Intelligent water flow monitoring system based on internet of things for residential pipeline

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ABSTRACT

Providing sustainable water supply is a huge challenge for Malaysia whereby the residential areas are still equipped with the conventional water meter with lack of monitoring options. In order to detect the locations of internal leakage, the process requires costly plumber service while manual comparison may be inaccurate and time-consuming. Therefore, digitalization transformation aligned with the industrial revolution IR 5.0 is crucial especially with the recent occurrences of high water bills reports during the movement control order (MCO). The objectives of this project is to develop an intelligent water flow monitoring system using Arduino as a microcontroller and to construct a system that can monitor the water usage behaviour at any distant with internet of thing (IoT). It can be installed anywhere in a pipeline whereby the water flow sensor measures the real-time water parameters. The data transferred to the cloud are sent to the homeowner to display the accuracy and availability of their water system via Blynk, a mobile-compatible and user-friendly application that generates clear data visualization. The key goal of this project is to provide a wireless, mobile, economical and systematic solution for residents to self-monitor their water consumption as compared to the conventional manual monitoring.

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1. INTRODUCTION

Achieving sustainable water supply has become a global concern around the world as it is one of the main essential need of human being apart from other field such as the agriculture, farming and industry as well as commercial entities [1]. Although providing sustainable water supply is always the top priority, water utility keeps receiving complaints over high water bills. It has been reported recently during the movement control order (MCO) held in Malaysia which highlighted a series of complaint in Selangor, Kuala Lumpur and Negeri Sembilan regarding high water bill despite no one being at home as well as unusually higher water bill measured as compared to the previous average usage [2], [3].

Currently, the conventional way suggested by the water utility to check the possibility of leakage in internal plumbing of a house is by comparing the water meter reading at the main pipe outside the house compound before going to bed with the reading in the next morning under the condition no one was using the water throughout the night [4]. This method is lack of accuracy and inefficient as kids for example might have used the water to go to the toilet during the night or the homeowners could have forgotten to record the meter reading first thing in the morning. Thus, various measures have been implemented to monitor this situation other than ensuring continuous and accurate supply and reduces water loss either due to utility's downside and leakage problem or poor consumption behaviour of the end user themselves [5], [6]. One of the common solutions is by providing smart water management system in general with the help of internet of things (IoT). IoT may be defined as the interconnection between objects via wired or wireless network without the physical presence of the user that often makes a system convenient for distant monitoring purpose [7], [8].

A number of water management system have been implemented in previous years. For example, [9] is developed as smart water management system by using microcontroller ZR16S08 Raspberry Pi and wireless sensor nodes to monitor the water loss in water distribution network by collecting information into a web server. The IoT based water management system built by Rajurkar *et al.* [10] applied at a house in a flat system aims to minimize the water wastage by notifying the user whenever the water limit usage has been exceeded. Besides, Shavarsidha developed "IoT based flow control system using Raspberry PI" for a large campus which reports any violation of maximum water level in an overhead tank that is equipped with automated submersible pumps via SMS [8]. Gautam forecasted water usage and compares the collected data with the actual consumption for an urban house using ultrasonic sensor, Arduino and a wifi module [5]. A pressure sensor was applied M. M. Srihari in the water management system that measures the water flow pressure and consequently detects water leakage location other than the pH sensor that senses the pH level and the water quality [11]. Meanwhile, the available water level is observed in a water management system built by Navin that is implemented in big apartments [12]. There are also several other IoT systems focusing on the water leakage monitoring issue in general in their smart water management system [13]-[15].

On the other hand, reducing water contamination has become the main objective in the smart water system built by Radhakrishnan and Wu [16]. A study to focus on improving the communication between tenant and landlord in terms of water and power consumption is done by Santos *et al.* [17]. The monitoring of power and water consumption of a residential house via an android application on phones and tablets is made possible in the proposed system. The system reading is verified with having no significant difference between the manual wattmeter and water meter. It is convenient for both tenant and landlords to clearly informed with the real usage. The temperature and pH level of water supply is measured in other system proposed in [18]. Although it is mentiond that a water quality sensor will determine whether the water is polluted or not, it is not clealrly mentioned which paramater reading will become the indicator.

