Pakistan Aqua surveillance and control using IOT and LoRa Protocol

Abdul Razzak[1], Waheed Ahmed[3]
Computer Science Department, Sindh Madressatul Islam University, Karachi, Pakistan.
Razzakbhutto36@gmail.com, Waheedswe@gmail.com

AneesHaneef[2], Abdullah Ayub[4]
Computer Science Department, Benazir Bhutto Shaheed University Lyari, Karachi, Pakistan
Aneeshanif639@gmail.com, Abdullah.ayub@bbsul.edu.pk

Received: 18th April 2023; Accepted: 21st June 2023; Published: 1st July 2023

Abstract: Pakistan is facing a severe shortage of water, and the situation is expected to worsen in the future because of the mismanagement of water resources, lack of proper infrastructure to store and distribute water, climate changes etc. To address these issues, the government of Pakistan needs to implement effective water management policies, improve water infrastructure, and promote water conservation measures. Additionally, the country needs to address the root causes of water pollution, such as industrial and agricultural practices, and ensure that water is managed in a sustainable manner. Thus this country becomes the most water intensive economy in the world. To address these issues one solution has been analyzed and developed with use of LoRa modulation techniques and IOT enabled sensors and gateways to send and receive data of Aqua usage at extremely low power over long distances with aim to monitor water Usage and generating accurate financial Bill. During development process V-Model or Verification and Validation Model is utilized with parallel for both device testing and software development. Through this research work we reviewed many research papers and found that none of them have used LPWAN technology for proper water usage and we conclude that LPWAN is more reliable to be use due to low power, low cost and wide area coverage range for Pakistan Aqua Industry for Proper water usage and generating the accurate billing which benefit to Pakistan economy using end to end IOT sensors and LoRa protocol. During research two-week data has been analyzed and found that, this project can be implemented for Pakistan Aqua Industry initially for housing and can be extend for industrial level for more effective Surveillance and Control.

Keywords: LoRa (Long Range), Smart Aqua-meter, IoT (Internet of Things), Real-time Monitoring, Bill Payment, V-model, User Interface, LPWAN.

1. INTRODUCTION

Pakistan is facing a severe shortage of water, and the situation is expected to worsen in the future because of the mismanagement of water resources, lack of proper infrastructure to store and distribute water, climate changes etc. To address these issues, the government of Pakistan needs to implement effective water management policies, improve water infrastructure, and promote water conservation measures. Additionally, the country needs to address the root causes of water pollution, such as industrial and agricultural practices, and ensure that water is managed in a sustainable manner. In the fast-growing society and rapid growth population, aqua needs became an important issue, especially in sectors such as industry, households, urban areas, agriculture and fish farming. The main problem is the efficient use of water and the increase of Aqua pollution in places. Water bacterial contamination has been reported due to the progress of industrialization and environmental pollution [1]. Conventional methods are methodologically complex and imprecise, external electrodes or probes are expensive, and absence of real data transfer and analysis. [2].

The goal of the internet of things to enable smarter, better choices that create a more sustainable future. LoRa (LoRaWAN) is a new modulation technique optimized for long range, low power, and low bit rate communication. Both Wi-Fi and cellular networks are dependent on providers, creating cost and coverage limitations. With LoRa technology's long range and low power consumption and GPS free geo location capabilities, with full control and traceability of water or Aqua usage is achieved. It covers Kilometers of Area data transmission between node and Central Hub, Traditional Network solution transmit data using (WIFI, GSM, or Wired connection) that are costly where at every node we have to provide data connection further more They cannot carry data between one node to another which is Kilometer Away.

Aqua Industry Surveillance and control Provide Network solution LoRa (long Range) that Transmit Data in Kilometers with Ease, this is coast Effective and Easy to implement [5]. Right now, LoRa is monitoring and analyzing water systems to more effectively address shortages, floods and environmental regulations [5]. The network that covers a wide area with low power consumption is specific for IoT applications. It creates a low-cost infrastructure for connecting multiple objects. They provide long-distance connectivity, for inexpensive battery-powered devices that need to transfer small amounts of data regularly over their long lifetimes. [6]

There is need of solution which covers the above said issues related to Surveillance and Control of Pakistan Aqua Industry. Keeping in view one solution has been analyzed and developed with use of LoRa modulation techniques and IOT enabled sensors and gateways to send and receive data of Aqua usage at extremely low power over long distances with aim to monitor water Usage and generating accurate financial Bill using the V-shape SDLC model with sequential execution of processes and device testing. This paper is divided into five sections including background, problem statement, methodology, findings with Discussions and conclusion.

Due to fast-growing population and urbanization, the demand for Aqua is increasing day by day in various use cases like, agriculture, industry, home, hospital, etc. Besides, the world is adapting new technologies to enhance the quality of life. However, rapidly changing lifestyles and increased paying capacity have affected the use of Aqua [7-8]. As there is Aqua meter being used in different countries there is no such implementation in Pakistan. Aqua industries in Pakistan are vastly underdeveloped due lack of knowledge and technology and maintaining such an industry comes with challenges and can become very costly as is there is no efficient way to surveillance and regulate Aqua utilization.

