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IoT-based Remote Control Water Distribution System

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Abstract: This paper presents the design and implementation of an IoT-based remote control water distribution system. The system allows the water supply operators to control valves remotely to regulate the flow of water. The valve control is done using an IoT platform, which allows the system to be controlled remotely through a mobile application. Operators can use a mobile application to quickly respond to leakage events and close valves before significant damage occurs. In addition, the DTMF calling system can be used to remotely send numeric information or signals using the touch-tone keypad on their phone to close the valve even in the absence of an internet connection. The system is designed to improve the efficiency of water distribution by reducing water loss and providing accurate control over the distribution of water. The prototype was tested, and the results showed that it was able to provide accurate control over the distribution of water and reduce water loss. The system is scalable and can be adapted to different water distribution systems. Overall, the IoT-based remote control valve system presents a promising solution for improving the efficiency and sustainability of water distribution systems.

Keywords: *Internet of Things (IoT), Remote control, Water distribution, Valve control*

1. Introduction

Water is the most precious resource on the planet, and efficient water management is essential for meeting the growing demands of an expanding population. Unfortunately, water loss due to pipeline leaks is a common problem that affects water distribution systems around the world. According to a study by the Central Pollution Control Board, India loses an estimated 70% of its treated water to leaks and inefficient distribution systems. This problem is not unique to India, with many other countries also facing similar challenges.

Historically, water distribution systems in India have relied on manual valve control to manage water flow and pressure. An operator had to be assigned in each location to operate each of the manual water supply controls, which took a lot of time. He goes here and manually turns the valve on or off. If there was a leak in the water line, hundreds of liters of water may occasionally be squandered. However, this manual approach is labour-intensive, and inefficient, and often leads to delayed responses during water leak events, which can cause significant damage and wastewater. Prior studies have explored the use of automated systems to improve valve control and prevent water loss. However, many of these solutions are costly, complex, and require significant maintenance.

In this project, we propose an IoT-based remote control water distribution system that aims to improve valve control efficiency and response times during pipeline leaks. Our idea is that by using an observatory kit comprising an ESP8266, DTMF, logic circuit, driver unit, and digitally controlled valve, we can enable operators to control valves remotely and respond more quickly to leak events. The system will offer the operators to respond proactively to mitigate further damage in real time. Overall, our project aims to provide a scalable, cost-effective, and easy-to-maintain solution to address the water loss problem due to pipeline leaks. Our goal is to contribute to the sustainability of water resources by reducing water loss and improving the efficiency of water distribution systems.

Background and Related Work

Water management and conservation is a critical issue that has been the focus of extensive research in recent years. Many studies have explored the use of IoT-based systems for water management and conservation, with a focus on improving efficiency and reducing water waste.

One study, published in the International Journal of Engineering and Technology by R. K. Sharma, K. S. Yadav, and K. C. Roy[6], developed a smart water

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management system using IoT and machine learning algorithms to optimize water distribution and reduce waste. The system included sensors to monitor water usage and quality, a microcontroller to collect and process data, and a cloud-based platform for data storage and analysis.

Another study, published in the Journal of Water Process Engineering by Weiwei Zhang, Ling Wu, Jianjun Wu, and Xinhua Zhao[7], developed an IoT-based system for water quality monitoring in real time. The system used a combination of sensors, communication modules, and cloud-based platforms to collect and analyze data on water quality parameters such as pH, temperature, and turbidity.

In terms of water distribution systems, there have been several studies exploring the use of IoT-based systems for remote control and monitoring of water flow.

Overall, there has been significant research on the use of IoT- based systems for water management and conservation, with a focus on improving efficiency, reducing water waste, and optimizing water distribution. These studies have provided valuable insights and guidance for the development of similar systems, such as "IoT-based remote control water distribution system".

2. Literature Review

H. T. Yu, X. Q. Wu, Z. Y. Zhang, and Y. J. Liu[1] have designed and implemented an IoT-based remote control valve system for industrial applications. The system uses a remote- control valve unit (RCVU) to control valves remotely, which is connected to a central controller unit (CCU) via the IoT. The system offers benefits such as reduced labor costs, improved operational efficiency, and increased system reliability, but also has potential drawbacks such as the need for stable internet connectivity and security risks associated with the use of the IoT. In conclusion, the authors demonstrate that an IoT-based remote control valve system can be a viable solution for industrial applications that require remote valve control. The system developed in this paper can be used as a basis for further research and development in this area.

