IoT System for Monitoring Quality of Water

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Abstract: Water as a natural resource has so much impact on human lives. The diversity of water use makes this resource in constant demand, so its quality is crucial for humans. Pollution of water and many other critical natural resources is an increasingly common problem people face. That is why they have been trying to find various ways to prevent pollution. When it comes to water quality, it can be said that its traditional monitoring is very time-consuming and is also subject to irregularities. Thus, the advances in the Internet of Things (IoT) technology have provided innovative and valuable approaches for designing special purposed embedded systems. This paper proposes an IoT system design intended to monitor water quality in real-time. The prototype is based on an Arduino Uno microcontroller and several sensors to detect water parameters, such as pH-value, temperature, and turbidity. The results obtained from the proposed system are forwarded through the ThingSpeak web IoT platform and then are displayed on an Android application, which is specially developed to provide real-time monitoring. This implementation has been shown as a helpful solution for observing the water quality that people consume daily.

1 INTRODUCTION

The Internet of Things, known as the IoT, refers to millions of physical devices connected to the Internet to collect and share data. In a broader sense, it is a dynamic and global network infrastructure in which intelligent objects and entities are used in conjunction with electronics, sensors and software to improve connectivity, data collection and exchange [1]. This type of network generally has many nodes that communicate with the environment and exchange data while reacting to events, activating control operations, or changing the physical world. Because of the cheap computer chips and the ubiquity of wireless networks, it is possible for any object, regardless of its size, to be part of the IoT system if it can be connected to the Internet.

The IoT is also expanding its capacity for environmental issues [2]. Globally, a large number of deaths are caused by polluted water. The garbage that water collects during its flow has a harmful and destructive impact on vegetation and ecosystems. Therefore, ways to prevent this are being devised daily. First, checks are made to determine if the water consumed is clean and of good quality. To check this, people have designed water quality testing systems. All this is done to enable the water quality to be brought to the desired level.

The conventional method of water quality control consists of sampling the water that should be tested. These samples are then taken to a testing and analysis laboratory [3]. However, this approach is not expensive for everyday use and, because it uses time and power significantly. As a result, this paper proposes implementing a water quality monitoring system as a low-cost system, which provides water quality checks in real-time and storing the data on the cloud. This proof-of-concept implementation is based on quality control through several sensors using IoT technology. Any object that can get its IP address can be part of the proposed IoT system. Connecting objects themselves and adding sensors gives them a certain level of digital intelligence. The IoT makes the world around us more intelligent, simpler, and more responsible [4].

This paper is organized as follows: Section 2 gives an overview of different state of the art solutions. Section 3 describes the proposed IoT system for monitoring the quality of water. Section 4 presents the implemented system design and discusses the real-time monitoring results. Section 5 concludes the paper.

2 STATE OF THE ART

Although 71 per cent of the Earth is water-covered, it is slowly but surely losing its quality [5] Unfortunately, people are not aware that they are losing the most important resource on Earth. In order to eliminate such problems related to river water quality, several technologies have been created for their protection. For example, the authors of [6] researched a wireless sensor network (WSN) to collect real-time water quality parameters. Additionally, the authors of [7] proposed an online water quality monitoring system, where the information was transmitted using GPRS, and thus the water quality parameters were considered. Furthermore, the authors of [8] designed a web-based network to monitor pollution using ZigBee. Data was collected from multiple sensors, which were then routed to a web server over the WiMAX network to monitor water quality on long distances. This system was able to monitor pollution in real-time. Another approach of water quality monitoring was proposed in [9]. This system was powered by solar energy and used a remote sensor network. The base station received information from those sensors, and it was powered by solar energy (energy harvesting).

All of these systems mentioned above measure the quality of water in rivers. River water quality can be determined visually, but drinking water is not the case. So far, not many solutions have been found to measure the quality of drinking water.

