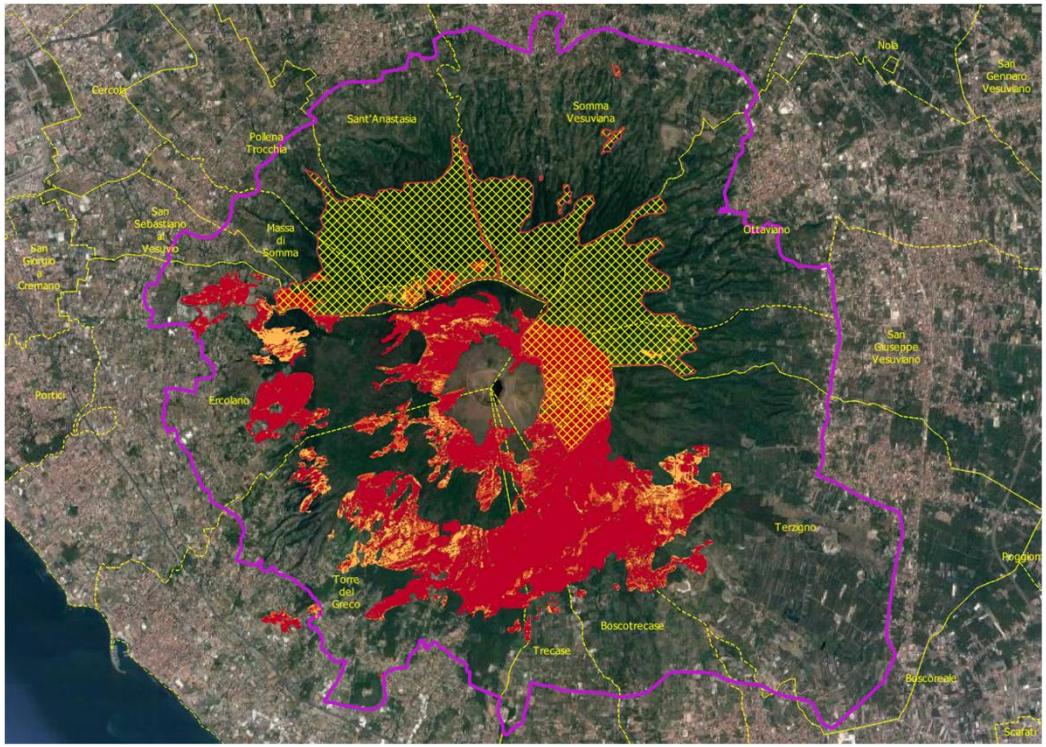
- *IoT conceptual framework in order to support the activities pursued by the FRAC Program*

Monitoring the wooded areas under risk of fire in the so called "Vesuvius' red zone"

Determine the OPtimal Evacuation Route for Animals (OPERA) in case of fire, for each of the animal species living in the red zone

IoT for measurements

Area under surveillance: territories surrounding the Mount Vesuvius



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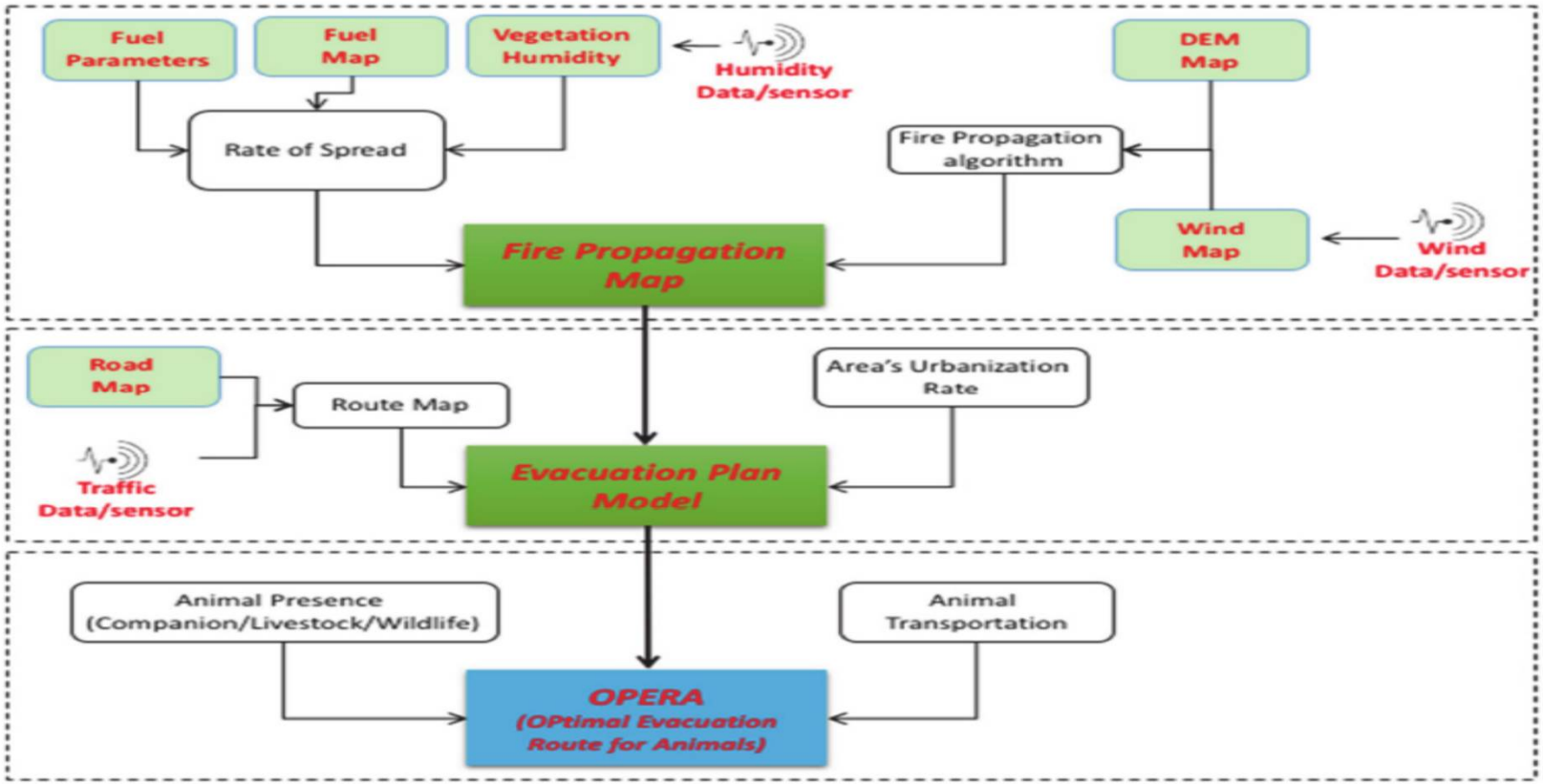
Architecture of the proposed conceptual framework



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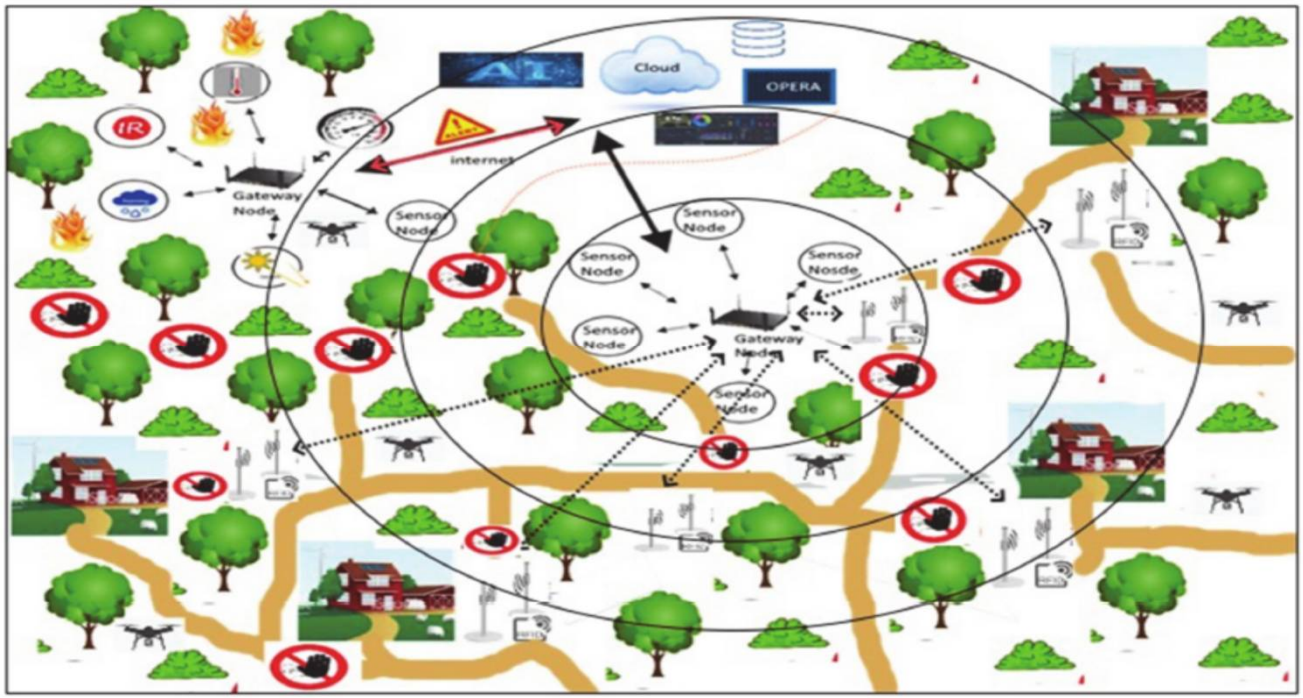
Schematic representation of a possible IoT system solution for early detection and monitoring of fire in forest areas.



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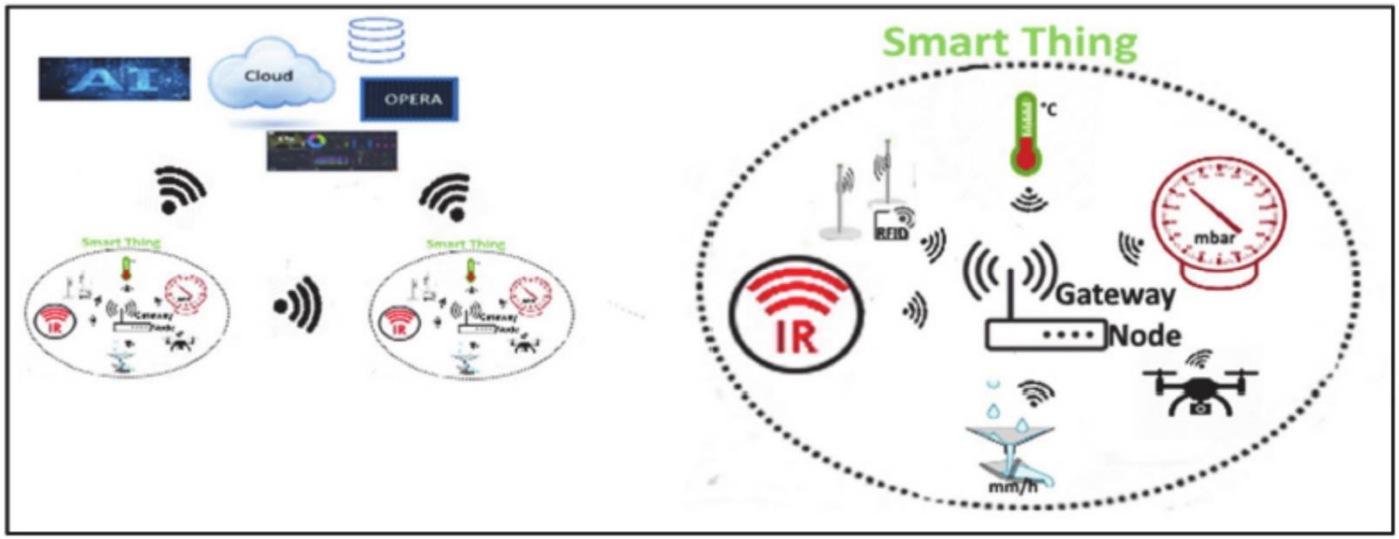
Inter-networking connectivity

Smart devices with sensing and actuating capabilities.



