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IoT Water Quality Monitoring for Smart City

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ABSTRACT

In line with the recently launched Malaysia's Smart City Framework, a real-time water quality monitoring system had been developed for Water Quality Monitoring in Smart City. The system measured the pH and turbidity of the water source. These parameters were essential in order to detect water contamination. These sensors are connected to Arduino microcontroller, which processes and analyses the data. The data will be sent via the WiFi connectivity to the cloud and the smartphone for monitoring purposes. A mobile application had also been developed to display the readings of the physiochemical parameters. The results demonstrate that the system had successfully process, transmit and display the readings.

Key words : IoT, Smart City, Water Quality

1. INTRODUCTION

The quality of drinking water plays a vital role in the well-being and the health of human beings [1]. Drinking Water Distribution System that carries water from water resources such as reservoirs, water tanks and rivers to industrial, commercial and residential areas through complex buried pipe networks hence putting the water quality at risk of contamination [2]. In [2], a real-time water quality monitoring system for drinking water using wireless sensor network had been presented. The system used a Zigbee module to send the water quality parameters such as pH, turbidity and temperature to the user via the SMS alert. While in [3], the same parameters in [2] had been analyzed and sent to the user via XBee wireless module and displayed on the LCD and will alert warnings from the buzzer when the parameters are unsafe.

In [4], a real-time mobile-based water temperature monitoring system that could aid the aquaculture farmers in the improvement of aquaculture. Raspberry Pi had been used as the microcontroller and sent to the mobile via internet connectivity.

Lastly, in [5], a survey on monitoring water quality using various projects using wireless sensor networks (WSN) had been presented. The findings indicate that the project relies heavily on the mobile network. A review done by [6] on water quality monitoring techniques concludes that there is a need for a continuous and online quality monitoring system to ensure that the water quality is always monitored. Also, in [6], microwave techniques [7-17], that can determine the contaminants in the water had been discussed.

Hence, in this project, a device was developed to detect the PH value of water and the level of turbidity of the water by using technology which the given result will be more precise and more efficient compared to the existing tools. By using this device, the quality of water can be detected faster, accurate and finally; the cost can be reduced. This device has a pH sensor, temperature sensor and a turbidity sensor connected to a module called Arduino. The end devices will be connected via Wi-Fi as the Arduino also connected to a Wi-Fi module. The end-user can get the result instantly via an app called Blynk as it connected to a smartphone. The sensor that detects the pH value will pass through the information to the Arduino, and the result will be shown on the mobile devices.

For pH value, it primarily expressed with a numeric scale ranging from 0-14. The acidity level is ranging from 0-6, while alkali is ranging from 8-11. Neutral pH can be obtained when the numeric scale stops at 7. While Turbidity refers to the cloudiness of a fluid caused by the increased number of very tiny particles which, individually, is invisible to us. Moreover, turbidity measurement is vital in testing the quality of water. This Internet of Things (IoT) prototype can also be used in other application such as in home environment [18] or agriculture sector as in [19-20].

2. METHODOLOGY

SDLC is known as software development Life Cycle, where it is a framework defining tasks performed at each step in the software development process. There few types of SDLC model that can be used. In this project, the agile model is used because it is easy to use and to understand as it requires minimal resources. In this model, plans can be developed quickly, and it has rapid processes to be achieved.

The information that is needed in this project was gathered and analysed based on the related project so that the project objective and scope can be determined.

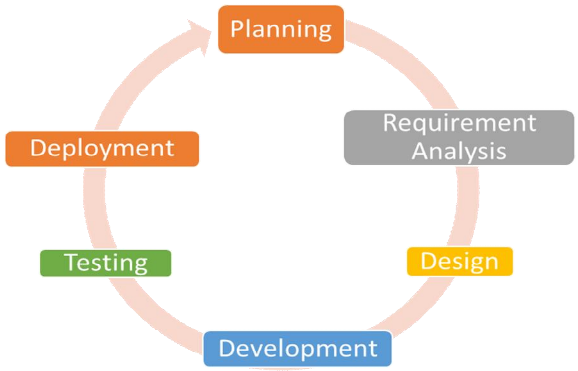

Figure 1: Agile Model

Figure 2 shows the topology of the IoT Water Quality Monitoring System in a diagram form. Arduino Uno will be used as the microcontroller for this project. The sensors needed in this project consist of a pH sensor and Turbidity sensor. Wi-Fi module is used to send the results to the smartphone via Wi-Fi. The results were sent through Blynk software, where the results will be shown on the smartphone.

