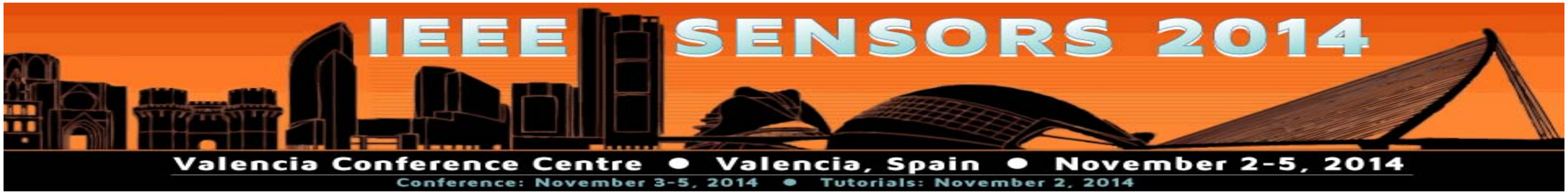

A Maker Friendly Mobile and Social Sensing Approach to Urban Air Quality Monitoring

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ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development

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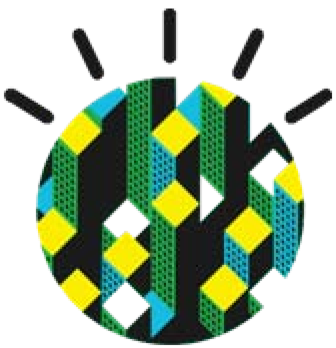
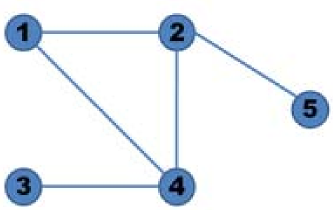
Outline

- Motivation
- The Maker Friendly – Open Source Choice
- The MONICA Architecture
-     The Sensor Node
-     Backend
-     GUI
- A possible Business Model
- Understanding limitations
- Conclusions

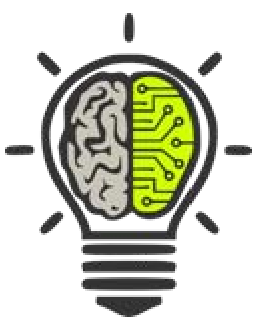
Motivation (1)



A new concept of citizenship is spreading throughout all Europe and US. In their evolving smart cities, citizens want to become an **active part** of the intelligent management of their environment. EU is significantly funding the research endeavour.



Currently, air quality monitoring is based on data gathered by official organizations through networks of fixed locations. Highly accurate data, but sparse networks.



Availability of low cost, low power, portable personal analyzer and cooperative air quality monitoring models may help to significantly **densify these networks**, eventually enabling good policies.

The Open Source Ecosystem Choice

Can we meet citizens and social requirements with exiting open source / low cost technologies?

One possible route is to provide **a way for the citizen to easily obtain/build their own sensor node and quickly start participating to the air monitoring challenge** but….

