Smart Cities
System for Monitoring Microclimate Conditions based on Crowdsensing

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Keywords: Smart Cities, Internet of Things, Microclimate Conditions Monitoring, Crowdsensing.

Abstract: The aim of this paper is to provide an overview of technologies, application domains and services for smart city development. We developed, implemented and evaluated a system for monitoring microclimate conditions based on crowdsensing. The developed system aims to demonstrate one of the ways of integration of Internet of Things, web and big data technologies. This system measures microclimate conditions in smart city such as: temperature, humidity, and air pressure. In this way citizens can receive quick information about microclimate conditions in their environment, such as smart buildings and homes, and to share information via web application and social media services. As a system support, web application that provides services of microclimate conditions is developed.

1 INTRODUCTION

More than half of the world's population lives in cities (Kourtit, Nijkamp and Arribas, 2012). The trend of further influx of population from rural areas is expressed. Cities tend to become "smarter" and to improve quality of life. Information and communication technologies (ICT) are enabling further transformation of traditional cities into smart cities (Mohanty, Choppali and Kougianos, 2016).

The development of smart city is often linked to the realization of the following elements (Vlacheas et al., 2013): smart economy, smart mobility, smart environment, smart people, smart living, and smart governance. According to these elements, smart city can be defined as a city that connects the physical infrastructure, IT infrastructure and business infrastructure, in order to use the collective intelligence of the city, and to have an impact on economic growth and a high quality of life (Vlacheas et al., 2013). The main aims of the implementation of a smart city are related to solving urban problems such as: transportation, health, education, electricity consumption, environmental protection (Lee, Phaal and Lee, 2013).

Internet of things (hereinafter: IoT) is important technology for development of smart city infrastructure. Internet of things technologies enable connecting a large numbers of users, intelligent devices, services and applications on the Internet (Gubbi et al., 2013). IoT technologies should be used for building IoT infrastructure for smart city. IoT infrastructure should enable connecting intelligent devices in a unique network, and using different kind of sensors, actuators, tags and readers in residential and commercial buildings, roads, street lighting, etc.

Some examples of the implementation of IoT applications in smart cities are: traffic control system, smart parking solutions, detection of the air pollution levels, smog, carbon dioxide, noise, monitoring weather conditions, alarming in emergencies, etc. (Bahga and Madisetti, 2014).

Recent trend in smart cities is crowdsensing, where citizens via smart phones participate in collecting and sharing data from smart city environment (Cardone et al., 2013).

The paper gives an overview of the smart cities concept and its application domains. IoT technologies and infrastructure for the development of smart cities are shown. The aim of this paper is to propose a system for monitoring microclimate conditions based on crowdsensing. The proposed system is based on IoT, web and big data technologies. This system should enable measuring microclimate conditions by citizens and sharing information about temperature, humidity, and air pressure via web application and microblogging services such as Twitter. A web application that enables preview of these microclimate parameters is

Jezdović, I., Nedeljković, N., Bogdanović, Z., Labus, A. and Radenković, B.
Smart Cities - System for Monitoring Microclimate Conditions based on Crowdsensing.
DOI: 10.5220/0006430701080115
In *Proceedings of the 14th International Joint Conference on e-Business and Telecommunications (ICETE 2017) - Volume 2: ICE-B*, pages 108-115
ISBN: 978-989-758-257-8

developed. Furthermore, citizen can monitor microclimate conditions daily, weekly or monthly.

2 SMART CITIES

Smart city represents an urban space that accelerates economic growth, offers a high quality of life and makes easy the involvement of citizens in the management of health, education, public utilities, business, transportation and public safety services (Sánchez et al., 2014).

The cities that have predisposition to become smart can use IoT technologies and crowdsensing applications to collect and share data in the real time (Cardone et al., 2013). Crowdsensing is ICT tool which focuses in different areas such as environment, citizen collaboration, urban traffic systems, health/fitness and social networking (Farkas and Lendák, 2015). The advantage of crowdsensing is the usage of services based on the sensing data (Petkovic et al., 2015) and it is a cheaper way to implement smart technologies in the cities because they do not require expensive infrastructure (Talasila et al., 2013).

