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IoT based Sustainable Water Flow Monitoring System

Bachelor of Science in Computer Science

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Co-Supervisor:

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Certificate

We accept the work contained in the report titled “1761_FYP-3”, written by MINAHIL EJAZ AND IQRA BIBI as a confirmation to the required standard for the partial fulfillment of the degree of Bachelor of Science in Computer Science.

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June 24th, 2021

Abstract

This project is about an "IoT-based Water Flow Monitoring system", a system that will be measuring the Water Flow Rate, Water Consumption, and the Bill, accordingly, will be supplied to households directly and the authorities (CDA). On the installation of the system, Users will be provided with a mobile application where the information about water flow rate, water consumption, and the bill can be seen. Users can also complain through the application if they have any queries regarding the bill. On the other hand, there will be a web server given to the admin from where the admin can have all the access to web server where all the readings and calculations are shown on run time.

Acknowledgments

First, we thank Allah and then we would like to appreciate the personal without which this could not have happened. Thanks to our supervisor Dr. Naveed Bhatti for his immeasurable support and encouragement regarding to this study and work. His advice and help were invaluable for this project. We sincerely thank to him for his time and dedication.

We express our gratitude to our parents and family members for the love, sacrifice, support, and courage they have given us to make this project a success. They have always been back bone to what we are today, and no words can describe their dedication, hope, and their belief as well in achieving our goals. We would like to thank anyone who has contributed this project is hidden or open. Their comments and reviews were crucial to our success in this project.

We thank the staff of the Computer Science Department, Air university and other students, who have helped us in many ways and made our educational path pleasing and memorable.

MINAHIL EJAZ, IQRA BIBI
Islamabad, Pakistan

June 2021

"We think someone else, someone smarter than us,
someone more capable, someone with more resources will solve that problem.
But there isn't anyone else."

Regina Dugan

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Acronyms and Abbreviations

DSA	Data Structure and Algorithms
OOP	Object Oriented Programming
PF	Programming Fundamentals
SE	Software Engineering
SQL	Structured Query Language
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICODE	Unique, Universal, and Uniform Character enCoding
XML	Extensible Markup Language

Chapter 1

Introduction

1.1 Project Background/Overview

Water is one of the most important substances in the world. Its consumption is increasing day by day, which gives rise to water scarcity, and it is expected that Pakistan is destined to run out of the water by 2025 [1] [2]. So, there is a dire need for possible solutions to overcome this crisis. For this purpose, there should be an appropriate method to measure the consumption of water and then bill the property according to the amount of water used. Our objective is to design a sustainable water flow monitoring system with a battery-less sensor. This sensor will produce energy for itself to work.
In related projects we have seen a novel approach to performing automated water-meter reading for an update of consumption information from houses is described here. The smart metering approach proposed differs from existing commercial methodologies by making use of IoT hardware and smartphone app. This scheme permits both Meter Reader as well as individual domestic/industrial consumers to use regular smartphones to perform meter reading and update to utility's portal/database for billing and payment. The proposed scheme reduces overheads on Utilities in handling meter reading and billing for water distribution in metropolitan and large urban conglomerates. [9]

1.2 Project Description

Water is one of the most important substances in the world. Its consumption is increasing day by day, which gives rise to water scarcity, and it is expected that Pakistan is destined to run out of water by 2025 [1] [2]. So, there is a dire need for possible solutions to overcome this crisis. For this purpose, there should be an appropriate method to measure the consumption of water and then bill the property according to the amount of water used. Our objective is to design a long-life water flow monitoring system that will have a greater working life than the previous systems, by adding an energy harvesting module.
For water metering, we will use Micro Hydro Electric Generator [3] [4] which will provide voltage to ESP32 [5] [6]. From these voltage readings, we can infer that at this flow rate, we get this voltage reading. The generator will be fitted inside the pipe for harvesting energy. When water flows through the generator, it will generate a voltage. The generator will not produce a fixed rate voltage. Because voltage is not fixed, we cannot provide direct voltage to the microcontroller. So, we will involve a capacitor in between the generator and the

battery to provide a constant rate voltage to ESP32.
Along with Micro Hydro Electric Generator, initially, we are going to use a magnetic Hall Effect Sensor to make a lookup table between voltage level and water flow. For the water metering at the ends of the house, a Magnetic Hall effect water flow meter sensor [7] [8] will be placed. The water flow meter sensor consists of a pinwheel sensor and a hall-effect sensor. When water flows through the pipe, the pinwheel sensor will measure how much liquid has moved through it. The integrated magnetic hall effect sensor will output an electrical pulse with every revolution. It changes the magnetic field which will cause the output of the sensor to go either high or low. We will get an output of the sensor which is a square wave signal which can be easily used to calculate the rpm (revolution per minute) of the rotating shaft. This data will be sent to microcontroller ESP32 [5] and analysis of data can show how much water is flowing.
These water flow measurements will be sent to Server by ESP32 [5] . By comparing the results calculated by the water flow sensor and the voltage generated by the generator we can evaluate the correctness of calculations. Billing will be calculations. There will be two angles to see these calculations. One is the admin-side and the other is the client-side. Both sides would have restricted access rights to the data.

1.3 Project Objectives

- One of the objectives is to detect water flow that passes through the pipe. A water flow meter sensor will be used for this purpose.

- Another objective is to make a sustainable water flow monitoring system. Using a generator (F50 Micro-hydro DC Water Flow Pump Turbine Hydroelectric Power Energy Generator). Which will increase overall life time of the project.

- Real-Time Data Collection is one of the Smart Water Flow monitoring system's objectives. Just like a doctor uses a stethoscope to measure your heart rate, a smart water flow monitoring system can measure water flow through the sensor in real-time by sensing the water flow rate.

- One of the objectives of this system is to provide the Application to the user. Users will be provided with a smart water flow monitoring system or Application to see their water consumption. This system will also deliver calculated bills based on consumption. It will help them reduce their use of water. . At the same time, users are advised of abnormal water use to reduce water loss.

1.4 Project Scope

Project scope is the part of project planning that involves determining and documenting a list of specific project goals, deliverables, tasks, costs, and deadlines.

Water is one of the most important substances in the world. Its consumption is increasing day by day, which gives rise to water scarcity, and it is expected that Pakistan is destined to run out of the water by 2025 [1] [2]. So, there is a dire need for possible solutions to overcome this crisis. For this purpose, there should be an appropriate method to measure the consumption of water and then bill the property according to the amount of water used. Our aim is to design a sustainable water flow monitoring system that will be measuring water flow rate, water consumption, and the bill accordingly.

Deliverables:

A sensor (Esp32) measuring water flow rate, a generator charging Esp32, a server storing and manipulating data receiving through Esp32, an application for the users to see details about the consumption of water and billing details.
Tasks:

- Measuring the water flow rate in liters per minute/ seconds using flow sensor Esp32.
- Real-time data collection and storing it on a server to manipulate results and displaying it to the user via an application.
- Generating energy for Esp32 through the flow of water using the Micro Hydro Electric generator.
- Creating a Mobile application for the users.
- Testing and documentation of project.

Cost:

INNOVITECH SOLUTIONS AND DISTRIBUTORS

INVOICE

Invoice # 697
Invoice Date: September 9, 2020

BILL FROM
Innovitech Solutions & Distributors
+923491059571

BILL TO
Miss Minahil Ijaz

SR#	DESCRIPTION	QTY	PRICE	TOTAL
01	Miro hydro generator 12V MHG-12DC (imported)	2	5000	10,000
02	Arduino YF-201 Flow sensor	4	480	1920
03	Lithium ion 3.7V cell	2	200	400
04	Lithium cell BMS charge balancer W-203	3	250	750
05	Buck convertor LM2596	1	400	400
06	433Mhz Lora sx1278 with antenna xl1278-smt-spi interface long range transceiver wireless module	2	4000	8000
07	Arduino Mini Atmini 328p	4	700	2800
08	Breadboard	2	150	300
09	Connection wire ribbon M2M, M2F, F2F	9	150	1350
10	Microcontroller ESP32	4	950	3800
			Sub Total	29,720
			Shipping & Handling	200
			Discount	-60
			Total	**Rs.29,860**
				PAID

TERMS AND CONDITIONS
Returns are not accepted.
Exchanges in case of damaged products/goods are only possible within 7 days of delivery.

Thank you for your business!

Timeline:

- Jan- Feb: working on Micro Hydro Electric Generator
- March: working on Mobile Application
- April: Testing of project
- May-June: Final Documentation

