

Automatic Water Distribution System Using Wireless Sensor Network

Abubakar Ndagi and Csaba Zoltán Kertész

Abstract—Water distribution sector is currently facing operation challenges, especially in urban areas, as a result of climate change and high rate of urbanization experienced in these areas. These two aforementioned factors pose a threat of water shortage in these cities and consequently affects the water distribution sector as there will be interruption in water supply. To mitigate this, efficient management of the entire distribution process and automated monitoring and control systems are needed. This paper showcases such an automated water distribution system that is responsible for providing clean water to urban residents. The system uses an IoT (Internet of Things) approach for constant and real-time monitoring of water supply from the Base Station down to the water tanks of each block of house. Water levels and water quality are continuously monitored in the end-user's water tanks, and the tanks are automatically refilled based on user requirements and Base Station planning. Both end users and water board managers can follow the water flow information in a user-friendly web application.

I. INTRODUCTION

It is known that water is the most essential substance on the earth [1], been that it is required by all human beings, plants, and organisms for their survival. In order to protect and conserve the economic and social well-being of urban cities of which they are known for, it is very important to ensure that natural resources such as water are accessible to meet basic needs of people. Although, due to natural and human factors such as climate change and urbanization, urban areas are threatened by water shortages [2] and water scarcity.

Such an example is Kwali, a local government area in the Federal Capital Territory of Nigeria with a population of about 128,100 [3]. The outcome of climate change and urbanization has made the residents of this community to drill boreholes in their houses in order to have access to water for their daily activities. Although this water appears clean, it contains invisible contaminants, hence, putting the health of the people in great danger.

A solution to this can be a centralized water distribution system, but the scarcity of water requires very good control over this system. Precise measurements and automatic control can be done using Wireless Sensor Networks. The WSN is made up of a coordinator and multiple sensor nodes

installed in every water tank. Each sensor node is made up of a microcontroller with a wireless connectivity feature, water level sensor and other sensor modules from which values will be read and transmitted to the central server.

Several such solutions been developed in recent years. For example, Chowdhury et al. [4] illustrated how to avoid wastage of water as a result of water overflow from the tank using IoT-GSM-based device which will enable people to monitor and have control of their tanks via an Android mobile App. Another solution by Rapelli et al. [5] handles tasks such as water monitoring, distribution, and billing. Analysis and calculations were done using sensor values, from which water usage and bills were calculated.

In this paper we propose an IoT approach for continuous and real-time monitoring of water distribution using LoRa module which will allow the sensor devices to transmit sensor data only when there is data to be sent and then the device will go back to sleep again. This will help to prolong the life span of the battery sensor devices, since the transmitter is not always on. Continuous monitoring water distribution will guarantee proper distribution, which will allow for the collection of records such as:

- Available water in tanks: this will keep track of the amount of water in the tank of the user and if the water level is low, a notification will be sent to the base station server using LoRa wireless communication device and then the pump connected to that user tank will be turned on.
- Flow rate: the flow rate will be used to determine the amount of water in volume consumed by the user at any particular time and based on this, a bill consisting of a calculated amount based on water consumed by the respective user will be sent to his/her email at the end of every month. The user can pay this bill online by accessing the website.

IoT is a fast-growing paradigm that allows electronic devices and sensors to communicate through the Internet in order to improve our standard of living [6]. IoT makes use of smart devices and the Internet to provide state-of-the-art solutions to both existing and future problems and challenges in areas such as technology firms, public and private companies, government and non-government organizations throughout the world. With the help of a central base-station, it is possible to monitor the entire system from anywhere. Data is continuously uploaded to the cloud which is a live server hosted on Bluehost Domain Server, this allows