The system is accessible on the smartphone through the MQTTlens interface medium that helps the data transfer and storage. A launchpad CC3200 with built-in microcontroller and Wifi is used as the center of circuit operation. Meanwhile, two nodes concept namely sensor node and sink node are adopted in the system [19] whereby sensor node will send the measured data to sink node which is later stored in the database and transferred into graphical form for the users to interpret. However, despite providing clear visualization on PC, it has not been mentioned that the display platform used which is Makerplot by graphical user interface (GUI) is campatible for smartphones and tablets.

On the other hand, it has been found that there are numerous studies in acuaqulture which aimed for similar objectives of providing efficient water monitoring system. The pH and water level for hydroponics plant are automatically monitored using pH and water level sensors as the input [20]. Author decided to choose Arduino Mega as the microprocessor due to its sufficient amount of pins for digital and analogue input and output as well as the memory capacity. However, the monitoring cannot be executed remotely in case of unexpected events as the data is not transferred to other platform. Another different water quality monitoring platform is used for aquaculture field namely LabVIEW software that is interfaced with temperature and pH level sensor inputs [21].

Not only the data measured by the automated proposed system are verified of having very small error percentage compared to the manual data, it also saves much time other than capable of producing alarm for any violation of pre-set conditions. Meanwhile, the water quality of multiple aquaculture tanks are monitored in [22] by detecting the temperature and water level of tanks before transmitting the data to thingspeak IoT platform with the help of RaspberryPi as the microcontroller. Further analysis on the data stored are made possible through IoT technology. On the other hand, in this proposed system, the pH and temperature level of a fish pond are measured and sent via Bluetooth technology to the customized application namely "MIT App Inventor 2" provided by the Google and compatible for Android users [23]. The wireless operation is controlled by Arduino Uno as the microcontroller. Although distant monitoring is achieved, the bluetooth communication can be further upgraded into other IoT technology.

Recently, internet of thing (IoT) has become one of the most popular and emerging technologies in controlling any system efficiently [24]. IoT provides connectivity between a network of devices, sensors and other inputs and outputs which enables them to communicate and function accordingly without man-ual supervision by the user [25]. The ESP32 wifi module plays a big role in IoT as it provides several advantages that includes having great power and capability to connect other than available in the market at low cost [26].

In this project, the "Development of water flow monitoring system based on internet of things (IoT)" is developed to help the homeowner individuals to self-monitor the water supply system of the house by installing the system at the desired pipelines. The monitoring process is much efficient with the aid of IoT whereby user is able to observe the water flow parameters displayed on the mobile application from a distant. Other than that, the interface of Blynk Application used is also very user-friendly and visually clear for any type of users. Therefore, this project will benefit and provide a simple yet intelligent solution for a large number of homeowners in residential areas.

2. METHOD

2.1. Block diagram

The block diagram of the project is shown in Figure 1. The input and output of this project are controlled by Arduino UNO, a microcontroller with analog and digital input and output connectors that is programmed via the Arduino integrated development environment (IDE) software through the USB cable connection with the computer. The water flow sensor YF-S201 is the input of the project that reads two parameters of the water supply system namely the volume and the rate of water flow.

On the other hand, the outputs of the project consists of the ESP32 module, organic light-emitting diode (OLED) screen and LEDs (light-emitting diodes). Applying internet of thing (IoT), the ESP32 module has Wi-Fi processor and provide data transfer to the cloud via the Blynk application as the platform. The OLED screen dis-plays the water flow and the water volume while the LEDs act as indicators of the system condition.

