Towards Context-Aware Smart Healthcare Platform

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Abstract— **This paper deals with the context-aware smart healthcare platform, based on IoT and citizen sensing. The proposed platform provides support to smart cities' citizens in the form of air quality visualization in their surroundings and by appropriate notifications in case of dangerous pollutants level is sensed. It also provides medical assistance based on "help needed" function, and where available, on the medical record of a patient that uses the platform services. The platform is interactive, so the information sent by the users and the requests for help will be processed. Platform development is based on a special kind of social machine that is capable to capture the city's sensors data, analyze these data and to interact with appropriate business processes. On return, that interaction results with several goals achieved with the project. Presented dashboard visualization allows decision makers, e.g. medical staff, to take proper actions on time and on-the-fly. On the other side, citizens that suffer from a variety of disease problems are able to report an air pollution incident, and ask for help, if they felt worse. The platform itself has a wider usability value and may be deployed to other smart services in a city, e.g. waste management, smart transportation, energy savings, etc. It is also scalable and open for a variety of sensor devices ranges from smartphones, wearables, and other IoT that resides in a smart city, and for different forms of crowdsensing methods. Finally, concluding remarks emphasize the future research directions.**

Keywords- air quality; context-awareness; crowdsourcing; IoT; s-health; smart city; social machines;

I. INTRODUCTION

The rising world of sensor technologies makes it possible to have a number of interconnected devices to communicate with their embedded environments. These connected devices are known as the Internet of Things (IoT), and make their sensing, actuating and communicating possibilities to be used in a new generation of applications development in favor of smart cities, new industry trends, and many other domains [1], [2].

When we back to cities there is a proven track that in urban areas many problems exist that decrease quality of life due to traffic density, inadequate waste management, etc. IoT devices bring the opportunity to build a new generation of city services that are capable to take care of these problems. Smart city concept uses ICT technologies, public resources, city infrastructure and social information to provide a better quality of life and public administration support, as well [3]. Jimenez et al. [4] define a smart city as "*A developed urban area that creates sustainable economic development and high quality of life by excelling in multiple key areas; economy, mobility, environment, people, living, and government*".

It is no easy to achieve. Despite the unprecedented revolution of wireless devices and applications that giving people the opportunity to access online services anytime, anywhere on the move, without proper solutions that would support their social interactions people are feeling isolated, as concluded by Roussaki et al. [5]. In addition, Kajan emphasizes the need to develop a new generation of –semantically, - knowledge, and even – intelligence driven mediators that should be capable to deal with an unpredictable behavior of social world populated with entities that have sensing and responding capabilities at the same time [6].

This paper is motivated by a fact that many people are suffering by the bad air quality in high-populated urban areas, especially those who suffer from asthma, lung problems, allergy, and other problems connected to the respiratory system. In that sense we propose here an architecture of a system that is capable to acquire data from city sensors, actually citizens and things (in the context of this paper, air pollution sensors), analyze these data and trigger appropriate actions by citizens themselves, city decision makers, and by healthcare specialists, as well.

Our contributions are, but not limited to, (1) identification of relevant functions that smart health systems should provide, (2) definition of a generic framework, and (3) design and development of context-aware smart health platform.

The rest of the paper is organized as follows: section 2 defines some key terms used in this paper with special attention to air-quality and gives a brief overview of related work, section 3 describes key components of the proposed framework, whilst section 4 demonstrates some system functionalities. Finally, the conclusion section gives some usability points of the proposed solution and list future research.

II.   SOME DEFINITIONS AND RELATED WORK

This section deals with some related definitions and then continues with an overview of related work on smart healthcare.

A.   Some definitions

Solanas et al. [7] define Smart Health as "*the result of the natural synergy between m-health and smart cities, from the ICT perspectives as well as that of individuals and society*", where m-health represents healthcare services delivered via mobile phones.

Context-awareness is a generic term for any information available for situation description of an entity [8], [9]. An entity could be a person, place, physical or computational object, or in general a resource. In [10], Dey defines a system as context-aware "*if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task*". Our platform is based on two context sources, here and after, city sensors: citizens and IoT. For the former the usual way to sense data from people is to use crowdsourcing, a term has been coined by Howe to define a "*ways to tap the latent talent of the crowd*" [11]. This process is also known as collective intelligence acquisition because many people are smarter than few. For the later, Qin et al. [12] define IoT from a data perspective as "*In the context of the Internet, addressable and interconnected things, instead of humans, act as the main data producers, as well as the main data consumers. Computers will be able to learn and gain information and knowledge to solve real-world problems directly with the data fed from things. As an ultimate goal, computers enabled by the Internet of Things technologies will be able to sense and react to the real world for humans*".