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Challenges

- Not easy maintenance operations
- Severe working conditions
- Green philosophy according to infrastructure
- Cheapness and easy deployment
- Choice of the best fitting and durable energy harvesting system

Uses

- Real time monitoring of fire key parameters
- Real time evacuation monitoring and control
- Simple and effective mean of information exchange

New promising idea

The proposed network is also complemented with a gateway node, operated according to a black box model, that allows post–disaster analysis.

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Second Case of study

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IoT-Oriented Technologies for Measurement Networks of Environmental Radiation

The problem

Measuring and monitoring the concentration of possible nuclear pollutants turns out to be advisable or mandatory in several environmental contexts; the fast availability of an appropriate response plan allows, in fact, the consequences of radiation to be reduced or completely removed.

Fukushima disaster

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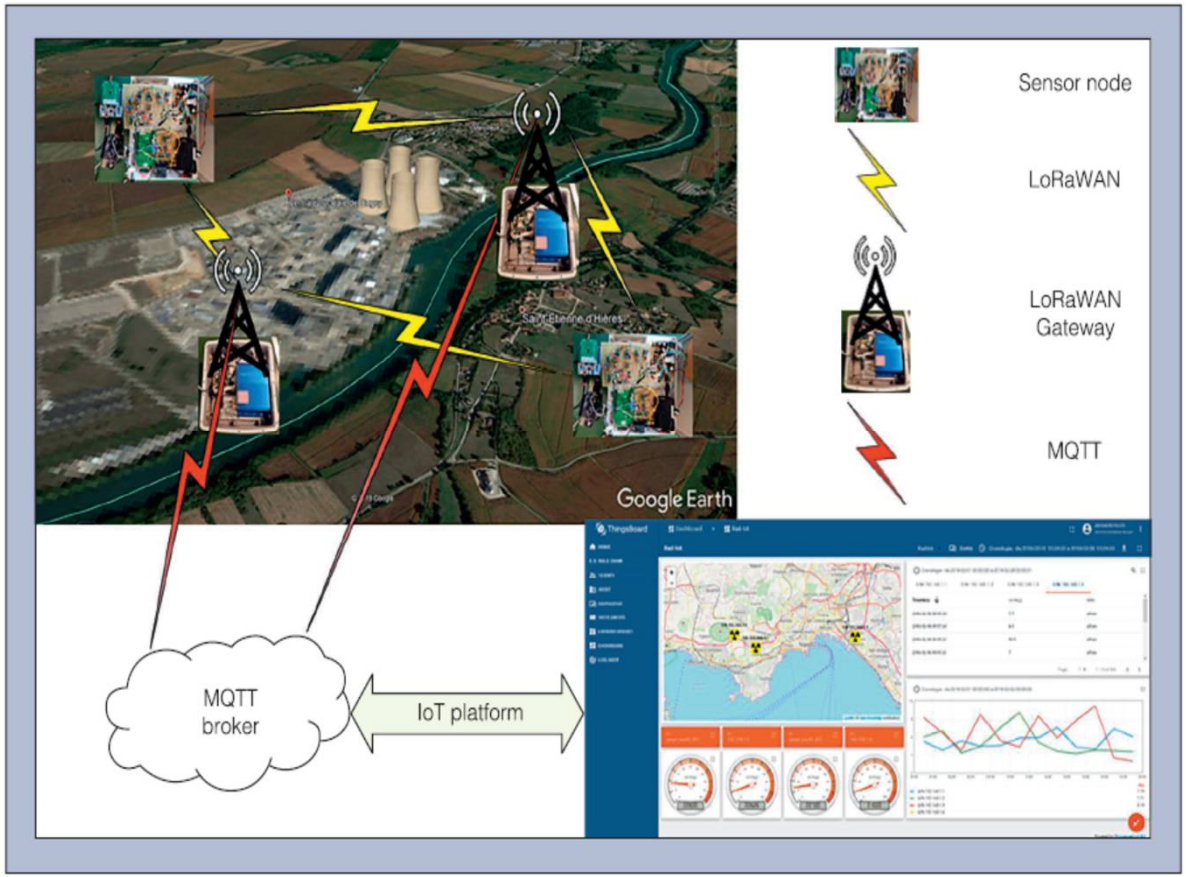
IoT-Oriented Technologies for Measurement Networks of Environmental Radiation

How IoT can help?

Use of Internet of Things (IoT) to realize an integrated platform based on a cost-effective wireless sensor network (WSN) for monitoring environmental radioactive pollution.

Principle scheme of the proposed IoT platform for radiation monitoring.



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Regarding the communication layer:

Low power consumption and wide area coverage (*LPWAN*).

15 km in open space and about two km in an urban environment

The local sensor network has a star topology, with individual nodes that can register themselves and communicate with one or more LoRaWAN Gateways, while remaining independent from one another.

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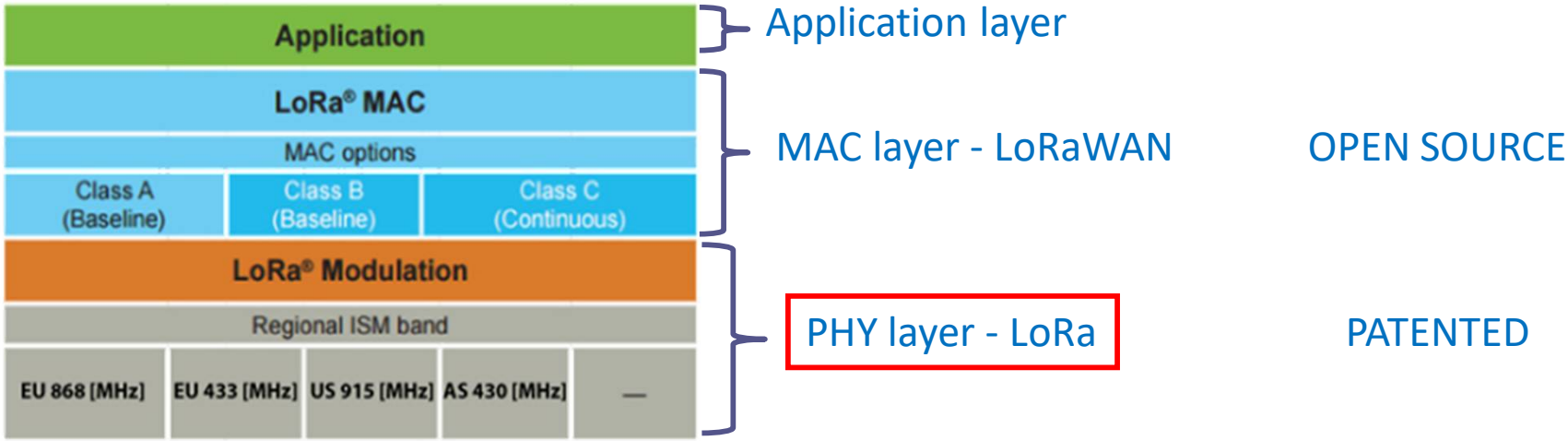
LoRa and LoRaWAN



LoRaWAN is a MAC layer generally but not exclusively based on LoRa modulation.

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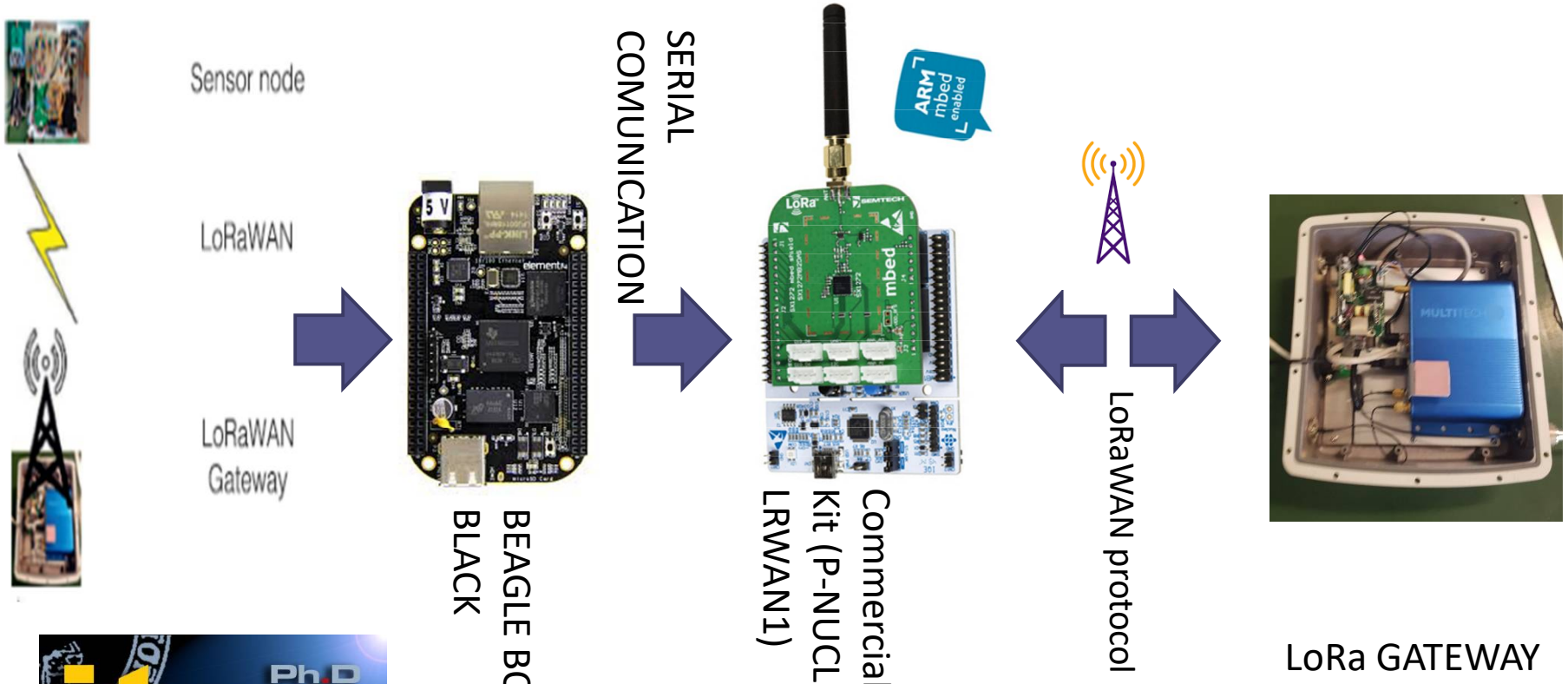
LoRaWAN comunication module and LoRaWAN Gateway



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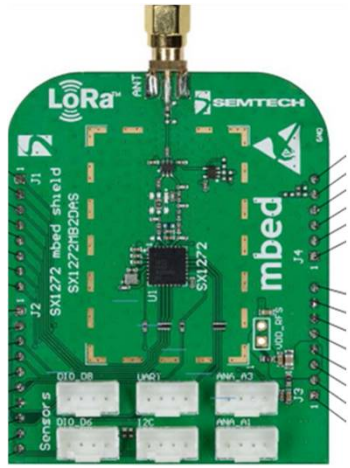
Serial LoRa modem

The LoRa communication modules will be realized by means of devices produced by ST Microelectronics, that is the NUCLEO-F401RE MCU Board equipped with the Semtech SX1272 LoRa shield.



