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Air4People: a Smart Air Quality Monitoring and Context-Aware Notification System

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Abstract: Over the last years, air pollution and air quality have received increasing attention in the scope of Internet of Things and smart cities, since they can seriously affect citizens' health. However, current systems for air quality monitoring and notification lack essential key requirements in order to be effective as far as users' access to the information is concerned and, particularly, the provision of context-aware notifications. This paper presents Air4People, an air quality monitoring and context-aware notification system, which submits personalized alerts to citizens based on several types of context, whenever air quality-related health risks are detected for their particular context.

Keywords: Context Awareness, Air Quality, Internet of Things, Mobile Application, Service-Oriented Architecture.
Categories: D.2.11, D.m, H.4.m, L.7

1 Introduction

Air quality is one of the key topics in the focus of Internet of Things (IoT) applications and smart cities [Neirotti, De Marco, Cagliano, Mangano and Scorrano 2014, Ortolani and Vitale 2016]. Certainly, air quality deserves special attention since it plays an essential role for citizens nowadays and is currently a worldwide concern [Castaldo, Pisello, Pigliautile, Piselli and Cotana 2017, Taha 2015]. Among other consequences, air pollution can seriously affect citizens' health; particularly, air pollution may worsen and favour certain illnesses or even cause death to specific risk groups [Shekarrizfard et al. 2017, Wong, Alias, Aghamohammadi, Aghazadeh and Nik Sulaiman 2017, World Health Organization 2013]. Indeed, air quality monitoring is a fundamental issue to be tackled by the whole society in general, and a representative sample of citizens (such as elders and children, people doing physical exercise outside and those who have some types of lung disease) in particular.

The fact is that due to this worldwide concern, several IoT systems for air quality monitoring have been created over the last years. Nevertheless, the problem is that monitoring alone is not enough; it is necessary to guarantee that air monitoring and notification systems are effective regarding citizens' use of such information. For this purpose, these systems have to fulfill the following requirements: (1) air quality information and alerts have to be updated in real time; (2) the information has to be actively provided to citizens in a clear and user-friendly way; (3) the information provided to users, in particular to risks groups, needs to be adapted to their specific characteristics and (4) the system should also take into account the type of activity the user is going to be involved in and adapt notifications accordingly.

Currently, most systems providing air quality information lack several of the previously mentioned characteristics: information does not reach citizens in a simple way, notifications do not consider citizens' specific characteristics and notifications do not take user physical activity into account ['CITI-SENSE' 2016, 'SmartSantander's Team' 2014, Scribd 2018].

In order to tackle these challenges effectively, and to pay spetial attention to context-awareness issues [Alegre, Augusto and Clark 2016], this paper presents Air4People: an air quality monitoring and context-aware notification system. A server side of such a system has been proposed in [Garcia de Prado, Ortiz and Boubeta-Puig 2017], which consists of an Event-Driven Service-Oriented Architecture (Event-Driven SOA) capable of both processing data coming from multiple IoT air information sources and notifying users in real time when a health risk for their particular context is detected. This architecture expected to receive the user context, but did not deal with context acquisition. In this paper, the system client-side is proposed, whose main contributions are how the user's air quality relevant context is obtained and how the user can be notified accordingly through a mobile application. Additionally, we have included sentiment analysis notifications based on air quality-related tweets.

The rest of the paper is organized as follows: Section 2 provides background information, while Section 3 presents the most relevant related work. Then, Section 4 describes Air4People's software architecture in general, and REpresentational State Transfer (REST) offered services, context acquisition and social networks sentiment analysis in particular. In Section 5, an overview of the developed mobile application and its evaluation are presented. Finally, Section 6 provides a discussion on the proposal's benefits, drawbacks and future lines of work, and Section 7 ends with conclusions.

2 Background

In this section, air quality background is described. Moreover, the sensor network deployed in Andalusia (Spain) and used as event producer in this work is presented. Then, context awareness concepts are described.

2.1 Air Quality

Since there is a lack of an internationally recognized standard for measuring air quality levels, several indexes have been created over the last years for reporting air quality [Boubeta-Puig, Ortiz and Medina-Bulo 2017]. These provide us with information about how polluted or clean the air is in a particular area and what related effects on citizens' health might be a concern.