IoT is very suitable for implementing a water quality monitoring system [10]. In such a scenario, a device with built-in sensors can connect to a platform that integrates data received from different sensors and then perform analysis. Such a robust IoT platform can determine which information is helpful and ignored. The information can identify patterns, make recommendations, and identify potential problems before they occur. Several proposals of embedded and IoT based solutions of water-quality monitoring systems are discussed in [10-12]. Even neural networks can be used in this kind of project. For example, the authors of [13] proposed a new water quality prediction method that was based on long short-term memory (LSTM) neural network, an artificial recurrent neural network (RNN) architecture used in deep learning. Here, a prediction model was established, and data set of water quality indicators in Taihu Lake was used as training data. A series of simulations and parameters selection was carried out. Finally, the proposed method was compared with two methods: one was based on a backpropagation neural network, and the other was based on an online sequential extreme learning machine. Another interesting approach that used a multiple linear regression model to determine the correlation among water quality parameters is given in [14].

3 PROPOSED SYSTEM DESIGN

In order to determine the quality of drinking water in real-time, a simple system has been constructed that would calculate the water quality, depending on the value of the parameters that the system itself would detect. In our proposal, not only a hardware model is developed, but also it is integrated with a web and mobile application for water quality monitoring. The proposed hardware device is connected to the cloud using a web service (ThingSpeak.com). The end-user will see the values obtained through the sensors through a developed Android application in a format understandable to him. The architecture of the proposed IoT-based system, including: hardware local unit, ThingSpeak platform and Android application, is presented in Figure 1.

The Core of the IoT-based system is the web service ThingSpeak.com. The hardware local unit detects the data received from the sensors and sends them to the Internet, to a specific channel on ThingSpeak.com. The Android application reads the same data from the status channel of ThingSpeak.com and displays them to the user in an appropriate way suitable for him. The types of data that the sensors detect are pH value, temperature and turbidity of the water. Each of theese sensors measures the value separately through a code, then sends that value through the corresponding channel on ThingSpeak. With a unique ID key, this information reaches the Android application of the end user.

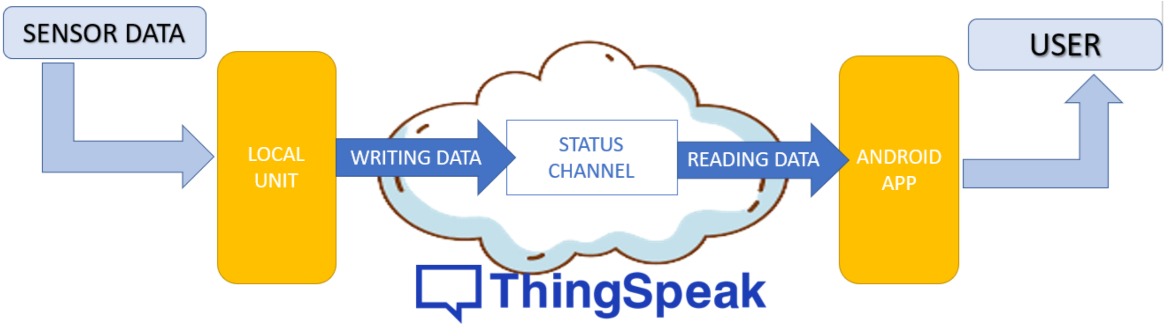

Figure 1: Proposed IoT system for monitoring quality of water.

3.1 Hardware Design

The hardware design of the local unit in the proposed system is based on a low cost Arduino Uno microcontroller board that is easily programmable and flexible [15]. It is based on the ATmega328P microcontroller. The Arduino Uno board is programmed using the Arduino IDE software which is the official software introduced by Arduino.cc. For the purpose of designing a water quality monitoring system, the Arduino Uno microcontroller board is connected to three sensors purposed to detect: pH value, temperature and water turbidity.

The pH value or hydrogen indicator is a measure of the activity of hydrogen ions in solution [16]. The pH sensor gives a result in the range from 0 to 14 pH value. Acidic solutions have a lower pH value, while alkaline ones have a value greater than 7. The natural pH value of water is about 7 (neutral point). The pH sensor can determine if the substance being tested is acidic, basic or neutral. The pH sensor is powered by 5V and easily connected to the Arduino board. Measuring the pH value can provide indications for corrosion of pipes, accumulation of solid materials etc. In the environment, a variable pH value can be an indicator of pollution. The normal range for pH value is from 6 to 8.5. If the pH value reaches above 8.5, the water is considered hard, which would probably cause damage to the pipes.

