LORA-ENABLED WIRELESS SENSOR NETWORK FOR WATER CONSUMPTION READING AND BILLING USING OPTICAL CHARACTER RECOGNITION

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ABSTRACT

The increasing demand for accurate and efficient water consumption monitoring has highlighted the limitations of traditional meter reading methods, which rely on manual labor and are prone to human error, accessibility issues, and delays in billing. This research introduces a LoRa wireless sensor network system that performs automatic bill calculations from water consumption data through Optical Character Recognition (OCR) technology. The system integrates an ESP32-CAM module for photographing water meter readings with an OCR algorithm for data extraction and LoRa communication to transmit readings to a central gateway. Data is stored in a cloud-based platform, providing a digital web interface for real-time water consumption tracking. Evaluation results demonstrate improvements in data transmission range, reading precision, energy efficiency, and response time. The proposed system contributes to water conservation by enabling users to track leaks and monitor water usage patterns, benefiting both consumers and water utility providers.

1.0 INTRODUCTION

Traditional water meter reading methods present significant challenges, including human error, accessibility issues, and delayed billing. In Batangas Province, water companies rely on manual readings, where personnel record consumption data on paper. This method often results in inaccuracies, undelivered bills, and operational inefficiencies, especially during adverse weather conditions. According to Tanauan Water District Operations Manager Joel Posas, inaccuracies in readings and billing delays are persistent problems. With only six personnel assigned to read 42,000 meters, completing a full reading cycle takes 14 days, further delaying bill generation and increasing workload.

LoRa (Long Range) technology offers a low-power, long-range wireless communication solution ideal for transmitting water consumption data without requiring a direct internet connection. LoRa's ability to cover vast areas with minimal power consumption makes it suitable for smart metering applications, reducing the dependency on manual readings while ensuring reliable data transmission.

Optical Character Recognition (OCR) is another emerging technology in automated meter reading. OCR extracts text from images, allowing water meters to be read digitally through image processing. OCR-based reading can achieve over 99% accuracy, eliminating human errors associated with manual readings [1].

This study integrates LoRa and OCR to develop an automated water consumption reading and billing system. The proposed system captures water meter readings using OCR and transmits the data wirelessly via LoRa to the water provider's database. Consumers can then access their usage information through a web platform. By combining these technologies, the research aims to improve billing accuracy, reduce operational workload, and enhance the efficiency of water meter reading. The study, conducted in Tanauan City, Batangas, will evaluate the feasibility and reliability of using LoRa and OCR for water consumption monitoring.

1.1 Objective of the Project

The main objective of this study is to design and develop a water consumption reading system that uses Long-Range technology and digital image processing to read, transmit, and record water consumption. Specifically, the study aims to:

- Identify a LoRa module that optimally balances power consumption, transmission range, accuracy, physical size, and cost-effectiveness for reliable transmission of data from remote water meters to a central server;
- Employ the OCR algorithm for accurate water consumption reading and to use LoRa communication technology for transmitting data to a gateway;
- Develop an application that is ready for deployment which enables the operators and users to access their water consumption readings through Internet of Things (IoT); and
- Test and evaluate the system's performance in terms of transmission delay, transmission range,

reading accuracy, and the overall power consumption.

1.1.1 Scope and Limitation of the Project

The study focuses on developing a water consumption reading system that integrates Optical Character Recognition (OCR) for automated meter reading and LoRa technology for remote data transmission. This system reduces typographical errors in manual reading and enables efficient remote monitoring, particularly in urban areas with large user bases. The research involves deploying two meter-reading devices and two repeaters at different locations to assess performance across varying distances. Key features include localized processing for independent OCR reading, reliable long-range communication via LoRa, and power management through a scheduled sleep-wake cycle. A gateway handles data requests, transmission, and cloud integration, while a web interface allows users and administrators to access consumption data. Security is ensured through AES encryption, though data storage security is beyond the study's scope. The system follows a star-of-stars network topology and adheres to LoRaWAN and NTC regulations. Limitations include susceptibility to extreme weather conditions, potential data collisions at peak transmission times, and challenges in reading obstructed meters. OCR accuracy was validated through multiple tests on various meter types to refine the algorithm.