SX1272MB2DAS

SX1272 Features

- 157 dB maximum link budget
- +20 dBm - 100 mW constant RF output vs. V supply
- +14 dBm high efficiency PA
- Programmable bit rate up to 300 kbps
- High sensitivity: down to -137 dBm
- Bullet-proof front end: IIP3 = -12.5 dBm
- 89 dB blocking immunity
- Low RX current of 10 mA, 200 nA register retention
- Fully integrated synthesizer with a resolution of 61 Hz
- FSK, GFSK, MSK, GMSK, LORA and OOK modulations
- Built-in bit synchronizer for clock recovery
- Sync word recognition
- Preamble detection
- 127 dB+ Dynamic Range RSSI
- Automatic RF Sense with ultra-fast AFC
- Packet engine up to 64 bytes with CRC
- Built-in temperature sensor and Low Battery indicator

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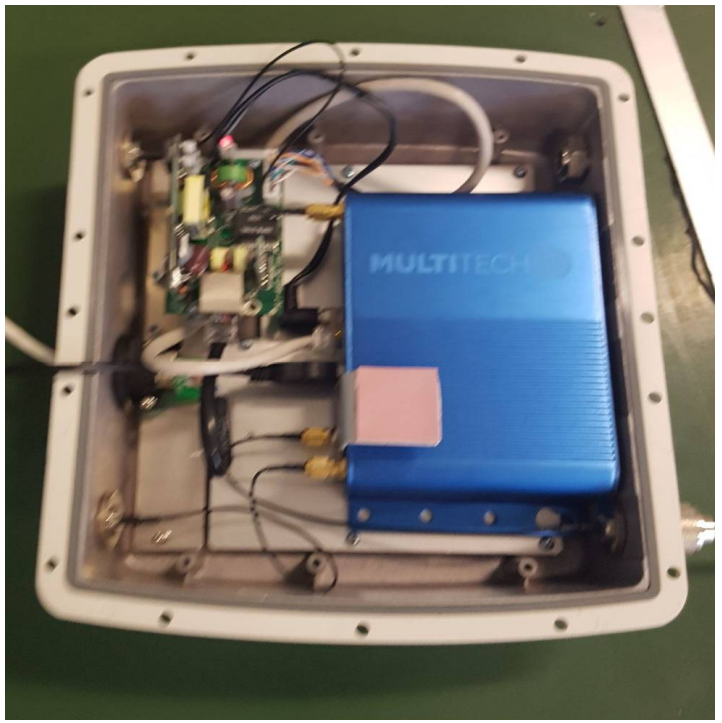
LoRa GATEWAY

For long-range communication, you want to adopt MultiConnect® ConduitTM gateway from MultiTech; The Gateway exchanges data with network nodes via the LoRaWAN protocol and communicates with the open source IoT platform via its mobile or Ethernet connection.

Conduit® is a programmable gateway that uses an open Linux development environment



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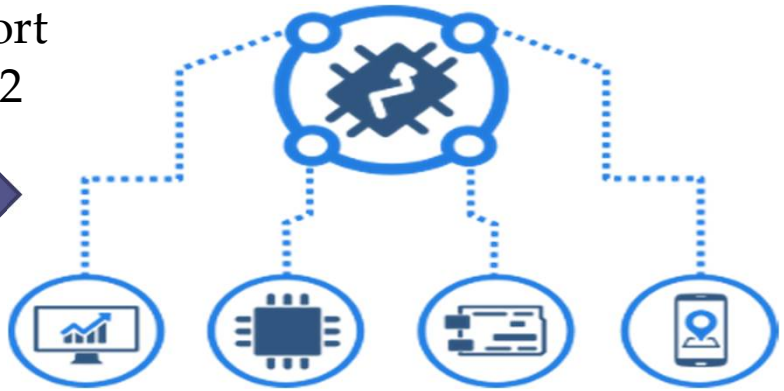
Message Queue
Telemetry Transport
ISO/IEC PRF 20922

IoT Platform THINGSBOARD



MQTT is a lightweight application protocol that allows devices to communicate effectively and asynchronously and is designed for TCP/IP networks..

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MQTT how it works

The broker is a messaging server that matches interests between subscribers and publishers with subsequent messages dispatching. In other words, a publisher sends messages on a specific topic to the broker. A subscriber (i.e., a consumer who subscribes to messages posted on the same topic) receives them from the broker when available

This communication model greatly simplifies the protocol and turns out to be one of the main application layer protocols for IoT applications.

MQTT Protocol is easy of use. It is essential when lower battery usage are on the first place for future solutions.

MQTT has a very short message header and the smallest packet message size of 2 bytes.

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MQTT how it works

MQTT Protocol ensures high delivery guarantees.

There are 3 levels of Quality of Services:

- at most once: guarantees a best effort delivery.

- at least once: guaranteed that a message will be delivered at least once. But the message can also be delivered more than once.

- exactly once: guarantees that each message is received only once by the counterpart

MQTT also provides users with options of Last will & Testament and Retained messages. The first means that in case of unexpected disconnection of a client all subscribed clients will get a message from a broker. Retained message means that a newly subscribed client will get an immediate status update.

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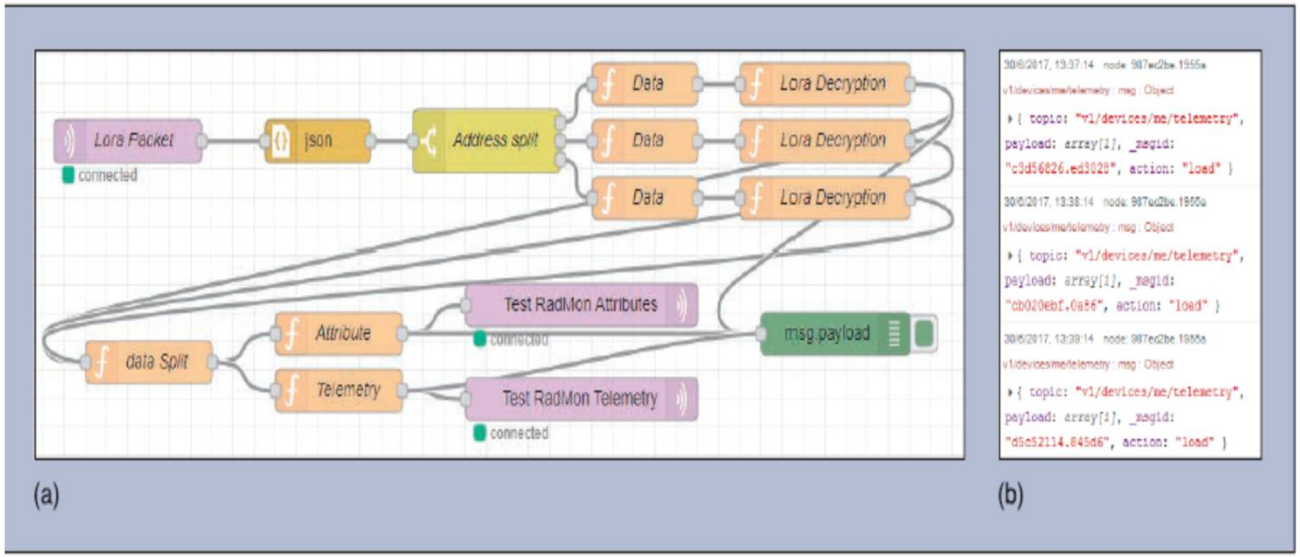
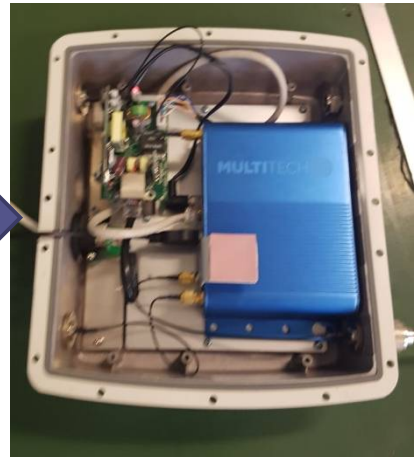


(a) Node-red flow implemented in the LoRaWAN Gateway for testing the IoT monitoring platform. (b) Example of messages sent to the dashboard of final IoT platform.

Node-Red



LoRa GATEWAY

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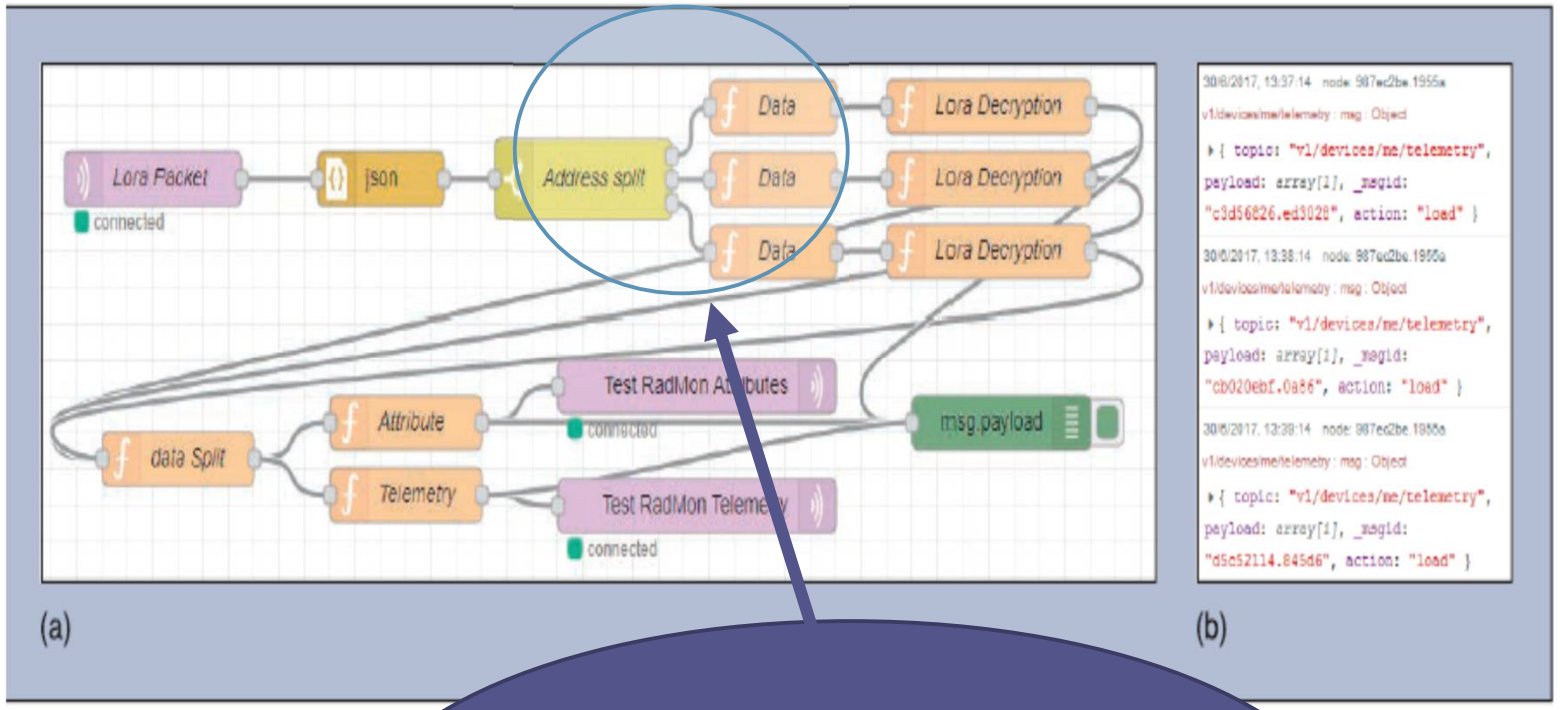

data are differently decrypted according to the specific LoRa address of the sensor node