In order to calculate the current air quality level for a particular location, each index requires the most relevant pollutants to be measured: Particulate Matter ($PM_{2.5}$ and PM_{10}), Carbon Monoxide (CO), Ozone (O_3), Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2). Each air quality level belongs to a value range, for instance, the US AQI [U.S. Environmental Protection Agency 2014] establishes a 51-200 range for moderate air quality level. However, a different range for the same level is set by other indexes, such as a 4-6 range in the UK DAQI [UK Department for Environment Food and Rural Affairs 2013].

Although Air4People could be used in conjunction with any of these ranges, currently it works both with the air quality level classification provided by the US Environmental Protection Agency (EPA) [U.S. Environmental Protection Agency 2014][U.S. Environmental Protection Agency 2016] as well as with the air quality levels proposed by the Andalusian regional government Environmental Office (AEO) [Junta de Andalucía 2017]. From all the available pollutants, the most common and relevant ones for health-related issues (O_3, CO, NO_2, $PM_{2.5}$ and PM_{10}) have been taken into account in this work.

In this regard, following the control of every air pollutant whose concentration is relevant for citizen health is essential. Depending on the concentration of each pollutant, citizen health might be affected in a different way. Table 1 shows, as an illustration, level 4 Ozone values in 8-hour periods and how they affect several risks groups as well as population in general as well as which are the recommended actions [U.S. Environmental Protection Agency 2016].

<table>
<tr><th>Index Agency</th><th>Value Range</th><th>Unit</th><th>Health Concerns</th><th>Actions to Protect your Health</th></tr>
<tr><td>EPA</td><td>0.086-0.105</td><td>ppm</td><td rowspan="2">Greater likelihood of respiratory symptoms and breathing in people with lung disease (such as asthma), children, older adults, people who are active outdoors (including outdoor workers), people with certain genetic variants, and people with diets limited in certain nutrients; possible respiratory effects in general population.</td><td rowspan="2">The following groups should avoid prolonged or heavy outdoor exertion: People with lung disease, such as asthma; children and older adults; people who are active outdoors. Everyone else should limit prolonged outdoor exertion.</td></tr>
<tr><td>AEO</td><td>120-180</td><td>µg/m3</td></tr>
</table>

Table 1: Information for Ozone 8-hour period of level 4

2.2 Andalusian Air Sensor Network

The total area of the Andalusian region is 87 268 Km^2 (33 694 square miles) and it currently has a population of around 8.4 million people. The air sensor network for sensing air pollutants in this region is composed of several sensors that belong to the Andalusian government, together with other sensors whose owners are other public and private enterprises. Every station gathers the air pollutant measurements taken from the eight Andalusian provinces. These sensors are located in representative zones with the aim of optimizing the information about pollution spatial distribution. Some of them are located in zones in which sensor readings are not too influenced by local conditions, while others are located in zones where local conditions – such as road traffic pollution – may impact sensor measurements. Figure 1 shows how sensors have been located around the Andalusian territory.

Therefore, depending on the particularities of every zone, stations may have more or less sensors for the following pollutants: O_3, CO, NO_2, $PM_{2.5}$ and PM_{10}. In addition, other sensors are in charge of measuring some meteorological elements: wind, precipitation, moisture, solar radiation, pressure and temperature. The whole network is composed of 91 air sensor stations (646 sensors, 86 200 measurements/day) and 12 meteorological towers (231 sensors, 3 400 measurements/day).