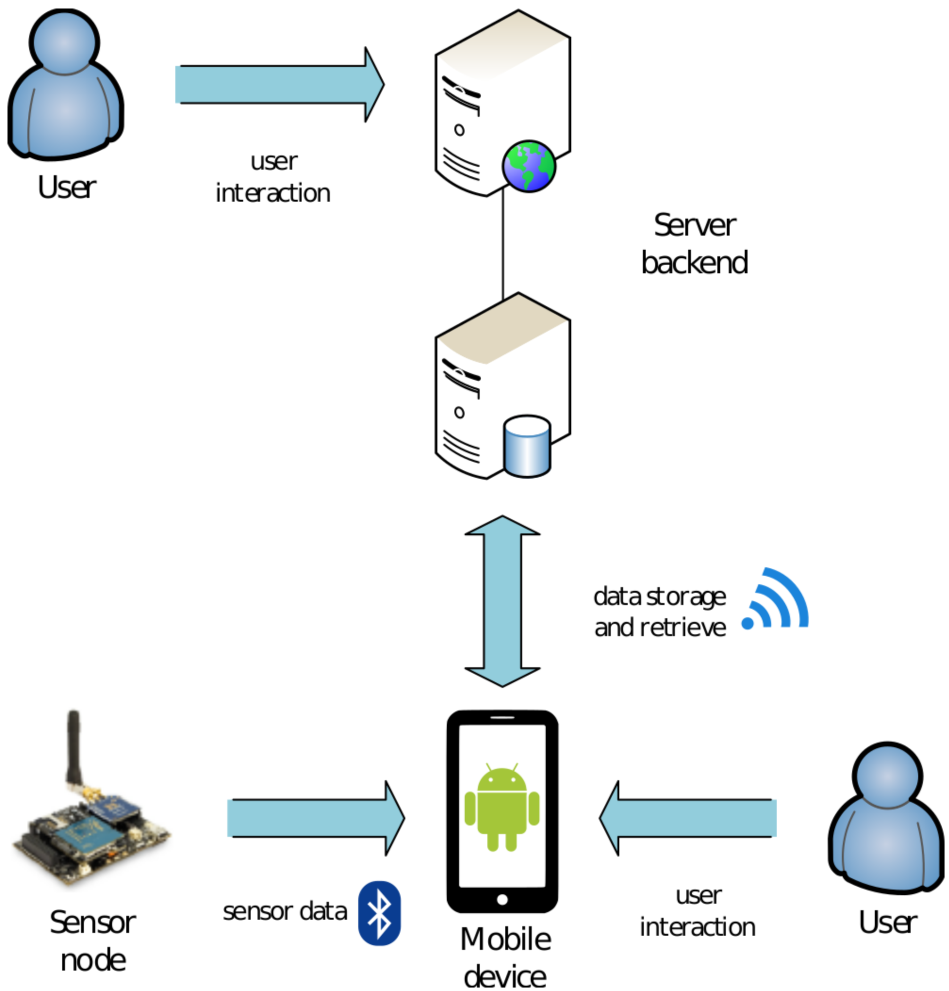
.Existing air pollution crowd sensing designs are all based on ad hoc developed prototypes, not documented in their assembly and therefore not reproducible by the average citizen, which does not have electronic knowledge nor resources to implement. Why not going open?

.To manage the large amounts of data that would be produced is **challenging**, also considering the heterogeneity of data generated by mobile devices nowadays. Can modern open source solutions help?

.Chemical sensing is still a challenging issue for low cost sensing architectures for their unspecificities and instabilities…..

How far can we reach?