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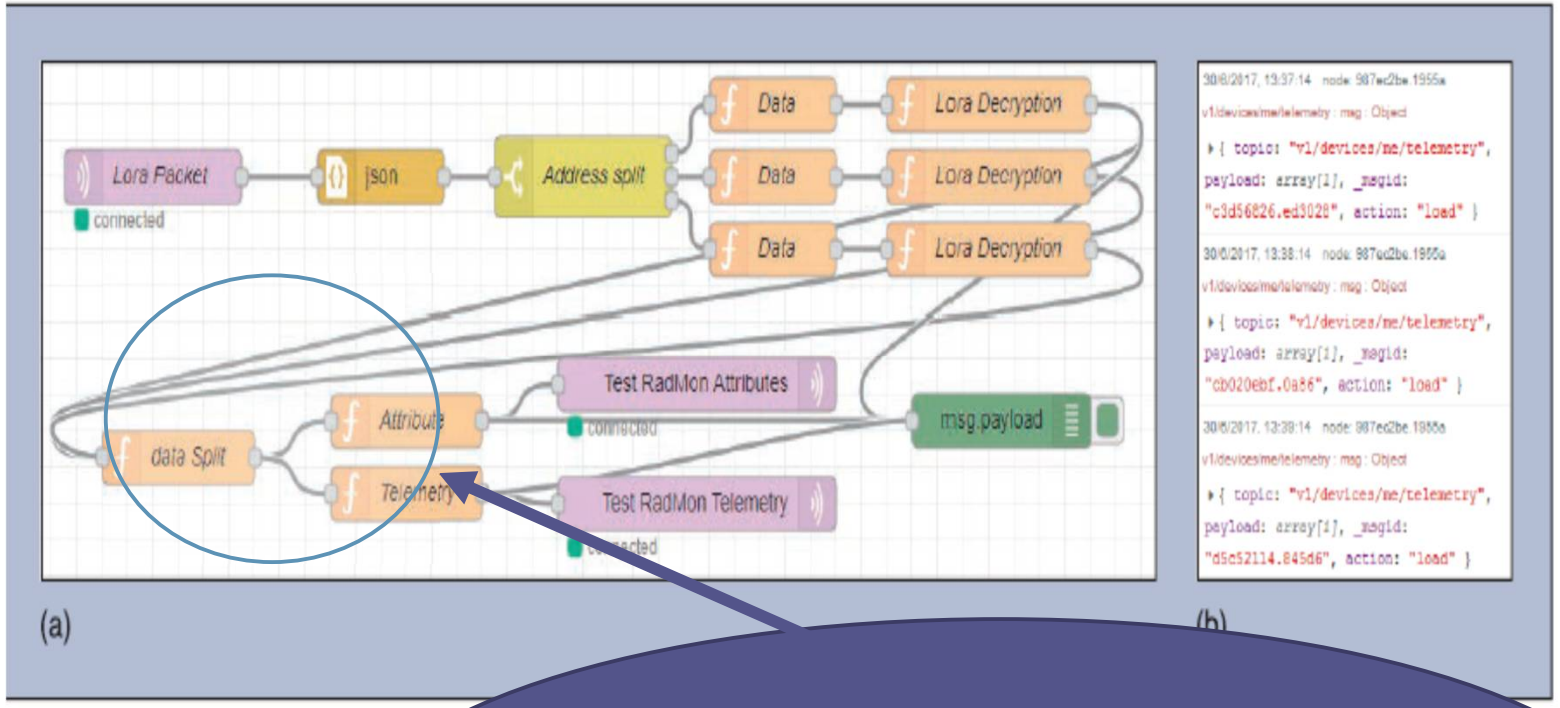

Each message contains both general information (referred to as "Attributes" and including node ID and operating status) and measurement results (referred to as "Telemetry").

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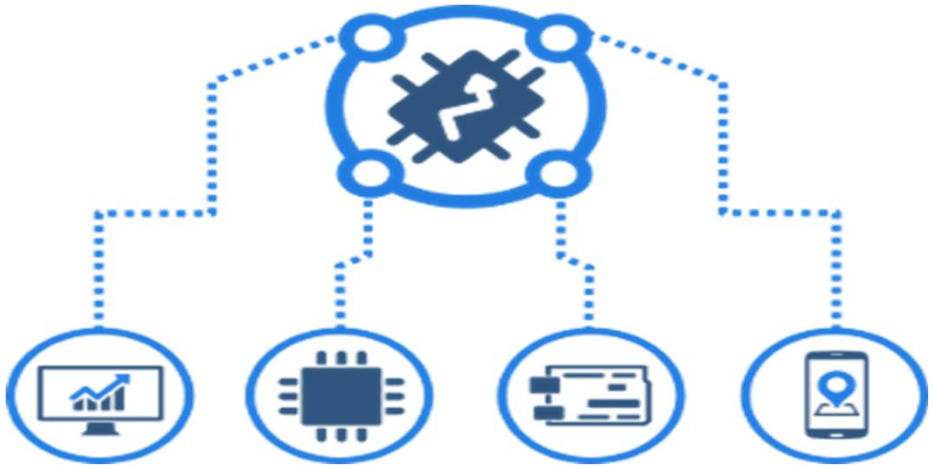
IoT Platform THINGSBOARD



Real-Time IoT Dashboards
Fleet Tracking
Telemetry Data Collection
Data Visualization
Horizontal scalability
IoT Rule Engine
Fault-tolerance
Security

Asset Management
Alarms Management
100% Open-source
Microservices Monolithic
SQL, NoSQL and Hybrid database

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The open-source IoT platform, namely ThingsBoard, was adopted to store and visualize monitoring data.

This way, it is possible to:

- **view the node status (active, inactive, or alarmed)**
- **view historical trends of measurements carried out by the active sensors**
- **update name and physical location of nodes**
- **update acquisition parameters (e.g., characteristic times, storage frequency),**
- **update calibration parameters (e.g., conversion factors, threshold limits).**

Example of dashboard exploited in ThingsBoard for radiation monitoring

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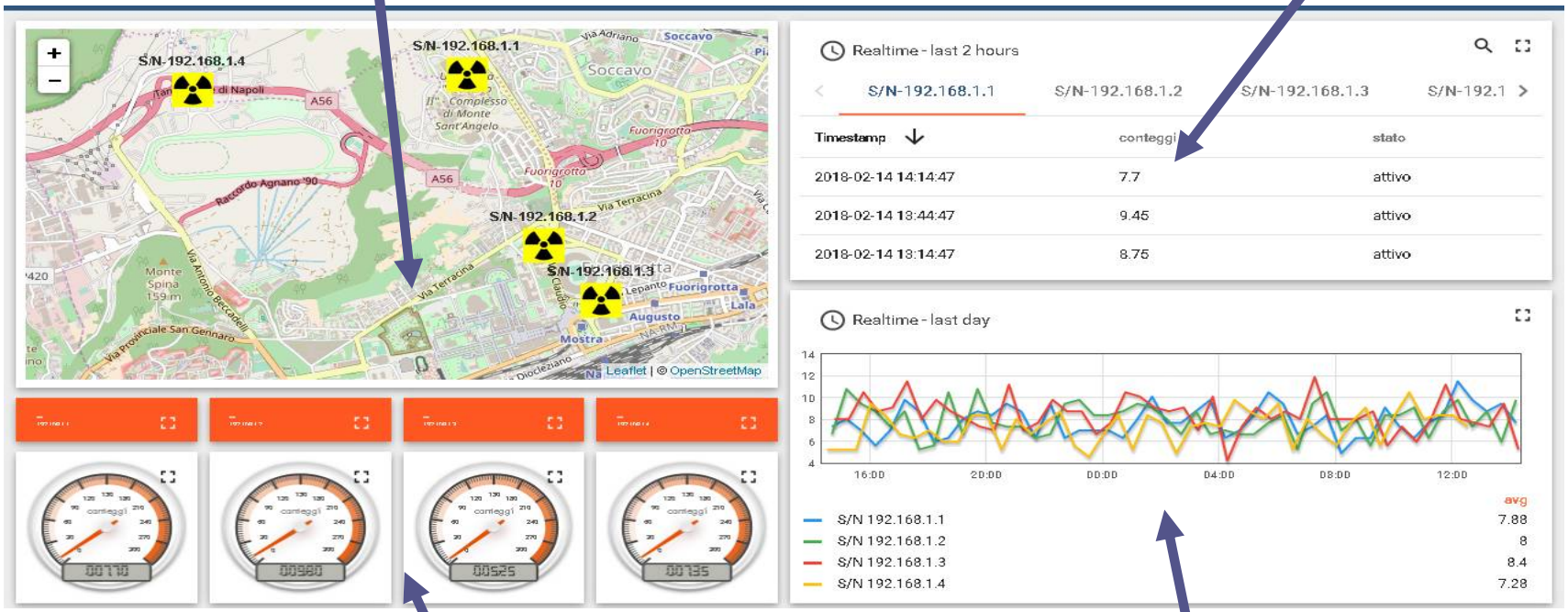
Map of sensors

Main feature
Sensor Log



Analog indicators

Diagrams that represents the time evolution

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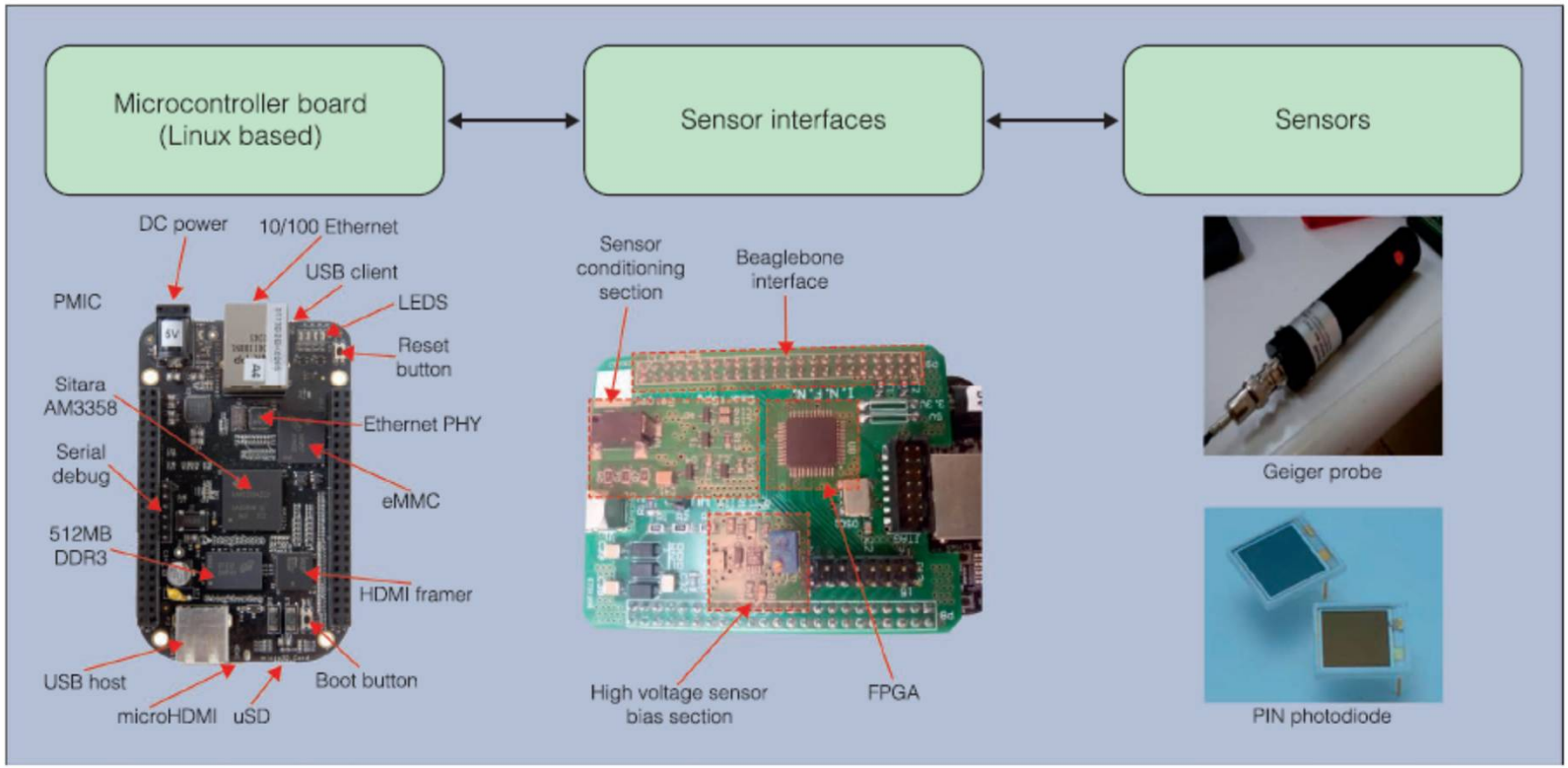
Each sensor node consists of three modules:



Hardware architecture of Geiger sensor node.