Water turbidity is a quantitative measure of the presence of particles in a liquid. It is an optical characteristic of water and measures the amount of light scattered by a material in the water when light is passed through a sample of water [17]. The turbidity sensor is quite simple, and the output is also quickly produced. The value required to calculate the turbidity is NTU (units for nephelometric turbidity). Low NTU values indicate high water clarity, while high values indicate low water clarity. There is a special connection between the voltage and the water turbidity. The graph representing this connection is given in Figure 2. The given equation of turbidity and voltage dependence is only applicable if the sensor gives a value of around 4.2V for pure water and if the output for voltage is in the range of 2.5 to 4.2V. If the correct value is not obtained during testing, a calibration is required.

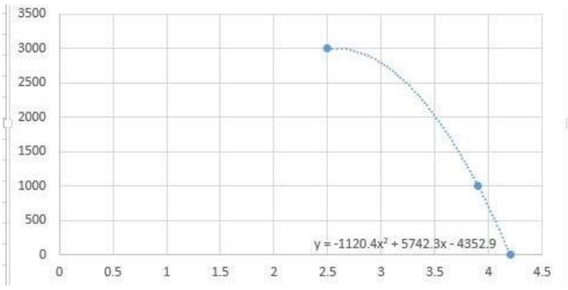

Figure 2: Voltage dependency of turbidity.

The DS18B20 temperature sensor is a convenient choice of water temperature sensor [18]. It gives results with high precision and has a fast response. Increased temperature also means increased voltage (ex. 250 mV means 25 °C.). The temperature that can be measured with the mentioned sensor is in the range of -55°C (-67°F) to 125°C (257°F).

The Wi-Fi module is a crucial part of the project development, as it is a necessary component of the proposed system that makes it an IoT product. The proposed system would not be IoT-based if the entire system were not connected to the Internet and if the obtained data was not displayed on the Internet. ESP8266 ESP-01 [19] is a low-cost Wi-Fi module that allows microcontrollers access to the Wi-Fi network. This module is placed on a miniature development board (24.8 x 14.3 mm) that contains a Wi-Fi chip with an integrated TCP/IP protocol stack. This module is a standalone SOC (system on chip) that does not need a microcontroller to manipulate inputs and outputs as we would typically do with an Arduino since ESP-01 acts as a small computer. The ESP8266 ESP-01 module is pre-programmed with AT command set firmware, which allows it to connect directly to an Arduino device and get as much Wi-Fi connectivity as a Wi-Fi shield. Once the connection is established, the Wi-Fi is tested using AT commands. Those commands are used for controlling MODEMs.

3.2 ThingSpeak Platform

The most important part of the whole research is the web service ThingSpeak.com [20]. It is an open IoT platform that enables collection of sensor data to cloud, analysis and visualization of collected data and triggering actions according to the received data. The software is written in the Ruby programming language and allows users to communicate with devices that are connected to the Internet. This web platform facilitates data access by providing APIs to devices. HTTP and MQTT protocols are used for data transmission over the Internet.

In this research, the ThingSpeak web service is used to visually display the data received from the sensors of the implemented system for monitoring quality of water. Initially, in order to use this web service, a user profile must be created. When creating the profile, a channel is created through which the data are going to be displayed on the website. The created channel contains three fields for the three sensors (pH value, temperature and water turbidity) and additionally one field which is empty, but is created for the purpose of future expansion of the project and its debugging.

When creating a channel, a special key (API key) is generated, which is the channel identification code. This API code can be used to access the channel in order to display the values obtained during the measurement. Initially, the sensors in the project record the values locally. The next step would be to transfer these values to ThinkSpeak.com. In order for the results to reach the appropriate ThingSpeak.com channel, a TCP connection must be created (via its IP address). The string of values, which will be sent through a successfully established TCP connection, will be graphically displayed.