1.1 The Degree Project Report

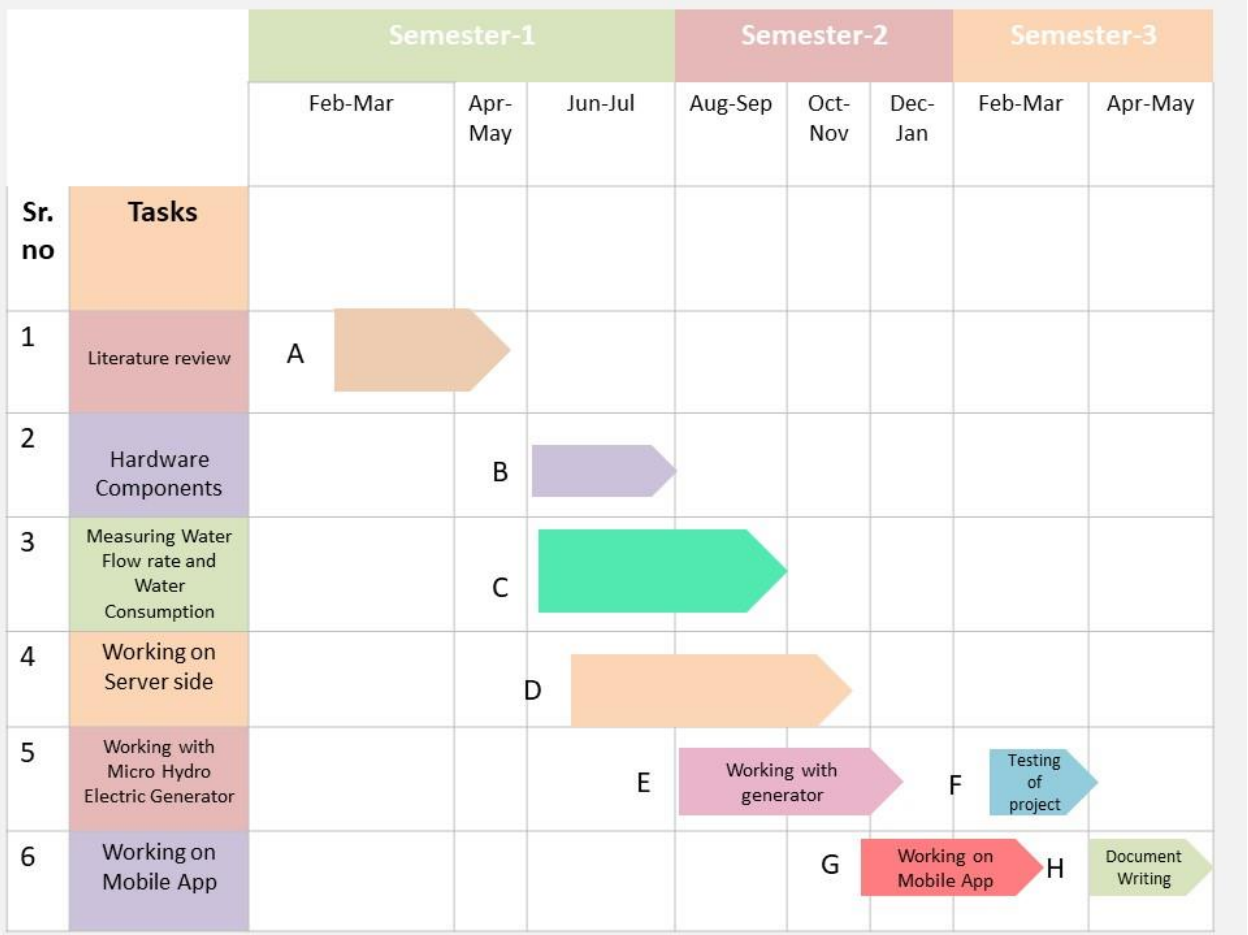


Figure 1.1: Final Year Project Gantt Chart

Chapter 2

Literature Review

A novel approach to performing automated water-meter reading for an update of consumption information from houses is described here. The smart metering approach proposed differs from existing commercial methodologies by making use of IoT hardware and smartphone app. This scheme permits both Meter Reader as well as individual domestic/industrial consumers to use regular smartphones to perform meter reading and update to utility's portal/database for billing and payment. The proposed scheme reduces overheads on Utilities in handling meter reading and billing for water distribution in metropolitan and large urban conglomerates. ["M. Suresh and U. M. :. J. Chandapillai, "A novel smart water-based on IoT and smartphone app for city distribution 15anagement," 19 October 2017."] There is no energy harvesting module in these projects. Our project "IoT-based water flow monitoring system " is a self-energy generating system so, we have increased the overall lifetime of the system using a generator (F50 Micro-hydro DC Water Flow Pump Turbine Hydroelectric Power Energy Generator). As the system runs generator starts producing energy to recharge the battery (2400 mAh Li-ion 3.7V) and hence the system can run for a larger time.

Chapter 3

Requirement Specifications

3.1 Existing System

A novel approach to performing automated water-meter reading for an update of consumption information from houses is described here. The smart metering approach proposed differs from existing commercial methodologies by making use of IoT hardware and smartphone app. This scheme permits both Meter Reader as well as individual domestic/industrial consumers to use regular smartphones to perform meter reading and update to utility's portal/database for billing and payment. The proposed scheme reduces overheads on Utilities in handling meter reading and billing for water distribution in metropolitan and large urban conglomerates. [9]

Limitations/Drawbacks of existing systems:

The system mentioned above, and other related systems use electricity for their entire working, there is no energy harvesting module used in these projects. which costs a lot and hence is the biggest downside of them.

3.2 Proposed System

Our project "IoT-based water flow monitoring system" is a self-energy generating system using a generator (F50 Micro-hydro DC Water Flow Pump Turbine Hydroelectric Power Energy Generator). As the system runs generator starts producing energy to recharge the battery (2400 mAh Li-ion 3.7V) and hence the system can run for a larger time. The life of our project is much greater than the previous related projects and the maintenance cost once the system is installed is negligible which is a big achievement.

3.3 Requirement Specifications

Functionality

Identifier	FR-01
Title	Enter name
Requirement	User will be able to enter their Full Name in the text field for signing up. The name length should be 3 to 30 characters long
Source	User
Rationale	This requirement will provide the user a facility to be able to create account.
Restrictions and Risk	N/A

Dependencies	N/A
Priority	High

Table 3.1: FR-01

Identifier	FR-02
Title	Enter Email
Requirement	User will be able to enter email in the text field for signing up.
Source	User
Rationale	This requirement will provide the user a facility to be able to create account.
Restrictions and Risk	N/A
Dependencies	N/A
Priority	High

Table 3.2: FR-02

Identifier	FR-03
Title	Enter username
Requirement	User will be able to enter unique username in the text field for signing up.
Source	User
Rationale	This requirement will provide the user a facility to be able to create account.
Restrictions and Risk	Username will be unique.
Dependencies	N/A
Priority	High

Table 3.3: FR-03

Identifier	FR-04
Title	Enter Password
Requirement	User will be able to enter the password in the text field for signing up.

Source	User
Rationale	This requirement will provide the user a facility to be able to create account.
Restrictions and risk	N/A
Dependencies	N/A
Priority	High

Table 3.4: FR-04

Identifier	FR-05
Title	Enter Phone Number
Requirement	User will be able to enter the Phone Number in the text field for signing up.
Source	User
Rationale	This requirement will provide the user a facility to be able to create account.
Restrictions and risk	N/A
Dependencies	N/A
Priority	High

Table 3.5: FR-05

Identifier	FR-06
Title	Validate username
Requirement	System will be able to validate email address entered by the user
Source	Admin
Rationale	To create user account with specified information on system server.
Restrictions and risk	Duplicate emails may cause confusion.
Dependencies	FR-03
Priory	High

Table 3.6: FR-06

Identifier	FR-07
Title	Validate name

Requirement	System will be able to validate name entered by the user.
Source	Admin
Rationale	To inform the user if he/she enters an invalid name (e.g., $ character in name)
Restrictions and risk	N/A
Dependencies	FR-01
Priory	High

Table 3.7: FR-07

Identifier	FR-08
Title	Submit details
Requirement	User will be able to click on submit button to create his/her account.
Source	User
Rationale	This requirement will provide the user a facility to be able to create account.
Restrictions and risk	N/A
Dependencies	None
Priory	High

Table 3.8: FR-08

Identifier	FR-09
Title	Enter username
Requirement	User will be able to enter username in the text field to login to his/her account.
Source	User
Rationale	This requirement will provide the user a facility to be able to log in to their account.
Restrictions and risks	N/A
Dependencies	N/A
Priority	High

Table 3.9: FR-09

Identifier	FR-10
Title	Password.
Requirement	User will be able to enter his password to login to his account.
Source	User
Rationale	This requirement will provide the user a facility to be able to log in to their account
Restriction and risk	N/A
Dependencies	N/A
Priority	High

Table 3.10: FR-10

Identifier	FR-11
Title	Login.
Requirement	The User will click on login option.
Source	User
Rationale	To allow the user to login to the application.
Restriction and risk	N/A
Dependencies	N/A
Priority	High

Table 3.11: FR-11

Identifier	FR-12
Title	Account verification
Requirement	System must verify the account whether it exists or not.
Source	Admin
Rationale	System checks the account is authenticated or not.
Restriction and risk	To prevent unauthorized accounts. Security issues
Dependencies	N/A
Priority	High

Table 3.12: FR-12

Identifier	FR-13
Title	Real time values on server
Requirement	System display real time values coming from the sensors.
Source	Project owner
Rationale	To allow the admin to see water flow rate and water consumption rate.
Restriction and risks	Risks: Internet connection may fail.
Dependencies	N/A
Priority	High

Table 3.13: FR-13

Identifier	FR-14
Title	View button
Requirement	System will have a view button to get the information.
Source	User
Rationale	To allow the user to see the calculated bill.
Restriction and risks	Risks: Internet connection may fail. Restrictions: User must have to register the account first.
Dependencies	FR-01
Priority	High

Table 3.14: FR-14

Identifier	FR-15
Title	Pay Bill
Requirement	System will have a pay button to pay the bill.
Source	User
Rationale	To allow the user to pay the calculated bill.
Restriction and risks	Risks: Internet connection may fail. Restrictions: User must have to register the account first.
Dependencies	FR-01
Priority	High

Table 3.15: FR-15

Identifier	FR-16
Title	Water Flow Sensor.
Requirement	Water should pass through the water flow sensor.
Source	N/A
Rationale	To allow the admin to view the water flow rate.
Restrictions and risks	Sensor may not work accurately. Sensor may not fix in the pipe properly.
Dependencies	N/A
Priority	High

Table 3.16: FR-16

Identifier	FR-17
Title	Micro Hydro Electric Generator.
Requirement	Water should pass through the generator which produces the voltage for the ESP (32) and Water Flow sensor.
Source	N/A
Rationale	N/A
Restrictions and risks	Micro generator may not work accurately. Micro generator may not fix in the pipe properly.
Dependencies	N/A
Priority	High

Table 3.17: FR-17

Identifier	FR-18
Title	Insert User in database
Requirement	The Admin shall click on insert user option to insert user.
Source	Admin
Rationale	To allow user to register his account.
Restriction and risks	User must request to register an account.
Dependencies	F-01
Priority	High

Table 3.18: FR-18

Identifier	FR-19
Title	Delete User in database
Requirement	The Admin shall click on delete user option to delete user.
Source	Admin
Rationale	To allow user to remove his account.
Restriction and risks	User may not request to remove his account.
Dependencies	F-01
Priority	High

Table 3.19: FR-19

Identifier	FR-20
Title	Update database
Requirement	The Admin shall update database to resolve bugs, internal errors, and other technical issues.
Source	Admin
Rationale	To maintain the productivity, technical issues slow down the productivity.
Restriction and risks	Overloads, performance constraints and capacity issues
Dependencies	F-01
Priority	High

Table 3.20: FR-20

Non-Functional Requirements

Identifier	FR-01
Title	Usability
Requirement	The user shall be able to make use of all functionalities in the application by manually interacting with the application

Table 3.21: FR-01

Identifier	FR-02
Title	Performance

Requirement	The user shall be able to make use of all functionalities in the application by manually interacting with the application

Table 3.22: FR-02

Identifier	FR-03
Title	Maintenance
Requirement	Sensors should measure the flow rate whenever water will pass through the pipes without any delay.

