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COST Action TD1105

3rd International Workshop *EuNetAir* on

New Trends and Challenges for Air Quality Control

University of Latvia - Faculty of Geography and Earth Sciences

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MOBILE AIR QUALITY MONITORING WITH LOW-COST SENSORS - PILOTING EXPERIENCE IN ZAGREB

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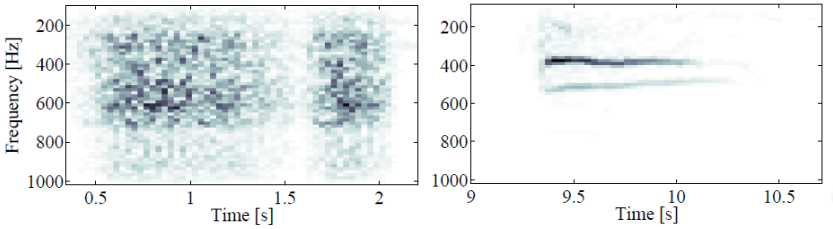
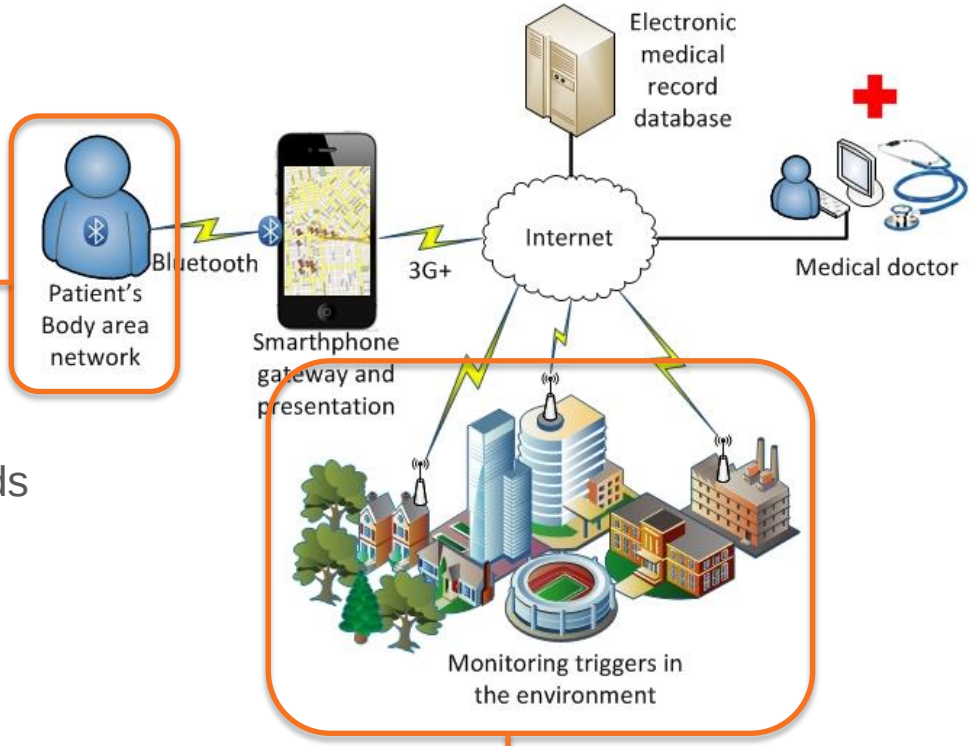
Motivation

- Entry point: technologies for chronic respiratory disease management (allergic asthma)
- Monitoring of patient and the environment



(a) Spectrogram, normal (N08) (b) Spectrogram, wheezing (W07)



- Acoustic monitoring of symptoms
- wearable classification of respiratory sounds

- Personalized, mobile chronic disease management systems
- Long-term medical, environmental studies
- **High spatial resoultion required**

- Personal exposure monitoring
- Urban canyons characterization
- Industrial fence-line monitoring