We can make Aqua surveillance and regulation very efficient and cost effective by using IIOT sensors, Lora modules connected to a LORA Network. By utilizing this technology, we design a new standard for monitoring and regulating

Aqua industries in Pakistan. As we observed supply Aqua issue in Bahria Town Karachi & DHA it was big concern for them that they were unable to monitor the Aqua usage, Billing and Aqua Quality of Residence, there were IOT based solutions for such problems but the main issue was they are unable to cover wide area and also too expensive for any industries to implement them, to address these issue we have proposed one network base surveillance solution using the LoRa (Long Range network). LoRa technology provides an energy efficient way to connect sensors everywhere. LoRa enables sensors and gateways to send and receive data at extremely low power over long distances.

As the rapid development of Information technology, information transmission is becoming more intelligent. The use of traditional methods is becoming history, in same the use of traditional Aqua reading methods will become history. As the traditional methods cannot meet the needs of new and digital era.[9]. In Pakistan Aqua Industry is not advance there is no proper mechanism for Aqua surveillance and control, if we take look on Billing and Aqua usage issue there no accurate Billing being generate as per Aqua usage. Also, Aqua Quality is major concern in Pakistan. There are protocols which integrate the IOT and sensors for monitoring the water usage but all have limitations of cost and bandwidth and latency.

To address these issues one solution has been analyzed and developed with use of LoRa modulation techniques and IOT enabled sensors and gateways to send and receive data of Aqua usage at extremely low power over long distances with aim to monitor water Usage and generating accurate financial Bill etc. During development process V-Model or Verification and Validation Model is utilized with parallel for both device testing and software development.

2. LITERATURE REVIEW

Following papers represent some of the latest research in the field of water surveillance and control using LoRa modulation and IoT sensors. They provide a comprehensive overview of the challenges and opportunities associated with using these technologies for water surveillance and control, and highlight the potential benefits of adopting these technologies in real-world applications.

The authors of the paper [1] conducted experiments to evaluate the performance of the sensor and to demonstrate its ability to accurately measure the bacterial quality of water. The results showed that the sensor was able to accurately and reliably measure the bacterial quality of water, and was able to detect the presence of bacterial contaminants in a short amount of time. The authors conclude that the portable sensor with disposable electrodes is a promising new tool for water quality assessment and can be used in a variety of applications, including environmental monitoring, industrial process control, and public health monitoring.

The authors of this paper [3] reviewed a wide range of literature in this area and identified the most promising and innovative technologies for monitoring water and sanitation interventions. The authors found that in-situ and remote sensing technologies have great potential for improving our understanding of water and sanitation interventions, and for enabling the real-time monitoring and evaluation of these interventions. However, there is a need for further research and development in this area to overcome the current limitations and challenges of these technologies.

The paper [5] "Design and Implementation of a Mixed IoT LPWAN Network Architecture" by Rubio-Aparicio, et al. presents a novel design for a mixed IoT LPWAN (Low-Power Wide Area Network) network architecture. The authors conducted experiments to evaluate the performance of the mixed IoT LPWAN network architecture and to compare it with existing solutions. The results showed that the mixed IoT LPWAN network architecture was able to provide improved coverage, lower power consumption, and reduced costs compared to existing solutions. The authors concluded that the mixed IoT LPWAN network architecture is a promising solution for IoT applications and can be used in a variety of applications, including environmental monitoring, industrial process control, and public health monitoring. The authors also suggest that further research and development is needed to further improve the performance and capabilities of the mixed IoT LPWAN network architecture.

The paper [7] "A Novel Smart Aqua-Meter Based on IoT and Smartphone App for City Distribution Management" by Suresh, Muthukumar, and Chandapillai presents a novel solution for city water distribution management using the Internet of Things (IoT) and smartphone technology. The authors aim to provide a cost-effective and efficient solution to manage the city's water distribution system, which is an important challenge in many cities around the world. The authors propose a smart Aqua-meter system that integrates IoT and smartphone technology. The system consists of smart water meters installed at homes and businesses, a central server, and a smartphone app. The smart water meters measure the water consumption of each home or business and send the data to the central server in real-time. The smartphone app provides an interface for users to monitor their water consumption, pay their bills, and receive notifications in case of water leaks or other issues.

In this Paper [9] the authors propose a smart Aqua-meter system that integrates cloud computing technology. The system consists of smart water meters installed at homes and businesses, a cloud server, and a user interface. The smart water meters measure the water consumption of each home or business and send the data to the cloud server in real-time. The cloud server processes and stores the data, and the user interface provides an interface for users to monitor their water consumption, pay their bills, and receive notifications in case of water leaks or other issues. The authors concluded that the smart Aqua-meter system based on cloud computing is a promising solution for water resource management and can be used in regions around the world. The authors suggest that further research and development is needed to improve the performance and capabilities of the system and to make it more widely available to regions and users.