The Monica Architecture

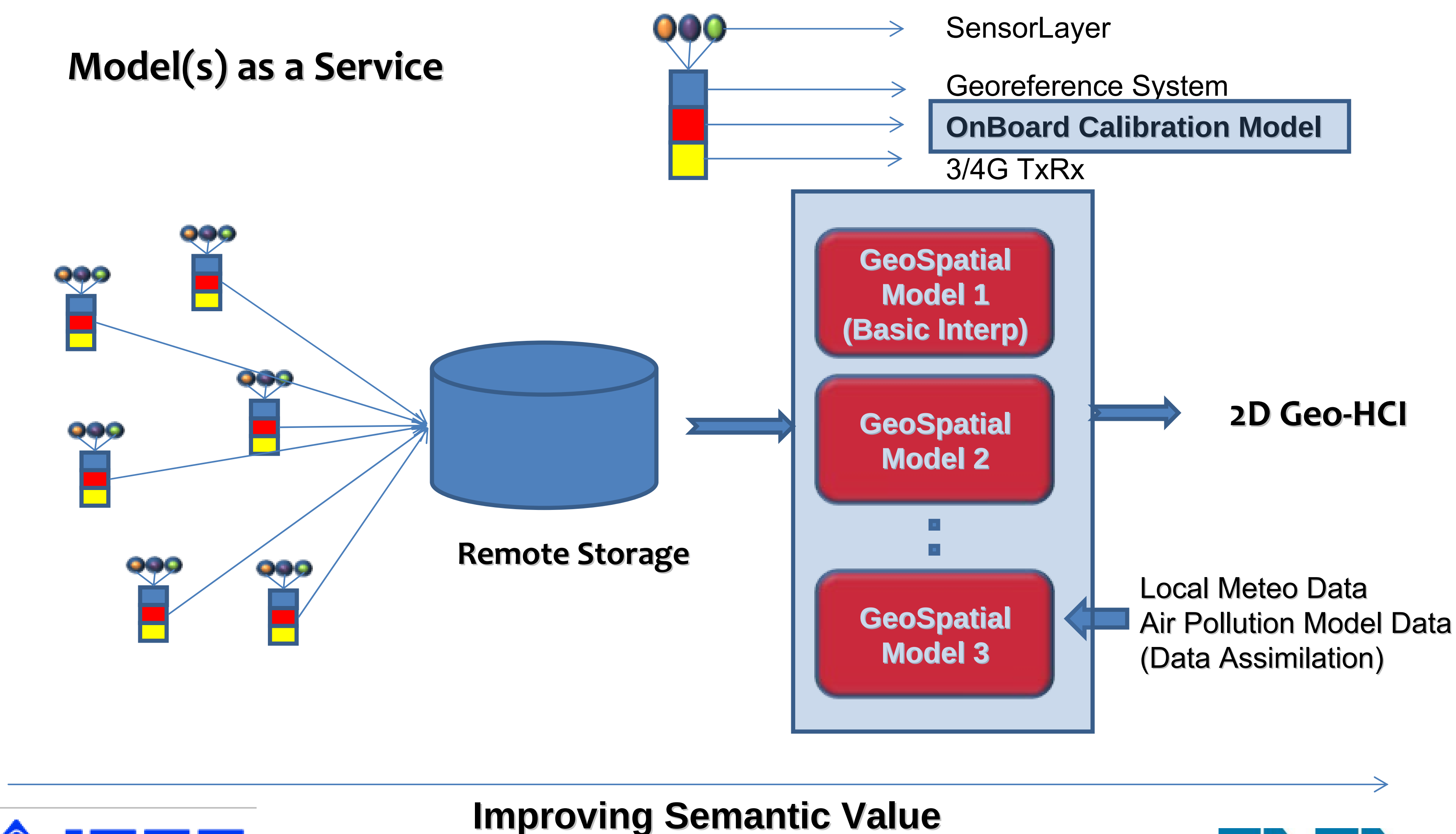


Social Sensor Networks

Sensor nodes connect via Bluetooth to users' personal mobility terminals that localize and send the data to the backend server from which, with a model based approach, is used to reconstruct city air pollution status for users availability anywhere.

Modular: it is possible to change the specifics of one module without affecting the whole system.

The Monica Architecture (2)



Sensor Node

- Involving citizens in the monitoring process → allow to build their own nodes
- Possible choice:
  - Libelium CD S.L. Gas sensor board based on MOX sensors
  - Ad-hoc “open” design with Alphasense EC sensors+Arduino Clone

3D Printed Node Case

- Libelium :Sensors equipped: Figaro TGS2442 (CO); MiCS 2710 (NO2), MiCS 2610 (O3), RH and temperature (for sensor response compensation).
- Measured Battery Lifetime: **60 hours**.
- At the current stage, off-the-shelf calibration is used, so to provide a *qualitative* air pollution index. **In progress: on-field calibration.**

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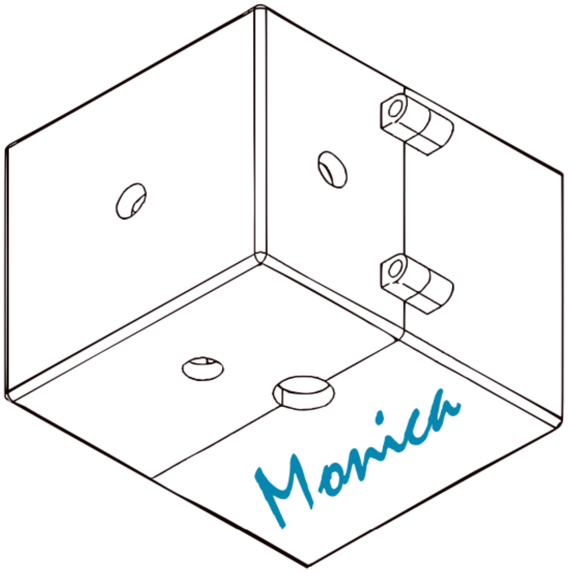
Sensor Node (2)



