CAPTOR

Collective Awareness Platform for Tropospheric Ozone Pollution

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Authors
Santiago Rodrigo-Muñoz, Oscar Trullols, Aina Soler-Galvez,
Jose M. Barcelo-Ordinas, Jorge Garcia-Vidal (UPC)
Kun Mean Hou, Hongling Shi, Xunxing Diao, Jianjin Li, Christophe de Vaulx and Tian Bin (UCA)

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List of Abbreviations

AC	Alternating current
API	Application Programming Interface
DIY	Do It Yourself
GUI	Graphical User Interface
LAN	Local Area Network
mAh	mili-Ampere-hour
NO2	Nitrogen Dioxide
O3	Ozone
QoS	Quality of Sercivce
QR code	Quick Response code
PVC	PolyVinyl Chloride
Vcc	IC power-supply pin

Executive Summary

Description of the work

This deliverable is an extension of Deliverable D2.2.(a) that described how to build the nodes we use for monitoring purposes following the DIY (Do It Yourself) philosophy. Each node is composed by a communications subsystem and a sensing subsystem that are packed in a waterproof box. The main target is that citizens with low knowledge on technology are able to build their own monitoring nodes.

We consider two versions of monitoring nodes:

- **Captors**: are based on the Arduino platform and use Metal Oxide sensing devices. We consider them easier to build, but probably not as accurate or reliable as the other model.

  This type of node was deployed during the first campaign and will also be deployed during the second campaign. During the first campaign and in the new design some new features have been added based on the experience obtained during the first campaign.

- **Raptors**: are based on the Raspberry-Pi 3, uSu-Edu and use an electrochemical sensing device. The design is optimized for achieving a greater accuracy, reliability and low power (RAPTOR end-device is powered by standard battery) but they need more professional building process.

  This type of node was not deployed during the first campaign and will be deployed during the second 2017 summer campaign.

Objectives

This deliverable covers the following topics and issues:

- Description of the changes performed in Captor nodes for the 2017 summer campaign
- Description of the future work for improvements on both types of nodes

1. The DIY Captor v1.2 node

1.1. Differences with respect v.1.1 node

During the 2016 summer campaign it was observed the following problems with respect the v.1.1 captor version:

- When the captor node was moved from the Lab to the volunteer's home, some of the connections of the breadboard were disconnected or produced malfunctions. The consequence was that there were changes in the scale of the data, or even missing of data.
- Moreover, there were problems with the Wifi connections of some of the volunteers.
- Sometimes the database was collapsed due to several accesses from nodes, producing the loss of data.

The following solutions have been added in order to produce a most reliable node and solve the aforementioned problems:

- The breadboard has been substituted by a board where the components and wires are soldered.
- 3G USB connection with a global telecom operator has been added as main communication channel. The Wifi connection is kept as a secondary communication channel in case the 3G fails.
- Board and communication chipsets are fixed inside the box.
- A monitoring software has been built in order to be able to check on real time whether the node is disconnected.
- The software inside the node also has been upgraded to send the data to a CSV server in order not to block the database where the data is stored. From the CSV server, more reliable, the data is introduced to the database.

1.2 Electronic Board Sensor Circuit

In Del 2.2.(a) is described how to build a captor node using a breadboard. The description is in section 1.1 of that deliverable and comprises 19 steps. In order to substitute the breadboard by a electronic board sensor circuit, we follow the same first 13 steps as described in Del 2.2.(a). Then, we substitute from step 14 to step 19 by the following steps[1]:

14. First, we have to convert the circuit shown in figure 1 in a schematic prototype board. This scheme shows how resistors in figure 1 have to be interlinked in the electronic board.

[1] We keep the step numbering of Del 2.2.(a). That means that we go on from step 13 by substituting steps 14 to 19 by the ones described in this deliverable.

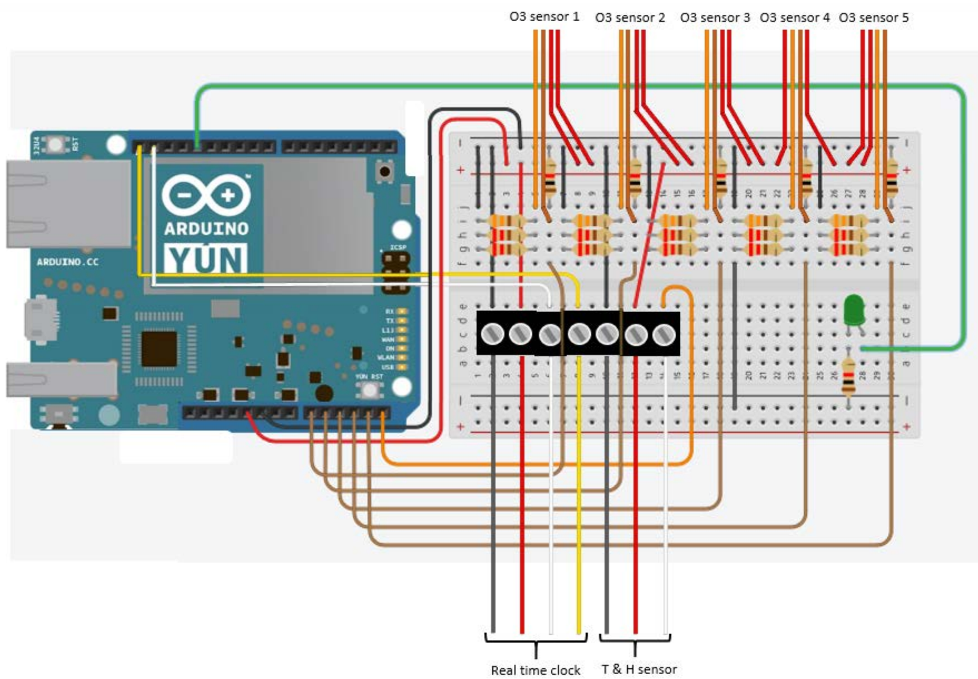


Figure 1 Breadboard circuit design

The following figure shows a proto-design that was first tested and that represents the same circuitry than the breadboard of figure 1. This design is performed using any free software for design of circuits, e.g., TinyCAD.