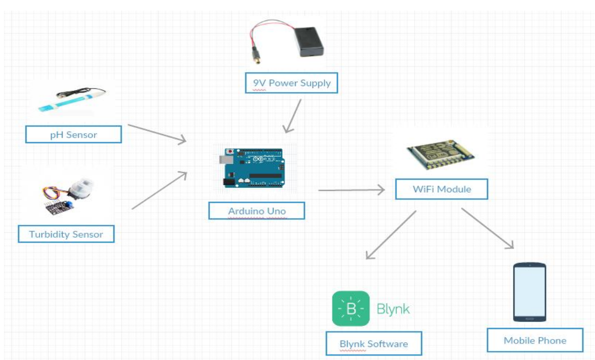

Figure 2: Topology of the IoT Water Quality Monitoring system

Figure 3 shows the prototype of the IoT Water Quality Monitoring system.

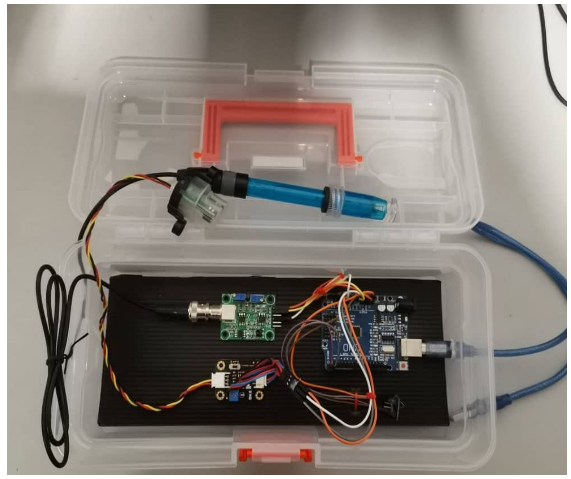

Figure 3: Prototype of the project

3. HARDWARE AND SOFTWARE

Arduino Uno will be used as the microcontroller for this project. The sensors needed in this project consist of a pH sensor and Turbidity sensor. Wi-Fi module is used to send the results to the smartphone via Wi-Fi. The results were sent through Blynk software, where the results will be shown on the smartphone.

3.1 Hardware

A. Turbidity sensor

Turbidity sensor [21] can detect water quality by measuring level cloudiness/haziness in the water. It can detect suspended particles in water by measuring the scattering rate and the light transmittance, which changes with the amount of total suspended solids in water. As the total suspended solids increases, the liquid turbidity level increases. This Arduino turbidity sensor has both analogue and digital signal output modes. The mode can be selected according to the MCU as the threshold is adjustable in digital signal mode. It needs to be connected to the ADC before being connected to the Arduino.

B. pH sensor

pH sensor [22] is a device to measure the level of acidity or alkalinity of a solution; the pH scale ranges from 0 to 14. The pH indicates the concentration of hydrogen [H] + ions present in certain solutions. It can accurately be quantified by a sensor that measures the potential difference between two electrodes: a reference electrode (silver/silver chloride) and a glass electrode that is sensitive to hydrogen ion. This sensor gives an output in the form of an analogue signal. It requires ADC before connected to the Arduino. The accuracy of the sensor is ± 0.1 pH.

C. Arduino Uno

The central controller for this project is Arduino Uno. It is a microcontroller based on the ATmega328P. It has 14 digital input/output pins, six analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with AC-to-DC adapter or battery to get it powered up.

D. Wi-Fi Module

The ESP8266 Wi-Fi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to the Wi-Fi network. The ESP8266 is capable of hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware so that it can merely hook with an Arduino board and get about as much Wi-Fi-ability as a Wi-Fi Shield offers. The ESP8266 module is an extremely cost-effective board with a vast and ever-growing community [23]. This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application-specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimum PCB area. The ESP8266 supports APSD for VoIP applications and Bluetooth co-existence interfaces, it contains a self-calibrated RF allowing it to work under all operating conditions and requires no external RF parts [23].

