Collective Awareness Platform for Tropospheric Ozone Pollution

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List of Abbreviations

A/D	Analogic/Digital
3G	Third Generation
CSV	Comma-Separated Values
NE	North-East
NOx	Nitrogen Oxides
SD card	Secure Digital card
VOCs	Organic Volatile Compounds

Executive Summary

Description of the work

The aim of deliverable D3.2a is to report on the initial testing of sensor nodes during the summer 2016 monitoring campaign. This deliverable presents a review of the nodes deployed during their campaign and the periods of time during which they were operational. Deliverable 3.3a will report on data validation and quality.

Objectives

This deliverable covers the following topics and issues:

- It presents a review of the nodes deployed during the 2016 campaign and the periods of time during which the nodes were operational.

Report on initial testing of sensor nodes

1. Introduction

The nature and impacts of air pollution effects on human health and ecosystems are relatively well known at present. It is for this reason that monitoring and quantifying the ambient concentrations of atmospheric pollutants is of major relevance. In particular, because of the high tropospheric ozone concentrations registered in rural areas, project CAPTOR aims to produce dense and high-quality network of sensor nodes to monitor the concentrations of this type of pollutant and to determine its spatial and temporal evolution. Tropospheric ozone is a secondary pollutant which originates from photochemical reactions linked to its gaseous precursors nitrogen oxides (NOx) and organic volatile compounds (VOCs), and solar radiation.

The aim of CAPTOR is to monitor ozone concentrations in rural areas, using low-cost and widely distributed sensors. To this end, a number of sensor nodes was deployed in the study area (Catalonia testbed) during summer 2016, which are able send data remotely and also to store them in an internal memory card. At the end of the summer campaign (July to September 2016), the nodes were collected and taken back to the lab for data analysis. The data collected were used to perform an initial study on node performance, data availability, and ozone concentrations. The data were also used as a basis for comparison with the results from the upcoming 2017 and 2018 summer campaigns within the project.

2. Aim of this deliverable

The aim of deliverable D3.2a is to report on the initial testing of sensor nodes during the summer 2016 monitoring campaign. This deliverable presents a review of the nodes deployed during their campaign and the periods of time during which they were operational. Deliverable 3.3a will report on data validation and quality.

The 2016 summer campaign included three monitoring periods:

1) Calibration phase 1: prior to the monitoring campaign, this period covered the month of June 2016. The nodes were installed in the IDAEA-CSIC air quality monitoring station in Barcelona. During this period, the nodes were inter-compared with reference ozone data from the air quality monitoring station.
2) Monitoring campaign: between July and mid September. The nodes were deployed in the study area (Figure 1).
3) Calibration phase 2: after the monitoring campaign, this period covered the month of September 2016. The nodes were installed in the IDAEA-CSIC air quality monitoring station in Barcelona. During this period, the nodes were inter-compared with reference ozone data from the air quality monitoring station.

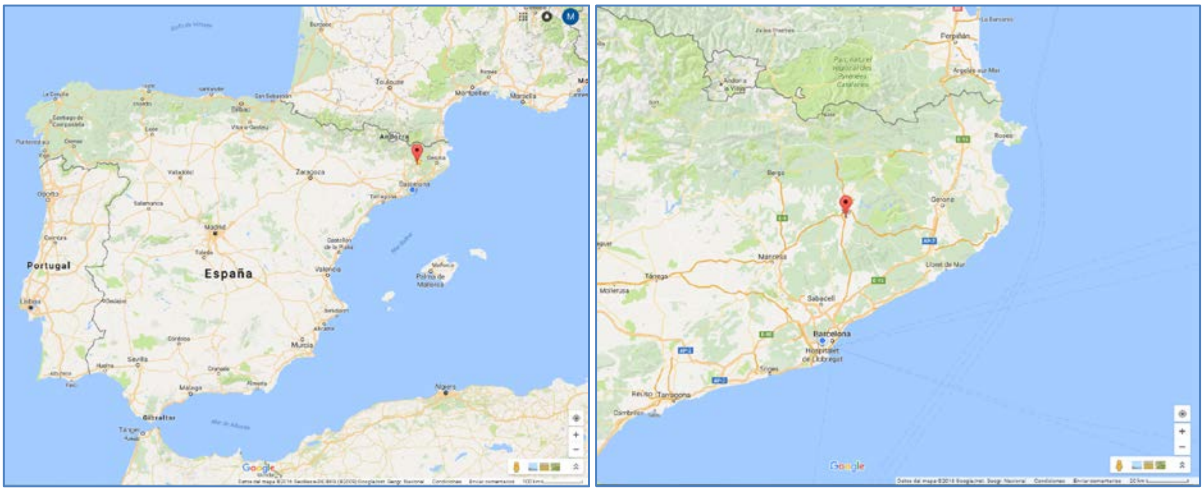

Figure 1. Location of the study area, between Barcelona and Vic, in Catalonia (NE Spain).

