Original Research Article

Residential Water Tanks with IoT: A Solution for Household Water Consumption Monitoring

ABSTRACT

In recent years, water scarcity has become a challenging problem faced by people in developing countries, especially in big cities where the population is very high. One of the causes is the unwise use of water, for instance, letting the faucet in the kitchen or bathroom on after using it, overusing the water in washing car or other vehicles, and wasting water when taking a bath. Most households in Indonesia use a groundwater well as their source of water and store it in a water tank. Moreover, they tend to waste water without knowing it. Therefore, efficiency and monitoring of water consumption play a vital role in decreasing the scarcity of water. This paper focuses on efficiency and monitoring household water consumption by designing a system for a residential water tank that is integrated with internet of things technology. The system will send the data on water consumption to a cloud server. Then, users are be able to monitor it through a mobile device. With the data, users could change their habit in using water and start to use it wisely. Thus, the water shortage can be prevented.

Keywords: Water scarcity; efficiency, water consumption; residential water tank; internet of things

1. INTRODUCTION

A water scarcity is a condition where the available of fresh water for people is less than the water demand [1]. It has been faced by many people from different parts of the world. It has also attracted a large number of researchers who are working to solve this problem [2]. Even though the Earth consists of 70% water, the amount of fresh water available is only about 3%. It makes fresh water very important and limited, particularly in big cities in developing countries [3]. In addition, the growth of the population and the impact of urbanization have increased the water demand. Also, the water shortage is made worse in many countries by the growth of agricultural irrigation [4]. Thus, the water crisis may become a threat to the world [1].

In Indonesia, most households get their fresh water from groundwater wells and store it in tanks before using it for daily necessities [5]. In addition, they think that the water is limitless. The truth is that it is not [6]. If it is always used without restriction and not taken care of carefully, it can be depleted [7]. Moreover, one of the reasons that the water shortage is happening is the unwise use of water [8]. In fact, many people tend to use water more than they need and waste it without knowing it. For instance, people tend to keep the faucet in the kitchen or bathroom on after using it, overuse the water when washing cars or other vehicles, and waste water when taking a bath or shower [5]. These behaviors are driving the world into a water crisis. As a result, the wise use of water plays an important role in alleviating the water shortage [2].

With the advent of the Internet of Things and related technology, it is possible to make things easier [9]. One of them is monitoring household water consumption by integrating the internet of things with a residential water storage tank. By controlling water usage wisely, it can help preserve the environment in general and avoid a water crisis [1]. There have been studies on the use of IoT for water tanks [10]. Several studies proposed an architecture based on IoT to monitor water level and quality in a residential water tank [11]–[16]. [17] used an ultrasonic sensor to measure the level of water in a tank. The system can be implemented to tank underground or overhead. They also used pump switching systems to control the water. In research by Saravanan et al. [18], they designed a system with an internet of things that can distribute water from a tank for people in urban areas who live in apartments or flats. A tank system based on IoT that can fill the water automatically was presented by Durga et al. [19]. It aimed to reduce water waste, save electricity, and improve water distribution efficiency. Other projects focused on an IoT smart system for water tanks with an Android application [20], [21]. They can control and monitor the water level using an Android-based smartphone. Another study created a system with Arduino for monitoring the color change in the water tank for safe drinking water [22]. It uses pressure sensors, grayscale, and RGB color.

Despite a lot of research that has been done previously, to the best of our knowledge, there are no simple and affordable IoT system for a residential water tank that focuses on measuring water consumption and monitoring it on a mobile phone through a Blynk client application. In this paper, we contribute some additional aspects compared to the previous studies. Firstly, we design a simple prototype and affordable system using IoT technology for monitoring the water usage of a household water storage tank. The hardware components that are used in this study are cheap enough that everyone can buy them. In addition, the design system is very simple and dedicated to measuring water consumption. Secondly, we use the Blynk IoT platform to monitor water usage data in real-time. The users will be able to see the data on their mobile phones.

The rest of the paper is presented as follows: system design on this study is outlined in Section 2. In Section 3, results and discussion are described. Finally, the paper concludes in Section 4.