Figure 4 shows the process of developing and assembling hardware for IoT Water Quality Monitoring system. The hardware need in this development is Arduino Uno, pH sensor, Turbidity sensor, Wi-Fi module, analogue to digital converter and jumper cable. The functionalities are implemented in real-time via smartphone.

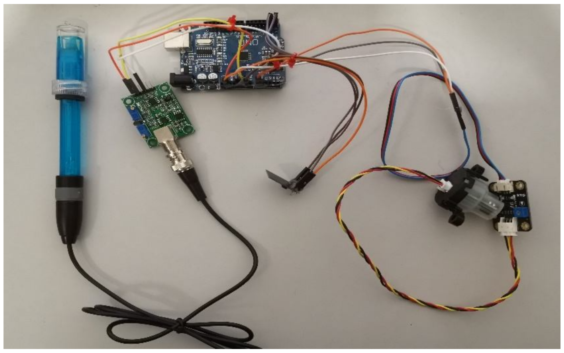

Figure 4: Hardware of the project

3.2 Software

In this project development, three different software are required for successful implementation.

A. Blynk

Blynk is a new platform that allows users to quickly build interfaces for controlling and monitoring hardware projects from iOS and Android device. After downloading the Blynk apps, the user can create a project dashboard and arrange buttons, sliders, graphs, and other widgets onto the screen. Using the widgets, user can turn pins on and off or display data from sensors.

Blynk supports most Arduino boards, Raspberry Pi models, the ESP8266, Particle Core, and a handful of other conventional microcontrollers and single-board computers, and more are being added over time. Arduino Wi-Fi and Ethernet shields are supported, though it can also control devices plugged into a computer's USB port as well.

B. Arduino IDE

Arduino is an open-source platform used for building electronics projects. It consists of both a physical programmable circuit board or a microcontroller and a piece of software, or IDE (Integrated Development Environment) that runs on a computer to write and upload computer code to the physical board.

C. Dec-C++

Dev-C++ is a free full-featured integrated development environment (IDE) distributed under the GNU General Public License for programming in C and C++. It is written in Delphi. It is bundled with, and uses, the MinGW or TDM-GCC 64bit port of the GCC as its compiler. Dev-C++ can also be used in combination with Cygwin or any other GCC-based compiler.

3.3 Prototype Development and Testing

Firstly, the user needs to establish a network between the microcontroller and the smartphone via hotspot. When the microcontroller has connected to the smartphone, a few samples of water will be tested by using a turbidity sensor and pH sensor. Both sensors will send an analog signal which will be converted into a digital signal to the microcontroller. The data will be forwarded to the smartphone via the Wi-Fi module and the Blynk application will pick up the reading and both readings will be shown on Blynk application. If the connection is not established between the smartphone and the microcontroller, the result cannot be obtained and there will be no reading shown even though the sensor probes were in the water samples because no connection has been made.

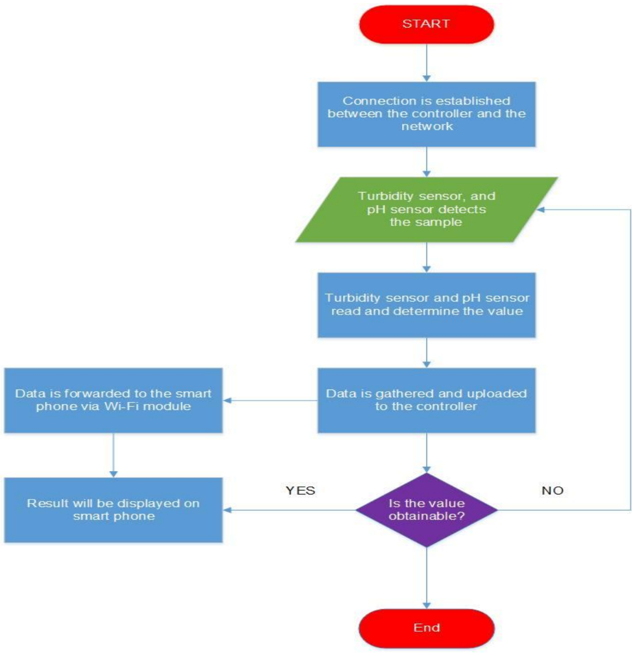

Figure 5: The Flowchart of IoT Water Monitoring System

4. RESULTS AND DISCUSSION

Figure 6 shows the connection between the end user's hotspot and the Arduino. The end user must turn on the hotspot so the Wi-Fi module (ESP8266) can be connected to the smartphone. When the connection was established, it allows the system to connect with Blynk. The connection will establish automatically when the hotspot turned on. It is because the hotspot's SSID and password have been embedded in the Arduino to make the connection stable and reliable. The sensors' reading will be shown through the Blynk application. By using the Blynk application, the refresh rate is 1 second which makes it a real-time system.