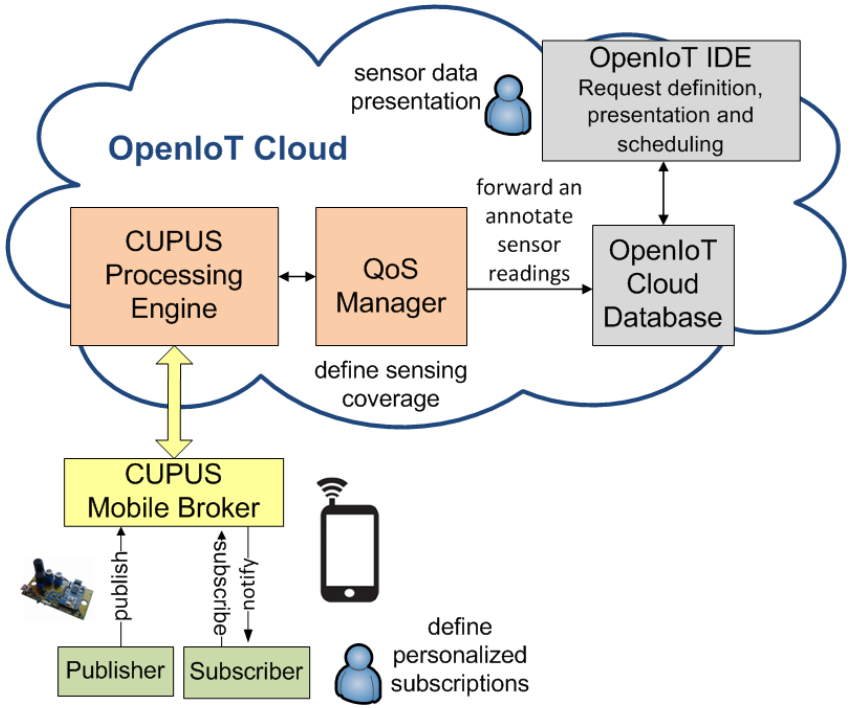
System concept: air quality „crowdsensing”

- „Crowdsensing” / „participative sensing”: air quality sensing using a network of personal mobile gas sensors?
- Citizens producing data - interesting concept, but…
  - Applicability to AQC: usability, data validation, business models…
  - Implementational issues, test deployments

FER air quality crowdsensing system architecture

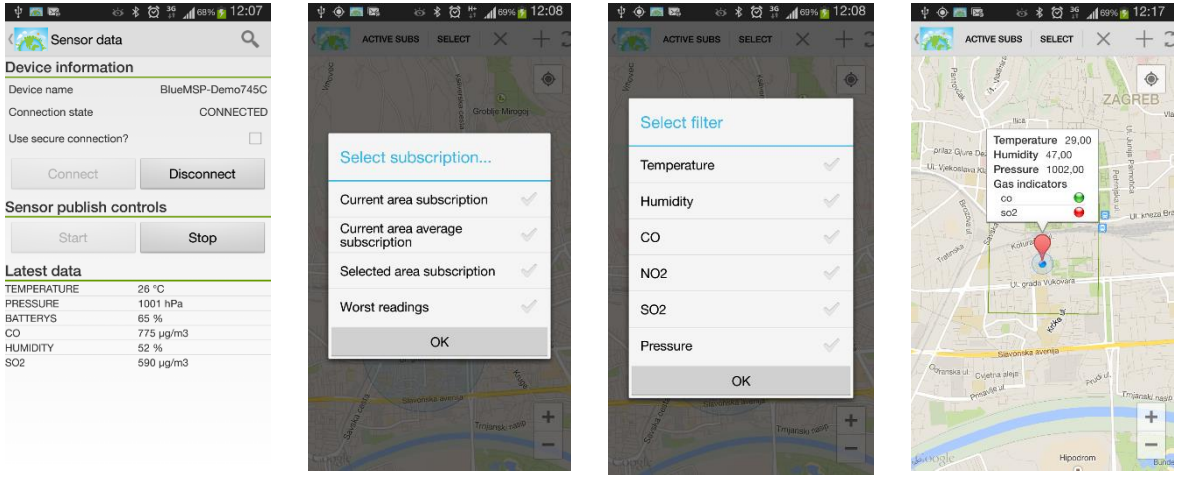
- What does system consists of?
  - Mobile/wearable air quality sensor
  - Smartphone + application for data collection, transport, visualization
  - open source cloud-based storage/processing infrastructure (OpenIoT + CUPUS)
  - Presentation – web user interfaces

