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Design and Development of IoT Based Water Leakage Monitoring System

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ABSTRACT

Nowadays, water leakage has become one of the major issues in the water distribution system, and it can cause a lot of water loss through water pipelines. Hence, causing financial loss if it goes undetected at an early stage. In this project, we present the principle of real-time monitoring water leakage systems via the Internet of Things (IoT). IoT is an important component of smart tracking and real time monitoring, which connects people and systems through wireless technologies. The device used to analyse the water leakage in the pipeline is the water flow sensor. The water flow sensor is utilised in this research to measure the water flow rate in the pipeline in order to solve all water-related issues such as leakage and usage. The system focuses on standard housing pipes, and the collected data is displayed through a smartphone. In addition, a newly developed fully integrated water leakage system had been designed and built. The result shows that the system is fully function and provide high accuracy and stability of water flow rate with 98% of accuracy. The system is also capable of transferring real-time data to smartphones via the Blynk application and alert the users when leaks are detected, and the reading is more than the lower and upper limit of the threshold data.

Keywords: IoT, water leakage, flowrate, Blynk, flow sensor.

1. INTRODUCTION

In recent years, Malaysia's water industry is plagued with ineffective water management. According to the World Bank, water management inefficiency has resulted in water losses of up to 50% in one of the states in Malaysia which is Pahang; due to pipe leaks, while the national average is now at 35%, nearly three times that of developing nations. Additionally, the government intends to cut non-revenue water (NRW) to 25% by 2020 [1]. This demonstrates that pipe leakage is a significant concern in the water management system. As a result, these factors are the main elements researchers to propose a better, more accurate, and dependable water leakage monitoring system. Water flow rate monitoring is one approach for detecting leaks. A volume flow rate is defined in engineering theory as the quantity of fluid traveling through a specific cross-sectional area per unit time (m3/s) [2]. Water flow rate is critical to monitor since a rapid shift in water flow might signal that a pipe is leaking [3]. Therefore, a water flow sensor can be used as a device to measure the flow rate of water in the pipeline.

Recently, the development of IoT water leakage systems has been extensively studied by M. S. Mehta et al. [4]. This research presented a Leak Monitoring Device that builds a nodal network of systems that continuously monitor the flow of water and may deliver timely alerts. The study used two water flow sensors to monitor the water flow rate and it will be located at both ends of the pipe. According to the research, if there is a change in flow rate at the pipe's ends, this might indicate that the pipe is leaking. A similar approach proposed by Arya Vijayan et al. [5] by developing a system that can detect pipe leakage by obtaining the inflow and outflow values. This study shows that if the differential between the two sensors exceeds 60 L/hr, a leak in the pipe

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has occurred. However, none of these researchers discusses the degree to which their various systems are accurate.

Another study by [6] proposed a leakage detection system using a similar water flow sensor and claimed that out of twelve iterations, the system has a 99.4% accuracy in measuring the correct value. Arduino Uno microcontroller had been used to analyse the data and publish it on the website for monitoring purposes. However, this system has a few drawbacks as it does not have easy access to monitor the data. Meanwhile, Hafiz Kadar et al. [7] have conducted research that used an Arduino to monitor the water level and the volume and amount of water production utilising mobile apps. The sensors in this system will detect any radical changes, and SMART2L will send an email alerting the user and controlling the pump automatically.

In this paper, a more sustainable and effective IoT system will be developed to solve water related issues using an advanced microcontroller, TTGO Lora Esp32. The TTGO Lora board provides many advantages, such as a 0.96-inch blue OLED screen and a Lora module chip SX1276 with a rapid frequency (868-915 MHz) and excellent durability. [8]. Lora stands for "Long Range" and it is a long-range wireless communications technology developed by the LoRa Alliance. [9]. Additionally, the developed system is capable of monitoring flow rates through the Blynk apps on smartphones. Blynk application that utilized in this research had proven for its high data transmission transfer rate compared to other platforms, so that it will be more useful in a real time monitoring application [10]. Water Flow sensor had been chosen in this study and the overall system will be powered by a rechargeable battery with USB charging module. By focusing on the problem of water for domestic application, the system will be tested to standard housing PVC pipes ½ inches in diameter. In addition, easy installation features for the developed system had been considered during the design and 3D printing phase.