3.3 Android Mobile Application

The water quality monitoring system displays the specific parameters important for measuring water quality. In the previous part of the research, the obtained values were displayed on the monitor in the Arduino IDE and on the website ThingSpeak. However, these values are not correctly presented so that everyone would understand. That is why an Android application has been designed.

The Android application consists of several cards. Each of the cards represents a different parameter measurement. When a measurement is made, and its values are displayed on the web service, a card is also created to display them on the Android application. Figure 3 shows one of the cards representing values of a measurement that do not meet the standards for clean water.

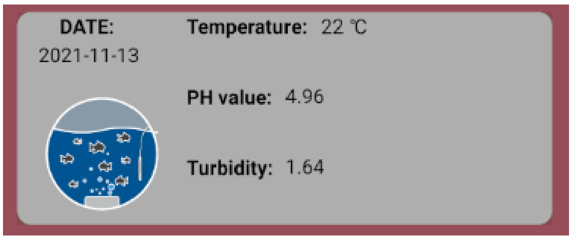

Figure 3: Card layout for displaying result values.

Figure 3 also shows the date when the measurement was made. The layout is quite simple but still meets the required functionality. The values of each measurement are displayed in separate fields. The turbidity value depends on the sensor data obtained in volts. The background of the card itself depends on the measured results. A blue background will appear if the pH value is greater than 6.5 and the results obtained from the turbidity sensor are greater than 2 NTU. For all other possible scenarios, the data will be red. Does the question arise in what way the values are obtained? As already mentioned, each channel in ThingSpeak has its key to access that channel. The application uses the same key to access ThingSpeak.com. The channel is accessed via a URL string where a key is specified[1].

The result of this would be a JSON string that contains the parameters of all the measurements along with the time and date when they were made. The string looks like this:

{"channel":{"id":1529598,"name":"Water Quality Monitoring System","latitude":"0.0","longitude":" 0.0","field1":" Actuator 1","field2":"Actuator 2"," field3":"Temperature","field4":"Turbidity","field5

[1]https://api.thingspeak.com/channels/1529598/feeds.json?api_key=IWRDIXMCOFUGBU1S

":"PH","field6":"Spare","created_at":"2021-10-07T18:00:01Z","updated_at":"2021-10-07T18:00:01Z","last_entry_id":8},"feeds":[{"created_at":"2021-10-28T17:41:33Z","entry_id":1"field3":"25","field4":"0","field5":"6.67","field6":"0"},{"created_at":"2021-10-28T17:44:14Z","entry_id":2"field3":"25","field4":"1.59","field5":"6.59","field6":"0"}]}

This is actually the string that the application gets, but it filters it in a special way in order to present the values more clearly to the end user.

4 PROPOSED SYSTEM IMPLEMENTATION

All components of the monitoring system that were previously discussed are complete. The application is designed, the code is written and tested, and the hardware is connected. The next step is to connect all the parts correctly and check if the system operates as expected and if the obtained results are acceptable. The test was performed on drinking water, with samples taken from various sources.

The hardware components are correctly connected so that they can get a value for the appropriate parameter, hopefully in an acceptable range. When designing the device, the focus is on the design of the end-user application.

The microcontroller is powered via a USB cable connected to a computer, but of course, there is the possibility of developing and expanding this device for further power supply from a battery or solar energy through a solar collector. The critical element for Internet access, the Wi-Fi module, is powered in the same way. Figure 4 shows the fully connected system that measures the parameters.

Once the first step in the final test is completed, i.e. the components are connected, it is necessary to execute the appropriate code in order to be able to read and display the values obtained during the testing of the water sample. Concrete testing is performed on relatively clean water, as expected that the values obtained will be minimal below the normal clean/water limits. The corresponding test results displayed on the Arduino IDE serial monitor are shown in Figure 5.

