IoT Based Water Quality Monitoring System for Rural Areas

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Abstract - To ensure that safety is guaranteed, it is essential to implement monitoring in real-time for the quality of potable water. This work is about the use of Internet of Things (IoT) technology to develop an affordable system to control water quality in real-time. Several sensors are integrated into the system to measure various chemical and physical water properties, such as conductivity, pH, turbidity, and temperature. The core controller, which can also be the microprocessor, manages the processing of data captured by the sensor. The visualization of data can be accomplished on cloud computing via the Internet.

***Keywords* – water quality monitoring, Internet of Things, Arduino, cloud computing.**

I. INTRODUCTION

Although potable water is an essential resource for humankind, the real-time management of portable water utilities is faced with several challenges as a result of the depletion of water sources, outdated infrastructure, and population increase. Therefore, there is an urgent need to develop new systems for water quality control.

Water quality evaluation in conventional strategies consists of an analysis of water samples in the laboratory collected by hand at several sites. Although these strategies are effort-intensive, time-consuming, expensive, and do not provide real-time information concerning water quality that could be essential in making decisions of safeguarding public health, they are informative about the chemical, biological, and physical water properties [1-5]. There is a need to develop new approaches taking advantage of Internet-based tools to control water quality due to the decline of efficiency of current strategies.

There has been a substantial development of Internet-based technologies to manage and control water utilities. However, the number of monitoring sensors to be installed and calibrated across a wide area is large; therefore, such technologies are quite expensive. Also, the employment algorithm for these technologies has to be suitable for a specific area.

Based on the above problems, the present work has proposed an IoT-based system that is cost-effective for managing potable water quality in real-time. For this reason, Arduino is the main controller used in this system along with a specialized IoT module to ensure the sensor information from the key controller can be accessed or visualized on mobile phones through Wi-Fi or via cloud computing. The structure of the remaining work is as follows: Section II consists of relation with IoT, section III presents the general flow diagram of the proposed approach, section IV discusses the empirical work and outcomes, and section V outlines the concluding remarks concerning the undertaken work.

II. THE RELATION WITH IoT

Daily life has been completely revolutionized, whereby IoT has enabled the establishment of connections between various things, intelligent technologies, and sensors [6]. IoT, an extension of the Internet [7], makes innovative services more productive as well as efficient and allows instant access to information concerning physical objects. The main technologies related to IoT include cloud computing, wireless sensor networks, and worldwide computing.

Cloud computing is a processing unit characterized by affordability and extensive scale. Various researches have provided an in-depth discussion concerning cloud computing features [8-11]. IoT is applied in different fields such as monitoring of water quality and environment and home automation. The prerequisites of IoT used to monitor water quality include separate monitoring algorithms, an expansive distribution network, and a large number of sensors [12-14]. The present research proposes a system for monitoring the quality of water, whereby the information collected by the sensors can be acquired through cloud computing.

III. METHODOLOGY

The current part addresses the theoretical aspects associated with IoT-based control of water quality in real-time. In particular, this part is divided into two sections, including those with the individual system elements and those that are respectively concerned with the general block diagram linked to the proposed system.

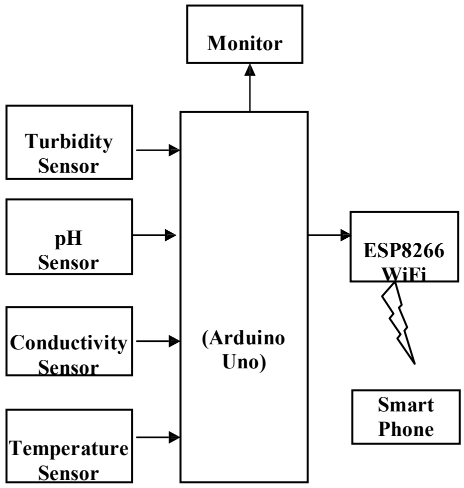

Fig. 1. General block diagram

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Figure 1 presents the general blocked diagram linked to the proposed system. It is evident from the diagram that the system is linked to the main controller, Arduino Uno, and consists of several sensors measuring various properties of water, including conductivity, turbidity, pH, and temperature. It is responsible for processing the collected sensor information and making the data accessible online through cloud computing.