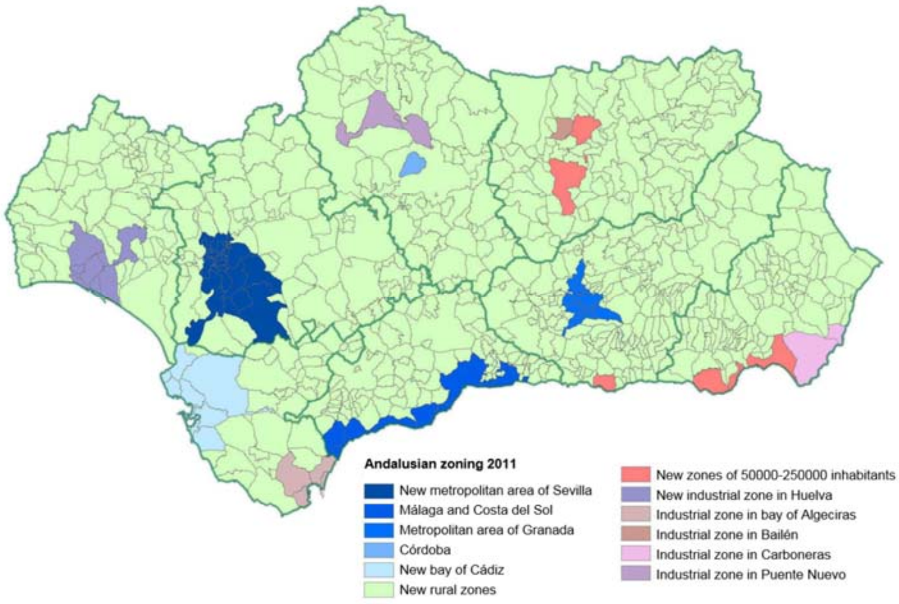

Figure 1: Map of air quality zoning in Andalusian territory

Such sensor information is sent to a main server by General Packet Radio Service (GPRS) or Internet. The data sent to the server is stored in a database and published in a web site. By using a web form, users can ask for downloading air data measured during a specific period of time; this information can be retrieved in PDF or HTML formats. However, this is a strong limitation for those that would like to process the information in real time as well as integrating it with third-party systems.

For this reason, the Andalusian regional government provides us with an on-demand service to receive the air sensing data in an own dedicated server every 10 minutes. Our server-side platform is responsible for real-time analysing and correlating this information, detecting unhealthy air quality levels for citizens, as well as promptly notifying alerts to them through their phones, depending on their particular context, as it will be explained later.

2.3 Context-Awareness

Context can be defined as any information that can be obtained related to a person, place or application and that might be relevant in order to improve the interaction between the final user and the application [Dey 2001]. Context information is in general specific to each system, so that some information might be considered as part of the context in a given system but not in another one. This is why context has been faced from several perspectives in a wide range of particular proposals and classifications [De Backere, Bonte, Verstichel, Ongenae and De Turck 2017, Immanuel and Raj 2015, Kim, Kim, Kim and Jung 2016, Peinado, Ortiz and Dodero 2015, Sundermann, Domingues, Conrado and Rezende 2016, Xu, Yin, Deng, N. Xiong and Huang 2016].

The term *context awareness* supports the fact that the obtained context information is properly used by the system so as to improve the mentioned user-application interaction [Abowd et al. 1999]. Therefore, a system is context-aware if it uses the context to provide relevant information or services to the user, adapting the system behaviour to the particular needs of a specific user.

In this scope, context awareness has become a fundamental requirement for software engineering, since nowadays it takes part of citizens' day-to-day life. However, there is a limited amount of context-aware services that users can benefit from, and there are several surveys which identify several gaps for context-aware applications in general [Harchay, Cheniti-Belcadhi and Braham 2015] and for context-awareness for IoT in particular [Gil, Ferrández, Mora-Mora and Peral 2016]. Not surprisingly, the European Union identifies, among the Horizon 2020 challenges, research and development for context-aware IoT computation [European Research Group in the Internet of Things 2012].

3 Related Work

Over the last few years, several relevant works have been developed for air quality monitoring, as described below.

Many of them have been proposed by national governments with the aim of trying to alleviate the consequences of breathing unhealthy air and only focus on measuring air quality levels in particular national or local areas. Some examples can be mentioned, for instance EnviroFlash [EPA - US 2018] is one of the most well-known air quality systems, which is based on US AQI. Its main limitation is that air quality is measured per hour and only over the United States. Europe has also developed its own system, called European Air Quality Index [European Environment Agency 2018]. This tool presents similar disadvantages to the American one: hourly measurements in cities and regions across Europe. Besides, none of them provides the means for facilitating its integration with third-party systems, services or clients. The government of Canada has also created a web tool based on Canada AQHI [Government of Canada 2016]. Hourly air quality measurements are made for a particular Canadian location, which the end user must select on a map. This task is time-consuming, being an impediment to real-time monitoring of air quality levels. In addition, once again this tool lacks an appropriate interface to be integrated with other systems. A similar functionality Android app has been developed by the Department for Environment Food & Rural Affairs in the United Kingdom [Department for Environment Food & Rural Affairs - UK 2018] to monitor air quality following UK DAQI [19].

Despite governmental applications, we have selected the most relevant systems published over the last years.