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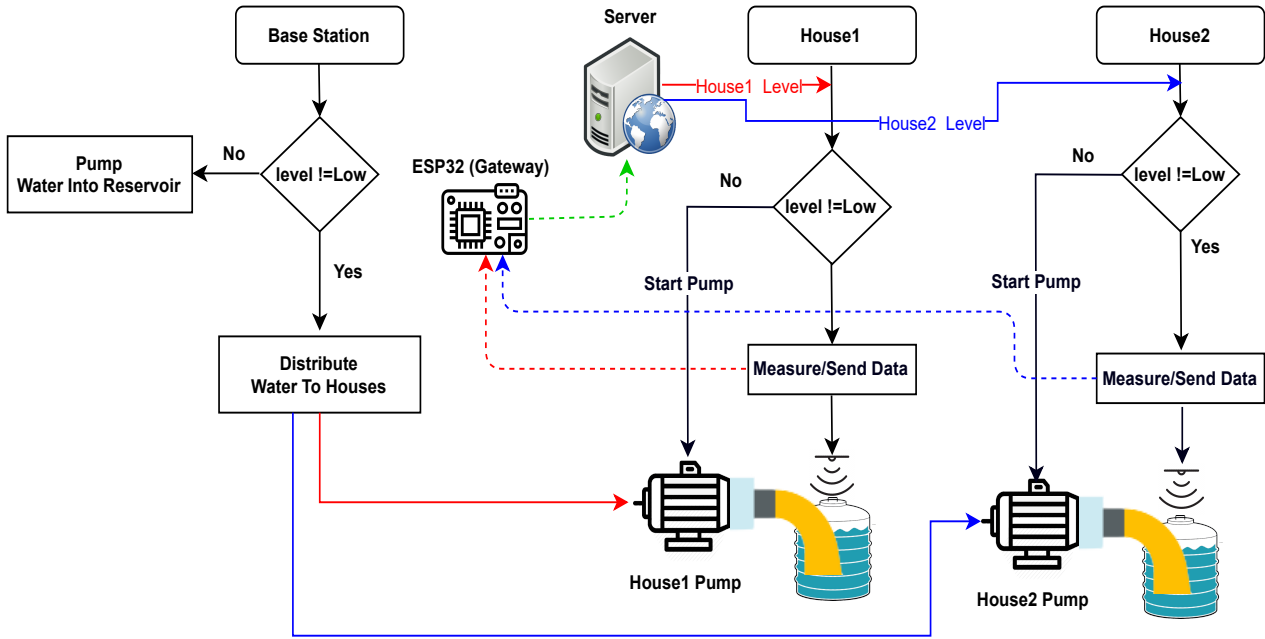


Fig. 1. Proposed System Workflow.

data/records to be seen and tracked in real time. Through microcontrollers (ESP32 and Arduino), several sensors such as water flow sensor, ultrasonic sensor, turbidity sensor, etc. can be connected and controlled. This means that data can be monitored and also, operations may be controlled from the Internet using an efficient client-server communication.

II. PROPOSED SYSTEM

The main aim of this paper is to use the fundamental ideas of Internet of Things (IoT) to come up with a system that will help to combat and overcome the aforementioned problems regarding the mitigation of the effects of climate change and urbanization in urban cities. Figure 1 shows the functional flow of the proposed system. It consists of two parts:

- **Base-Station:** this is the central system that is used to supply water and keep track and records of water usage for every user. When the level of water in the tank is low, the Arduino microcontroller automatically turns on the pump and starts pumping water into the main reservoir tank. In the same way, the pump is automatically turned off when the tank is full. A turbidity sensor was also connected to the Arduino microcontroller to ensure water quality.
- **Users (Houses):** this refers to houses that consumes the water. An Arduino is connected to this sub-system. Also, an ultrasonic sensor and Lora RFM95 module were connected to the Arduino microcontroller. The ultrasonic sensor is used to continuously monitor the level of water in the user's tank, these values are transmitted wirelessly to an ESP32 which is a central gateway for collecting data from several houses and upload it to the server every 30 seconds with the help of the

Lora modules installed on the Arduino microcontroller. Finally, the ESP32 updates the user's water level on the live server with the ultrasonic sensor values. When the user's water level is low, the water pump attached to this user will automatically turn on and starts to pump water to the user's tank. The water pump will also turn off automatically when the tank is full.

III. HARDWARE COMPONENTS

A. LoRa RFM95 Module

LoRa (Long Range Radio) is a communication protocol developed by Cycle and later Semtech, which works on an ISM frequency band (either 433, 868 or 915MHz). The RFM95 module employs an SX1276 chip [7] which is already proven to offer several kilometers of range on low data rate applications [8].

B. ESP32-WROOM-32D

The type of ESP32 used in this project is ESP32-WROOM-32D because it is a low-cost and very efficient microcontroller with Wi-Fi feature and TCP (Transmission Control Protocol) / IP (Internet Protocol) stack [9]. The Wi-Fi operates on 2.4GHz frequency, and can also use other protocols such as MQTT, HTTP, and HTTPS. These features enable the helps the microcontroller to connect with a Wi-Fi protocol and also to make TCP/IP connections.

C. Arduino Microcontroller

Arduino is a widely known and most used open-source platform for developing electronics projects [10]. Arduino is made up of a circuit board (for coding instructions) and also an IDE that runs on compatible machines or computers, which can be used for writing and uploading codes to the

microcontroller. Arduino Uno R3, which is based on the ATmega328 microcontroller, and Arduino Mega, which is based on the ATmega2560 microcontroller, were used to develop the proposed system.

