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# Wireless water usage monitoring system for home/small premises

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**ABSTRACT**

The fourth Industrial Revolution has led to tremendous change in industrial automation. Measurement system can be seen as an important tool implemented in various fields because it enables us to access essential data from the environment or desired location. One of the essential measurement systems in industry, company or home is water usage monitoring. Water usage monitoring is the regular collection of information on the total amount of water drawn from sources during a given period. It enables a company or industry to understand water usage patterns and identify potential inefficiencies. For instance, a hotel premise who wants to monitor its water usage per room basis. Monitoring is also essential to set reduction targets of water used. The paper presents the development of wireless water usage monitoring system. This system consists of two nodes which are sensor node and sink node. The sensor node collects the water usage data and send them to the sink node. An ultrasonic sensor, Light-Emitting Diode (LED) and buzzer are attached to the sensor node as alert system for the user in case of water wastage occurrence. The sink node receives data from the sensor node wirelessly and mark this data time stamp by referring to a Real Time Clock (RTC) and store it in the database. The database is attached to sink node with Secure Digital (SD) card module. Furthermore, a Graphical User Interface (GUI) is used to display the water usage data in graphical form for easier user interpretation. The proposed wireless water usage monitoring system is suitable for home and small premises usage.



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## 1. INTRODUCTION

Industry 4.0 enables the integration of traditional industries with cutting edge internet technologies, whereby smart products are integrated into intertwined digital and physical processes [1, 2]. In this context, we see emerging adoption of various kinds of intelligent equipment that can be supported by wired or wireless networks, providing users with both real-time and delayed signals [3]. The main advantage of implementing wireless connectivity among devices in industrial automation is that those devices can be made mobile, without any restricting cables [4].

Nowadays, the quantity of clean water is decreasing due to water pollution and many people use it in the daily life for multiple purposes. Quality requirements for water differ by intended use. Sustainable management of water resources for different uses will not only need to account for demand in water quantity, but also for water temperature and salinity, nutrient levels and other pollutants [5, 6]. In addition, climate

change poses an additional threat to water security because changes in precipitation and other climatic variables may lead to significant changes in water supply in many regions [7-9]. Therefore, some simple preventive measures need to be done to reduce the wastage of the clean water for example turn off the water tap after use or repair the water pipe when broken. Authors in [10] provides a comprehensive insight into the global environmental impacts by households whereby between 50% and 80% of total resources, including water are used. In [11], social marketing intervention is proposed to assist in preserving essential goods and services such as water.

The ability to improve management of water supplies is becoming increasingly important as demand for water continues to escalate [12, 13]. Safeguarding against future water shortages is not just about producing enough water to meet demand. Equally as important is the need to control the amount of water that is lost in transit between the point of production and the end user. Losses attributable to water leakage are a major concern in any water network. Even a small leak could potentially result in the loss of thousands of liters of water if left undetected. There are many benefits of monitoring water usage including analysis of water usage trend, identifying increment in consumption that is in need for further investigation for example sudden increase could indicate a leak and establishing reductions in water usage following the implementation of water efficiency measures [14, 15].

Therefore, people are realizing that there is a need to create a system that can help to observe the quantity of water usage to prevent the wastage of clean water, as proposed by inventors in [16, 17]. Based on the water monitoring system, user can analyze the quantity of water flow from one place to the other place. For example, if a user transfer 10 liters of water from a location to another, but the reading of water flow meter at receiver only shows 7 liters, user can analyze and start to suspect that maybe there is water leakage somewhere in the water pipe. User can take immediate action such as checking the water pipe for leakage to be repaired or calling the maintenance personnel to repair the water pipe to prevent wastage of clean water and avoid high financial load. In addition, monitoring water usage will help companies to understand and manage consumption, identify opportunities to reduce wastage and save money.