Personal Environmental Information System (PEIS) [Schaaf, Kobernus, Falgenhauer, Pielorz and Watson 2013] is a system in which the user can use a mobile application to follow the air quality components of his interest; however, it is not particularized for risks group. In addition, a 2-3 days forecast is given. It is not a native application, but an HTML5-based one, which prevents the system from sending mobile notifications. In fact, this system provides notifications, but these are based on the mobile application constantly polling the system, which requires a lot of battery consumption compared to a publish-subscribe mechanism. The system can integrate third-party sensors and provides a process to standardize the data.

Common Sense [‘Common Sense’ 2012] proposes a platform to monitor air quality information (CO, NO_2, O_3) coming from devices installed on street sweepers as well as Temperature and Humidity readings coming from mobile phones. Some applications have been designed to facilitate and scaffold novice contributions made by community members, scientists and regulators. These applications allow us to monitor personal exposure to a pollutant, inspect recorded tracks about the pollution data observations and questions made by novice users, and identify locations with poor air quality but only when the user enters an address and a time range.

CITI-SENSE [‘CITI-SENSE’ 2016] is a thorough EU project for air quality monitoring. It consists of a solution that integrates a web portal with a personal toolkit for pollutants monitoring and a smartphone application that allows users to share their perception of air quality. However, CITI-SENSE platform lacks a REST API available for users: data have to be downloaded in CSV format or directly into an Excel spreadsheet. In addition, information is not particularized for risk groups.

OpenSense II [Scribd 2018] monitors air pollution through sensors deployed in electric cars and bicycles, but citizens can also contribute data collected or generated from their mobile devices. Again, air quality notifications cannot be customized based on risk groups.

SmartSantander [‘SmartSantander’s Team’ 2014] is an EU project that proposes a huge infrastructure with around 20 000 sensors deployed in public transportation vehicles to monitor several pollutants. This platform includes a REST API that allows developers to query the last air-pollutant-related observation from any node in the infrastructure. However, air quality levels and air quality notifications are neither calculated nor sent to risk groups. Thus, personalized health recommendations are not provided to citizens.

Therefore, the revised systems have relevant features, but none of them can provide context-aware air quality notifications to final users, where their personal characteristics and current activities should be taken into account.

A more detailed study in related work on the server side architecture is shown in [Garcia de Prado et al. 2017]; as expected the client-side work is very dependent on the server-side one: it is difficult to provide a good client side without a good infrastructure on the server side. Most of the client-side approaches in this scope lacks of personalization since they do not properly deal with the user context.

4 Air4People

In this section, we first of all give a general overview of Air4People software architecture, secondly we describe Air4People REST services; thirdly, we focus on context acquisition and finally on the functionality of social networks sentiment analysis.

4.1 Software Architecture

Air4People is a system which facilitates air quality monitoring and user notification. Its architecture high-level design, represented in Figure 2, is composed of a server infrastructure, a context-aware client mobile application and Google Awareness and Firebase support. The server infrastructure is based on a Context-AwaRe Event-Driven Service Oriented Architecture (CARED-SOA) [Garcia de Prado et al. 2017].