The paper [17] "Smart Aqua Quality Monitoring System Design and KPIs Analysis: Case Sites of Fiji Surface Aqua" by Mamun et al. presents a design and analysis of a smart Aqua quality monitoring system. The system was developed to monitor the quality of surface Aqua in Fiji and to provide a means of evaluating key performance indicators (KPIs) related to Aqua quality. The authors describe the design of the system, which includes a set of sensors that measure various parameters related to Aqua quality, such as pH, temperature, dissolved oxygen, and conductivity. The data collected by the sensors is transmitted wirelessly to a central control unit, where it is processed and analyzed. The authors conclude that the smart Aqua quality monitoring system is a promising solution for monitoring Aqua quality and improving Aqua management practices. They suggest that further research and development is needed to improve the performance and capabilities of the system and to make it more widely available for Aqua management applications.

The paper [21] "Using LoRa Technology to Monitor and Control Sensors in the Greenhouse" by Salih and Noori explores the use of LoRa technology for monitoring and controlling sensors in greenhouse environments. The authors aim to provide a solution that can help greenhouse farmers monitor and control the environment inside the greenhouse, such as temperature, humidity, and light intensity. The authors concluded that the use of LoRa technology for monitoring and controlling sensors in the greenhouse is a promising solution and can help farmers improve the efficiency of their operations. The authors suggest that further research and development is needed to improve the performance and capabilities of the system and to make it more widely available to farmers and greenhouse operators.

Here's a summary table [1] comparing the different works in terms of sensors used, applications and unique contributions and novelty of each paper.

Table 01: Summary of Various Sensors

Paper	Sensors Used	Applications	Novelty
[1]	Portable sensor with disposable electrodes	Water quality assessment, environmental monitoring, industrial process control, public health monitoring	Portable sensor with disposable electrodes for accurate and reliable measurement of water bacterial quality
[3]	In-situ and remote sensing technologies (reviewed literature)	Real-time monitoring and evaluation of water and sanitation interventions	Emphasizes the potential of in-situ and remote sensing technologies and the need for further research and development
[5]	Mixed IoT LPWAN network architecture	Environmental monitoring, industrial process control, public health monitoring	Design and implementation of a mixed IoT LPWAN network architecture with improved coverage, lower power consumption, and reduced costs
[7]	Smart water meters, central server, smartphone app	City water distribution management	Novel solution integrating IoT and smartphone technology for efficient water distribution management
[9]	Smart water meters, cloud server, user interface	Water resource management	Integration of cloud computing technology for real-time monitoring and management of water consumption

[17]	Sensors for measuring pH, temperature, dissolved oxygen, conductivity	Aqua quality monitoring, Aqua management practices	Design and analysis of a smart Aqua quality monitoring system with wireless data transmission and key performance indicator (KPI) evaluation
[21]	Sensors for monitoring temperature, humidity, light intensity	Greenhouse monitoring and control	Utilization of LoRa technology for monitoring and controlling sensors in greenhouse environments, improving operational efficiency

By reviewing the literature none of above has used the LoRa modulation and IOT Sensors for real time monitoring for water usage and accurate billing for water consumption.

3. METHODOLOGY

Methodology for Aqua Surveillance and control using LoRa modulation and IOT Sensors comprises the following steps

1. Study the Literature: In first step will go through the various research papers, articles, web sources and reports related to Water Surveillance and control with IOT Sensors will gather the all useful information, processes involved and techniques used for related topic.
2. Sensing and Data Collection: Install a network of IoT sensors in the water distribution system to collect data on water usage and maintainability. The sensors can communicate with a central system using the LoRa modulation technique, which provides long-range, low-power wireless communication.
3. Data Processing and Analysis: Collected data from the sensors is processed and analyzed for accurate water usage and billing using software tool.
4. Real-time Monitoring: The central system monitors the water usage in real-time, and sends data to cloud as well as web application database for accurate bill generation
5. Web application Development with Firebase technology which is a cloud-based platform developed by Google for building and managing mobile and web applications. It provides a number of services for developers to help them build, test, and grow their applications.
6. Data Visualization: The collected data will be visualized using dashboards with a clear understanding of the current water usage andthe impact of their decisions in form of accurate billing.

The Proposed system, as shown in Fig 1, contains novel approach by dividing the process into three main components which enable the real-time monitoring through the use of IOT sensors and LoRa (Long Range) Gateway for modulation purposes. This division brought the significant and novelty to the work and adds uniqueness. The detail description of each division is given below.

Aqua Monitoring Devices

Water Quality Sensors: These sensors track different aspects of water quality, including, conductivity, temperature, dissolved oxygen, turbidity, and pH level. They are deployed in various bodies of water.

Water Level Sensors: These sensors keep an eye on the water level in reservoirs, tanks, and other bodies of water.

GPS Modules: GPS modules give location data to track the physical location of the devices.