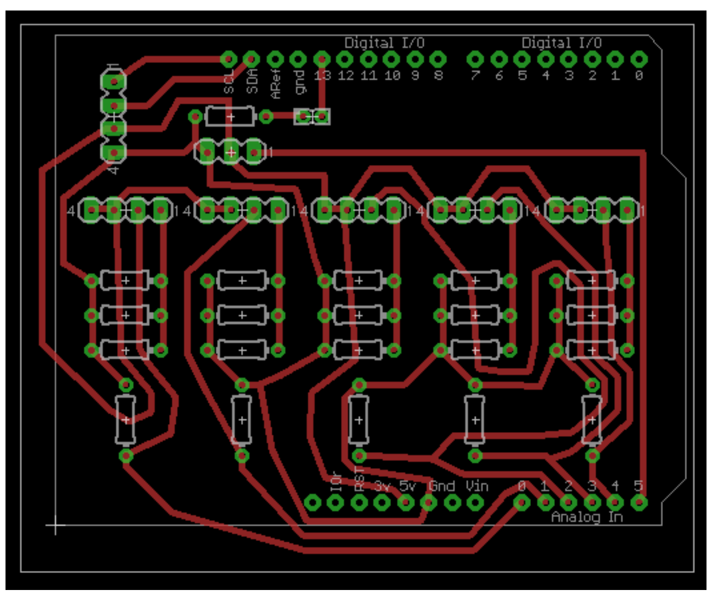


Figure 2 Electronic circuit design

Now there are **two possibilities for building the electronic board**: by hand (step 15) or sending the scheme to a manufacturer (step 16). The second option is useful if a specific number of boards are bought, since the cost given by manufactures in general are cheap if a minimum number of boards are built. In the CAPTOR project, since we have to build near 50 nodes, we ordered 75 boards, thinking that we may use some of them by the off-springs.

15. Board build by hand and final version when the board is connected to the Arduino board:

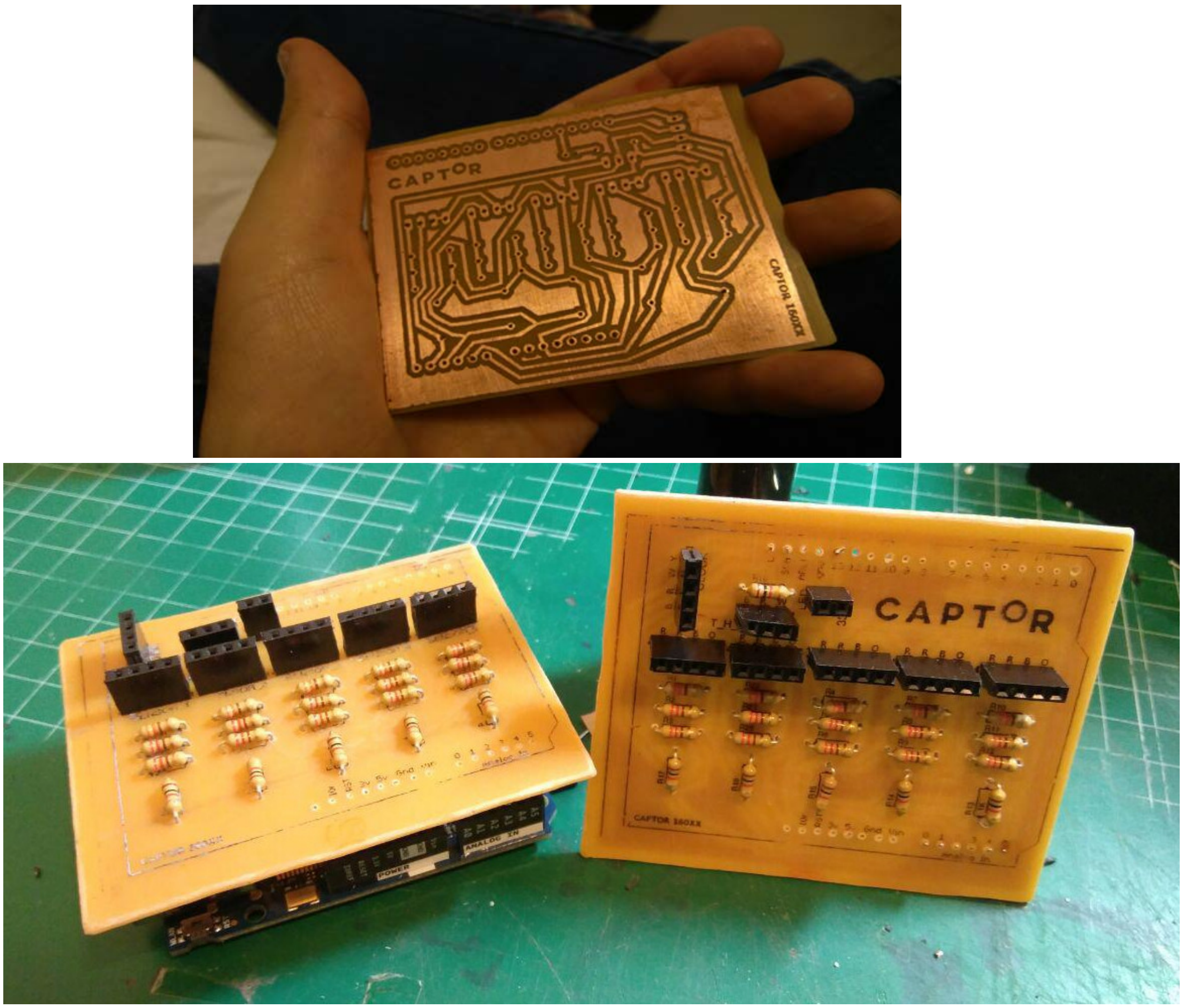


Figure 3. Board build by hand

16. Final Board design for the manufacturer:

    The first row are to plug male pin sockets that later will allow to connect to the Arduino board. The row of sockets labelled as “sensor_1” to “sensor_5” are for wiring the sensors as explained in step 11 of Del 2.2.(a). The sockets with a resistor drawn are for soldering a resistor (the same that in the broadboard).