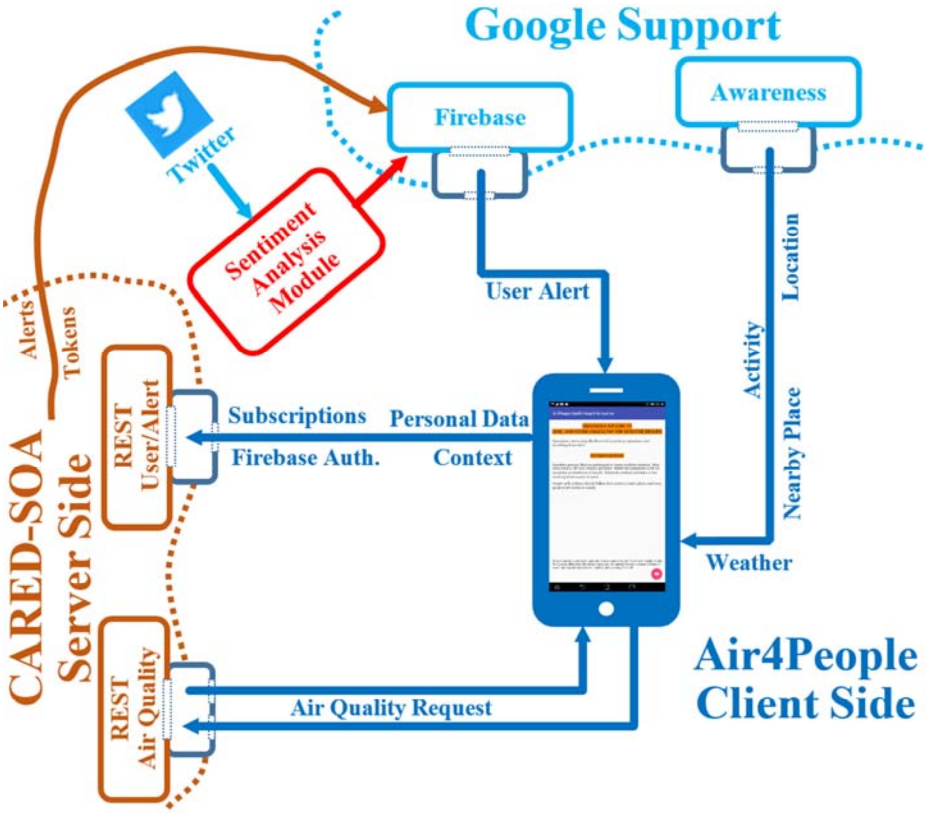

Figure 2: Map of air quality zoning in Andalusian territory

The present paper focuses on the client side of the architecture and on how the user context is obtained (both in blue in the illustration). Besides, we have added a new module to integrate social networks in the server side (red in the illustration).

Please pay special attention to the interaction of the mobile application with the REST services, the Firebase platform [Google 2018] and Google Awareness API [Google Developers 2018], as well as the new sentiment analysis module, which are later explained in the following subsections, respectively:

- REST services in the architecture server-side allow the client (1) to set their personal details and notification subscription preferences, (2) to send contextual information and (3) to check air quality values for a particular date, upon request.
- The Firebase platform facilitates user secure login with the REST services and mobile notifications under subscription.
- Besides, it is also particularly relevant to pay attention to how Google Awareness API has been used in order to obtain users' relevant context with regards to air quality.
- Finally, the new module that monitors Twitter to analyse people's tweets about air quality will provide us with additional mobile notifications to advise interested users with air quality sentiments and news.

Air quality monitoring involves measuring several pollutants, the most relevant ones being O_3, CO, NO_2, $PM_{2.5}$ and PM_{10}. Currently, Air4People server side is monitoring air quality in the Spanish Andalusian region. The Andalusian Governmental Department of Environment establishes ranks for each air pollutant at five levels: good, acceptable, unhealthy for sensitive groups, unhealthy and very unhealthy. With the support of a pulmonologist, a set of recommendations have been established for citizens according to the air quality level and the citizen's context. For instance, an acceptable value of Ozone – with no recommendation for healthy people – would imply recommending people with lung disease not to engage in physical activity outside.

4.2 REST Services

Two REST services are provided in the architecture server-side:

- **Users/Alerts service** provides operations to read the information about available subscription alerts, and – with Firebase authentication – to post and update information about users, their context and their subscription. In particular, personal context, fixed location and fixed activity schedule are provided at registration and monitored location, physical activity, nearby place and weather are updated constantly. This REST service currently allows to access the resources described in Table 2.
- **Air quality service** provides operations which are able to read all the available information about each air quality station, sensor and measurement (current and historical data). Currently, all Andalusian regional government stations are included in the system, which receives air quality measurements every ten minutes (see Section 2.2). Currently, this REST service allows us to obtain a large catalogue of GET resources, both in Spanish and English. Such API operations are fully operative and can be consulted at http://airservices.uca.es/Air4People/swagger.json and invoked at the corresponding endpoints.

Resource Name	Resource Functionality
GET RESOURCES	
Pathologies	It returns all the available pathologies which are taken into account as context in the system.
AlertsOfPathology/{pathology}	It returns all the alerts which are relevant for a pathology.
KindOfAlerts.	It returns all types of alerts available for subscription.
LevelsOfAlert/{alert}.	It returns all levels for a particular type of alerts available for subscription.
Areas	*Areas*. It returns all the available areas (location) for which the system can provide alerts.
POST RESOURCES	
User	It receives the information for a new user registration in the system.
User Information	It receives the information of the personal data of a user already registered in the system.
UserSubscriptions	It receives the alert subscription data of a user already registered in the system.
UserLocation/{lat}/{long}	It receives the location (latitude and longitude) of a user already registered in the system.
PUT RESOURCES	
UserInformation	It modifies user personal data in the system.
UserSubscriptions	It modifies user subscription data in the system.
DELETE RESOURCES	
UserInformation	It deletes user personal data in the system.
UserSubscriptions	It deletes user subscription data in the system.