Wireless Sensor Network (WSN) has gained wide use in data collection in various applications such as environment monitoring, energy consumption monitoring and control, and industrial condition monitoring. In [18], flow rate/temperature sensors are placed at different detection spots in a house to collect water usage data. On the other hand, authors in [19] have designed a water pipe leakage monitoring system for long-distance aboveground water pipelines. An adaptive sampling strategy is proposed to reduce the number of data samples by sending data only when significant parameter value change occurred, and water consumption in household is used as a case study [20]. In addition, since traditional way of manual meter reading is inconvenient and time consuming, authors in [14, 21-25] have proposed smart water management system or smart meter to provide the user with real-time data for water consumption but with a rather complex solution.

This project is developed to solve the aforementioned problem, and targeting water usage monitoring at home or small premises. In this system, user can track the quantity of water being used in an hour or a day. User can install the water usage monitoring system to the water pipe at desired location such as water pipe in toilet to view the quantity of water used daily. If the quantity of water used is too high and continues to flow for a long time, user can suspect of either any user forget turn off water tap after using or water pipe is broken. In addition, an alert function is also added to the system. When a user in the location forgets to turn off the water tap after using and try to leave, the system rings and alert the user to turn off the water tap before leaving. This can help to save the clean water and avoid financial loss.

Figure 1 shows the overall concept of the proposed system in this project. This project consists of two nodes known as sensor node and sink node. Only scalar data is transmitted in this project. In addition, the project uses existing water flow meter sensor on the shelves. The sensor node is equipped with water flow meter sensor while the sink node is attached to PC to receive data from sensor node. The data transfer is done wirelessly. The database is connect to sink node and used to store the water usage data. A Graphical User Interface (GUI) is also used to view the result which is the current quantity of water used and total water quantity used in real time.

## 2. WATER USAGE MONITORING SYSTEM DESIGN

The methodology implementation is aimed to ensure the project is complete in such ways that all the problems faced is solved with a solution which is mostly applicable. Besides that, the methodology also helps to ensure well function of the product all the time.

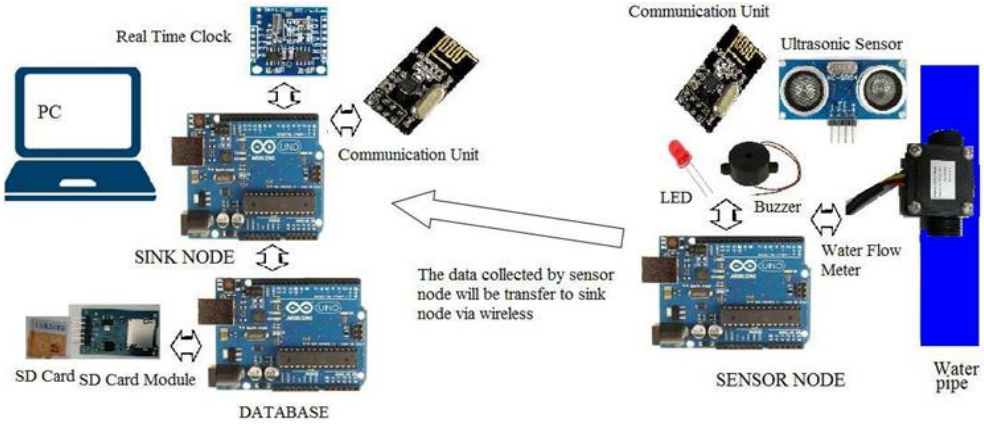


Figure 1. Overall system setup

### 2.1. Planning

Planning the whole process for the development of this project by gathering information about the hardware and software used is needed. In this planning phase, the major elements that need to discuss that is literature review study of the existing water usage monitoring system to know the concept of the system.

In the phases of literature review study, the progress is to learn and understand the concept of the water usage monitoring system with the water flow meter sensor. Besides that, understanding the concept of data transmission wirelessly is also included because the data transfer from sensor node to sink node is done through wireless. The research of component used in this project such as the operation of ultrasonic sensor to detect the user and LED as well as buzzer is also studied. Usage of Real Time Clock (RTC) to record the real time with the data from sensor node and the operation of micro SD card module to store the data are also studied.