- Interoperability (sensors, smartphones)
- System-level energy efficiency
  - Dynamic allocation of system resources
  - Maximization of sensors' and smartphones' battery life
  - optimized usage of cloud processing and storage resources



FER air quality crowdsensing system features

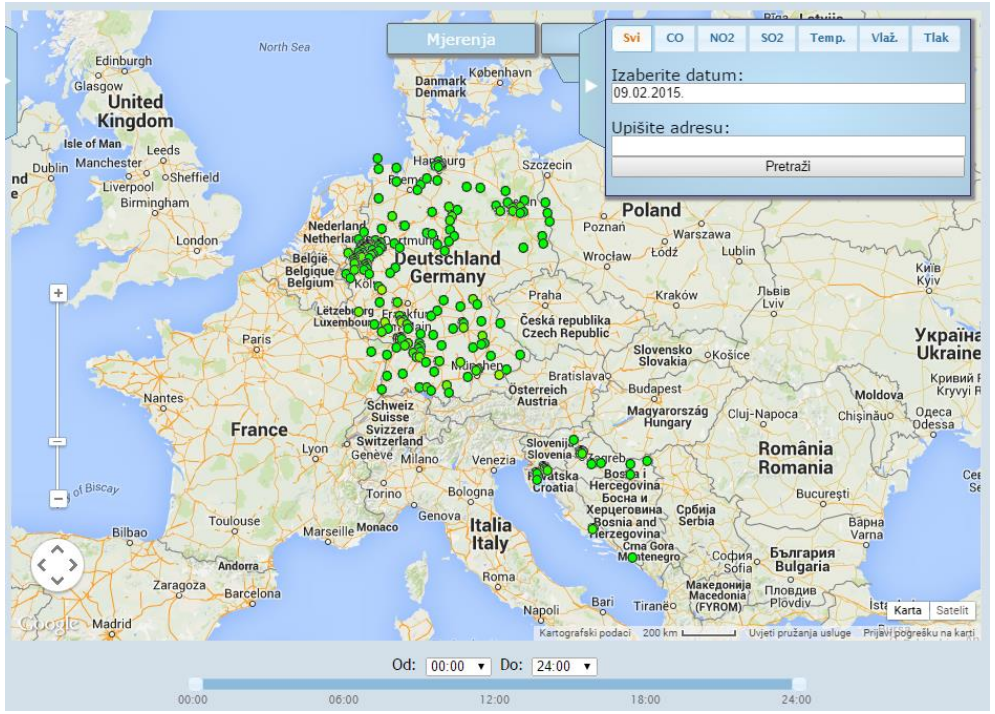
- Subscription-based data collection/sharing
- „Publish-subscribe paradigm”: sensors → publishers, users → subscribers
- real-time delivery of a personalized set of information of interest:
  - data generated by a specific set of sensors
  - arbitrary, even movable, dynamically-changeable area of interest

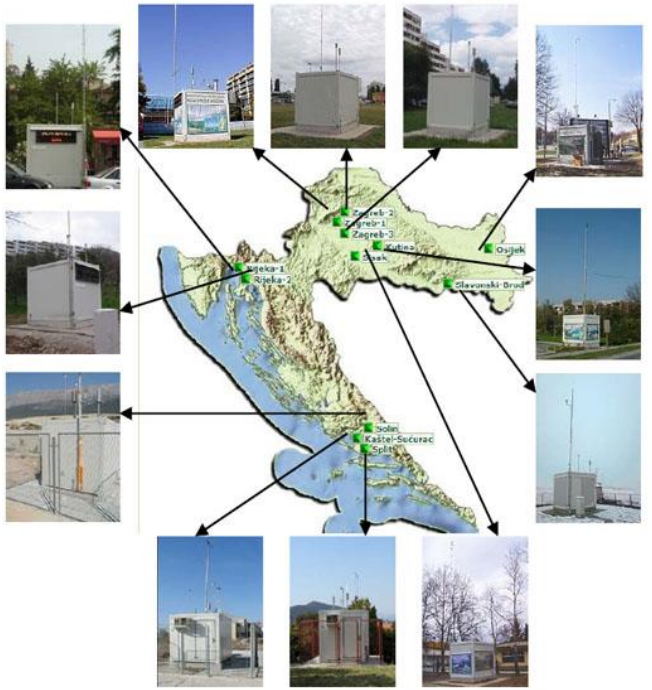


- Tailored for: personal exposure tracking, industrial fence-line monitoring, urban canyon monitoring
- Information trading – new business models, „sensing as a service”