With the development of the smart phones and advanced technologies (GPS, microphone, camera, etc.), the citizens can collect data from the urban areas. Along these lines people can be a part of the smart cities and their services (Farkas and Lendák, 2015).

One of the crowdsensig solutions is e-participation. People can post collected information to the social media such as Twitter, Facebook, Instagram, Foursquare, etc., and that can be called participatory-social sensing. The data that can be collected includes:

- environmental measurements (temperature, humidity, air pressure and emissions of the harmful gases in order to get level of the air pollution),
- geolocations,
- traffic information (collision during rush hour, police presence, traffic jams, accidents and traffic noise),
- different parameters for detection of fire and the reconstruction of infrastructure.

Data collected and evaluated in real time can be used in numerous analyses and validations. The shared information through social media needs to be analysed and used by the different organizations and government. The obtained information can make cities smarter and better for living. The final goal that needs to be achieved is to raise consciousness and environmental awareness of the citizen (Bellavista et al., 2015).

2.1 Smart City: Application Domains

The development of smart city implies application of IoT solutions that enable: the implementation of smart parking, automation of traffic signals, lights on roads; installation of sensors in the road infrastructure, buildings, houses, apartments, hospitals, educational institutions; installation of sensors for the detection of fire, electricity and water consumption, air pollution, temperature, humidity, radiation, etc.

Areas of application of IoT solutions in smart cities can be categorized in several application domains (Radenković et al., 2017): administration, participation program and public safety; buildings and houses; health care; education, traffic and energetics. Smart city application domains are shown in Figure 1.

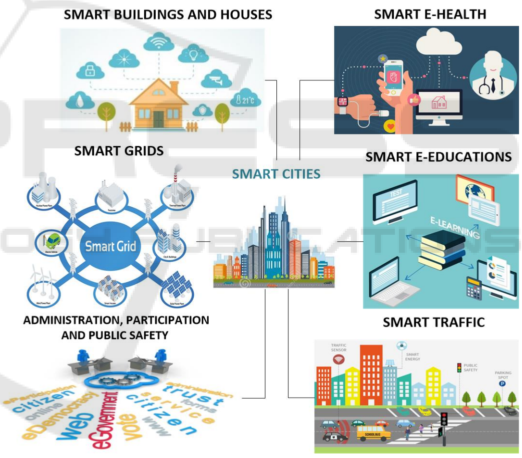

Figure 1: Smart city: application domains.

2.1.1 Administration, Participation Program and Public Safety

The development of an efficient management system for smart city implies transparent, efficient and effective operation of all departments of the city government (Sabri et al., 2015), which includes: connectivity through information technology, disclosure of information via the Internet, keeping public records of requests of citizens and enterprises, resolving requests in the shortest time etc.

Participation of individuals and society in general is necessary for realization of the smart city (Estrada, Soto and D'Arminio, 2013). The usage of

IoT applications increases the possibility of the e-participation of the citizens. That can encourage sharing ideas and information via social media in order to improve the citizen's access to information, public services and public decision-making which impacts the well-being of society.

Important domain in smart city is public safety. The most common solutions in this area are related to the installation of a large number of cameras for monitoring different parts of the city (Bahga and Madisetti, 2014). This system can be improved by using IoT solutions and construction of necessary infrastructure for the collection, consolidation, analysis and visual presentation of information in real time. These activities allow effective planning and quick response of the competent government departments.

2.1.2 Smart Buildings and Houses

This domain refers to the automation system within a building or a house (heating, water, electricity, waste, etc.) into a single entity (Davidović and Labus, 2016). This includes communication between parts of the building, and communication with other buildings in the city in order to achieve energy savings and reduced maintenance costs (Radenković et al., 2017).