S. S. Sutha, S. Selva Ganesan, and S. Prakash [2] have designed and implemented an IoT-based system for remote valve control that includes a microcontroller-based valve actuator, a wireless communication module, and a cloud-based application. They evaluated the system's performance through experiments that showed high reliability, efficiency, and fast response times. The authors discussed the potential benefits of using an IoT-based approach for water management systems, such as improved efficiency and reduced water waste, while also acknowledging potential drawbacks such as the need for skilled personnel and the risk of cyber-attacks. Overall, the paper demonstrates the potential of IoT-based smart water management systems with remote valve control.

D. M. Kumar and G. C. Nayak[3] have designed and implemented an IoT-based smart irrigation system that uses a soil moisture sensor, a microcontroller-based valve actuator, and a cloud-based application for remote monitoring and control. The system has been evaluated through experiments and has shown high efficiency with optimal soil moisture levels and low energy consumption. The paper discusses the potential benefits and drawbacks of using an IoT-based approach for irrigation systems, highlighting the need for skilled personnel to operate and maintain the system and the risk of cyber-attacks. Overall, the paper demonstrates the potential of IoT-based smart irrigation systems with remote valve control, providing a flexible and scalable solution for remote monitoring and control of water flow in various irrigation applications.

Muhammad Imran, Fadi Al-Turjman, and Khalid Al-Mashhadani[4] have designed and implemented an IoT-based smart valve system that includes a microcontroller and a wireless communication module, enabling remote monitoring and control of the valve. The system has been tested and evaluated in terms of valve response time, reliability, and energy consumption. The results indicate that the system is highly efficient and reliable, with fast response times and low energy consumption. The potential benefits of using IoT-based smart valves for water management systems are discussed, including improved efficiency and reduced water waste. However, the authors also highlight the potential disadvantages of the system, such as the need for skilled personnel to operate and maintain the system, and the risk of cyber-attacks that could compromise the security of the system. Overall, the paper presents a promising solution for remote monitoring and control of water flow in various applications using IoT-based smart valves, offering a flexible and scalable approach to water management systems.

Hyeon-Soo Kim, Seung-Kyu Choi, and Jeong-Sik Choi[5] describe the development of an IoT-based valve control system for a smart factory. The system consists of a microcontroller- based valve actuator, a wireless communication module, and a cloud-based application for remote monitoring and control. The authors have evaluated the performance of the system through experiments and found it to be highly reliable and efficient with fast response times and low energy consumption. The potential benefits of using an IoT-based approach for valve control in smart factories were discussed, including increased efficiency and reduced downtime. However, potential disadvantages were also noted, such as the risk of cyber-attacks and the need for skilled personnel to operate the system. Overall, the paper highlights the potential of IoT-based valve control systems for smart factories, providing a flexible and scalable solution for remote monitoring and control of valves in industrial applications.

3. Methodology

The proposed IoT-based remote control water distribution system is a hardware-software-based project which was developed using a structured process that involved several stages, including project formulation, system design, implementation, and testing.

The first stage involved project formulation, which focused on identifying the problem of water loss due to pipeline leaks and developing a solution to address this issue. A thorough review of existing literature on automated valve control systems and IoT-based solutions was conducted to identify relevant technologies and approaches.

In the second stage, a system design was developed to address the challenges of water loss due to pipeline leaks. The system comprises an observatory kit that includes an ESP8266, DTMF, logic circuit, driver unit, and digitally controlled valve. The kit was designed to be mounted at various points along the pipeline and enables valves to be controlled remotely using a mobile application.

In the third stage, the system was implemented and tested on a pilot scale to evaluate its performance and identify areas for improvement. The system was installed in a test environment and operated for several days to assess its functionality and reliability. During the testing phase, the system was also evaluated for its effectiveness in responding quickly to prevent further water loss.

The fourth stage involved analyzing the data collected during the testing phase and identifying areas for improvement. The findings indicated that the system demonstrated prompt responsiveness in mitigating additional water loss. The data collected during the testing phase was used to refine the system design and improve its performance.