2. SYSTEM DESIGN

In this section, we describe the proposed architecture of the system in subsection 2.1. Then, we explain how to construct the system for prototyping with affordable hardware in subsection 2.2. In subsection 2.3., the performance metrics used in the study are provided. Finally, we present the experimental setup for this study in subsection 2.4.

2.1. Proposed Architecture

The general system of a residential water tank with the Internet of Things is shown in Fig. 1. The system consists of several parts, such as groundwater, a residential water tank, an IoT system for measuring water usage, an internet gateway, a Blynk cloud server, a user, and a household. Groundwater is the fresh water source for the household. The water will be pumped up and stored in the water tank. Then, it is going to be used later for daily necessities. The water tank is equipped with an automatic water pump and a water level sensor. The pump will work when the water in the tank is empty or below a certain lower-level threshold. If the water has reached a specific upper-level threshold, the pump will shut off. In this study, we do not discuss the system to fill the tank with water automatically. However, we only focus on measuring water usage.

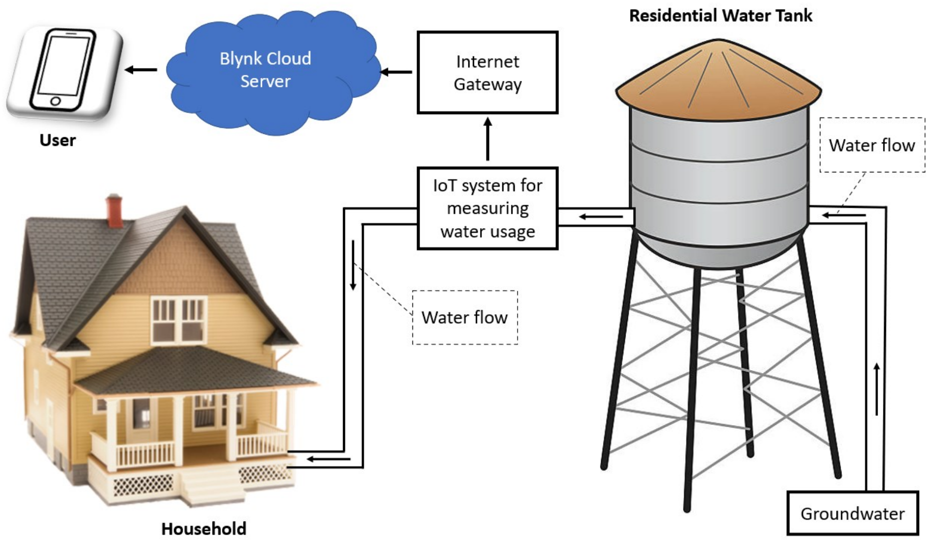

Fig. 1. Architecture design of residential water tank with IoT

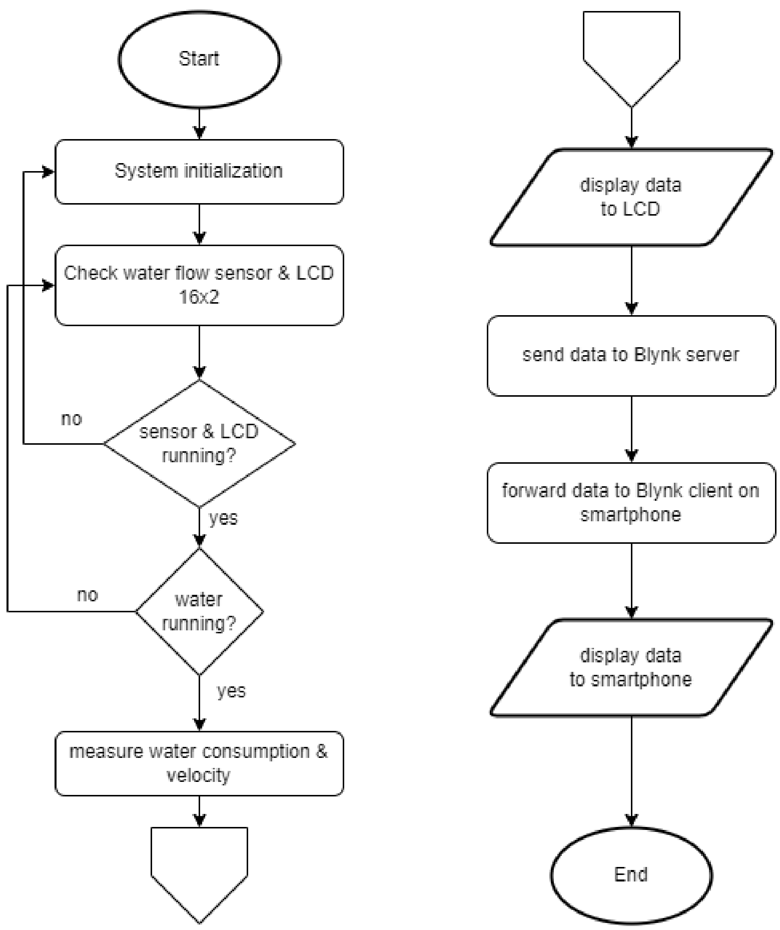

Fig. 2. Flowchart of residential water tank with IoT

If the people in the household need water, they will get it from the water tank. When the water is running, the IoT system will measure the water velocity and volume consumed by the household. This data is sent to the Blynk cloud server through an internet gateway. The user can see this data by accessing the Blynk server with a Blynk client application that is installed on the mobile phone. Also, the user can monitor the water consumption in real-time. As a result, they can make the arrangements based on the data and use water wisely. The components in the IoT system will be explained later in subsection 2.2.