Table 3.23: FR-03

Identifier	FR-04
Title	Accuracy
Requirement	Sensors should measure the flow rate whenever water will pass through the pipes without any delay.

Table 3.24: FR-04

Identifier	FR-05
Title	Communication
Requirement	ESP (32) should be able to automatically connect to the availably home Wi-Fi.

Table 3.25: FR-05

Identifier	FR-06
Title	Integrity
Requirement	The system shall prevent any unauthorized addition, deletion, or modification of data

Table 3.26: FR-06

Identifier	FR-07
Title	Security
Requirement	If user failed to login after 3 retakes, user will not be able to login again for one day.

Table 3.27: FR-07

Identifier	FR-08
Title	Cost
Requirement	If user failed to login after 3 retakes, user will not be able to login again for one day.

Table 3.28: FR-08

Identifier	FR-09
Title	Reliability
Requirement	Sensor readings must not be lost. ESP (32) will send data of sensor to server.

Table 3.29: FR-09

Identifier	FR-10
Title	Efficiency
Requirement	The application shall be able to achieve at least 70% performance capability with least expected processor and memory capacity.

Table 3.30: FR-30

- **Use Cases**

Use Case Diagram

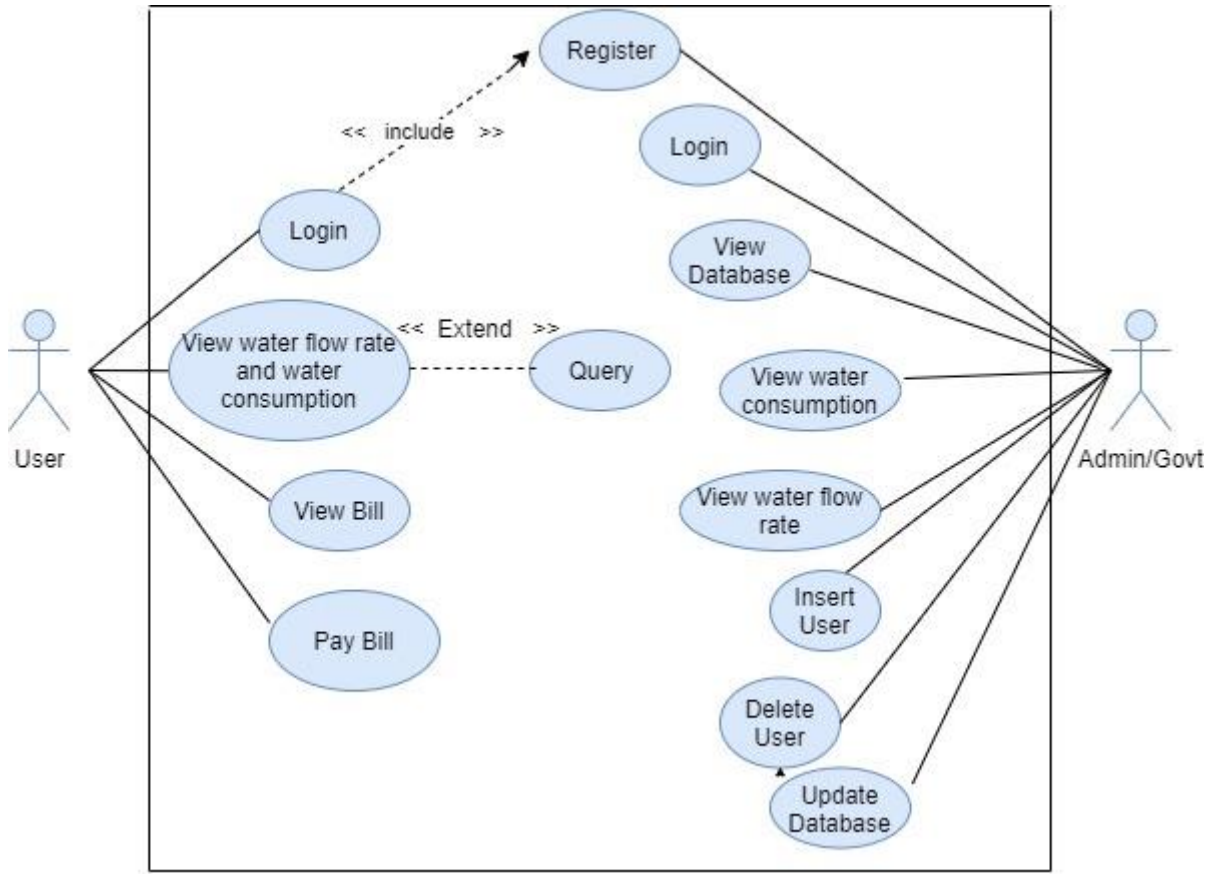


Figure 3.1: Use Case Diagram

Use Case Description

1. Use case: Login

Use Case ID:	UC-01
Use Case Name:	Log in
Actors:	User.
Description:	Let's the users join the application to view the information about the water flow rate, water consumption, and the bill.
Trigger:	User decides to take a view of the bill and all necessary data related to water billing.
Preconditions:	Users must sign in from their appropriate accounts. The application must be fully configured. User should write Id and Password they are provided with.

Post conditions:	After successfully login user can see different details on the application like water consumption and bill etc.
Normal Flow:	• User login to the application provided to them. • FrontPage of the application displays username, password, reset password, sign-in button, sign up button, and keep me log in check box. • The User enters his/her user Id. • The user enters eight characters in length password with uppercase, lowercase letters, and numbers. • User can reset his/her password anytime. 6-digit code will send to their provided email. By entering code, he/she will be able to change a password via email. • User can himself/herself log in by checking the box 'Keep me sign in'.
Alternative Flows:	There is no alternative flow.
Exceptions:	• In case, Id and passwords are incorrect, validation message will be shown on screen as "Invalid Email or Password" • In the case of three times wrong passwords, 30 mins wait message box will be displayed-see use case Wrong password.
Includes:	Register
Assumptions:	User has an authorized account.
Notes and Issues:	Null

Table 3.31: UC-01

2. Use case: register

Use Case ID:	UC-02
Use Case Name:	Register
Actors:	User.
Description:	Register new users in database.
Trigger:	User decides to take a view of water flow rate, bill and other necessary information.
Preconditions:	Users must have the water flow monitoring system in the pipelines of their houses.
Post conditions:	User can log in to the application to use it.
Normal Flow:	• The user requests to embed the system. • The user embeds the monitoring system in the pipelines of the house. • The user gets an Application to see get all the details about the system. • The user will register himself/herself through an App.
Alternative Flows:	There is no alternative flow.
Exceptions:	• In case, user gets the system and didn't register himself/herself, system will not provide water until he registers himself.
Includes:	Null
Assumptions:	• User knows the basic knowledge of using smartphones. • User understands English language.

Notes and Issues:	Note: all of the required information should be filled in carefully in an appropriate format.

Table 3.32: UC-02

3. Use case: view bill

Use Case ID:	UC-03
Use Case Name:	View bill
Actors:	User.
Description:	Show users details about the bill.
Trigger:	User can see the bill of water usage.
Preconditions:	User must have access to the application.
Post conditions:	User can see their bills.
Normal Flow:	• The user installs the mobile application • The user creates the account, and then log in to the account. • The user selects the view bill option. • The user sees another page where various information is displayed. • The user sees the complete graph of water usage. • The user sees the bill according to the amount of water usage. • The user sees all the details of the calculation of bill by clicking on details button. • The user sees Date and Time and the amount of water usage.
Alternative Flows:	Users can directly select the view bill option after login.
Exceptions:	• In case, user gets the system and didn't register himself/herself, system will not provide water until he registers himself.
Includes:	Null
Assumptions:	User has created an account and is using the system.
Notes and Issues:	Poor internet connectivity can cause a delay in showing bill details.

Table 3.33: UC-03

4. Use case: query

Use Case ID:	UC-04
Use Case Name:	Query
Actors:	User.
Description:	Users can inform the administration if they have any queries in the bill details.
Trigger:	So that the user can request to resend the bill if he/she finds any kind of error in the bill.
Preconditions:	The user must have checked and found some error in the bill calculations.
Post conditions:	User will be able to create query if the bill is not correct.

Normal Flow:	• The user is logged into the mobile application. • The user selects the view bill option. • In case the user finds some error in the bill he/she selects the 'Query' option. • The query is then received at the admin side. • Admin checks bill calculations and finds an error in the calculation. • On finding an error it is then corrected and sanded again to the user.
Alternative Flows:	There is no alternative flow.
Exceptions:	It may happen that the calculations done at the admin side may be correct but showing wrong at the user side due to internet or any other kind of error.
Includes:	Null
Assumptions:	User has verified that there is some mistake in the calculations of the bill.
Notes and Issues:	Bill calculations can be wrong due to poor internet connectivity.

Table 3.34: UC-04

5. Use case: pay bill

Use Case ID:	UC-05
Use Case Name:	Pay Bill
Actors:	User
Description:	User will be able to pay directly through the application.
Trigger:	So that the user can easily submit their bills online through the mobile application instead of wasting a lot of time in formal bank formalities.
Preconditions:	User must be registered and have installed mobile application.
Post conditions:	User can submit their bills directly through the application.
Normal Flow:	• User installs the mobile application • User creates an account, and then needs to log in. • Pay bill option is selected. • User needs to provide some details which appear after the selection of the pay bill option. • First need to enter the account number, tap on proceeds to pay, and finally select the payment method i.e. Credit/Debit card, easy paisa direct, jazz cash. • Enter the Submit bill button.
Alternative Flows:	There is no alternative flow.
Exceptions:	• In case any of the information is missing, wrong or not in the correct format the process will not be succeeded, and the application will give an error message to reenter the details.
Includes:	Null
Assumptions:	The bill is verified by the user to be correct.
Notes and Issues:	User found some errors in the calculations of the bill.

Table 3.35: UC-05

6. Use case: view water flow rate and consumption

Use Case ID:	UC-06
Use Case Name:	View water flow rate and water consumption.
Actors:	User.
Description:	User can see the water flow rate and water consumption on the application.
Trigger:	User wants to remain updated with their water flow rate and also the amount of water consumed.
Preconditions:	User must have installed and have made an account on the application.
Post conditions:	Users will be able to check their water flow rate and also the amount of water consumed.
Normal Flow:	• User logs in to the application. • Application shows options of view water consumption and view bill. • User clicks on it to see the bill and water consumption.
Alternative Flows:	There is no alternative flow.
Exceptions:	User may have checked values before the process of updating.
Includes:	Null
Assumptions:	User has created an account and is using the system.
Notes and Issues:	The application can show the wrong information due to poor internet connectivity.