FER air quality crowdsensing system features

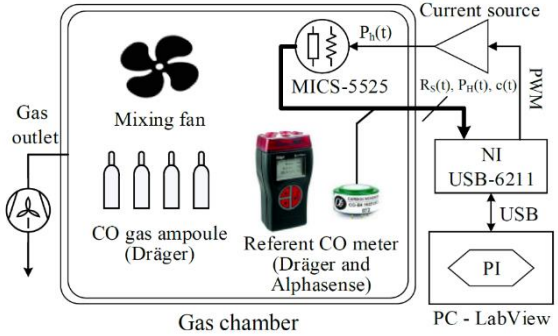
- Smartphone: real-time data visualization
- Web application: historical data presentation
- Integration of mobile air quality sensors with the data from public (municipal, national) air quality monitoring networks

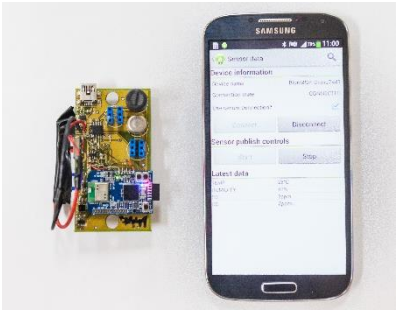


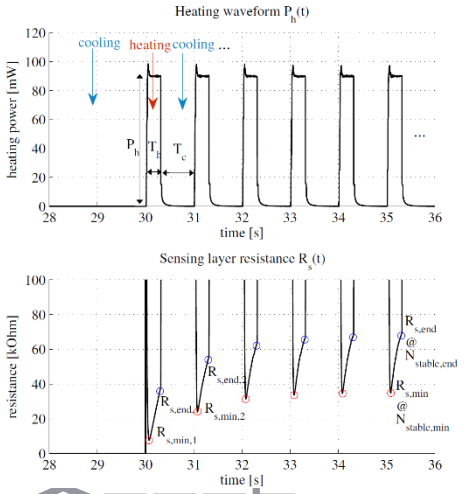


FER air quality sensors: MOX

- CO (E2V) MOX in scenario of on-demand heating / fast readout
  - response stability, sensitivity…
- Heater temperature control / sensing layer resistance readout circuity
- Optimization of pulsed heating sequence (output stability, energy per readout)







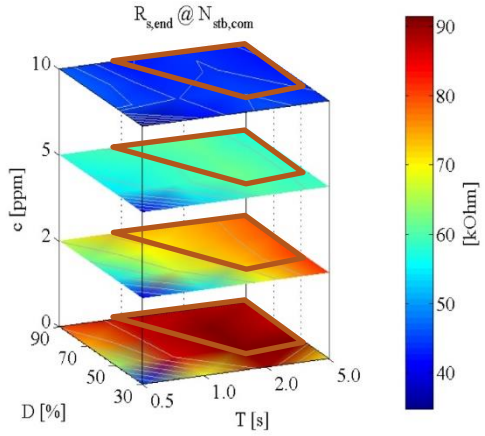


Fig. 6. $R_{s,end}$ [kOhm] versus gas concentration c, at $N_{stb,com}$.

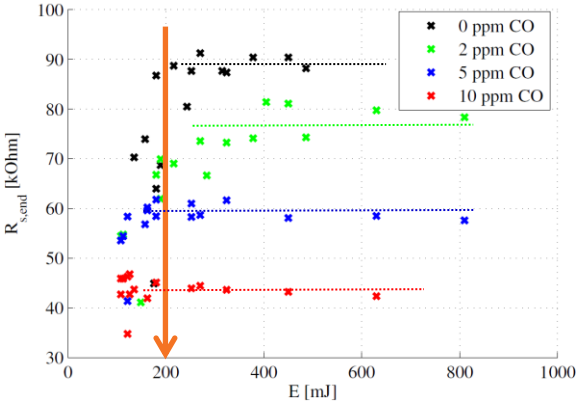


Fig. 5. Lower bound for the heating energy E. For more than 200 mJ, $R_{s,end}$ converges to a stable value characteristic for each c.