2.0 REVIEW OF RELATED WORK

The integration of LoRa (Low Power Wide Area Network) technology with Optical Character Recognition (OCR) in water consumption monitoring presents a novel approach that builds upon previous advancements while addressing key limitations. LoRa's long-range, low-power communication capabilities make it ideal for remote monitoring, while OCR enhances accuracy in reading meter data from images. Previous research has primarily focused on these technologies separately studies like Al-Shareeda et al. (2023) and Sundaram et al. (2019) explored LoRa's efficiency in IoT applications, whereas Jin et al. (2019) and Liang et al. (2022) demonstrated OCR's effectiveness in automated meter reading. This study distinguishes itself by integrating both technologies into a single system that not only improves data accuracy and transmission efficiency but also introduces a user-friendly interface for real-time consumption monitoring and management.
Recent studies have begun exploring integrative approaches, combining OCR with IoT and mobile applications to enhance water consumption monitoring ([1]; Concio et al., 2022; [4]). While these studies highlight the potential of automation in utility management, they often focus on either data transmission or image recognition rather than a holistic system. The current research aims to bridge this gap by leveraging LoRa for efficient long-range data transmission and OCR for precise meter reading, resulting in an optimized, real-time monitoring system. By synthesizing insights from existing literature, this study contributes to the advancement of smart metering technologies, enhancing both performance and user accessibility.

3.0 METHODOLOGY

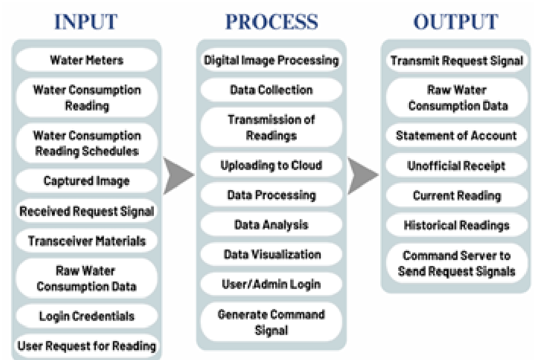

Fig. 1. Conceptual Framework

The automated water meter reading system integrates both hardware and software components to create an end-to-end solution platform. The hardware component follows an input-process-output structure, where the ESP32-CAM module captures images of water meters and converts them into text through digital image processing. These readings, tagged with user-specific IDs, are transmitted by the AI Thinker RA-02 LoRa module to a central gateway connected to the internet. Once uploaded, the data is sent to a server that activates the software system. The web application then organizes and processes the data, allowing users and administrators to view water consumption histories, billing information, and current readings. When users request updated readings, the web application sends commands through the gateway to the designated meter, enabling continuous and accurate monitoring.

Power efficiency, security, and scalability are key design priorities of the system. Sensor nodes operate on a 30-second active period followed by a 30-minute sleep phase, optimizing battery life while remaining responsive to commands. Reliable long-range communication is achieved using LoRa technology, configured with 20 dBm transmission power, a spreading factor of 12, and a coding rate of 4/8. All transmitted data is secured using AES encryption, and the 10-digit meter ID format supports over 3.6 million unique devices. Network reliability is further enhanced through repeaters that filter and forward only relevant signals. Each reading cycle supports up to 30 meters, with updated data made accessible through a user-facing website. By integrating OCR, LoRa communication, structured scheduling, and secure data protocols, the system offers a robust and scalable solution for remote water consumption monitoring.

