Real-Time Measurement and Analysis of Air and Water Parameters on the Territory of Montenegro

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Abstract— **This paper describes systems whose primary role is a measurement, display, and analysis of data based on the Internet of Things, with a focus on environmental parameters that directly affect the environment. Having in mind that Montenegro is an ecological state, it is necessary to justify its ecological status by investing in the development and preservation of the environment by applying modern technologies. Therefore, the paper points to the complexity and multidisciplinary between ecology and computer science.**

Keywords: ecology; modern technologies; Internet of Things (IoT); Application Programming Interface (API).

I. INTRODUCTION

Measurement of parameters that affect the quality of the environment, in addition to classical methods, are measured using sensor networks [1]. Finished sensor networks have a high price, they are mostly of the closed type, which indicates that they are not compatible with different manufacturers of sensor equipment.

In addition to ready-made sensor nodes, there are a large number of platforms that enable connection to the Internet of Things (IoT) devices. Some of the platforms are “Evira” [2] and “ThinkSpeak” [3]. “Evira” is a platform that has different types of monitoring, but is not free and is defined specifically for certain areas of application. The advantages of “Evira” are already defined control panels - dashboard design according to a modern user interface without the possibility of influencing the appearance of certain IOT measurement visualizers. The recommendation for using the platform is commercial sensors, which indicates large economic expenses. “ThinkSpeak” is an open-source platform that enables connection to IoT-based devices. On “ThinkSpeak” there is a possibility for graphical visualization, analytics, but without the possibility of changing the built-in functions. The basis for communication between the "Think speak" platform and IoT devices is the Application Programming Interface (API) [4].

The number of Internet users is increasing annually, despite the fact that half of the world's population does not have an Internet connection [5]. By the end of this year, 3.5 billion people in the world will use the Internet [5]. The number of devices based on IoT during 2021. amounted to 13.8 billion - yard devices and is projected that by the end of 2025 this number will grow to 30.9 billion devices [6]-[8]. Figure 1. shows the number of devices that use IoT technology, for the period between 2010-2025.

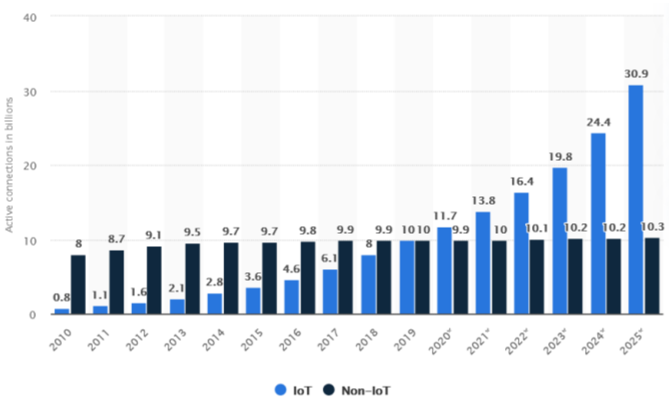

Figure 1. Projections for IoT devices in the world until 2025. (Source: https://www.statista.com).

By analyzing the presented values from Figure 1. it can be concluded that IoT is an emerging technology. Based on the actual trend, it will become an integral part of each device that uses the Internet as a resource for its normal functioning.

There are a large number of pollutants in Montenegro, including industrial centers and vehicles that use the principle of fuel combustion that directly affects the quality of air, water, as well as general environmental pollution [9]. Within the ECOMON project [10], a system was developed whose primary goal is the measurement, collection, and analysis of real-time data using IoT technology. Based on the measurement of appropriate parameters and the use of modern technologies, deviations from the nominal values were determined, which concluded which parameters to focus on (which parameters have a negative impact on the environment). A platform has also been developed that displays measurement results, graphical data visualizations, and generates predefined reports. The main advantage of the platform is the compatibility with sensors from different manufacturers and networking with third-party applications using API. The aim is to make environmental information available to all and to use it for purposes that will directly or indirectly affect the improvement of parameters that go beyond the permitted values as well as in the areas of additional research. Section II describes the technology used in the implementation of the system, while sections III and IV focus on all parameters important for air and water quality. Section V specifically explains the architecture of the entire system, as well as the platform in Section VI. Section VII refers specifically to the testing of implemented sensor nodes as well as the results received.

The work can contribute to the formation of the first outdoor IoT laboratory in Montenegro and the region. Data availability is open to all researchers for whom air and water quality parameters will be important for different types of research work.