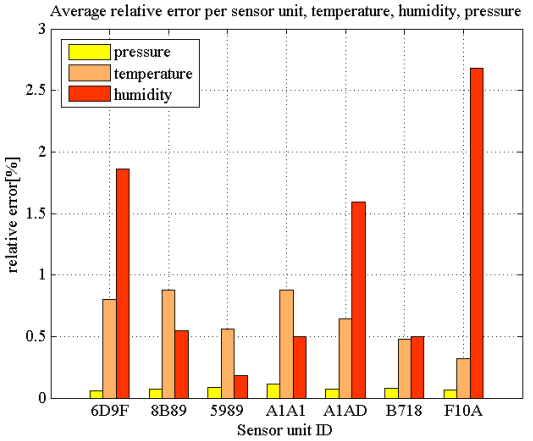
FER air quality sensors: electrochemical

- 2 gas sensors: CO and NO_2 or SO_2: Alphasense, A4-series, 4 electrode design
- Temperature, humidity, pressure
- Geo-locational data is provided from smartphone's GPS

- Interoperability: Bluetooth v2 radio featuring low power idle & RX mode
- Simple, energy efficient request-response readout interface

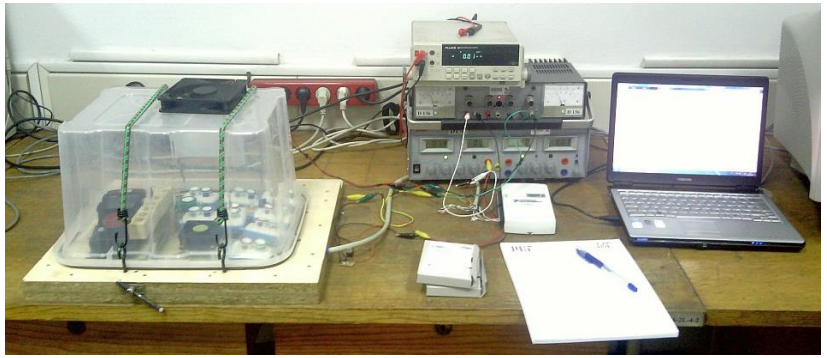
- Battery-powered, Li-Ion, 600 mAh, ~65 hrs autonomy @ 1 readout / min
- Mountng options: carabiner hook, belt-clip or bicycle mount

- **Modular design: sensor set, radio interface, casing → mobile, static installations**

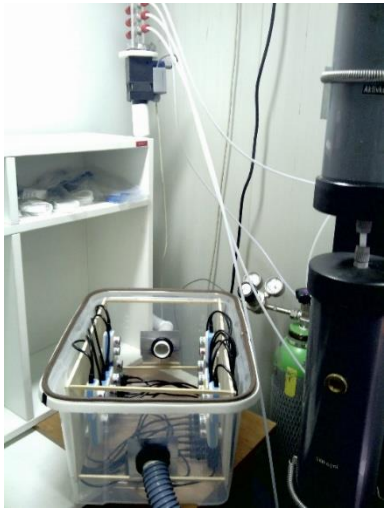


Gas sensor response verification

- Laboratory verification
  - Gas chamber
  - calibration ampoules (Dräger)
  - Referent instrument (Dräger)

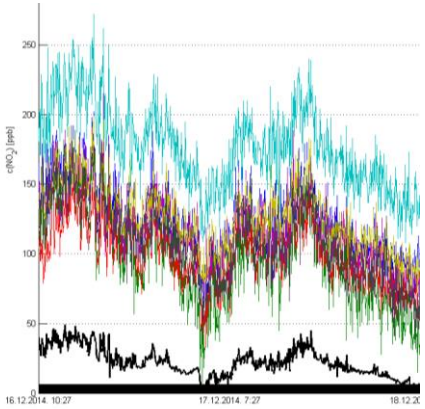


- Collocational calibration
  - In collaboration with Institute of medical research and occupational health, an accredited laboratory for AQC in Zagreb

