Urban Crowd Sensing Demonstrator: Sense the Zagreb Air

Aleksandar Antonić, Vedran Bilas, Martina Marjanović, Maja Matijašević, Dinko Oletić, Marko Pavelić, Ivana Podnar Žarko, Krešimir Pripužić and Lea Skorin-Kapov
Faculty of Electrical Engineering and Computing, University of Zagreb
Unska 3, Zagreb, Croatia
Email(s): {aleksandar.antonic, vedran.bilas, martina.marjanovic, maja.matijasevic, dinko.oletic, marko.pavelic, ivana.podnar, kresimir.pripuzic, lea.skorin-kapov}@fer.hr

Abstract—We demonstrate an urban crowd sensing application for monitoring air quality by use of specially-designed wearable sensors and mobile phones. The application is built upon the OpenIoT platform\(^1\) with the goal to support context-aware and energy-efficient acquisition and filtering of sensor data in mobile environments while ensuring adequate sensing coverage. We demonstrate how sensors and mobile devices jointly collect and share data of interest to measure air quality. In particular, we outline the main features of our wearable air quality sensors, present the data acquisition process as well as the user view of the system, which, in contrast to similar applications, provides a personalized real-time notification mechanism to mobile application users. The solution was used in an air quality measurement campaign “Sense the Zagreb Air” performed in the City of Zagreb, Croatia, in early July 2014 with 20 participants.

I. INTRODUCTION

The term urban crowd sensing denotes a group of smart city applications for mobile community sensing involving individuals who collect and share sensor data on the move in urban environments. Such applications can produce dense sensor readings, both in space and time, and provide the means to discover new phenomena in urban environments. They highly depend on mobility patterns of their users as well as their willingness and incentive to collect and share the data. Thus, mobile Internet of Things platforms need to support flexible data acquisition procedures in volatile environments while ensuring adequate sensing coverage.

We demonstrate a crowd sensing solution for air quality monitoring by means of wearable sensors and a mobile application developed at the University of Zagreb Faculty of Electrical Engineering and Computing. Volunteers carrying smartphones and sensors contribute the sensed data to the cloud servers, while all citizens using the application can receive measurements from the data cloud in real-time and only for areas of their particular interest. The unique characteristics of our solution are the following: 1) a flexible and energy-efficient data acquisition process in accordance with either application-specific sensing coverage for certain geographic areas, or continuous individual requests for sensor data and 2) personalized notification mechanism which delivers sensed data to mobile devices in near-real-time. This is achieved by means of our publish/subscribe middleware and Quality of Service (QoS) management component which are published as components of the OpenIoT platform\(^2\). Moreover, the innovative design of our air quality sensors produces small and robust sensing nodes adequate for outdoor experiments.

Relevant and comparable air quality monitoring solutions have been described in [1–3]. In contrast to [1, 2], our solution provides a real-time notification mechanism to end users, while our data acquisition process is more flexible compared to [3] in terms of the ability to suppress the sensing process and data transmission from a device to the cloud.

II. IMPLEMENTATION OUTLINE

The urban crowd sensing application for air quality monitoring is built upon the OpenIoT platform, as shown in Figure 1. For brevity of presentation, we depict only the main OpenIoT components affecting our design: the Cloud-based Publish/Subscribe for the Internet of Things (CUPUS) middleware, QoS Manager, OpenIoT Cloud Database and Integrated Development Environment (IDE).

CUPUS is an open-source publish/subscribe solution adequate for implementing crowd sensing applications which require flexible and energy-efficient sensor data acquisition [4]. Moreover, it ensures low data propagation time and can adjust

\(^1\)The EU FP7 project OpenIoT is the winner of the Open Source Rookie of the Year 2013. For more information visit www.openiot.eu

\(^2\)The OpenIoT platform is published as open source software (https://github.com/OpenIotOrg/openiot/).
the usage of cloud resources to the processing load. CUPUS integrates a processing engine running in the cloud and mobile broker (MB) for pre-processing sensor data on mobile devices. The cloud engine is a central processing unit which matches incoming sensor readings to user subscriptions and distributes matching publications to interested subscribers in near real-time. The MB enables the discovery of external data sources, e.g., wearable sensors, and flexible data acquisition from sensors attached to mobile devices.

The QoS Manager [5] continuously monitors the overall demand for sensor data and manages the data acquisition process to achieve a desired sensing coverage for observed areas while optimizing parameters such as overall energy and bandwidth consumption. Furthermore, it is used to annotate and forward the acquired data into the OpenIoT cloud database in the form of RDF\(^3\) triplets. Finally, the OpenIoT IDE interface can visualize the sensed data stored within the cloud database.

III. DEMONSTRATION

Our demonstration shows the functionality of the Android urban crowd sensing application for air quality monitoring. The application uses sensors producing the information on pollutant gas concentrations and meteorological conditions. Each sensor features electrochemical gas sensors for measuring atmospheric sub-ppm level concentrations of carbon monoxide, nitrogen dioxide, and sulphur dioxide, as well as temperature, relative humidity and atmospheric pressure sensors. It is powered by a rechargeable Li-Ion battery, with estimated autonomy of 3 days. The communication between a sensor and mobile device is achieved over a Bluetooth connection by use of a proprietary protocol which allows developers to initiate and stop the periodic sensing process on energy-greedy sensors when measurements are not needed.

In a use case scenario when a user defines interest to receive sensor readings collected close to his/her current location, relevant readings are delivered to his/her mobile device by use of the Google Cloud Messaging service. Users can also subscribe to receive average readings for an area produced on a time window of 15 minutes. Figure 2 shows the wearable sensors and mobile application running on two smartphones.

Smartphone a) displays a notification when a sensor reading is received from the OpenIoT cloud, while smartphone b) shows the application screen when a data reading is collected from a nearby sensor.

A subset of sensor data acquired during the air quality measurement campaign “Sense the Zagreb Air” on July 7th, 2014 is visualized in Figure 3. The web application displays changes of the data set over time, and it includes measurements from fixed environmental monitoring stations which are publicly available for Zagreb area.

IV. CONCLUSION

The paper demonstrates an urban crowd sensing application for air quality monitoring by use of wearable sensors and mobile devices. Our solution is energy efficient since it enables flexible data acquisition in mobile environments in accordance with user requirements and required sensing coverage. It can suppress the transmission of sensor readings from sensors and mobile devices to the cloud database to filter out redundant or unneeded data on mobile phones. Furthermore, the application provides a personalized real-time alert mechanism to mobile users.

ACKNOWLEDGMENT

This work has been partially carried out in the scope of the project ICT OpenIoT Project FP7-ICT-2011-7-287305 co-funded by the European Commission under FP7 program.

REFERENCES


\(^3\)www.w3.org/RDF