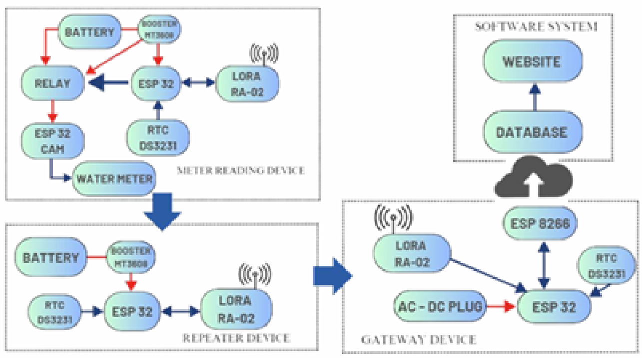

Fig. 2. System Block Diagram

Fig. 2 illustrates the systems' interlinking elements. A battery provides power to the microcontroller development board and the relay as soon as the LoRa module receives a request signal, or when it is the scheduled reading for the month. Subsequently, as the microcontroller processes the request, it will turn on the relay, which allows the camera module to activate and read the water consumption in the meter. As the processed data is transferred back to the microcontroller, the relay shuts off again to save energy, while LoRa transmits the information to the gateway. As soon as the LoRa receiver (gateway), acquires the data, another microcontroller powered by a mounted electrical socket will process the data and upload the information to the database. Data analysis and management take place, and visual representation of the data will be available on a website, viewable and accessible to the consumers and management.

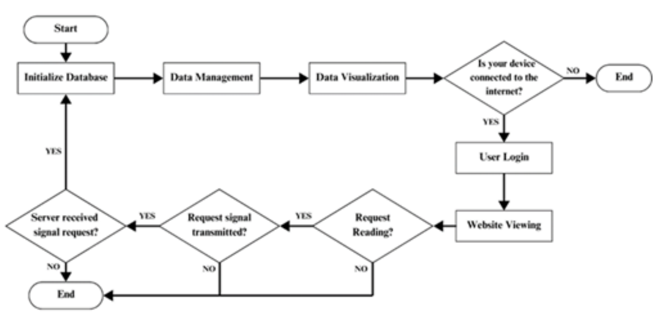

Fig. 3. Flow Chart

Fig. 3 presents the procedural flow of the system in the software component. As the system starts, it will initialize the cloud server where all data is saved. The data processing and analysis will take place to identify where each bit of data will be stored as part of data management. The data will then be prepared for data visualization. By this time, it will require internet connection to be able to log in and open the graphical user interface. If the device is not connected to the internet, then it will automatically end the system process. On the contrary, as the user opens the dashboard, he will be given a choice to view his current reading, a request signal will then be sent back to the receiver and wait for the transmitter to activate. As soon as the receiver receives the request signal, it will go back to the start of the system as that process will be done in the hardware component. But if the user does not want to see his current consumption, the system process will end.

4.0 RESULTS AND DISCUSSION

4.1 Prototype Setup and Deployment

Figures 4-6, presents the prototypes developed for the project. Several prototypes were created, including the gateway, repeaters, and sensor nodes.

Fig. 4. Gateway

Fig. 5. Repeater

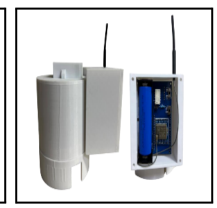

Fig. 6. Sensor Node

The gateway prototype, illustrated in Figure 4, consists of a case housing the PCB board, which integrates key components such as the ESP32 microcontroller, ESP8266 microcontroller, DS3231 RTC, and LoRa RA-02 module. These components are connected through the PCB and linked to an antenna powered by a 220V to 5V AC-DC converter. This prototype is specifically designed to transmit request signals, receive water consumption readings, and upload the collected data to the server.

The repeater prototype, as shown in Figure 5, is consist of a case housing the PCB board, which integrates key components such as the ESP32 microcontroller, the LoRa RA-02 module, a 3000 mAh 3.7V lithium-ion battery, and the DS3231 RTC. These components are interconnected through the PCB and connected to an antenna. This prototype is specifically designed to receive request signals and relay them to the sensor nodes corresponding to the requested sensor node ID.

The gateway was implemented by strategically placing it in an elevated location to transmit request signals and receive water consumption readings from the repeaters, as shown in Figures 2 and 3. Deployment targeted water meters, where the sensor nodes were positioned on top of the meters to perform optical character recognition (OCR). To initiate the system, the switches of the repeaters and sensor nodes were turned on, and these devices operated continuously with their programmed sleep and wake cycles. The gateway was also initiated and operated continuously without being turned off.