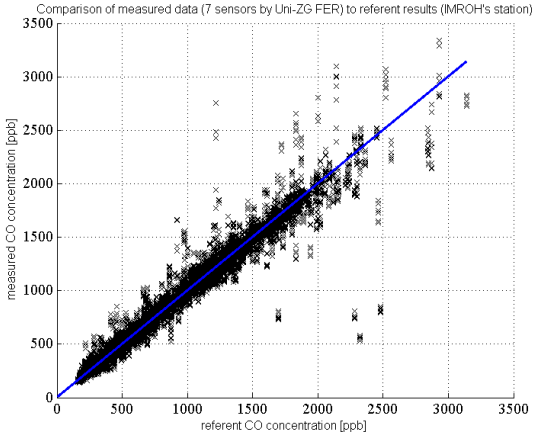


Preliminary results of collocational calibration

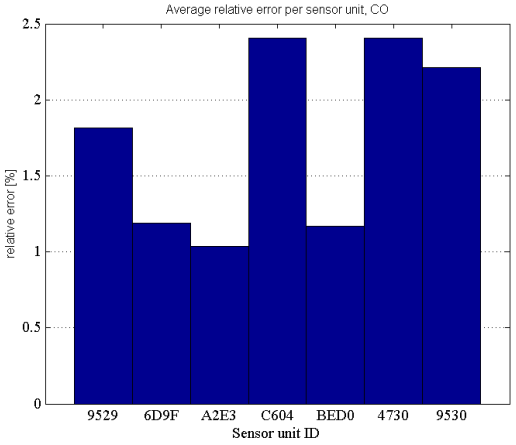
Raw data (NO_2, factory calibrated):



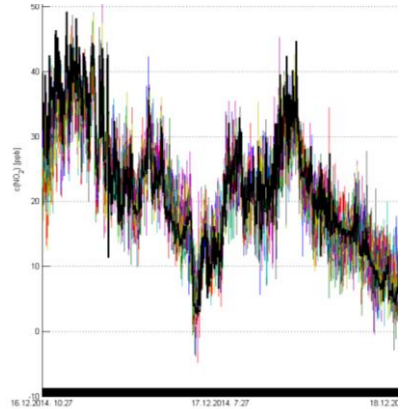
Overall results (7 sensor units):

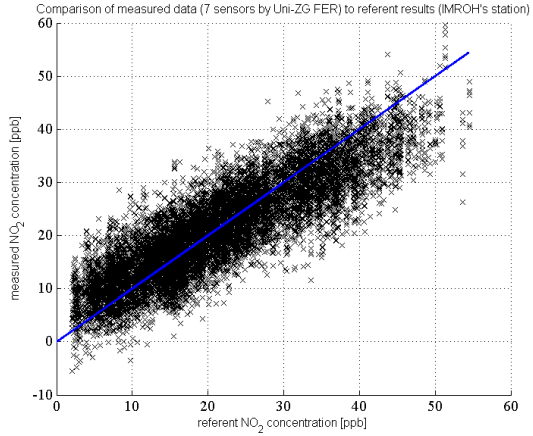


CO

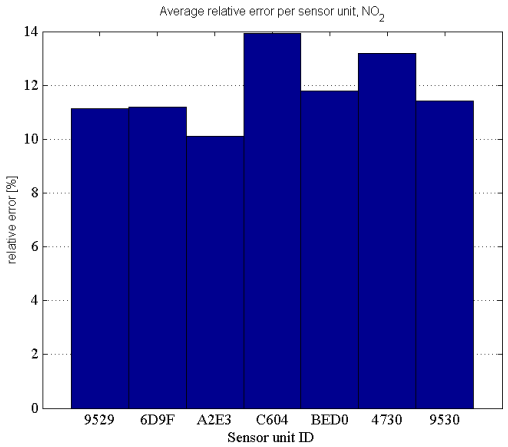


After linear LS correction of sensitivity and offset:





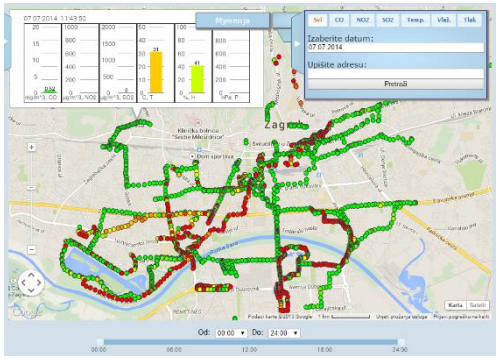
NO_2



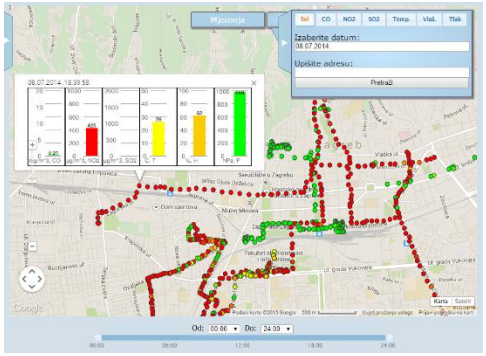
Outdoor experiments

- „Large-scale” air quality crowdsensing experiments:
- Zagreb, July, 2014
- 20 participants, University students
- end-to-end functional testing:
  - real-time data collection and delivery
  - Robustness: Bluetooth, mobile data, GPS
  - user adherence, ergonomy

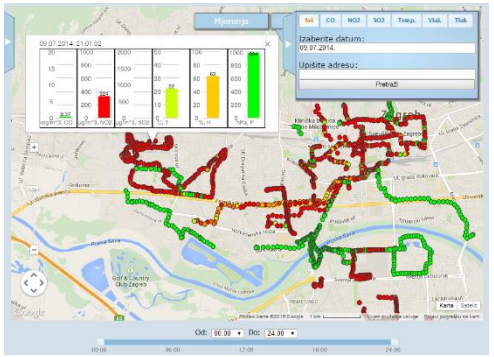
Preliminary outdoor experiments



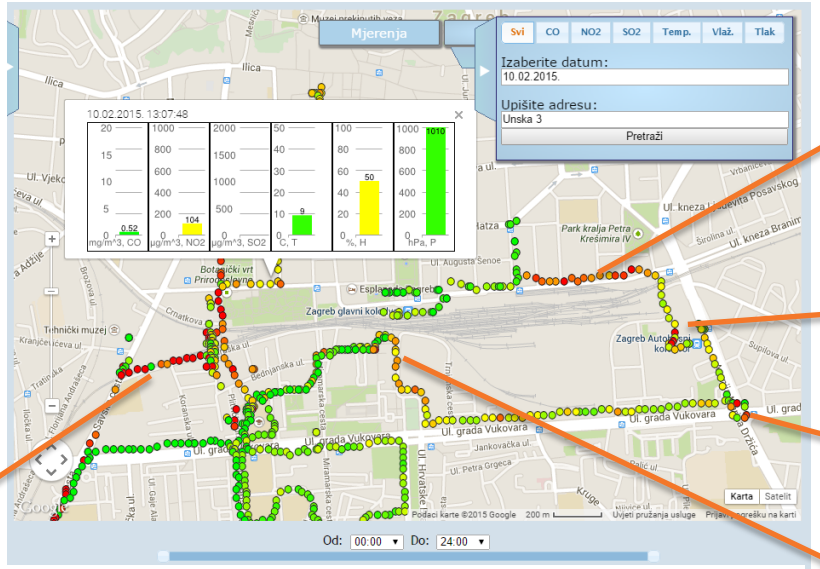
07.07.2014, 20 participants



08.07.2014, 20 participants



09.07.2014, 20 participants



an urban canyon?

