A PROJECT REPORT ON

"A Real Time Flood Monitoring and Warning System Via Social Media using IoT and Wireless Networks"

SUBMITTED TO THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

BACHELOR OF ENGINEERING
(COMPUTER ENGINEERING)

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ACADEMIC YEAR 2019-20

CERTIFICATE

This is to certify that the Project Entitled

A Real Time Flood Monitoring and Warning System Via Social Media using IoT and Wireless Networks

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is a bonafide work carried out by them under the supervision of **Prof. J.Y. Kapadnis** and it is approved for the fulfillment of the requirement of Savitribai Phule Pune University for the award of the Degree of Bachelor of Engineering (Computer Engineering). This project report has not been earlier submitted to any other Institute or University for the award of any degree or diploma.

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ACKNOWLEDGEMENT

We sincerely express our deep sense of gratitude towards our respected guide **Prof. J.Y. Kapadnis** and Head Of Department **Prof. J.A. Dandage** for his valuable guidance, profound advice, persistent encouragement and help during the completion of this work. His time to time helpful suggestions boosted us to complete this task successfully. He has helped us in all possible ways right from gathering the materials to report preparation. We express our thanks to our guide and Project coordinator for providing all kinds of co-operation during the course. Our sincere thanks to the Principal **Dr. R.L. Edlabadkar** for his inspiration. Finally, we are thankful to the supporting staff of Computer Engineering department and all those who directly or indirectly contributed to complete this work. We sincerely thank you to our project co-ordinator **Prof. M.T. Jagtap** for guiding us.

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ABSTRACT

Flood is the most significant disaster happened in almost every part of the world. When the event occurred, it causes great losses in economic and human life. Implementation of the advancement of ICT brings significant contribution to reduce the impact of flood toward the people and properties. This paper attempts to investigate the capability of internet of things (IoT) technology in reducing the impact of natural disaster specifically in flood disaster scenario. First, the concept of Internet of Things (IoT), key technologies and its architecture are discussed. Second, related research work on IoT in disaster context will be discussed. Third, further discussion on the propose Internet of Things (IoT) architecture and key components in the development of flood prediction and early warning system. The smart sensors will be placed at river basin for real-time data collection on flood related parameter such as rainfall, river flaw, water level, temperature, wind direction and so on. The data will be transmitted to data centre via wireless communication technology which will be processed and measured on the cloud service, then the alert information will be sent users via smart phone. Thus, early warning message is received by the people in terms of location, time and other parameters relate to flood.

Keywords:- *flood,disaster management, nodemcu, social media alerts, ultrasonic sensor, mqtt.*

LIST OF ABBREVATIONS

- 1. Iot:- Internet of Things
- 2. SDK :- Software Development Kit
- 3. SRS:- Software Requirement Specifications
- 4. API:- Application Programming Interface
- 5. FLWL:- flood-limited water level
- 6. IIS:- Integrated Information System.
- 7. ANN:- Artificial Neural Network.

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Chapter 1

Introduction

Flood is the biggest natural disaster happens in worldwide without prior warning. Floods will damage the crops, cars, buildings, homes and anyone in their path. Reservoir is the most efficient tool to save the water resource; Reservoirs are serving for different purposes in spatial and temporal method such as a hydropower generation, flood control, navigation, ecology and recreation. The flood-limited water level (FLWL), is the parameter to manage between the flood control and conservation, from that the annual maximum value is determined. It is done mainly according to design flood estimation flood series, while it neglects seasonal flood information. At present, many research works on IoT in disaster domain have been conducted. This section will provide a summary on research works that implement IoT technologies for addressing natural disasters. IoT technologies give benefits in terms of monitoring, tracking, controlling and sensing the environment using real time data. The use of IoT to improve environmental monitoring and management tasks. The results from their case study demonstrate that the Integrated Information System (IIS) based on IoT is valuable and efficient for complex tasks in environmental monitoring and management.