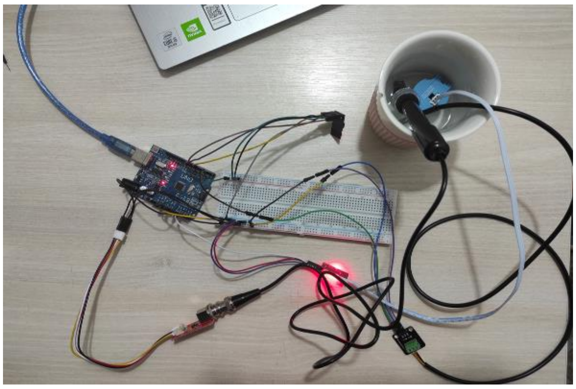

Figure 4: Implementation of the proposed IoT system for monitoring quality of water.

From the data shown in Figure 5, it can be seen that the sample on which the test was performed is relatively but not completely pure water. Values are expected - turbidity is 3.74 NTU, the temperature is 19 degrees, and the pH value is 5.36. When sending the sensor data, a TCP connection with ThingSpeak.com has opened automatically, and the values are displayed on the website in the appropriate field in the created channel. The sensor data values are represented by their size and the time the test was performed. These results are shown in Figure 6.

Finally, it is expected that these same data will be appropriately displayed on the card in the designed Android application. According to the JSON_URL that the application receives, the appropriate data of the measurement are filtered. Figure 7 shows that the results in the Android application are displayed exactly as expected. The parameters are written in a way that is understandable to everyone, and the measurement date is also given.

The results obtained when testing pure water show that the tested water is suitable for consumption, but still, more tests are needed to determine further the validity of the data and the system's operation before it can be deployed elsewhere. However, the prototype does not have many capabilities and therefore requires upgrades and extensions; to be able to transfer data over a wireless network to a remote laptop or mobile phone at any given time and location, and a stronger memory drive or the ability to store data in databases.

```
Reseting.......
RESET
Turbidity : 3.74
Temperature : 19 C
PH value :  5.36
Send ==> Start cmd: AT+CIPSTART="TCP","184.106.153.149",80
Send ==> lenght cmd: AT+CIPSEND=83
Send ==> getStr: GET /update?api_key=XJ4UOKUXXX3MAW6E&field3=19&field4=3.74&field5=5.36&field6=0
```

Figure 5: Results from testing, shown in Arduino IDE serial editor.

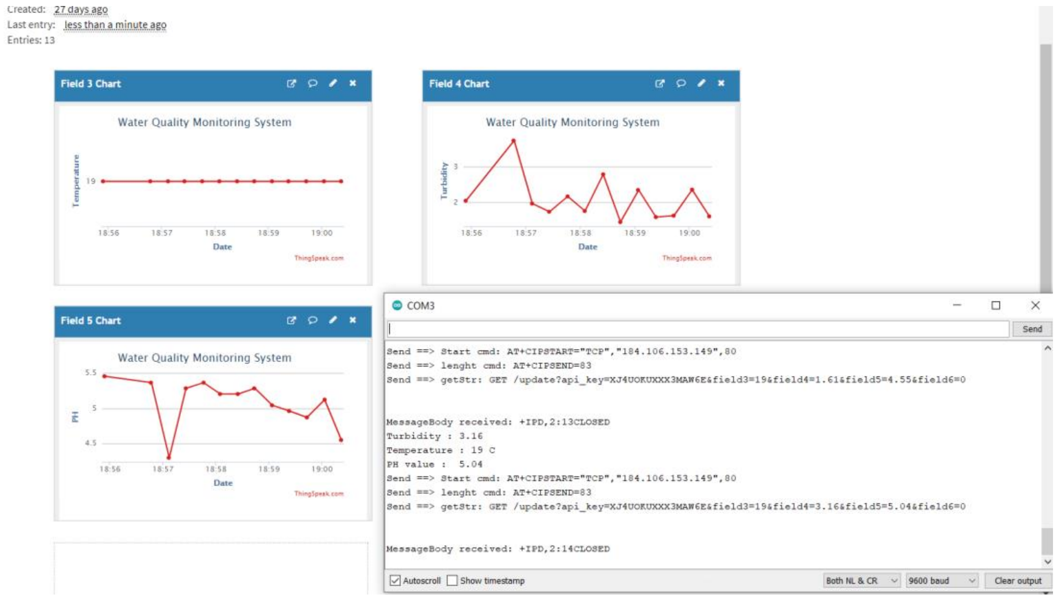

Figure 6: Results from testing, shown in ThingSpeak.com.