II. General System Requirements

System requirements are defined according to different types of users and areas of application. User requirements are as follows:

- Design and application of sensor nodes - Compatibility with all types of sensor equipment with the ability to configure sensor nodes and time intervals for sending data from a remote location. The price of such nodes is significantly lower than the price of commercial solutions.
- Monitoring and analysis of air and water parameters - Includes measurement that is guaranteed with precision and based on a large amount of such data can be used for additional research purposes.
- Development of a platform for monitoring measured quantities in real-time - The platform is adapted to all devices that have an Internet connection. The design of the platform includes a modern user interface that is easy to manipulate and obtain the appropriate parameters.
- Development of expert decision systems [11] - Systems basis of measured quantities with defined ranges, regulate according to user requirements to properly maintain the measured parameters.
- Ability to connect to third-party applications - Defining a unique API that allows connection to existing platforms whose primary role is in the field of IoT.

A wide range of sensors (transducers) [12] was used to implement the system, which measures the appropriate parameters of water and air quality.

In the first phase of the project, pilot solutions were implemented at "critical spots and points" in Montenegro, using more expensive commercial equipment. After testing the work and analyzing the obtained data, moved on to cheaper sensor solutions. Cheaper solutions are reliable with tolerant deviations of the obtained measurement results from commercial versions. A renewable power supply is used for the smooth operation of the sensor nodes.

The goal of the implementation is for the equipment to be modular and not to require specially qualified personnel for physical installation and commissioning. All sensors and sensor nodes have the possibility of integration with different platforms via API, based on which the compatibility of the entire system is indicated. The following figure shows a map with implemented sensor nodes in the territory of Montenegro.

Figure 2. Sensor network on the territory of Montenegro (measuring stations).

III. Environmental Parameters of Interests

Through the project, the measurement of water and air quality parameters was performed. Measurements were realized using sensors that directly measure the appropriate parameters, while individual parameters were obtained by finding the relationship between electrical and non-electrical quantities. During implementation, the focus was on the following parameters:

- Air temperature
- Air humidity
- Air pressure
- Amount of precipitation
- Wind direction and speed
- Gas concentration (MQ2-MQ9)
- Water temperature,
- pH value,
- Electrical conductivity,
- Turbidity of water,
- Water level and
- Oxygen level.

To measure these parameters two types of sensors belonging to the group of commercial and non-commercial sensors were used. Using commercial sensors, high precision has been observed that fits the user's requirements, but they also have a high-cost price. However, after switching to a cheaper solution, tolerant deviations of the measured values were observed. The following are the technical characteristics of the used sensors:

TABLE I. CHARACTERISTICS OF THE USED SENSORS

No.	Characteristics of sensors for air parameters				
	Sensor name	***Measurement unit***	***Minimum value***	***Maximum value***	**±**
1.	DHT11	°C	0	50	2
		%	20	80	5
2.	DHT22	°C	-40	125	0.5
		%	0	100	2-5
3.	BMP180	°C	-40	80	-
		mbar	300	1100	-
	Characteristics of gas sensors				
	Sensor name			***Model***	
4.	MQ2 – Analog Gas Sensor			Smoke	
5.	MQ5 – Analog LPG Gas Sensor			Gas	
6.	MQ7- Analog Carbon Monoxide Sensor			CO	
7.	MQ8 - Analog Hydrogen Gas Sensor			Hydrogen Gas	
8.	MQ9 – Analog CO/Combustible Gas Sensor			CO/Combustible Gas	
	Sensor characteristics for water parameters				
	Sensor name	***Measurement unit***	***Minimum value***	***Maximum value***	**±**
9.	DS18B20	°C	0	80	0.5
10.	Analog pH meter kit v2.0	-	0	14	0.1
11.	Analog electrical conductivit y sensor	ms/cm	10	100	2
12.	Turbidity sensor	NTU	0	3000	-
13.	Water-proof Ultra-sonic sensor	m	0.25	4	-
14.	Dissolved Oxygen Sensor	mg/l	0	20	-

Table I shows the characteristics of three types of sensors based on their application: air, gas, and sensors for measuring water quality parameters. Observing their characteristics, it was concluded that for the use of gas sensors, it is necessary to find the dependence between electrical and non-electrical quantities.

The following figure shows an implemented sensor node that uses IoT technology. The primary role of this sensor node is to measure air parameters.

Figure 4. Sensor node for measuring air quality parameters.