The use of IoT technologies in tackling the complexity in monitoring the flood specifically using rain gauges. IoT provides an interface for data streaming management in real time and at the back end provide data analysis and visualization. In this approach the data collected will be continuously transmitted via the Internet communication infrastructure, to the software components. The software components are designed to compute the stream flow and to quantify the spatial distribution of flood risk for each controlled watershed. The use of IoT and machine learning based embedded system to predict the probability of floods in a river basin. To develop A Real Time Solution to Flood Monitoring Using IoT and Wireless Sensor Network, we proposed a flood warning system which requires attention to three basic factors: Data collection via gaging, data processing, and the hardware and software required, and the dissemination of flood warning information. While automated flood warning systems are often surprisingly inexpensive to implement, the primary factor determining cost for any such system is the number of gage site locations. Severe flooding affected Indian state of Kerala due to unusual high rain during monsoon season. It was the worst flooding in Kerala in nearly a century. In which over 373 people died within fortnight. Thirty-five out of 42 dams within the state open for the first time in history. Kerala received heavy monsoon rainfall on the midevening of August and resulting in dams filling to capacity in the first 24 hours of rainfall the state received 310 mm of rain.

1.1 Motivation

In the current year i.e. 2019 maharashtra and kerala states faces several flood situations; in which many districts and millions were affected by the flood. Kolhapur , Pune and Nashik district mainly faces flood situation during the July, august and September month. Millions were affected by the situation. So many lost their lives and day to day life is disturbed and destroyed. This can be overcome by providing early warning of upcoming disaster by using available resources. Our main aim of this proposed system is to avoid upcoming disastrous situation by alerting those people who are going to face such situation. The People who faces flood situation mostly located nearby river bank. In the current year nashik mega flood level raised up to 25 to 30 feet. In Kolhapur district most of rural and urban areas were underwater.

1.2 Problem Definition

To design and develop a real time system that sense rising water level of river basin by using sensors which is going to transfer and store to database ; and as per condition a warning message is going to deliver to those people who's going affected by such situation.

Chapter 2

Literature Survey

[1] DIAO YanFang WANG BenDe ,Risk analysis of flood control operation mode with forecast information based on a combination of risk sources.Sci.China Tech. Sci.MAY 2008.

In flood control operations with forecast information, the hydrological risk comes mainly from the uncertainty of flood, which is represented by the uncertainty of flood process. A flood process includes flood volume, peak inflow and flood duration, which are apparently random variables in which the flood volume plays a major role in flood control. The first uncertainty is due to the reservoir storage change caused by sediment erosion and deposition, backwater storage, errors of measurement and other factors. The second uncertainty results from the instability in critical water levels of all designed frequencies. For instance, restricted by an approved designed flood level, when the highest water level is within this level, the reservoir might be at risk due to the poor stability of the dam.

[2]Ruan Yun, Vijay P. Singh ,2008, Multiple duration lim- ited water level and dynamic limited water level for flood control, with implications on water supply. Jour-

nal of Hydrology (2008) 354, 160 170.

Flood disaster mitigation should be based on a comprehensive assessment of the flood risk. This requires the estimation of the flood hazard (i.e. runoff and associated probability) and the consequences of flooding (i.e. property damage, damage to persons, etc.). "Flood Risk Analysis" investigated the complete flood disaster chain from the triggering event down to its various consequences. The working group developed complex, spatially distributed models representing the relevant meteorological, hydrological, hydraulic, geo-technical, and socio-economic processes. The proposed model concept is useful for the integrated assessment of flood risks in flood prone areas, for cost-benefit assessment and risk-based design of flood protection measures and as a decision support tool for flood management.

[3]**Azimah Abdul Ghapar, Salman Yussof and Asmidar Abu BakarAzimah Abdul Ghapar, Salman Yussof and Asmidar Abu Bakar,2018, Internet of Things (IoT) Architecture for Flood Data Management.Vol. 11,No.1(2018)**

In the developed system, a model is designed for monitoring the environmental parameters which has the ability to be used for flood disaster prediction.The environmental parameters like temperature, relative humidity, atmospheric pressure, rainfall etc. are sensed by an array of sensors and the measured data is sent to the microcontroller via Wi-Fi.A flood event is predicted beforehand using ANN model and it alerts the people for upcoming disaster according to the increase of rainfall and corresponding water level rising of the low-lying areas near river flow area. The amassed device data is uploaded to cloud database and the information is shared to the people over the smart phone in the form of SMS or tweet notifications. .

