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Design of an Internet of Things-based real-time and autonomous water quality monitoring system

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Abstract

Water is the most important resource that needs to be preserved. Due to the many sources of pollution, water management has become very essential, in particular with the increasing demands for water in the agricultural, industrial and other fields. To ensure the security of the water supply, quality must be carefully monitored and maintained in real-time. In conventional water quality monitoring, various problems occur during the analysis process, some values need to be measured immediately in the field, such as temperature, etc. Besides, values change if storage and transport conditions do not comply with hygiene standards, such as pH, etc. The values of water parameters are not stable but change continuously over time, as well as the problem of having information available at any time and place. With the integration of artificial intelligence in different fields, including the environment, and the further development of wireless sensor network technology based on the Internet of Things (IoT) that allows connections between different devices with the ability to exchange and collect data, we have designed an intelligent water monitoring system that can collect five water parameters that are more fundamental to be verified in parallel and real-time at high speed from multiple different sensor nodes. The collected values are sent to a computer database that is connected to the platform that can process the values received. The results of the first tests give very interesting values for all the parameters tested.

Keywords: water quality, monitoring ,wireless sensor, IoT, intelligent system

I. INTRODUCTION

Human activities have increased over the last century in different fields, such as the increasing demand for drinking water, agricultural needs, and the industrial domain affects our environment devastatingly. One of the essential kinds of this environmental effect is water contamination. Any water quality imbalance would have severe consequences for human health. and the natural equilibrium of all species. Therefore, it is critical to detect water pollutants and have adequate monitoring systems to ensure environmental sustainability. Water quality monitoring provides information on the location and evaluation of a pollution level based on a set of parameters summarized in three major characteristics: physical, chemical, and biological parameters [1]. These characteristics change depending on the use of water. Therefore, depending on the water consumption, some water characteristics are more important to monitor than others.

Further research on water quality monitoring systems employs wireless sensor network (IoT) technologies and connect to our work, such as Deqing and al. (2012) [2] Proposed automatic GSM-based water quality testing and reporting systems capable of measuring the pH, conductivity, oxygen dissolution and turbidity parameters. The proposed technique for anticipating data collected and processed is based on the data processor's microcontroller and the GSM module. However, this technology is expensive and cannot be offered by regular people. Rao et al. (2013) [3] A plan proposed to detect temperature, pH, conductivity, dissolved oxygen, light and potential for oxidation-reduction. The values collected are then transmitted to a local computer for data storage. The processing data is based on Arduino Mega 2560. However, this system has to be linked directly to the computer through a USB port, and it cannot be operated remotely.

Cloete et al. (2014) [4] system intended to detect temperature, pH, conductance and potential oxidation-reduction. This comprises a measuring node based on a microcontroller that processes the data and a ZigBee that sends the processed data. Vijayakumar et al. (2015) [5] Proposed a method for measuring temperature, pH, conductivity, dissolved oxygen and turbidity; Raspberry is used to processing data and transfers the data using WiFi. But the system has to be run under the Linux kernel, so the user must write commands using the keyboard every time to know the sensors are reading. Pradeep Kumar et al. (2016) [6] offered a low-cost system that can measure the temperature, pH and turbidity; Arduino UNO is used to process data. The system transfers the data using GSM/GPRS. However, the systems measure only the water physical characteristics. Ranjbar and Abdalla (2017) [7] projected a system that can measure pH, temperature, turbidity, and Ultrasonic sensor to measure the water level. To process data, the sensors are connected to a microcontroller type Arduino Mega 2560. The system can send measured water values to the final user through an SMS message. However, it does not save historical data. Parra et al. (2018) [8] proposed a system that collects the temperature, conductivity and turbidity the captured data are stored in the cloud, the system uses Arduino Mega 256 to process the collected data, and a module of WiFi to transfer data. This system measures only the water physical characteristics. Marco Carminati et al. (2019) [9] proposed a system that can measure the temperature, pH, conductivity, pressure and water flow, to process data Arduino ATmega328P is used, the system transfers the data using GSM/GPRS module. The proposed system's robustness and energy autonomy were demonstrated in the laboratory and in the field, with a pilot network of three nodes installed in a real water distribution network and running continuously for two months, thanks to an efficient energy harvesting solution applicable to compact commercial turbines. Furthermore, the absence of expensive components in the system would allow for widespread detection node dissemination. In addition, the study's growth will take into account the data security issue.