Overall, the methodology employed in this project involved a structured process that focused on identifying the problem of water loss due to pipeline leaks and developing an effective solution using an IoT-based and DTMF approach. The methodology included project formulation, system design, implementation, testing, and data analysis, and it enabled us to develop a reliable and efficient solution to address this critical issue.

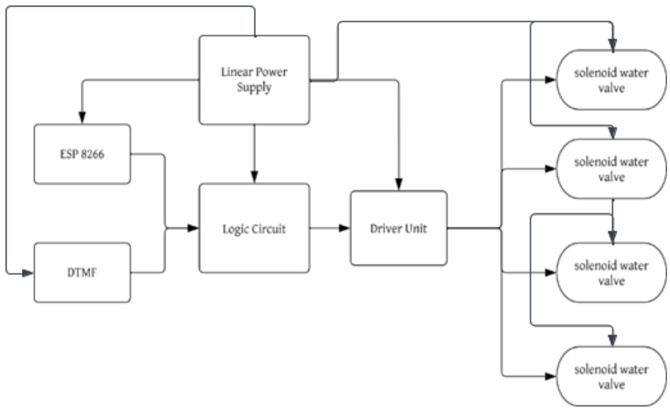

Fig 1: IOT-Based Remote Control Water Distribution System Flow Chart

Working of IOT-based Remote Control Water Distribution System (Figure 1): -

1. **Leakage detection:** When a leakage in the water pipeline is detected by a person, they would inform the operator.
2. **Operator response:** The operator would use the Blynk mobile application to select the area where the water pipe is leaking and click the "off" option on their smartphone.
3. **Signal transmission:** The Blynk mobile application would send a command signal via the internet to the IoT-Based system. The command signal would be received by the ESP8266 module, which is connected to the internet via Wi-Fi.
4. **Signal processing:** The ESP8266 module would process the command signal and transmit it to the driver unit.
5. **Valve control:** The driver unit would receive the signal from the ESP8266 module and use it to control the solenoid valve that controls the water flow in the pipeline. The solenoid valve would be turned off, stopping the water leakage.

When the internet is absent, the DTMF (Dual-Tone Multi- Frequency) calling system is used to remotely control the water distribution system. In this scenario, the operator would make a phone call to the DTMF system, and using the touch-tone keypad on their phone, they would send numeric information or signals to the system.

The DTMF system would be connected to the driver unit and solenoid valve, just like in the internet-based system. When the DTMF system receives the signals from the operator, it will convert them into electrical signals and send them to the driver unit. The driver unit will then send the electrical signals to the solenoid valve to close it and stop the water leakage.

Once the operator has confirmed that the valve has been closed, they can end the phone call. The DTMF system allows operators to remotely control the water distribution system even in the absence of an internet connection, providing a reliable backup option.

Overall, this system provides a reliable and efficient way to remotely control water distribution systems, improving response time and reducing water wastage due to leakage.