The term Social Machine (SM) has been coined by Tim Berners-Lee in [13] where he states that: "*Real life is and must be full of all kinds of social constraint the very processes from which society arises. Computers can help if we use them to create abstract social machines on the Web: processes in which the people do the creative work and the machine does the administration ...*" In [14] and [15], SM paradigm is described as the intersection of three main visions: (i) Social Software (as its foundations), (ii) People as Units of Computation, and (iii) Software. As this paradigm matures, we expect that any entity, be it software, person or object can be socially connected with each other, making relationships and determining different levels of interactions.

Air Quality Index (AQI) is the value of measurements of the main pollutants on a daily basis [16]. It judges how much air is polluted and how it is connected with the health of people in the area where measurements have taken. AQI talks about influence to health after hours to few days after polluted air has been inhaled. EPA [17] calculates AQI for five major air pollutants defined by the Clean Air Act [18]. These are ozone

(O_3), particulate matters (PM10), sulfur dioxide (SO_2), Nitrogen Oxides (NO_x) where x denotes its variants NO_2, NO_3, N_2O_4, and N_2O_5, and Carbon Monoxide (CO). For each of these pollutants, EPA establishes national standards for air quality in order to protect health in a living environment. According to SEPA, the most polluted air in Serbia is after high values of PM10.

AQI may vary between 0 and 500, where higher values point to a higher degree of polluted air and higher influence on health. For example, AQI equal 50 is related to good air quality with the small potential to be dangerous to public health, whilst values greater than 300 points to a health-dangerous level of air quality. The values of AQI are divided into six categories. For each of these categories, the appropriate level of concern is associated as given in Table 1.

TABLE I.   THE IMPACT OF AQI ON HEALTH

AQI level	Meaning	Value
Good	Satisfactory level of air quality; the impact on health is low and no risk	0-50
Moderate	Acceptable level of air quality with moderate impact on the health of a small number of people	50-100
Unhealthy for sensitive groups	Level of air quality that can affect the health of sensitive groups	101-150
Unhealthy	Everyone can be exposed to the negative effects of pollution on health, sensitive groups may have serious health problems	151-200
Very unhealthy	Alarming state: everyone can feel the negative effects of pollution on health	201-300
Dangerous	A critical situation, the health of the entire population is affected by pollution.	301-500

B.   Related work

Air quality monitoring in cities is interested in various aspects. In [19], Relevathy et al. emphasize the importance of air quality systems, how different polluters influence people health and propose a solution of sensory-driven air quality system. In [20], Corno et al. propose a platform for data acquisition and visualization based on air-pollutant sensors that reside on smart bicycles. Garzon et al. describe a mobile application prototype intended for informing citizens of a smart city in New Zealand about air quality [21]. In [22], the proposed system is based on Web, but also supports Android phones with notifications to subscribers in case of air-polluted threshold has exceeded.

In [23], Alshamsi et al. describe an IoT-based air quality monitoring system that uses notifications to subscribers and to a central authority, as well. In [24], Calbimonte et al. discuss studies that connect air quality and health and propose semantic data layers to deal with. A proposal for air quality data visualization from sensors built-in automobiles is described in [25]. In [26], Dutta et al. propose a sensor-based system that uses crowdsourcing of subscribers and replays with a map of pollution on return. Air quality monitoring systems with prediction intended for smart health is proposed in [27], whilst the importance of BigData in such systems is emphasized in [28].

In Serbia, there is a system for visualization of air-pollution map [29], but the number of locations and cities that are covered by that system is very small, whilst any interactions

with citizens have not provided. Bogdanović et al. made a step further by developing a system for early warnings to air pollution in Serbian cities, but it resides on Web portal only and also missed to provide online real-time interactions with citizens [30].

