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IARIA

LPWAN technologies for developing advanced system in the current society

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UNIVERSIDAD DE GRANADA

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Dr. Sandra Sendra (sansenco@posgrado.upv.es) received her degree of Technical Engineering in Telecommunications in 2007. She received her M.Sc. of Electronic Systems Engineering in 2009 and her Ph.D. in electronic engineering (Dr. Ing.) in 2013. Currently, she is associate professor at the Polytechnic University of Valencia (Spain). She is Cisco Certified Network Associate Instructor since 2009 and HP-ATA instructor since 2015. She is vocal inside the IEEE Spain Section for the term 2020-2021, member of the Membership Development group for the term 2018-2019 and active member inside the IEEE WIE Spain for the term 2016-2018.

She has authored 6 book chapters and 2 books. She has more than 110 research papers published in national and international conferences, international journals (more than 45 with ISI Thomson JCR). She has been the co-editor of 8 conference proceedings and guest editor of several international journals. She has been the co-editor of 9 conference proceedings and associate editor in 6 international journals. She has been involved in more than 100 Program committees of international conferences, and more than 50 organization and steering committees. She is currently leading a national project and two local project related to the development of a WSN for environmental monitoring.

Outline

1.- Wireless Sensor Networks (WSNs)

2.- LPWAN technology

- Sigfox
- NB-IoT
- LoRa
- Comparison

3.- LoRa-based Hardware for IoT

4.- LoRa-based Applications

Acknowledgment

Wireless Sensor Networks (WSNs)

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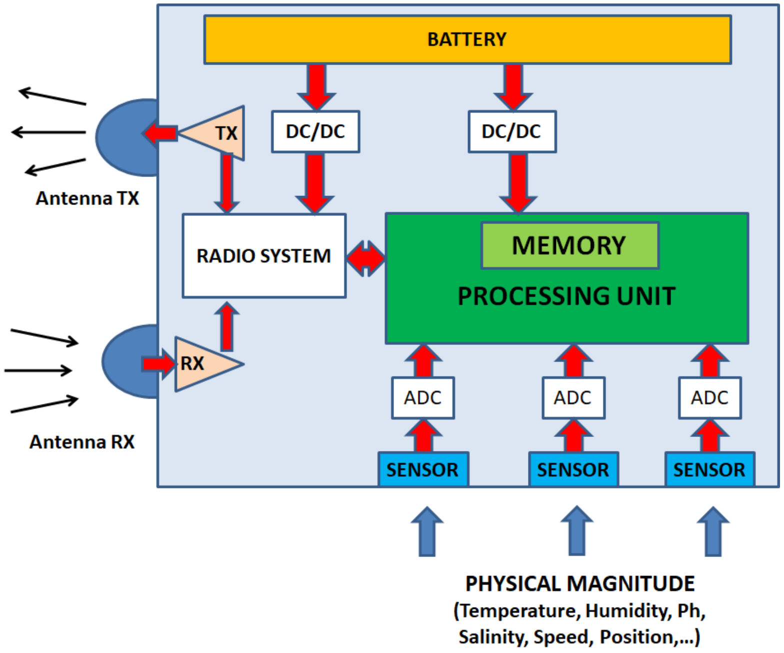
- A wireless network sensors can be defined as a set of small, autonomous, easy-to-deploy devices called nodes.
- The nodes are formed by a sensor unit, a microcontroller, a transceiver (transmission / reception of messages) and internal batteries powered by solar panel.
- Each node has the capacity to wirelessly intercommunicate with the rest of the nodes, sending the captured information to a central point (gateway), from which and through the web the information is stored in a server so that it can be analyzed and consulted in the real time in the control center.



- The Internet of Things (IoT) refers to the inter-connection and exchange of data among devices/sensors.
- IoT applications have specific requirements such as long range, low data rate, low energy consumption, and cost effectiveness.
- The widely used short-range radio technologies (e.g., ZigBee, Bluetooth) are not adapted for scenarios that require long range transmission.
- Solutions based on 2G, 3G, and 4G are able to provide larger coverage
  → consume excessive device energy.
- IoT applications' requirements have driven the emergence of a new wireless communication technology: low power wide area network (LPWAN).

- The field of application of technology is very diverse, from agriculture, livestock, industrial processes, home automation, environment, logistics, security, accessibility, Smart Metering, Smart Home or Smart City, among some of the most prominent sectors.

- The advantages of this technology are:
  - Ease and speed of installation and deployment
  - Low consumption
  - Scalability
  - Devices with own autonomy and without cables
  - Reduced maintenance
  - Remote monitoring in real time, which reports to the client optimization of resources and processes
  - Versatility to adapt the system to the client's needs
  - Ability to couple several sensors in a single communication node
  - High capacity of self-organization and self-configuration with the rest of the nodal devices of the network, which allows the mobility of the devices.

- The evolution of technologies and the ability to interconnect different devices have led to the existence of networks capable of communicating and acting together, creating what is known as Internet of Things (IoT).

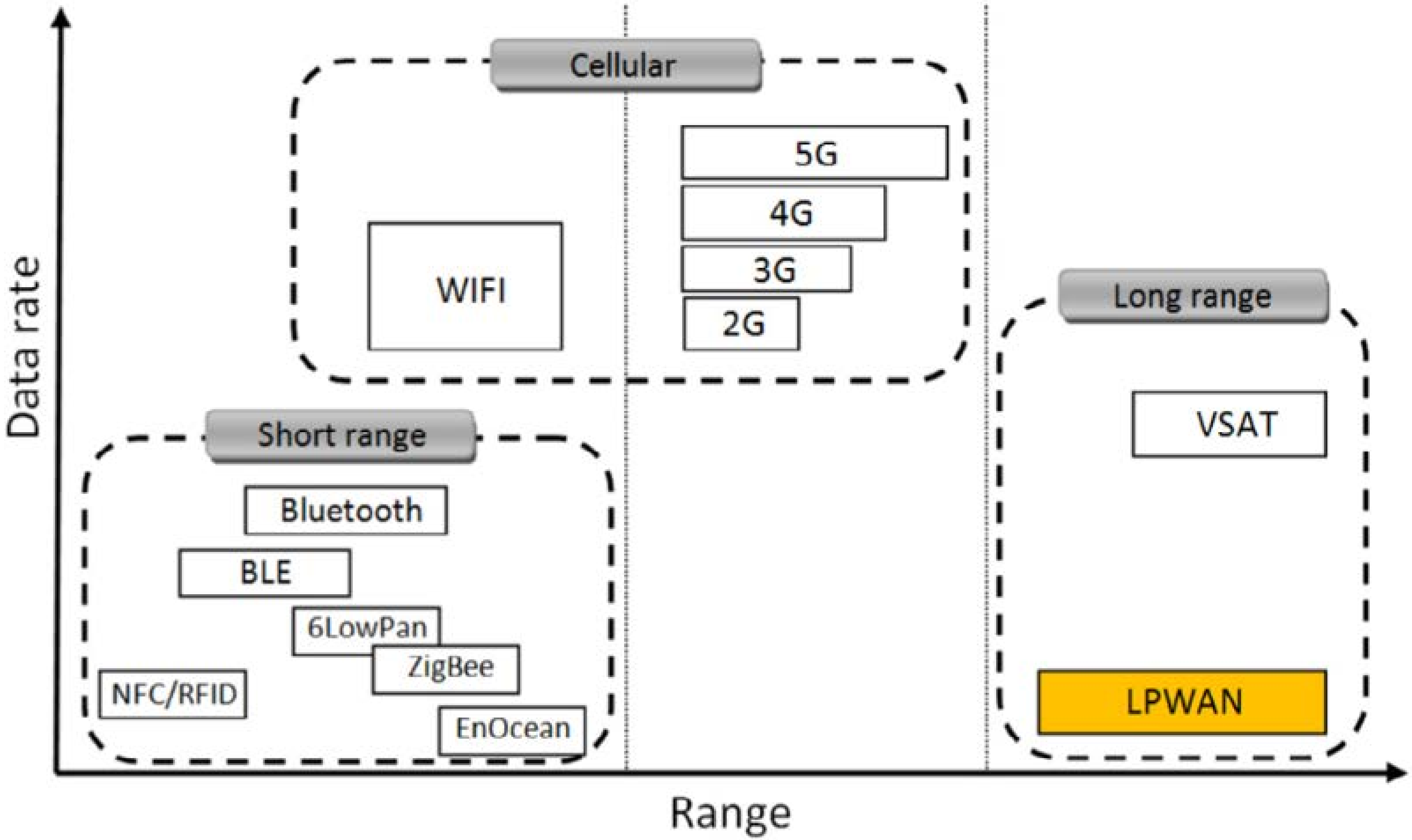
- Thanks to sensors and actuators, it is possible to measure our environment and share data which, collected by platforms, allows the developers to create useful applications for the society.

LPWAN technology

- LPWAN is increasingly gaining popularity in industrial and research communities because of its characteristics:
  - low power,
  - long range,
  - low-cost communication
- Long-range communication up to 10–40 km in rural zones and 1–5 km in urban zones.
- Highly energy efficient and inexpensive,

- Cost of a radio chipset being less than 2€ and an operating cost of 1€ per device per year.

- LPWAN is highly suitable for IoT applications
  - Only need to transmit tiny amounts of data in long range.
  - Many LPWAN technologies have arisen in the licensed as well as unlicensed frequency bandwidth.
  - Sigfox, LoRa, and NB-IoT are today’s leading the lasts proposed solutions.

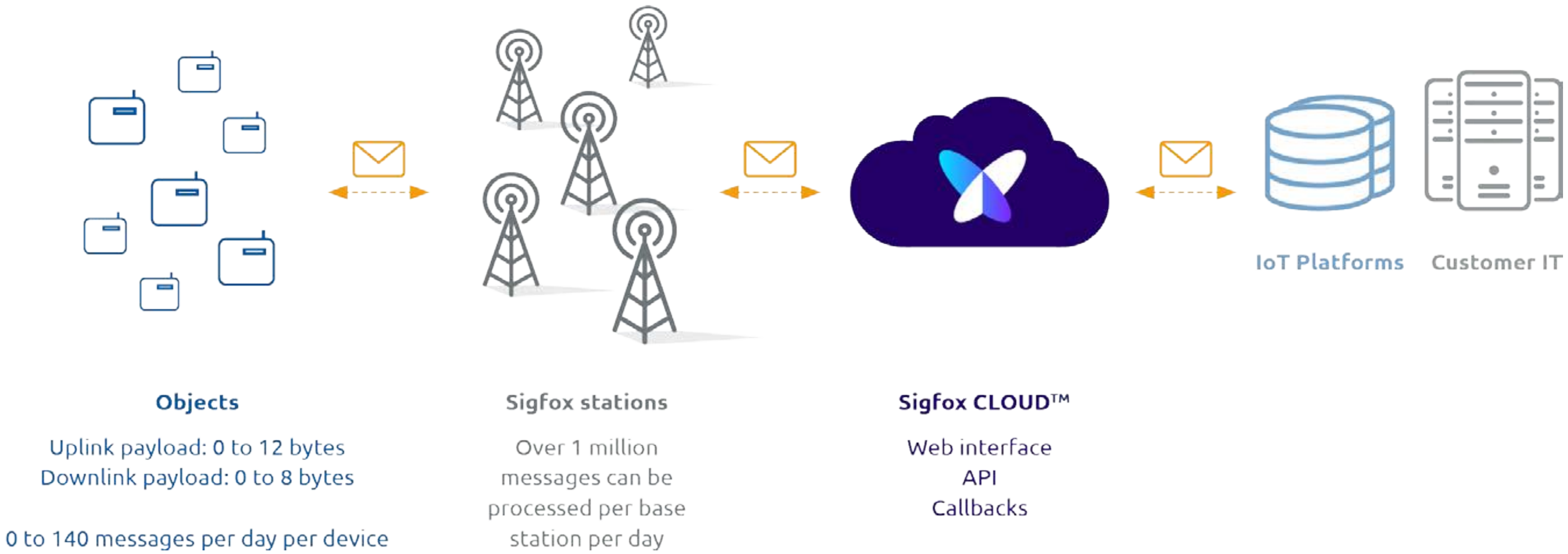

Cellular
5G
4G
3G
2G
WIFI
Long range
VSAT
LPWAN
Short range
Bluetooth
BLE
6LowPan
ZigBee
NFC/RFID
EnOcean
Data rate
Range

Sigfox

- Sigfox is an LPWAN network operator that offers an end-to-end IoT connectivity solution based on its patented technologies.
- Proprietary base stations equipped with cognitive software-defined radios and connect them to the back end servers using an IP-based network.
- The end devices connected to these base stations using binary phase-shift keying(BPSK) modulation in an ultra-narrow band (100 Hz) sub-GHZ ISM band carrier.
- Sigfox uses unlicensed ISM bands, for example, 868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia.
- By employing the ultra-narrow band, Sigfox uses the frequency bandwidth efficiently and experiences very low noise levels, leading to very low power consumption, high receiver sensitivity, and low-cost antenna design at the expense of maximum throughput of only 100 bps.

Overview of the Sigfox global network

- Sigfox is a public network based on a star network architecture. A device is not attached to a specific base station unlike cellular protocols. The broadcasted message is received by any base station in the range, 3 in average.



https://www.avnet.com/wps/portal/ebv/solutions/iot/sigfox/

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Overview of the Sigfox global network

Very long range

- Low bit rate and simple radio modulation enable a 163.3 dB budget link leading to long-range communications.

High network capacity

- The small footprint of Ultra Narrow Band (*UNB*) enables more simultaneous signals within the operation band. In addition, the objects are not attached to a specific base station.

- They broadcast their messages which are received by any base station in the range (3 in average).

- There is no need for message acknowledgement. UNB modulation, spatial diversity coupled with the time and frequency diversity of the radio frames repetitions lead to a high capacity of the Sigfox network.

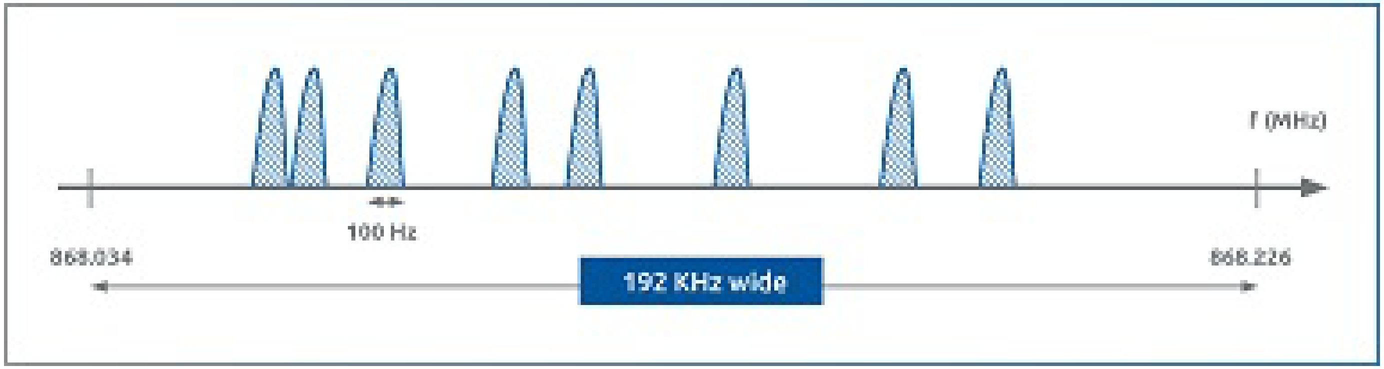
High resilience to interferers

- UNB intrinsic ruggedness coupled with spatial diversity of the base stations offer great anti-jamming capabilities. UNB is extremely robust in an environment with other spread spectrum signals. UNB is the best choice to operate on the public ISM band.
-

Sigfox radio technology overview

- Sigfox uses 200 kHz of the publicly available and unlicensed bands to exchange radio messages over the air (868 to 869 MHz and 902 to 928 MHz depending on regions).