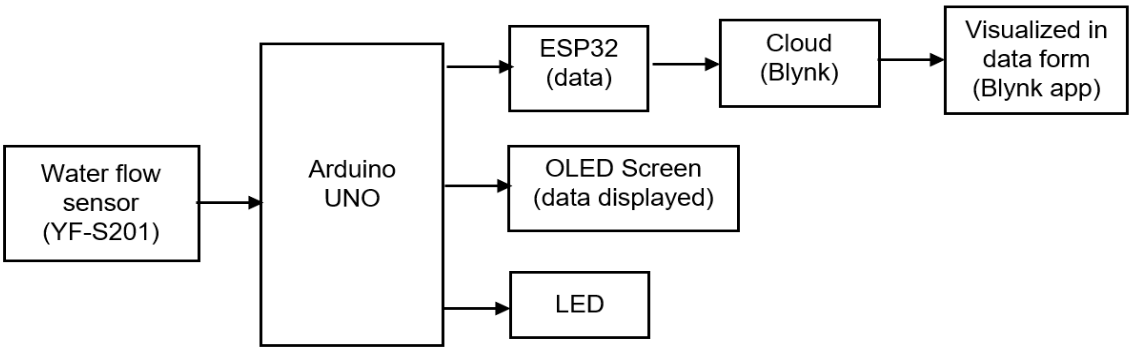

Figure 1. The block diagram of the project

2.2. System flowchart

Figure 2 shows the system flowchart of the project. The installation of the project is inside the water supply pipeline whereby the YF-S201 reads the water flow rate and the volume of water passing through. The flow rate parameter reflects the amount of volume of the water per time in litre/minute. Unlike water monitoring system for aquaculture field where the pH level is significant to be observed, volume and flow rate are the two parameters monitored in this scope of project that is much suitable for residential application.

Then, the pre-programmed Arduino UNO determines the categories of the water flow rate. There are three categories that include increasing rate, constant rate as well as zero rate (no water flow) which later are indicated by green, yellow and red LEDs respectively.

Following this, the input parameters are displayed on the OLED screen. IN order to utilize the internet of thing (IoT), the volume and the flow rate data rec-orded are then sent by the ESP32 to the cloud and visualized via the Blynk application platform.

2.3. Schematic diagram

Figure 3 displays the schematic diagram of the project in the Proteus software which shows the connections between the input module. Arduino microcontroller and the output module of the system.| The water flow sensor acts as the input which reads the water volume and flow-rate values while the wifi-module is the output medium that sends the measured data to the cloud.

