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## **Development of IoT-based water reduction system for improving clean water conservation**

**Key words:** water reduction system, water management, Internet of things, water flow sensor, mobile application

### **Introduction**

Nowadays, the condition in which the demand of domestic water cannot be fulfilled has been perceived by many parts of the world that caused by the rapid growth of population (Liu et al., 2017). One way to prevent water scarcity is by managing the usage of water with the intention of reducing the amount of water used. Developing innovative methodologies, tools and techniques that aim to combat water quantity losses becomes a priority action that must be done (Kanakoudis et al., 2017), in order to provide effective information to the people or community for their contribution to water conservation, thus create more sustainable and desirable future. Currently, there are many tools that can help people

to use less water or to limit water consumption, such as flow restrictors, low flow showerheads, water efficient white appliances, water efficient toilets, and urinal sensors (Queensland Government, 2009). Another device that provides real time feedback about water consumption with more accurate to the user is smart water meter. The main advantage of using smart water meter is that the user can monitor directly and receives more accurate information regarding to the user's water consumption compared to conventional water meter, via the Internet of things (IoT) technology and Android smart phone (Sønderlund, Smith, Hulton & Kapelan, 2014).

Household appliances that generally use the largest amount of water in daily life are washing machine, shower, and toilet. The general usage of sanitary water consumption in residential indoor could reach up to 111 l daily, in which: 31.4 is used for shower, 23.3 for toilet, 23.0 for kitchen sink and 12.4 for wash-

ing machine. The use of shower, toilet, kitchen sink, and washing machine make up about 81% of the total apartment water use (Jordán-Cuebas et al., 2018). Depends on the tank reservoir volume, toilet water use could vary considerably. The general water usage for ordinary toilets could be 7.5, 9, or 13 l per flush (Gormley, Aspray, Kelly & Rodriguez-Gil, 2017). However, for the sake of water usage reduction, it is also possible to flush the toilet with 6 l of water (USDoE, 2013).

The Internet of things has been utilized to monitor and evaluate the system of energy consumption in almost every aspect of daily life, including in the field of water management system. In the present paper, clean water reduction strategy is designed by the help of IoT devices such as water flow sensor to measure the volume of water consumption on washing machine, shower, and

toilet. The amount of water consumption will be monitored in real time through an Android application in smart phone that connected to those IoT devices. By the help of user consideration, the application of this system on such a small house or apartment may has a great potential in reducing the amount of clean water used.

### Methodology

The designed framework of water reduction strategy using IoT-based system is illustrated in Figure 1. The system starts by reading the water consumption that used by three household appliances that were considered using a lot of water, which are: washing machine, shower, and toilet. The water volume usage will be measured by water flow sensors that installed to the washing machine, show-

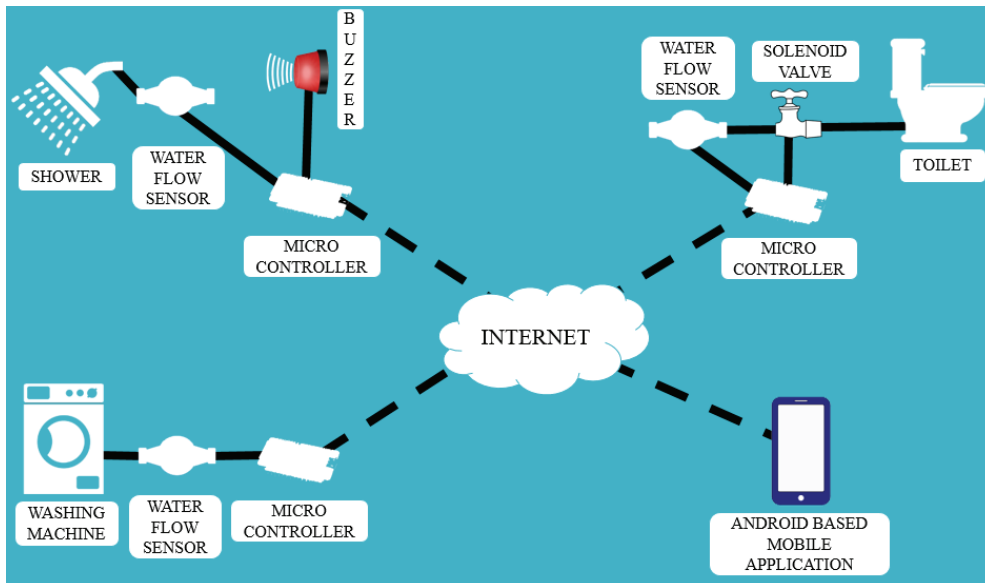


FIGURE 1. Design framework of IoT-based clean water reduction

er, and toilet's pipelines. A microcontroller that connects to each water flow sensor was utilized to send the data of water usage to the cloud server through Internet. In the case of shower, besides installing water flow sensor like in washing machine, a buzzer was installed to alarm the user before the consumption of water reached the maximum limit. User can input the maximum limit of supplying water volume for shower according to their real requirement. For the toilet, after flushing the user should press a "Refill" button on their smart phone as a signal order to open the solenoid valve to automatically fill the toilet's water tank for 6 l of clean water. The data of water consumption from these three household appliances will be sent to a cloud server and the user could access the data through an Android application.