Table 3.36 UC-06

7. Use case: insert user

Use Case ID:	UC-07
Use Case Name:	Insert User
Actors:	Admin.
Description:	Insert new users to use the system.
Trigger:	Maintaining data in the database will help to calculate the bill and show it to the user through the mobile application, from where users can easily view and submit their bills.
Preconditions:	The user must have created an account and wants to be the part of the system.
Post conditions:	Admin can add new users.
Normal Flow:	• First, the admin creates the database to keep and to maintain the records. • Admin fetches the user information he/she provided in sign-up process. • Admin inserts the user using the 'InsertUser'. • After inserting the user, user becomes be a part of the database.
Alternative Flows:	There is no alternative flow.
Exceptions:	• If somehow wrong information of any user is entered and then gets saved it can cause errors in the whole process. So, it is needed to enter the information carefully.
Includes:	Null
Assumptions:	The user has installed the system in his/her house and has made the account on the application.
Notes and Issues:	User may not have made an account on the application.

Table 3.37: UC-07

8. Use case: update database

Use Case ID:	UC-08
Use Case Name:	Update database
Actors:	Admin.
Description:	Admin can update the database whenever a user is added or deleted or changes credential information.
Trigger:	If a user wants to change credential information for some reason, there should be an option to accommodate it.
Preconditions:	The user changes his/her credential information.
Post conditions:	Admin can update the database.
Normal Flow:	• The user has made some changes in his/her credential information. • Admin is notified that some user has changed information. • Admin searches for that person's record in the database. • On finding the record admin updates it according to the changes made by the user.
Alternative Flows:	There is no alternative flow
Exceptions:	If the admin makes errors during the updating process it can cause different errors which can affect the overall efficiency of the system, so these things must be kept in mind during the updating process.
Includes:	Null
Assumptions:	A user is added or deleted.
Notes and Issues:	Due to the poor internet connectivity database may not be updated.

Table 3.38: UC-08

9. Use case: view water flow rate

Use Case ID:	UC-09
Use Case Name:	View water flow rate.
Actors:	Admin.
Description:	User can see the water flow rate on the application.
Trigger:	Admin wants to check water flow rate to calculate the bills.
Preconditions:	Admin must have installed and have made account on the application.
Post conditions:	Admin will be able to see the water flow rate and measure the bills accordingly.
Normal Flow:	• Admin logs in to the application. • Application shows options of view water flow rate. • Admin clicks on it to see the water flow rate to calculate bill of the users.
Alternative Flows:	There is no alternative flow.
Exceptions:	User may have checked values before the process of updating.
Includes:	Nothing.
Assumptions:	User has created an account and is using the system.
Notes and Issues:	The application can show the wrong information due to poor internet connectivity.

Table 3.39: UC-09

10. Use case: delete user

Use Case ID:	UC-10
Use Case Name:	Delete User
Actors:	Admin
Description:	Admin can delete any user who is no longer a part of the system.
Trigger:	Admin will delete the users that are no longer a part. The user may have left the house from where the rate of flow of water is measured or may user have changed the source of water consumption or in case the user did not pay the bill.
Preconditions:	User must be inserted in the database.
Post conditions:	Admin can delete users who are no longer the part of system.
Normal Flow:	• Admin has its own website. • Through the website, the admin can see all the information about water consumption and billing system • Admin sees all the users and their bills. • Run-time data is shown on the website. • Admin warns the users in case they did not pay the bill. • Admin deletes the unwanted users from the system. • Admin will answer every query of the user.
Alternative Flows:	There is no alternative flow.
Exceptions:	In case admins delete the user that has paid the bill, the user has the right to contact the admin.
Includes:	Nothing.
Assumptions:	User is no longer a part of the system.
Notes and Issues:	Admin may have deleted a user mistakenly.

Table 3.40: UC-10

11. Use case: view water consumption

Use Case ID:	UC-11
Use Case Name:	View water consumption.
Actors:	Admin.
Description:	User can see water consumption on the application.
Trigger:	Admin wants to check water consumption to calculate the bills.
Preconditions:	Admin must have installed and have made account on the application.
Post conditions:	Admin will be able to see the water consumption rate and measure the bills accordingly.
Normal Flow:	• Admin logs in to the application. • Application shows options of view water consumption. • Admin clicks on it to see the water consumption to calculate bill of the users.
Alternative Flows:	There is no alternative flow.
Exceptions:	User may have checked values before the process of updating.
Includes:	Null
Assumptions:	User has created an account and is using the system.
Notes and Issues:	The application can show the wrong information due to poor internet connectivity.

Table 3.41: UC-11

12. Use case: view database

Use Case ID:	UC-12
Use Case Name:	View Database
Actors:	Admin
Description:	Admin can view the database to see the records of users and also to get data to calculate the bill.
Trigger:	Admin should have a database where he can store and see all the information about users and their water consumption.
Preconditions:	Users must be inserted into the database.
Post conditions:	Admin can view database.
Normal Flow:	• The user consumes water. • Water consumption rate is shown on the website • All data is gathered, and calculation is done. • Admin sees the data on run-time. • All the data is stored in the database. • Admin views all the users, their water consumption rate and calculated bill. • Admin also receives the queries of the users and resolves them
Alternative Flows:	There is no alternative flow.
Exceptions:	• In case, the user is newly entered, then it will be inserted in the database. • In case, the user is no longer a part of the database, the admin can remove him/her. • In case, user's data needs to be changed, the admin can update him/her.
Includes:	Null
Assumptions:	Admin must have access to view database.
Notes and Issues:	Admin cannot view the database due to poor internet connectivity.

Table 3.42: UC-12

Chapter 4

Design

4.1 System Architecture

The water flow measuring sensor is measuring the rate of flow of water of a house and sending data to ESP32. The Micro-Hydroelectric Generator is generating electricity to charge ESP32. All of the data from ESP32 is going to the server database. Users will install a Mobile application that will show billing details and consumption of water as shown in the fig 1. The government side will have a Web Application to see the record of each user. Both Mobile and Web Application will fetch data from the database.

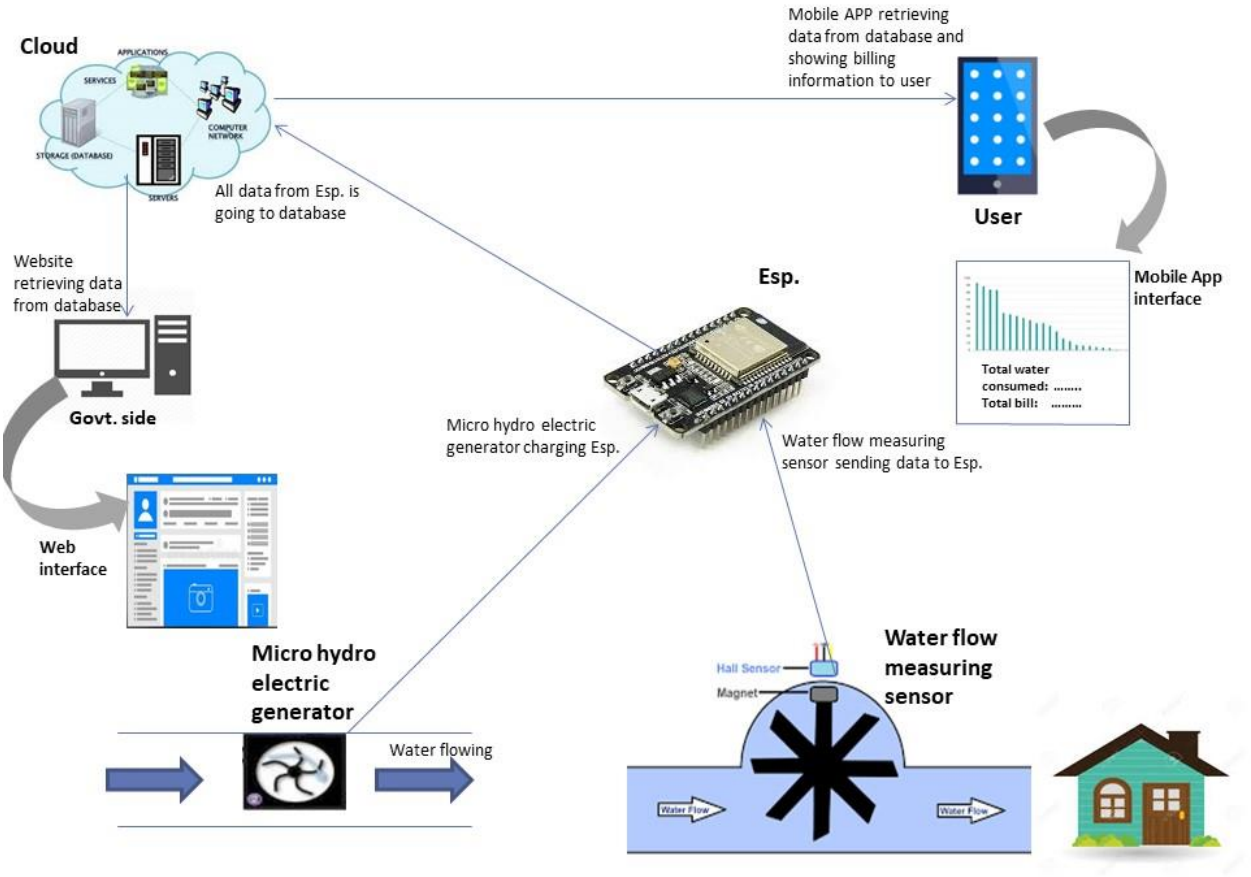


Figure 4.1: Application Architecture

4.2 Design Constraints

In the situation when there is no water flow through the system, the sensor may start sensing the pressure of air blowing through it and can change the readings which is not desirable because can cause calculation errors.
another constraint is that we cannot make a cost-free system after the installation because we need to charge the battery a bit through an external source, as the generator is not able to generate the amount of energy needed to run the system entirely.

