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IoT based model for monitoring and controlling water distribution

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Abstract. These days, because of increment in relocation from a provincial territory to urban ranges, the population in urban areas is obviously expanding quickly together with the requirement for comfortable living. With increase in population, urban areas have expanded, water becomes one of the major problems in a city particularly water distribution, interfered with water supply, water protection, water utilization and furthermore the water quality. To overcome water supply related problems proper monitoring and controlling system must be implemented. The developed system consist of different IoT devices like water pressure sensor, ultrasonic sensor, solid state relay switch, motorized electric water valve, Raspberry PI, GSM module and Arduino UNO micro-controller. This paper focused on the monitoring and controlling of water distribution using IOT based model. It aims to design and develop a low cost reliable and efficient technique to improve water distribution in the community. A prototype was developed to simulate the operation of a water distribution. Also, a web application was created as a front-end system for monitoring the status of the different pumping stations as well as controlling. Also, fuzzy logic algorithm was integrated into the developed prototype system to be more scientific in making decision. As a result, the experiment was successful and passed all the conditions set for monitoring and controlling water distribution using IoT based model.

1. Introduction

According to recent survey, growth in population caused cities to face water distribution issues. Many communities suffer from insufficient water supply for their day to day needs. Lack of monitoring and controlling water distribution becomes a serious problem. Some areas in a city will have enough supply of water while other areas do not have. This is due to some problems in the distribution line such as damage pipeline cause by over pressure or low water pressure where in water cannot reach consumers located on a high-ground areas or far away from the pumping stations or water tank. All of these issues concerning water distribution are because of lack in real-time monitoring and controlling mechanism and due to its manual or traditional operation.

Today, cities are now transforming and started to adapt smart technologies for sustainable communities. As they participate for economic advancement and the facilities that increase to their vibrancy, water has become a priority in their checklists [1]. Creating water sustainability requires a multidisciplinary approach. It also requires state of the art equipment to facilitate the operation and management especially in collecting and analyzing data to initiate an action for smart management, planning and decision making.



The City of Ilagan in the province of Isabela is under continues development to improve the quality of living for its constituents. It is the capital and the largest town in the province that has 91 barangays and targeting to become a smart city. The water distribution in the city particularly the barangays in the Poblacion area is under the management of the City of Ilagan Water District (CIWaD). The continues development in the city such as construction of commercial buildings, subdivisions, residential houses and business establishment, water supply becomes one of the priority. Currently, CIWaD continue in expanding their coverage to provide the needs of the community and providing the needed amount of water daily for the consumers is a serious matter. The poor mechanism in monitoring and maintaining water distribution has become the problem of the management due to its manual operation that requires human intervention. As to date, the geographical jurisdiction of CIWaD covers 24 barangays within and near the Poblacion area. Currently, CIWaD manage 7 water reservoirs where in 2 are located in a high ground and 5 elevated tank. There are also 22 pumping station deployed in the different areas within the jurisdiction connected in a series that supply waters to the community and to the water reservoirs

According to Mr. Moises P. Pascual, Water Utility Management and Development Officer, in an interview conducted, monitoring of facilities is still in a manual operation. It requires 2 operators to be deployed in every pumping station but due to lack of manpower, 1 operator maintains two pumping stations that cause maintenance and monitoring issues. Thus, this study is very timely because providing sustainable community is one of the city's priorities.

The focus of this paper is the use of IoT technologies for the development of intelligent water management system for CIWaD in monitoring the status of the different water tanks and pumping stations as well as water pressure. Controlling system is also included to the proposed system to avoid tanks from over filling, pipe leakage due to over pressure. A prototype was developed for simulation and testing. In particular, Arduino micro-controller and other IoT devices were used for monitoring and controlling. Also, a web application was developed as front-end for monitoring the status of the operation.

This paper is limited only to CIWaD water distribution and management. Result and evaluation of the study was based and conducted only on the developed prototype.

2. Review of Related Studies

The popularity of IoT technologies is growing due to its capability in developing various application and only little portions is currently available in the community. Its domain includes health-care, transportation, logistic, smart environment and many more [2].

Prachet Verma et al. [3] developed an IoT based for water distribution in a campus. They developed a system that will distribute enough water to each tank to satisfy local demands. In their study, ultrasonic sensor has been used to monitor the water level in a tank.