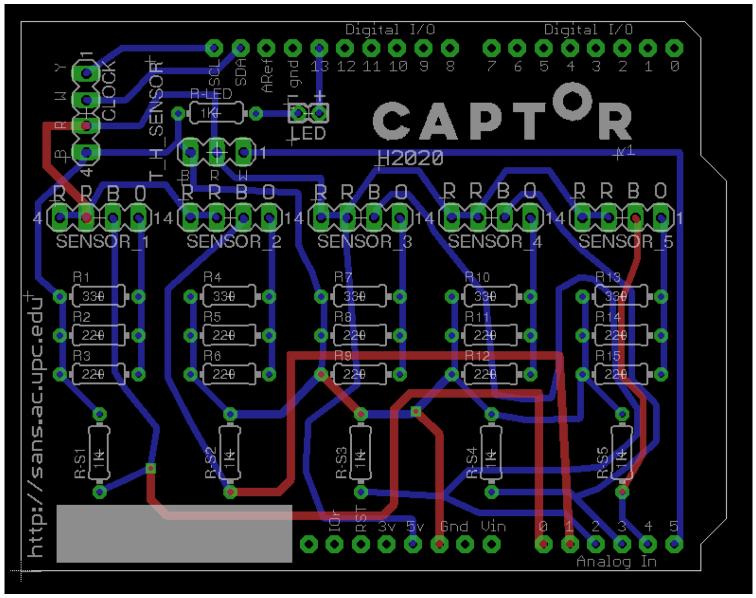


Figure 4. Board design sent to the manufacturer

17. Board delivered by the manufacturer and final version when connected to the Arduino.

Figure 5. Final electronic board circuit

Figure 6. Electronic board circuit mounted with the Arduino Yun

18. No the final step is to connect the wires of the sensors to each socket. The final captor node is shown in the following figure:

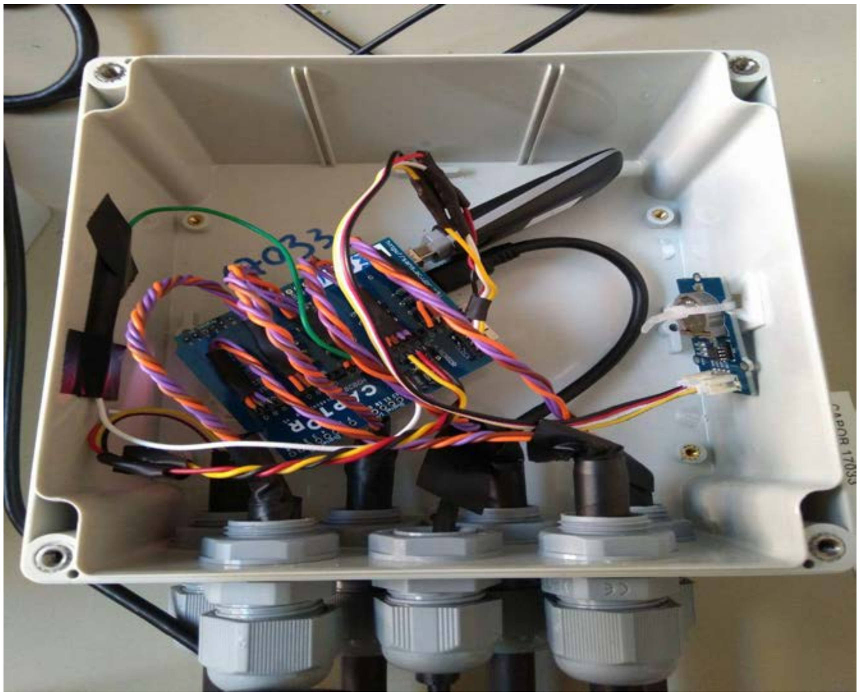


Figure 7. All hardware mounted on the box

The Hardware is ready. Now the Software is the same as in section 1.2 of Del 2.2.(a), steps 20 to 24.

As it can be seen in figure 7, instead of using a WiFi connector, a USB 3G connection is plugged to the Arduino socket. The only difference with the previous design now is that this USB have a SIM card with a Telecom company that assures the connectivity with the server. In our case, we have used emnify (https://www.emnify.com/) a company that provides connectivity for IoT devices across all Europe at low costs.

Finally, two software tools are added the management of the nodes. This software does not affect the building of the nodes, but help the administrators of the network to check the reliability of the connection.

The first one is a monitoring software that pings the node and checks that the node has Internet connectivity. The second one is a CSV server that clones the data sent by the node with respect the Commsensum database. This also is for reliability, since the introduction of data directly to the database sometimes had disruptions causing the loss of information.

These features are included in the release of the software to the users that build a captor node. Thus, when the user downloads the software as described in Del 2.2.(a), the new release send a copy of the data to the CSV server and allows pings from a monitoring server handle at UPC.

2. The new RaptorV2 platform

In this section we describe the improve RaptorV2 platform designed for the 2017 summer campaign by taking into account the requirements of all the captor partners: outdoor deployment facility standard and Raptor end-device lifetime (4 months).

2.1 RaptorV2 devices

The Raptor Platform prototype contains tree main devices: Raptor node or Raptor end-device, Multisupport Raptor Local server and Raptor remote server. In this second version, we updated all these three parts.

2.1.1 RaptorV2 node

Raptor node hardware

The RaptorV2 node hardware has an air temperature and humidity outdoor sensors (Figure 8). The air temperature and humidity values are needed to calibrate the O3 and NO2 values.

To meet the requirement of the 2017 summer campaign (4 months lifetime), we substituted the 2*4.5V standard 3LR12 battery by 6*1.5V standard LR20 battery (Figure 9). Moreover, to meet the outdoor (Raptor end-device) deployment requirement, new packaging of RAPTOR platform were designed (Figure 10). Note that the previous packaging on the Raptor was not easy to attach to an iron tube or bar for outdoor deployment. Therefore, the improvement of RaptorV2 hardware platform meets all requirements for 2017 summer campaign.