[4]**Nur-adib Maspo, Aizul Nahar Harun, Masafumi Goto, Mohd Nasrun Mohd Nawi, Nuzul Azam Haron, 2019,Development of Internet of Thing (IoT) Technology for flood Prediction and Early Warning System (EWS), vol-8 Issue-4,Feb-19**

The smart sensors will be placed at river basin for real-time data collection on flood related parameter such as rainfall, river flaw, water level, temperature, wind direction and so on. The data will be transmitted to data centre via wireless communication technology which will be processed and measured on the cloud service, then the alert information will be sent users via smart phone. Thus, early warning message is received by the people in terms of location, time and otherparameters relate to flood.

[5]**Simon Haykin, Neural Networks A Comprehiensive Approach.**

We have utilized a wireless sensor network (WSN) to collect data and used a linear regression model with multiple variables for real-time and accurate flood prediction results. Increase in water level indicates flood if it exceeds the flood line.

[6] **G. Furquim, F. Neto, G. Pessin, Jo Ueyama, J. P. De Albuquerque, Combining Wireless Sensor Networks and Ma- chine Learning for Flash Flood Nowcasting, IEEE, 2014.**

The destruction of ecosystems in urban areas, caused by several types of pollution and irregular housing, has had a serious effect on the environment and altered the local climate, resulting in an increase in the number of natural disasters. This has led to physical damage and financial problems caused by material and human losses in large urban areas. We have been attempting to build a Wireless Sensor Network (WSN) to collect measurements from a river located in an urban area which in turn allows the WSN to give alerts to the local population. The results show that different data representation can lead to results significantly better for different stages of nowcasting.

[7]Nur-adib Maspo, Aizul Nahar Harun, Masafumi Goto, Mohd Nasrun Mohd Nawi, Nuzul Azam Haron, Development of Internet of Thing (IoT) Technology for flood Prediction and Early Warning System (EWS) ,Feb-2019, ISSN:2278-30375,Vol-8 Issue-4,Feb-2019.

For flood disaster, information on hydrology such as rainfall, water level, flow discharge and other components such as wind and temperature, etc. are required to be collected, processed and measured to generate a meaningful information which will be used for flood prediction and disseminate early warning information. With IoT enable devices like sensors, information can be quickly acquired, analysed and communicate in real-time. related parameters such as WSNs collect water level and water flow data. Weather station collects temperature, wind speed and direction. Thus, the compound of sensors and their autonomous coordination with well manage in data processing, analysis and display the useful information to be understandable by community people would help to predict the occurrence of flood disaster and send the early warning to people to take appropriate and effective actions before disaster occurs.

[8]P. Mitra, R. Ray, R. Chatterjee, R. Basu, P. Saha, S. Raha, R. Barman, S. Patra, S. Saha Biswas and Saha, Flood forecasting using Internet of things and Ar- ti-

ficial Neural Networks, Information Technology, Electronics and Mobile Communication Conference, IEEE, 2016.

The Internet of Things (IoT) is one of the major technological trends which is utilized to monitor natural and human made resources to help in predicting and detecting exigence events like flood, fire, gas and water leak that can pose an intimidation to human life. This paper proposes a novel wireless prototype of a live weather monitoring station that uploads weather information received from the array of sensors to cloud database from a remote location which can be monitored from anywhere. The weather data is recorded, monitored and processed to forecast the different weather events and predict the upcoming disasters. The proposed battery powered cost-effective system can be installed anywhere within a locality or building to serve the maximum people. Instant alert messages will be received to phone via text, e-mail and social media notification through this web application. The user can view weather forecast for his location that he can share with the entire world.

Chapter 3

Software Requirement Specification

3.1 Introduction

3.1.1 Project Scope

This flood alert system is basically useful to get idea about flood in forecast to do the sensing of the incoming water level for detection of flood is done by implementing sensors. In this way water level will be sensed by the sensor and concerned messages will be given to the controller then it will take the further action on that command.

3.1.2 User Classes and Characteristics

1. User:-

The user is the authority will monitor the system by using the website. The system will notify the user using text and mails. The user is may be the municipalty officer or any other higher authority who will maintain the sewage system of the city.

2. NodeMCU:-

NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the development kits. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects.

3.Cloud System:-

The Cloud system is storage where we can store our data coming from sensors like ultrasonic sensor and water level sensor. The cloud system will display the readings using the website.