In a study conducted by Ejiofor Virginia Ebere and Oladipo Onaolapo Francisca [4], the automatic detection of water level in a tank is done by a comparator circuit. They used the electrical conductivity property of water as an advantage. The copper conductors serve as the water level sensor. When the copper sensor touched by water, voltage runs to the copper which in turn is transferred to the comparator circuit for further processing. Then a micro-controller uses this signal coming from the comparator to control the water pump.

Also another study for automatic water tank filling system was conducted suitable to be used in home activity to reduce energy consumption due to water spills [5]. This study also helps the community to analyze their water consumption. The prototype can be used to solve water pump problems due to the operations of the manual switch as well as the floating ball tap to stop the water tank filling.

3. System Architecture

In this work, the IoT-based model for monitoring and controlling of water distribution system consists of the following major units: ultrasonic sensors, pressure sensor, motorized electric water valve, GSM

module, Arduino micro-controller, Raspberry Pi and the solid state relay switch. Figure 1 below describes the flow of operations in the system as well as their inter-operability.

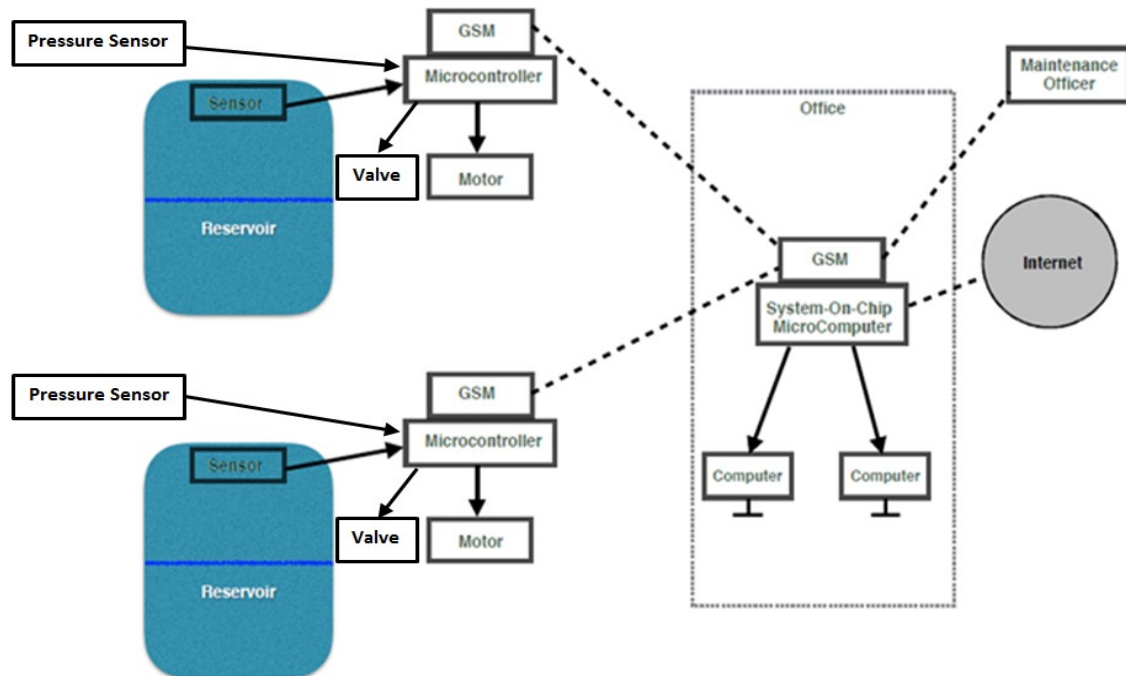


Figure 1. System architecture.

To monitor the level of water within the tank, a water level sensor was installed. As the level of water increases or decreases in a certain point, the micro-controller will activate the water pump relay switch to turn on or off to avoid water tank overflowing or unfilled. Same process also implemented in controlling water pressure to avoid damages in the pipeline. If the water pressure increases or decreases, the micro-controller also activate the motorized electric water valve to rotate at a certain point to control the flow of water.

Here, GSM is also used to send a message when there is an activity made by the micro-controller. An SMS will be sent to the office through the GSM module to report the status of activity in a particular water reservoir or pumping station. The System-on-chip microcomputer that will be located in the office will store the received data then sends an update to the maintenance officer regarding the received report through SMS. The System-on-Chip microcomputer will be configured also as a web server to install the developed web application for the management to view the status the different water reservoir and pumping stations. The web application can be access using a computer within the office connected to a network and can be access also through the Internet.