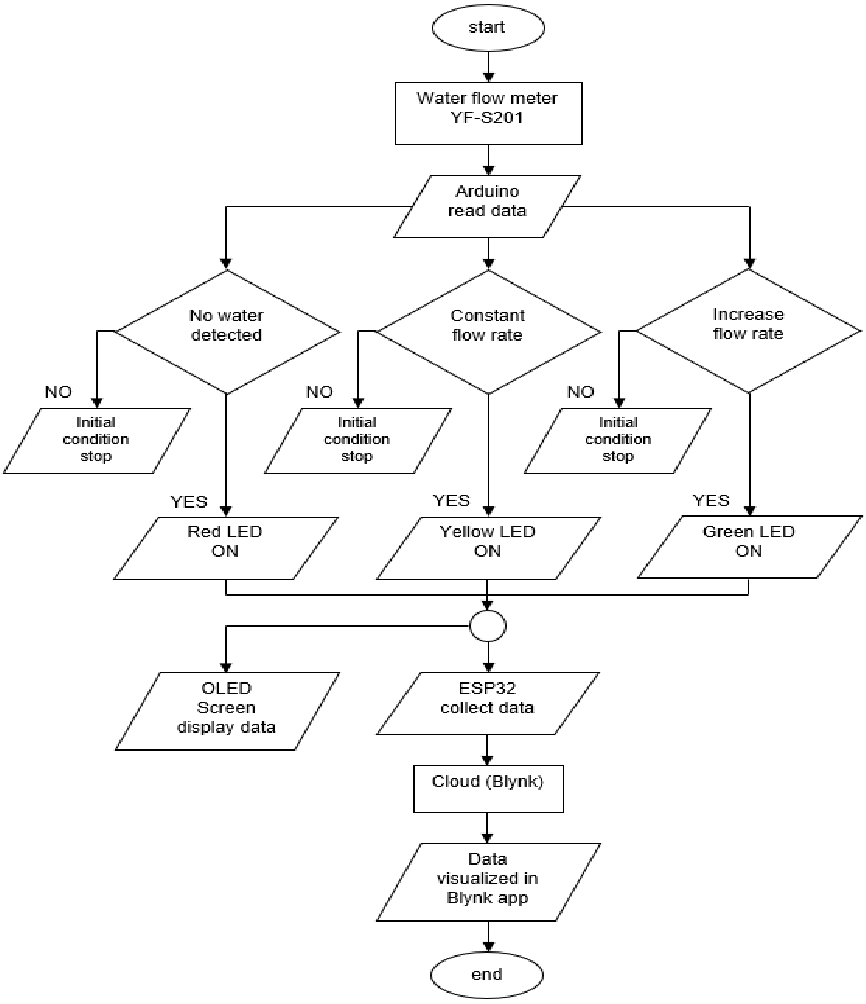

Figure 2. The system flowchart of the project

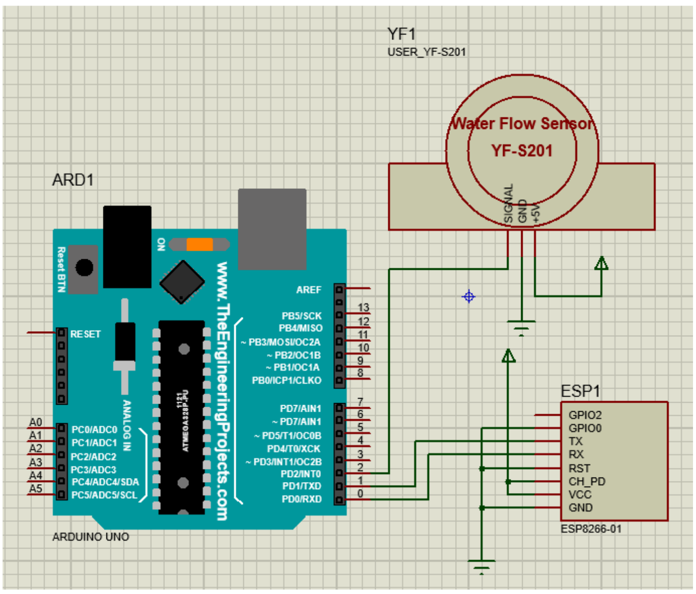

Figure 3. The schematic diagram of the project

3. RESULTS AND DISCUSSION

Figure 4 shows the prototype of water flow monitoring system. It is installed in the water supply pipe-line. The first category is zero water flow rate as shown in Figure 5. At this condition, the red LED is turned on and the zero flow rate reading is displayed on LED screen. The zero reading data is also sent to the cloud via ESP32 and visualized in the flow rate meter and water consumption graph on the Blynk Ap-plication. It is also observed that the yellow LED is also turned on due to the constant zero rate measured.

The second category is when the water flow rate is increasing as displayed in Figure 6. The green LED is turned ON while the OLED screen and meter reading on Blynk show the real-time flow rate and volume. However, the increasing pattern can be easily captured from the water consumption curve on the Blynk Application. Finally the third category is the constant water flow rate as depicted in Figure 7. The yellow LED lights up while the OLED screen and flow rate meter on Blynk show the real-time flow rate and volume. The constant trend is clearly displayed on the water consumption graph on Blynk as the system constantly sending the data to the application via the ESP32 module.