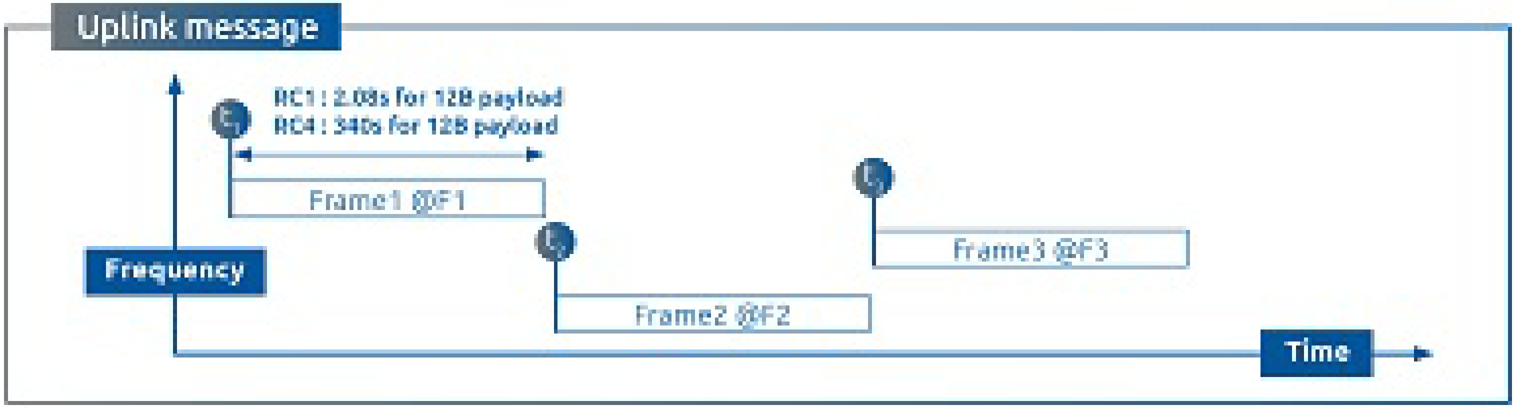
- Sigfox uses Ultra Narrow Band (UNB) technology combined with DBPSK and GFSK modulation. Each message is 100 Hz wide and transferred at 100 or 600 bits per second data rate depending on the region.



https://www.avnet.com/wps/portal/ebv/solutions/iot/sigfox/

Random access to the radio frequency resource

- The transmission is unsynchronized between the devices and the network.
- They broadcast each message 3 times on 3 different frequencies (frequency hopping).
- The base stations monitor the spectrum and look for UNB signals to demodulate.



https://www.avnet.com/wps/portal/ebv/solutions/iot/sigfox/

Small messages

- Sigfox has tailored a lightweight protocol to handle small messages.
- An uplink message has a maximum 12-bytes payload and a downlink of 8 bytes.
- For a 12 bytes data payload, a Sigfox frame will use 26 bytes in total.

https://www.avnet.com/wps/portal/ebv/solutions/iot/sigfox/

NB-IoT

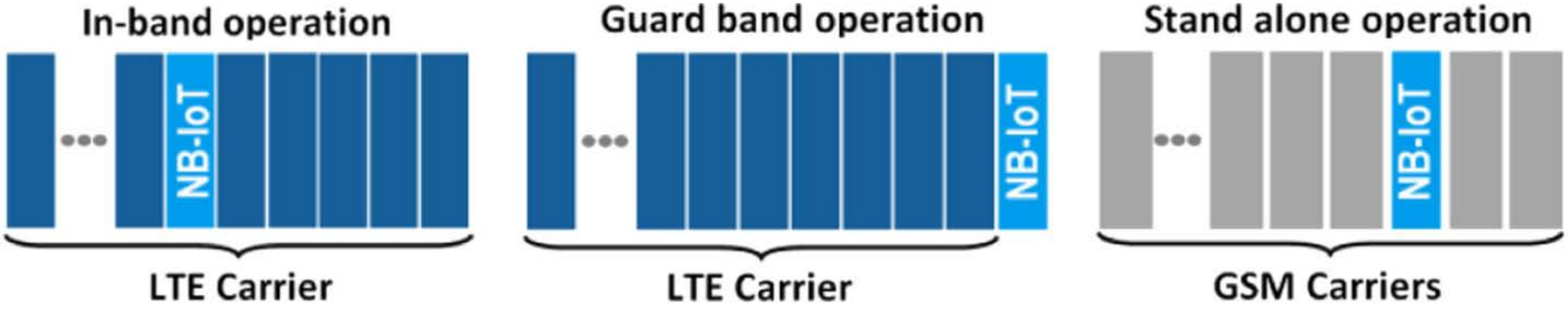
What is Narrowband-IoT?

- NB-IoT is a technology that allows devices used in our daily lives to connect to the internet and to send small amounts of data.
- It is a technology that uses cellular networks as infrastructure.
- Batteries to last up to 10 years, depending on the frequency of sending of the messages.
- The binary rates it offers are 63 Kb / s.
- Ideal technology for monitoring in transportation or industry, environmental monitoring or applications such as smart meters.

What is Narrowband-IoT?

- NB-IoT uses licensed spectrum bands, so there is no interference with other technologies,
- Robustness of communications, not dependent on the number of devices in the vicinity.
- Many of the frequency bands reserved for NB-IoT are in the 700 and 800 MHz range → easy penetration into buildings and basements, making the technology able to operate in a greater number of scenarios.
- Low consumption orientation based on cellular telephone networks is LTE Cat M1.
- Transmission speeds up to 375 kb/s.

- NB-IoT is a Narrow Band IoT technology is specified in Release 13 of the 3GPP in June 2016.
- NB-IoT can coexistwith GSM (global system for mobile communications) and LTE(long-term evolution) under licensed frequency bands (e.g., 700 MHz, 800 MHz, and 900 MHz).
- It is placed at the frequency band width of 200 KHz, which corresponds to one resource block in GSM and LTE transmission.



Mekki, K., Bajic, E., Chaxel, F., & Meyer, F. (2019). A comparative study of LPWAN technologies for large-scale IoT deployment. *ICT express*, *5*(1), 1-7

LoRa

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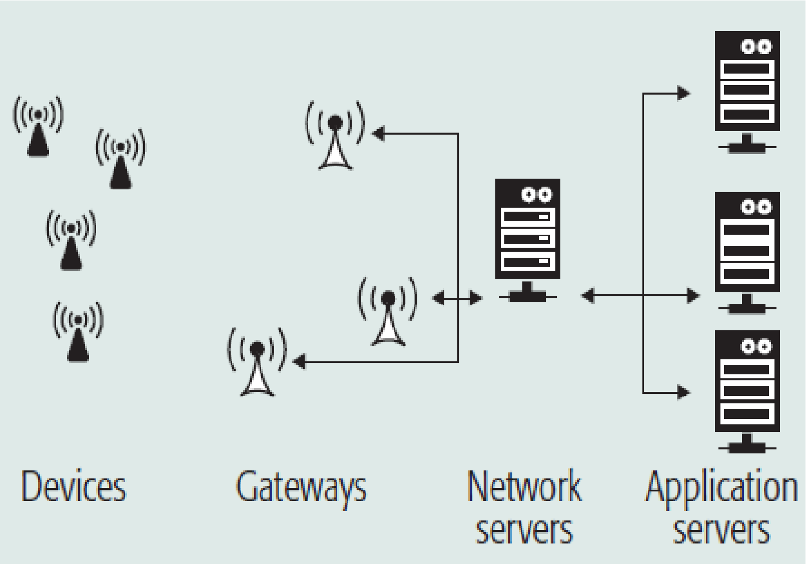
LoRaWAN Introduction

LoRa ≠ LoRaWAN

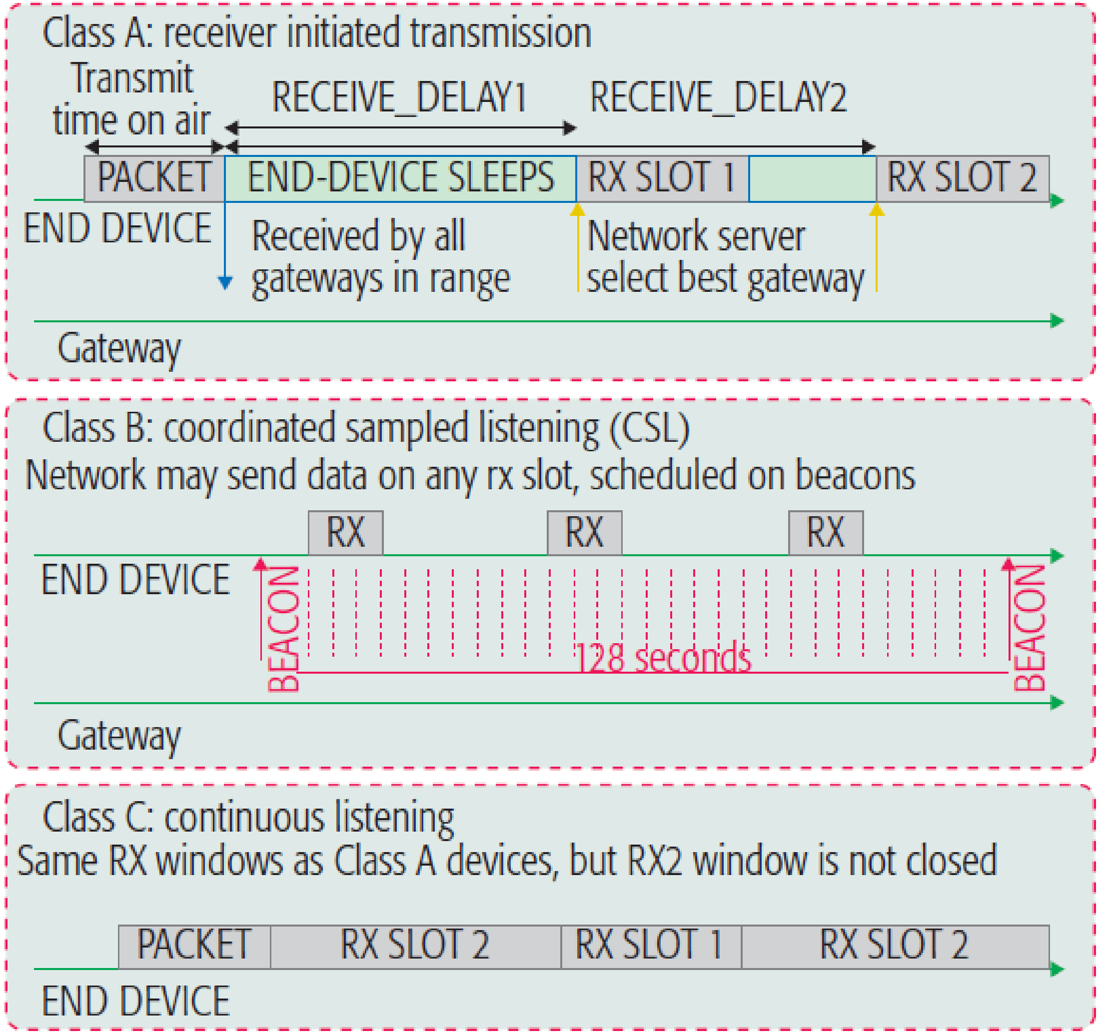
- The first thing that needs to be clarified is that LoRa and LoRaWAN are not the same, LoRa is the type of radiofrequency modulation patented by Semtech. Its main advantages are:
  - High tolerance to interference
  - High sensitivity to receive data (-168dB)
  - Based on chirp modulation
  - Low power Consumption (up to 10 years with a battery *)
  - Long range: 10 to 20km
  - Low data transfer (up to 255 bytes)
  - Point to point connection
  - Working frequencies: 915Mhz America, 868 Europe, 433 Asia
- It is the ideal technology for connections over long distances and for IoT networks that can be used in smart cities, places with little cellular coverage or private networks of sensors or actuators, that's why LoRaWAN was born.

LoRaWAN Introduction

- Unlike other IoT technologies, LoRaWAN does not use a mesh network architecture.
- Although mesh networking may be useful to increase the communication range, it also affects the device battery life due to the forwarding of messages. → LoRaWAN uses a star topology
- LoRaWAN allows end devices to have bidirectional communications, although they are asymmetric, since uplink transmissions (from end devices to gateways) are strongly favored.



LoRaWAN Introduction



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LoRaWAN Introduction

- The underlying PHY layer for the three classes is the same.

- LoRa is a proprietary spread spectrum modulation scheme which is based on chirp spread spectrum (CSS).

- Some of the key properties of this modulation are scalable bandwidth, constant envelope, low power, high robustness, multipath and fading resistant, Doppler resistant, long-range capability, enhanced network capacity, and geolocation capabilities.

- Using different spreading factors (SFs), the developer may trade data rate for coverage or energy consumption. The spreading factor is defined as

$$SF = \log_2\left(\frac{R_C}{R_S}\right)$$

RS and *RC* are the symbol and chip rates

LoRaWAN Introduction

- The usage of a high SF decreases the data rate but increases the maximum distance between the transmitter and the receiver, and vice versa.
- Since transmissions using different SFs are orthogonal, it is possible to receive multiple frames simultaneously.
- LoRa error correction reduces the bit rate by a factor rate code = 4/ (4+CR), where code rate (CR) is an integer value between 1 and 4.

$$Rb = SF \times \frac{\frac{4}{4+CR}}{\frac{2^{SF}}{BW}}$$

- Since SFs vary from 7 to 12, and frames sent with different SFs can be decoded simultaneously, the maximum aggregated bit rate (assuming *BW* = 500 kHz and *CR* = 1) is 43 kb/s.

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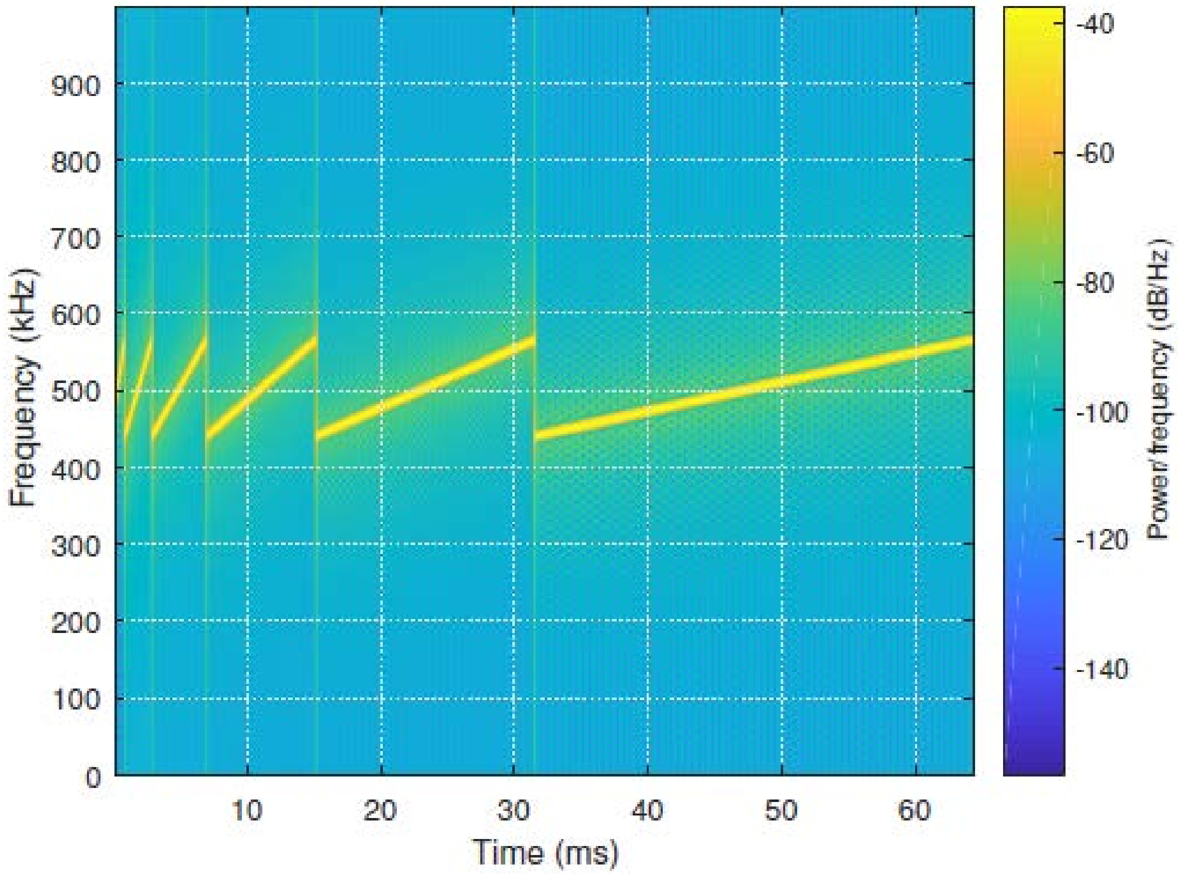
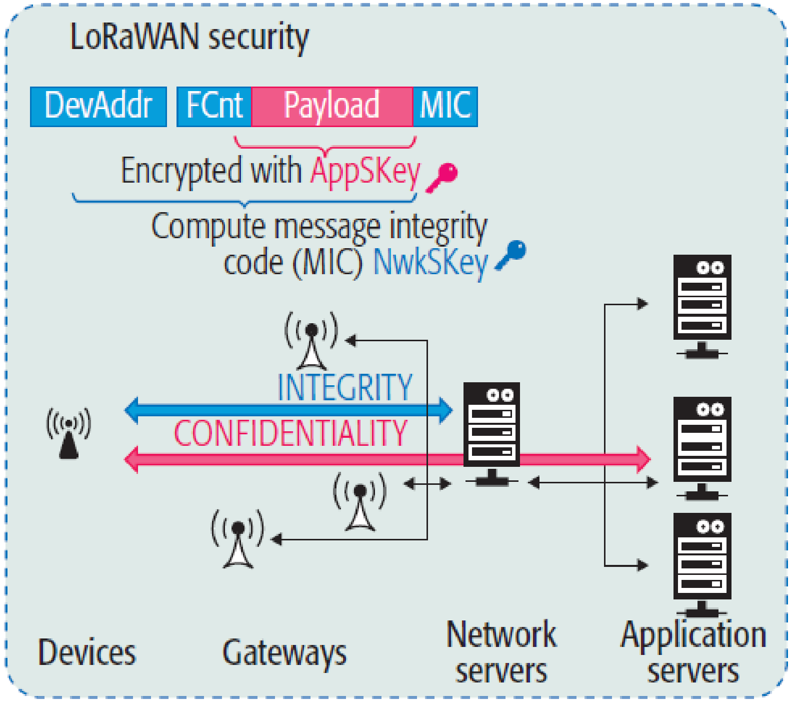
LoRaWAN Introduction



It shows how frequency, time and power vary according to the SF used.