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Geiger

SS340	
Operating voltage	350 V
Measurement range	0.1 µSv/hr - 2 mSv/hr
Plateau length	200 V minimum
Dead time	110 µs
Temperature range	-10°C to +50°C
Gamma sensitivity	Tipically 2 cps/µSv/hr
Energy sensitivity	H*(10) for 45 keV - 1.5 MeV
Housing connector	MHV
Dimensions	Ø25 x 135 mm
Active Area	40 mm

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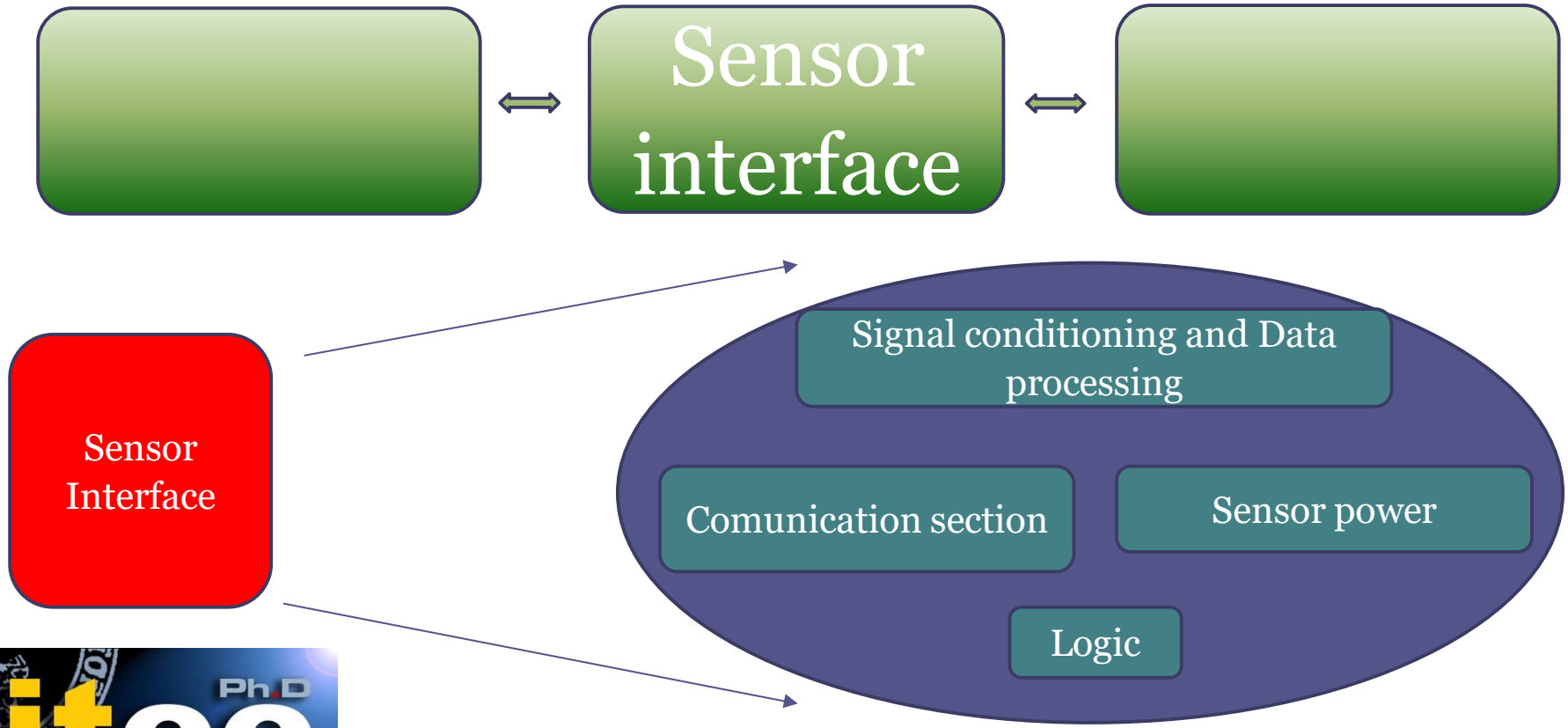
Sensor interface



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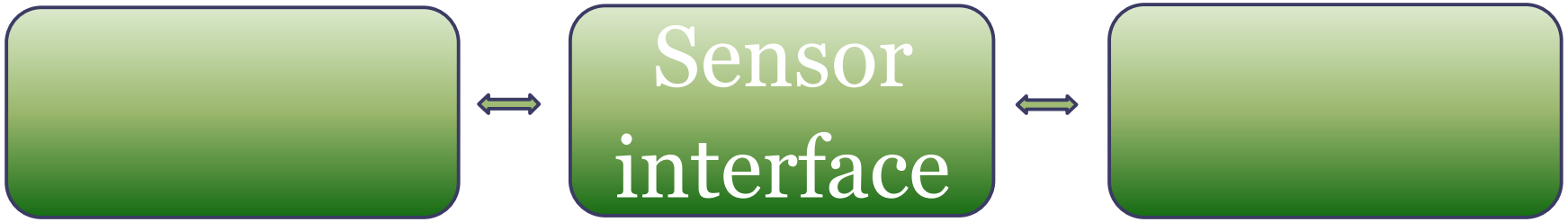
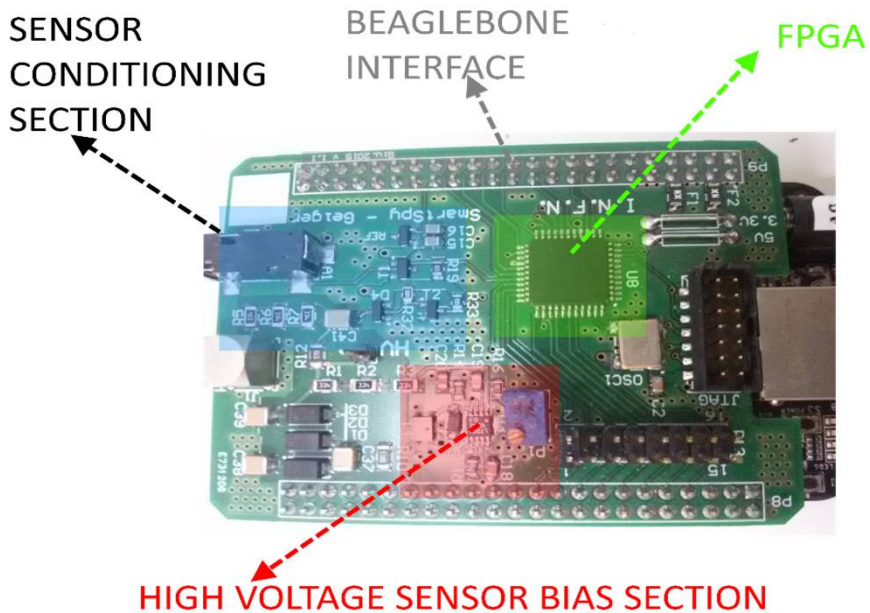
Geiger sensor interface





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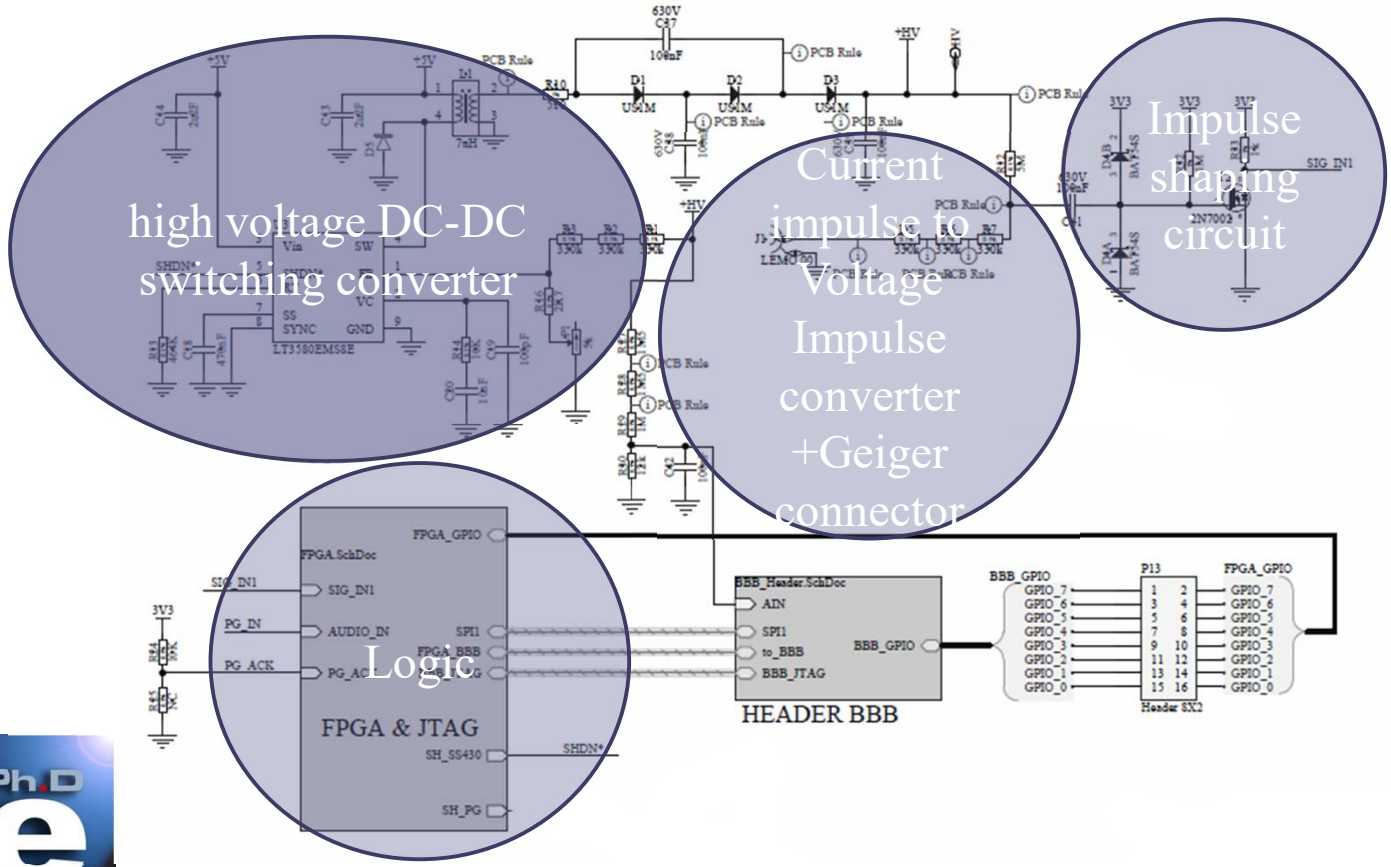
Geiger sensor interface



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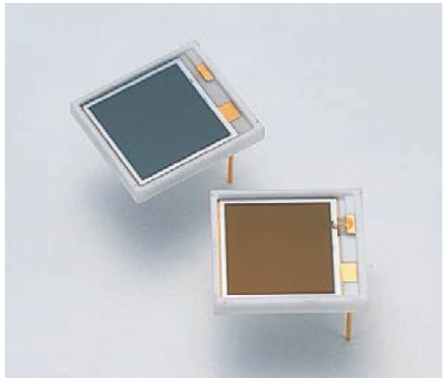
Alpha Spectrometer



Hamamatsu S3590 Si PIN photodiode

S3590-09	
Spectral response range λ (nm)	340 to 1100
Active area (mm)	10 × 10
Depletion layer thickness (mm)	0.3
Reverse voltage VRmax (V)	100
Temperature range (°C)	-20 to +60
Dark current ID VR=70 V (nA)	6
Terminal capacitance Ct f=1MHz VR=70 V (pF)	40
Window material	Unsealed
Dimensions (mm)	14.5 x 12.7

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Gamma Spectrometer

ORTEC-276 Preamplifier	
Integral Nonlinearity	<±0.02%, 0 to +10 V.
Temperature Instability	<±0.005%/°C, 0 to 50°C.
Output Rise Time	<100 ns for test input or fast scintillator.
Output Fall Time	Time constant of 50 µs.
Output Noise	<50 µV rms with ORTEC Model 572 Amplifier and time constant of 1 µs.
Conversion Gain	Nominally 5 µV/eV with 2- by 2-in. NaI(Tl) crystal and PMT gain of 106;
Saturation Level	+10 V into an open circuit; +5 V into 93-Ω load.
Voltage Divider	Resistor-divider connected to 10-stage PMT base. Total resistance 1.49 MΩ, resulting in bleeder current of 0.6 mA with typical high voltage of 1 kV.
Integral Nonlinearity	<±0.02%, 0 to +10 V.