Our solution intersects the advantages of the aforementioned related work. Data is acquired from sensors located at dedicated locations across smart city infrastructure. The system works in favor of a smart health solution, whose intentions are given in [31]. Data acquisition is based on constant listening city sensors, whilst the visualization is provided on the Web page and at a smart device (e.g. mobile phone), as well. Furthermore, a certain level of interaction between subscribers and system applications is provided, at the moment by notifications and call for medical help function. Finally, system development is supported by a framework that includes a social machine that acts as a middleman between city sensors and smart city applications [32].

III. ARCHITECTURAL FRAMEWORK

In case of cities which are not yet equipped with appropriate ICT infrastructure devoted for polluted air monitoring and connected with health services that are usually provided in urban environments, also, citizens rely on limited possibilities for many important actions. These are, for example, being informed about air quality, their perception is based on personal experience with pollution inhalation, when an incident occurs it is usually unknown to whom it should may be reported, and to be the worst a citizen with a disease must call an ambulance alone (or by somebody nearby), and provide necessary data like location, symptoms, personal data, recorded diagnosis, etc.

The proposed system for smart air quality monitoring is based on a generic framework consisting of three layers as shown in Fig. 1. The bottom layer is a *sensor layer*. It has two kinds of sensors (machine and human) both connected to a proper smart city initiative, in this case, smart health platform. Machine sensors include air pollution sensors and smart devices owned by subscribers to a particular initiative. The former report their measurements of air-pollutants at their geolocations, the later are either alarms that inform authorities about an aero incident or help requests intended for medical assistance, or both. Human sensors are the most intelligent entities in a smart city and they are able to provide useful information to decision makers in a form of collective intelligence acquired either periodically by crowdsourcing or on the fly, at the time of the incident.

Social machine layer is intended for wrapping data from sensor layer, organizing data into clusters by some predefined rules and for interacting with the appropriate application inside the Smart Health initiative. This layer serves as a unique middleware that, on the one hand, separates sensor heterogeneity and applications heterogeneity (actually, their business processes), and, on the other hand, establishes a connection between social and business artifacts [33]. Nigam and Caswell define *business artifacts* as a concrete, identifiable, self-describing chunk of information that can be used by a business person to actually run a business [34]. Example of the business artifact, in the context of this work, is a medical record of a patient that has chronic breath disease, like asthma, allergy, etc. In the context of smart cities social

artifacts are defined by Kajan et al. [35] as "*any form of online activity (e.g., tweet, tag, and* endorse) that occurs over an open Web 2.0 application, but also to any form of online activity over ubiquitous Web (e.g., data emitted and actions triggered by the captured sensor's signals, etc.)*". In the context of this paper, online activities originate from the sensor layer, whilst business processes execute in cloud-based applications that belong to Smart health ecosystems of a smart city.
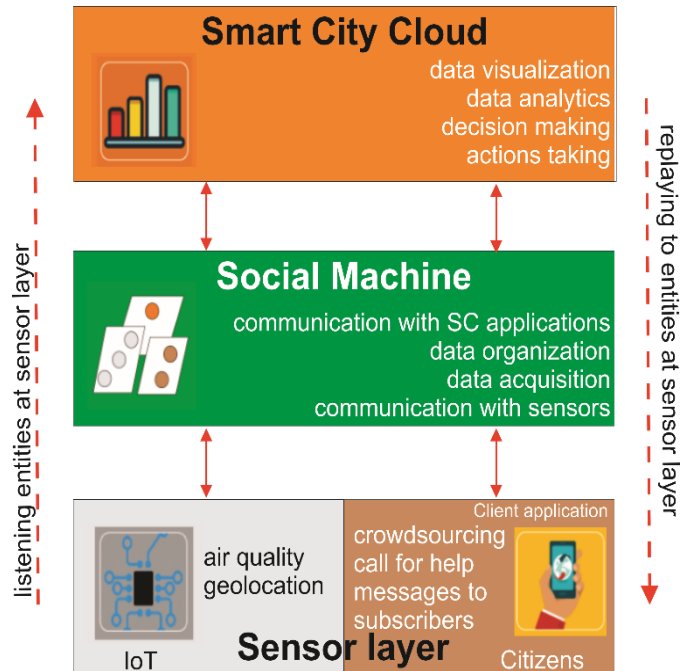

Figure 1. A framework for Smart Health

Cloud layer consists of appropriate applications that handle smart health initiatives in a city. This layer is responsible for data analysis originated from the sensor layer and enhanced by social machine layer. Also, this layer, using data analysis, decides what is required. For example, in the case of crowdsourced collective intelligence decision makers may write new rules for traffic management or establish higher standards to be applied in industry filters, etc. In case of on-the-fly communications with sensors, decisions are urgent and require either notifications consisting of easily understandable messages (e.g. leave this area ASAP) or sending an ambulance to a place where incident report match the call help. Data provided by city sensors and all interactions with them are stored in a database. This layer also provides current polluted-air visualization and these maps are available to all on the system dashboard via Web portal or mobile applications at subscriber's phone.