In addition, it also involves learning about the method to write the programming code for sensor node and sink node to ensure that the system can function as desired. Besides that, the method of using the graphical user interface (GUI) to view the result of quantity of water usage in water pipe is also studied and analyzed. Table 1 shows list of hardware used in order to complete the project and make the water usage monitoring system function well.

Table 1. List of Hardware

| No | Item | Quantity |
|---|---|---|
| i | Arduino Uno R3 | 3 |
| ii | nRF24L01 Single Chip 2.4GHz Transceiver | 2 |
| iii | FS200A G1/2 water flow sensor | 1 |
| iv | HC-SR04 Ultrasonic Sensor | 1 |
| v | DS1307 Real time clock | 1 |
| vi | Micro SD card module | 1 |
| vii | Micro SD card | 1 |
| viii | Buzzer | 1 |
| ix | LED | 3 |
| x | Resistor | 1 |
| xi | Ceramic capacitor 104 (0.1µF) | 2 |
| xii | Male-male Jumper Wires | 10 |
| xiii | Male-female Jumper Wires | 30 |
| xiv | USB Cable A-B type | 2 |
| xv | 9V DC connector (Arduino power supply) | 2 |
| xvi | 9V battery | 2 |
| xvii | Breadboard (small) | 1 |

### 2.2. Design

In this design phase, there are two major elements discussed which are hardware and software designing, as illustrated in Figure 2. Hardware designing is needed to design the hardware with the several components that already study in the literature review. The hardware design involves incorporating processing unit, communication unit, and sensor unit. The software designing is needed to write the program

code for the whole system to function as desired. The software used to write the program code is Arduino IDE because this project uses the Arduino UNO as the processing unit. Besides that, the software used to operate the graphical user interface (GUI) need be easier understood by the user. For this project, the software used to study and view the result is Makerplot.