Prior to data gathering, the gateway was connected to the portable access point setup to upload water consumption readings to the server. Once the prototypes or devices were deployed, the system began its operation by requesting water consumption readings. The gateway received a command to initiate the request and transmitted a request signal to the repeaters, which relayed the signal to the sensor nodes. The sensor nodes read the water consumption data, transmitted it back to the repeaters, and subsequently relayed it to the gateway. Lastly, the gateway uploaded the acquired data to the website.

Fig. 7. Gateway Deployment Setup

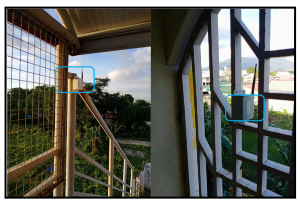

Fig. 8. Repeaters Deployment Setup

Fig. 9. Sensor Nodes Deployment Setup

4.2 Reading Accuracy Test

The reading accuracy test assessed the accuracy of water consumption readings by comparing sensor node measurements with actual visual readings. The accuracy was evaluated using an OCR algorithm for digital image processing. The percentage error was calculated using the formula provided in Eq. 1, and the average percentage error was obtained by averaging all individual errors. The system's accuracy was determined by subtracting the percentage error from 100%, as shown in Eq. 2.

The test involved capturing images of multiple water meters, with each tested three times to ensure reliability. The results indicated consistent camera configurations across all tests, confirming the stability and reliability of the initial setup. The accuracy evaluation revealed that the measured readings closely matched the actual values, with percentage errors ranging from 0% to 0.3681%, and an average error of 0.0578%. This low error rate demonstrated the system's high accuracy, achieving a final percentage accuracy of 99.71%. The system performed well, especially when water meters displayed whole numbers, though slight errors occurred when digits were partially obscured or when debris such as dust, moist surfaces, or leaves affected the meter display.

Table 1. Reading Accuracy Test Results

Water Meter	Measured Reading	Actual Reading	Percentage Error (%)
1	81.8	81.5	0.3681
2	167.6	167.3	0.1793
3	2404	2404	0.0000
4	1495	1495	0.0000
5	5	5	0.0000
6	5030	5031.6	0.0318
7	29	29	0.0000
8	452	452	0.0000
9	219	213.5	2.5761
10	460	460	0.0000
11	1763	1764	0.0567
Average Percentage Error:			0.2920

Eq.1 Percentage Error $\quad \% \text{ error} = \frac{\text{actual value} - \text{measured value}}{\text{actual value}} \times 100$

Eq.2 Percentage Accuracy $\quad \% \text{ accuracy} = 100\% - \% \text{ error}$

4.3 OCR Processing Time Test

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This test evaluated the processing time of the algorithm by testing eleven (11) different water meters with different appearances in terms of fonts, size of the numbers, and the surface clarity of the meter, as shown in Fig. 10.

Fig. 10. Tested Water Meters

Table 2. OCR Processing Time Result

Water Meter	Processing Time
1	0:04:31 mins.
2	0:04:49 mins.
3	0:03:05 mins.
4	0:01:59 mins.
5	0:01:27 mins.
6	0:03:48 mins.
7	0:01:50 mins.
8	0:02:50 mins.
9	0:02:15 mins.
10	0:03:02 mins.
11	0:03:23 mins.
Average	**0:03:00 mins.**

Table 2 shows the OCR algorithm's processing time is influenced by the design of the water meter, with newer models enabling faster and more accurate recognition due to their larger size, well-separated digits, and clearer fonts. These features allow the camera to capture more legible images, reducing errors and speeding up processing. In contrast, older models with smaller displays and cramped, less uniform digits slow down the OCR process, requiring more effort for accurate interpretation. This underscores the importance of meter design in enhancing OCR efficiency.