The flowchart for the system is presented in Fig. 2. At the beginning, the system will initialize and calibrate all the hardware. Then, it is going to check the water flow sensor and LCD 16x2 I2C. If the sensor and LCD work without problem, it will check the water. Otherwise, it goes back to the initialization process. If there is a flow of water, it means that the water is being consumed, and the system will measure it using the flow water sensor. If not, it will jump back to check the sensor and LCD process. It will also measure the water velocity. Then, the LCD will display the data. In addition, the system will send the data to the Blynk cloud server and forward it to the Blynk client on a smartphone. The data can be viewed and monitored by the user via the smartphone. Finally, the system will end.

2.2. Prototyping

The ESP32 microcontroller, a water flow sensor, a breadboard, a charger (5 V) with cable, a jumper cable, and a 16x2 LCD with I2C are the system's components. Also, their prices are presented in a list in Table 1. They are cheap and quite affordable. In total, it only costs around $20.

Table 1. Hardware components and their price list

Component	Price (USD)	Source
ESP32 DevKit V1	4	https://www.id.aliexpress.com
Water flow sensor YFS201 ¾ inch	6	https://www.id.aliexpress.com
Breadboard	2	https://www.id.aliexpress.com
Charger 5V with cable	3	https://www.id.aliexpress.com
Jumper cable set	1	https://www.id.aliexpress.com
LCD 16x2 i2c	4	https://www.id.aliexpress.com

Fig. 3 shows the schematic of the system for a residential water tank using IoT, and it is pretty simple. The microcontroller (i.e., ESP32 DevKit V1) is powered by a 5V charger. The water flow sensor and LCD need a power supply of 5 volts and get their power from ESP32. The sensor has three pinouts, namely VCC, GND, and Data Pulse. The VCC and GND are connected to pins VCC and GND of the ESP32 through the breadboard. The Data Pulse connects to GPIO23 of the ESP32. Meanwhile, the sensor consists of four pins, such as VCC, GND, SDA, and SCL. VCC and GND of the LCD are connected to VCC and GND of the ESP32. SDA goes to GPIO21, and SCL links to GPIO22 of the ESP32.