NaI(Tl) scintillation radiation detector (namely, 905-3 by Ortec, 2- x 2-". crystal

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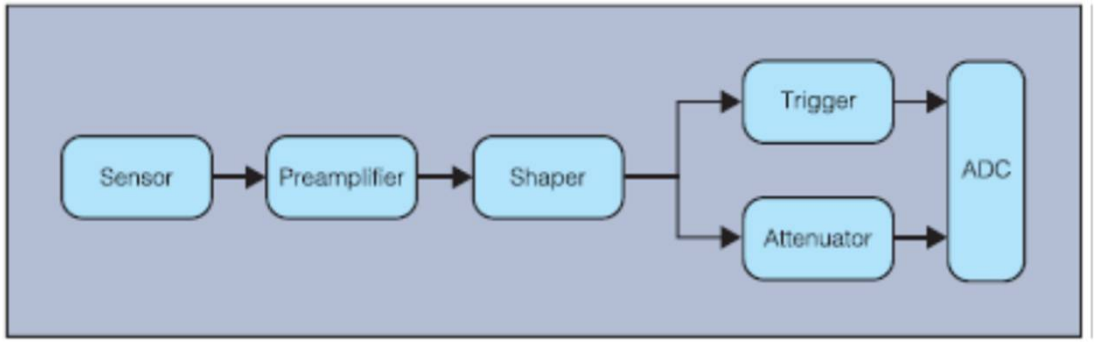
IoT-Oriented Technologies for Measurement Networks of Environmental Radiation

The sensor interface is mandated to carry out the radiation measurements; in particular, spectrometric measurements are provided as an energy level histogram of particles or rays impinging on the detector surface. The sensor interface is mainly composed by a sensor conditioning section, mandated to convert the current pulses provided by the sensor into a voltage signals compliant with the successive microcontroller ADC module.



Block diagram of the conditioning section for spectrometer nodes

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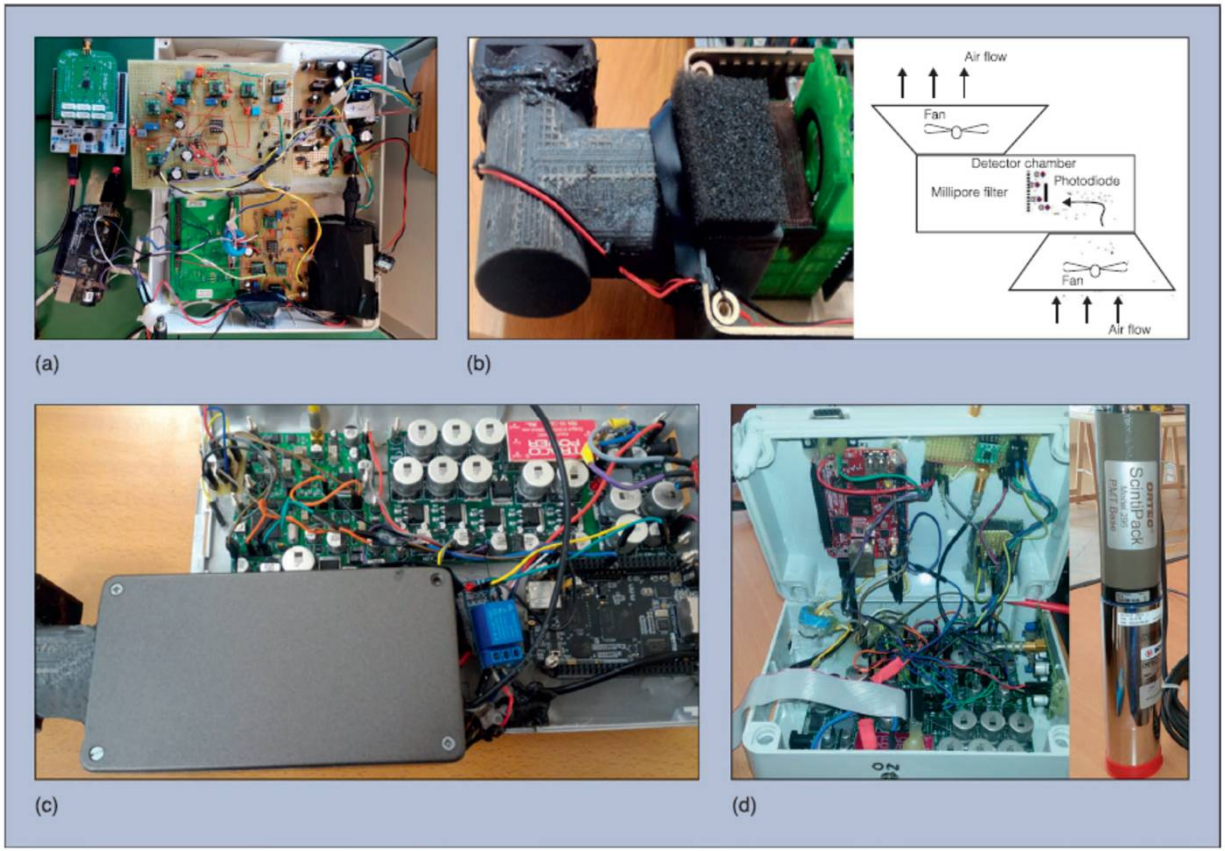

Implemented sensor nodes for radiation monitoring. (a) Sensor node communication module; (b) Air pumping system realized for sensor nodes based on a silicon detector; (c) Sensor node based on a silicon detector; (d) Sensor node based on a scintillation detector.

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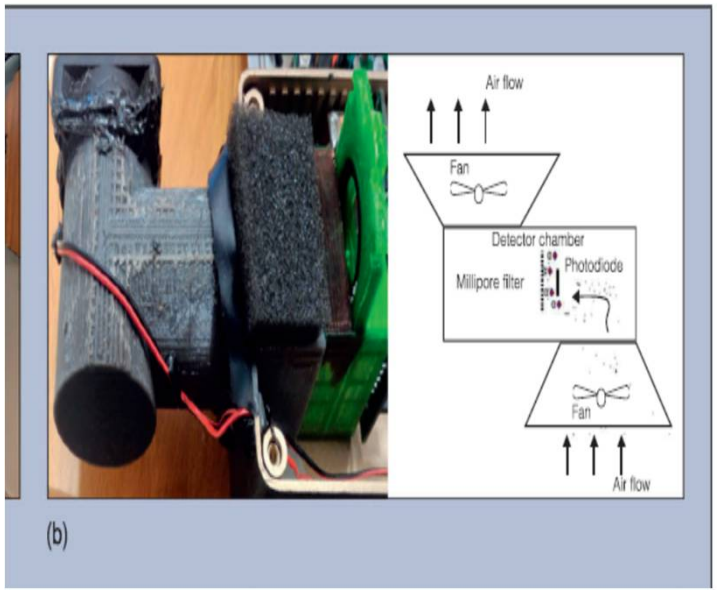

With specific regard to the case of alpha particles, the node exploiting the silicon sensor is equipped with a flushing system able to concentrate atmospheric particulate on a Millipore filter positioned at 1 cm in front of the detector, as shown in Fig b. This way, the energy loss by the particles along the path through the air is minimized, thus enhancing the node sensitivity. One critical issue is the light sensitivity of the silicon photodiode; the drawback has been overcome thanks to the geometry of the air pumping system implemented in 3Dprint technology.

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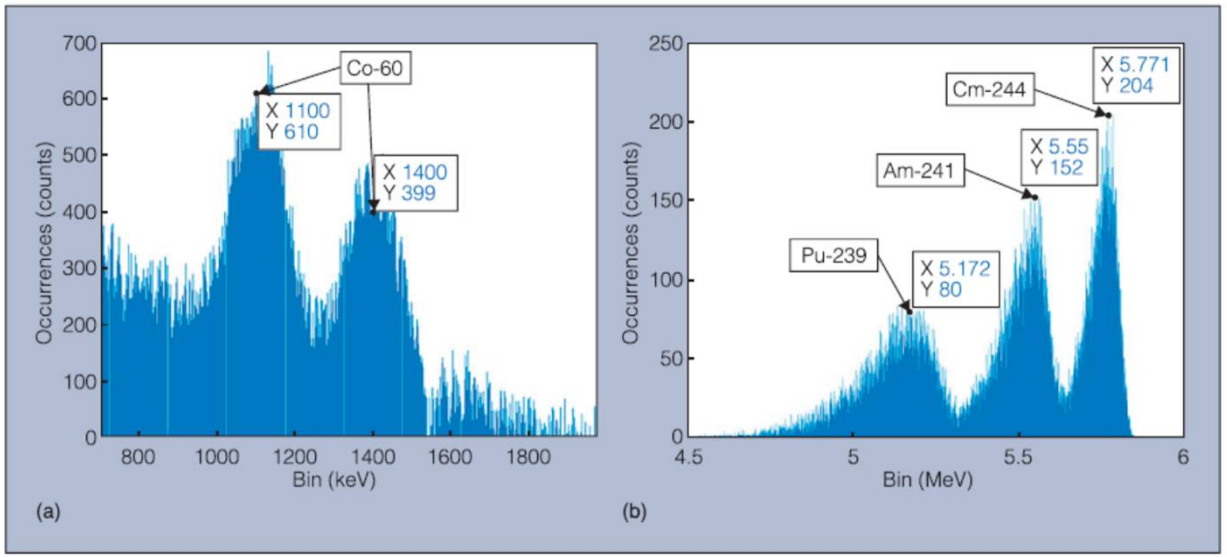
IoT-Oriented Technologies for Measurement Networks of Environmental Radiation

Energy spectra obtained by the realized wireless sensors for reference (a) gamma and (b) alpha ray sources.



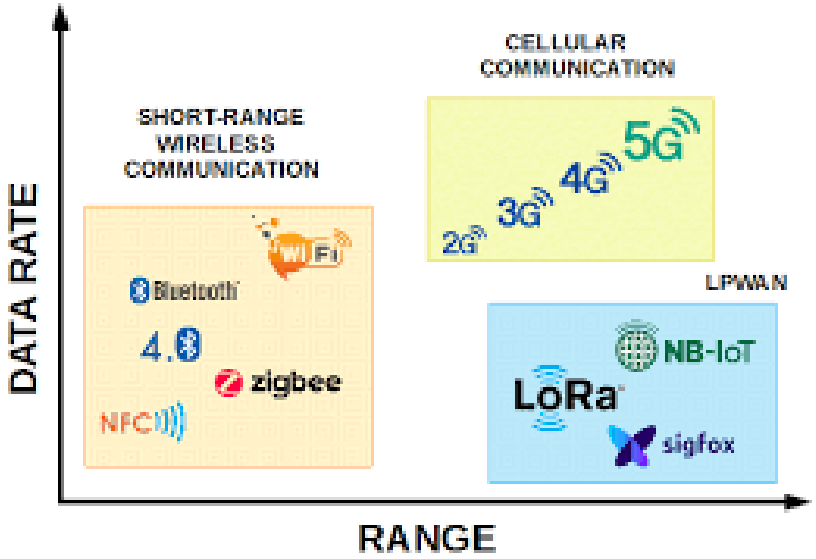
Measurements for IoT

The other path of my research is finding methods for the estimation of parameters that can be useful in order to analyse an IoT system, and new approaches that allow optimization of hardware resources.

