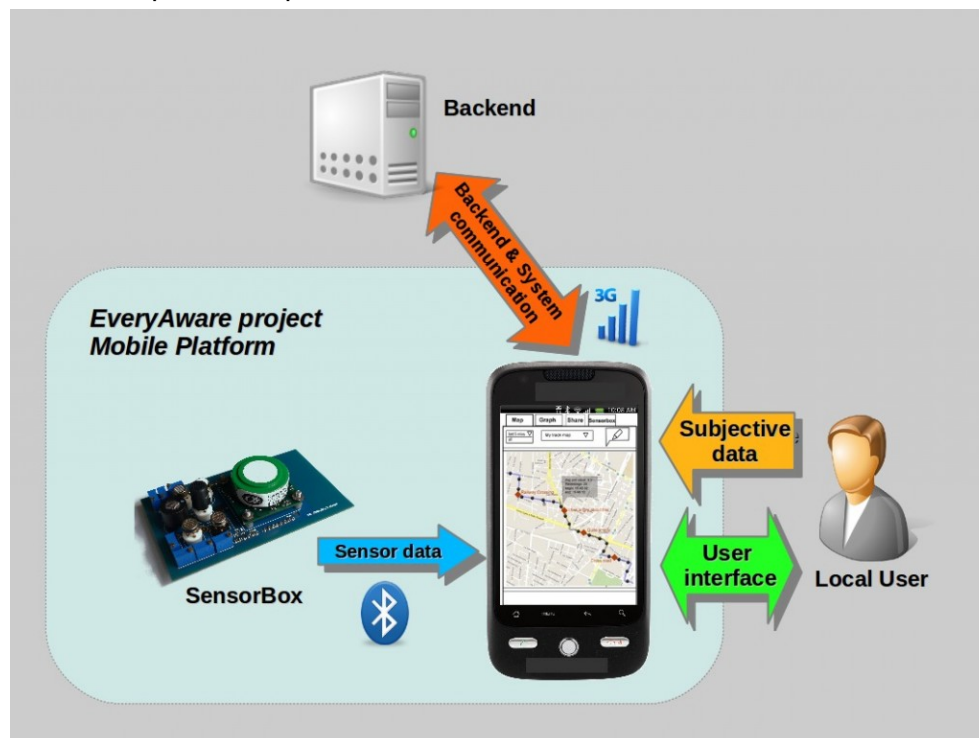




The EveryAware Sensor Box

Overview

The EveryAware sensor box is a portable device that measures concentrations of pollutants in the air and localizes them through a GPS. This is done once per second in order to have a detailed map of the pollution while the user is walking/cycling. Using a smartphone with the application AirProbe installed it is possible to visualise the measurement in real time, using a bluetooth connection with the sensor box. Moreover, using an Internet connection, AirProbe sends all the measurements to the EveryAware server that collects data from all users. Through dedicated Web Applications, available on www.airprobe.eu, users can access the ensemble of the data gathered by the community of users along as personalized information concerning personal levels of exposure to pollutants.



Sensor box design

The EveryAware sensor box is a small measuring system which uses different low-cost gas sensors to evaluate air pollution. It is small enough to be carried around in the external pocket of a backpack and is powered with an external battery using a mini USB cable.



The sensor box has a small fan that pushes external air into a chamber where there are eight different sensors that measure air pollutants, plus two sensors for temperature and humidity. In order to realize a small and low-cost device we used a series of low-cost gas sensors. These perform well in highly controlled environments like a lab while in real-life conditions their performance and accuracy are affected by a series of factors like wind, weather conditions or interfering gases. So it is very difficult to give a precise and reliable reading of a pollutant concentration with individual sensors. Hence the main challenge of our sensor box is to combine several different low-cost sensors in order to reduce disturbances and provide sufficiently accurate measurements. Our sensor box is calibrated against certified instruments detecting Ultra Fine Particle (UFP) and Black Carbon, the goal being that of providing reliable observables to quantify air pollution even without individually accurate gas sensors. In particular we are using the following sensors:

Alphasense CO-BF, CO sensor: Of all tested low cost gas sensors, this sensor obtained the best results for detecting the presence of traffic pollution. With its price tag of around 180 euro (sensor electronics included) it is also by far the most expensive selected gas sensor. Although the electrochemical cell does not use any electricity itself, the used sensor electronics do require up to 200 mW.