Smart buildings and houses are built to provide adequate conditions for life and make it safe and effective. Their characteristics are comfort, heat, sound and physical isolation and protection. Also rational and economical use of energy can increase the quality of life. Placing suitable sensors within the buildings or houses, such as vibration sensors, sensors for monitoring pollution levels, temperature and humidity (Goncalves, 2014), should reduce the need for expensive periodic structural testing by human operators and allow proactive maintenance and restoration actions, as well as providing real time information about the weather conditions.

2.1.3 Smart E-Health

One definition of e-health is that it represents a combination of medical and information technologies, referring to health services and information delivered from the Internet. The primary goal is to improve the efficiency, quality of health services and treatment methods (Solanas, 2014). From the aspect of IoT, the components of e-health are (Vukićević et al., 2016; Rodić-Trmčić et al., 2016):

- Telemedicine - refers to healing patients from long distance and involves the use of advanced technologies such as wearables (small electronic devices that consist of one or more sensors that can monitor the health status of the patients).
- Mobile health - means the provision of health and medical services in public health using mobile devices and services.

2.1.4 Smart Education

Smart cities provide a large number of educational services (Wolff, Kortuem and Cavero, 2015). The goal is to motivate and engage citizens in the educational process and to improve the overall level of the education.

The important part of the concept of smart education is to make smart classrooms. The smart classrooms are made of advanced multimedia technologies and their advantage is to increase efficiency of the process of knowledge transfer (Simić et al., 2016). The measurements that can be monitoring are parameters of physical environment such as temperature, air pollution, light, sound, smell, etc. New generation of classrooms are equipped with IT infrastructure and modern technologies for teaching: computers, mobile devices, projectors, smart interactive whiteboards, document cameras, microphones, cameras, etc. Technical equipment allows faster and more interesting approach to teaching and assessment and easy way to support the teaching process.

2.1.5 Smart Traffic

Transportation control is of strategic importance in the big cities. It is expected that the IoT application provide interactive management of the central system for monitoring and regulation of traffic. Based on the obtained data, traffic flows can be analysed and improved in real time.

The problem of traffic congestion is becoming serious because of population growth, process urbanization and motorization. Using ICTs and intelligent transport systems (ITS) for monitoring the traffic in the city, can increase safety, make traffic more effective, delay and long period of travelling and reduce environmental pollution.

As part of smart traffic, smart parking is based on sensors implemented by or in the road infrastructure. Intelligent displays and smart parking services can help to find a free parking slot in the city. The benefits of smart parking are faster time to locate a parking space, which means we can decrease emission of harmful gases from the car, reduce traffic congestion and noise pollution produced by cars.

2.1.6 Smart Grid

One of the main objectives of smart cities is connecting various energy sources in a single network and easy access to the system for energy distribution. A digital electricity network that store, distribute and act according to the collected information in order to improve efficiency, increase the reliability of the economy, save and control electricity consumption and service provision of electricity supply is called smart grid. Smart grid represents combination of hardware and software components and uses ICTs to produce and delivery electric energy. Benefits of using smart grids are (Lukic et al., 2016):

- efficient and reliable delivery of the electricity,
- increasing the number of the electric vehicles,
- users have greater control over power consumption,
- reduction of global emissions of carbon dioxide.

Using advanced technologies, it is possible to provide a service for monitoring the energy consumption of the whole city. This would help the governments to get a clear and detailed view of the amount of energy required by the different services (public lighting, traffic lights, control cameras, etc.).

3 IoT INFRASTRUCTURE FOR SMART CITIES

IoT infrastructure and services in cities can contribute to the optimization of traffic, energy consumption, administrative and other processes (Wang, Ali and Kelly, 2015). From the aspect of communication, management and data processing, multi-layered architecture of IoT in the smart cities consists of the following layers (Jin et al., 2014):

- layer for measuring and sensing,
- Network-Centric IoT layer,
- Cloud-Centric IoT layer,
- Data-Centric IoT layer.