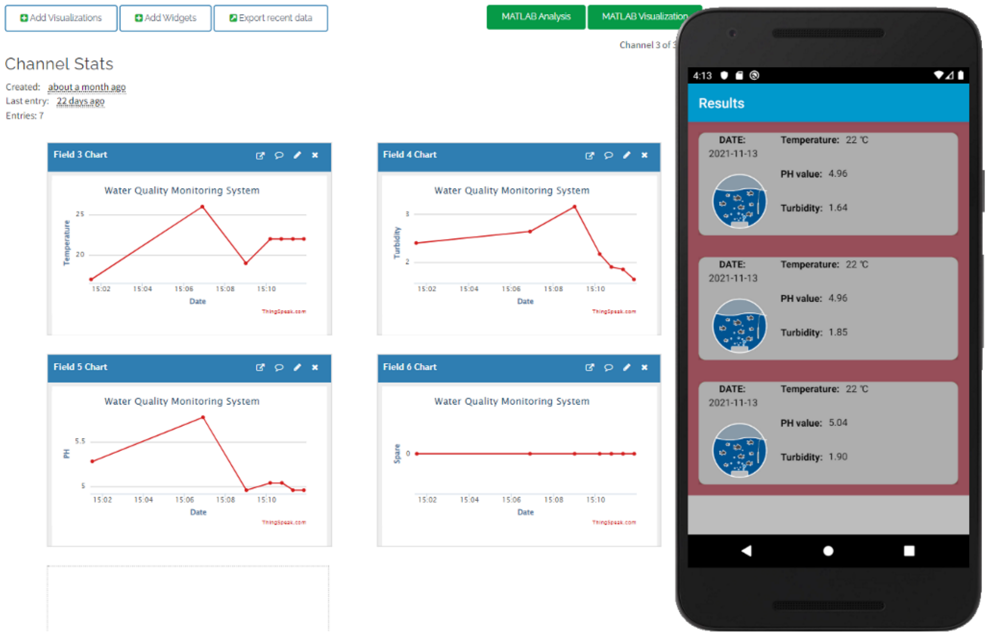

Figure 7: Results from testing, shown in Android mobile application.

According to that, an SD card could be used to allow the storage of quantities of Arduino data. The combined central system must be lined to prevent potential harmful defects from weather exposure. Regarding the sensors, the blur sensor must be upgraded or completely replaced. The opening at the top of the sensor for turbidity allows water to enter if the sensor is lowered too deep into the stream, and the inflow causes direct distortion in the readings. Its short cable means it is also strictly limited in use. A suitable replacement may be the Relihones digital blur sensor which is waterproof and offers a longer cable. Implementation of additional sensors in the project, thus its expansion will allow monitoring of additional parameters, especially the concentration of different ions.

Finally, changes may be made to the environment and the test schedule. Conducting the test of different liquids and more frequent reading of the data should provide much needed additional data and greater accuracy in determining the purity of the water and the validation of the monitoring system.

5 CONCLUSION

A fast, efficient, low-cost monitoring system is implemented and tested. The proposed system measures water quality in real-time and does not require people on duty. With this system, water testing is more economical, convenient, and faster. Although there is no need for external intervention, officials can still use it. They can consider the level of pollution that occurs in the water and transmit the warnings directly to the public. This can help prevent diseases caused by polluted waters and the presence of metals in them.

The proposed monitoring system for water quality is applicable when quick and effective actions are required to prevent extreme pollution levels. Indeed, the proposed system is easy to install and easily placed close to the target area. Monitoring can be performed even by less trained people. Approximately 20 euros were spent on the overall design of this device. It is also flexible and extensible. Given the low cost of this device, any household can afford it. By replacing the appropriate sensors and changing software programs, this system can monitor other water parameters. The monitoring time interval can also be changed as needed.

The current implementation of the proposed system has a wide application for meager costs. It provides real-time monitoring of water quality, which is way more efficient than traditional. What is of most importance, in this research, the ecological environment of the water resources is protected.

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