Measurements for IoT

Problem statement

Internet of Things paradigm requires even more reliable and long-distance communication systems.



LoRa technology, based on an efficient Chirp Spread Spectrum modulation can grant both long range distance and low energy consumption in the communication link.

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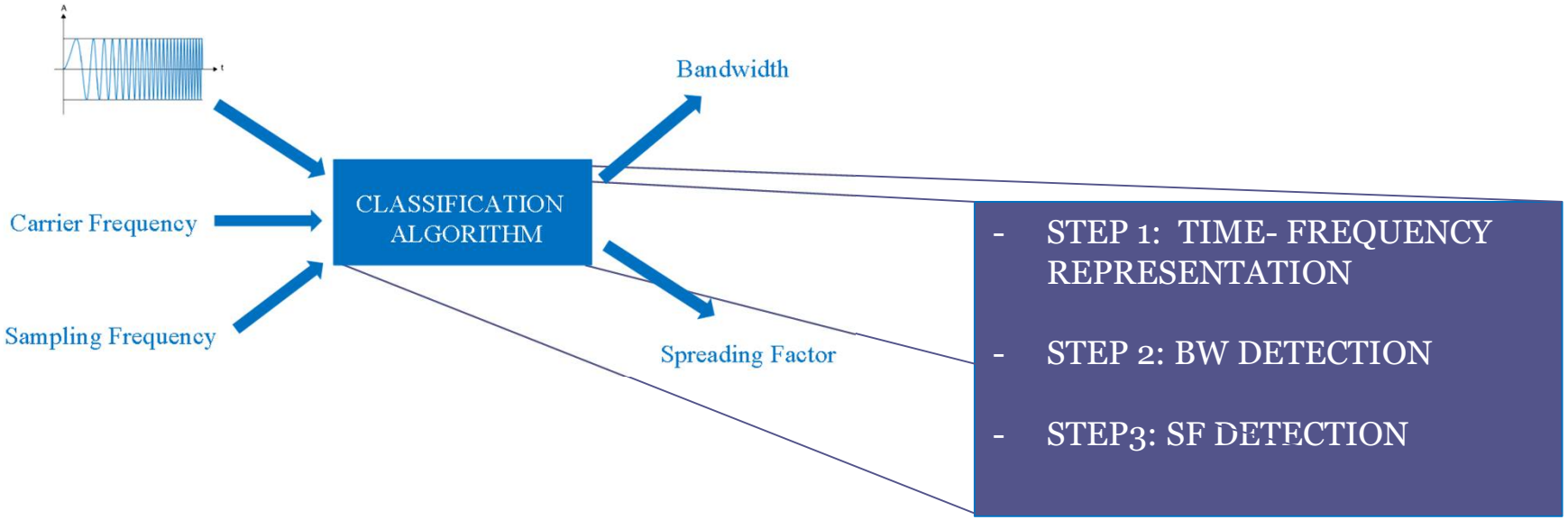
Measurements for IoT

Problem statement

THE CLASSIFICATION ALGORITHM

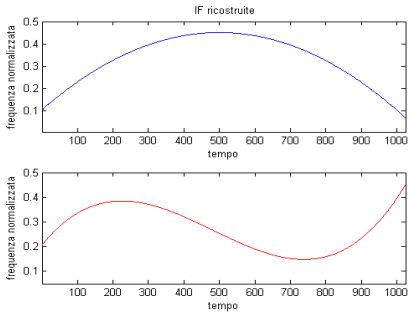


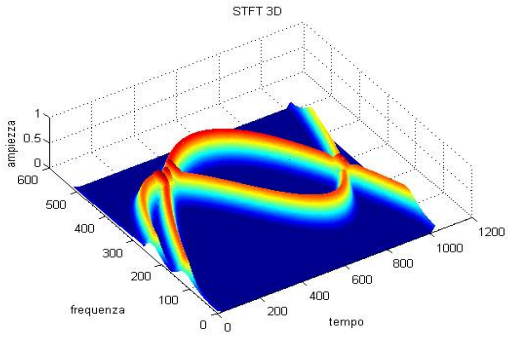
Measurements for IoT

Problem statement

It would be useful a methodology for maintenance and troubleshooting of LoRa networks sharing the same operating frequency interval.

In this context the estimation of instantaneous frequency (IF) of signals characterized by interfering IF trajectories, can be very useful, for example to analyse transmission system quality.





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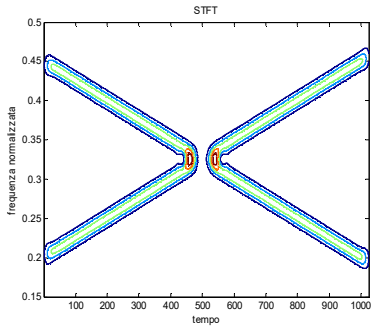
Measurements for IoT

Problem statement

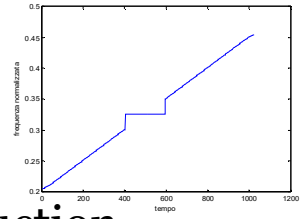
CT and WbT transform parameters are computed by means of the estimation of IF gained by TFR , which is obtained through the application of STFT .

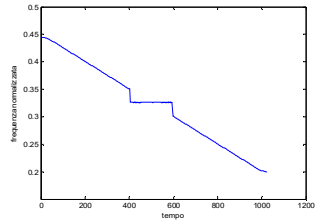
Interfering IF trajectories

STFT



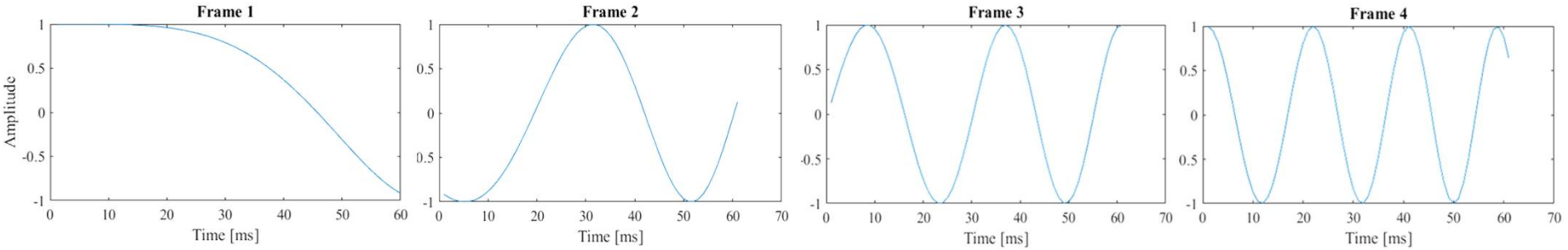
Bad reconstruction





Measurements for IoT

Proposal method



CS VIA DCT → RECOVERY ALGORITHM

CS VIA DCT → RECOVERY ALGORITHM

CS VIA DCT → RECOVERY ALGORITHM

CS VIA DCT → RECOVERY ALGORITHM

REATTACH THE FRAMES

Signal Frequency → CLASSIFICATION ALGORITHM ← Sampling Frequency

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Measurements for IoT

USB

Proposal method

Male-Male
SMA Cable

- Carrier Frequency: 868 MHz
- Transmission Power: 14 dBm
- Sampling Frequency: 10 MSamples/s
- Acquired window: 200 ms

SF/BW (CR4/5 and CR4/8)	125 kHz	250 kHz	500 kHz
7	BW125SF7	BW250SF7	BW500SF7
8	BW125SF8	BW250SF8	BW500SF8
9	BW125SF9	BW250SF9	BW500SF9
10	BW125SF10	BW250SF10	BW500SF10
11	BW125SF11	BW250SF11	BW500SF11
12	BW125SF12	BW250SF12	BW500SF12

Measurements for IoT

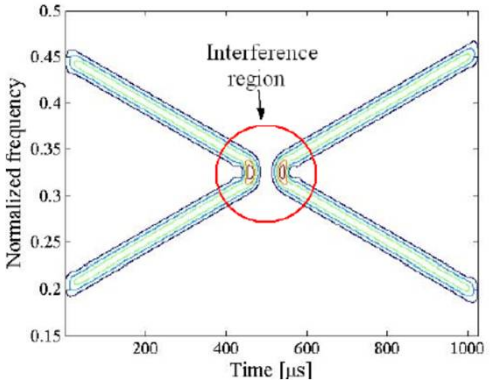
Proposal method

$$s(t) = x(t) + y(t)$$

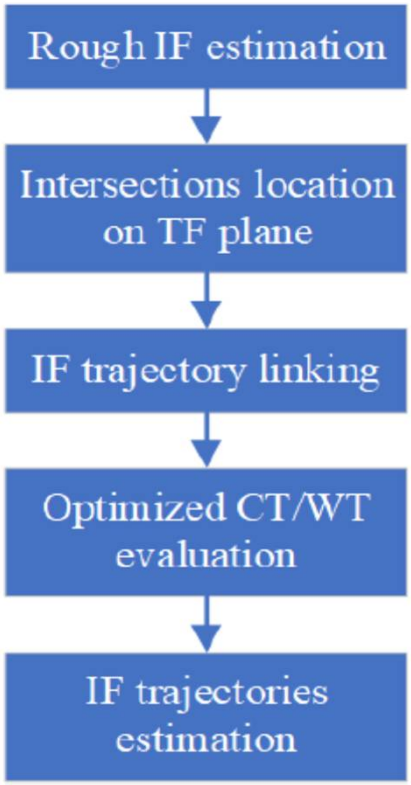
$x(t)$ and $y(t)$ are expressed by:

$$x(t) = \cos\left[2\pi\left(-125t^2 + 4.5\cdot 10^5 t\right)\right] \quad 0<t<1024\ \mu s$$

$$y(t) = \cos\left[2\pi\left(125t^2 + 2\cdot 10^5 t\right)\right]$$

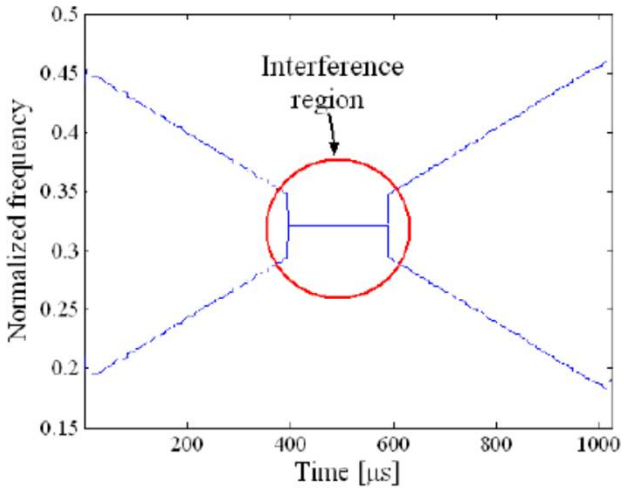


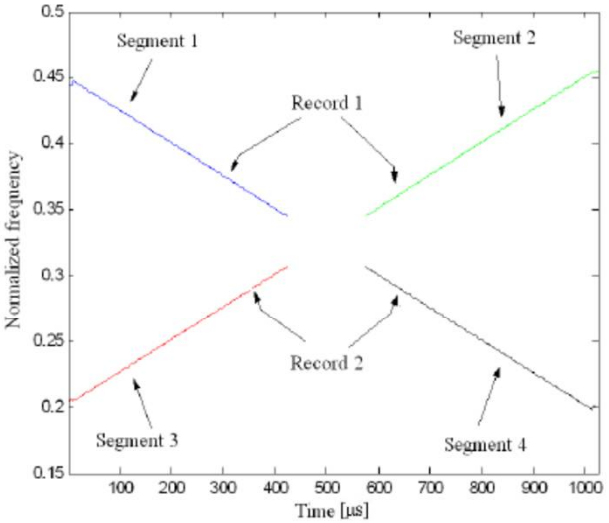
Block diagram of the proposed method

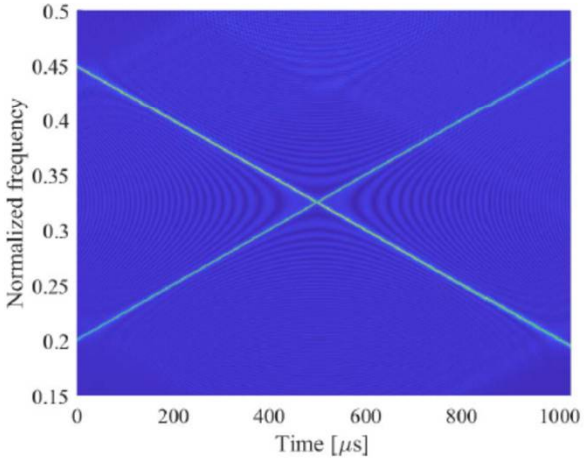


Measurements for IoT

Example







$$CT(m,k) = \sum_{n=1}^{N} s(nT) \cdot CM_1\left(mT - nT, k_m^1\right) + \sum_{n=1}^{N} s(nT) \cdot CM_2\left(mT - nT, k_m^2\right)$$