4.3 Design Methodology

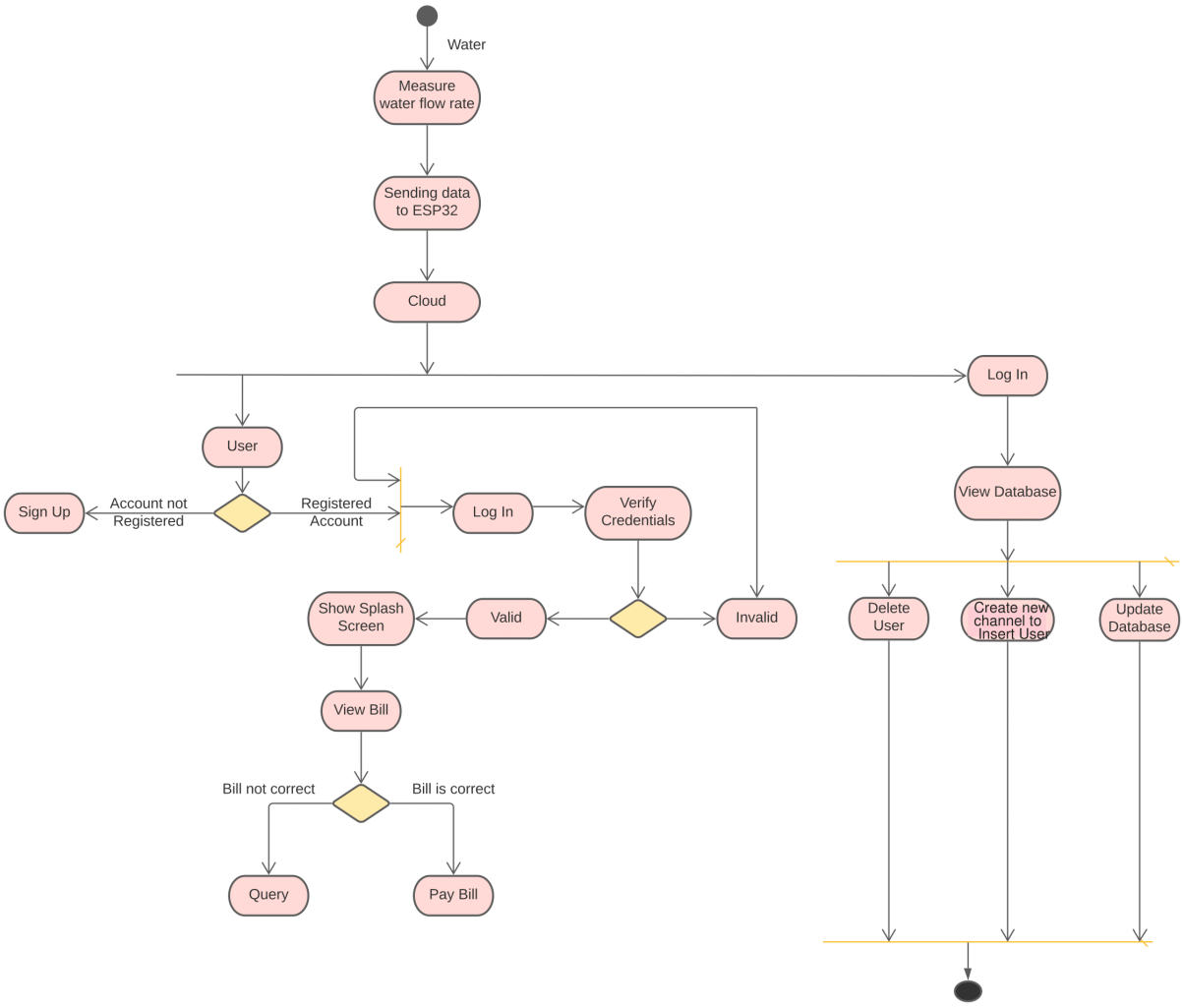


Figure 4.2: Design Methodology

4.4 High Level Design

This section describes in further detail elements discussed in the Architecture. Typical viewpoints are:

1. Conceptual or Logical view:

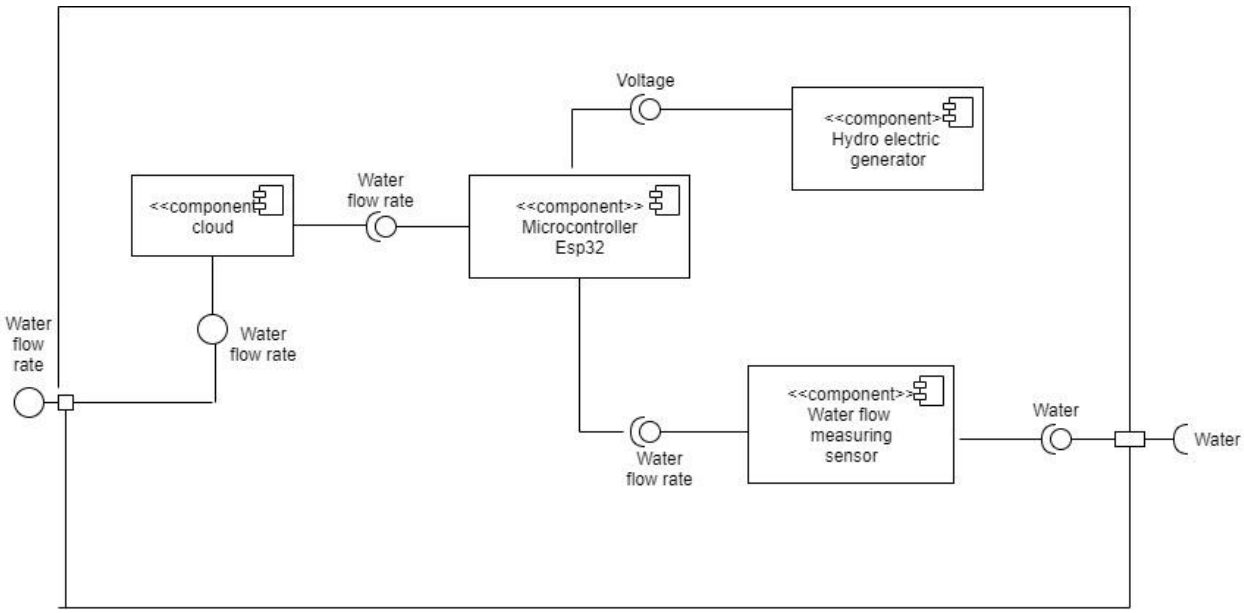


Figure 4.3: Component Diagram

2. Process view:

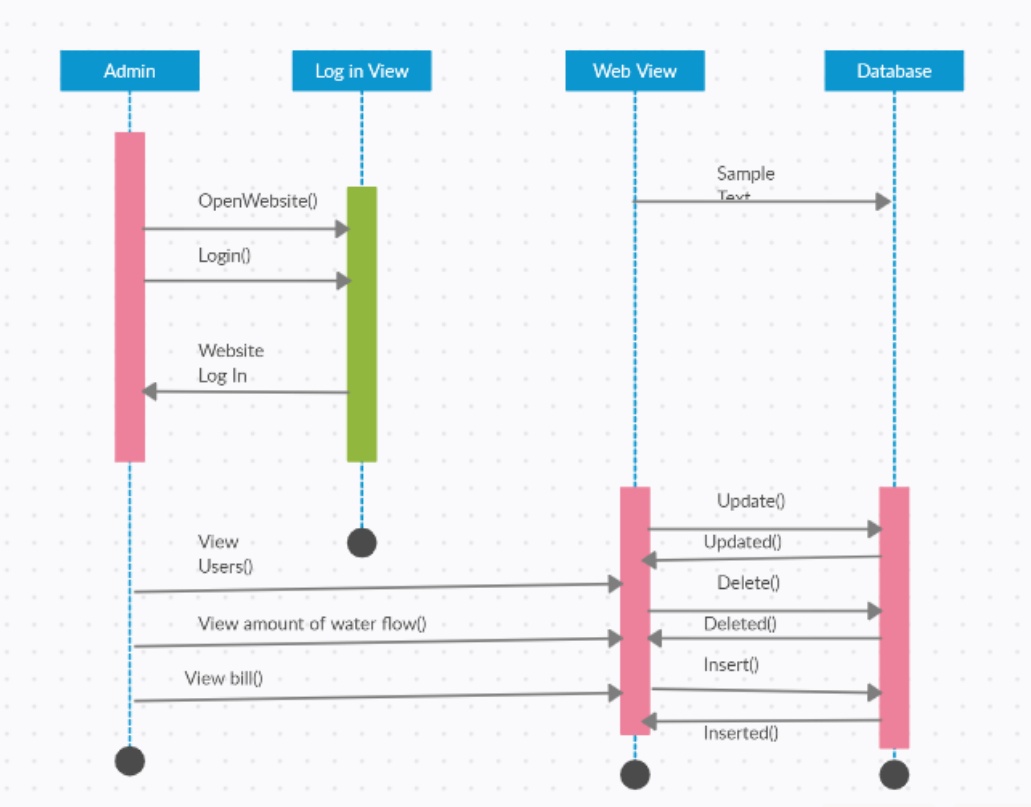


Figure 4.4: Process Interaction Diagram

3. Physical view:

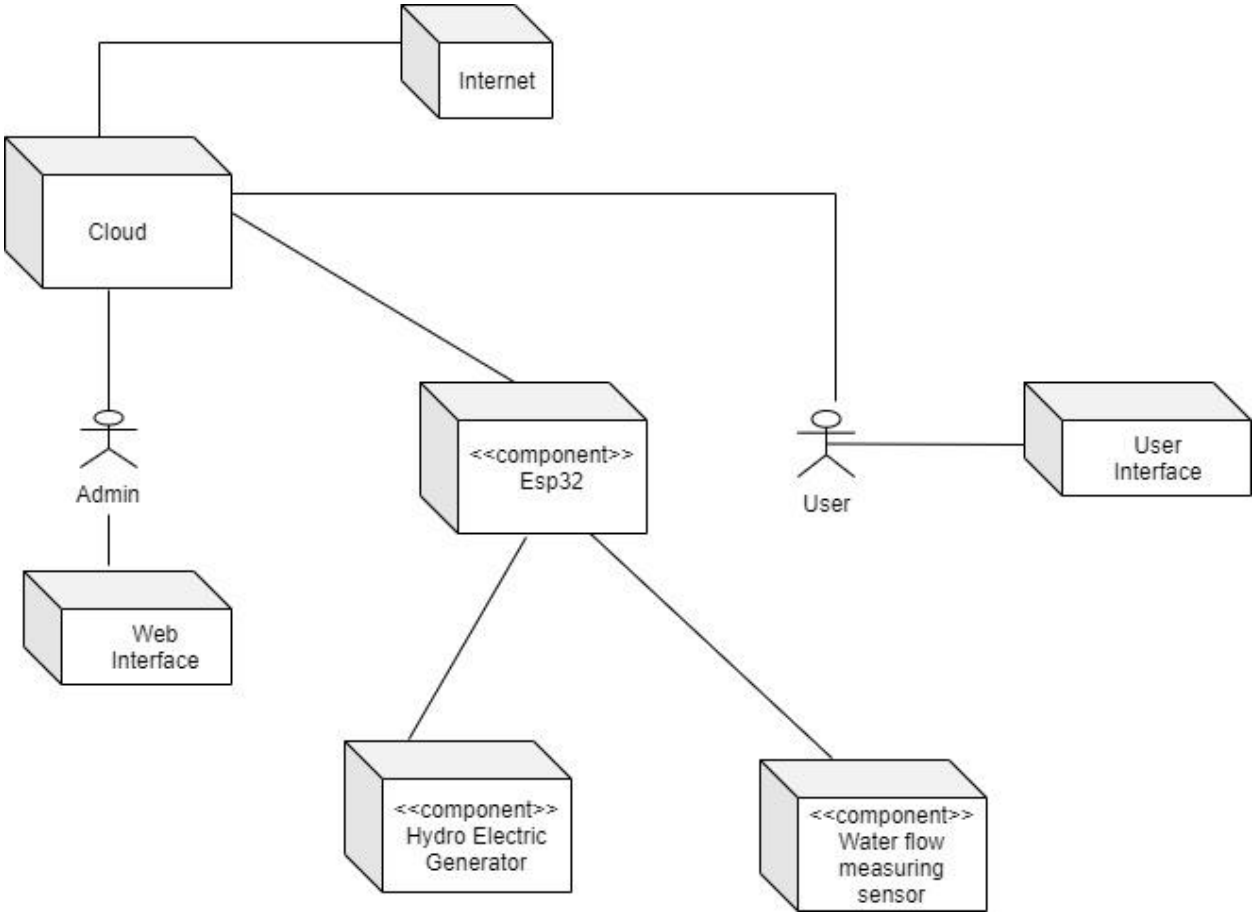


Figure 4.5: Deployment Diagram

4.5 Low Level Design

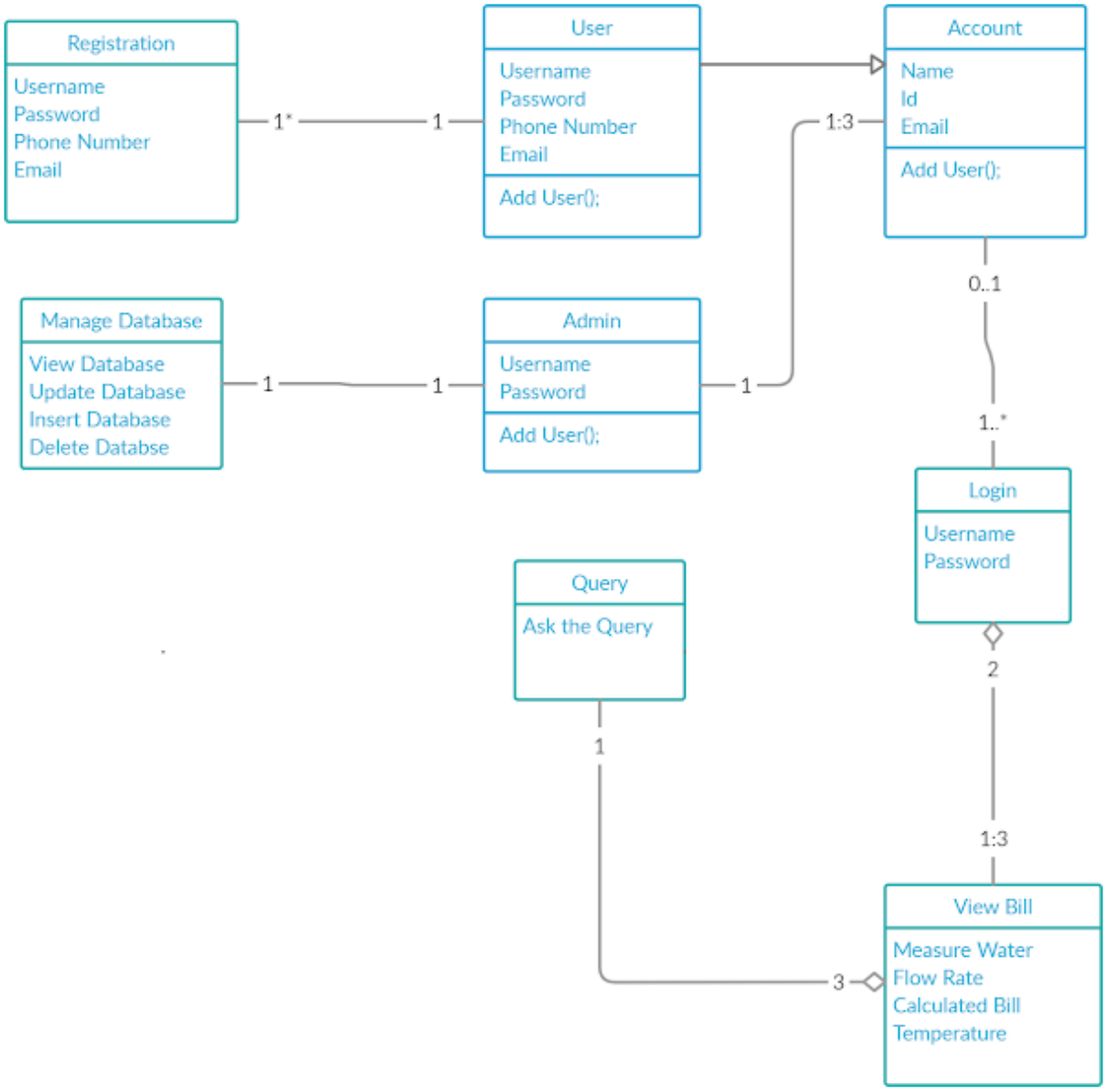


Figure 4.6: Class Diagram

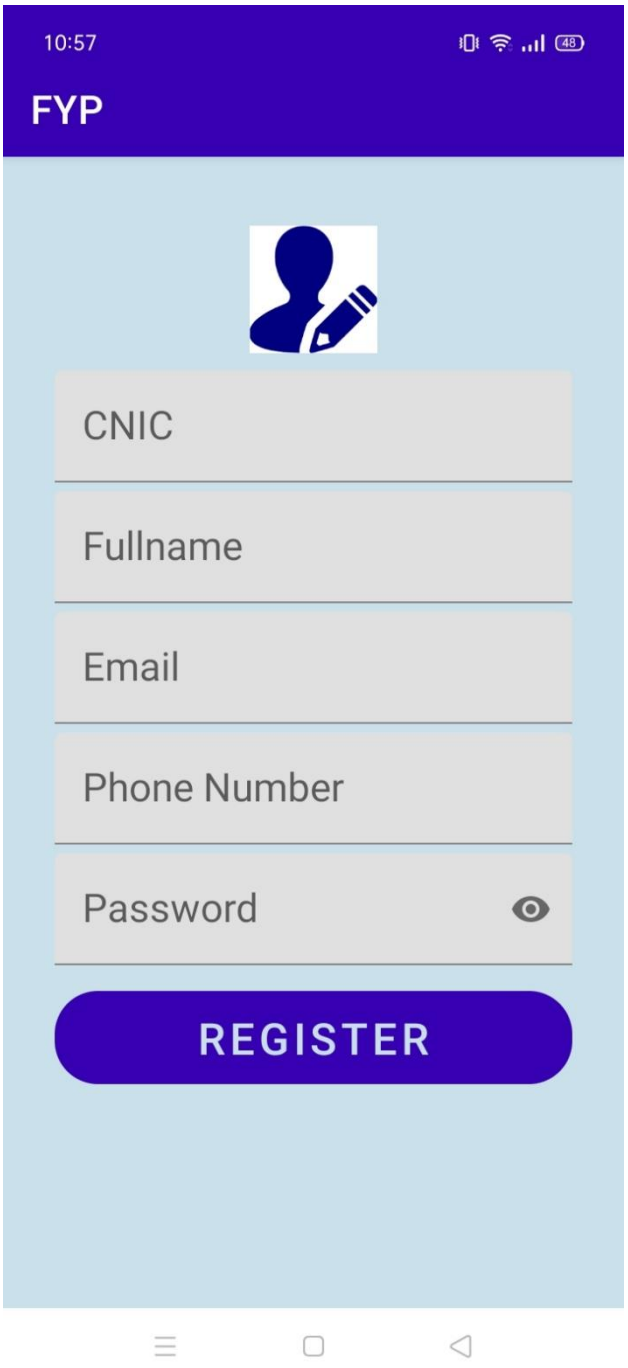
4.6 Database Design

We have used Firebase database, where all the information of user is saved. We are saving CNIC, Full Name, Email, Phone Number and password. We can insert new user, delete it, add a new user, or disable an account.

