Development of a crowdsensing IoT system for tracking air quality

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***Abstract*—The main aim of this paper is the development of a crowdsensing Internet of things (IoT) system for tracking air quality. The introductory part of the paper will describe the concepts of the Internet of things, m-health, smart healthcare and crowdsensing. The possibilities of applying crowdsensing methods for collecting data from the environment with the help of intelligent and mobile devices will be analyzed. A developed crowdsensing IoT system for tracking air quality will be presented. The developed system will use intelligent devices such as microcomputers, various IoT sensors and sensors embedded in mobile devices for monitoring the air quality parameters in the environment. This crowdsensing IoT system will enable citizens to receive information on the air quality in specific locations and via a developed healthcare mobile application.**

Keywords— Internet of Things, smart healthcare, crowdsensing, m-health, air quality

I. INTRODUCTION

Air pollution represents a global challenge, most prevalent in developing countries. The growing number of cars in the traffics, improper waste disposal, the opening of more factories in which mass production is carried out are just some of the sources of air pollution. Since developing countries are not able to invest in environmental protection due to a lack of resources, no action is taken to the prevention of the emission of harmful substances into the atmosphere, which consequently leads to endangering public health.

Stationary and mobile sources release various chemical pollutants, including suspended particulate matter (SPM), carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulfur (SOx), volatile organic compounds (VOC), and other toxics which may increase the occurrence of diseases such as lung cancer, pneumonia, asthma, chronic bronchitis, coronary artery disease, and chronic pulmonary diseases [1][2]. The problem of testing air quality and getting real-time information is present at the global level. Insight into the presence of harmful substances in the air in real-time would enable citizens to take appropriate actions and reduce their exposure, which would have a positive impact on both the public and their health. The global problem of testing air quality and getting real-time information could be solved by combining mobile healthcare and Internet of Things (hereinafter: IoT) concepts.

M-health represents a term used in the field of medicine and public health, which refers to the use of personal mobile devices to improve the provision of healthcare [3]. Mobile applications specializing in health typically include the use of mobile devices to collect clinical data, provide health information about patients to physicians and specialists, monitor patients' conditions in real-time, and directly provide health services through mobile devices [4]. In this way, doctors, patients and other stakeholders in the health ecosystem have improved communication, real-time monitoring and delivery of useful information, online consultations and other services using mobile health applications.

Mobile applications specializing in health usually enable the improvement of healthcare provision, engaging patients through participation in disease management and active involvement in their therapy [5]. These applications facilitate remote monitoring of patients' health, faster response to their needs, securely transfer confidential medical information between different healthcare institutions and increase the efficiency and effectiveness of medical business processes to improve the general health of patients [6].

Mobile health applications can be applied in the crowdsensing field [7]. Conceptually, mobile crowdsensing is a term for the wide collection and sharing of data in different domains via mobile devices, smartphones and tablets, using different sensors. These sensors can collect a huge amount of data. Also, not only smartphones can be used for crowdsensing, but also many other devices, such as IoT devices or consumer-oriented devices capable, which also can gather useful information [8]. By mentioned approach, the users share useful healthcare information that implies an increase in e-participation.

Smart healthcare is an increasingly popular concept that relies on the synergy of different engineering concepts and intelligent technical innovations applicable to healthcare [9]. Today, a significant number of applications belong to the category of smart healthcare applications. Some applications are used in clinical practice to eliminate paperwork. Some applications aim to empower patients, clarify symptoms, improve self-monitoring, etc. Applications are also often used to speed up the process of drug registration and reimbursement, as well as for research or studies conducted by epidemiologists.

The IoT represents part of many smart healthcare systems. In his paper [10], Fioccola describes the IoT as a paradigm that has recently become very popular in the context of modern wireless telecommunications. This paradigm represents "a globally distributed network of interconnected objects that are uniquely addressed and based on standard communication protocols" [11]. The basic idea of the Internet of things is the distribution of ubiquitous "objects" or "things" that are used for collecting and exchanging data.

This paper aims to provide a detailed description of the development of the crowdsensing IoT system for tracking air quality. The proposed system will provide users with real-time information about the locations where unfavorable parameters of air quality are located, their intensity and the prevention measures that users should take. Users via the developed smart healthcare application will be able to view the mentioned information via personal mobile devices.

II. II METHODOLOGY

Developed crowdsensing IoT system consists of Raspberry Pi microcomputer, Arduino microcontroller and appropriate sensors for tracking air quality parameters.

According to Painter [12], air pollution means "the presence of one or more pollutants in the Earth's atmosphere, in sufficient quantity to cause short-term or long-term adverse effects on human, animal or plant life, or the environment."

Air pollutants can be classified into two groups [10]:

- Primary pollutants - compounds of carbon, nitrogen, sulfur and halogen elements. They are released directly into the atmosphere from their sources and have a very strong impact on health.
- Secondary pollutants - nitrogen dioxide, hydrogen peroxide, ozone, sulfates and nitrates. They aren't emitted directly but are created by chemical processes in the atmosphere, acting on primary pollutants.

To measure the level of air pollution, the following parameters are mainly monitored: carbon monoxide (CO), carbon dioxide (CO2), nitrogen dioxide (NO2), methane (CH4), hydrogen sulfide (H2S), ozone (O3), ammonia (NH3), benzene (C6H6), ethanol (C2H6O), toluene (C7H8), propane (C3H8), temperature, humidity, amount of rain, light intensity, presence of flame or rain, tin oxide (SnO2), liquefied petroleum gas [10]. Additional parameters that can be monitored are sulfur dioxide (SO2), nitric oxide (NO2), as well as PM2.5 and PM10 particles [13]. The following sensors can be used for tracking mentioned air quality parameters [14]:

- The DHT11 is a digital temperature and humidity sensor.
- The MQ-7 sensor module is important for detecting the concentration of carbon monoxide (CO) in the air.
- The MQ-135 sensor module uses tin dioxide (SnO2) and it can be used to test for various harmful gases.
- The MQ-6 sensor module is mainly used to detect LPG-like gas, i.e. liquefied petroleum gas which is colloquially referred to as gas.
- The MQ-9 sensor module also uses tin dioxide (SnO2) for detection, which is characterized by low conductivity in clean air. This sensor can detect a wide range of concentrations of carbon monoxide and flammable gases.

Some of the mentioned sensors will be used for the development of the crowdsensing IoT system for tracking air quality since they can measure parameters that are important for monitoring air pollutants. Sensors are planned to be placed at different locations, where they will monitor the intensity of previously mentioned air pollutants. Sensors will be connected to the Arduino microcontroller. Since the mentioned sensor works with analog inputs, the values they read are in the range from 0 to 1024. Measured values will be forwarded to the Raspberry Pi microcomputer. On Raspberry Pi measured values will be processed using appropriate scripts. Appropriate mathematic formulas will be applied to values from some sensors.

Processed values will be forwarded to the mobile healthcare application via service. Therefore, the proposed system will be connected to the crowdsensing mobile application for the detection of allergens. The developed mobile healthcare application contains an interactive map, where the intensity of the parameters measured by the IoT system will be displayed to the end-user. Locations, where the system is set, will be pinned on the map as markers. By clicking on the marker, a text box that contains the names of the parameters and measured values will be shown to the user. Furthermore, the application will display an explanation of the measured value, therefore will understand if the air quality parameters are inconvenient.

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