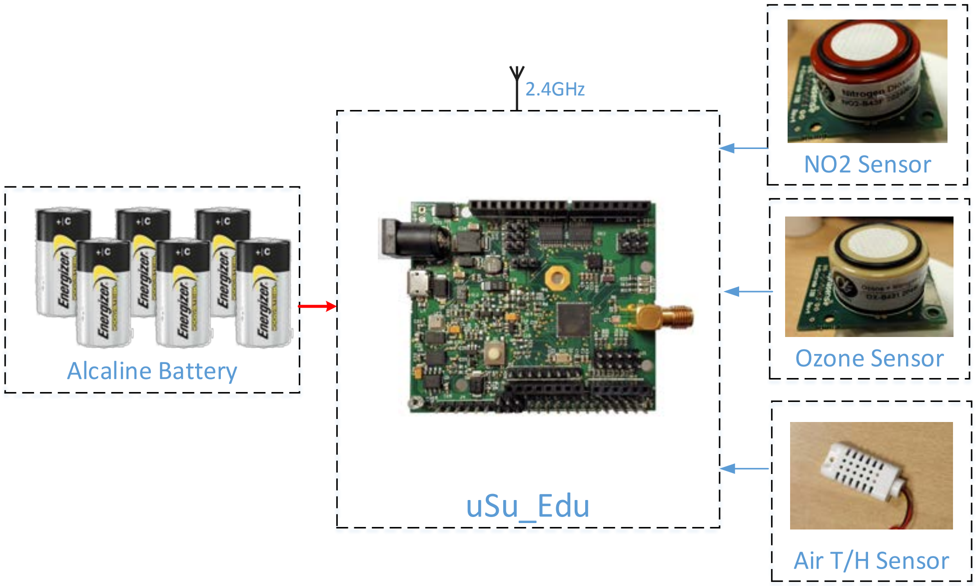


Figure 8. RAPTORV2 end-device hardware

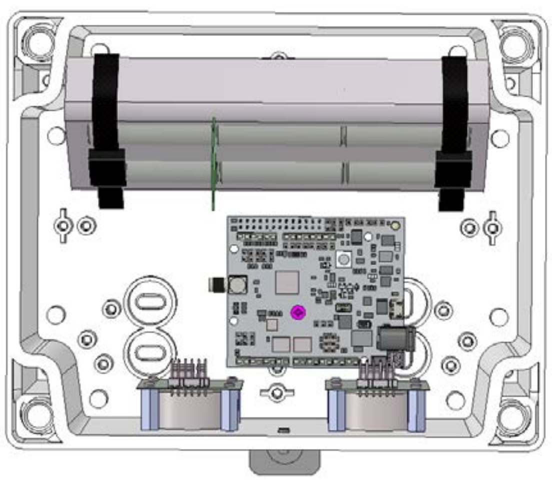


Figure 9. RAPTORV2 powered by 6*1.5V standard LR20 battery

Figure 10. New packaging of RAPTORV2 End-device for outdoor deployment

Raptor node V2 software

The new version of Raptor node V2 software fixes several bugs and supports new sensors: outdoor air temperature and humidity.

2.1.2 Multisupport RaptorV2 Local server

Multisupport RaptorV2 Local server hardware

New packaging of RAPTORV2 local server platform were designed to make it easier to attach 3G or 4G suction cup antenna (Figure 11).

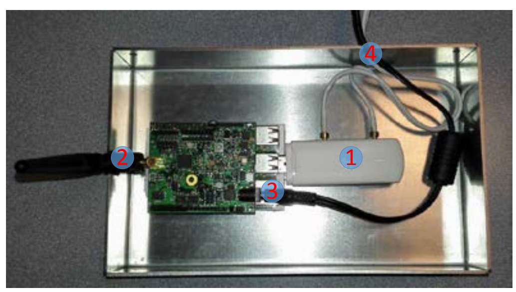


Figure 11. Multisupport Raptor Local server second version

Multisupport Raptor Local server software

We implement the specific firmware running on the uSu-Edu board to be served as coordinator to setup a star topology network. Each multisupport Raptor server can support 20 Raptor end-devices within a range of 50m to 200m (low cost antenna). Notice that this range may be increased by using appropriate antenna. To improve the robustness of the Multisupport Raptor Local server a heart-beat technique is adopted and developed to detect transient faults.

2.1.3 Remote Linux Server

To test and evaluate the performance of the Raptor platform all the sensory data and the QoS of Raptor platform must be analysed. The Figure 12 shows the global architecture of Raptor platform developed to support from sensor to end-user application. The figure 10 presents a user-friendly GUI structure to display the O3 and NO2 data on a smart phone by scanning the QR code assigned to each Raptor end-device. To achieve all the previous defined functionalities, the design and implementation of the remote server having the following functions:

- Remote server connection through LAN
- Data and error Log file
- Sensory data display
- Remote Raptor end device failure detection.

This remote server is based on a PC server running Linux.