The ESP32 works as the brain of the system. It processes all input and output from the system. It has 30 pins that can be used. There are 15 ADC (i.e., analog to digital converter) and 2 DAC (i.e., digital to analog converter) channels, 2 UART interfaces, 25 PWM outputs, 3 SPI & 1 I2C interfaces, and 9 touch pads. Also, it has 25 GPIO pins which are functioned for different purposes. For communication, it is embedded with a WiFi and Bluetooth BLE modules.

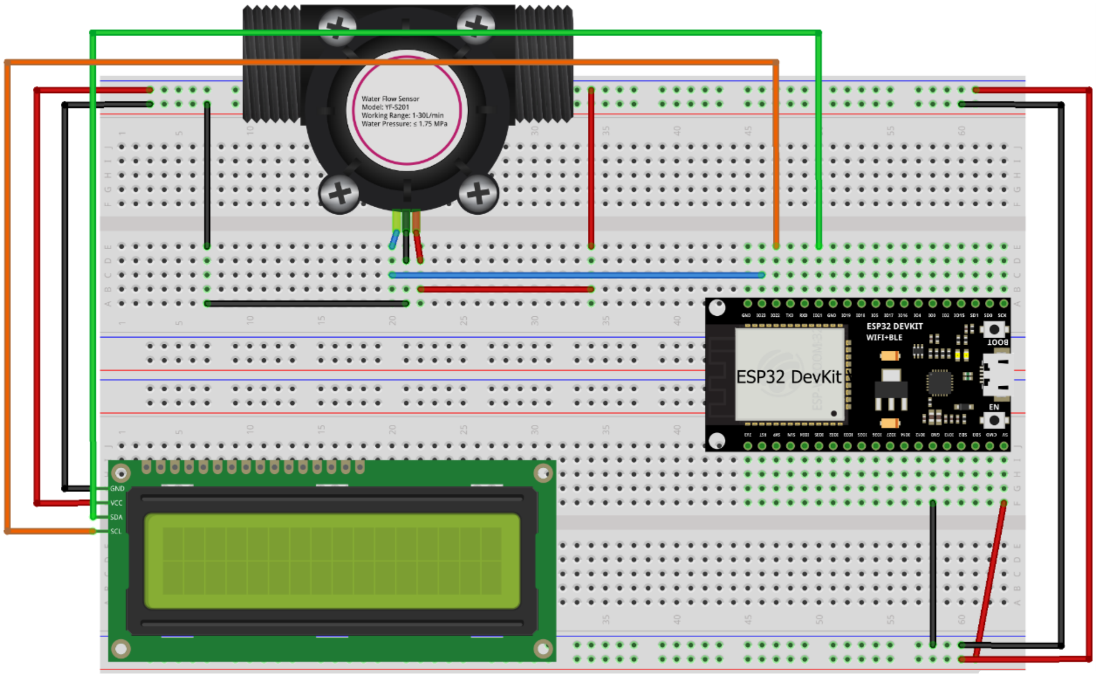

Fig. 3. Schematic of residential water tank with IoT

The flow water sensor model is YF-S201 with a hall effect sensor mechanism. A pinwheel sensor inside it measures how much liquid has passed through it, and it is positioned in line with your water line. A built-in magnetic hall effect sensor generates an electrical pulse with each rotation. Because the hall effect sensor is protected from the water pipe, it can remain dry and safe. If better than 10% precision is desired, thorough calibration will be needed. But it's fantastic for simple measurement chores.

A 2x16-character LCD module with a yellow backlight is called the LCD 16x2. It can show 16x2 characters on two lines. To communicate with the host microcontroller, it employs an I2C interface. Projects requiring the display of text, data, or ASCII characters of any kind employ this cost-effective LCD. Connect to the serial data line, ground, VCC, SDA, and SCL (serial clock line). This 5 VDC device can be located at either 0x27 or 0x3F on the I2C bus.

2.3. Performance Metrics

In this paper, we want to measure the amount of water that is consumed as well as the water velocity. The measurement unit for water usage is the cubic meter (i.e., m3). The cubic meter to liter conversion formula is as follows:

$$1\ m^3 = 1{,}000\ liters \quad (1)$$

Meanwhile, the unit of measurement for water velocity or flow rate is liters per minutes (i.e., *lpm*) that is defined as

$$lpm = \frac{L}{min} \quad (2)$$

where *lpm* is the flow rate of water, *L* is the amount of water in liters, and *min* is the time, in minutes, it takes to fill 1 liter of water.