inter-city bus station

crossroads

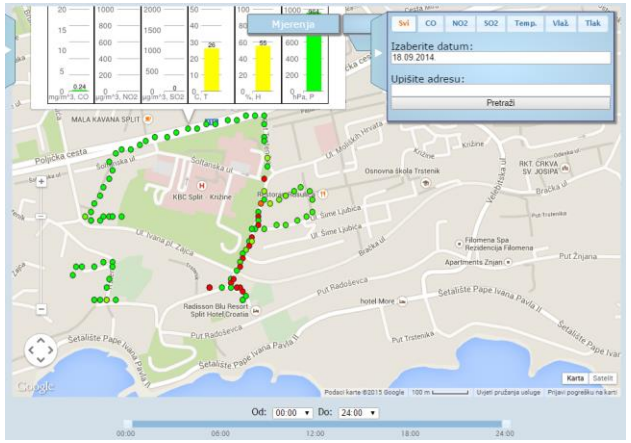
city bus-stop

city center, slow traffic

10.02.2015, 4 participants, collocationally calibrated sensors

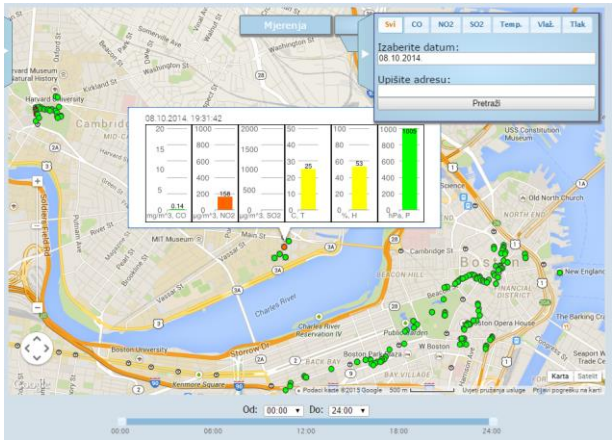
Preliminary outdoor experiments

- Additional test-runs:



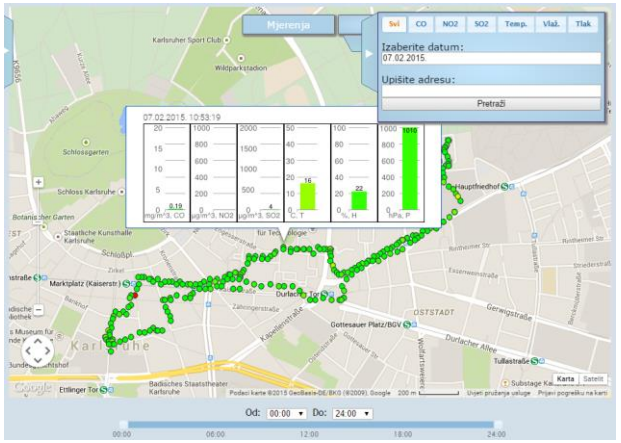
Split, Croatia

18.09.2014, 2 participants



Boston, MA, USA

08.10.2014, 3 participants



Karlsruhe, Germany

07.02.2015, 3 participants

- And, how's the air quality in Zagreb / Split / Karlsruhe / Boston…?
  - A mixture of both collocationally calibrated, and factory calibrated sensors
  - **Validation, inferences to be drawn by environmental scientists**

Upcoming work

- Singapore, April 1st-10th
- University of Zagreb, FER in collaboration with Singapore-MIT Alliance for Research and Technology (SMART), Centre for Environmental Sensing and Modelling (CENSAM)
- Deployment of 10 FER mobile sensors at JLD, in context of Singapore SMART Nation



Massachusetts Institute of Technology

SMART
Singapore-MIT Alliance for Research and Technology

senseable city lab:.::

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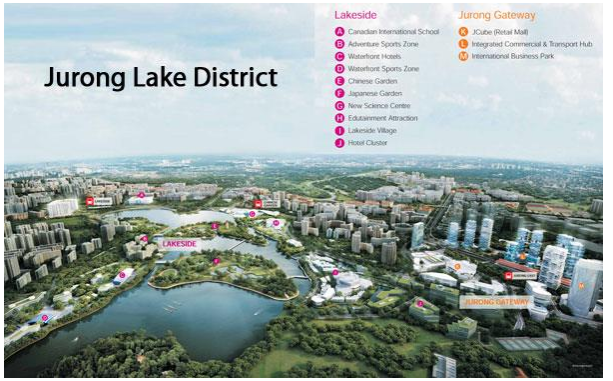

CONCLUSIONS

- Future work - Laboratory/outdoor experimentation:
  - Electrochemical sensor modelling: temperature, humidity, aging
  - In-network (online) calibration maintenance methods

- Open for collaboration opportunities as a provider of technology – contacts:
  - Sensors – prof.dr.sc. Vedran Bilas, vedran.bilas@fer.hr
  - Mobile/Software – prof. dr.sc. Ivana Podnar-Žarko, ivana.podnar@fer.hr