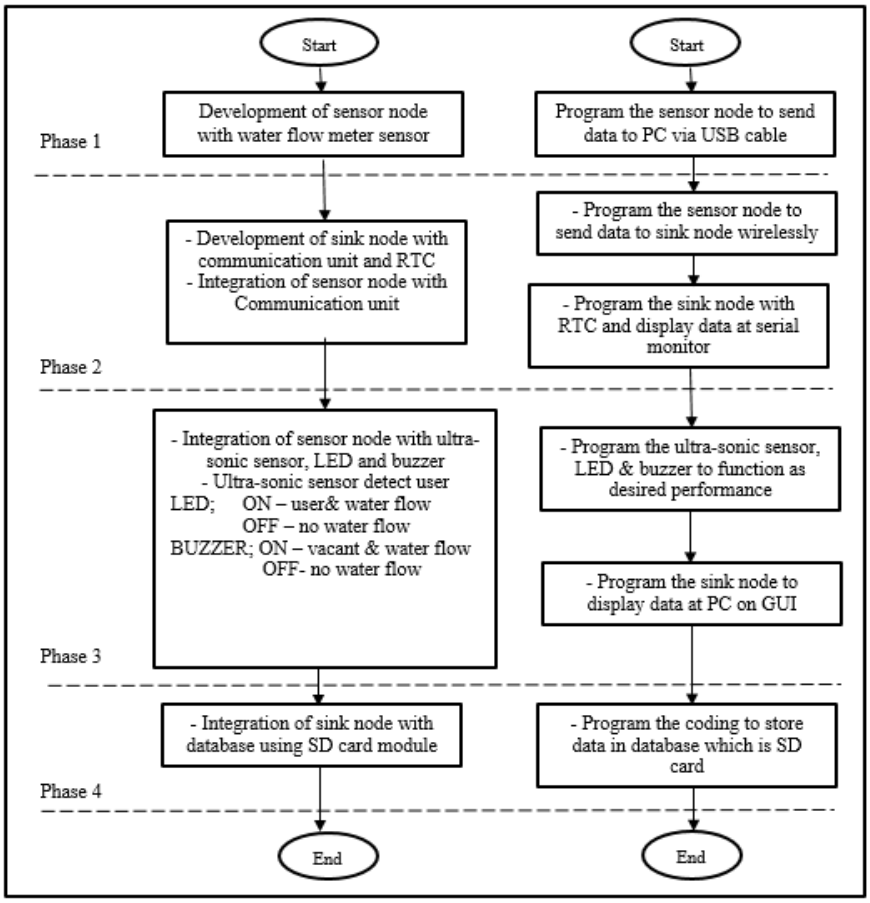


Figure 2. Flowchart of hardware and software design

### 2.2.1 Hardware Development

Development of hardware for the wireless water usage monitoring system in this project has four phases. First phase is the design and develop the sensor node. The sensor node includes the Arduino Uno r3 and connected to the sensing unit which is water flow meter sensor. Water flow meter sensor is used to collect the water flow data which is quantity of water usage.

Second phase is the design and development of sink node. The sink node also used the Arduino Uno r3 as processing unit with attached communication unit, which is nRF24L01 Single chip 2.4 GHz transceiver. In addition, the sink node is connect to real time clock (RTC) to record the data with time stamp. Sensor node is also attached to the same communication unit which is nRF24L01 Single chip 2.4 GHz transceiver and used for data transmission from sensor node to sink node wirelessly. The circuit diagram of sink node is shown in the Figure 3.

Third phase is integration of sensor node with ultrasonic sensor, LED and buzzer. Ultrasonic sensor is used to detect the user occupancy in the location needed such as bathroom or toilet. LED lights up when the user exists in the location and turn on the water tap. When user leaves the location and turn off the water tap, the LED automatically turned off. In addition, the buzzer rings when the user leave the location without turning off the water tap meaning that the water continue to flow leading to wastage. The circuit diagram of the sensor node show in Figure 4.

Last phase is the integration of sink node with database which is using SD card module to store the data of water usage sent from the sensor node. Since the sink node is connected with real time clock (RTC),

the data of water flow is stamped with real time and stored in the SD card. Figure 5 shows the circuit diagram of database.