1. **LoRa Gateway**

   The LoRa (Long Range) Gateway serves as the central hub for Aqua Monitoring Devices. It accepts data sent over the LoRa protocol by the devices and sends it to the IoT platform for additional processing. The LoRa Gateway has an internet connection to connect to the IoT platform and a LoRa transceiver to communicate with the aqua monitoring devices and Platform for IoT

2. **IoT Platform**

   Processing and storing of data: The IoT platform processes the data it receives from the LoRa Gateway. This consists of creating real-time alerts or notifications based on established rules and saving the data in a database for historical study.

   User Interface: Through a web-based application, the IoT platform offers a user interface that enables users to examine the monitored data, alter system settings, and get alerts.

   Analytics and visualisation: The platform might provide tools for data analytics to draw conclusions from the information gathered. It can produce visual representations of the data on water quality and level, such as graphs, charts, or maps.

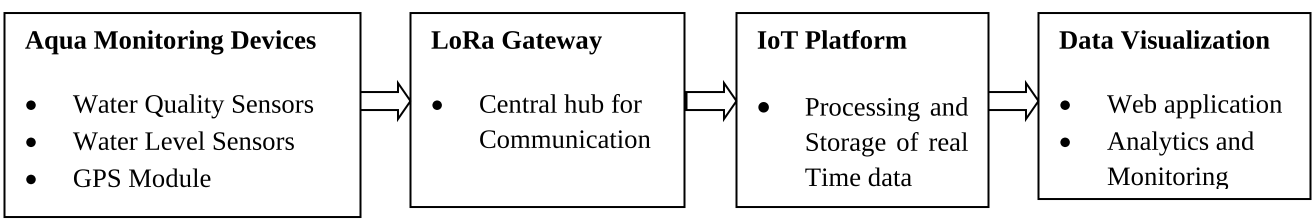

Fig 1: Block diagram of the proposed system.

The sensor- and GPS-equipped Aqua Monitoring Devices capture and wirelessly communicate water quality and level data using the LoRa protocol. The LoRa Gateway receives and transmits data as a bridge between the hardware and the IoT platform. In addition to offering real-time monitoring, historical analysis, and user engagement through a user interface, the IoT platform processes, saves, and analyses the data.

3.1 Network Infrastructure

As per requirements, data transmission between the nodes is sensitive and should not be leaked so, by noticing the safety requirements one solution is proposed with usage of intranet network which makes it an internal network and vulnerability chances of data leakage become much less.Initially data is collected using the Aqua meter which is implemented at endpoints nodes which transmit the data to receiving hub using the internet for cloud storage and further processing for Aqua usage and bill generation with real-time data.Fig 2 shows LoRa modulation implemnetation.

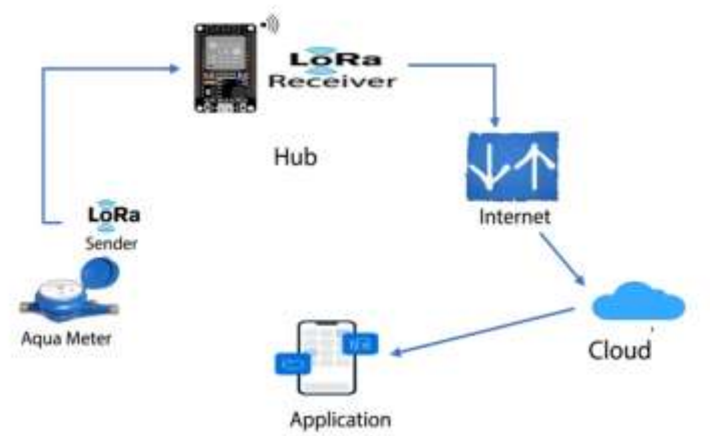

Fig 2: LoRa modulation implementation diagram.

3.2 Tools and Technology

LoRa Modulation Protocol is used with IOT sensors and Firebase Cloud based framework for web application development and data visualization

3.3 V-Shaped SDLC (Software Development Life Cycle) Model

In this study V-shaped SDLC (Software Development Life Cycle) model is used which is the extension of Waterfall model based on the sequential approach to software development. In this approach both verification and validation processes are analyzed at each stage of development to ensure that defects are identified and resolved promptly. V-shaped SDLC model had different phases like Requirements Gathering and Analysis, System Design, Coding, Unit Testing, Integration Testing, System Testing, User Acceptance Testing (UAT),Deployment and Maintenance. Through these key phases this model emphasis on Comprehensive testing, customer satisfaction and early detection of issues.

4. Results and Discussions

For implementing the proposed system, web application has been developed for collecting the sensor data and analyzing the results with accurate bill generation. First part contains the hardware connectivity for data collection, second part contains the Test Cases of water usage in different contents and third part contains the web application for data visualization.