## Results and discussion

### Hardware

The components used in this project of water reduction strategy are NodeMCU microcontroller, water flow sensor, solenoid valve and buzzer, which could be obtained easily from the market. The open source Arduino software (IDE) was utilized to program the NodeMCU microcontroller to read the water volume consumption, as it measures the volume of water, which flow through the water flow sensor and causing the rotor inside to spin simultaneously. At the time when the rotor spins, a voltage/pulse will be induced (Rajurkar, Prabakaran & Muthulakshmi, 2017). The use of NodeMCU module is to send water volume data

read from water flow sensor to a cloud server. Water flow sensor and microcontroller will be occupied along with the household appliances (washing machine, shower, and toilet) pipelines. The schematic diagram of all hardwares and its connection used in each household appliance in the present IoT-based water reduction system can be seen in Figure 2. Figure 2a exhibits the use of smart water meter in general, water flow sensor was connected to microcontroller to read water volume that flowed through washing machine's pipeline. In Figure 2b, a buzzer was connected to the microcontroller that used for the shower's pipeline. The buzzer's function is to alarm the user with different sounds that represents the usage of water to the consumption limit in percentage (75, 85 and 95%).

The user can lock the maximum limitation for shower water consumption, for example at 25 l. So, the sound of alarm will alert the shower's user when the water usage has exceeded 18.75, 21.25 and 23.75 l before it stops when the water consumption in shower reaches 25 l. Schematic for toilet's pipeline is depicted in Figure 2c. Additional components used are solenoid valve, 12 V power supply, 2.2 K resistor, TIP120 transistor, and diode. The 12 V power supply was used to power the solenoid valve which has the function to stop and control the water flow, while other components were used to support the control of solenoid valve. Solenoid valve has a magnetic rod which could block the water flow to the pipe when the rod is closed or to let the water flows when the rod is open (Gopalakrishnan, Abhishek, Ranjith, Venkatesh & Jai Suriya, 2017).

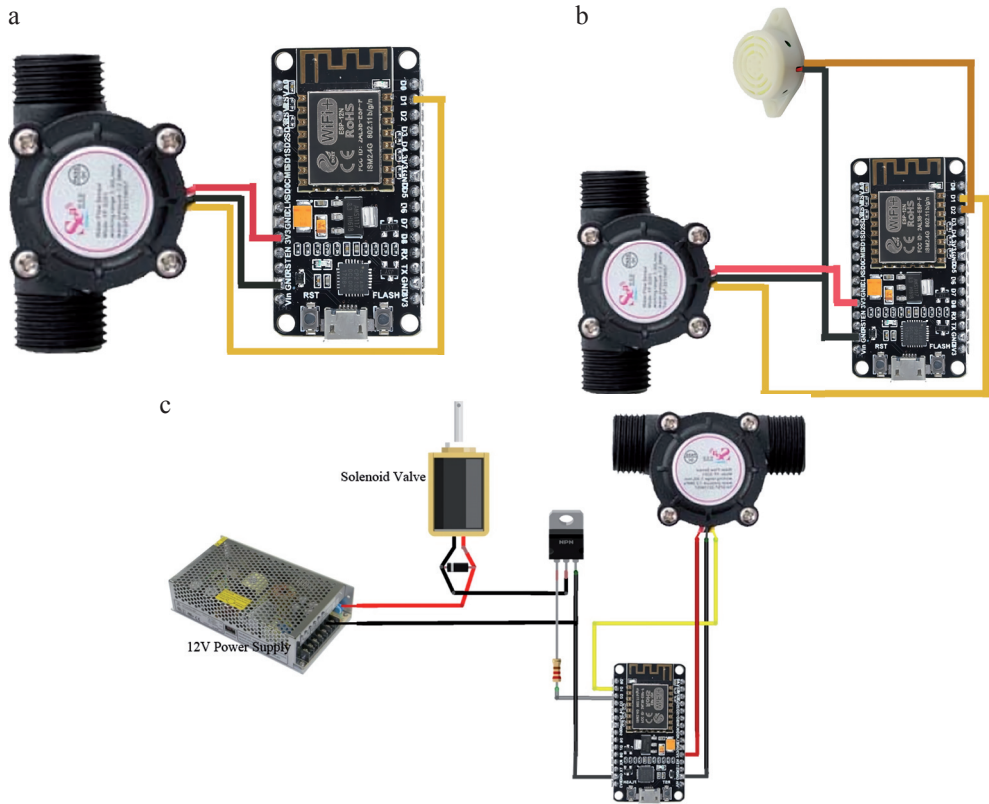


FIGURE 2. Schematic connection for hardware: a – used in washing machine’s pipeline; b – used in shower’s pipeline; c – used in toilet’s pipeline