LoRaWAN Security

- As security is crucial, it has been included from the initial versions of the standard.
- Security for LoRaWAN is also designed for low power consumption, low implementation complexity, low cost, and high scalability.
- The main properties of LoRaWAN security are mutual authentication, integrity protection, and confidentiality.



- An end device can be activated using either *over-the-air activation* (OTAA) or *activation by personalization* (ABP). The device stores the following information:
  - *DevAddr* (device address), *AppEUI* (application identifier),
  - *NwkSKey* (network session key), and *AppSKey* (application session key).

LoRaWAN Security

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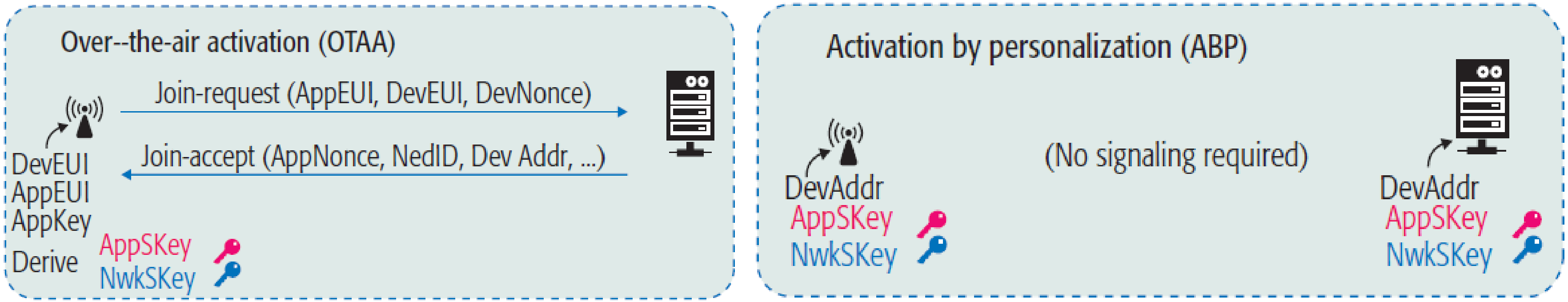
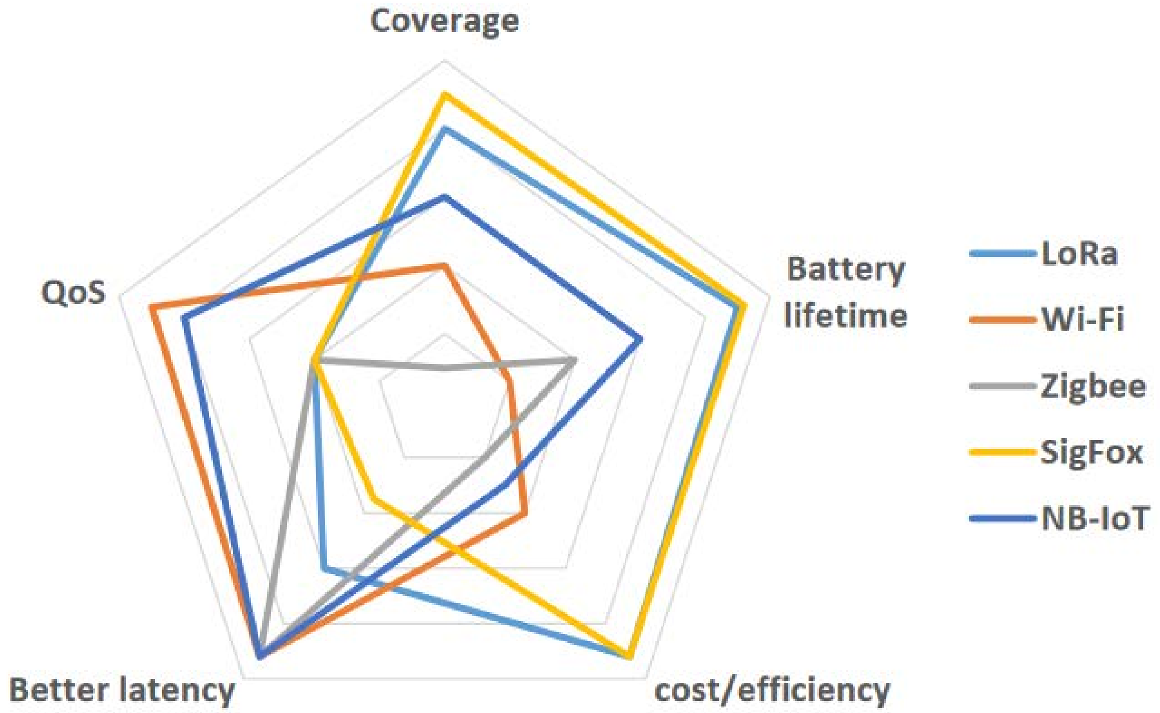


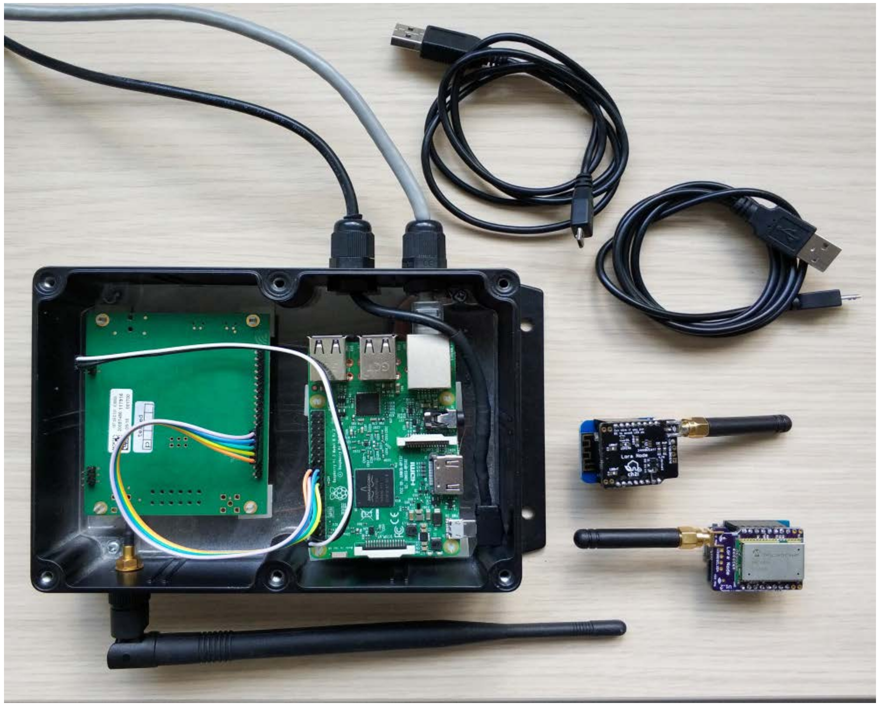
Comparison

	LoRa	Wifi	ZigBee	SigFox	NB-IoT
Frequency	868 MHz (EU); 915 MHz (USA); 433 MHz (Asia)	2.4 GHz and 5 GHz	868 MHz (EU); 915 MHz (USA); 433 MHz (Asia); 2.4 GHz	868 MHz (EU); 915 MHz (USA), 433 MHz (Asia)	Depends on the frequency licensed to LTE
Standard	IEEE802.15.4g, LoRa Alliance	IEEE802.11	IEEE802.15.4	SigFox (Owner)	3GPP Standard
Coverage	5 km (urban),20 km (rural)	50 m (indoor), 40 km (outdoor, as a function of the visibility)	10–100 m	10 km (urban), 40 km (rural)	1 km (urban), 10 km (rural)
Modulation	LoRa, FSK, GFSK	BPSK, QPSK, 16 QAM, 64 QAM, 256 QAM, 1024 QAM	BPSK, OQPSK	BPSK, GFSK	QPSK, OFDM (DL, SC-FDMA (UL)
Power consumption	Low	High	Medium-Low	Low	Low
Theoretical Data Transfer Rate	22 kbps (LoRa), 100 kbps (GFSK)	2.4 Gbps (IEEE802.11 ax, 2 streams with 1024 QAM)	250 kbps at 2.4 GHz, 20 kbps at 868 MHz, 40 kbps at 915 MHz	100 bps	10 Mbps
Price of end devices	3–5 €	3–5 €	2–5 €	>2 €	>20 €
Price of Gateway/ Base Station	100 € Gateway/ >1000 € Base station	20–600 € Gateway	40–1000 € Gateway	4000 € Base station	15000 € Base station

- Many factors should be considered when choosing the appropriate LPWAN technology for an IoT application including quality of service, battery life, latency, scalability, payload length, coverage, range, deployment, and cost. In the following.



LoRa-based Hardware for IoT



DIY multi-channel Raspberry Pi Gateway:

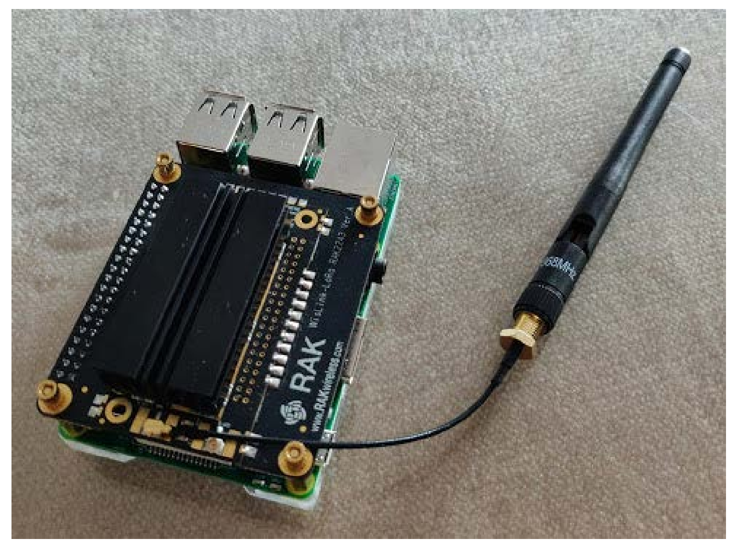
- Raspberry Pi 3 Model B,
- IMST ic880A concentrator with a maximum transmission power of 20 dBm
- an 868 MHz antenna with 2 dBi gain.

LoRa Lite by IMST

The LoRa Lite Gateway from German company IMST is a reasonably-priced eight-channel gateway based on their iC880A 868 MHz LoRaWAN concentrator and a Raspberry Pi, all fitted on a motherboard in a die-cast box.

Base on SX1301 LoRaWan Gateway Module

- Frequency band 433MHz/868MHz/915MHZ
- Sensitivity: down to -138dBm,   Output Power up to 20dbm
- open 8 channels uplink and 1 channel downlink for Makers
- SX1301 based processor
- USB or SPI interface



The Things Indoor Gateway

The following are the specs:

- Supports TTN and SLA
- Designed for indoor usage (prototyping)
- Features a setup and reset button
- USB-C port (for power only)
- Supports 868 or 915 frequency bands
- 8 channel, design v1.5 (with LBT)
- Integrated antenna
- ESP8266 SoC, allowing WiFi connectivity
- Able to be plugged directly into a wall outlet

TTGO LORA32 V2.0/433/868/915 MHz ESP32

- Chip Wifi ESP32 @ 80 MHz - 802.11 b/g/n
- 900 Mhz LoRa Module
- Compatible with Arduino
- OLED Screen 128x64 px
- MicroUSB (powering and programming)
- Antenna de 2dBi with SMA connector

- TTGO T-Beam node. It is built around the ESP32 chip.
- It has 4MB of SPI flash.
- It operates at 433 MHz, 868 MHz and 915 MHz.
- TTGO T-Beam node includes two antennas. A GPS ceramic antenna connected to a u-bloc NEO-6M GPS module and another LoRa antenna with SMA connector.
- It uses a LoRa chip from the HopeRF RFM9X family. The node has a total of 26 pins with GPIO, ADC, VP/VN, DAC, Touch, SPI, I2C, UART and Lora.
- It can be feed by batteries.

RAK811 LoRa Tracker
Wireless Remote Positioning Solution

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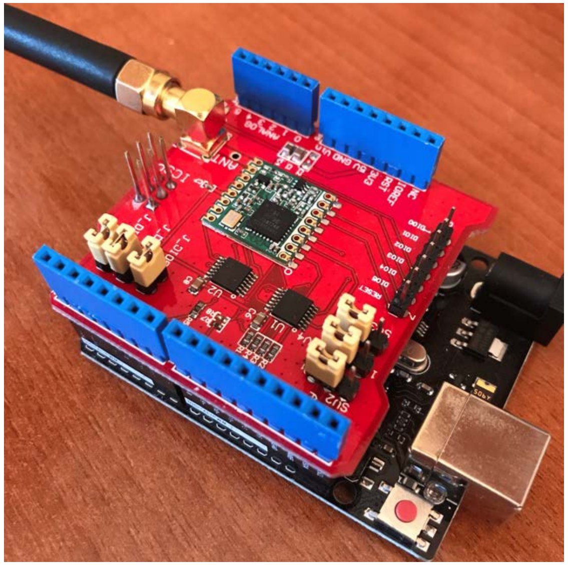
Dragino LoRa Shield board



Main features of Dragino LoRa Shield.

Parameter	Value
I/O pins compatible with Arduino	3.3V o 5V
Working Frequency	915 MHz / 868 MHz / 433 MHz
Current in Sleep Mode	1 µA
Antenna connection	SMA/I-PEX

Main features of RFM95W transceiver.

Parameter	Value
Modulations	FSK, GFSK, MSK, GMSK, LoRa y OOK
Sensitivity	-148 dBm
Preamble detection	-
RSSI range	127 dBm
Packaging System	256 bytes with CRC
Programmable Bitrate	Up to 300 kbps

Aplicaciones

- Smart Home
- Home Video
- Control Lights
- Snooze Button
- Take Pictures
- Wireless Trigger
- Remote Switch

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LoRa-based Applications

Performance of LoRaWAN Networks in Outdoor Scenarios

- The critical point in many scenarios resides in the energy consumption due to the batteries which feed these things.

- This is why so-called LPWAN technologies, which permit low power transmission, have been developed. In return, the transmission data rate is reduced (e.g., hundreds of kbps) but it is still enough for many IoT applications.