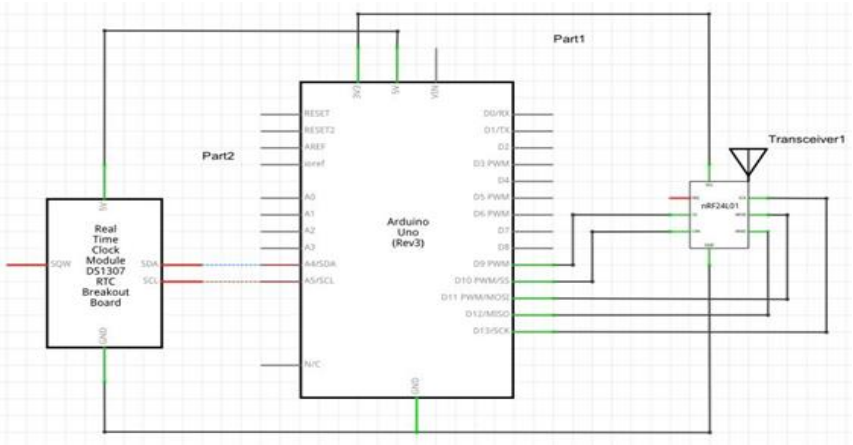


Figure 3. Circuit diagram of sink node

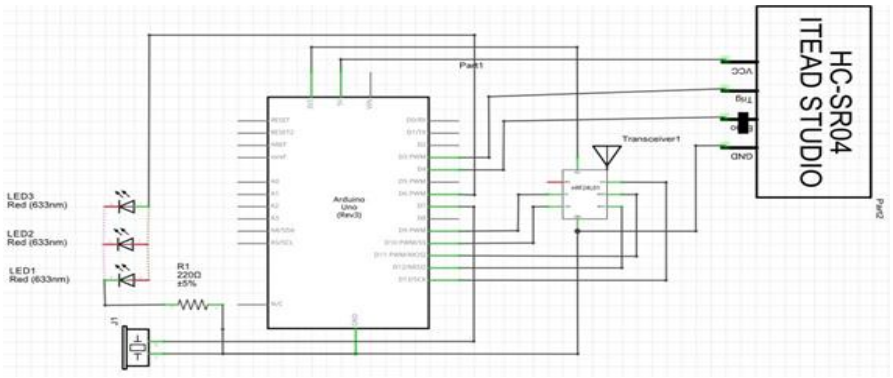


Figure 4. Circuit diagram sensor node

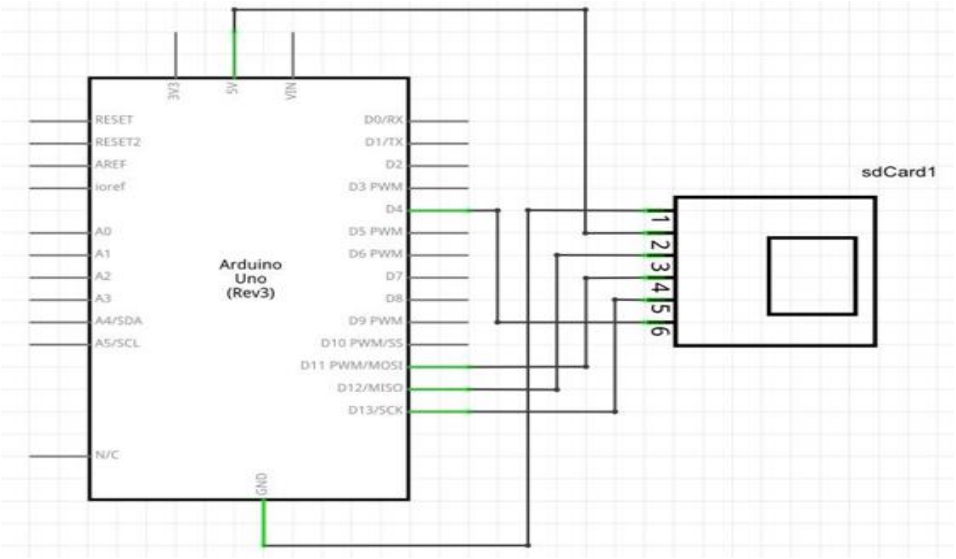


Figure 5. Circuit diagram database connection

### 2.2.2 Software Development

During the software development, first phase is focused on the program code of the sensor node to collect the water flow quantity data from the water pipe and send it to PC via USB cable and display it on the serial monitor in Arduino IDE software.

The second phase is to program the sensor node to send the data to sink node via wireless connection which is using nRF24L01 Single chip 2.4 GHz transceiver at sensor node and sink node respectively. This is important part of the program code because user can receive the water flow quantity data from remote location. In addition, sink node is equipped with real time clock (RTC) to mark the flow data with real time stamp.

The third phase is to program the ultrasonic sensor to detect the user in determining the occupancy of desired location where the sensor node is installed. Alert system is also programmed in this phase. Besides that, this phase involves the programming of the sink node to display data at PC on Graphical User Interface (GUI) by using Makerplot software. The GUI enable user to store the data in txt form in the PC for further review. Additionally, GUI can display the water flow quantity data in graphical format for easier analysis.

Last phase is to program the database by using SD card module to store the data needed. The data sent from sensor node to sink node need to be mark with real time stamp and then stored to database for further review. User can use the program code to view the data in SD card on serial monitor or user can also take out the SD card from SD card module and put it into SD card reader to view the data.

In short, the program code for sink node and sensor node need to be developed step by step following the phases to ensure the program code can be compiled without error and is working as desired. Figure 6 shows flowchart of sensor node system flow while Figure 7 shows flowchart of sink node system flow to ensure that the performance of the system is as desired.