3. Results

Due to the fact that the Captor nodes were designed and are not commercially available, an initial testing phase was necessary to assess the overall performance of the nodes from the point of view of operation, i.e., operating time *vs*. total time in deployment. This assessment was carried out for the total monitoring period in the summer 2016 campaign, which includes the two calibration period and the monitoring period itself. The results from this performance assessment are summarised in Figure 2. Two-tone colours are used for this representation: the green tones refer to the calibration periods, whereas the orange tones shown the data availability during the campaign when the sensors were deployed in the study area. The light colours (whether green or orange) indicate that the nodes were not reporting data properly. The strong colours (whether green or orange) indicate that the node was reporting data.

As shown in Figure 2, during summer 2016 a total of 20 nodes was deployed in the study area. Out of these, the following was observed:

- 1/20 nodes did not submit any data.
- 7/20 nodes did not submit any data during the campaign (July-September period, in orange), although they did report data during the calibration periods (green).
- 10/20 nodes reported data during the calibration and the campaign periods, but the datasets are incomplete.
- 3/20 nodes produced full datasets for the entire period (calibrations and campaign).

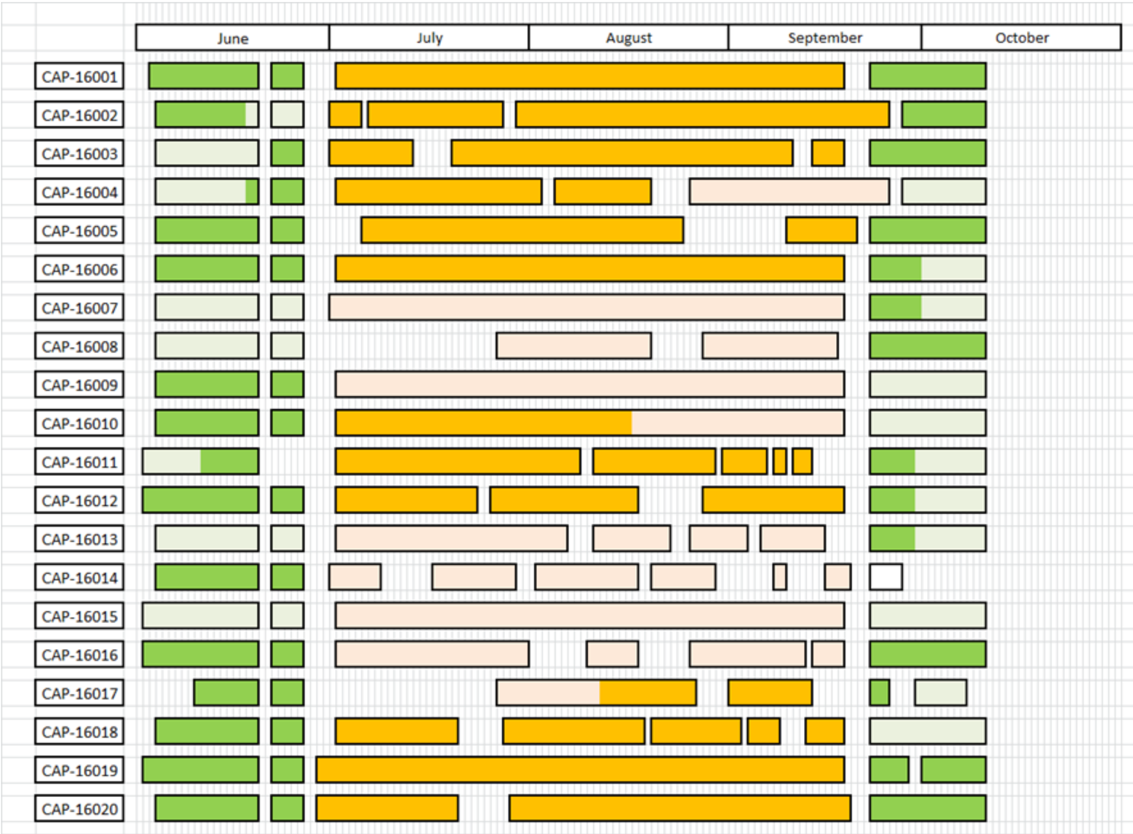

Figure 2. Graphical representation of the availability of the sensor data during the summer 2016 monitoring campaign.

These results suggest a relatively poor performance of the nodes, when looking at their operational time (data quality will be discussed in deliverable 3.3a). It is paramount to note that the 2016 summer campaign was considered a testing phase for the nodes and for their deployment strategy, and therefore as a learning ground for the upcoming 2017 and 2018 campaigns. The failure of the nodes in this campaign was due to different reasons, mainly related to IT issues such as lack of internet (WiFi) connectivity for data transmission, lack of connectivity to the database, lack of 3G coverage, or malfunctioning of the nodes. The main causes and their frequency of occurrence are shown in Figure 3.