- Because of their standardization and the usage of non-licensed spectrum, these technologies have become serious competitors of solutions based on cellular networks, such as Long Term Evolution-Category M (LTE-M) or NarrowBand-IoT (NB-IoT).

- The most popular LPWAN technologies are Sigfox, LoRaWAN, Ingenu TPMA, and nWave.

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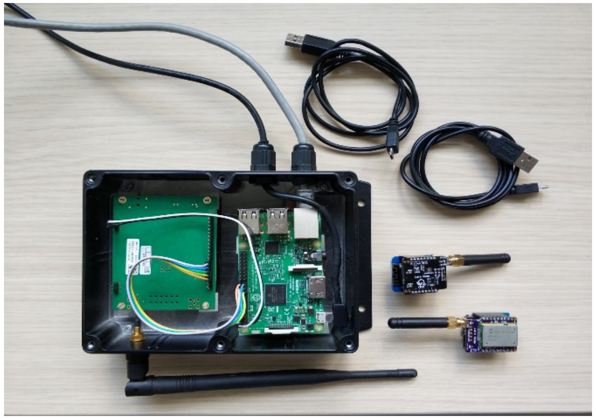
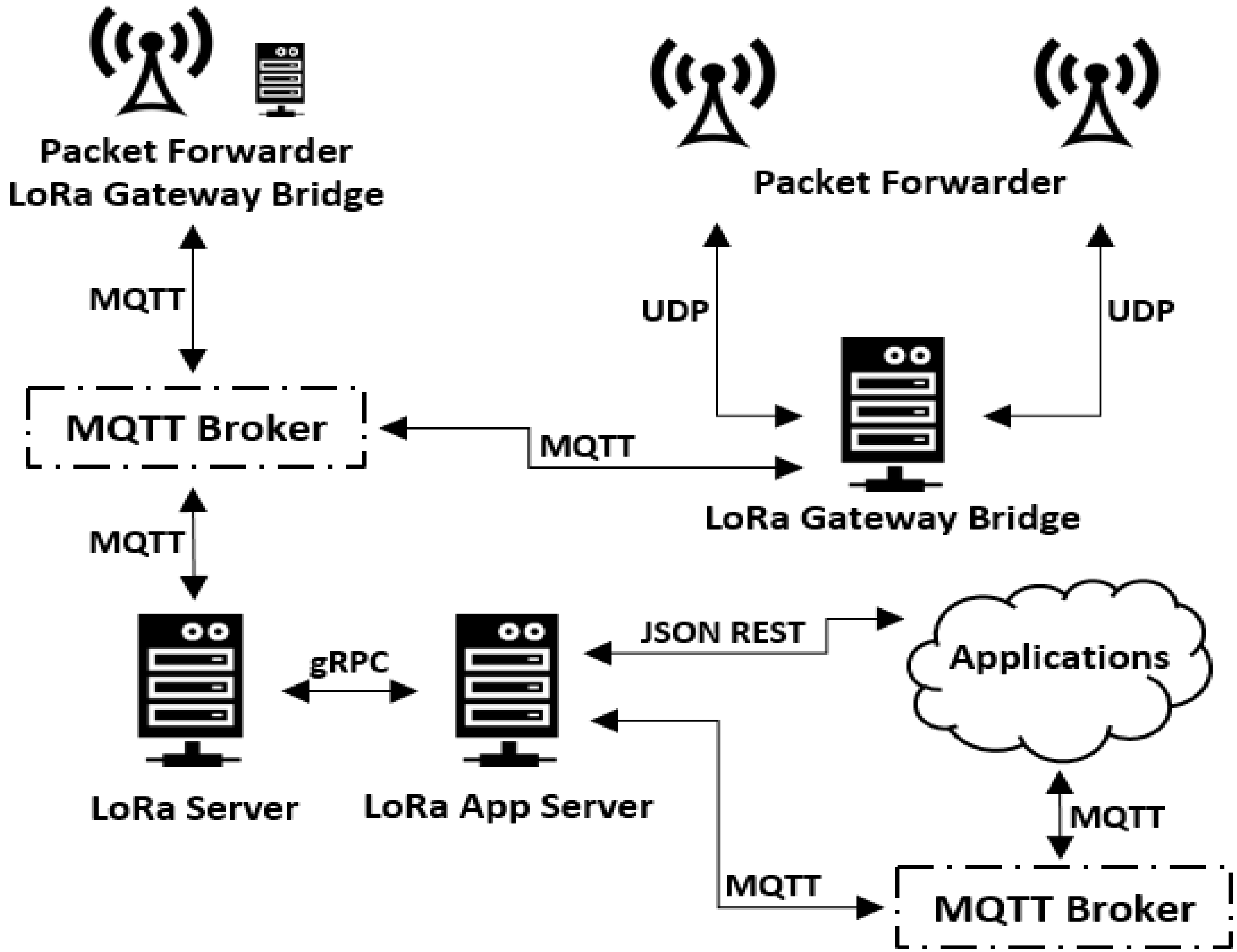
Components of a LoRaWAN network:

- DIY multi-channel Raspberry Pi Gateway: the chosen gateway is composed of a Raspberry Pi 3 Model B, an IMST ic880A concentrator with a maximum transmission power of 20 dBm and an 868 MHz antenna with 2 dBi gain.

- End-Device: the used end-device is based on the development board ’WeMos D1 Mini’, which uses the ESP8266 chip. A shield with the RN2483A chip (up to 14 dBm of TX power), which implements both the physical and the MAC layers of the LoRaWAN standard, is connected to the WeMos board. These are supplied by a external power bank.



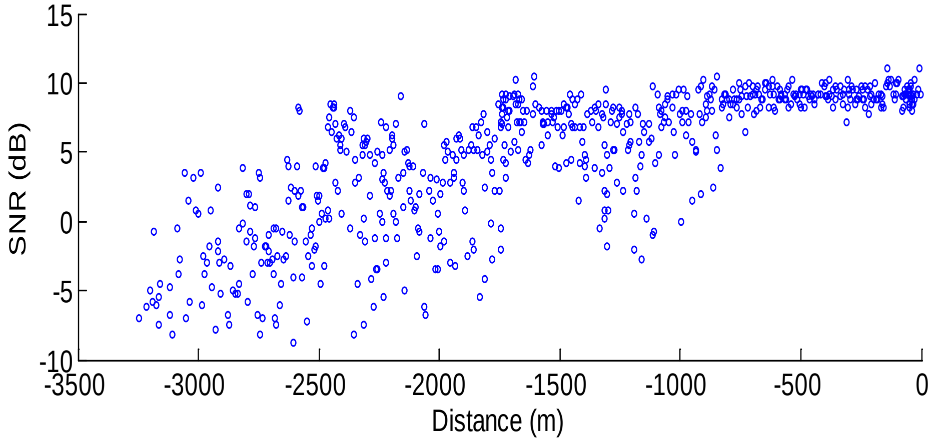
LoRa Server Architecture.

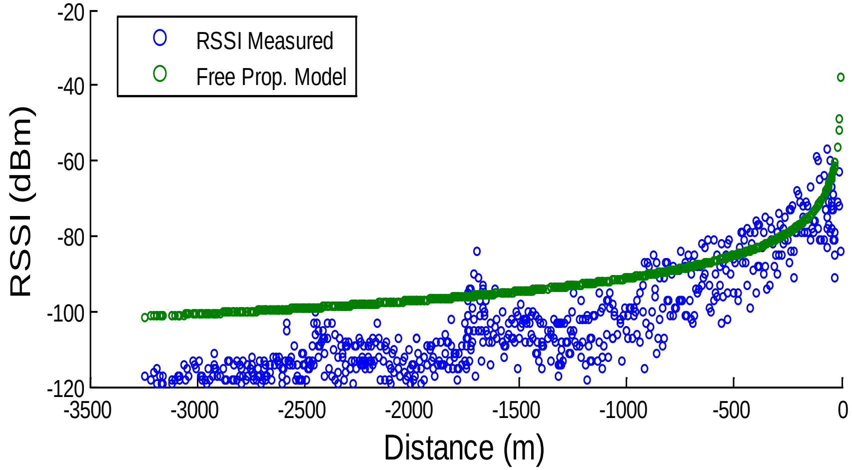


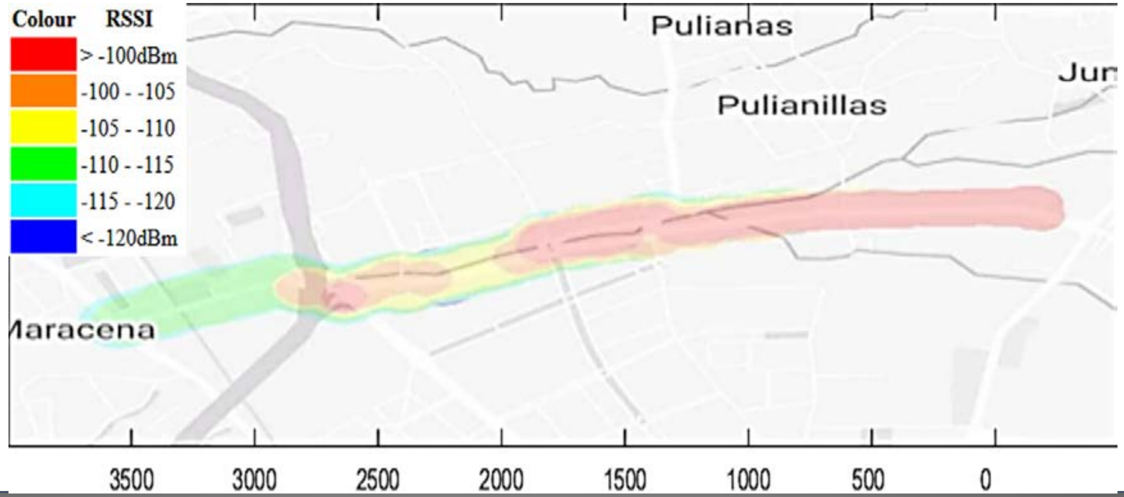
Highway Scenario

- The selected scenario is a road environment very similar to a highway.
- It has three lanes in each side and also, pedestrian and bike lanes which lets us walk to take the measurements.
- Measurements have been taken while walking. The evaluated parameters have been the SNR, the RSSI, the packets loss ratio and the coverage of the end-device.
- The road is place at the north area of Granada. The route has approx. 3.3 km with 74 m of gradient.
- The gateway, whose location is in (37.2136373, -3.5951833) geographical point, is placed on a bridge which crosses the road.

Highway Scenario Results



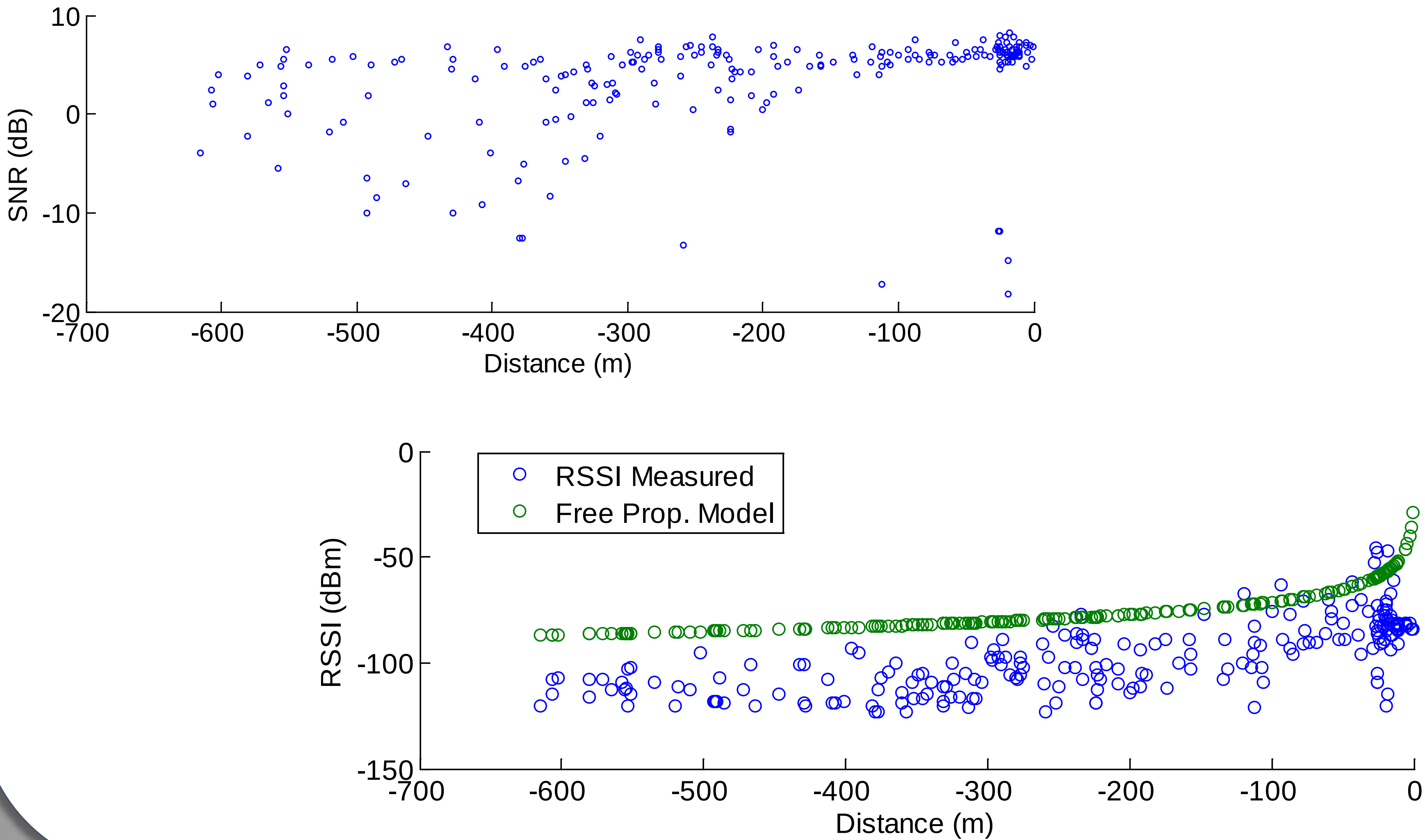




Coast Rural Scenario

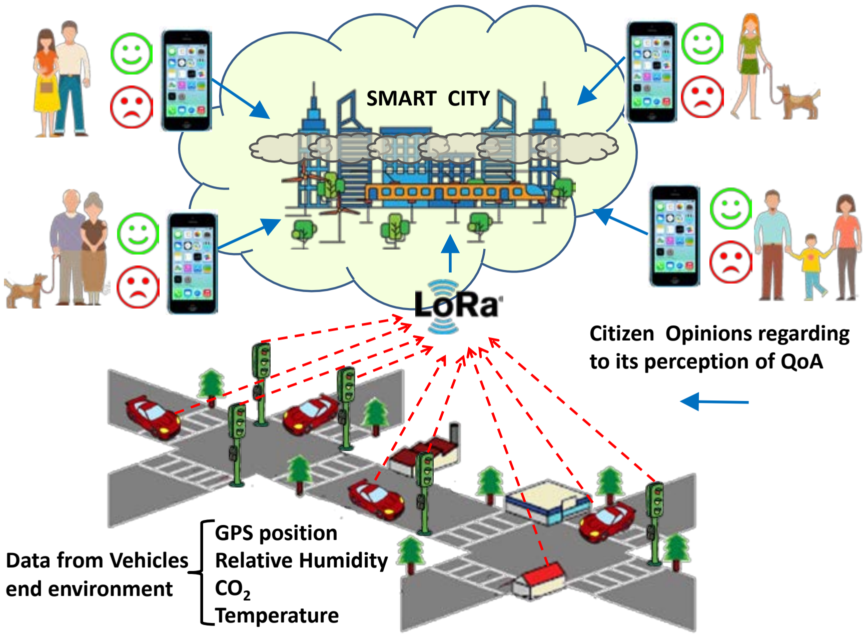
- The gateway with coordinates (38.932457, -0.099974) is placed on the terrace of a second floor house (~9m of height).
- The building is found at Oliva, a coast village of Valencia (Spain).
- The scenario is composed by several small houses and the climate conditions are also different (higher humidity).