4. Sensors:-

The sensors will play the main role in this system. The sensors include the ultrasonic and water level sensor which will read the input coming from the drainage system and send this readings to nodeMCU.

3.1.3 Assumptions and Dependencies

1. We have interface board for each device we want to control.
2. The system has an inteface to our central computer.
3. We have internet and wireless connections in our project.
4.We have all kinds of sensors which we need in the project.
5. We have GUI application and Database to manage and store the configuration for devices.
6. We have enough data acquisition, I/O and corresponding drivers.

3.2 Functional Requirements

1. Administrative functions:-

This system should provide the administrative functions like registration and login for normal users.

2. Authentication:-

Thr proposed system authenticate user by their username and password for security reasons.

3. External Interfaces:-

The system should provide the interface to other systems for external system for better performance.

4. Historical Data:-

For performance improvement we have to store the historical data of the system so that we can compare the performance of system.

3.3 Extrenal Interface Requirements

3.3.1 User Interfaces

The web based application is used to communicate with the system.

3.3.2 Hardware Interface

The computer system is used to control the system.

3.3.3 Software Interface

We need the Textlocal API for the text message alerts for users.

3.3.4 Communication Interface

The http protocol is used as communication protocol for this system.

3.4 Nonfunctional Requirements

3.4.1 Performance Requirements

The system should have a high throughput.It should handle complexity. The response time of the system should be minimum. System must be user friendly so, that user interaction will be smooth and efficiency increases.sample user logs should be analyzed properly. system classification should be done properly in less amount of time.system recommendation should be accurate enough that satisfy the user.

3.4.2 Safety Requirements

The system should have a high throughput.It should handle complexity. The response time of the system should be minimum. System must be user friendly so, that user interaction will be smooth and efficiency increases.sample user logs should be analyzed properly. System classification should be done properly in less amount of time.system recommendation should be accurate enough that satisfy the user.

3.4.3 Security Requirements

1. Working must be in formatted way.
2. No losses or causes due to the use of this system.

3.4.4 Software Quality Requirements

1. Adaptability:

Proposed System can be adapted easily to various operating environments.

2. Availability:

Can easily execute on currently available minimum configuration of hardware and software.

3. Correctness:

It will work correctly according to the valid input requirements.

4. Usability:

This system used in different mobile phones or any device.

3.5 System Requirements

3.5.1 Databse Requirements

The database required in this system is stored on the cloud. We store the historical data on cloud for future use.

3.5.2 Software Requirements

- Ardiuno IDE
- Google API
- Textlocal API
- Php Myadmin
- HTML,CSS

3.5.3 Hardware Requirements

- **NodeMCU ESP8266 12E :-** The ESP8266 module is developed by the espressif company to transfer the data wireless. The ESP8266 consists of the Wi-Fi module with integrated TCP/IO protocol stacks. ESP8266 is a low-cost wireless system which works on the AT commands.