4. Methodology

The IoT based model for monitoring and controlling water distribution is consisting of two circuit designs, the Monitoring and Controlling System using micro-controller and Web Server for monitoring using system-on-chip micro-computer.

4.1 Monitoring and Controlling System

This module is composed of Ultrasonic sensor, 5volts Analog Water Pressure sensor, Arduino UNO micro-controller, SIM800 GSM Shield module, 220VAC 2-way Motorized Electric ball valve and 240VAC relay switch. For monitoring, ultrasonic sensor was used in the prototype because of its capability to probe inside water tank non-destructively. The ultrasonic sensor is connected to the

Arduino UNO micro-controller and the signal send by the sensor will be interpreted and processed by the micro-controller to evaluate the distance or level of water in the tank. Based on the uploaded code, if the level of water requires filling the tank then the Arduino micro-controller will send signal to turn on the solid state relay switch where the water pump is connected. As a control measure, the same process to avoid overflowing while fills up the water tank or before it gets empty. If the water is already in a full level, the Arduino micro-controller will send signal to the solid state relay switch to turn off and when the water level is in a minimum level it will turn on. Also, controlling water pressure is done using a water pressure sensor connected to the Arduino UNO micro-controller. This is to maintain the acceptable pressure to distribute water in the main line to avoid breakage. The micro-controller sends signal to the solid state relay switch where the motorized electric valve is connected to close and open if the pressure is too low or exceed in the acceptable level. The micro-controller will also activate the GSM module that is connected to send data to the server to report the status of the water reservoir and current activities of the pumping station. The data will be sent through SMS which is believe as the most practical and economical way of communication. The monitoring and controlling system is also allowed to receive SMS send by the server located in the CIWaD office to override the built-in automatic controlling system of this module. Using the designed web application installed in the server, it can manually control a particular pumping station or water reservoir by sending SMS with predefined keyword message.

4.2 Web Server

This module is composed of two different components, the hardware and the software. The hardware component includes the Raspberry Pi 3 Model B, 5V power adapter/supply, Class-10 Micro-SD card, LED monitor, SIM800 GSM module, USB keyboard and mouse. The software component includes Raspbian Operating System, Linux version of Apache, MySQL, PHP (LAMP) for the web services and Python for the script used in sending and receiving SMS from the GSM module.

In this project the Raspberry Pi will be configured as a web server for viewing status or activities and controlling the different water reservoirs and pumping stations of CIWaD. The received report messages will then be extracted by the developed web application to get the necessary data for viewing in the web interface of the application. The GSM module also used to send message report to the maintenance officer assigned to a particular water reservoir or pumping station to inform about the current activity. The web application is also design for controlling the deployed monitoring and controlling system of the different pumping stations and water reservoirs by sending an SMS using a predefine keyword to override the current activities such as switching on and off a particular pumping station or opening and closing the gate valve of a particular water reservoir.

5. Results and Discussions

Based on the data gathered, the researchers come up with a design to address the problems encountered by the CIWaD and develop a prototype for simulation, testing and evaluation.

The researchers purchased all the needed hardware or equipment in building the prototype. After assembling the prototype monitoring and controlling system, the researchers immediately writes the codes, compiled and uploaded into the Arduino micro-controller. Also, the researchers setup and configure the Raspberry Pi as a web server and developed the web application to be used as front-end system for monitoring and controlling.

5.1 Testing

The researchers tested the prototype monitoring and controlling system to evaluate the accuracy of the data and the code uploaded. The inputs are the water level of the tank and the pressure of water flows in the pipeline. In the designed setup, an additional tank was used as temporary source of ground water where in the electric motor pump used to get water to fill the temporary water reservoir. To imitate the CIWaD water system, the temporary water reservoir was also placed on a higher platform so that the gravitational force of the water increases the pressure in the pipeline to meet the required pressure for

the testing. It was also labelled in inches as basis to measure the level of water. Figure 2 below shows the prototype layout design of a water distribution for the testing of the developed monitoring and controlling system.