Coast Rural Scenario Results



Collaborative LoRa-Based Sensor Network for Pollution Monitoring in Smart Cities

- Urban air pollution is a serious problem in many large cities on the planet.
- The intense traffic, together with factories that do not control their emissions, turns the air of cities of the world into clouds of smog.
- Air pollution will become the main environmental cause of premature mortality in the world.
- It is estimated that by 2050, the number of premature deaths resulting from air pollution will reach 3.6 million each year on the planet.
- Pollution deaths are usually linked to heart disease, stroke, or obstructive and chronic lung disease. It is also related to lung cancer and acute respiratory infections.



Collaborative LoRa-Based Sensor Network for Pollution Monitoring in Smart Cities

- Smart city →collaborative entity capable of combining data from different sources to make decisions and take measures to improve a situation.
- We focus our proposal on the control of pollution in cities. We consider: Wireless nodes based on LoRa
  - in vehicles
  - Fixed nodes installed in traffic lights and lampposts.
- Monitor the evolution of temperature, relative humidity and CO2 concentrations at the established points and combine all these data to build real-time maps of the evolution of these parameters.
- The proposed network becomes collaborative, as the opinion of citizens is introduced into the network and considered to make decisions on the actions to be taken.

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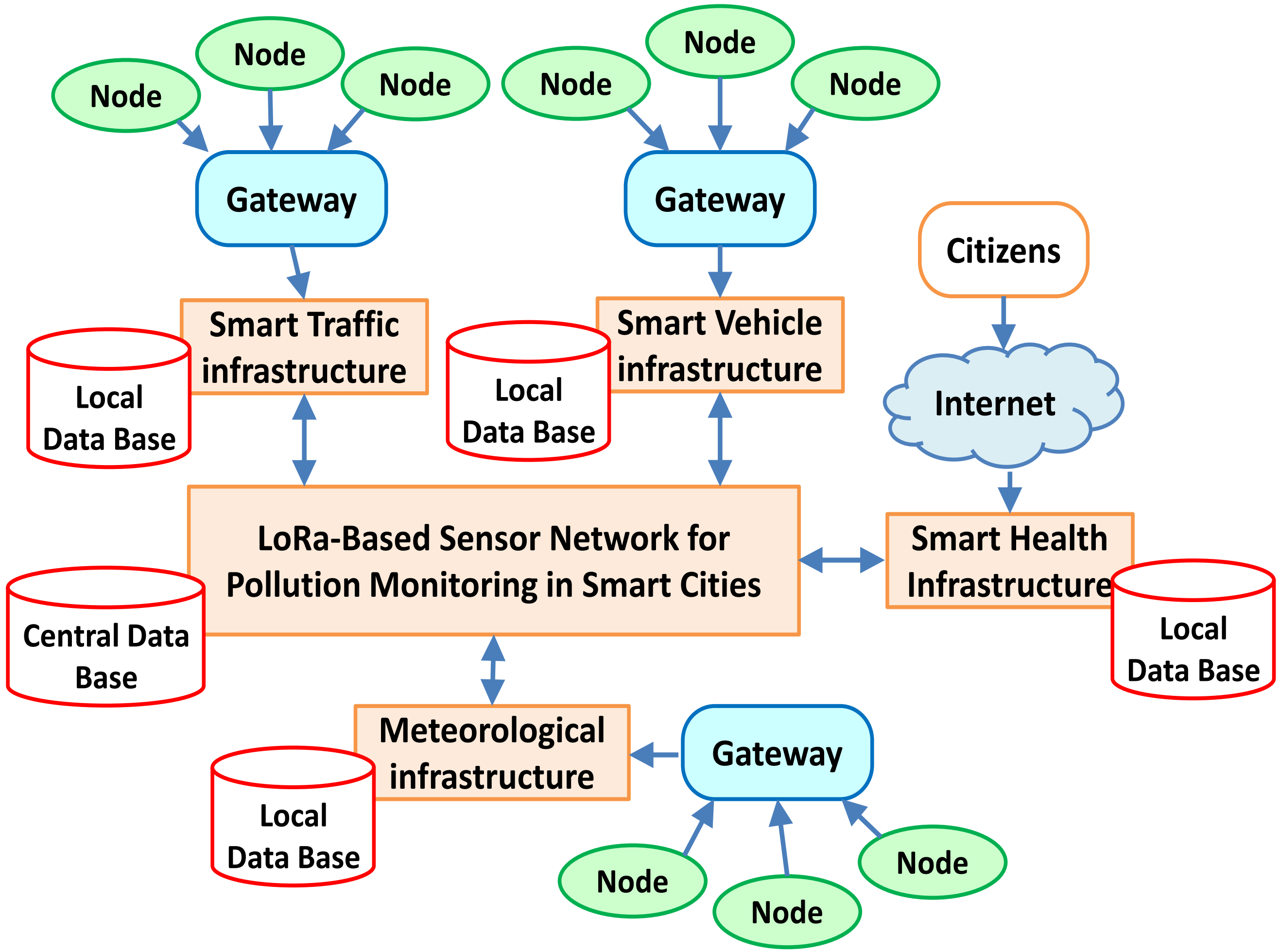
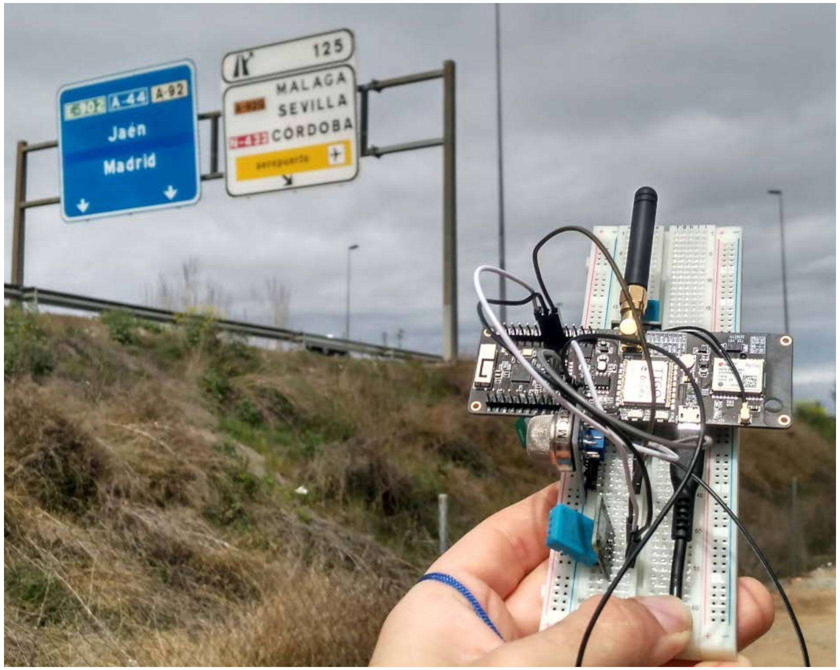
Smart City framework

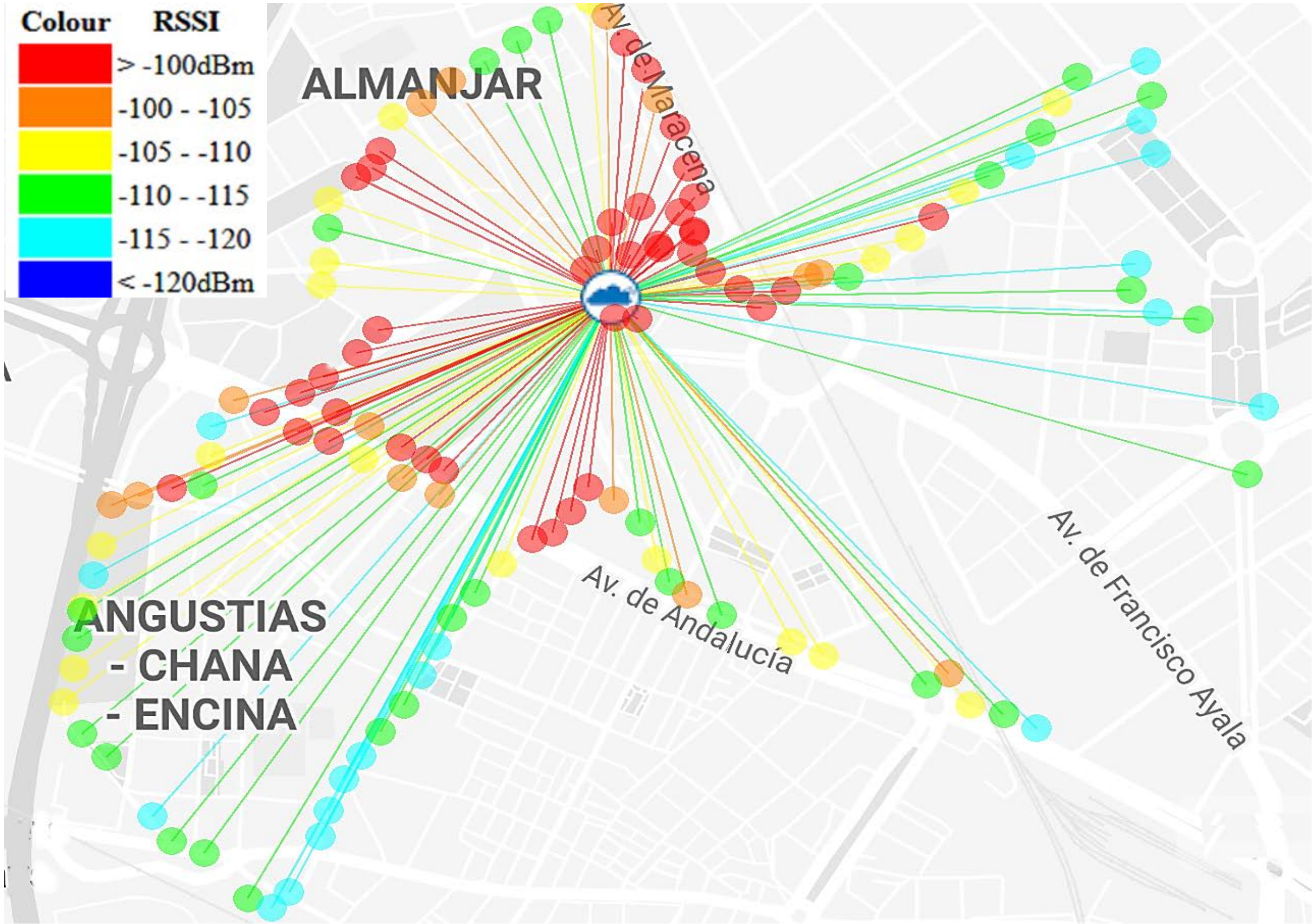


LoRa Node

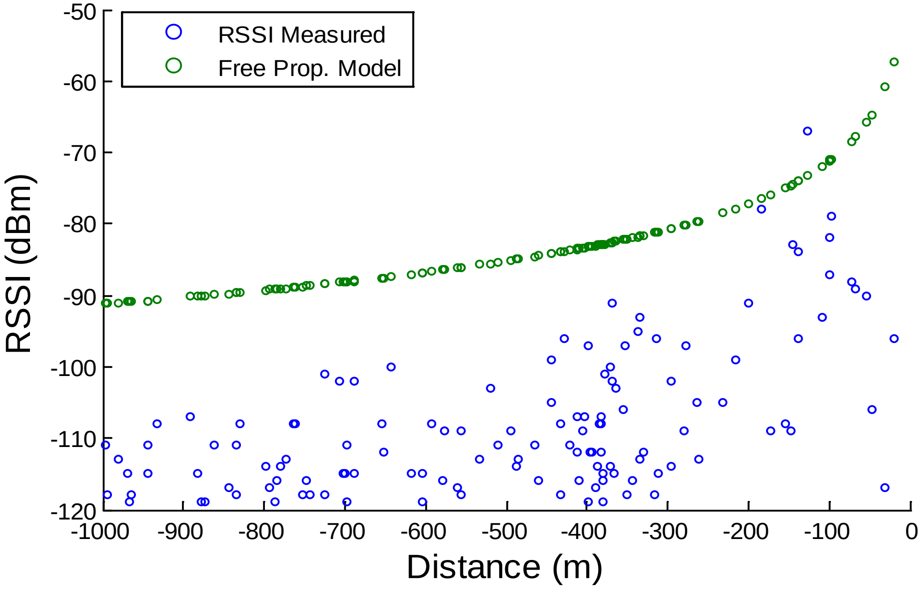
- To implement each node, we use a TTGO T-Beam node. It is built around the ESP32 chip. It has 4MB of SPI flash.
- It operates at 433 MHz, 868 MHz and 915 MHz, in our case we use the European ISM band at 868 MHz.
- Our TTGO T-Beam node includes two antennas. A GPS ceramic antenna connected to a u-bloc NEO-6M GPS module and another LoRa antenna with SMA connector.
- It uses a LoRa chip from the HopeRF RFM9X family. The node has a total of 26 pins with GPIO, ADC, VP/VN, DAC, Touch, SPI, I2C, UART and Lora.
- Finally, the node can be feed by batteries.