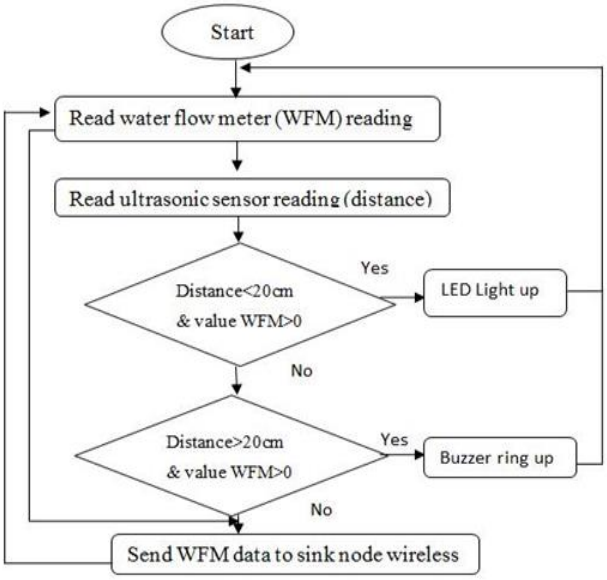


Figure 6. Flowchart for sensor node operation

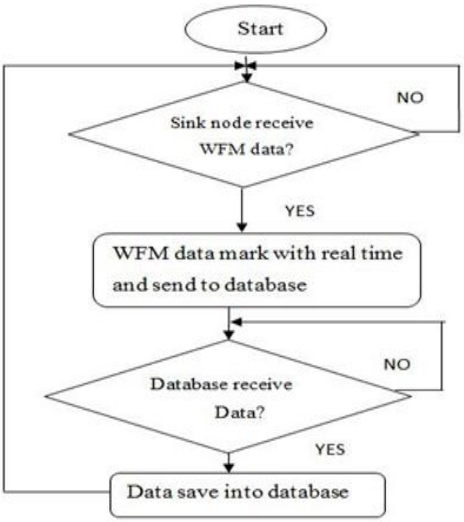


Figure 7. Flowchart for sink node and database operation

## 3. RESULTS AND DISCUSSION

This section discusses the result and the assessment from the experiments conducted in this project. After the development of the wireless water usage monitoring system, the system has been analysed to ensure the objectives are successfully achieved. A few types of testing is conducted which are taken as a measure for the functionality of the wireless water usage monitoring system.

### 3.1. Water Flow Quantity Value Test

This test is conducted in order to ensure that the quantity of water flowing through a pipe can be collected by the water flow meter. This test records the data by using 400ml, 500ml, 600ml and 700ml of water to determine the accuracy of the water flow meter used.

Results in Table 2 shows that the water flow meter is able to collect data with approximate value within ± 30ml. This value can be accepted since it is small value and the results does not vary up to more than 40ml. To further enhance the accuracy of water flow reading, it is advisable to use more advanced and higher-end water flow sensor but at the expense of higher cost.

Table 2. Result of Water Quality Collected by Water Flow Meter

| No | Water used (ml) | Water quantity show on serial monitor (ml) | | |
|---|---|---|---|---|
| | | 1st test | 2nd test | 3rd test |
| 1 | 400 | 382 | 396 | 429 |
| 2 | 500 | 519 | 505 | 485 |
| 3 | 600 | 591 | 610 | 622 |
| 4 | 700 | 712 | 685 | 707 |

### 3.2. Data Transmission Test

Figure 8 shows the result of sensor node which has successfully sent the data to the sink node through wireless which by using nrf24L01 transceiver. Each reading sent by the sensor node is the same as each reading received by the sink node, as shown in the picture with pointed arrows. The COM5 shows the result in sensor node and COM 6 shows the result in sink node. On the other hand, Figure 9 shows the result of the sink node with time stamp at each of the data received from sensor node by using real time clock. After testing the distance of the wireless data transmission, the maximum straight line distance between sensor node and sink node without obstacle is around 50m.