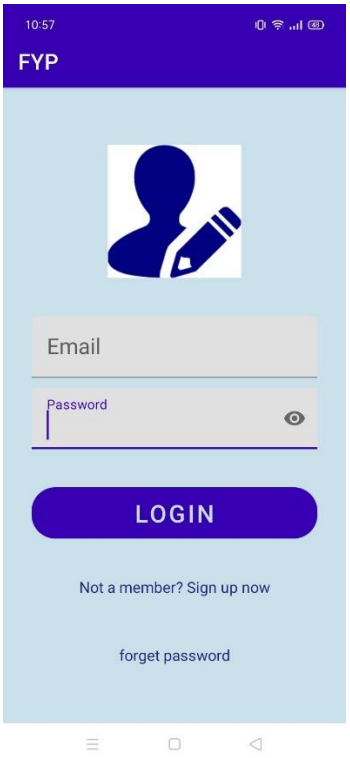
4.7 GUI Design

Design User Interface

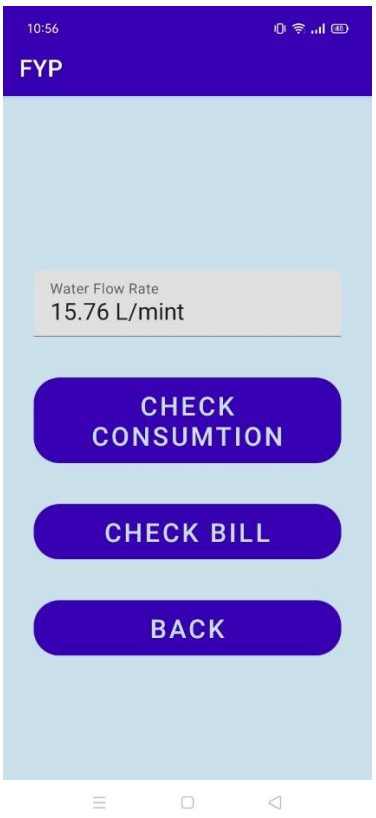
1. REGISTER ACCOUNT



2. LOGIN

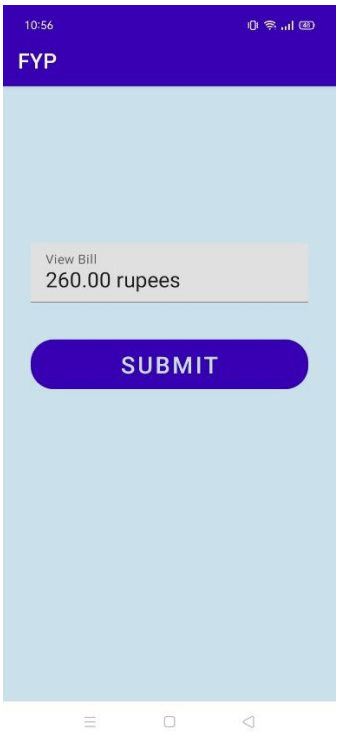


3. FLOW RATE



4. CONSUMPTION RATE

5. BILL



4.8 External Interfaces

Following are the external interfaces we used in our project:

Web Server

Microcontroller ESP (32) is sending data from the sensor to web server, where water flow rate, the water consumption rate and the calculated bill is shown according to amount of water passed through the pipe or used by the user.

User Application

The amount of water passed through the system or used by the user is shown to the user through an application. The water flow rate, the water consumption rate and the calculated bill is shown to the user as well.

Chapter 5

System Implementation

Implementation is the process of moving an idea from concept to reality. The System implementation is a realization of a technical specification or algorithm as a program, software component, or other computer system through programming and deployment.

5.1 System Architecture

- **F50 Micro-hydro DC Water Flow Pump Turbine Hydroelectric Power Energy Generator:**

  Description:

  The generator can produce 5v of energy through the flow of water. The output voltage of the generator is proportional to the pressure of water flowing through it.

  Features:

  - Made of high-quality material, durable in use.
  - Solid structure, low noise, stable working performance.
  - Smooth surface generator, no rust, no obvious scratch.
  - Compact size, light weight, easy to install.
  - The output voltage of the circuit without voltage regulator is proportional to the water pressure.

Figure 5.1: F50 Micro-hydro DC Water Flow Pump Turbine Hydroelectric Power Energy Generator

- **Water flow sensor (YF-S201)**
  YF-S201 Water Flow Sensor is placed inside the water pipe it contains a pinwheel sensor to measure how much water has passed through it. There is an integrated magnetic Hall-Effect sensor that generates an electrical pulse on every revolution. YF-S201 water flow sensor has only three wires and it can be easily interfaced between any microcontroller and Arduino board. It requires only +5V Vcc and gives pulse output.

Figure 5.2: Water flow sensor (YF-S201)

- **ESP32 Wi-Fi/Bluetooth wireless Microcontroller:**

  Esp. 32 has a built-in Wi-Fi module and it is used to get water flow rate values from the sensor and send them to the server using home Wi-Fi.

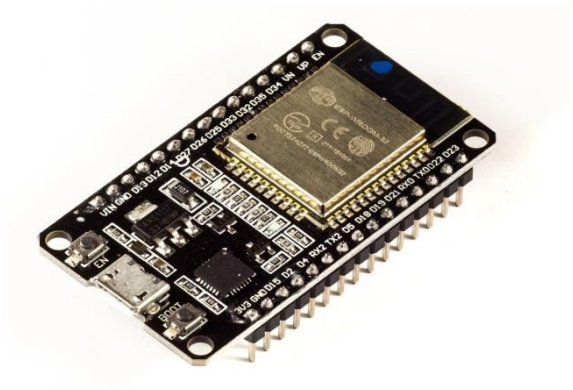


Figure 5.3: Microcontroller ESP(32)

- **Battery (mAh Li-ion 3.7V):**

  The battery is used to store energy produced by the generator and then this energy is used to charge the sensor and ESP(32).

Figure 5.4: Battery (mAh Li-ion 3.7V)

Chapter 6

System Testing and Evaluation

System testing of software or hardware is testing conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements. Be warned that many projects fall down through poor evaluation. Simply building a system and documenting its design and functionality is not enough to gain top marks. It is extremely important that you evaluate what you have done both in absolute terms and in comparison with existing techniques, software, hardware etc. This might involve quantitative evaluation and qualitative evaluation such as expressibility, functionality, ease-of-use etc. At some point you should also evaluate the strengths and weaknesses of what you have done. Avoid statements like "The project has been a complete success and we have solved all the problems associated with ...! It is important to understand that there is no such thing as a perfect project. Even the very best pieces of work have their limitations and you are expected to provide a proper critical appraisal of what you have done. The following are different types of testing that should be considered during System testing:

- **Graphical user interface testing**

  GUI of Web Server

  1) **Water Flow Rate**

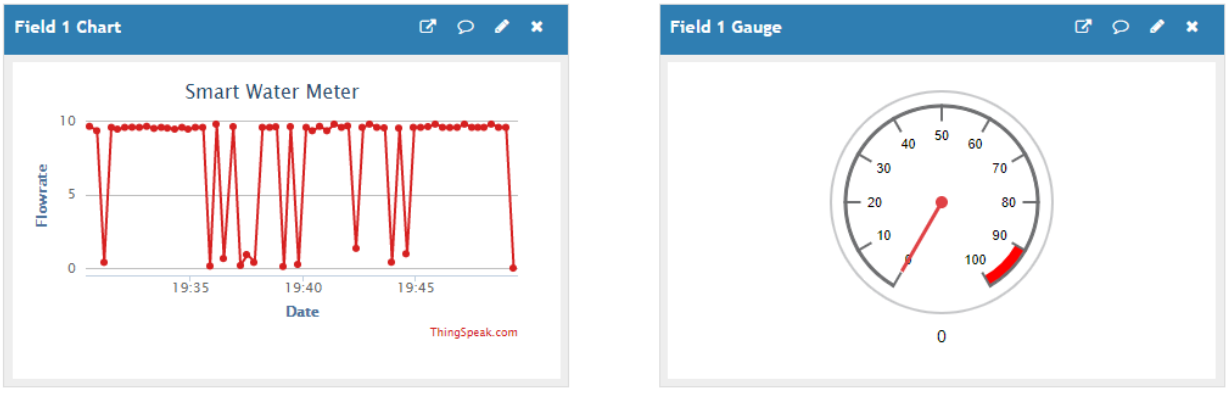


Figure 6.1: Water Flow Rate

2) Water Consumption Rate

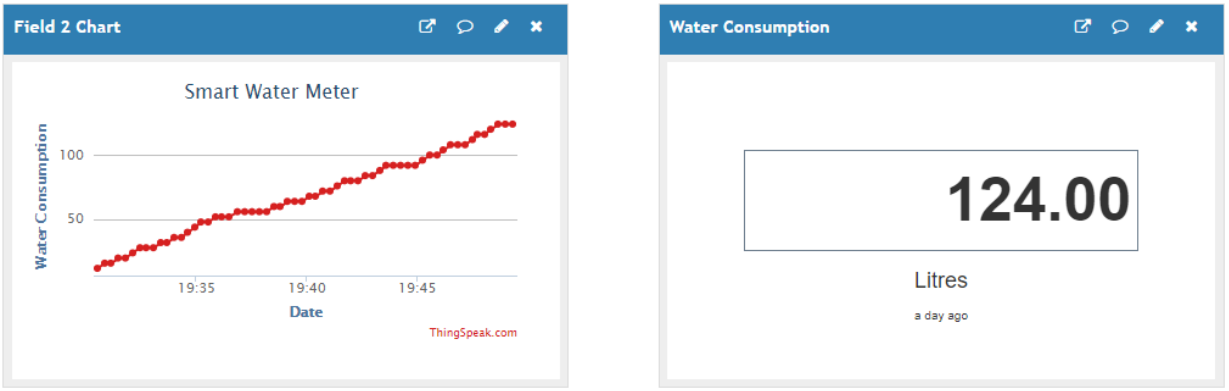


Figure 6.2: Water Consumption Rate

3) Calculated Bill

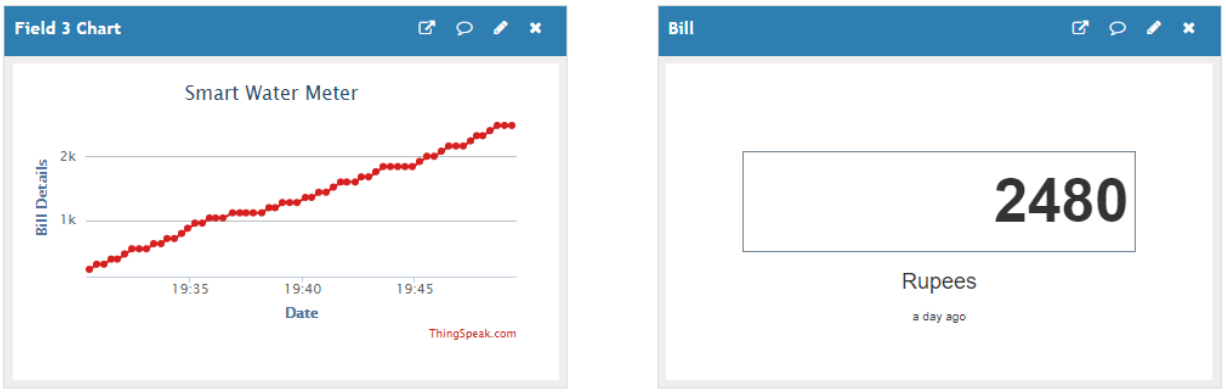


Figure 6.3: Calculated Bill

GUI of User App

1) Water Flow Rate

In this activity, user can see the water flow rate in milli liters.