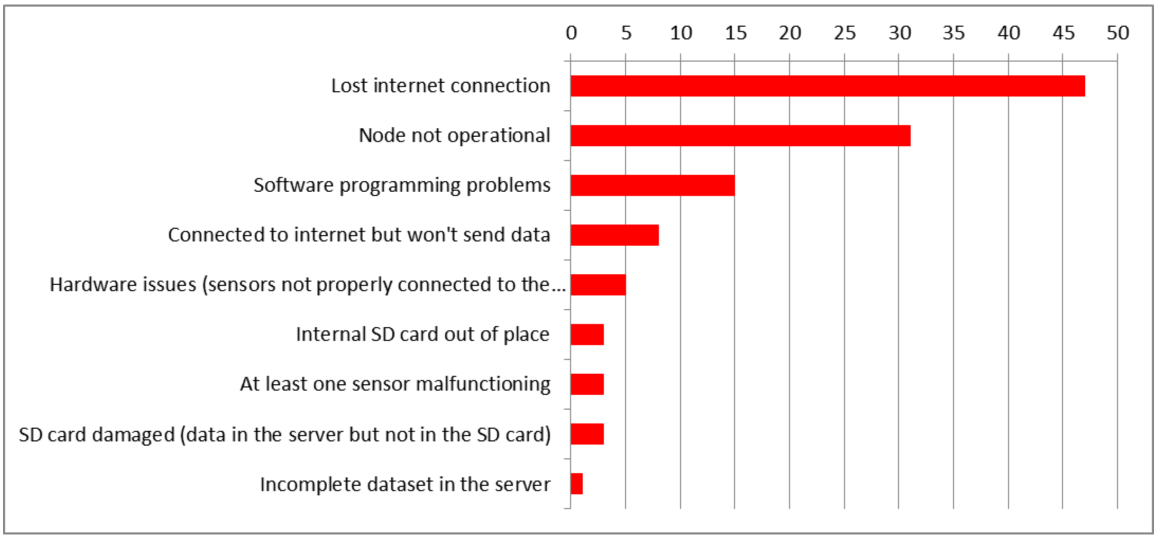

Figure 3. Summary and frequency of causes of node failure during the summer 2016 campaign.

We describe here the actions that are going to be taken to solve the IT failures identified during the 2016 campaign:

- Loss of Internet connectivity: there are three causes for loss of connectivity. In the volunteer homes the Internet connectivity was mainly using the WiFi-ADSL router owned by the volunteer. In this case, the main reasons for failures are (i) the volunteer switch off the power supply, e.g. being some days of holidays, and (ii) lack of WiFi coverage or degrading (attenuation) of the wireless signal due to the distance between the CAPTOR node and the WiFi router. In nodes deployed in reference stations without WiFi connection, 3G connectivity was used. In this case, the connectivity was better except in some case with low 3G coverage.
  The solutions proposed for these connectivity failures consist on the following: CAPTOR nodes will transmit on 3G always that the cellular coverage is fine. If not, WiFi with relays will be used. Moreover, the CAPTOR nodes have an SD card acting as a back-up storing device, where all the data is stored independently of being transmitted on real-time.
- The internal SD card sometimes was out of place. The reason is a spring that releases the SD card when the node is moved. The card will be fixed in the coming CAPTOR nodes.
- At least one sensor device malfunctioning. The calibration software will include an automatic mechanism to detect which sensor device is malfunctioning. This may be detected by comparison between sensor devices in the same node. However, if all the sensor devices malfunction at the same time is a hard task and a challenge to learn on-real time that the sensors have failed.
- Access to the database. The sensor nodes now access directly to the database uploading data using a Restful architecture. Since the nodes have different clocks and access the database in a non-synchronize way, the timestamps are not synchronized in the database, making difficult the task of calibrating and converting the readings in Ozone. Moreover, the database also may fail or be down causing loss of data. For this reason, an intermediate CSV server has been designed. CAPTOR nodes connect to this server that pre-process the data before insert them in the database. The pre-process align data, uniform timestamps and finds faulty readings.
- Software problems: the main problem has been the sample frequency of the sensors. The software has been improved to give time to the capacitors of the A/D converter to recover from the transient period.
- Hardware problems: the main problems detected have been related to (i) power supply to the circuitry. New circuitry will be added to have a stable power supply to the A/D converter, and (ii) some of the hardware components were not soldered with the aim of being flexible in changing faulty sensor devices. However, this flexibility has been at the cost of robustness. The new CAPTORs will have more components soldered to gain robustness.

4. Conclusions

The initial testing of sensor nodes evidenced significant sensor failures, with only 50% of the nodes (10 out of 20) generating data during the summer 2016 summer campaign. From the point of view of volunteer engagement, however, this campaign should be considered a success given that more than the 20 required volunteers were recruited. This campaign is considered a learning ground on which to build more successful 2017 and 2018 monitoring campaigns. A set of failure causes has been identified in the building of the CAPTOR nodes. For each of these causes, a set of actions have been defined to solve future failures and increase the robustness of the CAPTOR nodes. These actions include improving the Internet connectivity, to improve the storing of data in the Commsensum database, to improve Software bugs and hardware failures and to foresee sensor devices malfunctioning.