Furthermore, if the household obtains its water supply from a water utility company, the monthly water bill can be calculated using the following equation:

$$W_{cpm} = W_{upm} \; x \; P_{pcm} \qquad (3)$$

where W_{cpm} is the water cost per month, W_{upm} is the water usage in a month, and P_{pcm} is the price of water per cubic meter (i.e., m^3). However, in this case, where the water source is groundwater, the monthly cost is free.

2.4. Experimental Setup

For this experiment, we will implement the system and measure how much water the author's family uses by using the prototype. The household consists of five people, namely two adults and three children. We will conduct the experiment by running the system for a week, 24/7. The people in the household are going to use the water as usual for daily activities, such as washing machines, dishes, cooking, taking showers, washing vehicles, etc. The illustration is seen in Fig. 4. The system will measure the daily water usage for a week and show its statistics. Then, it will approximate the cost of the water consumed. The data is sent to the Blynk server. Finally, the user can see and monitor the data from a smartphone by using Blynk client apps.

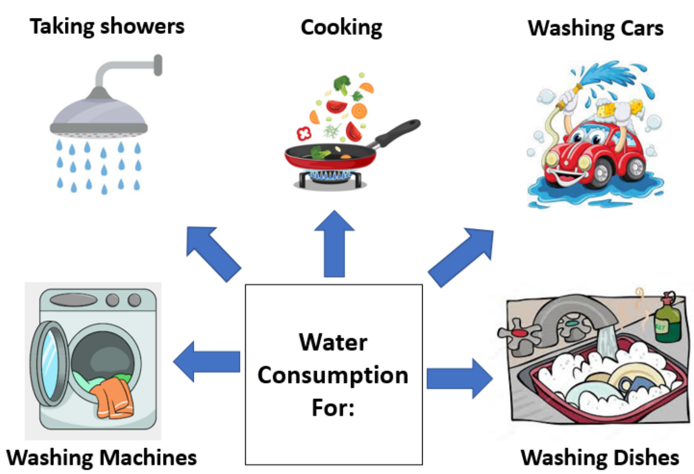

Fig. 4. Water daily usage for household in the experiment scenario

3. RESULTS AND DISCUSSION

We explain the experimental results in this section. The purpose of the experiment is to observe the water usage of a household. If the household overuses the water and wastes it, they can reflect on the way they use the water and start using it wisely and efficiently.

Fig. 5 depicts the results of household water consumption on weekdays, from Monday to Friday. The water usage is monitored every hour from 01:00 to 00:00. The system calculates how much water is used each hour and provides it on the graphic. The household is a good Muslim family that performs five prayers a day. Around 3:30 a.m., they begin their activities by preparing to perform the dawn prayer, called *fajr salaah*. As a consequence, they need to use water to perform a wudhu (i.e., a technique for cleaning certain body parts). It is seen from the graphic that they need around 40 liters of water daily for wudhu. The amount of water consumed increases until 6 a.m., then goes down at 7 a.m. Usually, the father and the children take a morning shower between 5 and 6 a.m. Meanwhile, the mother prepares to cook. That is why water consumption is quite high at that time, which is approximately 120 liters. Then the water usage goes up to 100 liters until 9 a.m. The mother uses it for watering the plants and the washing machine. From 10 a.m. to 4 p.m., the water consumption is low and varies between 10 and 58 liters. The highest water usage on weekdays is at 5 p.m., when all family members take showers. Then it goes down again until 12 p.m.