IV. IMPLEMENTATION

The working scenario of smart health platform is shown by the **B**usiness **P**rocess **M**odel and **N**otation (BPMN) [36] diagram, as per Figure 2, and it is described as follows:

- Continuous data acquisition from air pollution sensors.

- Data processing and visualization on public dashboard.

- Citizens are able to subscribe to this service by installing the mobile application and leave relevant

data there, including some offered keywords that best describe their health status. Some of the interactions between application and citizens are described by three cases as follows:
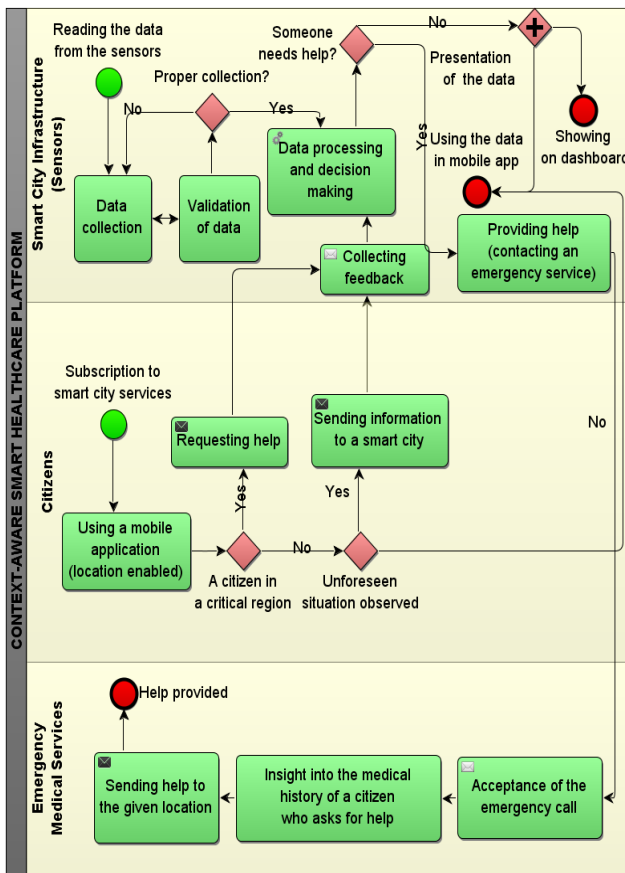

Figure 2.   Simplified BPMN diagram for handling the air pollution

- Case #1 Notifications: Air pollution in an area has increased over the threshold. The application maintains geolocations of their subscribers and notifies all subscribers in a polluted area. Notifications are handled by the algorithm shown in Fig. 3.

- Case#2 Health assistance call: If citizen, a subscriber to service, experiences some breathing problems, ask for help by pushing a special button, available on the client side of the application, that call is automatically passed to the health service. Using personal data that citizen left during subscription, geolocation and other data on the dashboard, health service may send an ambulance for help.

- Case#3 Incidental air pollution reporting: If citizen observed a critical situation (e.g. fire) it is available to report that situation to the server side of the application. After processing and confirmation application make this information public on the dashboard and sends warning to all subscribers in the area of the incident.

Business process modeling has been performed by Yaoqiang BPMN Editor [37]. We already have developed a solution to use that tool as a part of SM that takes care about tags that business process engineers and users are

able to add during modeling and run-time phase, as well [38].

The client side of the application is developed by Android Studio [39], whilst visualization diagrams are derived by using MPAndroidChart [40]. To display the dashboard, HTML5, CSS3, and JavaScript were used, while PHP was used for the server part, and the MYSQL database was used for the patient history database. Data from the pollutant sensors are preserved and used in JSON format. Application is running under Android OS from API 14+.