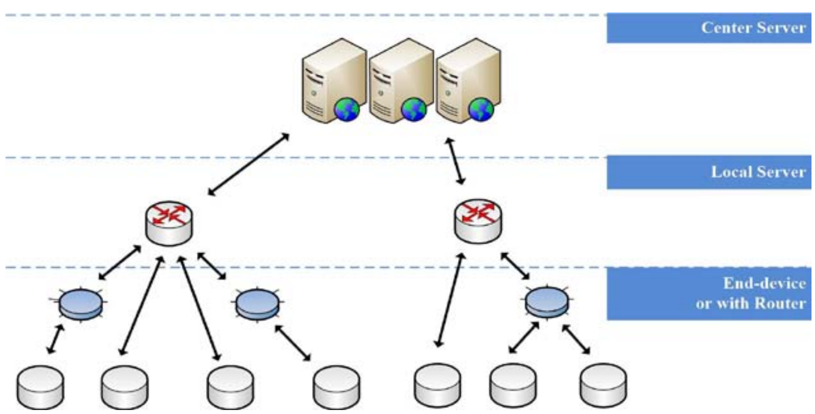


Figure 12. RAPTOR platform architecture

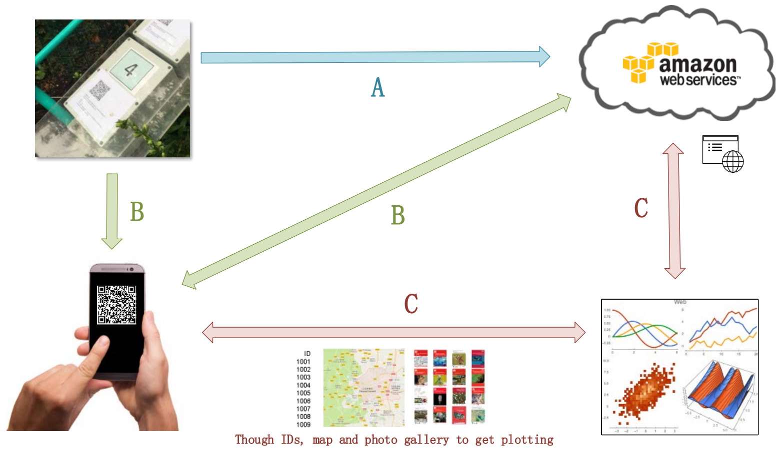
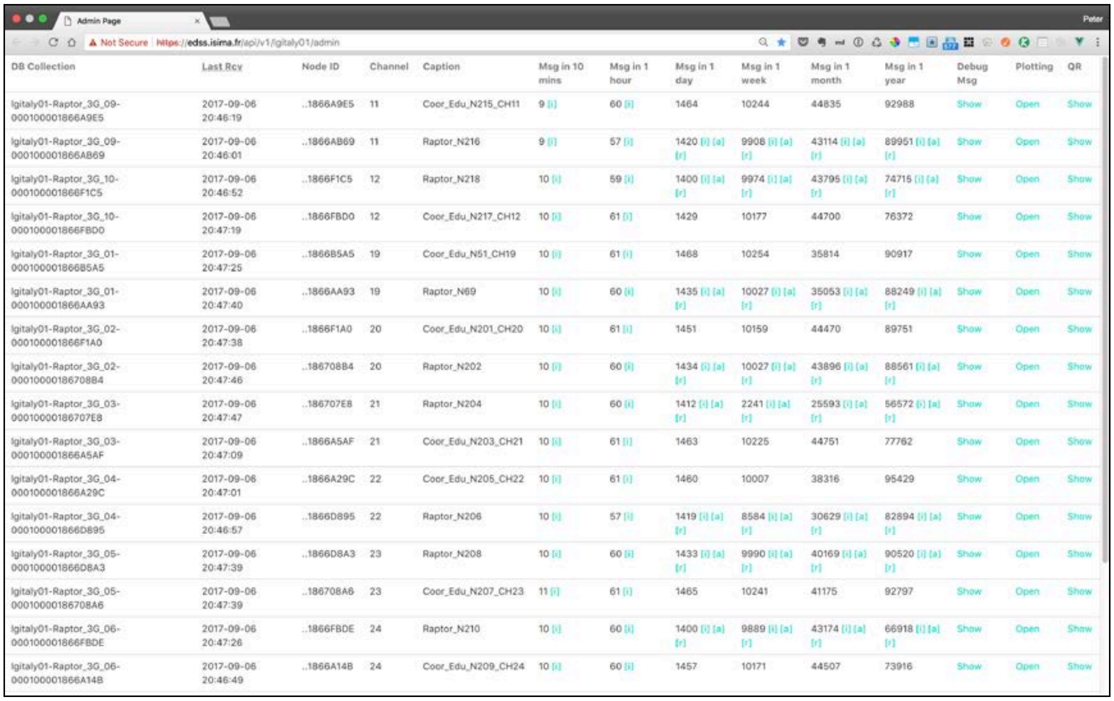


Figure 13. QR code scan to ease the O3 and NO2 data display

Remote server software implementation

Thanks to the data and error log file saved on the remote server, the performances of Raptor platform may be carried out:

- **Website:** for node management and data display etc. (in Figure 14 and Figure 15). Three sub-sites are setup for Spain, Austria, and Italy.
- **Web API for data upload and display:** provide web API for users (now is for UPC and CSIC) to retrieve the raw and calibrated data (in Figure 16)
- **Email Alarm:** when an error happens, the server will send alarm to the assigned users (shown in Figure 17)
- **QR code:** each node comes with a QR code. If user needs to know the data, he/she just needs to scan the QR code (you can scan the QR code in Figure 18, Figure 19, Figure 20, Figure 21 to see the data display).
- **Sensor calibrations** (in the section "2.2. New Calibration results")



Admin Page

Not Secure | https://edss.isima.fr/api/v1/igitaly01/admin

DB Collection	Last Rcv	Node ID	Channel	Caption	Msg in 10 mins	Msg in 1 hour	Msg in 1 day	Msg in 1 week	Msg in 1 month	Msg in 1 year	Debug Msg	Plotting	QR
Igitaly01-Raptor_3G_09-000100001866A9E5	2017-09-06 20:46:19	..1866A9E5	11	Coor_Edu_N215_CH11	9 [i]	60 [i]	1464	10244	44835	92988	Show	Open	Show
Igitaly01-Raptor_3G_09-000100001866AB69	2017-09-06 20:46:01	..1866AB69	11	Raptor_N216	9 [i]	57 [i]	1420 [i] [a] [r]	9908 [i] [a] [r]	43114 [i] [a] [r]	89951 [i] [a] [r]	Show	Open	Show
Igitaly01-Raptor_3G_10-000100001866F1C5	2017-09-06 20:46:52	..1866F1C5	12	Raptor_N218	10 [i]	59 [i]	1400 [i] [a] [r]	9974 [i] [a] [r]	43795 [i] [a] [r]	74715 [i] [a] [r]	Show	Open	Show
Igitaly01-Raptor_3G_10-000100001866FBD0	2017-09-06 20:47:19	..1866FBD0	12	Coor_Edu_N217_CH12	10 [i]	61 [i]	1429	10177	44700	76372	Show	Open	Show
Igitaly01-Raptor_3G_01-000100001866B5A5	2017-09-06 20:47:25	..1866B5A5	19	Coor_Edu_N51_CH19	10 [i]	61 [i]	1468	10254	35814	90917	Show	Open	Show
Igitaly01-Raptor_3G_01-000100001866AA93	2017-09-06 20:47:40	..1866AA93	19	Raptor_N69	10 [i]	60 [i]	1435 [i] [a] [r]	10027 [i] [a] [r]	35053 [i] [a] [r]	88249 [i] [a] [r]	Show	Open	Show
Igitaly01-Raptor_3G_02-000100001866F1A0	2017-09-06 20:47:38	..1866F1A0	20	Coor_Edu_N201_CH20	10 [i]	61 [i]	1451	10159	44470	89751	Show	Open	Show
Igitaly01-Raptor_3G_02-0001000018670884	2017-09-06 20:47:46	..18670884	20	Raptor_N202	10 [i]	60 [i]	1434 [i] [a] [r]	10027 [i] [a] [r]	43896 [i] [a] [r]	88561 [i] [a] [r]	Show	Open	Show
Igitaly01-Raptor_3G_03-00010000186707E8	2017-09-06 20:47:47	..186707E8	21	Raptor_N204	10 [i]	60 [i]	1412 [i] [a] [r]	2241 [i] [a] [r]	25593 [i] [a] [r]	56572 [i] [a] [r]	Show	Open	Show
Igitaly01-Raptor_3G_03-000100001866A5AF	2017-09-06 20:47:09	..1866A5AF	21	Coor_Edu_N203_CH21	10 [i]	61 [i]	1463	10225	44751	77762	Show	Open	Show
Igitaly01-Raptor_3G_04-000100001866A29C	2017-09-06 20:47:01	..1866A29C	22	Coor_Edu_N205_CH22	10 [i]	61 [i]	1460	10007	38316	95429	Show	Open	Show
Igitaly01-Raptor_3G_04-000100001866D895	2017-09-06 20:46:57	..1866D895	22	Raptor_N206	10 [i]	57 [i]	1419 [i] [a] [r]	8584 [i] [a] [r]	30629 [i] [a] [r]	82894 [i] [a] [r]	Show	Open	Show
Igitaly01-Raptor_3G_05-000100001866D8A3	2017-09-06 20:47:39	..1866D8A3	23	Raptor_N208	10 [i]	60 [i]	1433 [i] [a] [r]	9990 [i] [a] [r]	40169 [i] [a] [r]	90520 [i] [a] [r]	Show	Open	Show
Igitaly01-Raptor_3G_05-00010000186708A6	2017-09-06 20:47:39	..186708A6	23	Coor_Edu_N207_CH23	11 [i]	61 [i]	1465	10241	41175	92797	Show	Open	Show
Igitaly01-Raptor_3G_06-000100001866FBDE	2017-09-06 20:47:26	..1866FBDE	24	Raptor_N210	10 [i]	60 [i]	1400 [i] [a] [r]	9889 [i] [a] [r]	43174 [i] [a] [r]	66918 [i] [a] [r]	Show	Open	Show
Igitaly01-Raptor_3G_06-000100001866A14B	2017-09-06 20:46:49	..1866A14B	24	Coor_Edu_N209_CH24	10 [i]	60 [i]	1457	10171	44507	73916	Show	Open	Show