Kofi Sarpong Adu-Manu et al. (2020) [10] proposed a system that can measure the temperature, conductivity, dissolved oxygen and other chemical parameters. To process data Atmel ATmega1281 is used, the system transfers the data using GSM and Zigbee module. The system provides an efficient and sustainable approach to monitoring freshwater sources; It is required to prepare for a rise in the number of sensor nodes, taking into consideration sensor probes such as turbidity and total dissolved solids sensors, which are important criteria for detecting water quality, as well as the data security problem for the study's expansion.

II. PROPOSED SYSTEM

Our proposed Intelligent sensing systems can collect water parameters that are more. Therefore, it is essential that several nodes of various sensors check-in simultaneously and in real-time at high speed. We have created a system consisting of five components to feed the analyzer with water parameters permanently and simplify the water monitoring task:

- The perception module permits detection of the environment and measures the characteristics of the water. To check water quality, distinctive types of sensors, including pH sensor, Turbidity sensor, Dissolved Oxygen Sensor, Temperature sensor and Conductivity sensor.

- The communication module allows transferring Application and database recorded values. In our proposed architecture, We use a Wi-Fi module to send collected values from the Arduino card to the access point to transmit the recorded values to local space. The card may also communicate measured parameters to intelligent devices, like the intelligent watch, through a Bluetooth module for Arduino. Second, the access point is linked to the Internet to transfer the collected values. Lastly, the data is received from the local area and sent to the local computer and remote database.

- The storage module is capable of saving the values received and the information system. In our proposed system, the data gathered is transmitted to the platform-based SQL database to handle the information obtained. With the Internet protocol, the user may connect to the program and observe the measured parameters regularly.

- Processing module is responsible for processing the data received. We selected the Arduino Uno board module, a microcontroller board that functioned on the ATmega328 to gather information from all sensors. This microcontroller's card contains everything essential. It has a small size and low power consumption, it's the simplest and most economical and can be programmed with software available with the microcontroller.

- The application module exploits the results of the processing, helping managers make wise choices. This module usually sends alarms to the system managers and sends orders to the actuators.

III. RESULTS AND DISCUSSIONS

The system developed in this research was tested for the first step under potable water quality; We measured four parameters (pH, Temperature, conductivity, and Turbidity) using the conventional method and our developed system. The results showed a slight difference between the two methods for all measured parameters, as shown in the chart below. In the potable water case, the conventional method gave a Temperature of 15°C, a pH of 7.5, Conductivity of about 450 $\mu\text{S}/\text{cm}$ and a Turbidity of 2 NTU. Using our developed system, we got a Temperature of 14.6°C, a pH of 7.8, Conductivity of

about 423.5 $\mu\text{S}/\text{cm}$ and a Turbidity of 1.5 NTU. (Table.I)

TABLE I. Comparison of measurements for potable water

Systems	Measurements	T (°C)	pH	Conductivity ($\mu\text{S}/\text{cm}$)	Turbidity (NTU)
Potable Water	Conventional method	15	7,5	450	2
	IoT	14,6	7,8	423,5	1,5

The outcome was successful following our system first objective. These results demonstrate that the obtained values with the intelligent system are in high accordance and compatible with the conventional method by 97 to 99%. Therefore, the need to test other parameters on different water qualities.

For Framework activity, information such as the voltage level (Vout) that lands at the hub is crucial. A voltage divider is also likely to be employed to keep the hub's current voltage from becoming too high. It will be essential to refresh the data and acquire a new sensor adjustment state in this scenario. A voltage divider must be utilized to increase the Vout gap between the base and most extreme estimations of the NTC opposition.

At different temperatures, we can measure the Vout of the temperature sensor. The Fig.10. Represents the details as well as the computational model that is used to analyze it. In our condition, we can see the relationship between Vout and Temperature. The hub's limits are about 10 bits, and the maximum Vout that can be registered is 7 V.

The non-linear connection between temperature and resistance is a major challenge for thermistors. This project's temperature range is 0 to 70 degrees Celsius. Thermistors are effective up to 300 degrees Celsius, but the narrower operating range helps to compensate for the non-linearity.

The thermistor circuit is made up of a constant known input voltage and a series resistor with a known value set up as a voltage divider with an expressly specified thermistor. The voltage measured through the thermistor is then used to change the gain and offset of an operating amplifier. This adjusts the voltage calculation for the microcontroller's analog-to-digital conversion.

The goal of this sensor circuit is to read the potential difference of the thermistor and condition the signal to a suitable voltage range. The voltage across the thermistor is calculated using the voltage divider generated with R1 and the thermistor. In temperature sensor simulations, the voltage across the thermistor is represented.