IV. SYSTEM ARCHITECTURE LAYERS

Designing the layered structure of a global network is a challenge that includes heterogeneous networks that require the effectiveness and identification of a similar group function and network elements as a class. The layered framework of the recommended IoT water monitoring system consists of four layers, including Network layer (Ethernet shield and router), Perception layer (Devices and sensor in the physical world), Application layer (User interface), and the Service Management layer (Manage the collected information). Each layer is discussed as:

A. Perception layer

This layer consists of closely integrated sensors that are merged with the physical environment. The physical condition or sensor object chemistry is monitored by the sensor modules in real-time [15]. The main role of this layer is to collect data concerning the quality of water and the devices. Also, it is responsible for collecting and cost-effectively distinguishing the captured data, transforming data, and transporting the aware data to the Network layer [16]. Distinct sensors are used in such:

Turbidity Sensor: The reduction of the water transparency caused by the presence of an unresolved suspended substance can be termed as turbidity. The origin of the water molecules can be either organic or minerals. Turbidity is used to measure the light scattering effect; however, it cannot be used as a direct measure of suspended water particles. The role of these sensors is to determine the quantity of light diffused by the suspended solids. The level of water turbidity increases as the number of suspended solids rises in the water. Turbidity is measured in NTU (Nephelometric Turbidity Units) [17].

Fig. 2. Turbidity Sensor (SEN0189)

pH Sensor: pH sensor (SKU: SEN0161) is responsible for detecting the value of pH in water. It is presented in Figure 3. pH is a Latin word and an acronym for “the power of hydrogen” or “potential hydrogenii.” Hydrogen-ion concentration in the water-based solutions is responsible for showing the alkalinity and acidity in the solution.

pH uses a logarithmic scale that ranges from 0 to 14, with 7 being the neutral point. Besides, the values above the neutral point exhibit an alkaline or basic solution and the values below the neutral point present an acidic solution. Consequently, the normal pH range is from 6-8.5.

Fig. 3. pH Sensor (SKU: SEN0161)

TDS sensor: TDS (Total Dissolved Solids) is defined as the number of soluble solution milligrams in one liter of water. Generally, the high TDS values define the more soluble solids in the water and signify that the water is less clear. Therefore, these values can be used to determine the level of water cleanliness. The TDS pen measures the TDS values; however, it cannot transfer information to the control system for real-time monitoring to analyze the water quality. The kit of the TDS sensor is precise and can transmit data to the control system. It is compatible with easy to use, Arduino, as well as plug and play. Ppm (parts per million)) is the unit used to measure TDS [17].

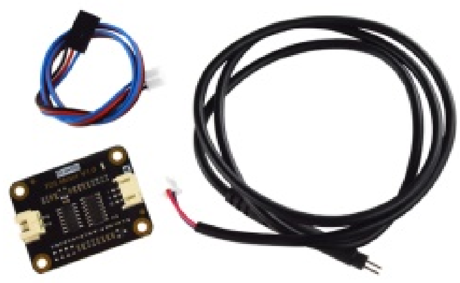

Fig. 4. TDS Sensor (SEN0244)

Temperature Sensor: This sensor (DS18B20), is used to measure water temperature—temperature increase results in the rise of the ionization rate. pH is dependent on the temperature; therefore, when the temperature increases, the ionization rate rises, and vice versa. Temperature is key in the measurement of water quality.

Temperature is regarded as an essential component for determining other applications for the analysis of the water quality. We opted to use DS18B20 to determine the water temperature whose range was from -55-125°C. This is illustrated in Figure 5.

Fig. 5. Temperature Sensor (DS18B20)

B. Network layer

The data is transmitted to the device and many layers for sharing the data resources, data packets routing, and system topology. The network layer classifies and aggregates collected data and sends it to the servers [15].

C. Service management layer

This is the brain of IoT, which stores the information from the bottom layers and processes it based on the analysis. The service management layer is considered as an information management center. Some of the critical elements are processing and analyzing technologies and expert systems.

D. Application layer

This layer represents the smart applications. The primary function of the application layer is to offer intelligent services to the users such as virtualization and smart notification depending on intelligence and netter findings of information executed by the service layer. ThingSpeak offers more applications such as analytics (analysis and virtualization) and action (ThingTweet, React and ThingHTTP)

SYSTEM IMPLEMENTATION

The main idea behind IoT involves integrating the device with a virtual world of the Internet, whereby they interact with each other by sensing and monitoring object and their surroundings.