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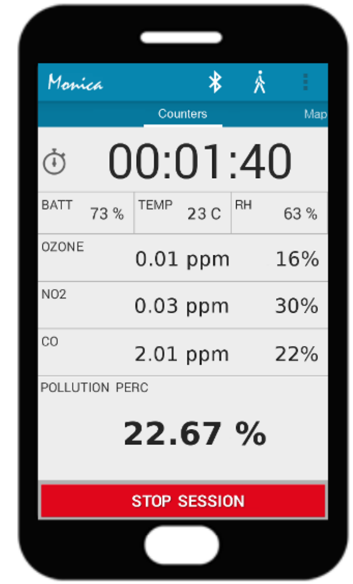
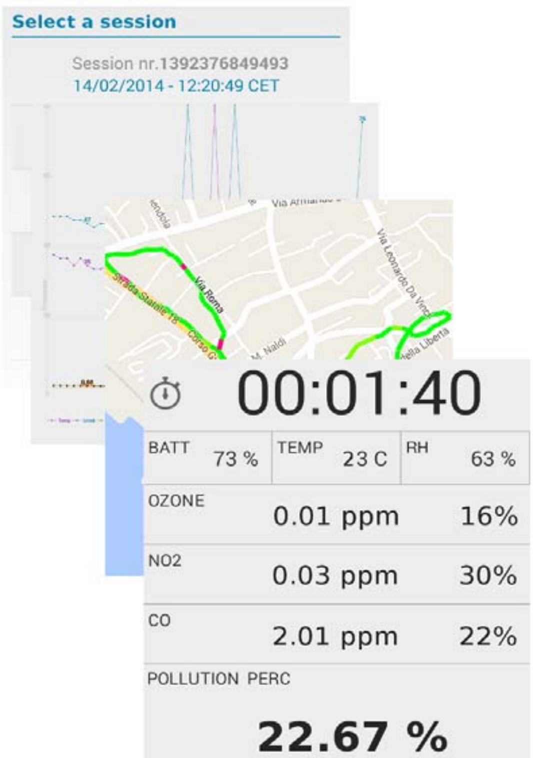


Android App
(Data capture, GPS tagging,
Local Calibration,
Data RxTx, Local 2D HCI)

Android app



Primary goals:

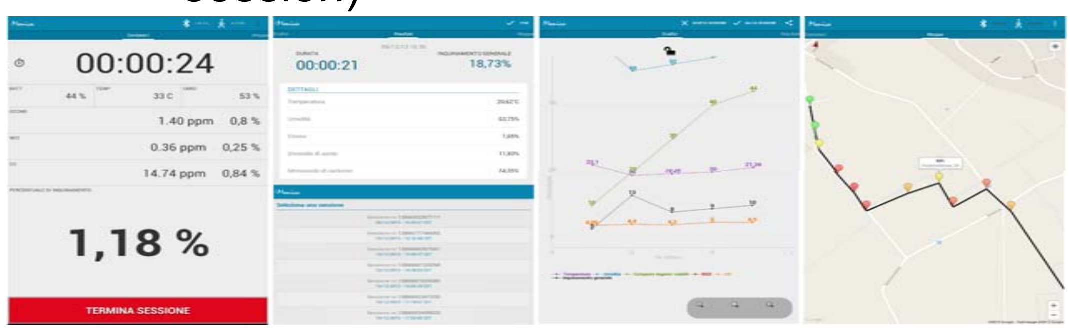
•A gateway between sensor node and backend server geolocalizing data;

•To provide a local calibration (neural networks based)

•To provide the user with a real-time and overall assessment of his personal exposition to allow the sharing of measurements both by relying on social networks platforms and by sending data the backend.