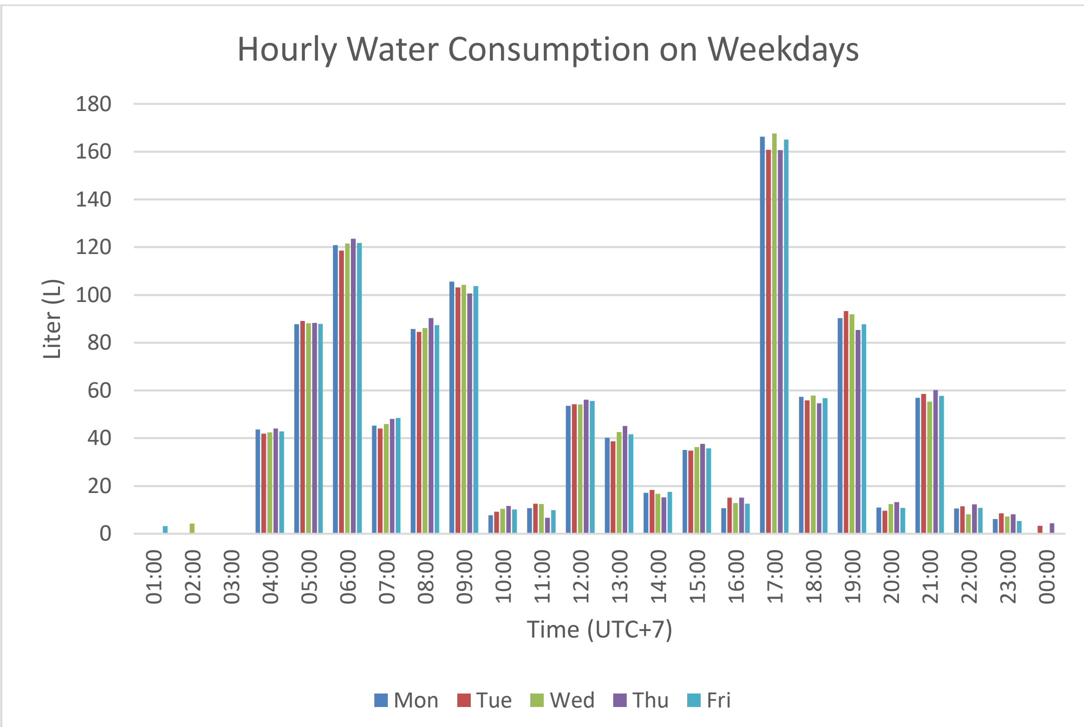

Fig. 5. Hourly water usage of the household on weekdays

The water consumption for the weekend can be seen in Fig. 6. Even on weekends, the household still begins its activities around 3:30 a.m. by performing the dawn prayer. The peak of water usage in the morning, which is roughly 350 liters, is at 7 a.m., when household members take showers. It is different from weekdays, when they take showers at 6 a.m. The second highest water consumption in the morning is at 8 a.m. It is time to wash the car, motorcycle, and bicycle. Then, from 9 a.m. to 4 p.m., it goes down and up. The household water usage is quite high again at 5 p.m., when they take afternoon showers. Moreover, water is needed quite a bit during the prayer times, such as at 4 a.m., 12 a.m., 3 p.m., 6 p.m., and 7 p.m. After 7 p.m., the water consumption decreases.