2. METHODOLOGY

Figure 1 shows, the developed system consists of a YF-S201 water flow sensor and TTGO Lora Esp32 Board as the microcontroller. The system's will be powered via rechargeable battery with a USB charging module to maintain good durability. The acquired data will be displayed on the Built-in OLED screen for site monitoring purposes. Finally, the system will utilize embedded Wi-Fi module in the TTGO Lora board transmit the data to Blynk application and the dashboard had been created to display and visualize the water flow rate data using meter gauge and real-time graph.

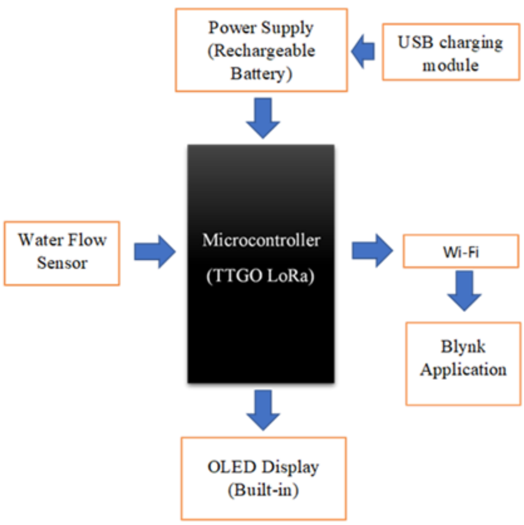

Figure 1. Block diagram for the proposed system.

2.1 System Configuration

In this study, the TTGO Esp-32 Lora board was used as a mini-computer that served as a communication link between hardware and software. TTGO Lora comes with a 0.96-inch-blue OLED Esp-32 module with an onboard lithium battery adapter. It also has the Lora module chip SX1276 with a fast frequency (868-915 MHz) and high durability.

Before configuring the system, the sensor's wire must be appropriately connected to the TTGO Lora board's pins. The pins connection for the sensor and microcontroller can be shown in Figure 2. The flow sensors' VCC (Red Wire) and GND (Black Wire) pins are linked to the TTGO Lora's 5V and GND pins, respectively, while the Signal pin (Yellow Wire) is attached to pin 32.

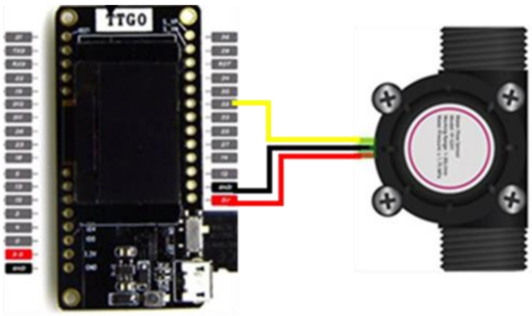

Figure 2. Pins connection for TTGO Lora and Sensor.

In this proposed system, Arduino IDE was used as a programming software to communicate with the microcontroller, sensor and IoT platform. In order to communicate the board, some libraries are required to be installed, such as ESP-32 and Adafruit SSD1306 library. The Adafruit SSD1306 library will enable the board to connect with the integrated 0.96-inch OLED screen for site monitoring purposes. Apart from that, the code for the water flow sensor will use an external interrupt function on signal pin 32. This is used to read the flow sensor's pulses. When the TTGO board detects a pulse, the pulse counter function is triggered to count the number of pulses. The water flow rates will be calculated using the equation, where the flow rate is pulse per minute divided by the calibration factor.