The lowest of the IoT infrastructure is the sensing layer. It consists of intelligent (smart) devices that collect and process information from the environment. Such a device must have the following physical components (Sanchez et al., 2014): power, memory, processor and communication interface.

The IoT solutions are usually based on the following smart devices: microcomputers, microcontrollers, sensors, actuators and modules.

Network-Centric layer in IoT infrastructure is responsible to provide a communication channel from sensors to the Internet, including the use of various technologies and network devices such as routers, base stations, and others.

Cloud-Centric layer is responsible to make available data and services to users. The role of the cloud technology is to create an environment in which the management and use of sensors can be offered as a service to end users.

Application layer consists of applications that use the data collected in the sensing layer to control different devices and smart buildings in the city.

3.1 Technologies for Smart City Development

Most of the existing solutions for smart cities are based on the integration of wireless communication technology, with the aim to create a flexible and scalable infrastructure. A special segment in the IoT infrastructure is a smart city solution that provides clients with mobility and continuity of network connection. The basic requirement is to enable the usage of various access technologies and provide communication with smart devices and objects from different locations.

Enabling technologies for the smart city development are: network technologies and protocols, mobile technologies, cloud computing and big data.

3.1.1 Network Technologies and Protocols

Internet of things is based on the use of computer networks to connect intelligent devices and applications. Intelligent devices can be connected in Personal Area Networks (PAN), Local Area Networks (LAN), Metropolitan Area Networks (MAN), Wide Area Networks (WAN) and sensor networks (Olivieri et al., 2015). When it comes to sensor networks, the most common application is Wireless Sensor Network (WSN) that allows wireless connection of sensors in sensor fields. Sensors are used to collect and send the raw data. Communication between two devices is established via direct connection or through access points installed on the network. Such communication is called M2M, and usually takes place using the IP protocol.

3.1.2 Mobile Technologies

Mobile technologies that have contributed to the development and implementation Internet of things are: mobile networks and the mobile Internet, Bluetooth, Radio Frequency Identification (RFID), Worldwide Interoperability of Microwave Access (WiMAX), Global Positioning System (GPS), Near Field Communication (NFC), ZigBee, etc.

3.1.3 Cloud Computing

Management of the smart city and data collected from sensors and with crowdsensing technology, should be stored at a reliable infrastructure such as the cloud computing. Cloud computing enables delivering computer resources on demand such as: infrastructure, servers, storage, applications, services and development environments. Generally and in the IoT context, there are three approaches in the use of cloud computing services (Despotović-Zrakić et al., 2013):

- Infrastructure as a Service (IaaS) - for development of smart cities infrastructure based and IoT,
- Platform as a Service (PaaS) - suitable for IoT project management,
- Software as a Service (SaaS) - in the IoT provides web-based applications for working with sensors, actuators, and other intelligent devices.

3.1.4 Big Data

The need for applying big data technology is often explained using three "V" model, under which are the main characteristics of big data (Laney, 2013): volume, variety and velocity.

IoT systems with sensor networks generate large amounts of data. A variety of sensors in short time intervals monitors parameters in the environment, such as the health status of people, plants and animals, buildings, atmospheric phenomena, earthquakes, river flows and events in the universe (Vanschoren et al., 2014). In addition to sensor networks, a large amount of data is generated by the mobile crowdsensing. Using crowdsensing techniques users, from their mobile devices, can send essential information about the state of traffic or noise pollution.

Due to the huge amount of data, it is necessary to use big data technology for their proper storage. It is necessary to integrate the collected data with data from other sensor systems, and then perform analysis. The analysis results should be available in real time and displayed in visual form suitable for users. Based on the results, fast notifying and alerting are performed in emergency situations and prediction of future states of the system.

4 SYSTEM FOR MONITORING MICROCLIMATE CONDITIONS BASED ON CROWDSENSING

Using a larger number of stations that measure the microclimate conditions such as temperature, humidity and air pressure, combined with geolocation data, residents of smart cities will be provided with more accurate information. If we take into account how social networks such as Facebook and Twitter have a stake in our daily life, an important part of the system is the station`s possibility to send microclimate condition directly on the social network. This allows residents of smart cities fast access to fresh information on the microclimate conditions in their part of town.