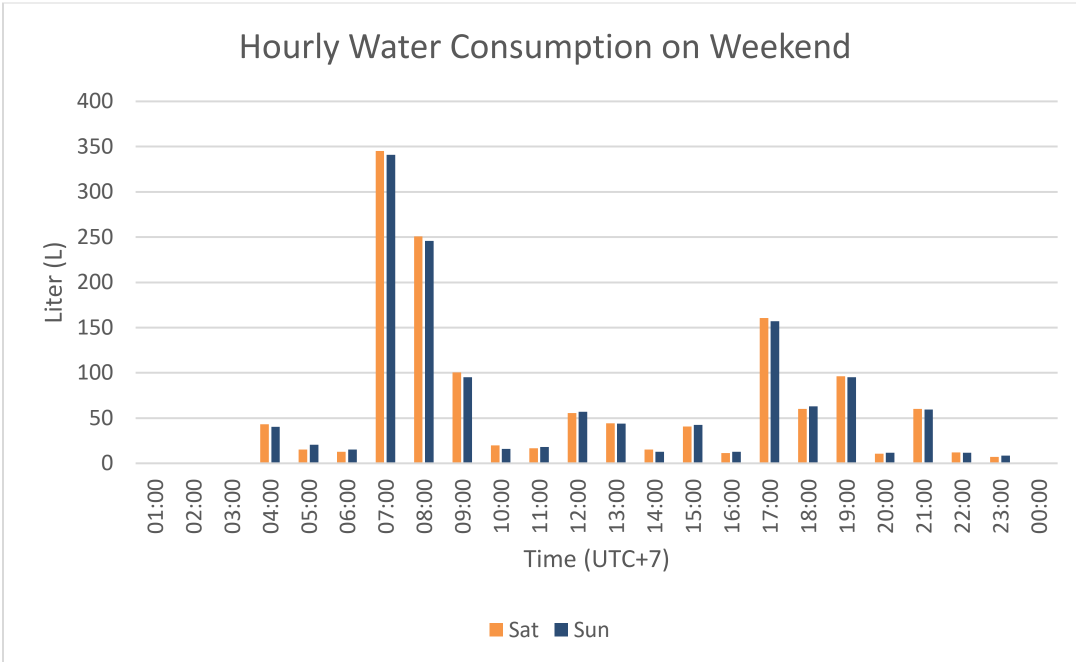

Fig. 6. Hourly water usage of the household on weekend

Fig. 7 presents the daily water usage of the household for a week from Monday to Sunday. It can be seen that water consumption during the week is lower than during the weekend. During the week, the daily water usage is about 1062 liters. Meanwhile, over the weekend, it reaches around 1378 liters. They use more water on the weekends to wash the car, motorcycle, and bike.

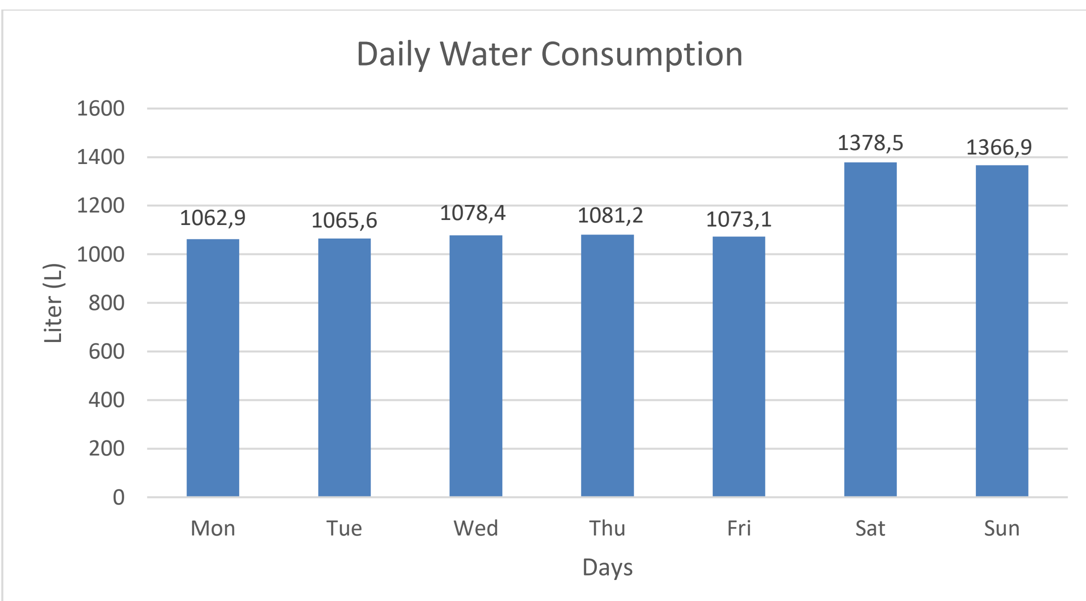

Fig. 7. Daily water usage of the household for a week

Table 2 shows the cost calculation of daily water usage for a week. It is assumed that the price of water per m3 is IDR 3540. This is applied to the Yogyakarta region in Indonesia. Also, the tariff is for households. It is shown from the table that the daily water usage varies from 1.0629 m3 to 1.3669 m3. Therefore, the daily cost is roughly between IDR 3,762 and IDR 4,838. Then, we can calculate that the cost for a week is about IDR 28,697.37. Also, the household needs around 8.1066 m3 of water each week for their daily activities.