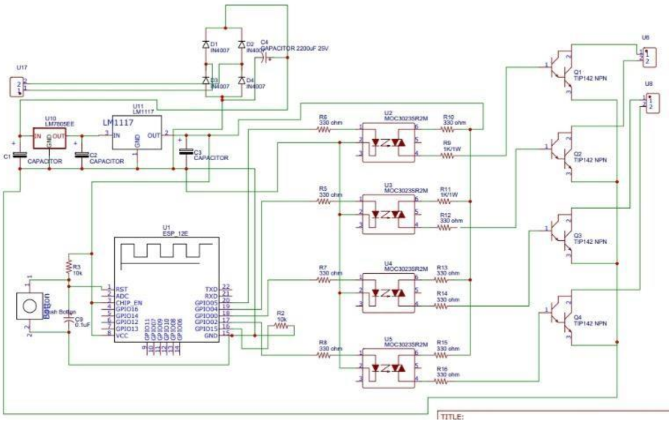

Fig 2: Circuit Diagram for IOT-based System

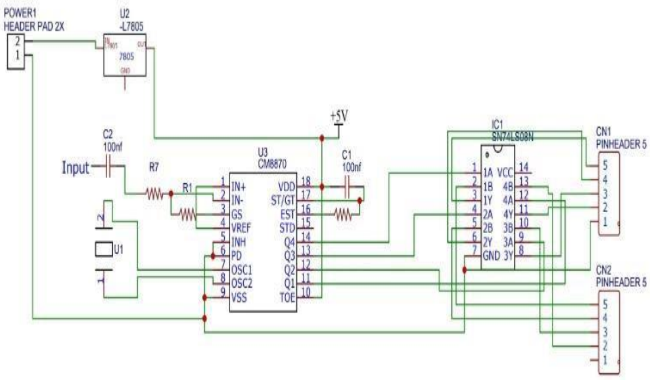

Fig 3: Circuit Diagram for DTMF Calling System

HARDWARE USED

Linear power supply

The Linear power supply configuration of our system, as shown in Figure 4, utilizes linear techniques to regulate the voltage output. Unlike switching techniques, this approach employs non-switching methods to ensure the correct voltage is provided at the output. The voltage is sensed and compared with a reference voltage using a differential amplifier, which generates a feedback signal to maintain the output at the desired voltage level.

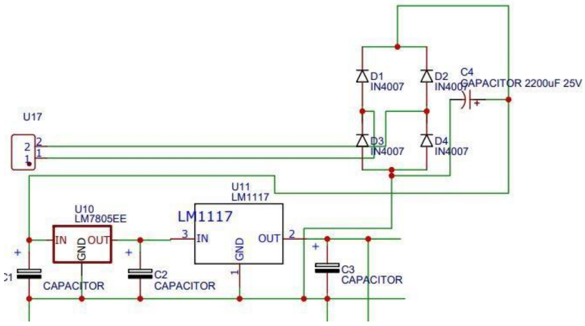

Fig 4: Circuit Diagram for Linear Power Supply

Solenoid Valve

A solenoid valve is an electronically controlled valve that consists of an electric coil with a movable ferromagnetic core (plunger) at its center. In its resting state, the plunger blocks a small opening. By applying an electric current to the coil, a magnetic field is generated, exerting an upward force on the plunger, and opening the orifice. This principle governs the operation of solenoid valves.

ESP8266

The ESP8266EX from Espressif is a highly integrated Wi-Fi System-on-Chip (SoC) solution designed to meet the efficiency, compactness, and performance requirements in the Internet of Things (IoT) industry. It offers complete and self-contained Wi-Fi networking capabilities and can operate as a standalone application or as a slave to a host MCU. When used as the application's main controller, the ESP8266EX quickly boots up from flash memory. It incorporates a high-speed cache to optimize system performance and memory usage. Additionally, it can be employed as a Wi-Fi adapter for any microcontroller design through interfaces like SPI/SDIO or UART. The ESP8266EX integrates various components such as antenna switches, RF balun, power amplifier, low noise receiver amplifier, filters, and power management modules, allowing for a compact design with minimal external circuitry. It also features an enhanced version of Tensilica’s L106 Diamond series 32-bit processor and on-chip SRAM, along with GPIOs for interfacing with external sensors and devices. The Software Development Kit (SDK) provides sample codes for different applications. Refer to Figure 6 for the ESP8266 Module illustration.

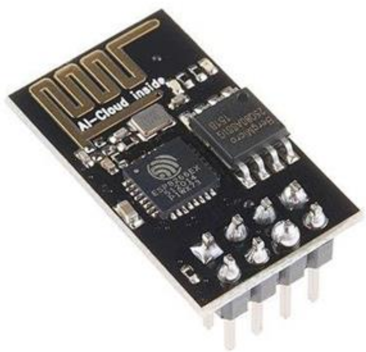

Fig 6: ESP8266 Module

DTMF

Dual-tone multi-frequency (DTMF) refers to the sound or tones produced by a telephone keypad when the keys are pressed. These tones are transmitted alongside the voice channel and serve the purpose of controlling automated equipment and conveying user intentions, such as dialing a specific number. Each key generates a unique combination of two tones at specific frequencies. Figure 6 depicts the DTMF.