Sensor nodes that measure water parameters can be used to check the quality of drinking, sea, and river water [13], or to control water parameters in pools where it is possible to breed certain kinds of fish.

One of the users of this system is the fishponds "Plantaže". On fishponds, various parameters are measured that directly or indirectly affect the way fish is fed. Figure 5. show the arrangement of sensors in the pool that measure the following parameters:

- Water temperature,
- pH value,
- Oxygen level and
- Pool water level.

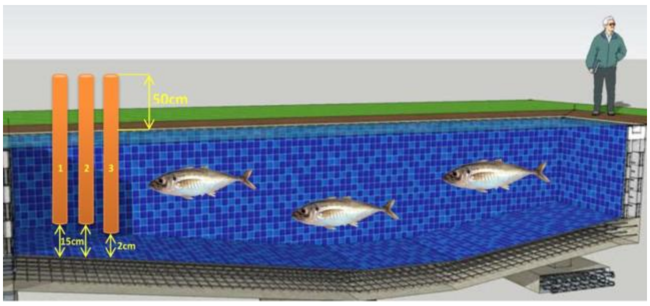

Figure 5. Sensor layout in a pool for fish.

Based on the measurement of these parameters, conclusions can be made which parameters are crucial, on which should be paid attention. Measurement in the experimental mode enabled the development of applied expert decision systems, whose primary role is to provide fish with adequate conditions for proper development through compliance with precisely defined standards. A special focus is placed on the way of feeding fish, i.e. measuring oxygen in the pool using appropriate sensors. The amount of oxygen in the pool indicates the amount of fish in it, which can determine how much food is needed to feed the fish in real-time [14]. Figure 6 shows the way of informing the user about the condition in the pool. In this case, the measured parameters are within the values of the allowed limits.

Figure 6. Information on the measured parameters in the pool.

IV. System Architecture

The architecture of the entire System is based on three-layer architecture [15]. The following elements of three-layer architecture are:

- Frontend,
- Backend and
- Database.

The frontend is implemented through web programming languages (HTML, CSS) and the appropriate frameworks. The graphical environment of the frontend refers to the manipulation of user data, sensor nodes, as well as graphical visualization and formation of necessary charts. The entire graphical environment is adapted to all devices that have Internet access.

The role of the backend system is communication with the server. This communication is implemented through the execution of scripts on the server-side according to user requirements, through the functionality of CRUD analysis [15]. Special functionalities are the generation of predefined reports with different search criteria.

The database is the third segment of the three-layer architecture, was created according to the relational model. The primary goal of this kind of relational database is storing measured quantities from the sensor nodes.

The following block diagram shows the structure of three-layer architecture:

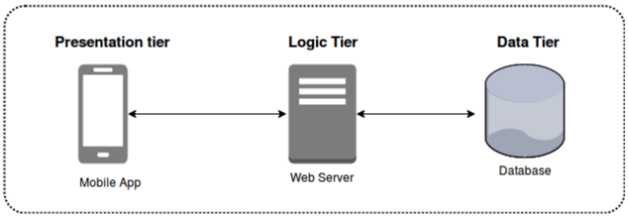

Figure 6. Three-layer architecture.

V. Platform

The complete platform for monitoring is located on the server in the university premises as well as in the Cloud which serves as a backup variant. Different user roles are implemented through the platform:

- Administrator,
- Client - User.

The system administrator has permission to add new users, sensor nodes, as well as generate total measurement reports that use the project platform. The client - user has permission to monitor the parameters of personal sensor nodes with the ability to generate reports.

Figure 7 shows the home page of the platform (front-end).

Figure 7. Platform home page.

Based on the observed parameters it possible to make conclusions about crucial parameters are crucial, which should be paid attention to. Measurement in the experimental mode of operation of sensor nodes provided the conditions for the implementation of expert decision systems that will indicate real-time information, warnings, and dangers. This mode of operation will ensure a quick response in order to stabilize the measured values.

The following figure shows the three segments that are an integral part of the expert decision system.

Figure 3. Expert decision system indicators in the application.

This expert decision system consists of:

- Information - indicate favorable system situations, i.e. messages that are based on allowed values,
- Warnings - represent low deviations from the permitted values and
- Dangers - are messages that need to be urgently reacted because the parameters have reached alarming values.

VI. Testing

The testing of the sensor nodes was performed by placing the pilot sensors at certain test sites and using the appropriate communication protocols networked with a central server, located on the university premises. The service life of the experimental sensors justified the expectations of users as well as the server-side on which the measured parameters are stored and read.

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