Figure 14. Admin page with the information of the Raptors and API URL addresses

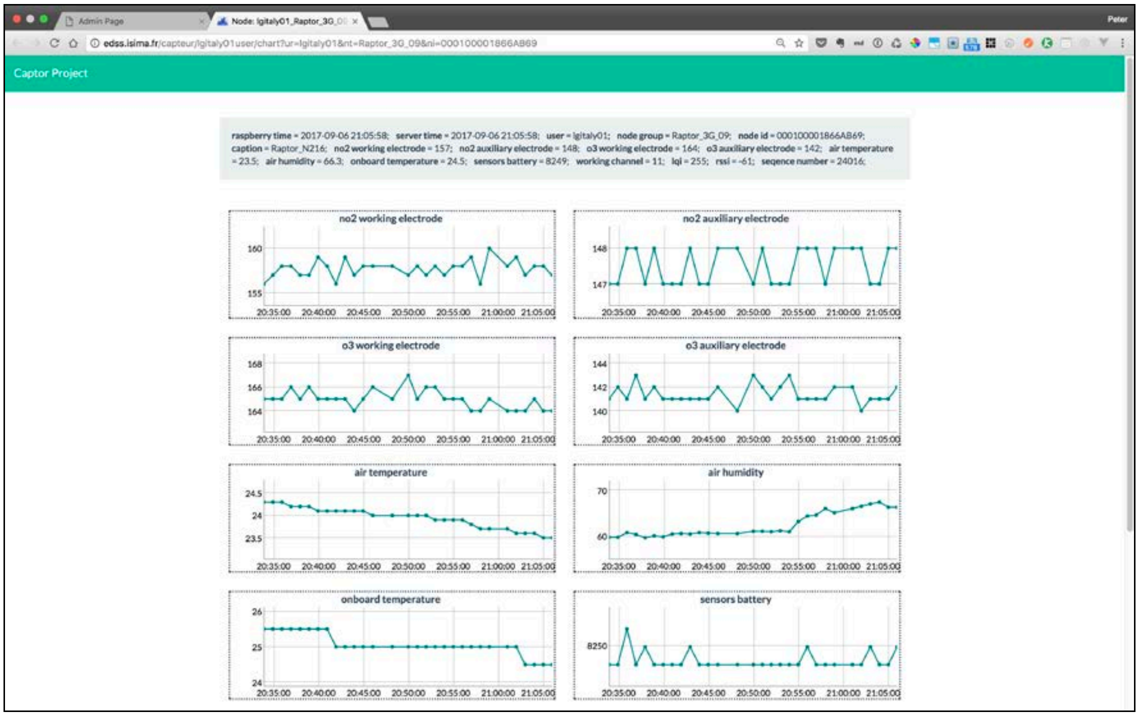
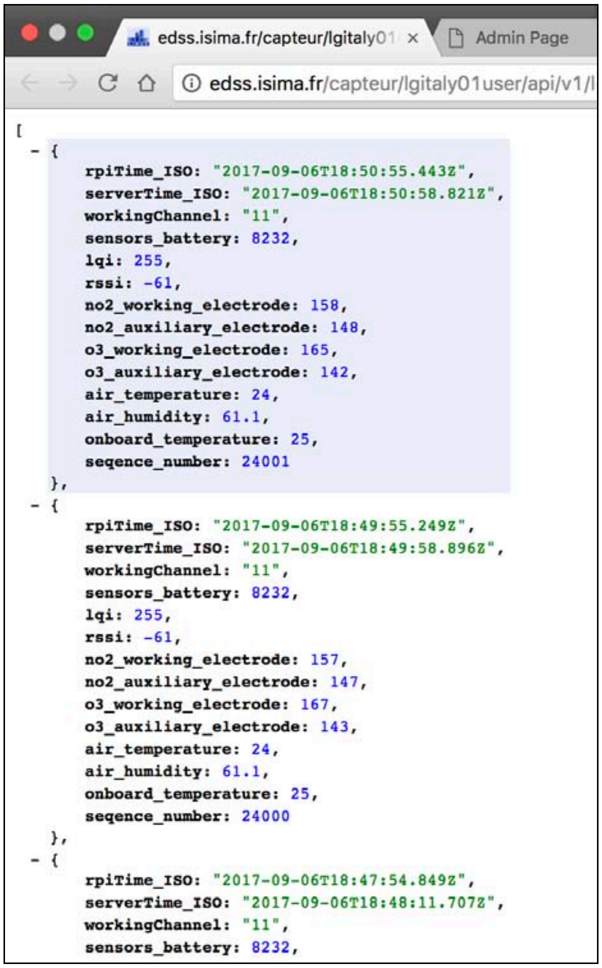
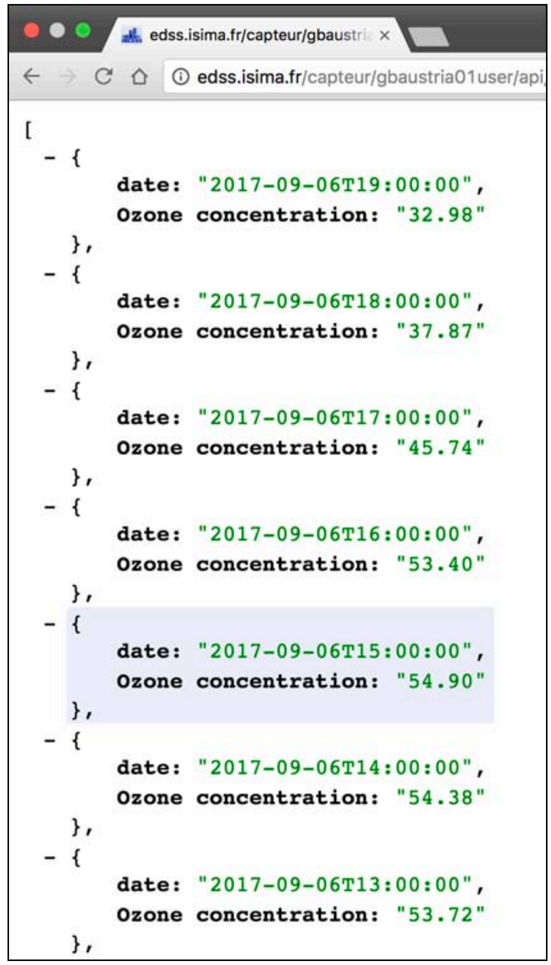