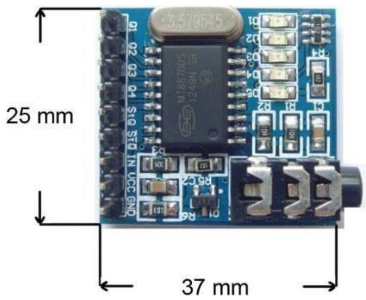

Fig 6: DTMF calling System

Optocoupler

An optocoupler is a semiconductor device designed to transmit electrical signals between two isolated circuits. It consists of two ain components: an infrared-emitting LED and a photosensitive device. Enclosed within a black box with connectivity pins, the optocoupler operates by utilizing the incoming signal from the input circuit to activate the LED, regardless of whether the signal is AC or DC.

The photosensitive device, located in the output circuit, detects the emitted infrared light and generates a corresponding output. Depending on the specific type of output circuit, the resulting output can be AC or DC. To initiate the operation, a current is supplied to the optocoupler, causing the LED to emit infrared light in proportion to the current flowing through the device. When this light reaches the photosensitive device, it conducts a current and switches on. Conversely, when the current through the LED is interrupted, the infrared beam is blocked, causing the photosensitive device to cease conducting.

Optocouplers come in four different configurations, which vary based on the type of photosensitive device used. In DC circuits, the commonly employed configurations are photo-transistor and photo-Darlington. For AC circuit control, photo-SCR and photo-TRIAC configurations are used. Within the photo- transistor optocoupler, the transistor can be either PNP or NPN. Notably, the photo-Darlington configuration consists of a pair of transistors, where one transistor controls the base of the other, resulting in enhanced gain capabilities.

SOFTWARE USED

BLYNK App

Blynk is a popular Internet of Things (IoT) platform that enables users to develop custom mobile applications to control and monitor IoT devices. The Blynk app can be downloaded from the Google Play Store or the Apple App Store, and it is used in conjunction with the Blynk IoT platform to create IoT projects. With Blynk, users can build custom apps for controlling a wide range of IoT devices, including sensors, motors, and other electronics. The app provides a simple and intuitive interface that allows users to drag and drop widgets to create their custom IoT applications. Blynk also provides a cloud-based IoT platform that users can use to connect their IoT devices to the internet. This platform includes an API that allows developers to create custom integrations with other IoT platforms and services. Overall, Blynk is a powerful and flexible platform for building custom IoT applications. Its ease of use and comprehensive features make it a popular choice for both hobbyists and professional developers.

Blynk server

Blynk server is a cloud-based platform that enables the development of mobile and web applications for the Internet of Things (IoT). It provides a user-friendly interface to create custom dashboards and control panels for IoT devices and allows communication between devices and mobile applications using various protocols such as Bluetooth, WiFi, Ethernet, and GSM. Blynk server also offers a range of widgets that can be added to the user interface, including buttons, sliders, gauges, graphs, and notifications.

BLYNK library

The Blynk library is a software package that allows developers to easily connect hardware devices to the Blynk platform for IoT applications. It provides a set of APIs and libraries that can be used with various microcontrollers and development boards such as Arduino, Raspberry Pi, ESP8266, and others. The Blynk library includes functions to send and receive data from the Blynk cloud server, handle user interface elements such as buttons and sliders, and interact with hardware devices such as sensors and actuators. It also supports various communication protocols such as WIFI, Bluetooth, Ethernet, and GSM. The Blynk library is available for free and can be easily downloaded and installed using Arduino or Platform IO IDE.

4. Results

This project aimed to address the issue of water leakage and waste in water distribution systems by developing an IoT-based remote control water distribution system. The system was designed to improve response times and reduce damage caused by leaks.

The system was developed using an observatory kit including the ESP8266, DTMF, Linear power supply, logic circuit, driver unit, and digitally controlled valve. The prototype of the system is created, and a mobile application is used to control the valves remotely. The DTMF calling system was used as an alternative in case of no internet. The results of the project showed that the IoT-based remote control water distribution system was successful in reducing water leakage and waste. By enabling operators to remotely control the valves, response times to leaks were improved, and damage caused by leaks was reduced. The mobile application was found to be a convenient and effective method for controlling the valves remotely. In addition, the use of the DTMF calling system as an alternative in case of no internet was found to be a reliable and effective redundancy method.