Table 2. Daily water consumption cost calculation for a week

Day	Liter (L)	Meter Cubic (m3)	Price/m3 (IDR)	Cost (IDR)
Mon	1,062.9	1.0629	3,540	3,762.67
Tue	1,065.6	1.0656	3,540	3,772.22
Wed	1,078.4	1.0784	3,540	3,817.54
Thu	1,081.2	1.0812	3,540	3,827.45
Fri	1,073.1	1.0731	3,540	3,798.77
Sat	1,378.5	1.3785	3,540	4,879.89
Sun	1,366.9	1.3669	3,540	4,838.83

Fig. 8 presents the display of water usage monitoring from the Blynk client on a smartphone. The system provides the data of current water used (current), flow rate, water cost (current), water cost (month), water consumption (month).

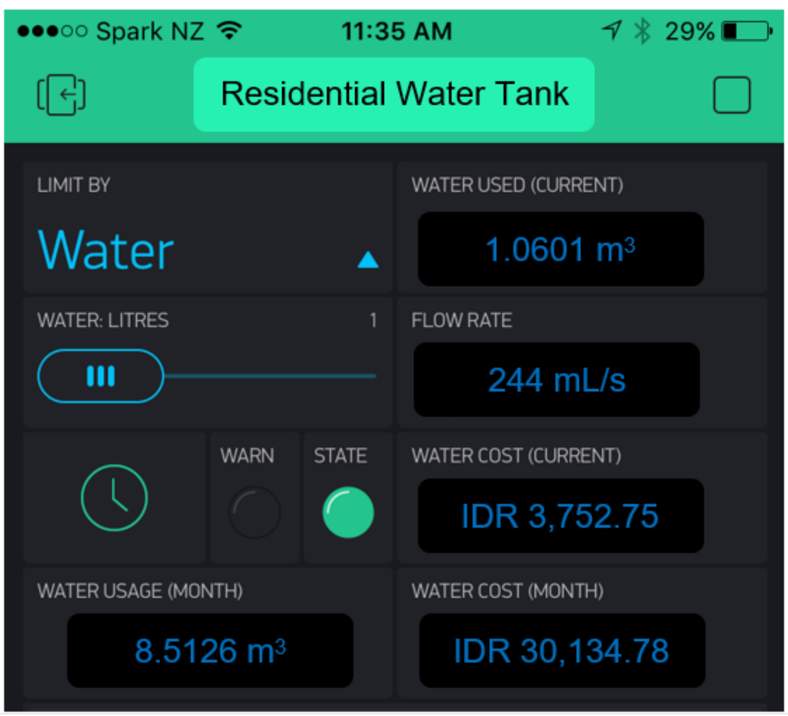

Fig. 8. Water consumption monitoring from Blynk client on smartphone

4. CONCLUSION

In this paper, we present a design system for residential water tank that is integrated with the Internet of Thing technology. The design is simple and affordable. We also made a prototype of the system. The cost to build it is about $20. The system focuses on measuring the water consumption of household. The measurement is done by using a water flow sensor. Moreover, we showed that the system can successfully send the data water usage to Blynk cloud server to be used later for user monitoring. The user can see the data in real-time from his/her smartphone that is installed a Blynk client application. Furthermore, it can help to control the water consumption of household. Thus, we conclude that this system can improve the water usage efficiency as well as the wise use of water.

Currently, the system can only measure water consumption. However, for future research, it can be added with extra features, for instance, a notification system with SMS (i.e., short message service), WhatsApp, or Telegram, a water level measuring system, a water leakage detection system, etc.

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