Hardware connectivity

1. ***Sending Node:*** Data sending node or detecting node is the node which senses the Aqua Flow and sends the data to receiving node with the help of LoRa. Here Data that passes through Flow Sensors sends Aqua Flow Rate to receiving side of Module. As shown in below Fig 3.

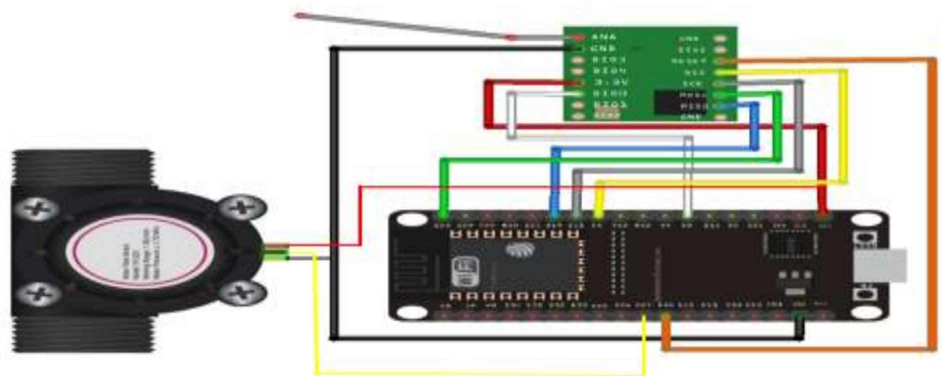

Fig 3: Sending side of the module with LoRa Protocol

2. ***Receiving Node:*** Data receiving node is the node which receive the data and transmit the data to Firebase/Cloud with the help of Internet then from Firebase data is accessed by Web Application, so Accurate Bill is generated and Aqua usage shown with the help of graph. Firebase is designed to be easy to use and integrate with other Google services, and it provides a number of SDKs and APIs to make it simple to add Firebase features to mobile and web applications. It's also designed to scale to meet the needs of growing applications, making it a popular choice for many developers. Data receiving module is shown in below Fig 4.

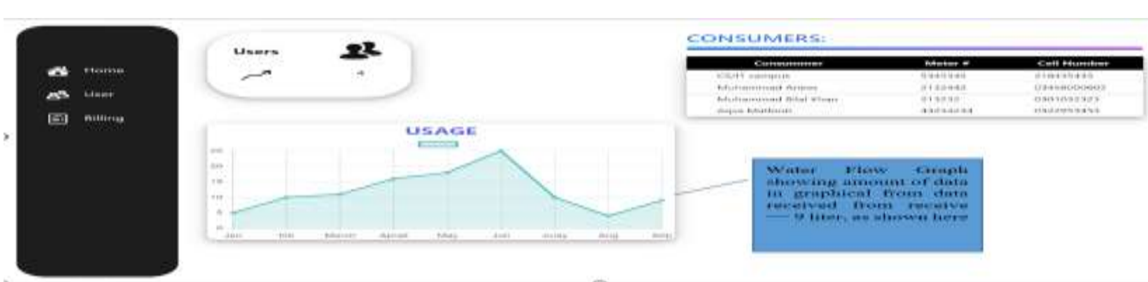

Fig 4: Receiving side of the module.

Graphical User Interaction / Application

The graphical user interface is designed by using web technologies. It is designed to make the raw data evident for those users who are unable to understand the raw data. Graphical user interface creates a user-friendly Dashboard for users with the help of Firebase technology which is a cloud-based platform developed by Google for building and managing mobile and web applications. It provides a number of services for developers to help them build, test, and grow their applications.

Test Cases: Several test cases of Aqua Industry Surveillance and control are Analyzed and verified and results are generated. List of the driven test cases is given below

Table 2: List of the driven test cases

ID	DESCRIPTION	STEPS	DATA	EXPECTED	ACTUAL	PASS/FAIL
1	Send Data from Firestore to Web App	1. Go to Firestore 2. Add default data 3. Save	Title: Ammar Cell #: 120023 Address: users address	These data should display in application	As anticipated,	Pass
2	Send Real Time data from IOT device and send it to Application	1. Flow sensor data to Lora 2. From Lora to Receiving Unit 3. then Send data to Real time data base	Aqua usage data in Number e.g., 3 liters	Data from Sending unit travel to Receiving Unit and then sent to Real Time Database	As anticipated,	Pass
3	Add New User	1. Click Add Button 2. Fill Fields 3. Submit	Title: Ammar Cell #: 120023 Address: users address	User To be Added	As anticipated,	Pass
4	Remove Uses	1. Go to users Section 2. Click delete for specific users	Remove action processed	Remove User	As Expected,	Pass

For Aqua consumption results are targeted for both Residential and Commercial consumers with analysis of two weeks data with water usage and bill generation and found that water usage in Commercial side is more than Residential side for this purpose system evaluated with Residential and commercial data separately.

Residential

Data gathered from residential user's week wise from 1 – 2 Weeks data of first week as show in below Fig 5& 6.