E2V MiCS-5521, CO sensor, and MiCS-2710, NO₂ sensor: These sensors are not well suited to be used as stand-alone air quality sensors due to quite large problems with cross sensitivities. We believe they have potential when being combined with other sensors in a sensor array. The sensors have proven to be able to react on low CO and NO₂ concentrations present in ambient air. With a price tag of less than 5 euro a piece, they are very attractively priced. Thanks to their micro-hotplate technology, their power usage stays quite low (less than 100 mW).

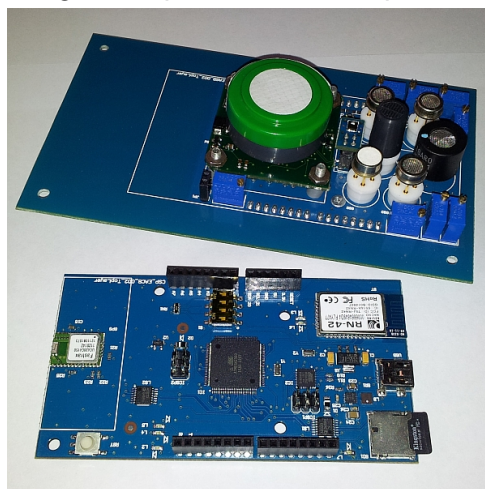
E2V MiCS-5525, CO sensor with charcoal filter: This sensor contains exactly the same sensitive element as the MiCS-5521 CO sensor. It only differs in the presence of a charcoal filter which has been added on top of the sensitive element. Although we noticed this charcoal filter to increase the sensor reaction time and reduce the sensor sensitivity, it also enhances the selectivity of the sensor. With a price tag of less than 5 euro, we believe it may be able to offer us a cost effective way to help distinguish the target gas from interfering gases.

Figaro 2201, gasoline and diesel sensor: This is a metal oxide sensor which contains two sensing elements. One which is specially designed to react on the presence of gasoline exhaust fumes (mainly on CO, H₂ and HC) and a second to react on the presence of diesel exhaust fumes (mainly on NO_x). Figaro designed this dual sensor for the automotive industry to be used in intelligent vehicle ventilation systems. Although this sensor was not included in the lab experiments, we observed this sensor to react to the presence of traffic pollutants in ambient air. Just as the E2V sensor, this metal oxide sensor seems to be quite sensitive to cross sensitivities, making it a requirement to combine it with other sensors in order to obtain reliable air quality measurements. With a price tag of around 15 euro and a power usage of around 500 mW, the Figaro has slightly less attractive specifications.

E2V MiCS-2610, Ozone sensor: The previous E2V sensors have proven to be very sensitive towards the presence of ozone during the field experiments. For this reason, we expect an Ozone sensor may be able to add additional useful information to the sensor array. Also this E2V sensor has a low power usage and price tag.

Applied Sensors AS-MLV, VOC (Volatile organic compounds) sensor: With this sensor, Applied Sensors is targeting automated ventilation systems which need to be able to detect bad indoor air quality. The concentrations of VOC in an indoor environment can be significantly higher from an outdoor environment. Since traffic pollution also contains VOC, this sensor may be able to add information to our sensor array.

Sensirion SHT21, T (temperature) and RH (relative humidity) sensor: Low cost gas sensors are very sensitive to changes in both temperature and relative humidity. By adding high quality temperature and humidity sensor to the sensor array we expect to be able to enhance the obtained measurements. The combined sensor of Sensirion was selected due to its high measurement precision and our good experiences in the past with these sensors.



Data gathered from sensors are read by a microcontroller board and stored on SD card. These measurements are saved together with the position given by a GPS module. A Bluetooth module allows the connection with a smartphone to transfer all the data collected for real-time visualization through the smartphone and/or forward to the main server.

Calibration

The raw values measured by the above sensors are used to compute an estimated Black Carbon (BC) concentration. This estimation is based on machine learning techniques that infer the relation between the 10 sensor values and the BC concentration measured by a reference device. Although individual sensors are not very accurate, after combining them we have obtained an estimation error (on average) of about 2 microgram per cubic meter. The BC concentrations are displayed both in the AirProbe app and online at www.airprobe.eu.