In the context of our project, **Figure 1** is a visual representation of the observatory kit used in the development of the IoT-based remote control water distribution system. This kit consists of several components that are essential to the system's operation.

The **ESP8266** is a low-cost Wi-Fi module that serves as the main controller for the observatory kit. It enables the system to establish a Wi-Fi connection with the internet and communicate with the server, enabling remote control of the valves. The **DTMF (Dual Tone Multi-Frequency)** decoder is a device that translates the audio tones generated by the mobile application or the DTMF calling system into digital signals that can be interpreted by the logic circuit. The **logic circuit** is responsible for processing the digital signals generated by the DTMF decoder and sending commands to the driver unit to control the digitally controlled valve. The **driver unit** is an electronic device that is used to control the digitally controlled valve. It receives commands from the logic circuit and sends signals to the valve to open or close it as required. The **digitally controlled valve** is a key component of the system, as it controls the flow of water through the pipeline. By enabling the valve to be remotely controlled, the system can quickly respond to leaks and reduce water waste.

Overall, **Figure 1** provides a clear overview of the various components of the observatory kit used in the project and how they work together to enable remote control of the water distribution system.

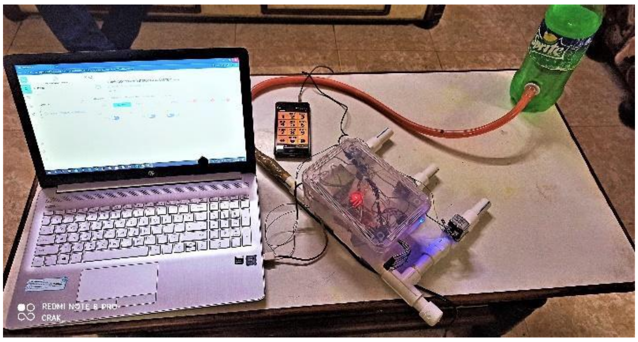

Fig 1 shows the observatory kit used in the project, including the ESP8266, DTMF, logic circuit, driver unit, and digitally controlled valve. All the required connections are made.

Figure 2 illustrates the successful establishment of an IoT connection between the observatory kit and the internet via the ESP8266 module. The ESP8266 module is shown connected to the internet through a Wi-Fi network.

To establish the IoT connection, the ESP8266 was configured to connect to a specific Wi-Fi network using the network credentials provided by the user. Once connected, the ESP8266 used the HTTP protocol to communicate with the server, enabling remote control of the valves through the mobile application.

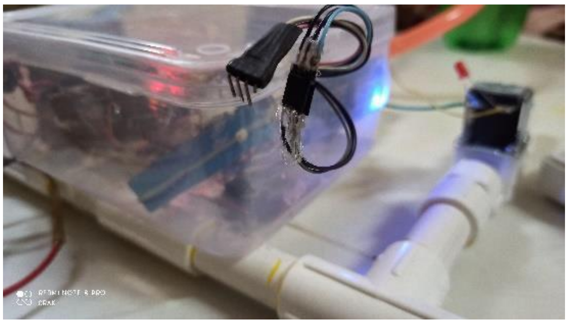

Fig 2 illustrates the successful establishment of an IoT connection between the observatory kit and the internet via the ESP8266 module

Figure 3 shows the dashboard of the **Blynk server**, which was used to control the on/off status of the valves in different areas of the water distribution system. The dashboard provides a visual interface for the user to monitor and control the status of the valves remotely.

As shown in **Figure 3**, the dashboard consists of a series of buttons that correspond to the valves in different areas of the water distribution system. Each button displays the current status of the valve, indicating whether it is currently open or closed.

To control the status of the valves, the user can simply tap on the corresponding button to toggle the valve between the open and closed positions. The status of the valve is immediately updated on the dashboard, providing real-time feedback on the state of the system.

Overall, **Figure 3** demonstrates the use of the Blynk server dashboard as a tool for remote monitoring and control of the water distribution system. By providing a simple and intuitive interface for controlling the valves, the dashboard enables efficient and effective management of the system, reducing the risk of water leakage and waste.