Table 2: Users/Alerts service resources

4.3 Context Acquisition

There are several contexts which must be taken into account regarding air quality and health related issues: *Location*, *Physical* and *Personal context* were considered in [Garcia de Prado et al. 2017]. Two additional types, which are *Nearby Places* and *Weather context*, have been incorporated in this work. In the following lines, each type of context is briefly described:

- **Location.** Air quality information and notifications will be based on the user's location; even though the usual behaviour of the application is to monitor user location, they can also add static locations to be taken into account for notification purposes.
- **Physical**. Since the amount of air reaching our lungs depends on the physical activity being carried out, physical activity levels for notifications will be

considered (for instance level 3 of Ozone could be safe for walking but not for running).

- **Personal.** Personal context refers to illnesses or particular conditions of the user which are related to how air quality affects his health (see [Garcia de Prado et al. 2017] for further details).
- **Nearby Places.** Some places have better air quality conditions and there are those whose conditions are worse. For instance, a park ought to have good air quality conditions. This information can be used to suggest that the user goes to a nearby park to breathe healthier air when air quality is unhealthy in the current location.
- **Weather**. Since other contexts are being used in this work to warn the user to, for instance, stay inside to prevent health risks based on air quality conditions, this information may also be used to complement all notifications and suggestions based on weather condition. People with respiratory diseases may be prone, for instance, to getting a cold. Therefore, it might be suggested that the user stays inside, when it is raining or snowing.

In order to obtain most of user's context information, Google Awareness API is used in the Air4People mobile application as explained below:

- Latitude and longitude from the user is obtained [Google Developers 2018].
- With regards to the physical activity, it can be obtained information about whether the user is in a vehicle, on a bicycle, running or walking, among others [Google Developers 2017]. Physical activity context may also be statically set by users with fixed habits.
- Personal Context is directly provided by the user when logging in the application, where he can set his age and whether he has lung diseases, lung or heart conditions, genetic variants or follows a limited diet.
- Google Awareness API also provides information about places around the user ['Google Places API' 2017]. In this work, for instance, it might be of interest if there is a park or a gym nearby (it may be suggested going for a walk or a run in the park, or it may be advised going to the gym instead in case of very unhealthy air quality).

Finally, it can be also obtained relevant information about weather conditions in the user's location (windy, icy, rainy, et cetera) [Birch 2016], which might be taken into account to send suggestions to the user.

4.4 Social Networks and Sentiment Analysis

As previously mentioned, we have included a new module in the server side, based on the use of the Apache Storm distributed real-time computation system, in order to analyze all the tweets sent from the Andalusian geographical area, grouped by province. The technological architecture of such a new module is out of the scope of this paper; however, we are interested on its functionality and how it interacts with the client side.

First of all, we have defined a dictionary with a list of terms related to air quality and we have valued them with a specific positive or negative weight. Then, we have constantly processed tweets stream in Andalusia evaluating both (1) their occurrences per province and (2) the sentiment analysis per tweet:

- On the one hand, when the occurrences of a term (for instance, pollution) in a particular province (for instance, Cádiz) exceed the defined threshold (for instance, 200) we submit a notification to all users in Cádiz (for instance, *Pollution is a concern in Cádiz today*).
- On the other, when sentiment analysis of particular tweets exceeds a defined threshold we also submit a notification to all users in Cádiz. For instance, if we have the following terms in our dictionary: *pollution, -3; difficulty to breathe -4, asthma -3*, a tweet *Pollution can cause difficulty to breath and worsen asthma symptoms*, would be evaluated at -10, reaching such a threshold and therefore also being submitted to subscribed users' newsfeeds.

5 Air4People Mobile Application

This section describes the Android application implemented to facilitate context-aware air quality notifications to interested users, as well as providing a resource-consumption evaluation.

5.1 Mobile Application Overview

The mobile application provides two main functionalities: (1) checking current air quality values at any available station and (2) receiving notifications concerning current air quality at one particular station of interest. Figure 3 shows two screenshots of the app (currently only in Spanish since it is working for Andalusian sensor network).