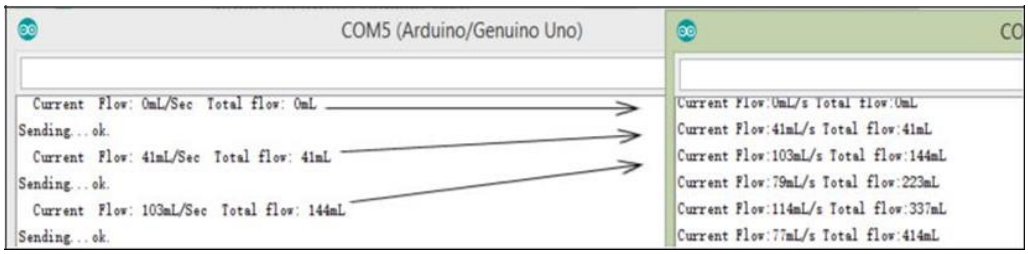


Figure 8. Data transmission from sensor node to sink node

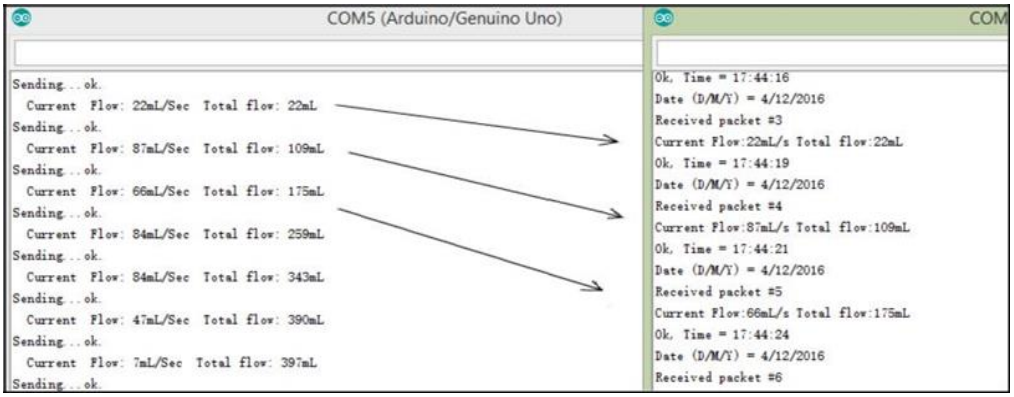


Figure 9. Data transmission of sensor node with real time stamp

### 3.3. Sensor Node Test

The sensor node test shows the results of the water flow meter sensor and alert system by using ultrasonic sensor together with LED and buzzer. The ultrasonic sensor is used to detect user is within 20cm. When user in front of it within 20 cm, it assumes that the toilet is occupied. LED lights up and when user leaves the location without turning off the water tap the buzzer rings. Figure 10 shows this situation in the serial monitor of Arduino IDE. The Serial monitor shows “User using water” and “LED light up” when user

is inside the toilet and using the water tap. Inversely, when the user leaves without turning off the water tap, the serial monitor shows "user leave but water flow" and buzzer rings. Figure 11 show the prototype view of the sensor node.