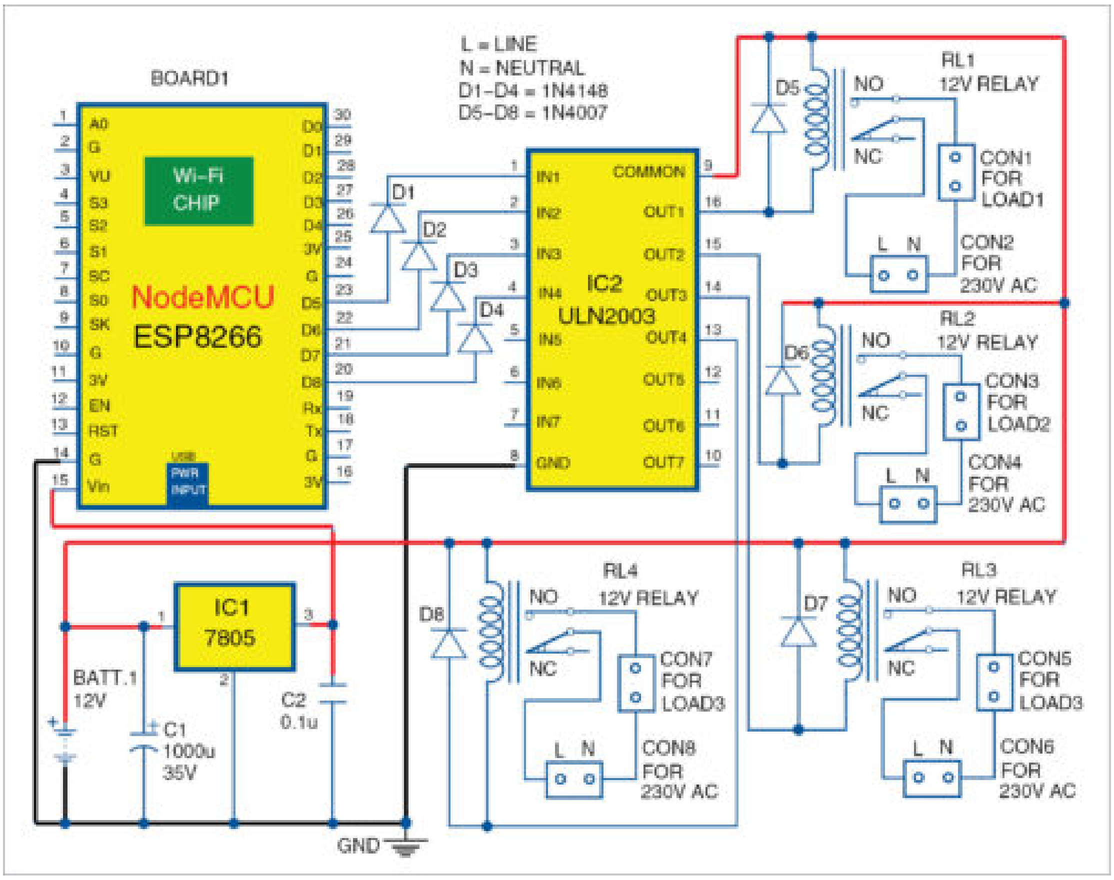


Figure 3.1: NodeMCU Circuit Diagram-1

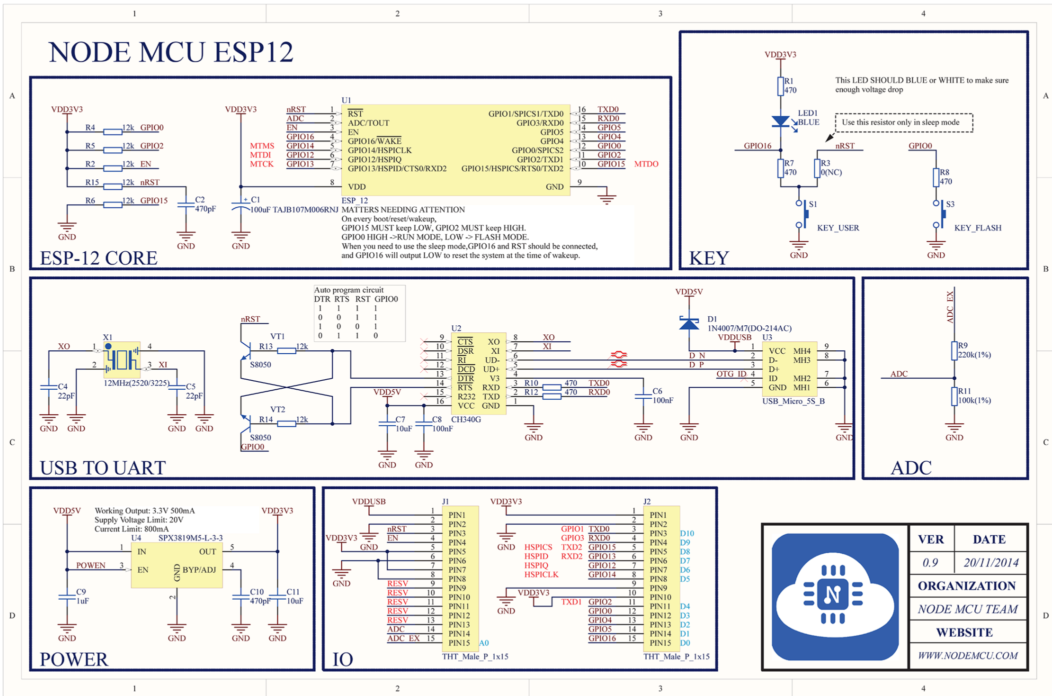


Figure 3.2: NodeMCU Circuit Diagram-2

- **Ultrasonic Sensor :-** Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules include ultrasonic transmitters, receiver and control circuit. The basic principle of work Using IO trigger for at least 10us high level signal. The Module automatically sends eight 40 kHz and detect whether there is pulse signal back. IF the signal back, through high level, time of high output IO duration is the time from sending ultrasonic to returning.