The pH electrode is a high-resistance single-cell battery that produces a voltage that is proportional to the pH of the water sample. The output voltage is between -430 and +430 millivolts on average. To interact with the microcontroller's ADC module, the electrode's 430 mV output voltage is transformed to a range of 0 to 7 V. To accomplish this effect, the output voltage is increased and an offset is applied.

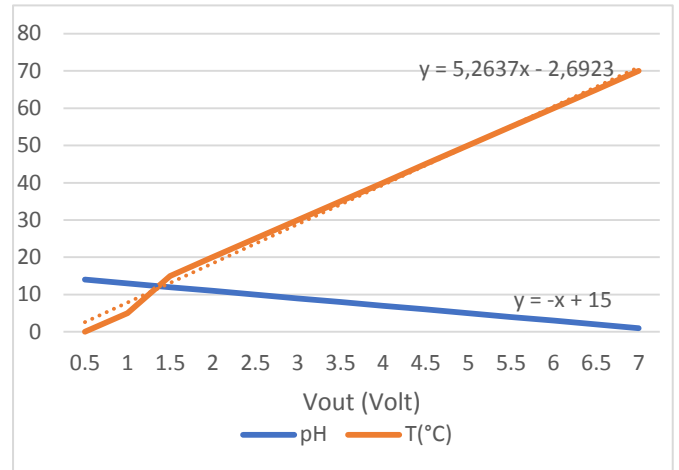


Fig.10. pH and Temperature Data

Furthermore, the information gained during this modification for the turbidity sensor must be adjusted as a result of the IR's resistance photo detector to Vout. We need to use a 3V voltage divider to increase the difference between both the intense and the base of Vout. Fig.11. shows the results by using a voltage divider, as well as a numerical model that matches this data. The code loaded into the hub for reading the Vout from the turbidity sensor and converting it to turbidity esteem appears to accomplish the hub's objectives. The device esteem is calculated in addition to the turbidity equation by integrating the data in Fig. 11 with voltage as the autonomous variable and turbidity as the dependent variable.

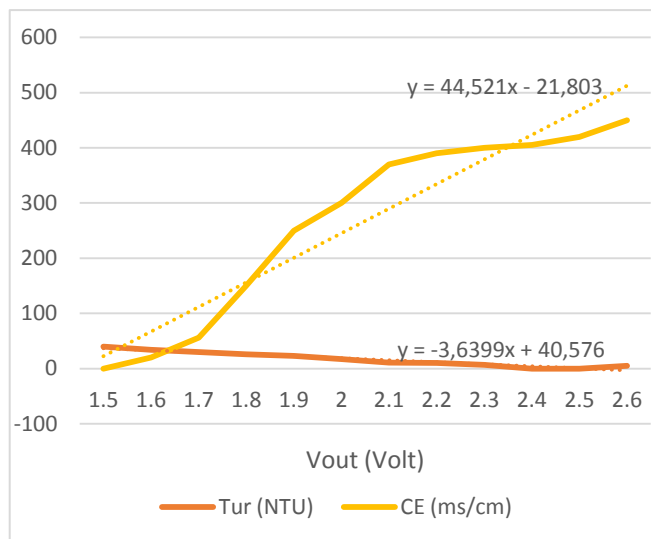


Fig.11. Conductivity and Turbidity Data

A conductivity sensor was used to measure conductivity between 20 and 450 mS/cm. V_{out} reflects the voltage through the cell of conductivity (appears as a variable resistor) and creates a square wave that the full-wave rectifier rectifies. The signal is then passed into a filter with a low pass, which smooth's out the resulting DC signal. A DC signal is generated by translating a high voltage AC signal to a DC signal.

IV. CONCLUSION AND FUTURE WORK

We have developed an intelligent water monitoring system that can gather up to 5 water parameters essential to be tested at numerous smart sensor nodes simultaneously and in real-time. Each of the parameters measured is as follows: electrical conductivity, pH, dissolved oxygen, turbidity and temperature. The captured values are transmitted to a database connecting the received values to the platform. The user may relate to the app over the Internet Protocol and observe the measured parameters reliably. The implementation provides a sustainable approach that can be used to monitor freshwater sources or underground water sources. It is not difficult to utilize the estimating framework and be updated with certain modifications in any geographical region. Rapid growth for IoT and big data analytics as emerging technologies, coupled with their aim to facilitate many metropolitan centers in the context of environmental sustainability, involves significant scientific and technical challenges that include communication and transmission of data, Storage and processing data, Security and privacy of data. Addressing these problems would improve the overall performance and utility of wireless water quality monitoring systems based on networks of sensors.

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