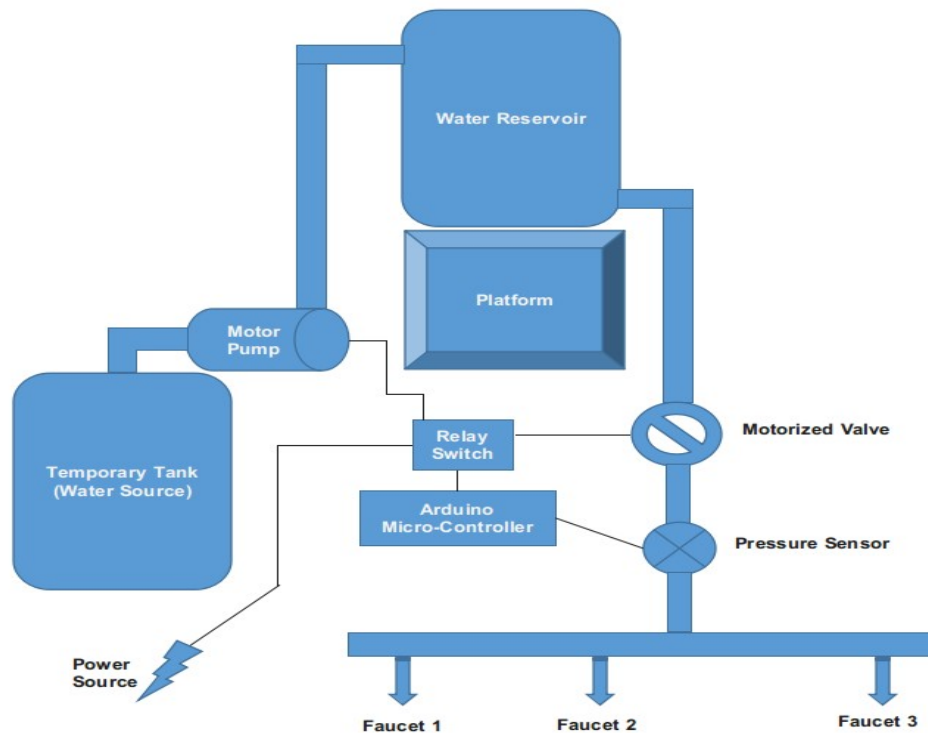


Figure 2. Prototype water distribution layout.

In the uploaded code, the researchers set a threshold values for monitoring water level and water pressure. This is for the system to decide what action to be taken.

To determine when to send report to the server or to turn on the motor pump to re-fill the water reservoir, several sub-parameters will serve as input. Also as a control measure while re-filling, the micro-controller will turn off the motor pump if it reaches the set maximum level of water. In sending SMS report to the server regarding the status of the water reservoir and what action to be taken to the motor pump, fuzzy logic algorithm was implemented. As shown in Table 1, the level of water measured in inches served as the input. Based on the uploaded rules into the micro-controller, it can provide SMS report or action to be taken as an output.

Table 1. Water level threshold.

Level	Status	Re-fill Action
20" and below	Low Level	Turn-On
21" to 35"	Normal	Turn-Off
36" to 40"	Full	Turn-Off

Likewise in monitoring and controlling for water pressure, the same process and algorithm was implemented. Here, pound per square inch (psi) is used as unit of measurement for water pressure. As shown in Table 2, the fuzzy logic algorithm used different input parameters measured in PSI as basis for the output.

Table 2. Water pressure threshold.

PSI	Status	Valve Action
3 and below	Low	Open
4 - 6	Normal	Open
7 and above	High	Close

On the server side, all the SMS reports received were posted in the web application. Also, a notification message was sent to the registered operator cell phone number to inform about the status of a particular pumping station or water tank. The web application also includes controlling mechanism to override the deployed monitoring and controlling system. Table 3 below shows the pre-define keywords used in SMS message sent by the developed web application to manually turn off or on the pumping station and open or close the motorized electric valve of the water tank. A toggle switch is provided in the web interface to easily switch on or off a pumping station motor or the motorized electric valve.

Table 3. Pre-define keywords.

Pumping Station Motor	Motorized Electric Valve
PSM Off	Valve Close
PSM On	Valve Open

6. Conclusions and Recommendations

Providing good quality services for a sustainable community is a big challenge to the leaders. Based from the problems that the CIWaD management are now facing in terms of water distribution, the developed system can be a big help for them to address these problems. It allows them to utilize low-cost smart technologies to easily manage the distribution of water to the community. The developed prototype functions properly according to the specification and purpose. It successfully passed all the tests and met the expected result based on the different input parameters.

Finally, the continues development in technologies particularly IoT devices in terms of providing smart communities will have a great chance for this study to further improve the ideas and concept for future use.

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