D. HC-SR04 Ultrasonic Sensor

The HC-SR04 Ultrasonic Sensor is a sensor used for detecting distance of a target object by transmitting Ultrasonic Sound Waves with frequency higher than the limit with which human can hear [11]. In our system, it was used to detect the water level of the tanks by measuring the distance of the water surface from the top of the tank.

E. Submersible Water Pump

As the name suggests, a submersible water pump is a device with hermetically sealed motor closely coupled to the body of the pump and can function effectively inside the water [12]. This device was used in the project to pump water into the reservoir of the base station and was also used to pump water into the tank of the end user.

F. Flow Sensor

Two water flow sensors were connected to the pipe that conveys water to the user from the water pump assigned to the user from the base station. The first flow sensor (FlowSensor1) was placed just at the starting point of the pipe from the base station, and the other (FlowSensor2) was placed at the end of the pipe to the user's tank. When the water pump is turned ON, water flows from the reservoir to the user along this pipe through the two flow sensors. The water flow sensors continuously measure the rate of water and also detect water leakage on the pipe if the rate of water flow on FlowSensor1 is different from rate of water flow on FlowSensor2. YF-S201 flow sensors were used, which operate based on Hall Effect [13]. Water flowing through the sensor rotates a propeller, and the hall sensor produces 4.5 pulses for each liter of water flowing through it, which is counted by the microcontroller.

IV. SERVER-SIDE SOLUTION

The server side was installed and configured extensively on Blue Host Domain server, which can be accessed anywhere around the world at anytime. PHP script, HTML, Bootstrap, JavaScript, jQuery, and CSS were deployed on the server to render the animation on a web page. The server side consists of two sub-systems, each with different functions as described below:

- Admin side: On this part of the system, the administrator has the most extensive access and overall control of the entire system and users. The administrator is responsible for creating account for users, editing and deleting user accounts if needed. The "Level" chart indicates the level/amount of water in the reservoir and the "Turbidity" chart indicates the water quality (0 indicates that the water is absolutely clean). The administrator monitors the entire water distribution process, and when the system detects water leakage in any of the pipes, it

sounds an alarm and also shows the pump number from which the leakage was detected. In this way, the admin can take the necessary actions required. Figure 2 shows the web interface for the admin.

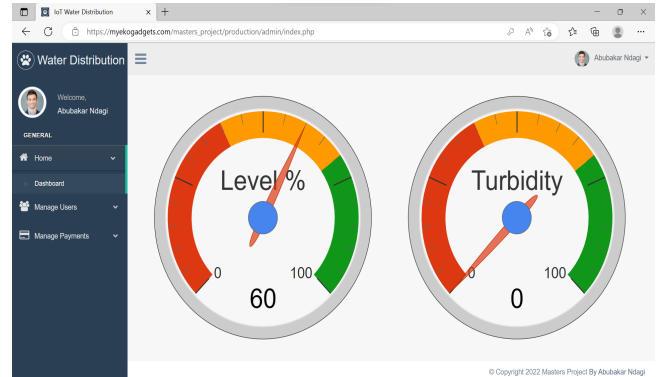


Fig. 2. Admin Dashboard

- Client side: On this part of the system, clients can log in to their respective accounts. After logging-in to their accounts, they can be able to see The "Level" chart which indicates the level/amount of water in their tank and the "Volume" chart which indicates the amount of water in volume consumed so far by the user for that month. Through this platform, the user will receive a bill with information on the amount of water consumed and the total amount to be paid by him/her. A payment gateway is integrated on this web application where the user can make his/her payment for the bill received. Figure 3 shows the web interface for the user.

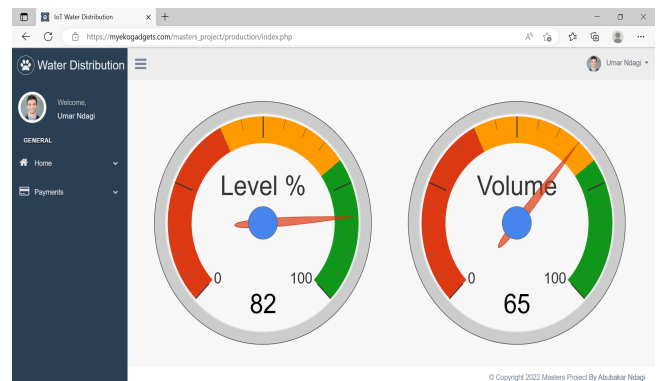


Fig. 3. User dashboard

V. CONCLUSION

Experiments were conducted on a prototype system with a base station and two houses. The experimental setup presented on figure 4.