Week – 01

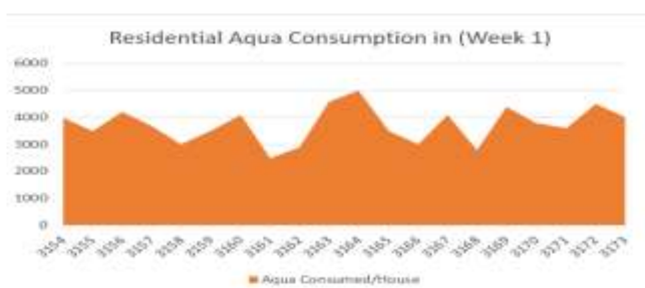

Fig 5: *Aqua Consumption of Residential Users within week 1*

Week - 02

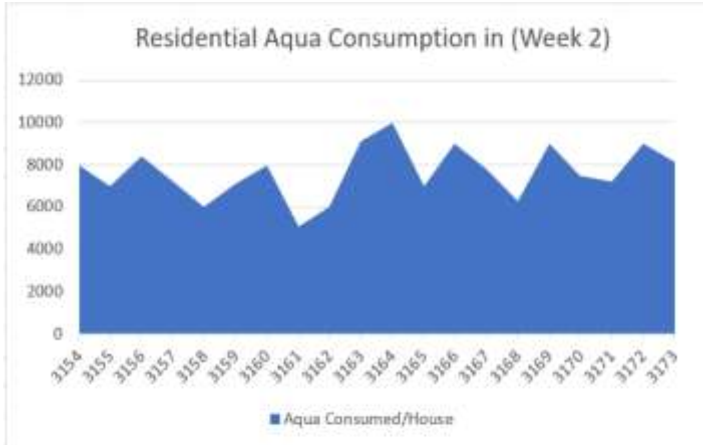

Fig 6: *Aqua Consumption of Residential Users within week 2*

Commercial

Data gathered from Commercial users' week wise from 1 to 2-week data is show below in Fig 7 & 8.

Week – 01

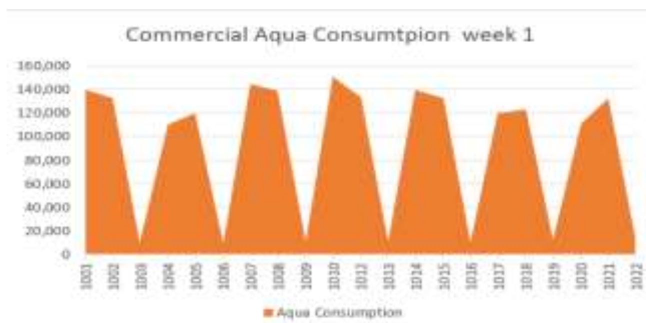

Fig 7: *Aqua Consumption of Commercial Users within week 1*

Week -02

Fig 8*: Aqua Consumption of commercial Users within week 2*

Now Within Commercial Consumers there are multiple targets that consume Aqua and their usage varies from each other's and there working pattern is also different from each other's, lets discuss different Commercial Consumers differently. The Targeted Consumers are (Hotel, Car Wash Station and Restaurant) Show in Fig 9, 10, 11, 12, 13 and 14.