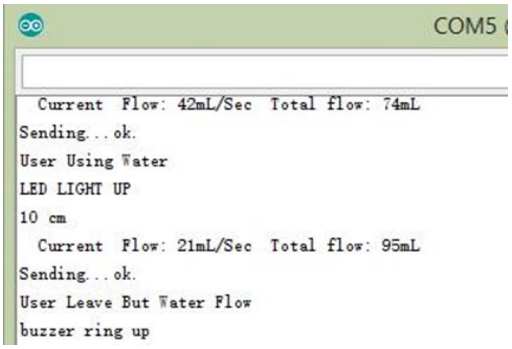


Figure 10. Result of sensor nod test

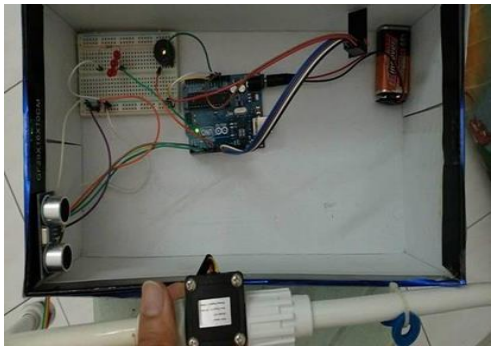

Figure 11. Prototype of sensor node

### 3.4. Graphical User Interface (GUI) Test

The GUI used in this system to display the data is Makerplot. Figure 12 shows the graph of current flow, ml/sec (black line) and total used, ml (red line) in GUI to facilitate user analysis of the water flow data. Moreover, meter of right side can show each data in digits form and can set the maximum value to activate the alarm by clicking the alarm enable button in GUI. In this test, the maximum value of total used to activate the alarm is set to be 600ml. When the value of total used reading is over 600ml, the GUI produces sound which shows the alarm is activate. Furthermore, this GUI enable the user to save the data into txt form by clicking the log to file button with name of txt file.

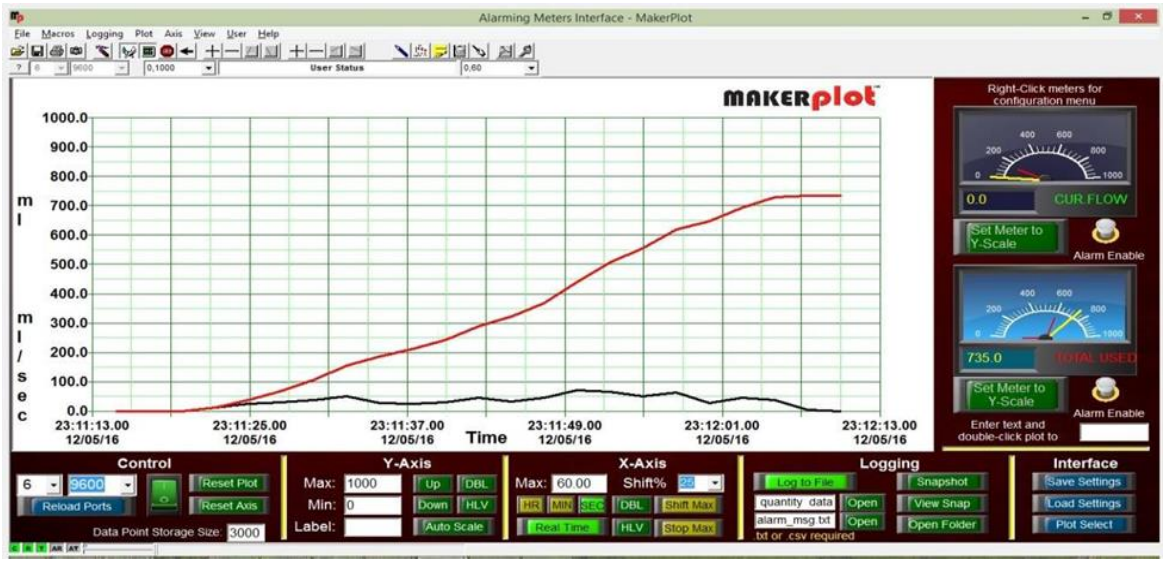


Figure 12. Graph from data in GUI

## 4. CONCLUSION

Based on the results presented, a wireless water usage monitoring system has been successfully developed. The sensor node has successfully monitor the water flow in desired water pipe and transferred the data to sink node (PC) wirelessly which is then saved to the database. Graphical data has been successfully displayed on Graphical User Interface (GUI) module at PC to display the water usage reading in real-time by using Makerplot. Besides that, the sensor node is equipped with alert function which is able to detect the existence of user in the location and light up LED and ring the buzzer to remind the user if they forgot to turn

off water tap. The sensor node can be installed in the bathroom and user can receive the data through wireless connection to sink node within 50m. In short, this project can help to facilitate the monitoring of water flow data and is able to alert the user to turn off the water tap after used. Hence, it can reduce wastage of clean water and save the cost for paying water bill.

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