This paper presents a system for monitoring microclimate conditions based on crowdsensing (Figure 2). System is developed as a project of E-business Department, which exist at the Faculty of Organizational Sciences, University of Belgrade.

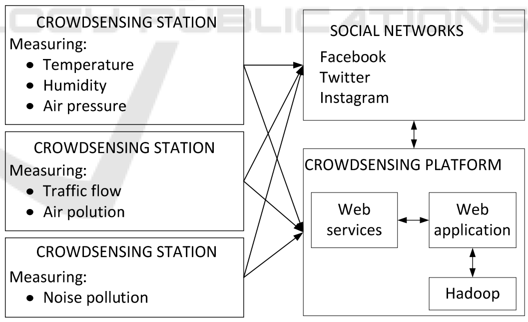

Figure 2: System for monitoring microclimate conditions based on crowdsensing.

The proposed system collects data from different types of crowdsensing stations and enables sharing data directly on crowdsensing platform and social networks. The crowdsensing platform integrates web application, web services and Hadoop. This paper shows the implementation of the crowdsensing station that measures the microclimate conditions such as temperature, humidity and air pressure (Figure 3). Although the system is developed in the academic environment, the simplicity of the system allows ordinary citizens to build it by themselves and use it to send and receive data from the server. Participating in this process they become a part of crowdsensing network.

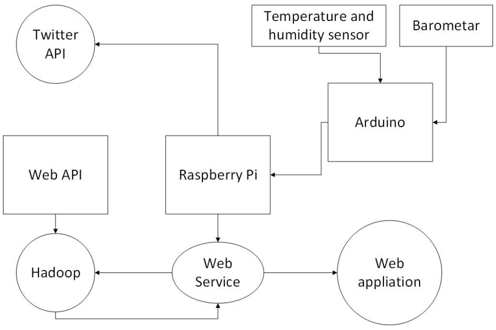

Figure 3: Crowdsensing station for monitoring temperature, humidity and air pressure.

Crowdsensing station for monitoring temperature, humidity and air pressure consists of: microcomputer, microcontrollers and sensors. Devices connected in a real environment can be seen in Figure 4.

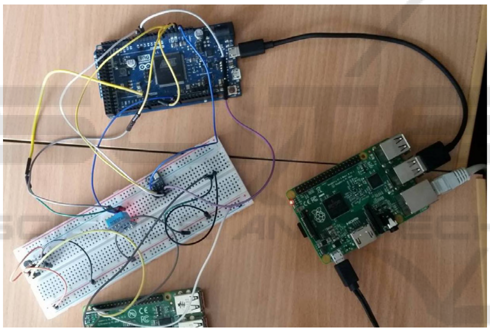

Figure 4: Connected devices in a real environment.

DHT11 sensor measures the temperature and humidity, while a barometer measures the air pressure. Both sensors are connected to the Arduino microcontroller. Arduino is getting its power from the Raspberry Pi which is powered by a +5.1V micro USB supply. Raspberry Pi and Arduino communicate through Serial Communication. This type of communication is essential for all micro-controllers to communicate with other devices. Raspberry Pi via web service sends the data to the database for further analysis and storage. Users can access weather data through web application. Connection to the Internet is realized through Raspberry Pi device via Ethernet adapter or WiFi module.

The use of the above mention devices is optional. The system can be implemented using other microcomputers and microcontrollers such as xMega or ESP8266, but it is important that system meets the requirements of web services and platform.

As a system support, a responsive web application was developed (Figure 5). The application design was developed using HTML and CSS technologies, while logic is based on JavaScript and PHP programming language.