Then, the same flow rate will be delivered in real-time to the Blynk Server utilising the Wi-Fi protocol that has in the TTGO Lora board. A database will be established synchronously in the Blynk application for the purpose of monitoring the water flow rate on a smartphone. Lastly, when a leak is detected, the system will notify the user by sending a notification to their smartphone. The possible water leakage for this option is obtained through the threshold method. The method classifies anything under a certain level of threshold flow rate as possible water leakage.

2.2 System Integration

After the IoT components were programmed, all components were integrated into one complete circuit to secure the connection during field testing. The schematic design of the hardware is illustrated in Figure 3.

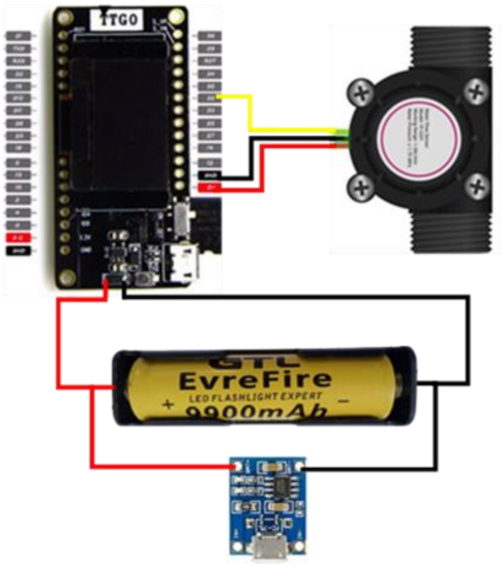

Figure 3. A schematic design for hardware.

Next, the IoT-WLMS case was developed to integrate all components used as one compact device by using Autodesk Fusion 360. This ensures that all electrical components were shielded from any possible water spills and easy to install for site monitoring. Finally, the casing will fabricate by using 3D printing technology and the system was tested for its functionality to send the flow rate data automatically in real-time.

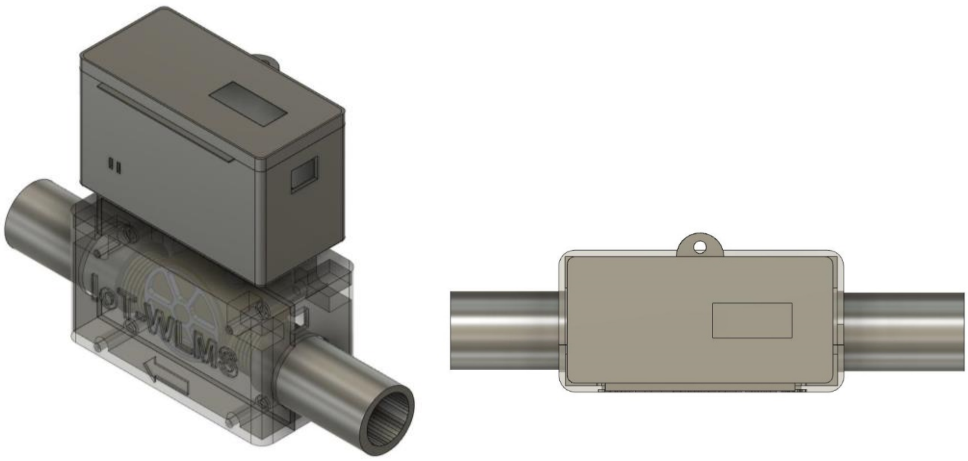

Figure 4. Designed casing using Autodesk Fusion 360.

2.3 Experimental Setup

2.3.1 Sensor Calibration

During sensor calibration, the water flow rate produced by the sensor was compared to the maximum flow rate offered by the water pump specification. A submersible aquarium pump with a power of 20W and a maximum flow rate of 15L/min was used to flow the water into the pipe and passing through the water flow sensor. The calibration factor was set to 3,4 and 5. This value will be entered in the coding respectively before the experiment is run. Finally, the data will be tabulated to illustrate differences and percentages of inaccuracy for various calibration factor values.