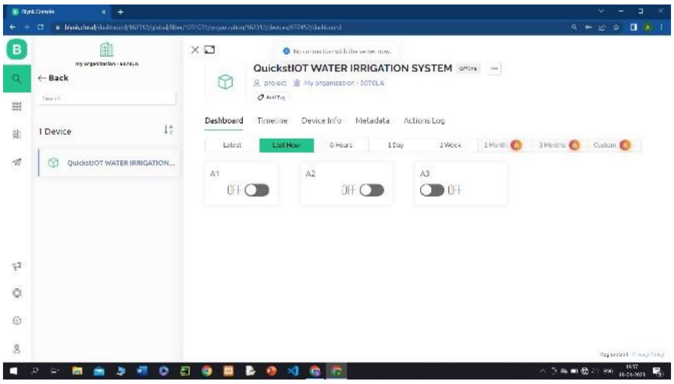

Fig 3: BLYNK Server Dashboard

Figure 4a shows the **Blynk server dashboard** with the Area 1 (A1) valve button switched on, indicating that the valve has been opened. This was achieved by tapping on the button corresponding to the A1 valve, which sends a signal to the observatory kit to open the valve.

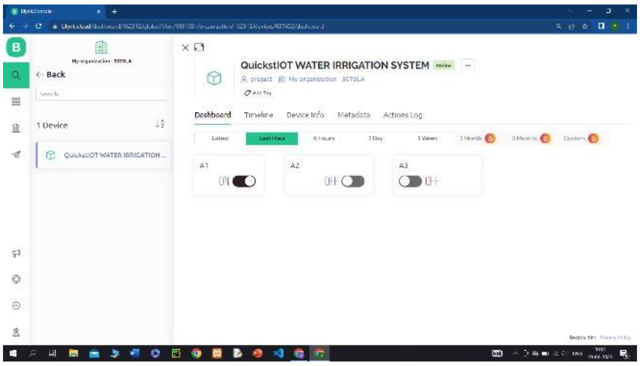

Fig 4a: Blynk server dashboard with the Area 1 (A1) valve button switched on

Figure 4b shows the resulting glowing of the red LED on the observatory kit, indicating that the A1 valve has been successfully opened. This LED is connected to the driver unit and is activated when the corresponding valve is opened or closed. The glowing red LED provides visual feedback to the user that the valve has been successfully opened, enabling efficient monitoring and control of the water distribution system. By using the Blynk server dashboard to control the valves remotely, the user can respond quickly to leaks and other issues in the system, minimizing the risk of damage and waste.

Overall, **Figures 4a and 4b** demonstrate the use of the Blynk server dashboard to control the valves in the water distribution system, as well as the resulting feedback provided by the observatory kit through the glowing of the red LED. This combination of remote control and visual feedback enables efficient and effective management of the system, reducing the risk of water leakage and waste.

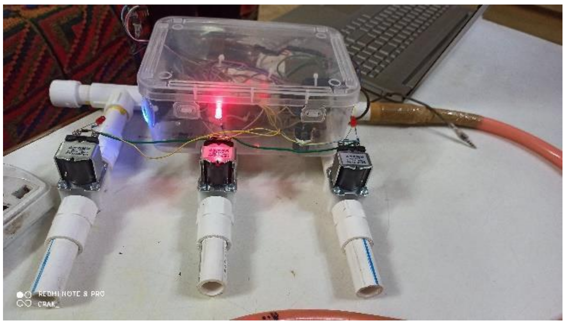

Fig 4b: shows the resulting glowing of the red LED on the observatory kit, indicating that the A1 valve has been successfully opened.

Figure 5a shows the connection between the observatory kit and the DTMF module, which enables the user to control the valves in the water distribution system using DTMF tones in the absence of an internet connection. As shown in the figure, the DTMF module is connected to the observatory kit using a set of wires, enabling the observatory kit to receive signals from the DTMF module.

Figure 5b shows the screenshot of the phone call made to the DTMF module, enabling the user to control the valves using DTMF tones. As shown in the figure, the user has dialed the phone number associated with the DTMF module and entered the corresponding DTMF tone for the Area 1 (A1) valve. This sends a signal to the observatory kit, which activates the valve and turns on the water flow.

Figure 5c shows the result of the valve activation, with the LED glowing to indicate that the valve for Area 1 (A1) is now open. As shown in the figure, the LED connected to the valve driver unit has turned on, indicating that the valve is now active and water is flowing through the system.