### Application design

In this digital era, smart phones have changed the way we live our lives. Things could be easily done through the help of a smart phone. By developing such application (app), users could access information regarding their water usage anytime and anywhere in real-time. In this study the Android-based application has been developed using the assistance of Android development program of Android Studio to visualize the water volume that has been consumed through the water flow sensor and to control the solenoid valve to refill toilet’s water tank.

The use of Android application as the user interface will make it easier for user to interact with the developed system. Protocol based on IoT is used to guarantee delivery of messages throughout the system. The microcontrollers will send the data of the water volume usage to the cloud server every time when the water flow passes through. In addition to that, whenever the application is accessed by the user, it connects automatically to the cloud server that provides the information of the water usage. The information of water usage of the three household appliances will be presented, and the sum

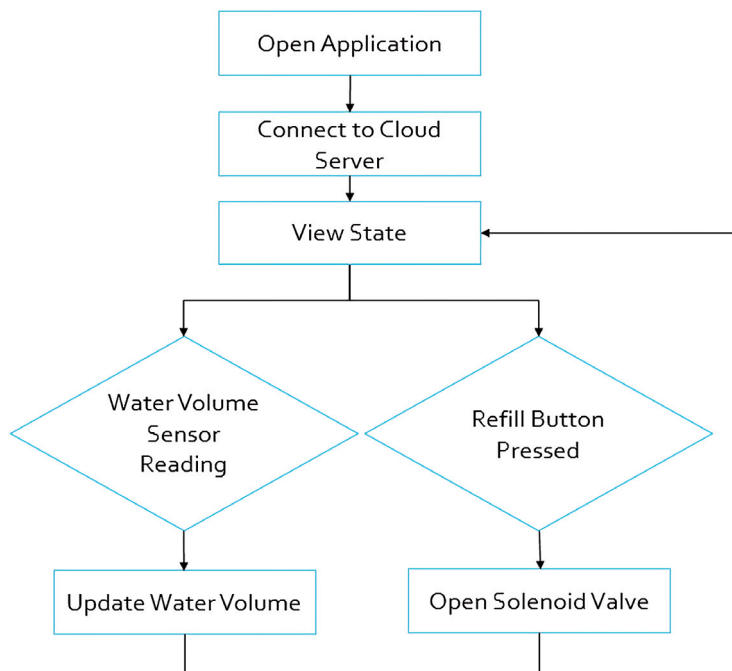


FIGURE 3. Flow of Android application process

of water usage will also be shown to the user. An addition of a “Refill” button was made to power up the solenoid valve in the toilet’s pipeline and fills the toilet’s water tank.

The flow diagram of Android application process can be seen at Figure 3. The associated visual display for Android-based mobile application in user’s smart phone to monitor the water consumption is depicted in Figure 4.

### Experimental result of the components

One of the components that we use in this project is water flow sensor, and this component must be firstly calibrated to measure the water volume passed through the pipe shows the accurate measuring number. Experiments were carried out to

compare the water volume measured by the water flow sensor in particular time (sensor read) and the water volume that manually measured by a cylinder glass (real volume). The calibration of water flow sensor was made by adjusting the Arduino IDE program so that the volume of water passing through the sensor was set not to exceed 7% of the actual volume. The measurement result of the quantity of water that being passed through the water flow sensor in predetermined time, the actual volume water and the percentage error as the comparison of those two is exhibited in the table. As shown in there, the comparison of the water volume that read by sensor and that are manually measured by cylinder glass shows no significant difference. This means that the sensor used in this