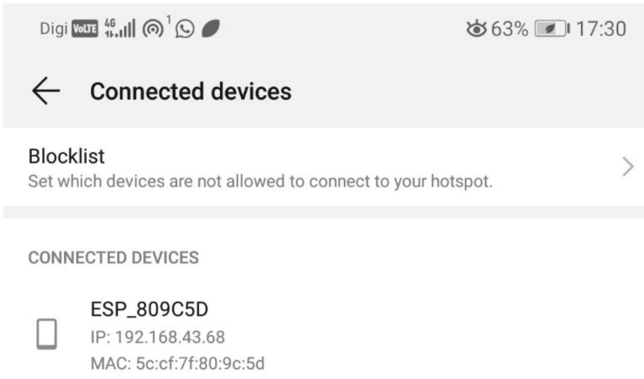

Figure 6: Wi-Fi Connection

After the connection has established, probes were dipped in the water samples in Figure 7 and the sensors detect the reading of the water samples. Then the data will be sent to the microcontroller in a form of analog signal which then will be converted to a digital signal by using Analog-Digital Converter (ADC) in Figure 8. The digital signal will be transmitted to the microcontroller.

Figure 7: Water Samples

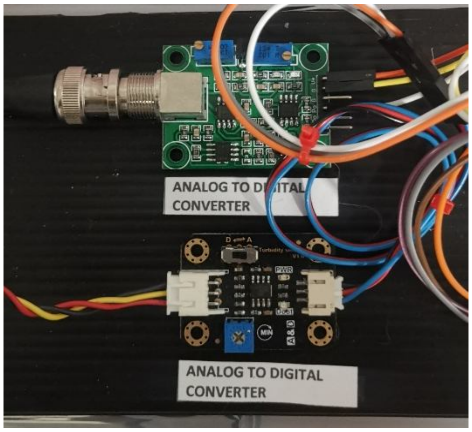

Figure 8: Analog Digital Converter (ADC)

After the microcontroller receives the data, the data will be sent to the Blynk application via the Wi-Fi module (ESP8266)

Figure 9 shows the Blynk's application GUI. The GUI displayed the pH value and turbidity value with cloud charts that store its data. The chart will be updated every second whenever the reading changes. The reading in the figure above shows that the pH level is neutral, and the turbidity level is slightly high.

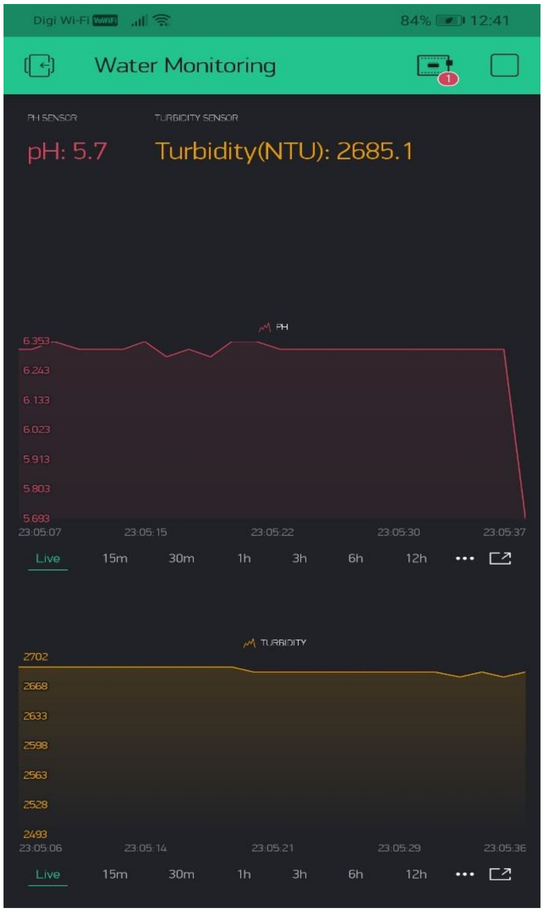

Figure 9: Blynk GUI

The project is also equipped with a notification system where it will notify the user whenever the pH and Turbidity level reaches a dangerous level, as shown in Figure 10. The indicated red icon indicated a warning sign message. The condition can be set directly through the application instead of changing the condition in the codes itself.