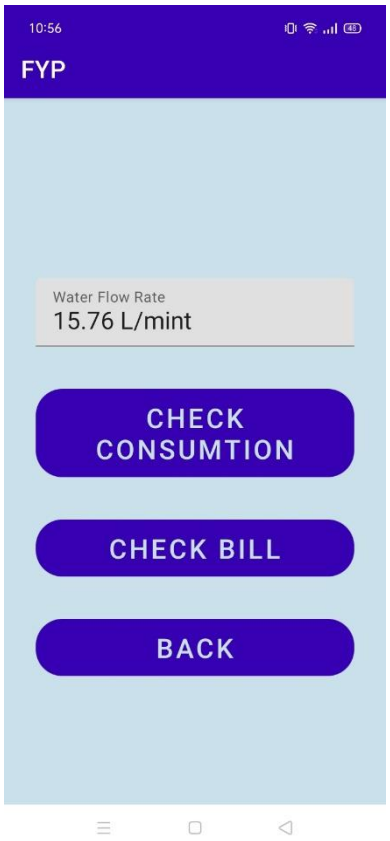


Figure 6.4: Water Flow Rate

Figure 6.5: Water Consumption Rate

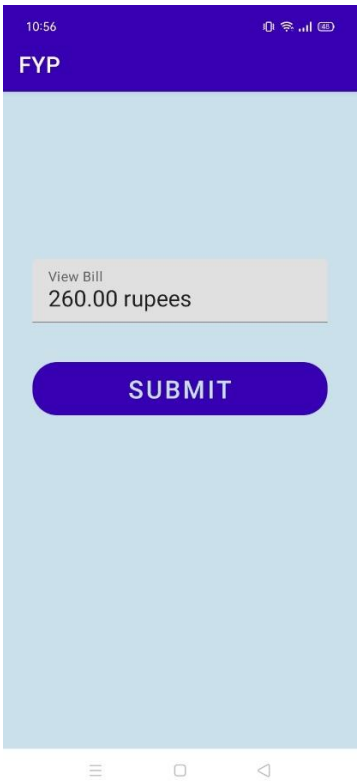


Figure 6.6: Calculated Bill

- **Usability testing**

The Water Flow monitoring system is easy to use. Application is made for users and Web server is designed for Administrators and all are simple to use.

- **Software performance testing**

  On the completion of our project, we have tested it to see the overall performance of the system. We have tested both hardware and software parts.

  Hardware Performance Testing:

- For hardware testing, first of all, we checked the performance of the Water flow sensor (YF-S201). We added 12 liters of water in a bottle and passed it through the sensor to see if it is sensing correctly or not. The results shown on the server were accurate.

- For the performance testing of the F50 Micro-hydro DC Water Flow Pump Turbine Hydroelectric Power Energy generator, we run the system once without attaching the generator and next time with the generator. In both cases, there was an obvious difference in the lifetime of the system. The case in which the generator was attached lifetime was much greater which means our generator is harvesting g a considerable amount of energy.

- Performance testing of the battery was also satisfactory it was able to store the energy produced by the generator and to charge the Esp 32 and the sensor.

  • Microcontroller Esp 32 was also able to receive data from the sensor and send it to the server.

- **Compatibility testing**

The Water flowing system is compatible with every household and any building. It is a 2ft long pipe with which our sensors and generator is connected. It has very low voltage and current value and therefore is not hazardous to the environment. This 2ft long apparatus works on Wi-Fi and hence can be connected to the main supply of water before distribution so it can monitor the whole water being used. It is 99% efficient in monitoring the water usage of any household or building.

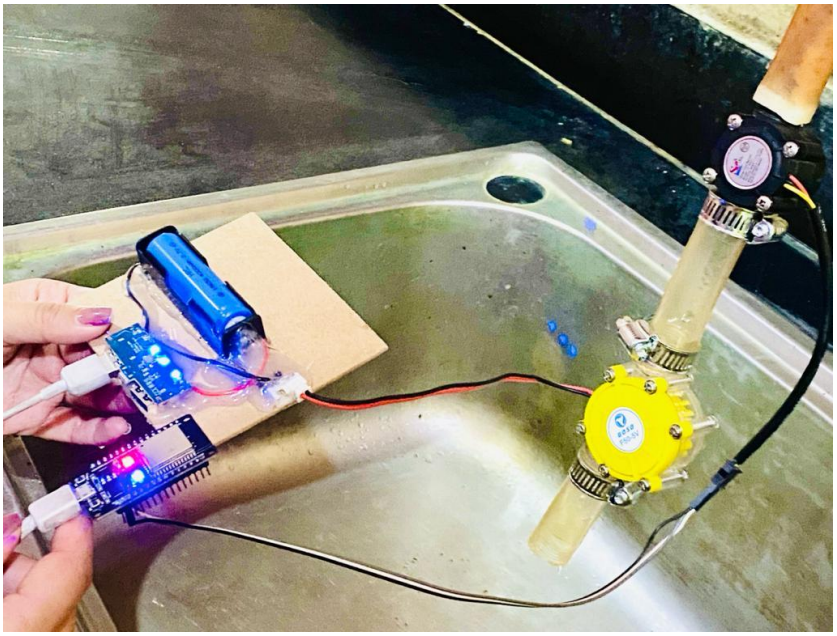


Figure 6.7: System Architecture

- **Load testing**

  Hardware testing:

  We tested our project with different rates of flow of water. We pass water from low to high rates, and it shows the exact amount of water that has passed through it even when the water flow rate was very fast.

  Software testing:

  We tested the web server and mobile application, no matter at what rate water is passed, it shows the accurate results. We flowed 12L of water through it and at different rates of flow of water, it shows the accurate results

- **Security testing**

We designed both the Web server and mobile application in a way that they are secure to use. There is no risk of data leakage on the server because of high security. It is able to show the correct data to the correct user. The credentials provided by the user on mobile application for the sign up are also highly protected only the user itself can see this data.

- **Installation testing**

After installing all the components and firmware into our system, we tested our project in real time. many tests were conducted to check the performance of our system. The tests and their resulted are listed below.

1. **Initial testing of project**

   We connected our system with kitchen tap to check the working of sensor and generator, we obtained the following results.

Liter of water used.	1	2	3	4
Generator Voltage produced (V):	3.4	3.5	3.3	3.6
Generator current (mA):	9.45	9.66	9.39	9.81
Water flow Sensor (Ltr) :	1	2	3	4

Table 6.1: results of test water flow sensor and generator on home tap.

2. **Testing with fast flowing water**

   To measure better values and working of our project we tested our project with fast flowing water from pump. The higher the pressure the greater voltage our generator will produce. We obtained the following results.

Liter of water used.	4	8	12	16
Generator Voltage produced (V):	4.8	4.9	4.8	4.8
Generator current (mA)	14.23	14.56	14.23	14.23
Water flow Sensor (Ltr):	4	8	12	16

Table 6.2: results of fast flowing water.

3. System life without generator supply

To check the lifetime of our project we conducted a test in which we charged our battery for different durations of time. we then ran our project without generator to see how long our battery lasts without being charged.

Battery Charging time (minutes)	Performance Time (minutes)
3	9.48

5	20.35
8	32.56

Table 6.3: Battery lifetime without generator.

From the results we conclude the battery (3.7V and 2400mAh) we have connected, can last up to 6877 minutes which is 4 days and 18 hours.

4. **System lifetime with generator:**
   By connecting the battery with the generator, we are charging the battery with voltage being produced by generator. This will charge our battery while it is being used and hence can increase its before being drained. The data we collected is listed below.

Battery Charging time (minutes)	Performance Time (minutes)
3	21.3
5	35.7
8	59.55

Table 6.4: Battery lifetime with generator.

From the results we conclude the battery (3.7V and 2400mAh) when connected with generator, can last up to 14212.8 minutes which is 9 days and 20.8 hours.

Chapter 7

Conclusions

The completion of our project “IOT based Sustainable Water Flow Monitoring System” took a time span of 14 months. Which consisted of research, testing and devoted efforts to create a secure system. The project was manufactured within safety limits and a series of tests were run to enhance its performance. The prototype manufactured is based on easy to use and replaceable parts, which allows easy repair and alteration in the system.
We draw the following conclusions from our work.

- Using small size product is portable and eases in installation.
- Water flow sensor monitors water flow in liters.
- Generator connected with supply line can also save energy and provide free charging to the system.
- Remote access to the system provides easy monitoring of water consumption.
- ESP (32) provides fast and reliable data transfer and accurate values.
- Readings of water flow rates and water consumption rates are shown both to admin through web server and user through an App.
- Water flow rates and water consumption rates are also shown in graphs.
- Users are provided with App where they can see water flow rates and water consumption rates and calculated bill.

Appendix A

User Manual

Software Interface

Application User Interface:

On opening the application, the first interface is to register the new users of the application. Users can register themselves by filling in the following field's data.

1. CNIC
2. Full name
3. Email
4. Phone Number
5. Password (password should be strong)

And then can click the 'Register' Button.

Next is the login page here a user who already has registered himself can enter his email and password to further use the application. If the user has forgotten the password there is an option to reset the password by clicking on the 'Reset Password' button.

On login the application shows:

1. Water Flow Rate

Next, there is an option to View ‘Consumption Rate’ and 'Pay Bill'. User can select any of the options.

Web Server Interface:

On the ThingSpeek server, we have created private channels; first of all, the user needs to signup on to the server and selects a private channel where he/she can see:

1. Water Flow Rate
2. Water Consumption Rate
3. The total amount of water consumed

4. Calculated Bill

Hardware Interface

To connect the hardware, check whether all components are present. Then follow the following procedure.

1. Connect water flow sensor and generator with pipe with the arrow facing pointing towards the outflow side of water.
2. Connect the pipe with main power supply with water sensor coming first and then generator.
3. Make the connections of water flow sensor with ESP.
4. Connect the generator with the battery supply so that it charges our battery.
5. Before placing the battery be sure to fully charge the battery.
6. Turn on the device and check the results on software interface.
7. Wait for 3-5 minutes for the system to start up.
8. In case of any issue Boot the System, if issue is not resolved then contact the producer.

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