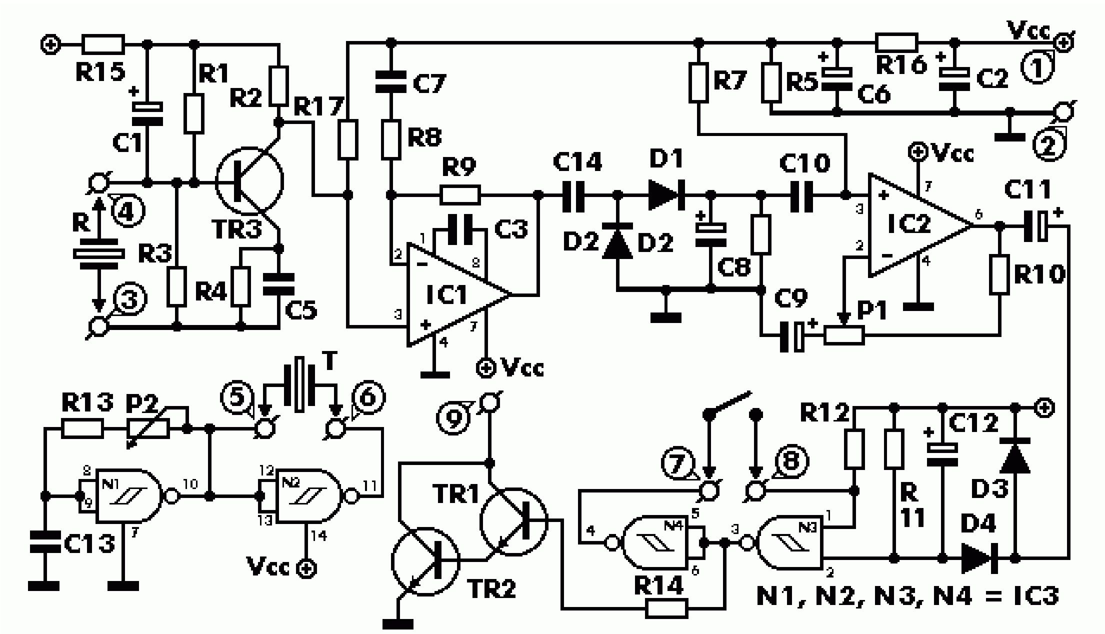


Figure 3.3: Ultrasonic Sensor Circuit Diagram

- **Water Level Sensor :-** Level sensors detect the level of liquids and other fluids and fluidized solids. The level measurement can be either continuous or point values. Continuous level sensors measure level within a specified range and determine the exact amount of substance in a certain place, while point-level sensors only indicate whether the substance is above or below the sensing point. Generally, the latter detect levels that are excessively high or low.