4.4 Transmission Range Test

This test evaluated the transmission range of the system to determine its performance in various ranges. The evaluation involved measuring whether successful transmissions occurred at different distances. This portion covers the testing for two (2) different repeaters

Table 3. Transmission Range Test Results For Repeater 1

Range (m)	SNR	RRSI	Error	Time Sent	Time Received	Transmission Delay
100	None	None	N/A	N/A	N/A	N/A
100	None	None	N/A	N/A	N/A	N/A
100	None	None	N/A	N/A	N/A	N/A
100	None	None	N/A	N/A	N/A	N/A
100	None	None	N/A	N/A	N/A	N/A
200	-9.5	-112	None	14:18:45	14:18:48	0:00:03
200	-16	-111	None	14:19:00	14:19:04	0:00:04
200	None	None	N/A	N/A	N/A	N/A
200	-16	-111	None	14:19:25	14:19:29	0:00:04
200	None	None	N/A	N/A	N/A	N/A
500	-5	-113	None	14:28:22	14:28:25	0:00:03
500	None	None	N/A	N/A	N/A	N/A
500	-10.25	-112	None	14:28:39	14:28:43	0:00:04
500	-11.75	-112	None	14:28:46	14:28:49	0:00:03
500	-12.25	-111	None	14:28:54	14:28:58	0:00:04
800	-19.25	-111	None	14:40:38	14:40:42	0:00:04
800	None	None	N/A	N/A	N/A	N/A
800	-18	-110	None	14:41:15	14:41:19	0:00:04
800	-11.5	-108	None	14:41:30	14:41:33	0:00:03
800	None	None	N/A	N/A	N/A	N/A
1070	-18.75	-109	None	14:49:51	14:49:55	0:00:04
1070	-20.25	-108	None	14:50:01	14:50:04	0:00:03
1070	-15.25	-110	None	14:50:07	14:50:11	0:00:04
1070	-15	-109	None	14:50:15	14:50:18	0:00:03
1070	-15	-109	None	14:50:29	14:50:32	0:00:03

The transmission range test was conducted by placing the gateway at FAITH and moving the repeaters toward Darasa, evaluating system performance at distances up to 1070 meters. The gateway sent signals that the repeater retransmitted within its coverage area to assess communication effectiveness. Results showed successful transmissions in open areas without obstructions, while signal failure occurred when buildings or walls blocked the line of sight. The system achieved a maximum effective range of 1070 meters in clear, unobstructed conditions.

Table 4. Transmission Range Test Results For Repeater 2

Range (m)	SNR	RRSI	Error	Time Sent	Time Received	Transmission Delay
100	-16.75	-106	None	10:03:46	10:03:50	0:00:04
100	-19	-107	None	10:03:54	10:03:57	0:00:04
100	-21.5	-105	None	10:05:03	10:05:06	0:00:04
100	None	None	N/A	N/A	N/A	N/A
100	-14.25	-106	None	10:05:19	10:05:23	0:00:03
200	-21	-110	None	10:11:38	10:11:42	N/A
200	-22	-110	None	10:11:53	10:11:57	0:00:04
200	None	None	N/A	N/A	N/A	0:00:04
200	-16.75	-113	None	10:13:40	10:13:43	0:00:03
200	None	None	N/A	N/A	N/A	0:00:04
500	-3.25	-110	None	10:24:01	10:24:05	0:00:04
500	-3.5	-109	None	10:24:10	10:24:14	0:00:04
500	-4.25	-109	None	10:24:18	10:24:21	0:00:04
500	-17.25	-109	None	10:24:32	10:24:36	N/A

The results showed that signal transmission failed when sensor nodes were blocked by buildings or walls, but successful transmissions occurred in open spaces with minimal obstructions. The maximum successful transmission distance was 1070m. In some cases, partial signal obstruction caused errors during transmission, but overall, the system performed well in open areas with fewer physical barriers.

4.4 Full Functional Implementation

This test evaluated the system's transmission delay, accuracy, and processing time. It involved both long-range and short-range setups using repeaters and sensor nodes placed at different locations.