Mobility session: the ability to record the air quality while moving in the city.

A synthetic index to allow the user to assess the local measured pollution level:
EPA Air Quality Index (and its time integral during session)



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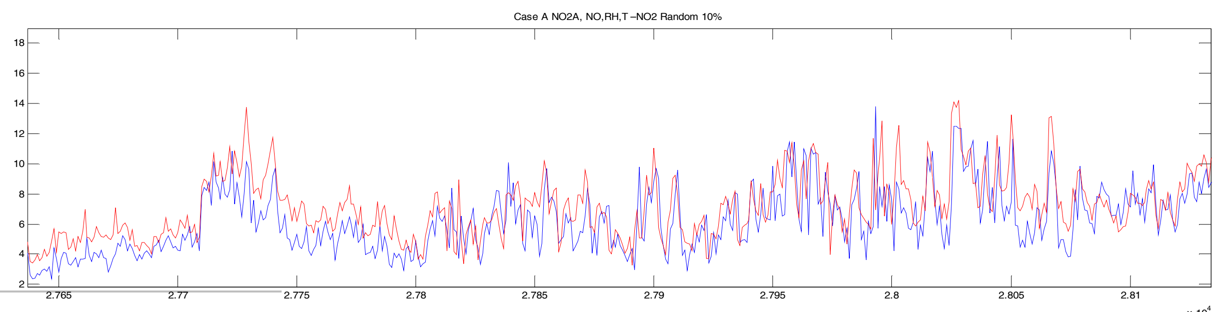
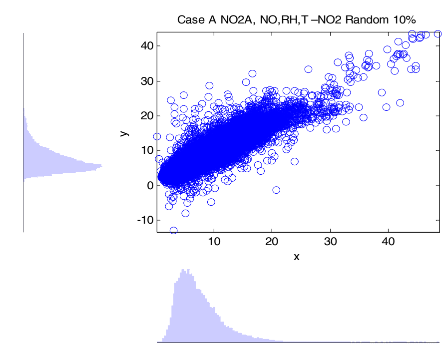
Neural Network based On board calibration

- **Sensor Cross-Sensitivities** can be approached with **multivariate calibration systems** taking advantage of the information available on interferents gases and physical phenomena (T, RH).
- Provided the availability of **enough field recorded data**, Neural network can be trained to perform multivariate regression to estimate pollutant concentration.
- Sensor Dynamic Dynamic Features or Dynamic Neural Model (e.g. recurrent networks, NARX, etc) can be helpful to reconstruct an **internal multisensor dynamic model** to cope with rapid pollutant concentration variation expected in the field while moving.
- The internal regression model altough not interpretable is extremely concise and do not need significant computational power to operate.

NO, NO2 (EC Sensors) + Rh,T	**NO2 (10sec)**	FFNN HN=10, Learning Algorithm:Trainlm, CV=10x	Train-Test Partition 1wK/4wk/Initial	MAE = 1.17 ppb	STD= 1.30 ppb	Correlation coeff = 0.90





Preliminary Results, Courtesy of University of Cambridge (Rod Jones Group)

Backend Server

Process of large amounts of information → handling data play a central role

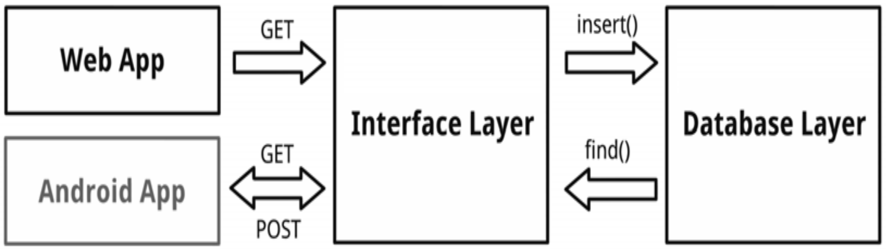
Why not a traditional RDBMS?