By default, the user can see the air quality values for the closest available station. Then, the user can set personal details (age, respiratory diseases, et cetera) when he logs in the first time and updates them at any later point in time. Equally, he can initially subscribe to the alerts of interest (there are alerts for the five existing levels of air quality conditions for each relevant pollutant) and change his subscription any time. This information is sent to the server side through the User/Alerts service invocation. The user can select in the map the particular station from which to receive the selected air quality alert levels.

Secondly, such application uses Google Awareness API, as previously described, in order to obtain user context (sent to the server side through the invocation of the User/Alert service) and to facilitate context-aware notifications (sent from the server side making use of Firebase). Therefore, air quality alerts will be received in the mobile device accordingly. As previously explained, Twitter sentiment analysis notifications will be also received in the app for the province which the user subscribed for.

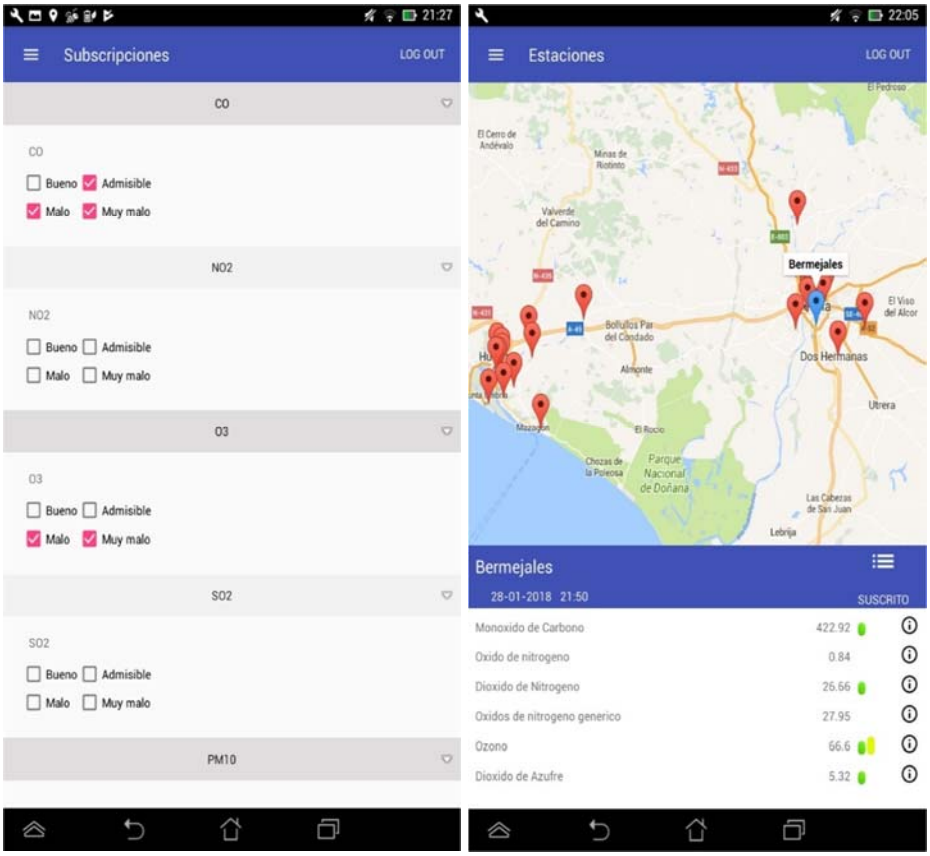

Figure 3: Air4People Mobile Application Screenshots

5.2 Evaluation

The mobile application performance in terms of resource consumption is key for the app to be accepted by the mobile users. For this reason, we evaluated the resource consumption of such application.

For this purpose we have made performance tests having location activated all the time. The test consisted of monitoring the resources consumed for one hour. All the tests have been carried out in a Huawei Honor 6x with a HiSilicon Kirin 655 Octa-core (4x2.1 GHz Cortex-A53 & 4x1.7 GHz Cortex-A53) processor, 3GB of RAM memory and 3340 mAh battery with Android 7.0(Nougat) as operating system.

During the first five minutes we were actively changing the user personal features and subscriptions. Then, the one-hour test was performed. We tested the system in the vicinity of the town of San Fernando (Spain) air quality station (current information about San Fernando air quality can be checked at http://airservices.uca.es/Air4People/moteCurrentQAirEnglish/San_Fernando. Through the mobile application, we subscribed to Good CO, Very Unhealthy SO, Acceptable NO_2, Unhealthy O_3, and Very Unhealthy PM_{10} and $PM_{2.5}$ alerts.