Table 5. Full functionality Test Results Repeater 1 and Sensor node 2024245001

Trials	Transmit Time	Received Time	Transmission Delay	Actual Value	Received Value
1	10:00:00	10:02:09	00:02:09	11	11
2	10:30:00	10:32:03	00:02:03	11	11
3	11:00:00	11:02:08	00:02:08	11	11
4	11:30:00	11:32:07	00:02:07	11	11
5	12:00:00	12:02:10	00:02:10	11	11
6	12:30:00	12:32:13	00:02:13	11	11
Average Transmission Delay:			**00:02:08**	**11**	**11**

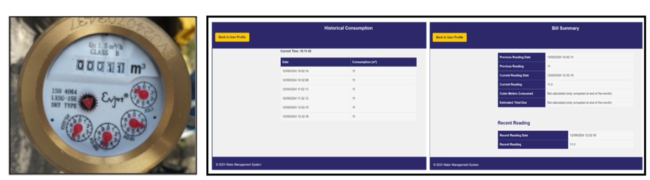


Fig. 11. Actual Water Meter & Website View, Historical, Bill Summary (1)

Table 6. Full functionality Test Results Repeater 2 and Sensor node 2024245002

Trials	Transmit Time	Received Time	Transmission Delay	Actual Value	Received Value
1	10:00:00	10:02:00	00:02:00	41	41
2	10:30:00	10:32:04	00:02:04	41	41
3	11:00:00	11:01:59	00:01:59	41	41
4	11:30:00	11:32:07	00:02:07	41	41
5	12:00:00	12:02:01	00:02:01	41	41
6	12:30:00	12:32:12	00:02:12	41	41
Average Transmission Delay:			**00:02:04**	**41**	**41**

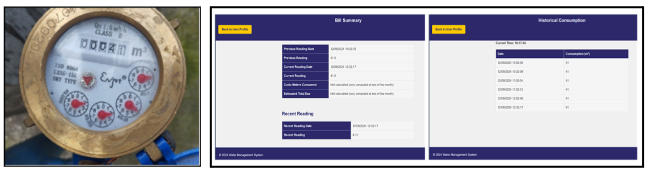


Fig. 12. Actual Water Meter & Website View, Historical, Bill Summary (2)

Tables 5 and 6 present the transmission delay test results conducted over a span of two and a half hours, comprising six trials from 10:00:00 to 12:30:00. The system showed consistent performance with minimal delay variation, indicating reliable data transmission. Accuracy was confirmed through repeaters and sensor nodes, with all transmitted values matching actual readings. This consistent performance, characterized by minimal variation, demonstrates the system's reliability in maintaining stable transmission times.

4.5 Power Consumption Test

Table 7. Power Consumption Test Result 1 Reading Cycle

TRIAL	Power Consumed (mAh)
1	9
2	10
3	9.9
4	9.9
5	11
Average	**9.96**

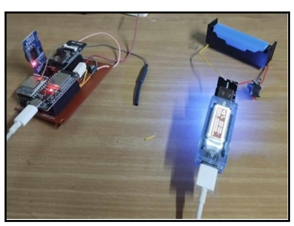


Fig. 13.Power Consumption Testing

To test the system's power consumption, the researchers first measured the current draw of each component individually to ensure precise data. A multimeter probe was connected in series with each component's power supply to monitor current usage during both sleep and active states. The ESP-32 consumed 10 µA in sleep mode and 50 mA in active mode; the DS3231 RTC drew 3.5 µA in sleep mode and 0.0035 mA in active mode. The MT3608 boost converter recorded 100 µA in sleep mode and 0.1 mA when active. The 5V relay and ESP-CAM both showed 0 µA/mA in both states, indicating no measurable consumption under the test conditions. The LoRa module used 0.2 µA in sleep mode and 11.6 mA when active. These measurements totaled to a system power consumption of 0.1137 mA in sleep mode and 61.7035 mA in active mode. This is seen in Appendix A.

To evaluate battery usage during actual readings, the researchers used a USB power consumption tester, as illustrated in Figure 13. They tracked the mAh consumed from the beginning of a reading process until it was completed. This method enabled accurate measurement of battery drain per reading cycle, helping assess the system's efficiency and battery life expectations.