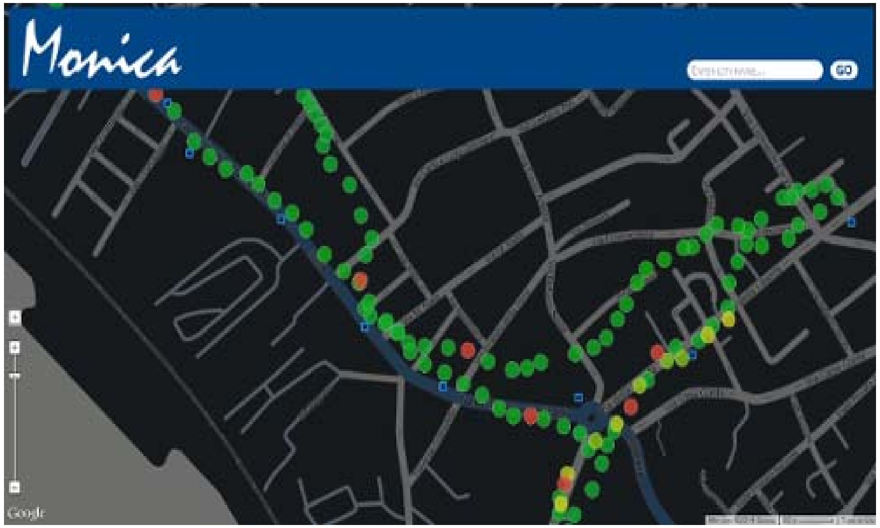
- NoSQL technologies are developed in response to a rise in the volume of data stored, the frequency in which this data is accessed, and performance and processing needs.
- Relational databases were not designed to cope with the scale and agility challenges that face modern applications, nor were they built to take advantage of the cheap storage and processing power available today.

Having the need for consistent data, and to be able to store at any time sensory data from many sources, a NoSQL database structure is the most suitable.

Among the Open Source available solutions, we chose the leading document oriented mongoDB which features auto-sharding, replication and integrated caching.

Backend Server





Backend server architecture is divided into two main layers:

1.MongoDB Database: stores the sensory data received through `insert()` command and provide it in response to `find()` command;

2.App: retrieves collected data with a HTTP/GET request and is further divided into:

a. Android app: uses retrieved data to list session logs and sends geolocalized data through a HTTP/POST request;

b. Web app: uses retrieved data to generate air quality heat maps.

Limitations and possible Business Models

Limitations:

-Notwithstanding the possibilities offered by recent open source HW and SW solutions, still, the limiting point is represented by low cost chemical sensors field performance.

-On board local dynamic multivariate calibration may help to reduce error under ppb levels for some species

-Field Performance up to now may allow for qualitative personal exposure assessment.

Possible Business Models:

-Target users by selling pre assembled HW and SW components as well as Calibration modules retaining open source approach on the base of sensor data sharing

-Target Government and or private sector (Real estate) by proposing high temporal and spatial density 2D model based geospatial pollution maps integrating fixed station data

Conclusions

In this work we proposed the design of a framework for highly distributed, maker friendly and user centric air quality monitoring, aimed to involve the citizen in multiple stages of the monitoring process.

Currently:
•a prototype sensor box, 3D printed, mountable on bike or transportable on a backpack, an Android app and a backend server on ENEA-GRID/CRESCO facilities;
•users capability of qualitative assessment;
•allow social sharing.

Future:
•on-field calibration, to provide **quantitative** measurement of pollutant concentrations;
•possible scenarios with single-board computers, to simplify the architecture and make the entire system cheaper and faster (see UDOO or Arduino Yún).
•Moving to a geospatial *data assimilation* based model

Thanks for your attention!

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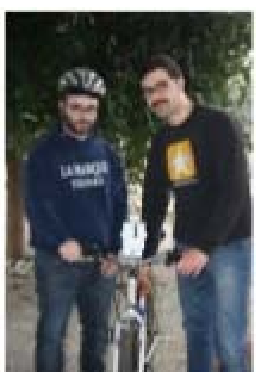

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