The whole solution is yet in an early stage, especially SM development. Due to the complexity and sensitivity of a domain, each component of a framework has carefully developed, tested and deployed, and continues to be. Besides technical challenges in front, there are many organizational challenges behind the project, e.g. assuring voluntary engagement of patients and other citizens, as well.

Figure 3.   Notification algorithm

Fig. 4 shows a visualization map in the area of the current location of subscriber and AQI values obtained from sensors nearby. Colors, given in usual EPA way, point to the air pollution degree and to its connection to the health of residents.
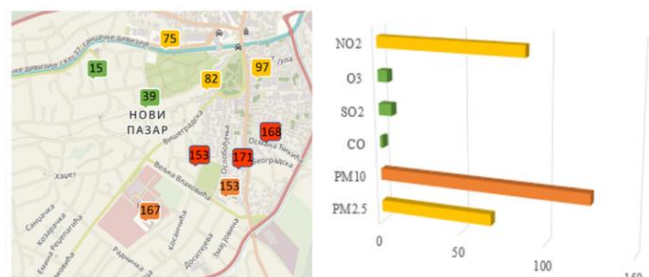

Figure 4.   Visualization map on the dashboard

The client side is developed as a demo application for Android OS with visualization specialized for smart devices and with several most used options. These menu options are shown in Fig. 5a, where a subscriber may either check current air pollution at his/her location, or activate various feedbacks, call for help, and set up own device when needed (language, user name, password, etc.). Air pollution degree visualization is

organized for every pollutant (NO₂, O₃, SO₂, CO, PM10, and PM2.5), as well as total AQI, as shown in Fig. 5b. In case that total AQI is higher than the acceptable threshold, subscribers give push notifications even if they don't run client application at the moment. Same way of notifications is used if there are a number o reports from nearby that inform about some human-visible incidents.
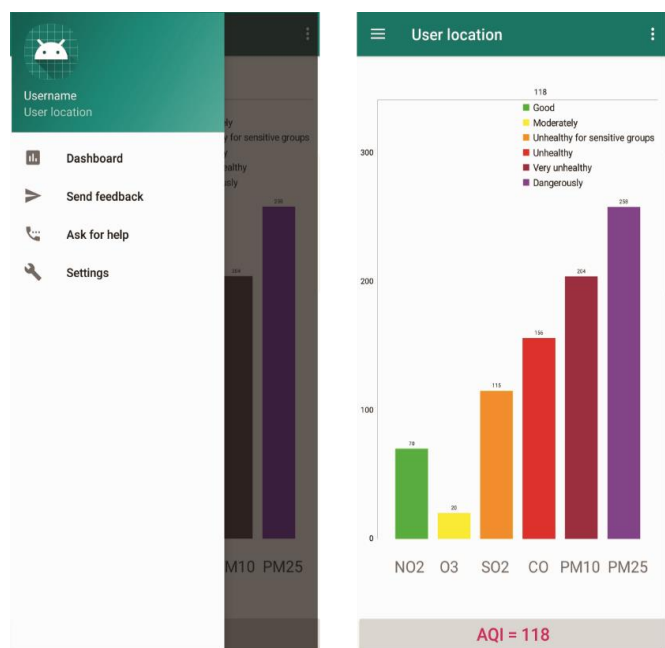
a) menu items   b) Air pollutants and AQI visualization

Figure 5.   The client side of the application: a) menu b) visualization map

V.   CONCLUSION

Existing air monitoring solutions in Serbia do not offer a comprehensive system that is able to deal with complex smart health requirements [31]. The proposed system is useful, but its realization requires much more sensors to be installed across the country. In addition, citizen education and their voluntary engagement in system use are crucial and may be foster by drilling into social artifacts via specialized social machine and measure key performance indicators related to citizen engagement into initiatives of a smart city. The proposed concept is open enough to capture other smart city ecosystems requirements, like environmental protection, traffic management, waste management, energy savings, etc.

Future research is devoted to make a concept of the social machine into full potential including business process management in health protection and to apply a variety of Web 2.0 techniques for taping into citizen's collective intelligence without exposing their health records and other personal data. Special attention to IoT security by vetting things prior to their deployment, the security of the cloud part as well as to the privacy of users will be paid, too.

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