An open-source IoT application, ThingSpeak, is regarded as an API used for data storage and retrieving information from things via the local area network or through the HTTP protocol. ThingSpeak provides a solution for analyzing data on-request from third-party sources, allows the creation of location tracking, sensor logging applications, and network of things that can update changes

Our implementation methods include software and hardware implementation. The hardware includes sensors, microcontrollers, and an Ethernet shield. Data collected by sensors is processed by a microcontroller, which sends the information to ThingSpeak via an Ethernet shield. Arduino is an open-source programmable circuit board that can be linked into various maker space projects, both complex and simple, used as a controller. On the other hand, software implementation involves data collection from the hardware, which is uploaded to the online database through the ThingSpeak. Generally, Arduino IDE software was used to develop the hardware part by establishing new channels in the ThingSpeak and writing the code and uploading it to the Arduino board.

Arduino Uno and sensors are the two components that are used by this system to work around the data. Arduino Uno works as a microcontroller while the sensors collect data for turbidity, PH, temperature, and conductivity. For Arduino Uno to be controlled by mobile phone and have access to the sensor's terminals, it is connected to ESP8266 Wi-Fi to allow data capture.

Collected data is uploaded to the Internet by an IOT module via cloud computing and can be accessed from mobile devices via Wi-Fi. Figure 2 presents the ESP8266 hardware circuit diagram exhibiting the connection between the IoT module and Arduino Uno.

IoT Module enables the transfer of quality water parameters from the sensor to the gateway. Sampled data from gateway and IoT module is sent to the server in the form of User Datagram (UDP) packets and stored in a database. The data is accessible from different locations through assigned different IP addresses.

V. EXPERIMENTS AND RESULTS

The proposed system consists of four sensors, including turbidity, temperature, TDS, and pH, which are connected to Arduino, as illustrated in Figure 1. The parameters measured by these sensors when placed in water include Turbidity, TDS, pH, and Temperatures.

Consequently, the microprocessor accesses and processes the information from all the sensors and eventually sends it to the ThingSpeak API via the network.

A. Water Measurement Temperature using a temperature sensor

Figure 6 exhibits the sensor measuring the temperature of water in the range from -50°C to 125°C.

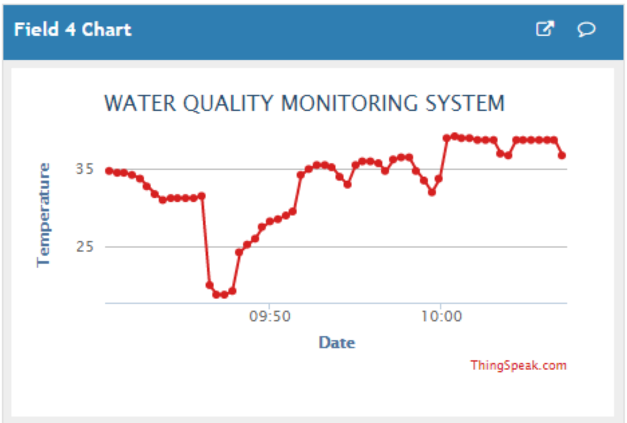

Fig. 6. Water Temperature Measurement

B. Measurement of water pH value using the pH sensor

Figure 7 indicates how the sensor measures the water pH value ranging from 0 to 14. Water is considered normal, acidic, or basic, depending on the results shown on the sensor. If the pH value is less than 7, water is grouped as acidic, if it is above 7, it is regarded as basic, and if the value itself is 7, water is grouped as good or normal. Acidic water is again classified as low acidic (pH 3-6), high acidic (pH 0-2), and low basic (pH 8-10). Also, water is classified in the same way as high basic (11-14) and low basic (8-10).