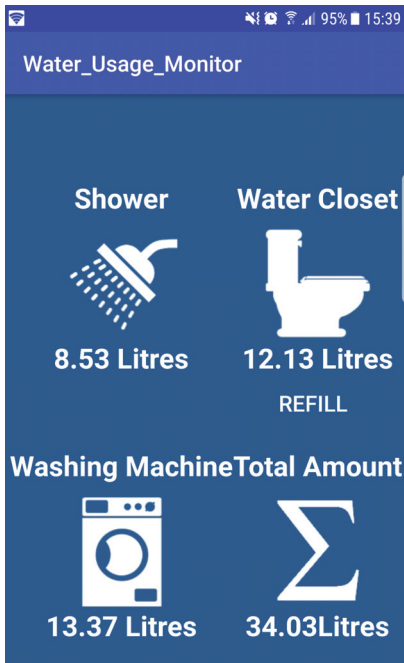


FIGURE 4. Android-based mobile application GUI

experiment was capable enough to measure the actual water consumption. The same procedures have been performed to other devices and the result shows the similar result of percentage errors, which lower than 5%. With the percentage error lower than 5%, this result shows that the device prototype work properly and its function performance in measuring water volume is in accordance with the project's objective.

### Potential water reduction of the developed system

The potential of clean water which might be saved by practical implementing of our system can be explained from the following feasibility study. Suppose a person uses 31.4 l of clean water for shower (Jordán-Cuebas et al., 2018), and

13 l of water for each flush (Gormley et al., 2017) for toilet use in a day. By using this system, a user can possibly reduce their water consumption on shower to 25 l which saves 6.4 l of clean water per day. As for the consumption used in conventional toilet can be reduced through solenoid valve in our system to 6 l per flush of water use, refers to USDoE policy (USDoE, 2013), thus it can save 7 l of water for once use of flushing toilet. For the reduction of clean water in washing machine usage, it will depend on the user by their own consideration in consuming the water. Through the water consumption data displayed on the system, the user is expected to have awareness and to realize the importance of regulating water reduction for subsequent use in washing machine usage. Suppose that the contribution of water reduction will come from the use of shower and toilet, the user can possibly save as much as 13.4 l of clean water per day. Within a month, each user could potentially save around 402 l of clean water or even more.

With the many advantages that can be obtained through the application of IoT-based smart water meters compared to the conventional one, such as: reducing the labour costs and direct control to the real water consumption, it will become appropriate if this system can be adopted and widespread implemented in residential customers to save million litres of clean water. In addition of being able to be used as one of the approaches to integrated water resource management, this system may also be one of the answers to key issues of water scarcity and water quality which are emerged in several parts of the world.



## Conclusions

We have successfully designed and implement the IoT-based water reduction system as a one way to realize the clean water reduction strategy or water conservation. This system which may potentially be implemented in such a small house or apartment, can monitor and provide real-time information on how much water consumed by the user daily. In this project, we used NodeMCU microcontroller, water flow sensor, solenoid valve, and buzzer to monitor water volume consumption at three household appliances (washing machine, shower, and toilet). Experimental testing of the smart meters in measuring the quantity of water supplied shows that these tools provide performance accuracy more than 95% from the actual water volume, which is good enough to be used for estimating the real water consumption of the user. The reliability of the remote access data through Android-based mobile

application demonstrates the good result to keep updates the water consumption records. Based on the feasibility study, each user may potentially save clean water up to 402 l monthly. Through this research, the IoT-based water management system program using smart water meters must be promoted as a substitution of the use of traditional water meter because it has several advantages, especially in motivating users to contribute to water conservation for more sustainable and desirable future.

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TABLE. Testing data result for the water flow sensor read after calibration

No	Sensor read [ml]	Real volume [ml]	Percentage error [%]
1	640	650	1.54
2	997	945	4.95
3	905	863	4.86
4	844	815	3.56
5	848	835	1.53
6	891	880	1.23
7	813	830	2.05
8	975	940	3.72
9	945	915	3.28
10	612	625	2.08
Average percentage error			2.88

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## Summary

**Development of IoT-based water reduction system for improving clean water conservation.** Water is one of the basic necessities of life; however, due to the increased growth of population and without any changes of people's current water consumption rate the world would face water scarcity in the near future. Developing tools and techniques that aim to combat the loss of water quantity becomes a priority action due to it can provide actionable information to the community in its contribution to clean water conservation. In this study, the IoT-based

water reduction system has been developed to measure water volume at three household appliances (washing machine, shower, and toilet) by installing flow sensors to those of each pipeline. Each sensor was connected to a microcontroller that sends water volume data and it will be stored in the cloud server. This technology could help users in reducing clean water consumption by: alarming user whenever water volume reaches 75, 85 and 95% of the limit volume for each showering session by installing a buzzer to the shower's pipeline; limiting the water used for the toilet flushing by installing a solenoid valve for the toilets' pipelines; and allowing users to access the information of all water consumption through Android-based mobile application. Through this study, IoT technology has great potential to support clean water reduction strategy due to it could save clean water up to 402 l monthly. Application of IoT technology can be started to be installed in such a small house or apartment in which the user can directly monitor their water consumption.

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