2.3.2 System Performance Testing

System performance testing is conducted to determine the performance in monitoring the water flow rate in the pipeline. A prototype is designed to test the system performance by using PVC pipe ½" and connected to the existing pipe with 4 faucets. In this test, the developed system will monitor various water flow rates in order to determine the present condition of water flow at the site. Furthermore, the system's reliability will be validated via data transmission between the hardware and the IoT platform. Finally, leakage simulations will be conducted to determine the values for the threshold data that will be included in the final coding. The design of the prototype is shown in Figure 5.

Figure 5. Water Flow Monitoring.

3. RESULTS AND DISCUSSION

3.1 Sensor Calibration

Table 1 shows the water flow sensor's percentage error at various calibration factors when the pump flow rate is kept at a maximum constant of 15 L/min.

Table 1 Percentage error at various calibration factors.

Calibration factor, c	Water flow rate, Q (L/min)	Percentage error (%)
3	22.22	48.13
4	16.67	11.13
5	13.33	11.13

The table above shows that the most accurate value for 15 L/min of flow rate is between calibration factors of 4 and 5. Therefore, the interpolation formula can be used in order to get the value between two points, where;

$$C = 4 + (15 - 16.67)\frac{(5-4)}{(13.33-16.67)} = 4.5 \tag{1}$$

Hence, the calibration factor of 4.5 was inserted into the coding and the result shows that the sensor flow rate was 14.81 L/min. In this case, the percentage error is 1.26% and has an accuracy of 98.74% from the actual value. This finding was in agreement with Rajurkar et al.[11] results, who also used a 4.5 of calibration factor for this flow sensor. This study shows that the YF-S201 water flow sensor produces about 4.5 pulses for every litre of liquid that passes through it every minute. In conclusion, the error of 1.26% might have been caused by the pump error and losses in the pipeline.

3.2 System Performance Testing

Next, the prototype is tested at various conditions of water flow. Figure 6 shows the graph for flow rate conditions during a given interval. All faucets will be fully opened and the next faucet will be opened after 1 minute.

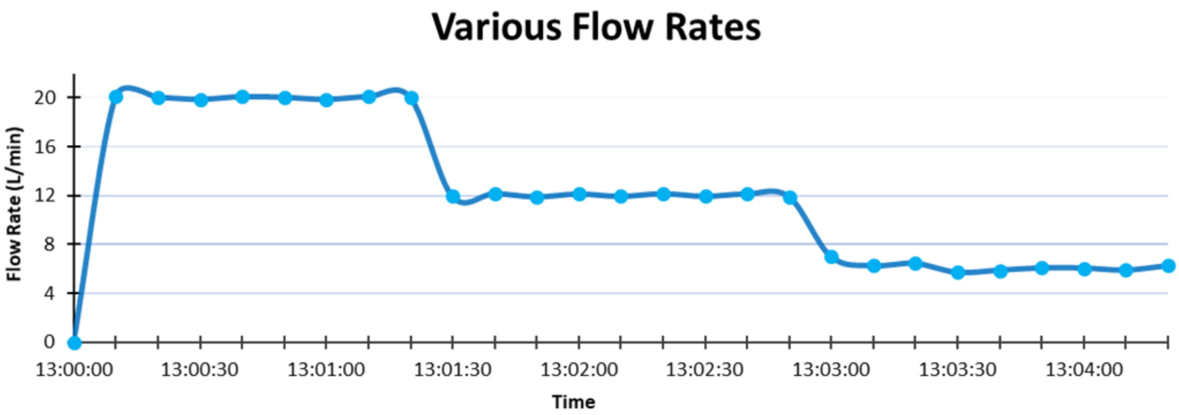

Figure 6. Graph of water flow rate at various conditions.

Figure 6 above shows that when no water is flowing, the flow rate is zero, and when the water is free to flow, the flow rate steadily rises to a constant value. The maximum flow rate during the testing is about 20.99 L/min, and at this stage, only one faucet was open. Then, the flow rate starts to decrease about half of the maximum point when two faucets were opened simultaneously. Meanwhile, when the opening faucets were increased to 3-4, the minimum flow rate was between 6.5 to 5.5 L/min. This shows that when the opening faucets are increasing, water pressure starts to drop [12]. Hence the flow rate also will be decreasing.