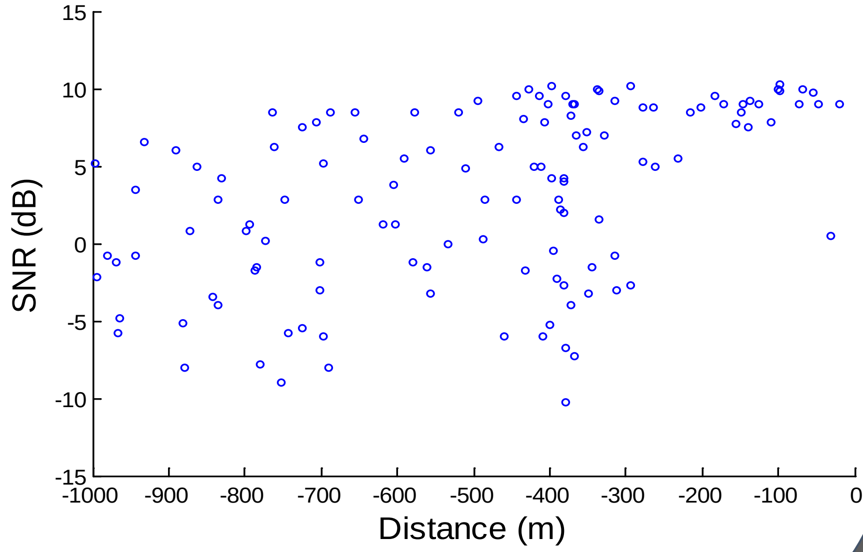


RSSI coverage over the measurement scenario

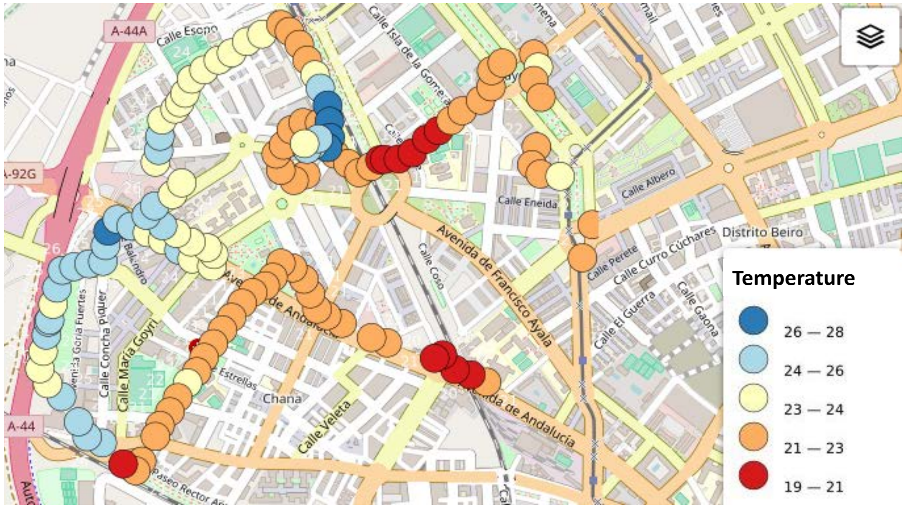


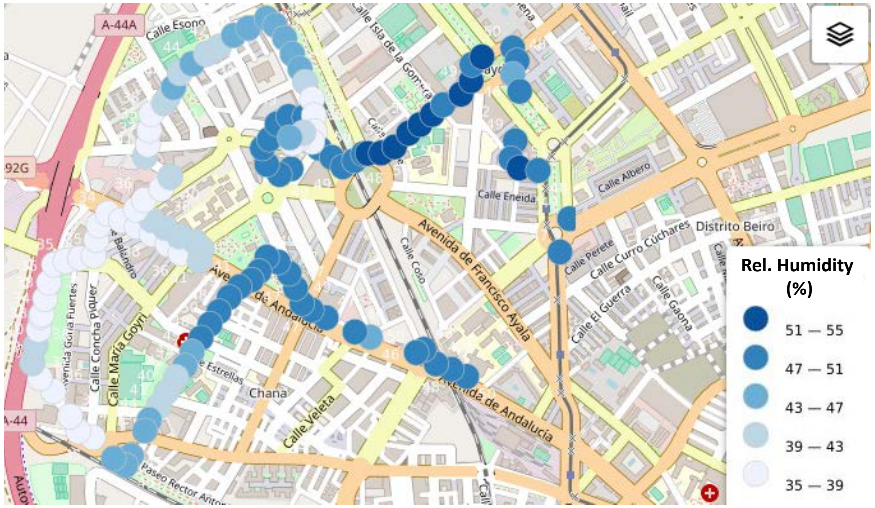
Network Measurements

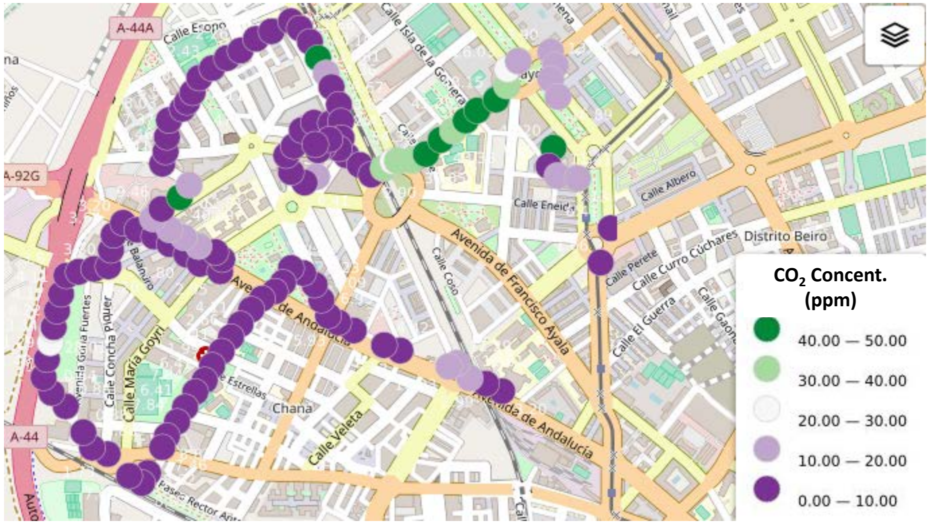




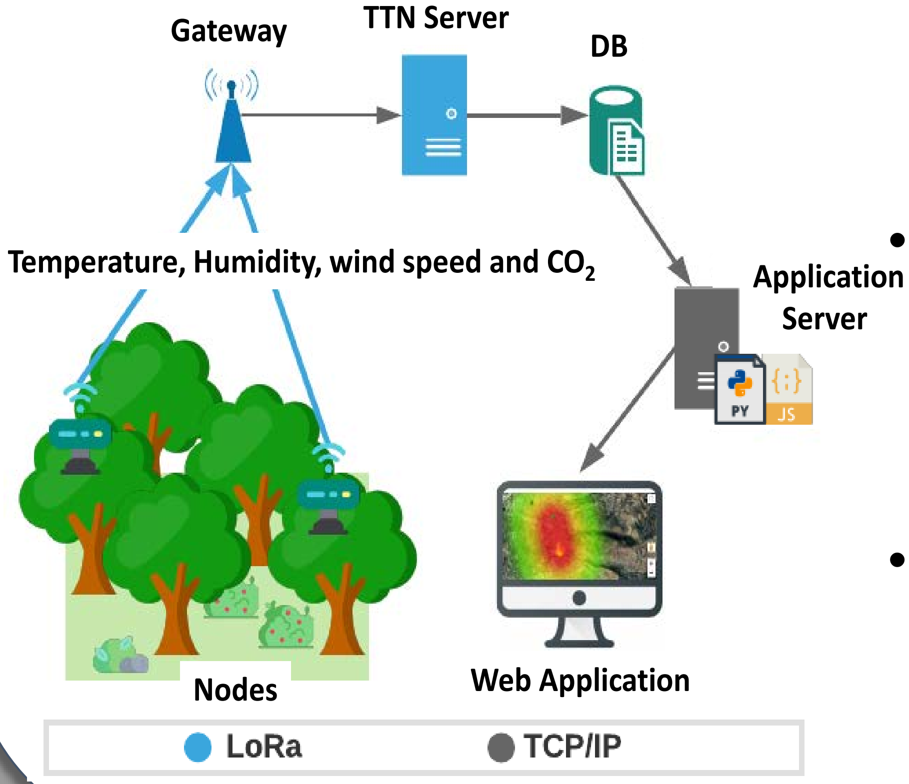
Environmental parameters





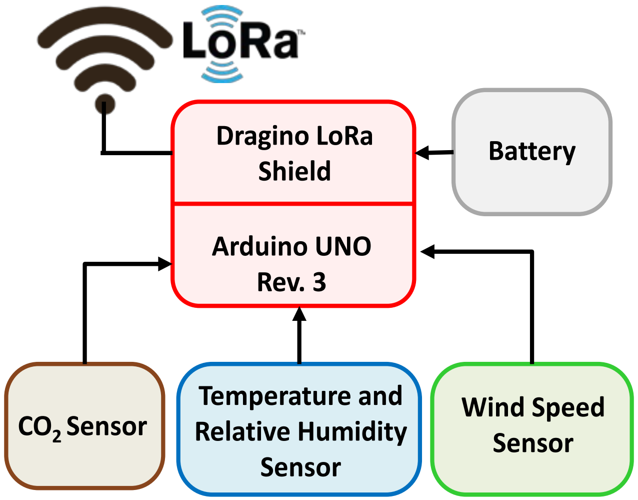


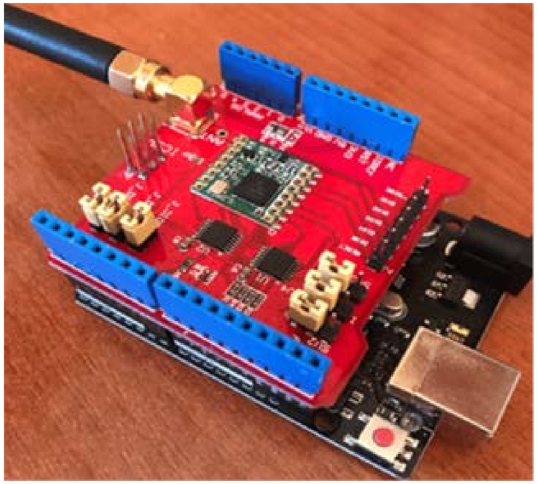
Low Cost LoRa based Network for Forest Fire Detection



- The system is composed by a set of LoRa nodes that collect information on relative humidity, temperature, wind speed and concentration of CO_2.
- These values will be sent to the TTN server through the LoRa gateway to finally be stored in the DB.
- The application server will perform requests to the DB and after processing the values, they will graphically representation on a website.

LoRa node

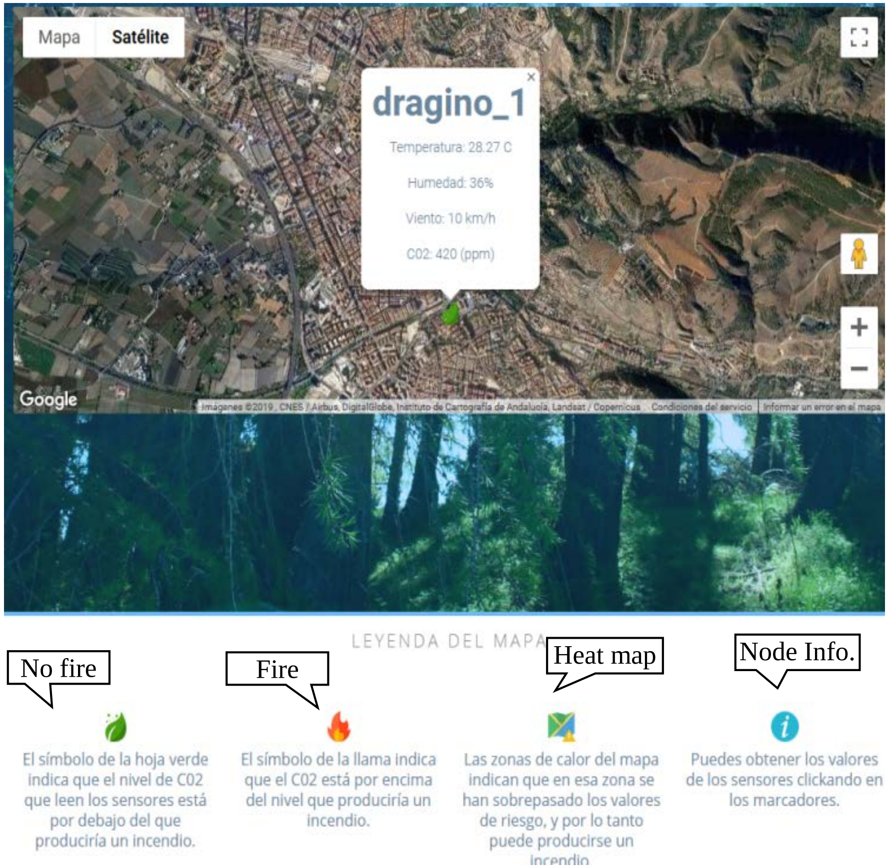


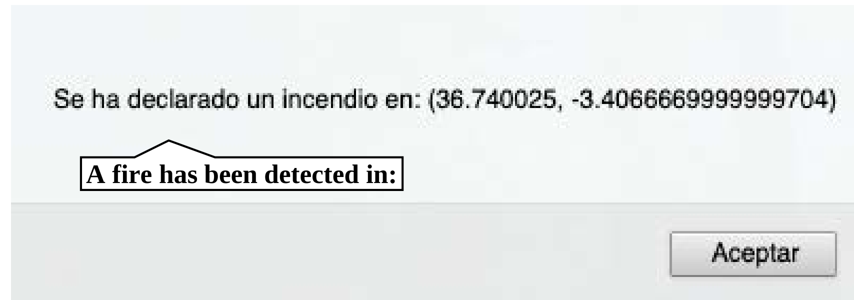


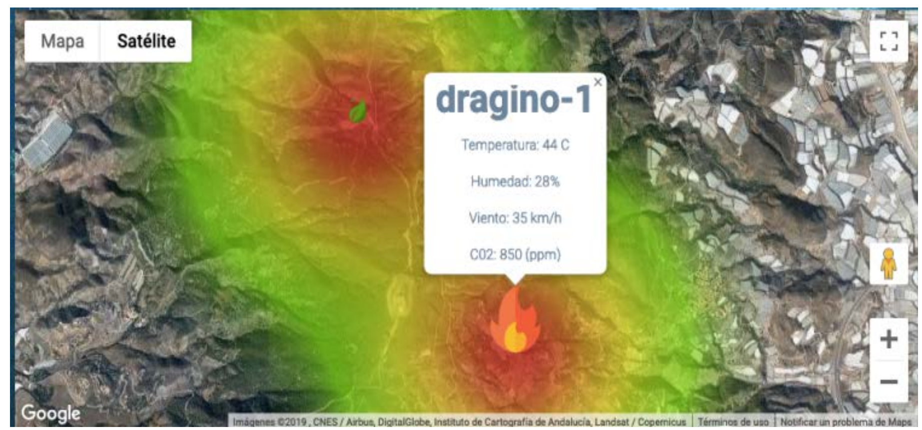
- Arduino Uno Rev3 module, which has a Microchip ATmega328P microcontroller and it is used to process the data. It has 14 digital inputs/outputs and 6 of them can be used for PWM outputs. It also has 6 analog inputs, a 16MHz oscillator and 32 KB of Flash Memory, 2 KB of SRAM and 1KB of EEPROM.

- Dragino LoRa Shield board compatible with our Arduino development board that incorporates the RFM95W transceiver with the SX1276 chip from Semtech. It will allow us the use of LoRaWAN modulation to establish the communication between devices. Our model is factory configured to work in the 868 MHz frequency band.

Web interface







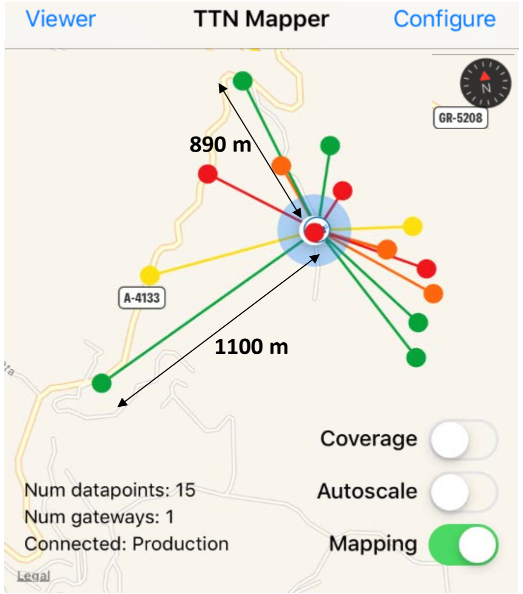
Results

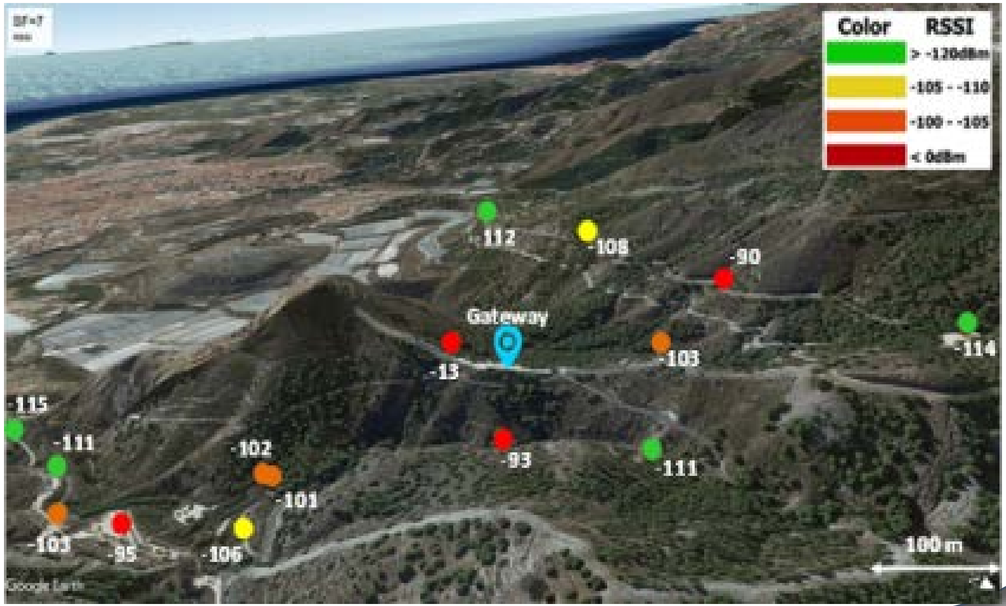
- The tests have been performed in a real environment.

