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

Dinko Oletić
Participant / dinko.oletic@fer.hr
University of Zagreb, Faculty of Electrical Engineering and Computing / Croatia
Motivation

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

- Acoustic monitoring of symptoms
- Wearable classification of respiratory sounds

- Personalized, mobile chronic disease management systems
- Long-term medical, environmental studies
- High spatial resolution 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 circuitry
- Optimization of pulsed heating sequence (output stability, energy per readout)

---

**Fig. 6.** $R_{end,\text{con}}$ [Ω/ohm] versus gas concentration $c$ at $N_{sh,\text{con}}$.

**Fig. 5.** Lower bound for the heating energy $E$. For more than 200 mJ, $R_{\text{end},\text{end}}$ converges to a stable value characteristic for each $c$. 
FER air quality sensors: electrochemical

- 2 gas sensors: CO and NO₂ or SO₂: 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
- Mounting 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):

After linear LS correction of sensitivity and offset:

Overall results (7 sensor units):

- **CO**
  - Average relative error per sensor unit: CO

- **NO$_2$**
  - Average relative error per sensor unit: 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
10.02.2015, 4 participants, collocationally calibrated sensors

An urban canyon?
Inter-city bus station
Crossroads
City bus-stop
City center, slow traffic
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
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