Figure 15. Raptor end-device Data display



(API to retrive raw data)



(API provide to UPC to retrive the O3 calibration data)

Figure 16. Data retrieving by APIs

Figure 17. An example of Raptor email alarm

The second version of Raptor platform were deployed on the roof of the ATMO Auvergne's reference station located in the Lecoq garden in Clermont-Ferrand, France (Figure 18). 13 Raptors (local servers and end-devices) were deployed in the reference station in Vienna by GLOBAL2000 (Figure 19). Notice that the Raptor platform (10 local servers and 10 end-devices) will also be deployed in Italy by Legambiente Onlus for 2017 summer campaign. Moreover, one Raptor platform is also deployed in Palau Reial reference station by CSIC in Barcelona (Figure 21).

User: smir
Group: Raptor_3G_02
Node ID: 000100001866FBFA
Caption: Raptor_N67

Figure 18. End-device deployed on the roof of ATMO Auvergne reference station in Clermont-Ferrand.

User: gbaustria01
Group: Raptor_3G_03
Node ID: 000100001866AC27
Caption: Raptor_N90

Figure 19. Deployment of Raptor nodes O3 and NO2 with QR code in Vienna by Global2000

User: lgitaly01
Group: Raptor_3G_09
Node ID: 000100001866AB69
Caption: Raptor_N216

Figure 20. Deployment of Raptor nodes O3 and NO2 with QR code in in Parco Colli Euganei, Veneto, Italy

User: upcspain01
Group: Raptor_3G_01
Node ID: 0001000018671537
Caption: Raptor_N70

Figure 21: Raptor end-device deployment in Palau Reial by CSIC, Barcelona Spain.

Appendix A: Shopping list for a Captor node

Index	Item	Supplier	Count per Node	Unit Price (€)	Subtotal (€)	Comment (code in supplier)
1	HUAWEI 3G USB E303 (captor 3G)	Zoom Informatica	1	29,50	29,50	Huawei E303
2	O3 gas sensor MICS-2610	cookinghacks	5	35,00	175,00	mics2614
3	Grove Temp&Humi sensor	cookinghacks	1	8,00	8,00	grove-twig
4**	Printed board**	pcbonline.es	1	2,90	6,00	Printed board
5	Grove-RTC clocks	cookinghacks	1	9,00	9,00	twig/grove RTC
6	Taps (10,7mm)	Farnell	6	0,12	0,74	1336184
7	cable gland M20 10-14 (stuffing box)	Farnell	6	7,31	43,86	2499302
8	cable gland M20 6-12 (stuffing box PG 13.5) power supply	Farnell	1	1,37	1,37	1174594
9	Box 160x160x90	Farnell	1	29,95	29,95	1554SGY
10	Arduino Yún with PoE	ondaradio.es	1	84,70	84,70	A000003
11	Heat shrink tube 19.1mm (termoretractile pipe)	ondaradio.es	6	1,92	11,54	TRS191N
12	Heat shrink tube 25.4mm (termoretractile pipe)	ondaradio.es	6	1,92	11,54	TRS254N
13	Tarjetas microSD (4GB)	ondaradio.es	1	4,39	4,39	1011967
14	Connector Cable DE 0,28 mm² Orange (10m) O3	ondaradio.es	1	2,53	2,53	CC2252NA
15	Cable Connector DE 0,28 mm² marrón (10m) O3	ondaradio.es	1	2,53	2,53	CC2252M
16	Cable Connector DE 0,28 mm² blue (10m) NO2	ondaradio.es	1	2,53	2,53	CC2252AZ
17	Cable Connector DE 0,28 mm² red (10m)	ondaradio.es	1	2,53	2,53	CC2252R
18	Cable Connector DE 0,28 mm² violet (10m)	ondaradio.es	1	2,53	2,53	CC2252V
19	Cable Connector DE 0,28 mm² grease (10m) NO2	ondaradio.es	1	2,53	2,53	CC2252G
20	Cable Connector DE 0,28 mm² black (10m)	ondaradio.es	1	2,53	2,53	CC2252N
21	Cable Connector DE 0,28 mm² green (10m)	ondaradio.es	1	2,53	2,53	CC2252V
22	Cable Connector DE 0,28 mm² yellow (10m)	ondaradio.es	1	2,53	2,53	CC2252A
23	Cable Connector DE 0,28 mm² white (10m)	ondaradio.es	1	2,53	2,53	CC2252B
24	batteries CR1225 (3V) for the RTC	ondaradio.es	1	1,20	1,20	CR1225
25	Cable USB-A a microUSB-B (+1m)	ondaradio.es	1	2,78	2,78	NI2765
26	Transformador AC-USB	ondaradio.es	1	7,47	7,47	PSUPUSB401
27	Pack 100 resistors 1K tolerance 5% (sensor load)	ondaradio.es	1	1,21	1,21	PR251KD
28	Pack 100 resistors 100K tolerance 5% (sensor load)	ondaradio.es	1	1,21	1,21	PR25100KD
29	Pack 100 resistors 330 tolerance 5% (O3)	ondaradio.es	1	1,21	1,21	PR25330HD
30	Pack 100 resistors 220 tolerance 5% (O3)	ondaradio.es	1	1,21	1,21	PR25220HD