Hotel

Week 1

Fig 9: *Aqua Consumption of Hotel within week1.*

Week 2

Fig 10: *Aqua Consumption of Hotel within week 2*

Car Wash Station

Week 1

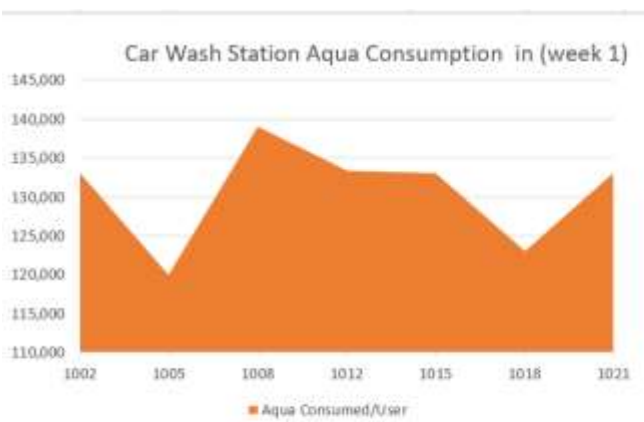

Fig 11: *Aqua Consumption of Car Wash within week1.*

Week 2

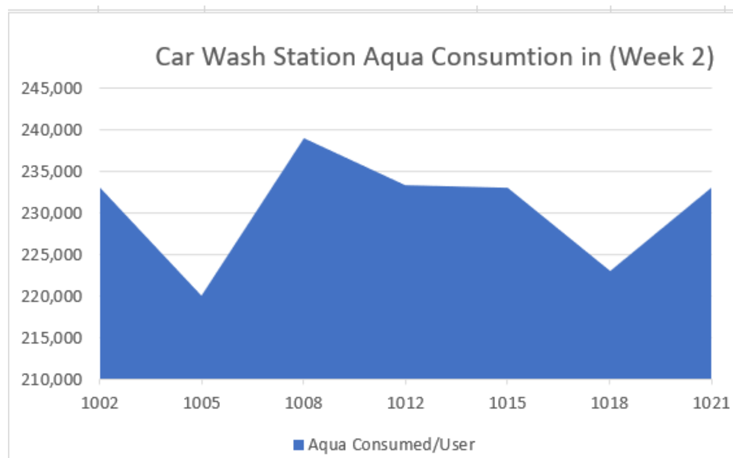

Fig 12: *Aqua Consumption of Car Wash within week 2.*

Restaurant

Week 1

Week 2

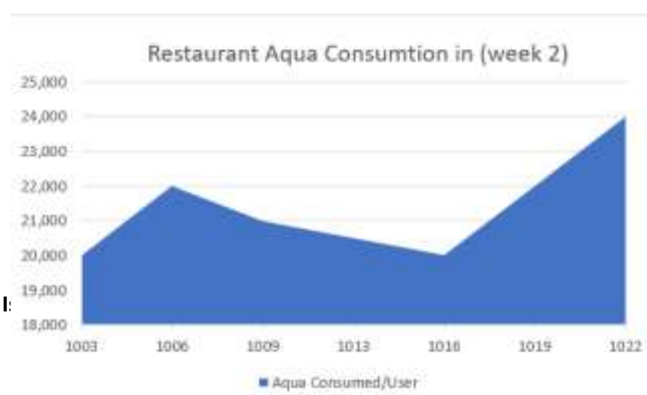

Fig 13: *Aqua Consumption of Restaurant within week 1.* Fig 14: *Aqua Consumption of Restaurant within week 2.*

After discussing Residential and Commercial Consumers both separately now let's discuss them whole together and analyze them as show below in Fig 15,16, and 17.

Final Aqua Consumption Result

Week 1

Consummers	Quantity Consumed/Liters	Rate/Liter	Amount/Rs
Commertial	1,768,000	2.5	4420000
Residential	74,710	1.5	112065

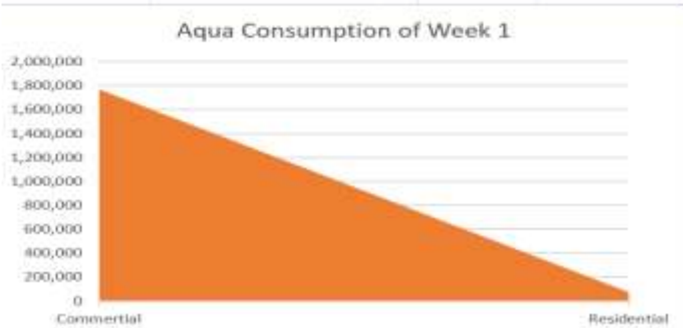

Fig 15: *Final Aqua Consumption within week 2.*

Week 2

Consummers	Quantity Consumed/Liters	Rate/Liter	Amount/Rs
Commertial	3,141,000	2.5	7852500
Residential	202,810	1.5	304215

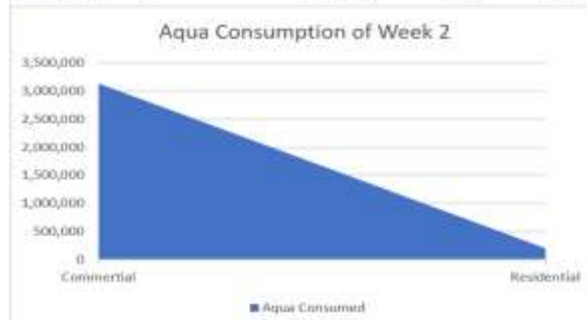

Fig 16: *Final Aqua Consumption within week 2.*

End Result

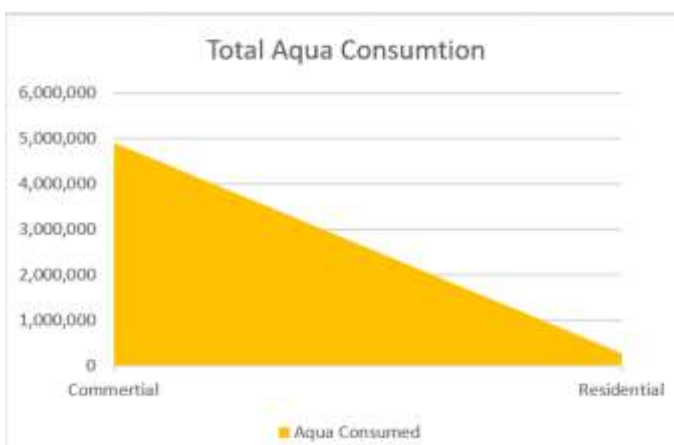

Fig 17: Total *Aqua Consumption*

5. Conclusion

Pakistan Aqua Industry Surveillance and control has different issues related to water monitoring and distribution with accurate billing. one solution has been analyzed and developed with use of LoRa modulation techniques and IOT enabled sensors and gateways to send and receive data of Aqua usage at extremely low power over long distances with aim to monitor water Usage and generating accurate financial Bill using the V-shape SDLC model with sequential execution of processes and device testing. Different ways of water usage has been analysed and discussed during the development of system for residential and commercial level and found that commercial has great use of water instead of residential. This work can be implemented for Pakistan Aqua Industry initially for housing and can be extending in future for industrial level for more effective Surveillance and Control.