Together, these figures demonstrate the use of the DTMF module as a backup control option for the observatory kit, providing a reliable and secure method for controlling the valves in the absence of an internet connection. This redundancy ensures that the system can be managed effectively in a range of scenarios, minimizing the risk of water leakage and waste.

Fig 5a: shows the connection between the observatory kit and the DTMF module.

Fig 5b: shows the screenshot of the phone call made to the DTMF module.

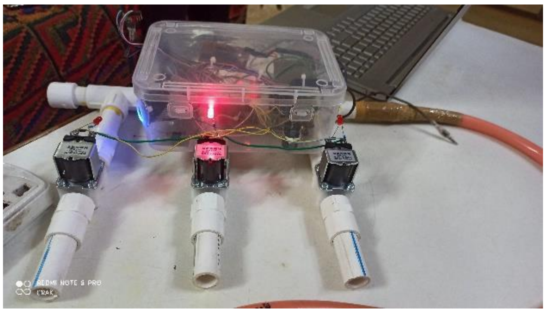

Fig 5c: shows the result of the valve activation, with the LED glowing to indicate that the valve for Area 1 (A1) is now open

Figure 6a shows a screenshot of the DTMF app that can be used to control the valves in the water distribution system. As shown in the figure, the app provides a user-friendly interface that enables the user to select the valve they wish to control and send the corresponding DTMF tone to activate it. This provides an additional option for controlling the valves, complementing the DTMF module and the Blynk app.

Figure 6b shows the result of using the DTMF app to control the valves, with the LED glowing to indicate that the valve for Areas 1, 2, and 3 (A1, A2, A3) is now open. As shown in the figure, the user has selected the valve for all three areas in the DTMF app and sent the corresponding DTMF tone to activate it. This sends a signal to the observatory kit, which activates the

valve and turns on the water flow. The LED connected to the valve driver unit has turned on, indicating that the valve is now active and water is flowing through the system.

Together, these figures demonstrate the flexibility and versatility of the observatory kit, which can be controlled using a range of methods including the DTMF module, the Blynk app, and the DTMF app. This provides users with multiple options for managing the water distribution system and responding to leaks, ensuring that the system can be operated effectively in a range of scenarios.

Fig 6a: shows a screenshot of the DTMF app

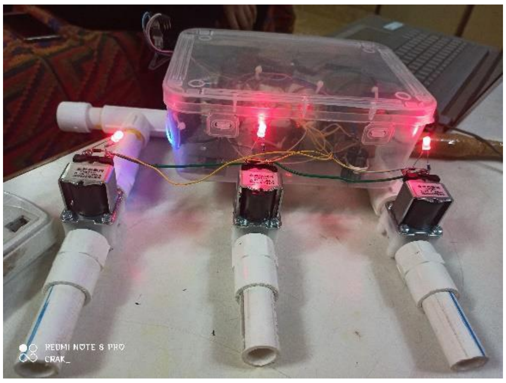

Fig 6b: shows the result of using the DTMF app to control the valves, with the LED glowing to indicate that the valve for Areas 1, 2, and 3 (A1, A2, A3) is now open.

The IoT-based remote control water distribution system developed in this project successfully addressed the issue of water leakage and waste in water distribution systems. The pictures showcased the step-by-step process of the project and demonstrated the successful development and installation of the system throughout the pipeline.

5. Conclusion

This project aimed to address the issue of water leakage and waste in water distribution systems. Through the development of an IoT-based remote control water distribution system using mentioned components and a mobile application, the project has achieved its objectives. The system enables operators to respond quickly to leaks and control valves remotely, thereby reducing damage and improving response times. The addition of a DTMF calling system as an alternative in case of no internet connectivity adds redundancy and ensures continuous valve control. This project provides a valuable solution that can improve efficiency, reduce costs, and improve system performance. In terms of future scope, this project can be extended to incorporate machine learning algorithms to optimize water distribution and reduce waste. Additionally, the system can be enhanced to include water quality monitoring and conservation features. Overall, the project has the potential to make a significant impact in the field of water management by providing a solution that addresses an important issue and improves system performance.

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