31	Pack 100 resistors 1K tolerance 1% (sensor load)	ondaradio.es	1	1,21	1,21	MF251K
32	Pack 100 resistors 100K tolerance 1% (sensor load)	ondaradio.es	1	1,21	1,21	MF25100K
33	Pack 100 resistors 10K tolerance 1% (sensor load)	ondaradio.es	1	1,21	1,21	MF2510K
34	Pack 100 resistors 330 tolerance 1% (O3)	ondaradio.es	1	1,21	1,21	MF25330H
35	Pack 100 resistors 220 tolerance 1% (O3)	ondaradio.es	1	1,21	1,21	MF25220H
36	Tub of PVC 2cm external diameter	servei estació	1	1,10	1,10	TUBO PVC GRIS
37	Tub of PVC 1cm external diameter	servei estació	1	3,15	3,15	TUBO PVC TRANSPARENTE
				Total Price	**464,37**	

** The printed boards were bought in a package of 75 units: the cost is a fixed cost of 60 Euros + 2.10 Euros/unit if there were 75 units. In total 217,59 Euros for the package of 75 printed boards. The cost per unit is then 2,90 Euros.

Appendix B: Shopping list for a Raptor node

	Item	Supplier	Node Type	Count per Node	Unit Price (€)	Sub total (€)	Comment
1	2.4G IEEE802.15.4 Antenna	Farnell	RAPTOR End-Device	1	5,41	5,41	http://at.farnell.com/rf-solutions/ant-24g-whj-sma/antenna-whip-sma-90d-2-4ghz/dp/1304038
2	uSu_Edu Board	SMIR	RAPTOR End-Device	1	100,00	100,00	uSu_Edu by LIMOS, UBP, France
3	Box for End-Device	Farnell	RAPTOR End-Device	1	12,63	12,63	http://at.farnell.com/fibox/ta201-610/box-grau-ip65-201x163x98mm/dp/1422670
4	Alcaline Battery	Farnell	RAPTOR End-Device	6	2,83	16,98	http://at.farnell.com/energizer/e300116200/pile-alcaline-4-5v-3lr12/dp/2507368
5	Alphasense NO2 Sensor, NO2-B43F	Alphasense	RAPTOR End-Device	1	63,00	63,00	Arthur Burnley <awb@alphasense.com>
6	ISB for NO2 B-Series sensor	Alphasense	RAPTOR End-Device	1	96,00	96,00	Arthur Burnley <awb@alphasense.com>
7	Alphasense OZONE Sensor, OX-B431	Alphasense	RAPTOR End-Device	1	63,00	63,00	Arthur Burnley <awb@alphasense.com>
8	ISB for OX B-Series sensor	Alphasense	RAPTOR End-Device	1	96,00	96,00	Arthur Burnley <awb@alphasense.com>
9	Male-Female Cable	RS	RAPTOR End-Device	1	2,78	2,78	http://fr.rs-online.com/web/p/products/7916454/
10	Female-Female Cable	RS	RAPTOR End-Device	1	2,78	2,78	http://fr.rs-online.com/web/p/products/7916450/

11	CRC9 Connector 4G LTE Antenne 35dBi	Amazon.de	RAPTOR Local Server	1	19,99	19,99	https://www.amazon.de/gp/product/B01N7DWGVB/ https://www.amazon.fr/URANT-Connector-Antenne-Amplifier-EC5377u-872/dp/B01MU4LOH3/
12	Box for Local Server	Farnell	RAPTOR Local Server	1	17,00	17,00	c.carvalho@aumelec.fr
13	2.4G IEEE802.15.4 Antenna	Farnell	RAPTOR Local Server	1	5,41	5,41	http://at.farnell.com/rf-solutions/ant-24g-whj-sma/antenna-whip-sma-90d-2-4ghz/dp/1304038
14	+12V 30W AC-DC Power Supply	Farnell	RAPTOR Local Server	1	24,45	24,45	http://at.farnell.com/xp-power/afm30us12c2/alimentation-2-5a-12v-30w-iec/dp/2319724
15	AC Power Supply Cable	Farnell	RAPTOR Local Server	1	2,78	2,78	http://at.farnell.com/pro-elec/sh10167r/power-cord-euro-to-fig-8-2m/dp/1283799
16	uSu_Edu Board	SMIR	RAPTOR Local Server	1	100,00	100,00	uSu_Edu by LIMOS, UBP, France
17	Huawei E3272 LTE Surf-Stick	Amazon.de	RAPTOR Local Server	1	66,99	66,99	https://www.amazon.de/gp/product/B00HT2HP6E/ https://www.amazon.fr/Huawei-E3272-Surf-Stick-150Mbps-microSD/dp/B00HT2HP6E
18	RASPBERRYPI-3 & MicroSD 16Go	Farnell	RAPTOR Local Server	1	43,09	43,09	http://at.farnell.com/raspberry-pi/rpi3-modb-16gb-noobs/sbc-raspberry-pi-3-model-b-16gb/dp/2525227
19	End-device home mounting plate	Aumelec	RAPTOR End-Device	1	22,00	22,00	c.carvalho@aumelec.fr
20	Air Temperature-humidity sensor	electronic-shop.lu	RAPTOR End-Device	1	15,00	15,00	https://www.electronic-shop.lu/EN/products/145359
					Total Price	**775,29**	