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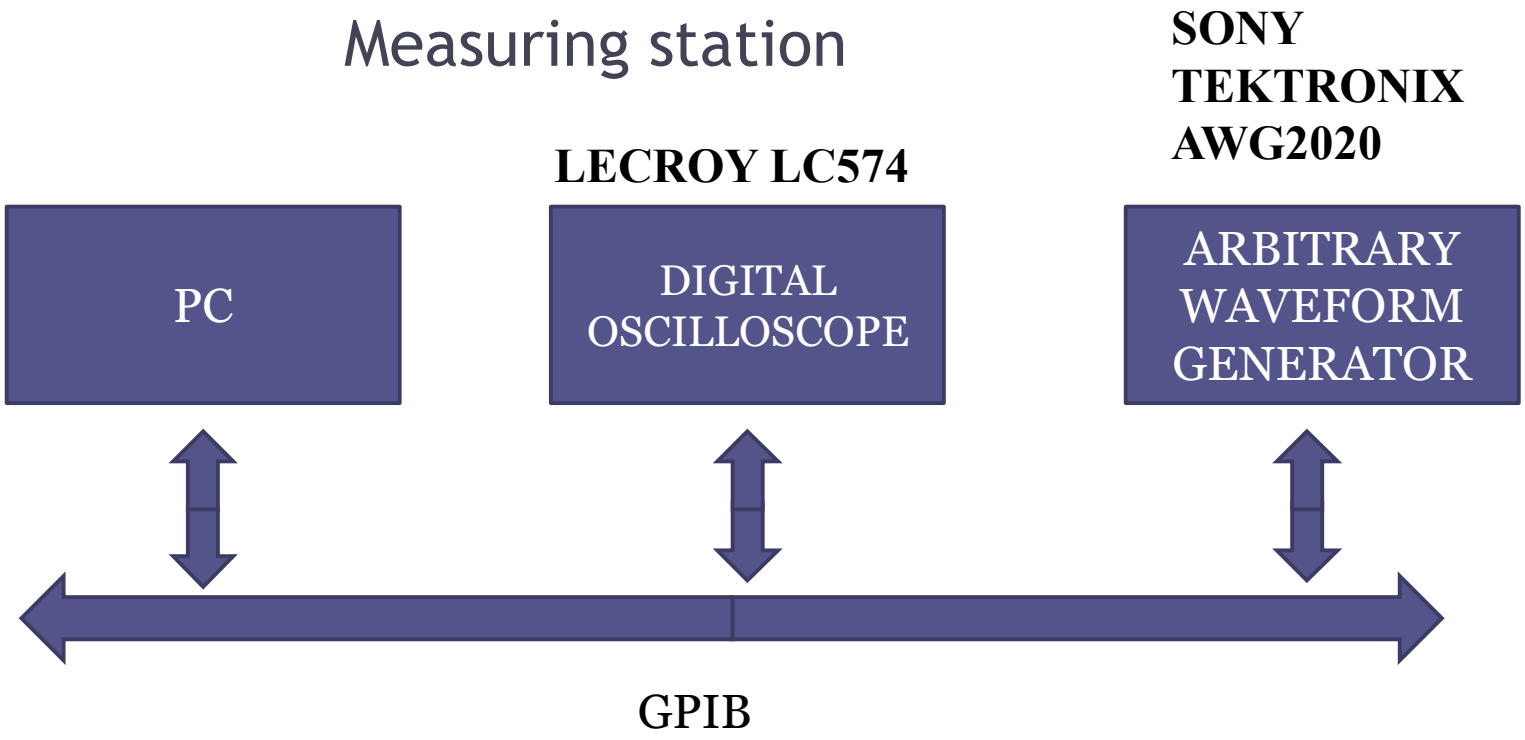
Measurements for IoT

Measuring station



OBSERVATION WINDOW: $T = 1024\mu s$

GENERATION FREQUENCY: $f_g = \frac{N_g}{T} = 32MHz$

SAMPLING FREQUENCY: $f_S = 1MHz$

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Measurements for IoT

Performances

To suitably appreciate the method performance, the root mean square, expressed in dB, of the difference (RMSD) between nominal and estimated IF trajectories has been evaluated; values of -29.9 and -29.8 dB, respectively have been experienced for the signals involved in the application example.

$$RMSD = \sqrt{\frac{1}{N}\sum_{k}\left[20\log_{10}\left(\frac{IFmeas_k}{IFreal_k}\right)\right]^2}$$

$$absolute_deviation_{max/mean} = \sum_{k}|IFmeas_k - IFreal_k|$$

Products

i. "IOT Enabling Measurement Applications in Industry 4.0: Platform for Remote Programming ATES," - Leopoldo Angrisani ; Umberto Cesaro ; Mauro D'Arco ; Domenieantonio Grillo ; PhD Student Alessandro Tocchi. 2018 Workshop on Metrology for Industry 4.0 and IoT, Brescia, 2018, pp. 40-45. doi: 10.1109/METROI4.2018.8428326

ii. "Guaranteeing safety of animals under risk of fire: conceptual framework and technical issues analysis"-TAMBURIS, Oscar, PhD Student Alessandro Tocchi et al. 2019 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor). IEEE, 2019. p. 100-104 doi: 10.1109/MetroAgriFor.2019.8909231

Publication

iii. Tamburis O, Giannino F, D'Arco M, PhD Student Alessandro Tocchi, Esposito C, Di Fiore G, Piscopo N, Esposito L. "A Night at the OPERA: A Conceptual Framework for an Integrated Distributed Sensor Network-Based System to Figure out Safety Protocols for Animals under Risk of Fire". Sensors (Basel). 2020 Apr 29;20(9):2538. doi: 10.3390/s20092538. PMID: 32365698; PMCID: PMC7249212.(27 April 2020)

iv. L. Angrisani, PhD Student Alessandro Tocchi, D. Ruggiero, R. S. Lo Moriello, G. de Alteriis and F. Capasso, "Estimation of Instantaneous Frequency in the Presence of Interfering Trajectories,", 2020 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), 2020, pp. 1-6, doi: 10.1109/I2MTC43012.2020.9128597, (25-28 May 2020)

Products

v. Angrisani, L., Bonavolontà, F., Dassi, C., Liccardo, A., Moriello, R.S.L., PhD Student Alessandro Tocchi, 7006649427;55825402400;57205436107;14631935200; 57212675767;5701488740;"On the suitability of compressive sampling for lora signals classification"(2020) International Review of Electrical Engineering, 15 (3), pp. 187-198.

(June 2020)

vi. R. S. Lo Moriello, PhD Student Alessandro Tocchi, A. Liccardo, F. Bonavolontà and G. de Alteriis, "Exploiting IoT-Oriented Technologies for Measurement Networks of Environmental Radiation," in IEEE Instrumentation & Measurement Magazine, vol. 23, no. 9, pp. 36-42, December 2020, doi: 10.1109/MIM.2020.9289067.

Credits Summary

Student: Alessandro Tocchi										Tutor: Prof. Mauro D'Arco										Cycle XXXIII																	
alessandro.tocchi@unina.it										darco@unina.it																											
	Credits year 1									Credits year 2										Credits year 3																	
		1	2	3	4	5	6				1	2	3	4	5	6					1	2	3	4	5	6	7	8	10							
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Total	Check				
Modules	20	0	0	9	9	0	0	18	20-40	15			2	6			8	10-20	5	12,0		4,0							16	0-10	42	30-70				
Seminars	7	0,6	0	2	1,6	4	1,5	9,7	5-10	7	0,4	1,4	1,2	0,6	4		7,6	5-10	5		0,3	0,5		3,3	0,2				4,3	0-10	21,6	10-30				
Research	33	7	11	7,8	1	7	1	34,8	10-35	40	10	3	6	10	7	8	44	30-45	45	9,0	14,0	16,0	4,0		10,0	2,0	2,0	2,0	59	40-60	137,8	80-140				
	60	7,6	11	19	12	11	2,5	62,5	58,8	62	4,4	9,2	17	11	8	60	59,6	62	55	21	14	21	4	3,3	10	2	2	2	79,3	60	201,4	201,4				

Table of Courses/Seminars

Year	Lecture/Activity	Type	Credits	Certification
1	Misure su sistemi wireless	Msc Course	9	Y
1	Sensori e Trasduttori di Misura	Msc Course	9	Y
1	IBM Q: building the first universal quantum computers for business and science	Seminars	0,4	Y
1	STM IoT Solution	Seminars	0,6	Y
1	Near-Zero-Index Photonics	Seminars	0,6	Y
1	Innovative design and material processing for additive manufacturing	Seminars	0,6	Y
1	Relaxation dynamics in soft materials	Seminars	0,4	Y
1	The Napoli Federico II IEEE Student Branch	Seminars	0,2	Y
1	New robust control methodologies for a broad class of nonlinear uncertain engineering systems	Ad hoc Course	1,4	Y
1	Italo Gorini 2018	Seminars	4	Y
1	NeaPolis Innovation Technology Day 2018	Seminars	1,5	Y
2	“MISURE E COLLAUDO SU MACCHINE E IMPIANTI”	Msc Course	6	Y
2	Internet censorship: enforcement, detection, and circumvention	Ad hoc Course	2	Y
2	MHD equilibrium and stability	Seminars	0.4	Y
2	Strategic Orientation for STEM Research &Writing	Seminars	1	Y
2	In & Out Chip Signal and Power Integrity	Seminars	0.4	Y
2	Machine Learning	Seminars	0.4	Y
2	Machine Learning	Seminars	0.4	Y
2	Industry 4.0: Factory virtual assistant	Seminars	0.4	Y
2	True Unipolar Electrocardiography and Application to Medicine	Seminars	0.6	Y
2	Italo Gorini 2019	Seminars	4	Y
3	Sensors Data Fusion and Measurement Uncertainty Management	Msc Course	12	Y
3	Design and Implementation of Augmented Reality Software Systems	Ad hoc Course	4	Y
3	How to Get Published with IEEE	Seminars	0.3	Y
3	Large Scale Training of Deep Neural Networks	Seminars	0.5	Y
3	How to Publish Open Access with IEEE to Increase the Exposure and Impact of your research	Seminars	0.3	Y
3	Network Systems, Kuramoto Oscillators, and Synchronous Power Flow	Seminars	0.2	Y
3	Italo Gorini 2020	Seminars	3	Y

Thanks for your attention!!!