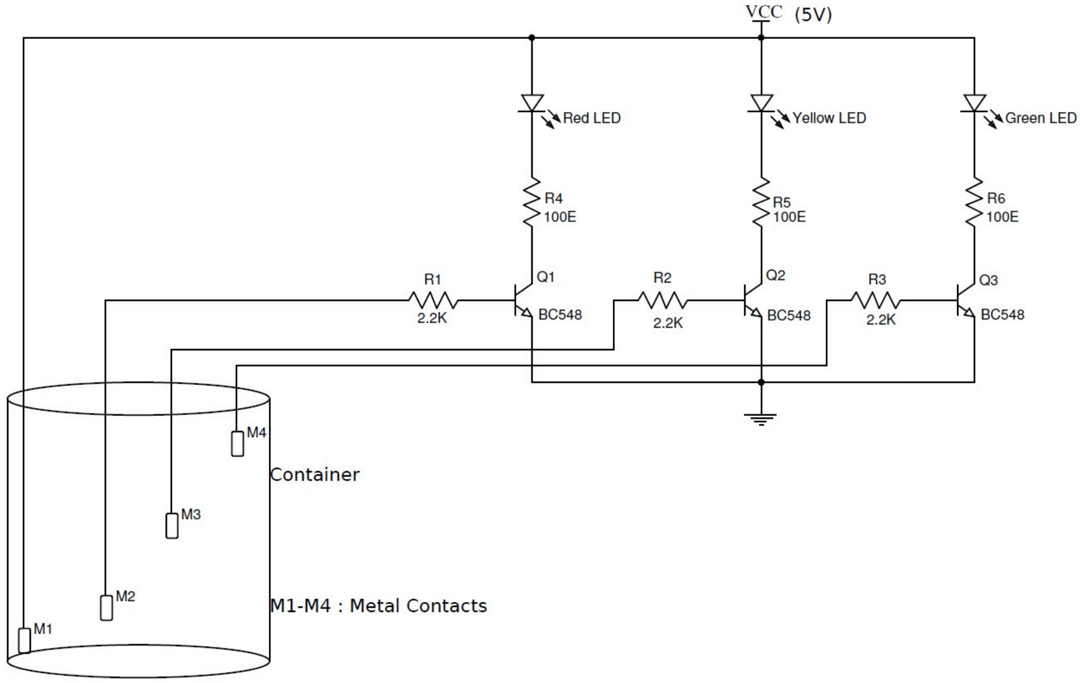


Figure 3.4: Water Level Sensor Circuit Diagram

- **Water Flow Sensor :-** The Water flow sensor gives the reading of the flow of water; whether it is in safe rate or not.