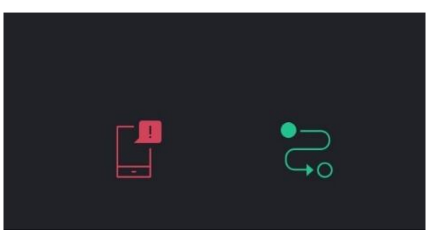

Figure 10: Notification System

If the pH level reached below 7, which is acidic and the turbidity level exceeded 3000, it will notify the user so the user can take appropriate action. The notification will show high and low, so the user will know the level of the quality of the water, as shown in Figure 11 and Figure 12.

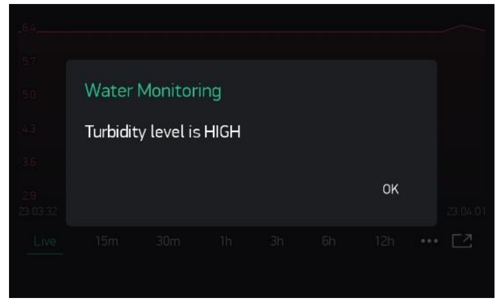

Figure 11: Notification of dangerous turbidity level

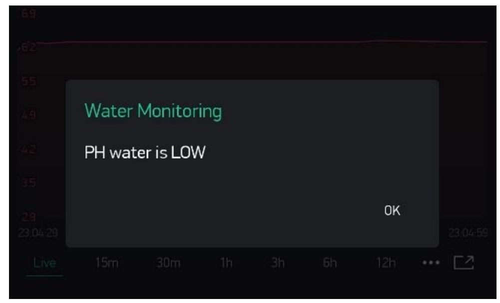

Figure 12: Notification of dangerous pH level

Another sample of water in Figure 7 is tested using the prototype, and the results is shown in Figure 13. In Figure 13, an alkali reading and high level on the turbidity value are obtained when both probes were tested in the water sample.

Figure 13: Sample Results

5. CONCLUSION AND FURTHER WORK

In this proposed work, the design and deployment of the real-time water quality monitoring system using wireless network had been presented. The readings of the pH and turbidity of the water samples will be later on displayed via mobile application. It can be concluded that this project had been successfully implemented. For further work, it is recommended to add more sensors to have more comprehensive readings to the system. Conductivity sensor and Flow sensor can be added to the system.

Since now LoRA (Low Range) is considered as the latest type of wireless connectivity in Smart City, perhaps this network connectivity can be used to replace the network protocol used in this project which is *802.11 b/g/n* protocol [26] which a single band that supports 2.4 GHz frequency.

APPENDIX

pH Sensor Functions

```
void setup()
{
  pinMode (phSensorPin, INPUT);
  pinMode(SENSOR1,INPUT);
  Serial.begin(ESP8266_BAUD);
  delay(10);
  Blynk.begin(auth, wifi, ssid, pass);

}

void loop()
{
   Blynk.run();


   int phmeasuringvalue = analogRead(phSensorPin);
   /*Serial.print("Nilai ADC Ph: ");
   Serial.println(phmeasuringvalue);*/
   double phstrength = 5 / 1024.0 * phmeasuringvalue;
   /*Serial.print("phstrength: ");
   Serial.println(phstrength, 3);*/



   Po = 7.00 + ((2.6 - phstrength) / 0.17);
   /*Serial.print("pH Value: ");
   Serial.println(Po, 3);*/
```

Turbidity Sensor Functions

```
voltage1=0.004888*analogRead(SENSOR1);
//inV
turbidity1=-
1120.4*voltage1*voltage1+5742.3*voltage1-
4352.9; //in NTU
```

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