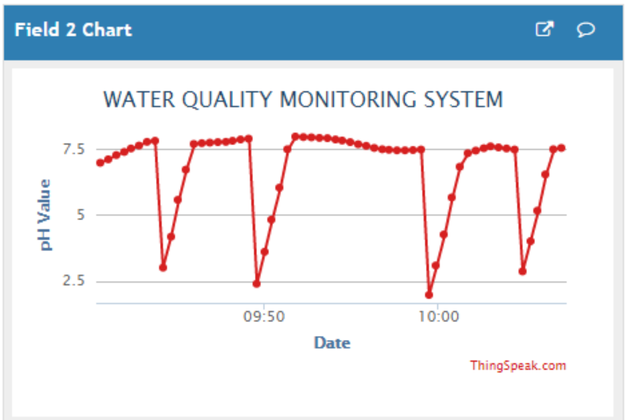

Fig. 7. Measurement of pH value

C. *Measurement of water TDS value using TDS sensor*

Any salts, minerals, or metal dissolved in water is referred to as the "dissolved solids". Total dissolved solids (TDS) has some small quantities of organic matter that are dissolved in the water and inorganic salts such as sulphate, chloride, sodium, potassium, magnesium, and calcium. The range of TDS is from 0 to above 1200 (World Health Organization). The unit of measuring TDS is ppm. The range of TDS below 300ppm is considered as excellent for drinking water, good (300-400ppm), fair (600-900ppm), poor (900-1200ppm), and unacceptable (above 1200). The TDS range is illustrated in Figure 8.

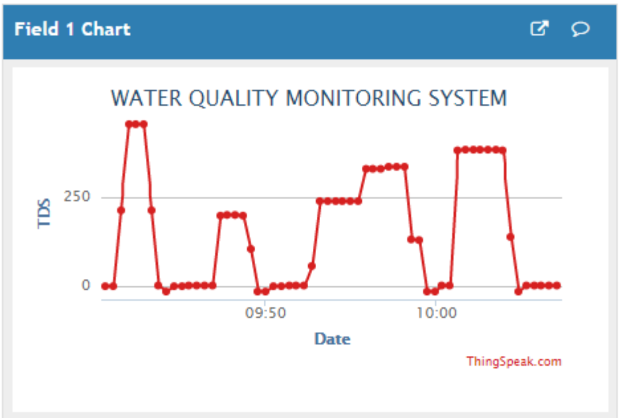

Fig. 8. TDS level Measurement

D. *Measurement of Water Turbidity using Turbidity sensor*

Its turbidity defines the clarity of the water. Water quality varies if it is mixed with any sand particles, mud, sand, or silt. Based on the norms of water quality, the range of normal water is from 0-5 NTU (Nephelometric Turbidity Units), although it can still surpass 5 NTU. Water is classified as mud mixed or turbid water if it goes beyond 6 NTU up to 3000 NTU. Figure 9 illustrates the water turbidity measurement.

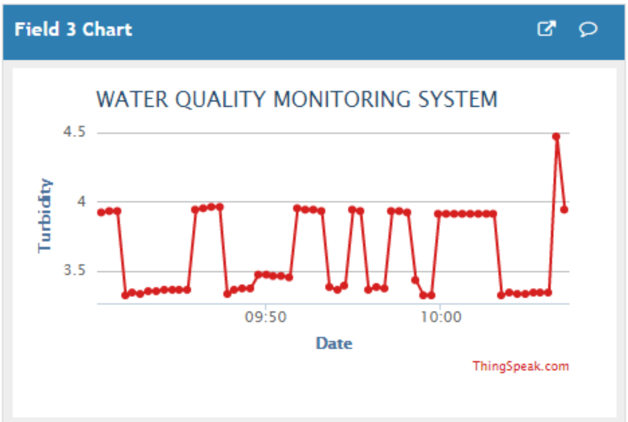

Fig. 9. Measurement of Turbidity of water

VI. CONCLUSION

The current work has recommended a new IoT-based system to control water quality in real-time. The proposed system consists of components such as Arduino Uno base unit, sensors to capture the data concerning water quality, and IoT (ESP8266 Wi-Fi). The benefits of using this system include the ability to process data, high efficiency, affordability, visualization in cloud computing and mobile devices via Wi-Fi and transmission. Consequently, the system can be applied in fields such as monitoring the environments with easy access to data regardless of the location.

Any work that will be done in the future will emphasize more on the development of a monitoring system strengthened by a wireless sensor network (WSN) and controlled through an online interface to allow internet-based monitoring from rivers. Also, it will focus on the data capture concerning the biological properties of water. This will allow data associated with water quality to be collected and sent to the appropriate authorities.

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