  - LoRa coverage in rural environment.
  - Data from sensors

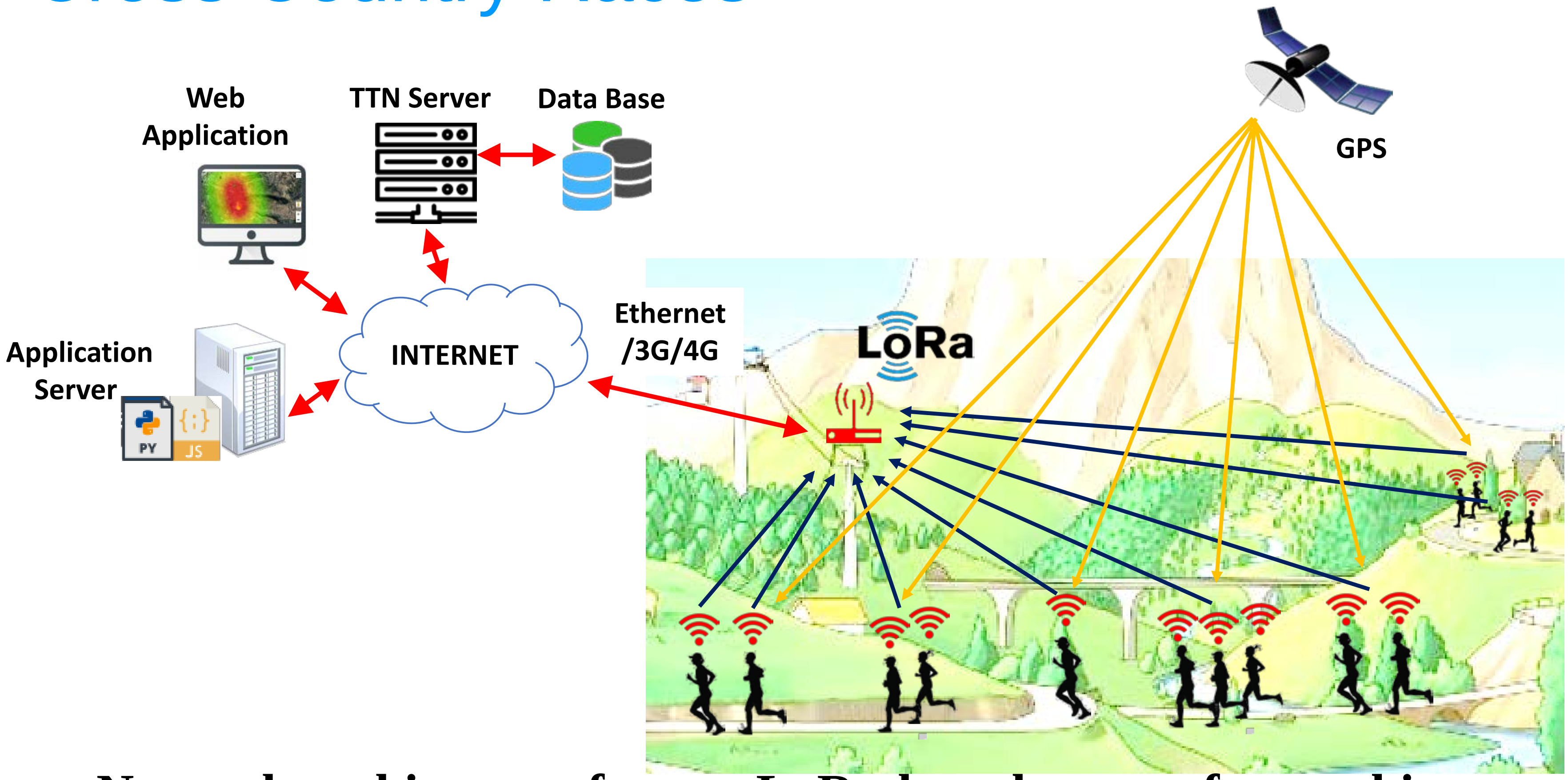
LoRa coverage in rural environment.

- A LoRa network like the one implemented in this proposal is capable of covering an area of approximately 314 ha (3,141,592.65 m2) which is equivalent to having a circular area of 1km radius.
- The LoRa technology would allow us to cover areas of up to 4km in scenarios where we have no obstacles.
- The scenario analyzed has large plant masses that cause a large dispersion in the signal.





LoRa-Based System for Tracking Runners in Cross Country Races



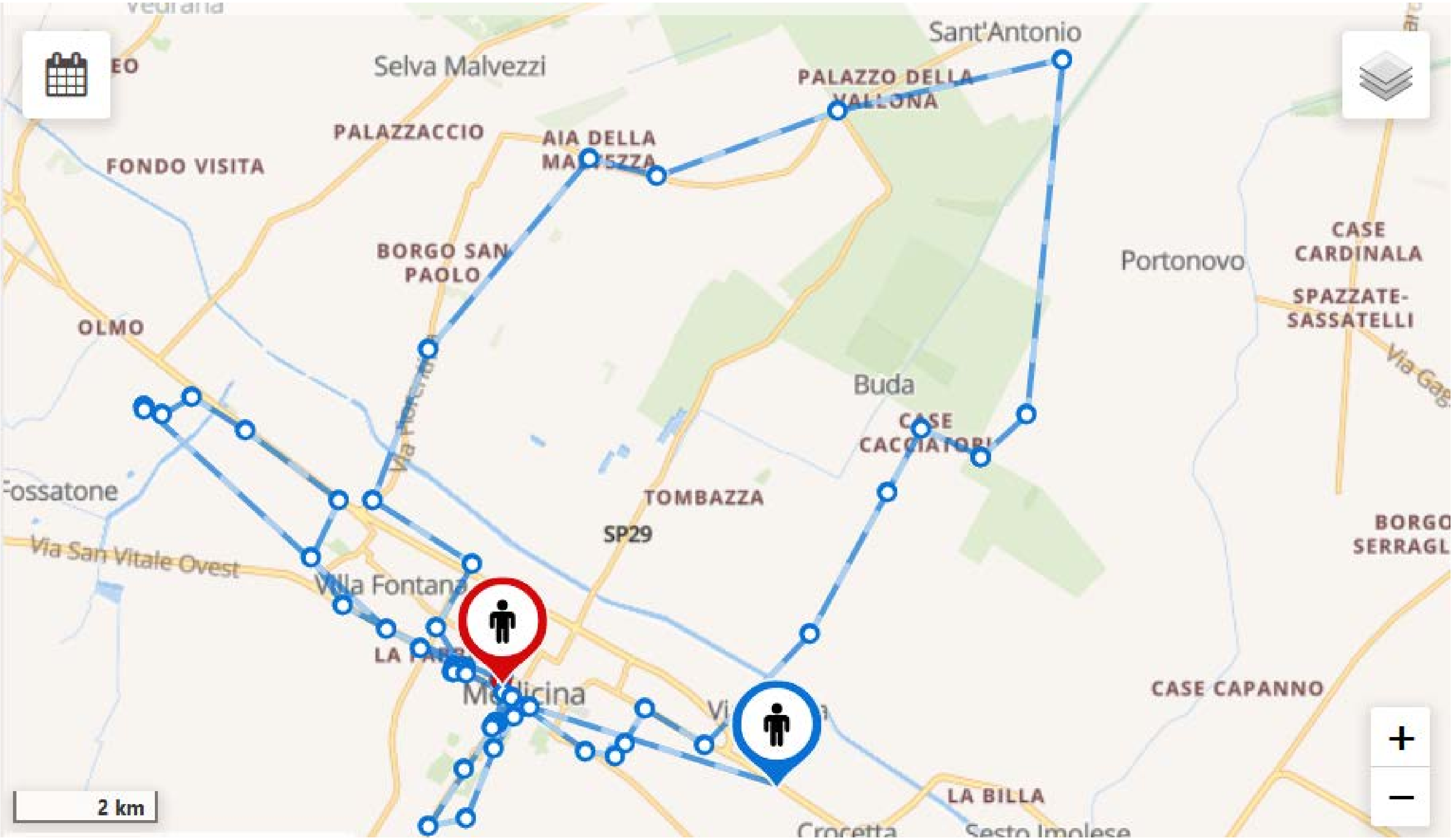
Network architecture for our LoRa-based system for tracking

Hardware used

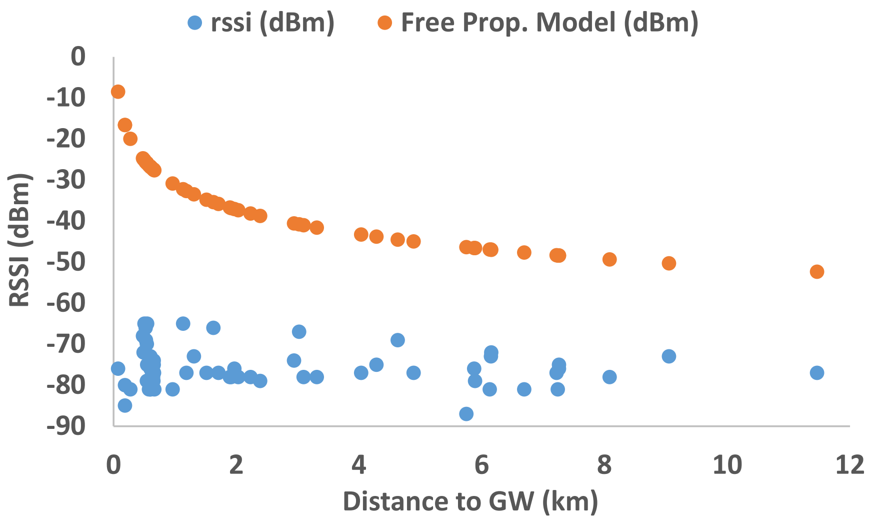
RAK2245 module with a RaspBerry Pi board

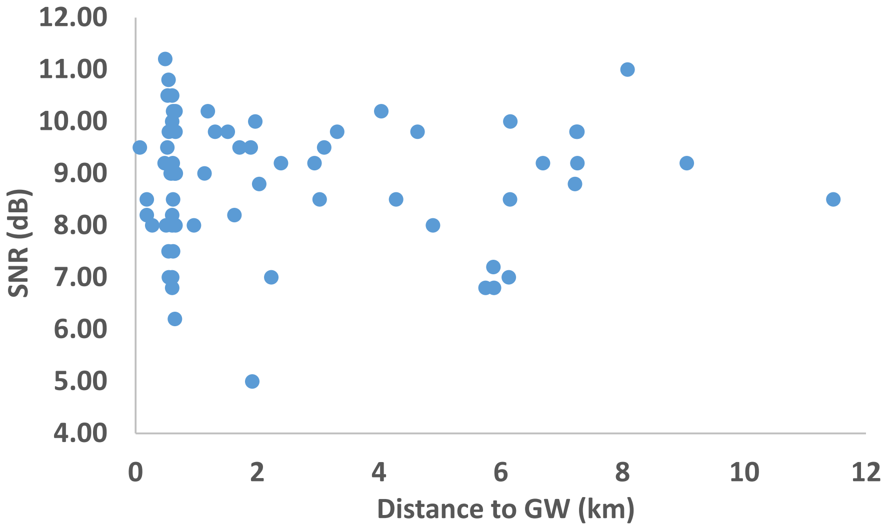
Dragino LoRaWAN GPS Tracker LGT-92

Results


Sant'Antonio
Selva Malvezzi
PALAZZO DELLA
PALAZZACCIO
AIA DELLA
FONDO VISITA
BORGO SAN
PAOLO
Portonovo
CASE
CARDINALA
SPAZZATE-
SASSATELLI
OLMO
Buda
TOMBAZZA
SP29
Via San Vitale Ovest
CASE CAPANNO
LA BILLA
2 km

Results


rssi (dBm)
Free Prop. Model (dBm)
RSSI (dBm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
2
4
6
8
10
12
Distance to GW (km)

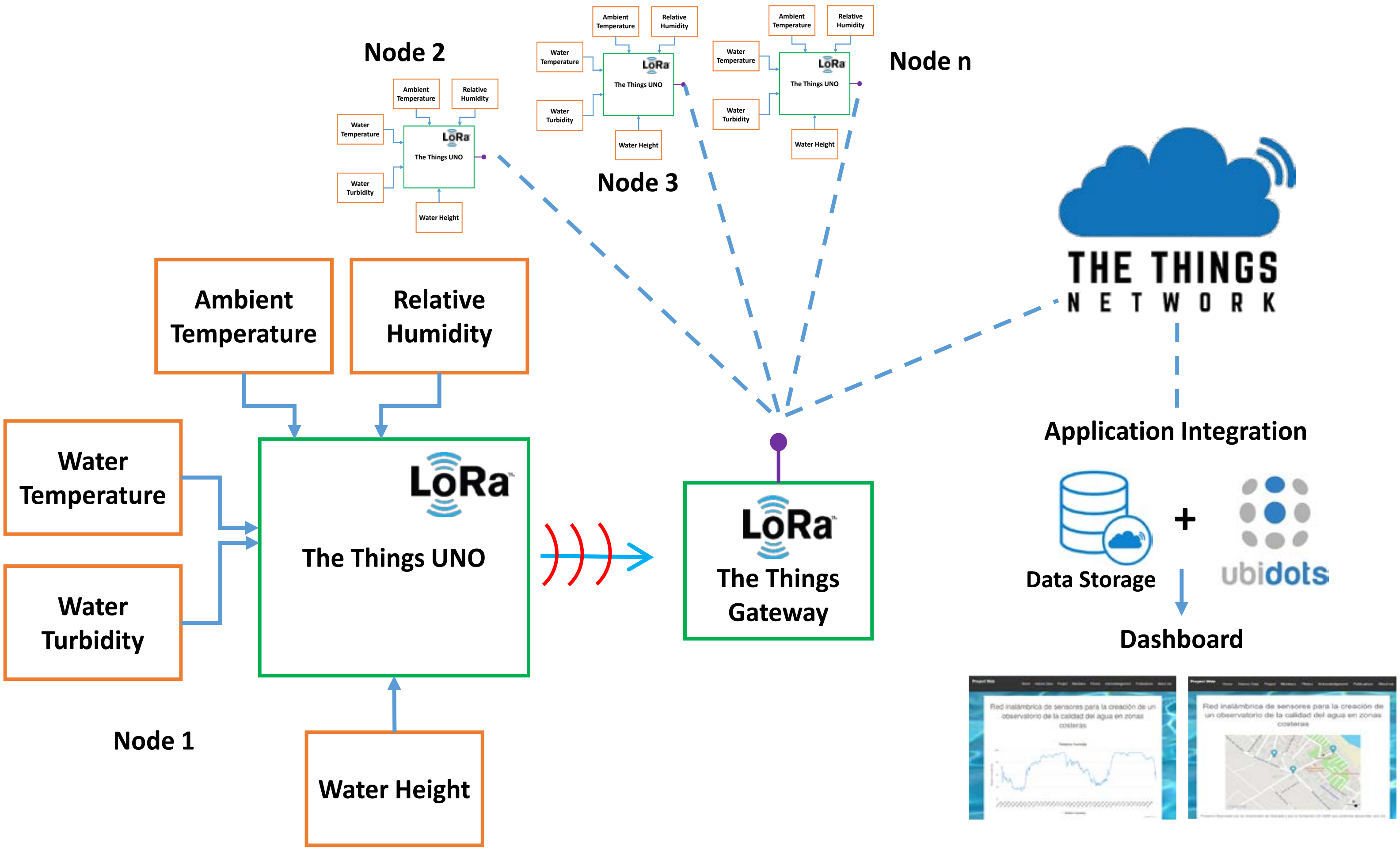

SNR (dB)
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
0
2
4
6
8
10
12
Distance to GW (km)

Wireless Sensor Network to Create a Water Quality Observatory in Coastal Areas

- Spain has approximately 8,000 kilometres of coastline.
- Multiple areas classified as protected natural spaces.
- High ecological value due to their biodiversity.
- A large part of the coastal population depends economically on coastal areas due to the presence of tourism and the productive activities carried out there.
- More than 600 facilities: marinas, yacht clubs, and nautical and sport stations.
- Professional activities: aquaculture and fishing

- Different press publications highlighted problems in the quality of bathing water in coastal areas.
- Given the current situation and the constant publications of news regarding the poor quality of certain waters,
- Necessary to apply corrective measures to try to solve and minimize the environmental impact that we are observing.
- Qualify any type of anomalies in our waters and environments that worsen their quality.
- This can be solved by using strategically located wireless sensor networks (WSNs) that continuously monitor water and atmospheric quality.