The water levels from both houses were measured correctly by the ultrasonic sensors and sent to the live server successfully. Water flow from the base station to the individual houses was also measured correctly without any leakage. The proposed system proved to be reliable in providing

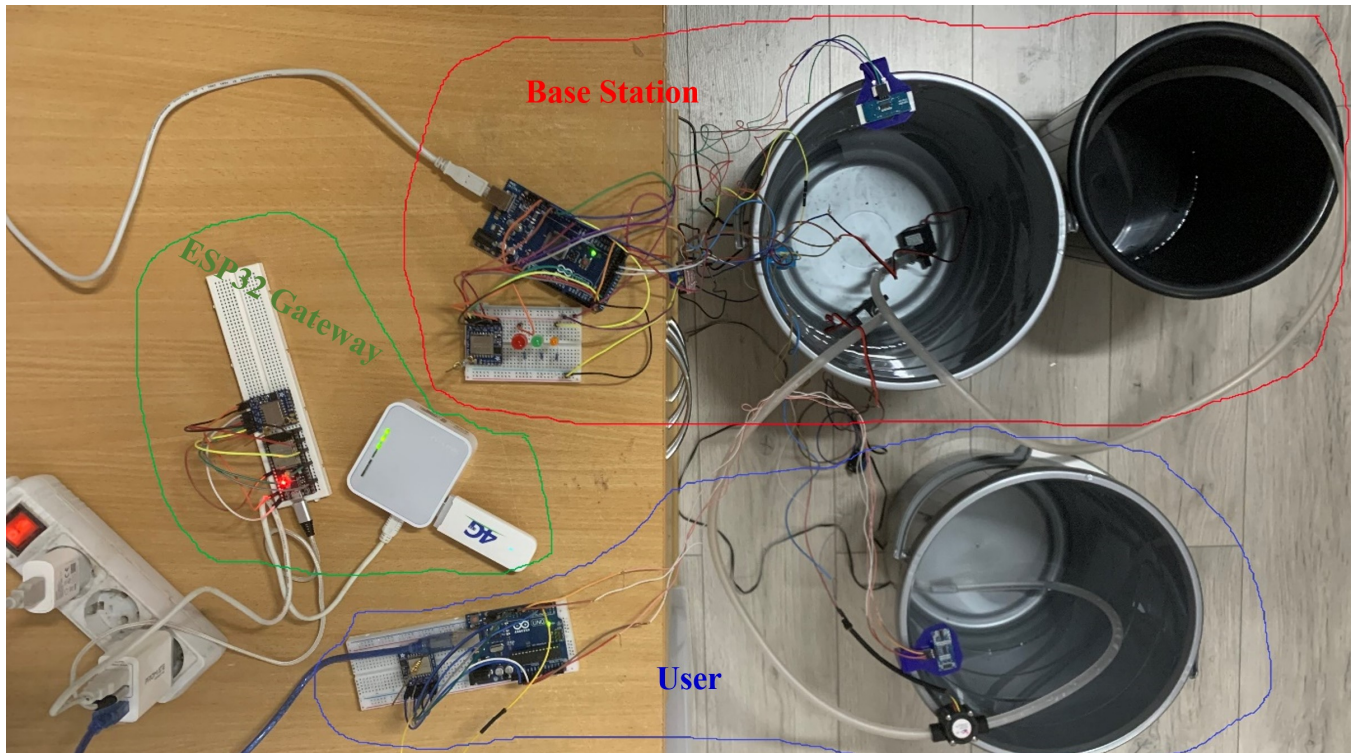


Fig. 4. Experimental setup

the needed amount of water for the houses. Water quality problems could also be properly reported automatically by the system.

Additionally, the system is able calculate the total volume of water consumed by the user. The bill appears and can be paid on the website within a period of two days. If the user fails to pay the bill after the given deadline, the system deactivates the pump connected to the user's tank.

The software and hardware solutions developed in the course of this project extensively solve the problems and challenges related to climate change and high rate of urbanization encountered in the urban communities. The developed solution is also light and flexible, which implies that it can be re-programmed to add further features in the future. The whole system works well and is fast enough for real-time data transmission. The server configuration was done extensively on a live server and so would be accessible from any mobile device with Internet connectivity at anytime and anywhere around the world.

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