Figure 4. The prototype of water flow monitoring system

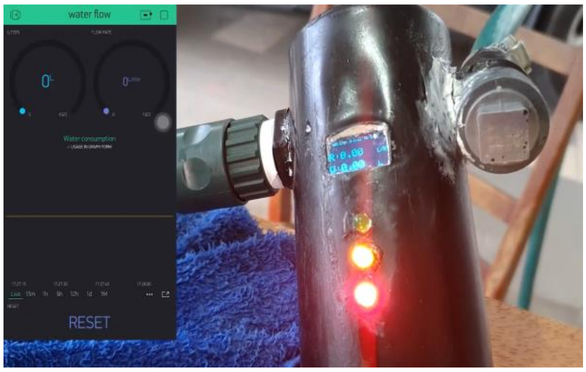

Figure 5. Red LED is turned ON when the flow rate is zero

Figure 6. Green LED is turned ON when the flow rate is increasing

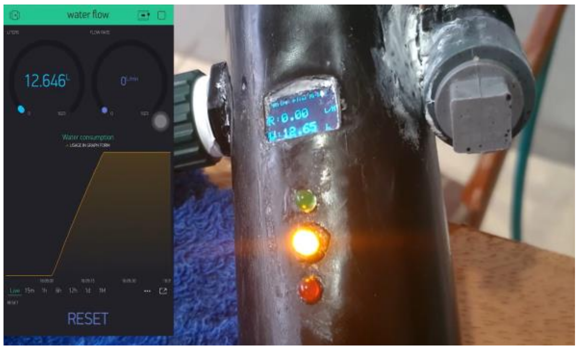

Figure 7. Yellow LED is turned ON when the flow rate is constant

As observed, the measurement process of this project can be remotely monitored via the internet of things (IoT) application. Figure 8 shows the interface of Blynk application for all three conditions. The water volume and real-time water flow rate data sent to the cloud and visualized on the Blynk application are very easy to understand as well as mobile-friendly. These features makes this project suitable for all types of users or the residance with the same purpose of monitoring the availability and accuracy of their water supply system. The accuracy of the real-time stored database enables the user tu access the data at any required time or duration for comparison purpose. Unlike the conventional way suggested by the utility in the occurance of high-water bill, whereby user is required to manually read the current meter reading before and after night time, this project excludes the human error that involves mistakes, slips of action and elapses of memory in terms of time consistency of measurement or even the recorded reading itself.

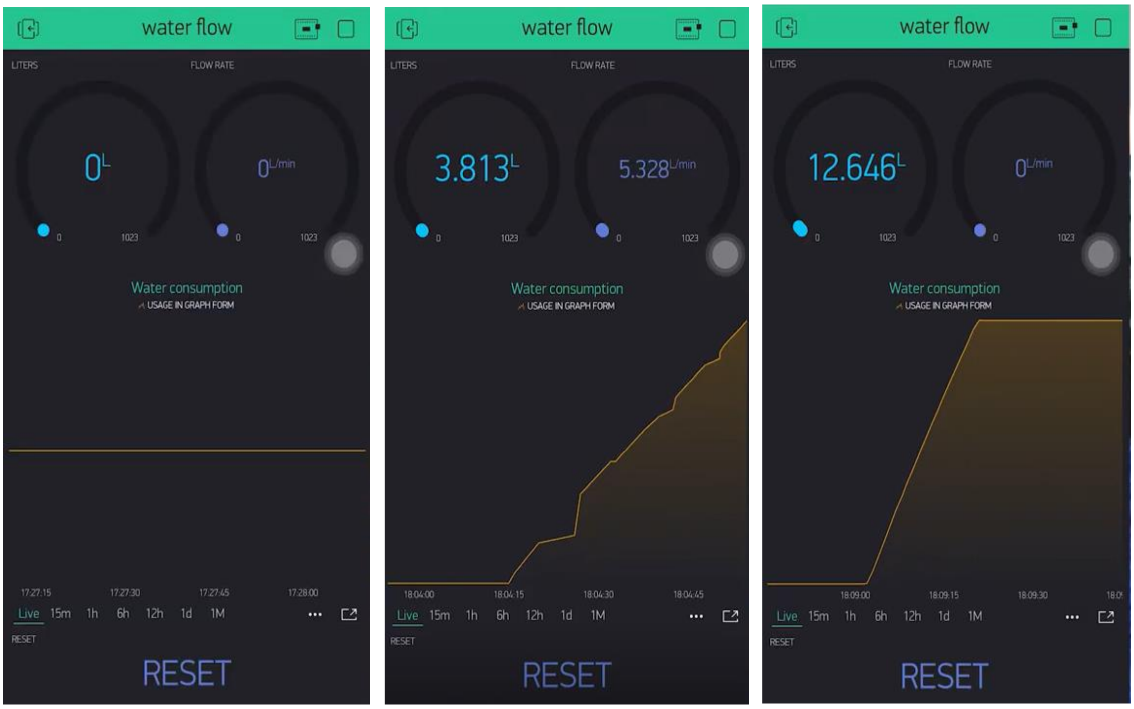

Figure 8. Interface of blynk application for all three conditions (zero volume and flow rate, total volume and increasing flow rate, total volume and constant flow rate)

4. CONCLUSION

In general, the water flow monitoring system based on IoT has been successfully developed by utilizing Arduino as the microcontroller. The results verifies that the water flow sensor YF-S201 has successfully detected the real-time volume and flow rate of the water in the pipeline. With the application of IoT, the residence of an area can be provided with the information of the accu-racy and availability of the water via mobile application with the help of cloud platform. It has been observed that the IoT system performs well and produce an accurate real-time database of the water supply parameters on the Blynk Application and the user-friendly feature makes this project has great value-added for future com-mercialization. The project can be further improved by making it 'smart monitor-ing' whereas the water flow can be adjusted automatically based on the pre-set conditions. Other than that, a massive database creation for regular monitoring and analysis of a water supply system might also help in optimizing the water usage by the user other than improving the quality of the water supply provided by the utilities.

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