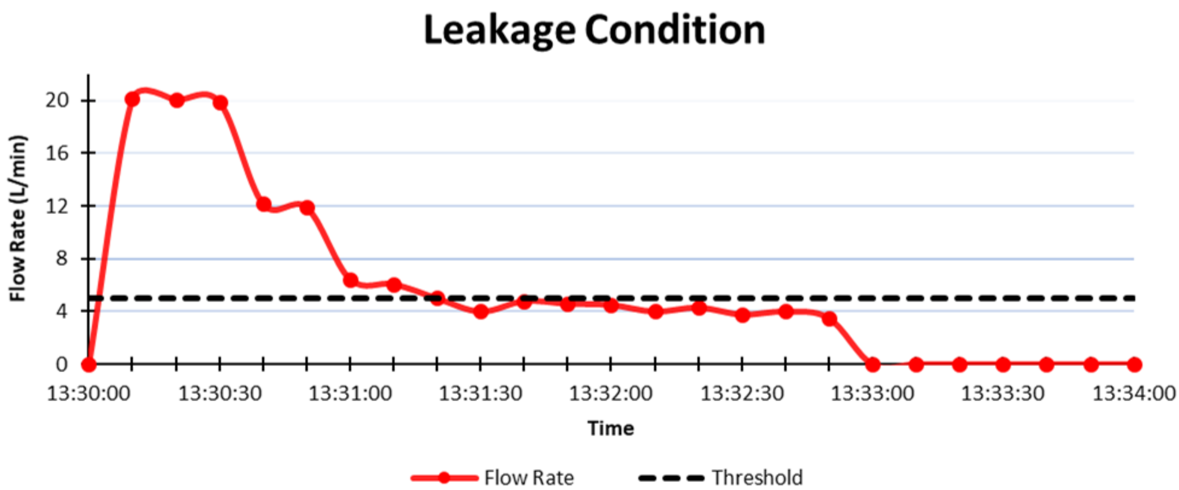

Figure 7. Graph of the leakage condition

From the minimum value of the flowrate, a 2 mm hole was made to consider that the pipe was leaking. As a result, the threshold data were obtained between 0< Q ≤5 L/min. Figure 7 shows a sudden drop of flow rate after 45 seconds to below 5 L/min. After 90 seconds, it shows that the pipe is fully closed after the user detects the leakage. The possible water leakage only shows a pulse when the flow rate is between threshold values for more than 5 seconds. The system will alert the users by sending a notification when leakage is detected.

Next, testing is done by placing the transmitters (device) and receivers (Blynk apps) at a certain distance. The experimental results show that transmitting data from transmitter to receiver rarely experience delays in the range of 0.1km to 14km. Meanwhile, the data transmission test only produces a time delay when the internet connection between the transmitter and receiver is unstable or interrupted. This indicates that the sensor data was successfully sent to the receiver so that the Blynk dashboard could display it in real-time. The findings also corresponding with previous research that says that the Blynk application has a faster data transmission than other platforms [10].

Figure 8. Results from the receiver and leakage notification from the Blynk apps

4. CONCLUSION

In this study, the development of IoT Based Water Leakage Monitoring System was conducted and investigated at ½ inch PVC pipe. As a result, the system can communicate successfully between microcontroller, sensor and IoT Platform that utilising the Arduino IDE software and the Blynk application. Experimental testing of the sensor in measuring the flow rate of water shows that this system provides performance accuracy of more than 98% from the actual water flow rate. The results also show that the developed system is very reliable in real-time monitoring, since the data transmission between receiver and transmitter does not show any delay during the testing session. In addition, the findings show that the pipeline's possible water leakage might occur if the flow rate is below 5 L/min. Finally, the implementation of the Internet of things (IoT) is necessary as water flow through pipelines can be observed at anytime from anywhere, which can save money and time.

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