Table 8. Battery Runtime

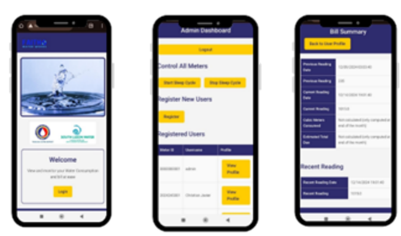
Readings	2000 mAh	2500 mAh	3000 mAh	4000 mAh	4500 mAh
1 / Month	2.17 Years	2.71 Years	3.25 Years	4.34 Years	4.88 Years
1 / Day	0.42 Years	0.53 Years	0.63 Years	0.84 Years	0.95 Years
1 / Week	2.14 Years	2.67 Years	3.20 Years	4.27 Years	4.80 Years
1 / 2 Weeks	2.16 Years	2.7 Years	3.23 Years	4.31 Years	4.85 Years

Table 8 shows the projected battery runtime for each of the batteries with different battery capacities when they are consumed in different time periods.

4.6 Website

Graphical User Interface

Mobile View



The researchers developed a website hosted within the Local Area Network (LAN) of the access point, allowing devices connected to the network to access it without issues.

5.0 CONCLUSION

Upon completion, several key conclusions were drawn: LoRa network transmissions are reliable when repeaters are placed away from obstructions and at elevated positions to maintain clear line-of-sight communication, ensuring accurate signal relay. The speed of OCR processing using the embedded algorithm varies depending on meter type and font size, with newer meters and larger, cleaner fonts enabling faster processing. A typical 3–4 second transmission delay occurs between the gateway, repeater, and sensor nodes under normal weather, so adding a 4–5 second buffer is recommended to maintain communication reliability during adverse conditions. The custom device casing fits most standard residential water meters but may not be compatible with all sizes. Overall, the system performs best in open areas and with newer meters, and it remains operational even in rainy conditions, demonstrating its adaptability and environmental resilience.

6.0 RECOMMENDATIONS

This section presents practical recommendations to address key issues identified in the study, aiming to mitigate challenges, foster innovation, and enhance future development. For large-scale deployment, multiple gateway channels on different frequencies should be used to reduce interference and balance processing loads. A fast and reliable access point is essential to prevent data loss during uploads from repeaters. Device durability remains a concern, as physical disturbances may disrupt internal components and affect operation; thus, semi-annual inspections are advised. The OCR algorithm should be tested on a wider variety of water meters to ensure broader compatibility, and a monitoring feature should be added to detect unusual or absent water consumption patterns. To extend operational longevity, a higher-capacity, compatible battery is recommended, allowing for annual maintenance. The device casing should be upgraded to resist heat, wear, and deformation, while the top cover should be replaced with acrylic to allow manual readings during system failures. Lastly, enhanced security features are necessary to protect devices from theft and other external threats.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

1. Hong, Q., Ding, Y., Lin, J., Wang, M., Wei, Q., Wang, X., & Zeng, M. **Image-Based Automatic Watermeter Reading under Challenging Environments**. Sensors, 21(2), 434, **2021**. https://doi.org/10.3390/s21020434

2. Jin, G. et al, **A Smart Water Metering System Based on Image Recognition andNarrowband Internet of Things** [Computer School of Yangtze University, Jingzhou 434023, China], **2019**. https://www.iieta.org/download/file/fid/20906

3. Liang, Y., Liao, Y., Li, S., Wu, W., Qiu, T., & Zhang, W. **Research on water meterreading recognition based on deep learning, 2022**. Scientific Reports, 12(1). https://doi.org/10.1038/s41598-022-17255-3

4. Madhuri Latha M. et al. **Automated Water Meter Reading through Image Recognition**. IJRASET, **2024**. https://www.ijraset.com/research-paper/automated-water-meter-reading-through-image-recognition

9.0 ABOUT THE AUTHORS


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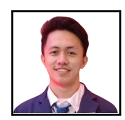
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10.0 APPENDIX

Appendix A - Power Consumption of Components

Component	Sleep (uA)	Active (mA)
ESP-32	10	50
DS3231	3.5	0.0035
MT3608	100	0.1
5V RELAY	0	0
ESP- CAM	0	0
Lo-Ra	0.2	11.6
Total	**0.1137**	**61.7035**