REFERENCES

[1] M. Grossi et al., "A portable sensor with disposable electrodes for Aqua bacterial quality assessment," in IEEE Sensors Journal, vol. 13, no. 5, pp. 1775-1782, 2013.

[2] M. H. Banna et al., "Online drinking Aqua quality monitoring: review on available and emerging technologies," in Critical Reviews in Environmental Science and Technology, vol. 44, no. 12, pp. 1370-1421, 2014.

[3] L. Andres et al., "A review of in-situ and remote sensing technologies to monitor Aqua and sanitation interventions," in Aqua, vol. 10, no. 6, p. 756, 2018.

[4] R. Zese et al., "Neural Network Techniques for Detecting Intra-Domestic Aqua Leaks of Different Magnitude," in IEEE Access, vol. 9, pp. 126135-126147, 2021.

[5] J. Rubio-Aparicio et al., "Design and Implementation of a Mixed IoT LPWAN Network Architecture," in Sensors (Switzerland), vol. 19, no. 3, 2019.

[6] 1oT the Art in LP-WAN Solutions for Industrial IoT Services, in Sensors, vol. 16, p. 708, 2016.

[7] M. Suresh et al., "A novel smart Aqua-meter based on IoT and smartphone app for city distribution management," in 2017 IEEE region 10 symposium (TENSYMP), pp. 1-5.

[8] R. Al-Madhrahi et al., "An Efficient IoT-Based Smart Aqua Meter System of Smart City Environment," 2021.

[9] X. Feng et al., "Design on Smart Aqua Meter System Based on Cloud Computing," in E3S Web of Conferences, vol. 237, 2021.

[10] B. Bhola et al., "Cloud Integrated with LoRa Aquameter Network: A Aqua Expense Repository," 2021.

11] A. Cominola et al., "Smart Aqua Metering and AI for Utility Operations and Customer Engagement: Disruption or Incremental Innovation?" in Hydro Link: Journal of IAHR International Association for Hydro-Environment Engineering and Research, no. 4, pp. 114-19, 2020.

[12] X. J. Li and P. H. J. Chong, "Design and Implementation of a Self-Powered Smart Aqua Meter," in Sensors (Switzerland), vol. 19, no. 19, 2019.

[13] V. Slaný et al., "An Integrated IoT Architecture for Smart Metering Using Next Generation Sensor for Aqua Management Based on LoRaWAN Technology: A Pilot Study," in Sensors, vol. 20, no. 17, p. 4712, 2020.

[14] A. Augustin et al., "A Study of Lora: Long Range & Low Power Networks for the Internet of Things," in Sensors (Switzerland), vol. 16, no. 9, 2016.

[15] F. Fahmi et al., "Clean Aqua Billing Monitoring System Using Flow Liquid Meter Sensor and SMS Gateway," in Journal of Physics: Conference Series, vol. 978, 2018.

[16] S. Venkat and R. Ranjith, "A Wireless Sensor Network Model for E-Metering and Fault Identification in Smart Aqua Distribution Systems," in International Journal of Innovative Technology and Exploring Engineering, vol. 8, no. 10 Special Issue.

[17] K. A. Mamun et al., "Smart Aqua Quality Monitoring System Design and KPIs Analysis: Case Sites of Fiji Surface Aqua," in Sustainability (Switzerland), vol. 11, no. 24.

[18] P. Yeram et al., "Smart Aqua Management System in Urban Areas Using LoRa Technology," SSRN Electronic Journal, April, 2020.

[19] P. Yeram et al., "Smart Water Management System in Urban Areas using LoRa Technology," in Social Science Research Network, 2020.

[20] X. J. Li and P. H. J. Chong, "Design and Implementation of a Self-Powered Smart Aqua Meter," in Sensors, vol. 19, no. 19, 2019.

[21] T. A. Salih and M. S. Noori, "Using LoRa Technology to Monitor and Control Sensors in the Greenhouse," in IOP Conference Series: Materials Science and Engineering, vol. 928, 2020.

[22] X. Wang et al., "A new V-net convolutional neural network based on four-dimensional hyperchaotic system for medical image encryption," in Security and Communication Networks, vol. 2022, pp. 1-14, 2022.

[23] P. Li et al., "A deep multimodal adversarial cycle-consistent network for smart enterprise system," in IEEE Transactions on Industrial Informatics, vol. 19, no. 1, pp. 693-702, 2022.