We have collected the evaluation results in Table 3. We have obtained such data making use of the Android application GSam Battery Monitor [GSam Labs 2017] and using Firebase performance utilities [Google 2017].

We have two sources of data traffic consumption: location data posted by the application and push notifications received by it. To understand these data, we have to bear in mind that there were 1034 air quality alerts over the Andalusian territory during the hour the system was tested; out of these, only 10 were for the San Fernando town area and only 3 conformed to the user's personal subscriptions. Besides, please note that we configured to system to submit the GPS position every 10 seconds only for performance tests; but with a rather lower frequency should be enough and the system would consume less battery and data. Therefore, we observe that the resource consumption is under a rational consumption rate.

Feature	Value
Battery consumption (µAh)	51 670
Percentage of battery consumption (%)	0.6
GPS usage (seconds)	33
Data posted to the server (after initial configuration) (bytes)	12 852
Data received through push notifications (bytes)	408
CPU UsAGE (s)	26
Background CPU Use (s)	0
Time Awaken (s)	20
Awakening (times)	485

Table 3: App Performance Results

It is important to mention that during the development of the application some close people used it and provided us with useful feedback concerning usability and functionality issues. The app was then improved accordingly. In the future we expect to follow a wider user experience evaluation.

6 Discussion

In this section, we discuss Air4People's benefits and drawbacks, as well as suggests improvements and future lines of research.

As benefits, we can highlight the versatility of the system: US EPA air quality level categorization is used as a reference. The EPA provides well-defined data clearly detailing which people are affected to a greater or lesser extent as well as which recommendations ought to be sent to affected citizens. Of course, the system is easily extensible to other air quality indexes, rather than the EPA and Andalusian ones, such as the European one (CAQI), and would be perfectly applicable to any country: we would only need to implement and deploy the new patterns in the system and update the database with the new motes. Besides, the system is scalable and extensible: it is scalable both in number of sensors (see [Garcia de Prado et al.

2017]) and also in number of users and, of course, it is extensible in matter of context conditions.

We would also like to mention the following Air4People limitations so far: the system sends email and mobile notifications. We are working on other alternatives (namely, social networks) to be included in the system in order to provide alerts in additional channels to reach more people. In addition, the system currently infers the physical context based on Google Awareness, but we plan to include additional ways to obtain the context for a further customization of alerts and recommendations sent to users.

As far as future improvements are concerned, we consider that citizens' feedback should be taken into account. Who knows what air quality currently is like better than those affected by it? This is why we plan to include people's feedback in the system.

Additionally, Air4People will be tested with risk group patients under the supervision of the local sanitary systems. Besides, the system will be extended to provide additional services to such sanitary systems. On the other hand, walking one step further on collaborative context-awareness [Garcia-de-Prado, Ortiz and Boubeta-Puig 2017] is also expected. In this regard the user could collaborate by providing additional information through the mobile application; for instance, it might be of great importance to know how an asthma patient feels with particular air quality conditions since such information can be useful for other asthma patients or for hospital staff.

Last but not least, we are currently working on ensuring the user data privacy as well as the security for the full system. On the one hand, the access to the User/Alert REST service from the app or from any other client will be protected with security mechanisms: we are evaluating several options —such as JSON Web Tokens, OAuth2 and Auth0— depending on every particular operation of the REST Service. On the other, we are planning to use a simple access token which limits the total number of requests for the REST Air Quality service, as well as the rate of requests per unit of time, in order to avoid the system to be overloaded by a distributed denial-of-service (DDoS) attack or an unsuitable use of it.

7 Conclusions

In this paper, a smart context-aware system has been proposed and implemented. This system can obtain relevant context from the user, provide real-time air quality information and notify citizens accordingly. With such a system, we can prevent unexpected health issues related to poor air quality conditions, as well as being able to suggest more suitable places or activities to users according to their context and current air quality. Therefore, the system provides one step forward in the scope of smart cities, improving life quality for citizens in general, and for risk groups in particular.

In the future we expect to progress on several open issues, namely, (1) providing air quality alerts through additional channels such as social networks; (2) inferring context from additional sources; (3) including user feedback and collaborative information in the system; (4) testing the system with a wide range of users, especially with risk group users and (5) ensuring user data privacy as well as the full system security.

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