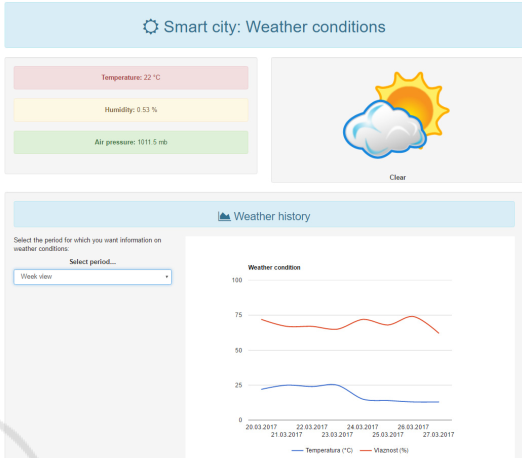

Figure 5: The screenshot of web applications.

Microcomputer, Raspberry Pi communicates with Web application through web services. Web services are based on the REST architecture. All data is represented in JSON format. Simultaneously all sent data are processed by using Hadoop (Figure 6). In addition to the data collected from the sensors, by using Hadoop, data on weather conditions obtained from an external web service are also processed. For visualization we used Tableau Desktop tool. It is data visualization software that allows multiple data sources and different data chart types.

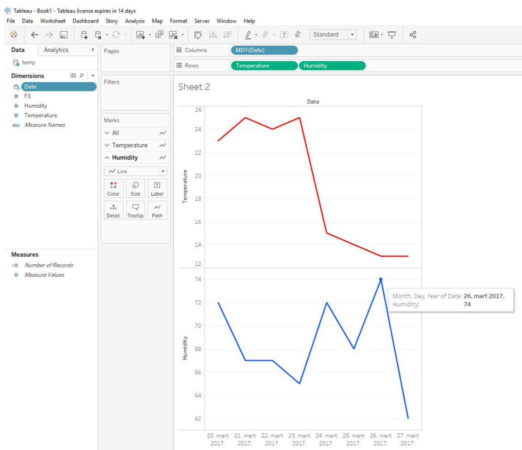

Figure 6: Chart view from big data visualization tool.

Hadoop provides the ability to store the large scale of data (generated from sensors, video/audio devices or the social media). Storing and processing data on the Internet requires scalability, fault tolerance, availability and that can be enabled by using cloud computing. Collected data from the social media (Twitter) is generated in an effort to analysed information (temperature, humidity, air pressure, etc.) provided by the people and gave them the feedback on weather conditions in all central cities of the state through social services.

Raspberry Pi device has built-in option to tweet the data obtained from the sensor at the desired time intervals. This option is achieved by using a tweeter-master library for Python programming language. Example of tweeting weather conditions is shown in Figure 7.

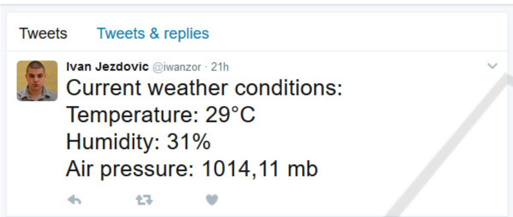

Figure 7: Tweet of the data obtained from the sensors.

5 CONCLUSIONS

This paper presents a system for monitoring microclimate conditions based on crowdsensing. The developed system was developed within the Department for e-business, at the Faculty of Organizational Sciences, University of Belgrade.

By using the proposed system users become a part of crowdsensing network that allows obtaining precise information about microclimate conditions based on their location. The main advantages of the present solution are ease of use, low cost of equipment needed for the implementation and easy upgrade. Because of these characteristics, the proposed system is suitable to be used by a large number of users.

Plans for further development are:

- creation of database of users with health problems that depend on weather conditions and adequate notification system,
- implementation of the GPS sensor which will collect information about the position and the place where the measurement is performed. Combination of GPS and microclimate data, allows us to group data based on the location and their mutual comparison from which we can draw more accurate data.
- development of the proposed crowdsourcing platform that enable sharing information from the crowdsensing stations by citizens.

ACKNOWLEDGEMENTS

The authors are thankful to Ministry of Education, science and technological development of the Republic of Serbia, grant no. 174031.

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