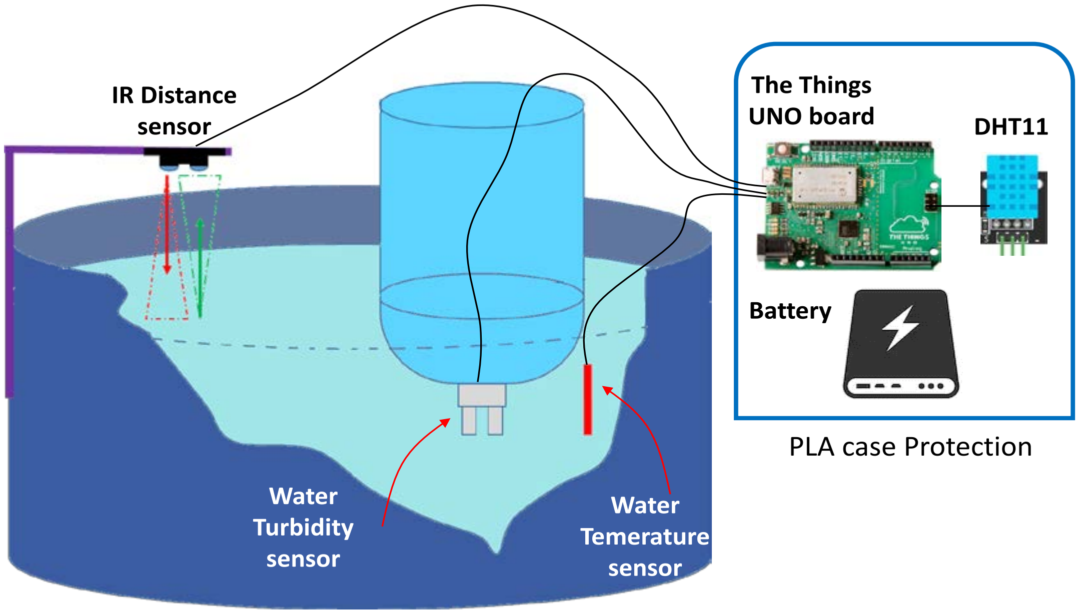
Proposed system



- The creation of these observatories is extremely useful for the application of Big Data techniques and artificial intelligence algorithms to improve the sustainability of a productive area or sector.
- These decisions will be directly related to the adequacy of the recommendations for the quality of coastal waters in port areas.
- The developed system will be deployed in a controlled environment for its testing and proper commissioning.
- Promote the tourist activity in an area, bringing what is known as “blue tourism” and ensuring that aquatic activities are carried out in excellent quality waters.
- Collected data can be displayed through a web portal → citizens have real-time access to the state of the waters and feel part of this project, to help preventing the pollution of our natural spaces.

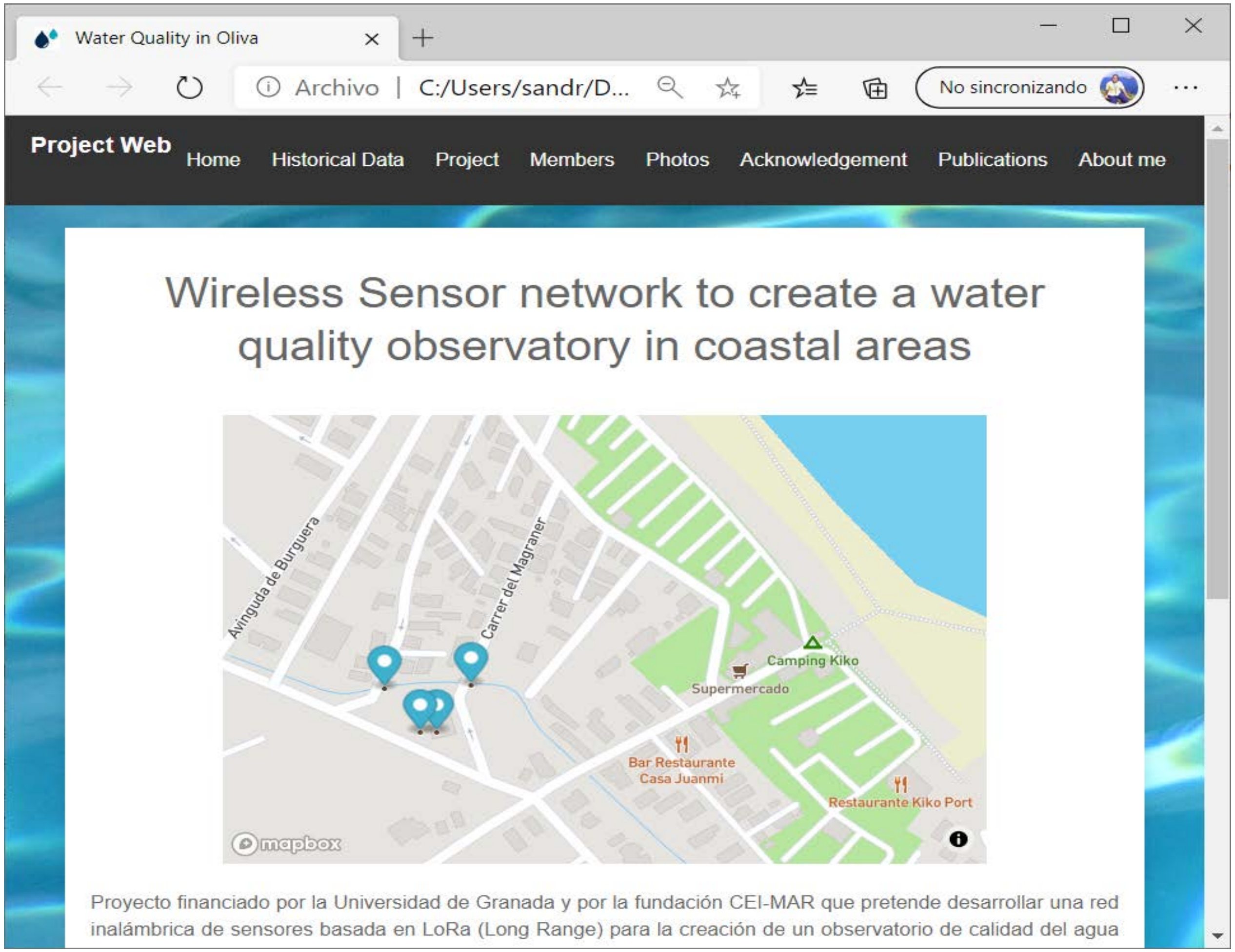
Hardware

LoRa Gateway and Nodes used to deploy our network



LoRa Gateway and Nodes used to deploy our network

Web-based User Interface



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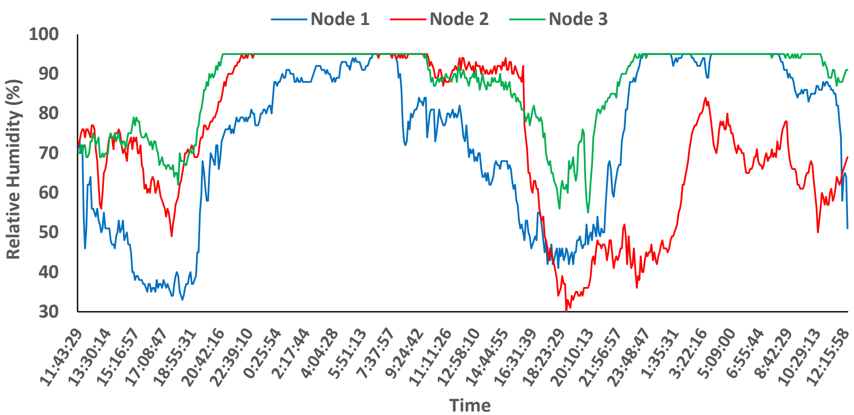
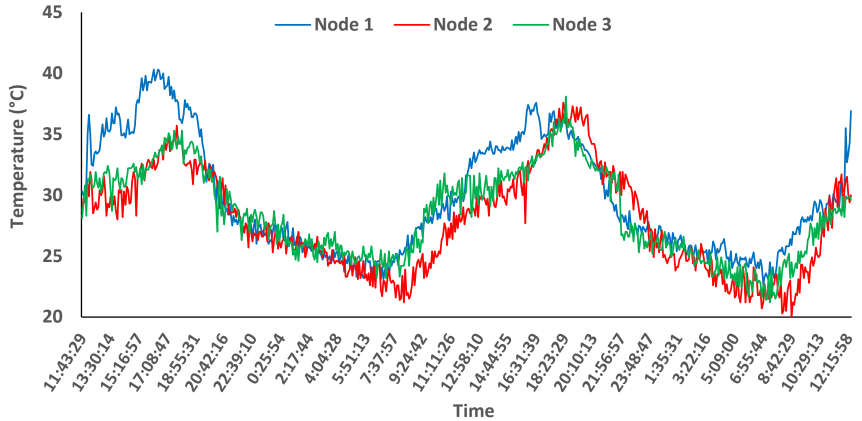
Results

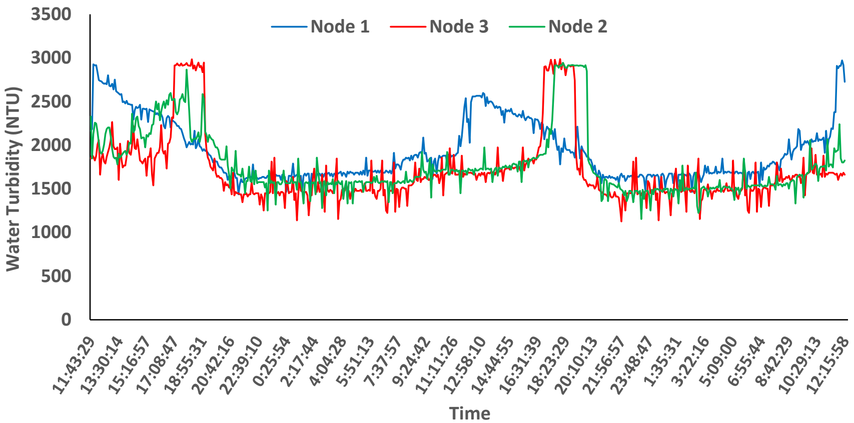
Results



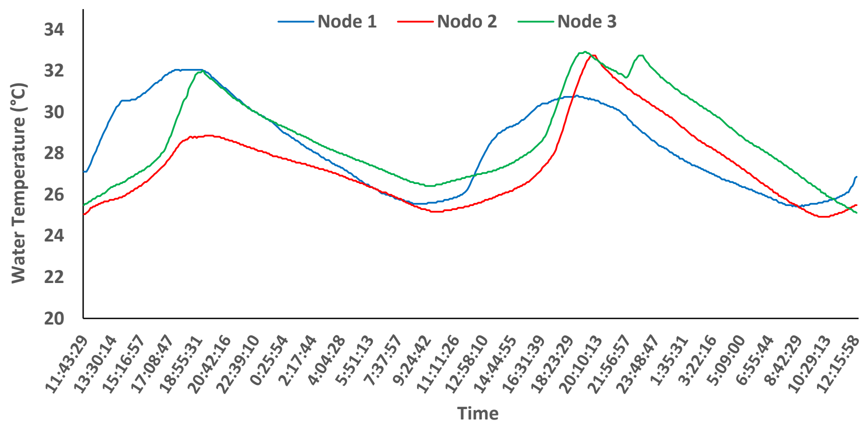
Node 1
Node 2
Node 3
Relative Humidity (%)
100
90
80
70
60
50
40
30
11:43:29 13:30:14 15:16:57 17:08:47 18:55:31 20:42:16 22:39:10 0:25:54 2:17:44 4:04:28 5:51:13 7:37:57 9:24:42 11:11:26 12:58:10 14:44:55 16:31:39 18:23:29 20:10:13 21:56:57 23:48:47 1:35:31 3:22:16 5:09:00 6:55:44 8:42:29 10:29:13 12:15:58
Time



Node 1
Node 2
Node 3
Temperature (°C)
45
40
35
30
25
20
11:43:29 13:30:14 15:16:57 17:08:47 18:55:31 20:42:16 22:39:10 0:25:54 2:17:44 4:04:28 5:51:13 7:37:57 9:24:42 11:11:26 12:58:10 14:44:55 16:31:39 18:23:29 20:10:13 21:56:57 23:48:47 1:35:31 3:22:16 5:09:00 6:55:44 8:42:29 10:29:13 12:15:58
Time



Node 1
Node 3
Node 2
Water Turbidity (NTU)
3500
3000
2500
2000
1500
1000
500
0
11:43:29 13:30:14 15:16:57 17:08:47 18:55:31 20:42:16 22:39:10 0:25:54 2:17:44 4:04:28 5:51:13 7:37:57 9:24:42 11:11:26 12:58:10 14:44:55 16:31:39 18:23:29 20:10:13 21:56:57 23:48:47 1:35:31 3:22:16 5:09:00 6:55:44 8:42:29 10:29:13 12:15:58
Time

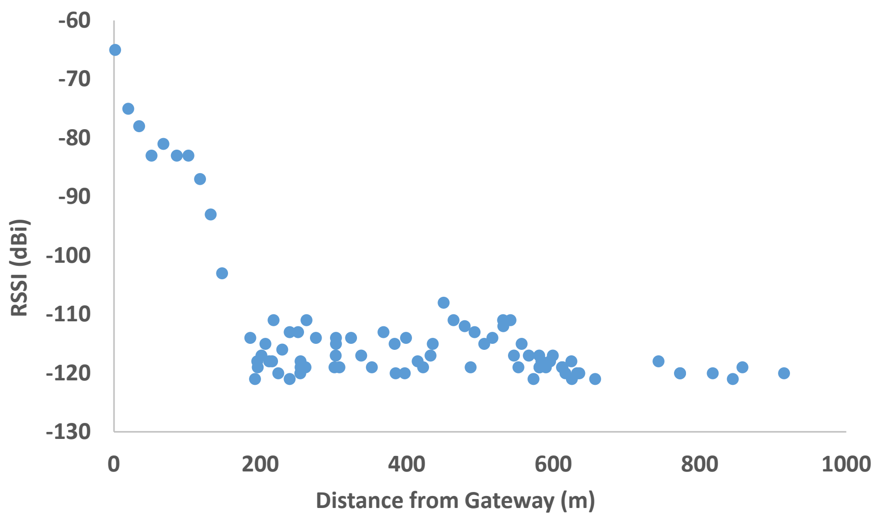


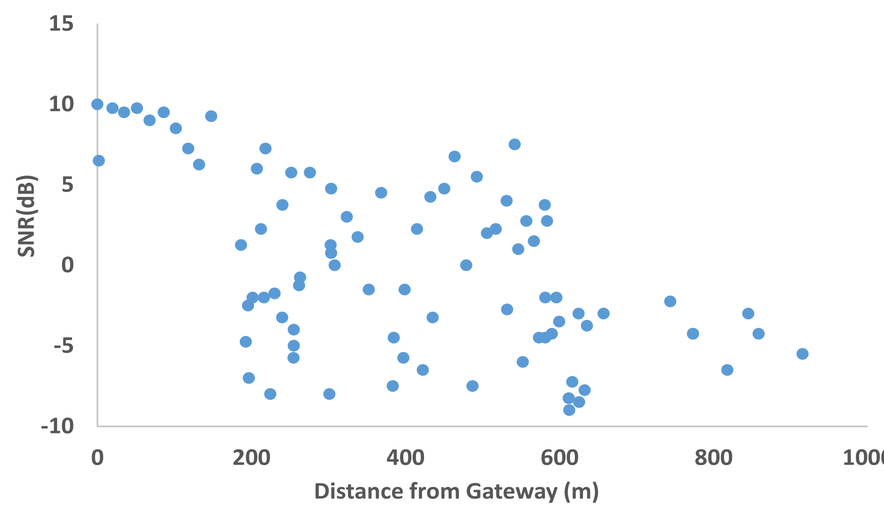
Node 1
Nodo 2
Node 3
Water Temperature (°C)
34
32
30
28
26
24
22
20
11:43:29 13:30:14 15:16:57 17:08:47 18:55:31 20:42:16 22:39:10 0:25:54 2:17:44 4:04:28 5:51:13 7:37:57 9:24:42 11:11:26 12:58:10 14:44:55 16:31:39 18:23:29 20:10:13 21:56:57 23:48:47 1:35:31 3:22:16 5:09:00 6:55:44 8:42:29 10:29:13 12:15:58
Time

Results

Colour
Signal
strong→
> -100 dBm
-100 - -105
-105 - -110
-110 - -115
-115 - -120
←weak
< -120 dBm

Results


-60
-70
-80
-90
-100
-110
-120
-130
RSSI (dBi)
0
200
400
600
800
1000
Distance from Gateway (m)


15
10
5
0
-5
-10
SNR(dB)
0
200
400
600
800
1000
Distance from Gateway (m)

References

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