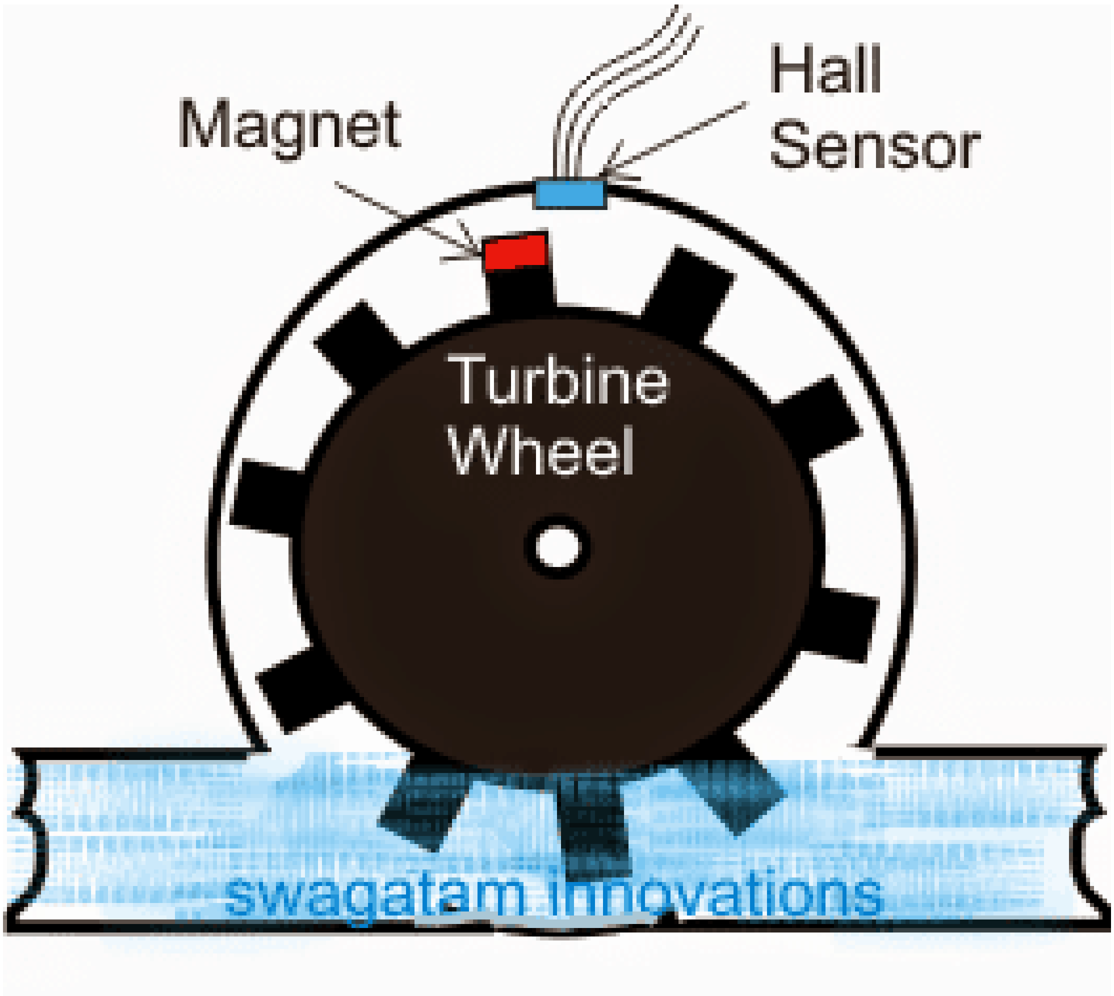


Figure 3.5: Waterflow Sensor Circuit Diagram

- **Temp Sensor :-** This sensor is used to measure change in atmospheric temperature and humidity. For this we are using sensor which works on one wire protocol and gives digital output.

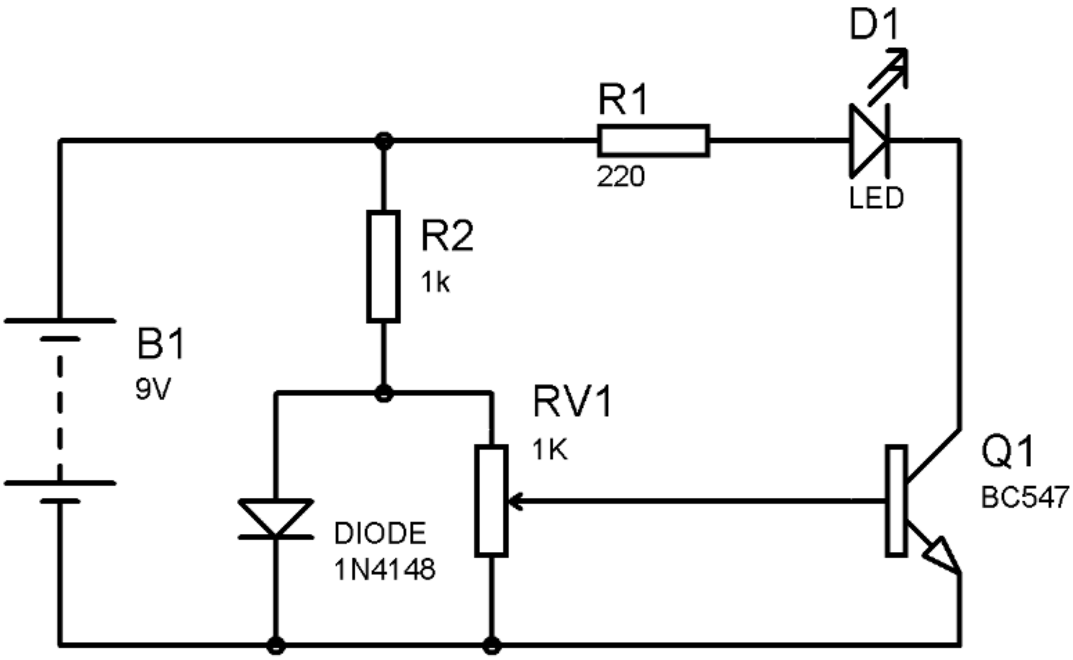


Figure 3.6: Temperature Sensor Circuit Diagram

- **A Working Computer System :-** Through the computer system we control the proposed system and the web application. It's minimum requirement is 4GB RAM,500 HDD, Core i3 or greater processor.

Chapter 4

System Design

4.1 System Architecture

1. There will be a node as shown in above diagram.
2. This node is the independent flood monitoring node equipped with necessary sensors and connectivity modules.
3. It has three major stages, Including Sensors, Controller, Wi-Fi interface to upload the information on server.
4. Data from various sensors are collected by the ESP and is then computed and uploaded on the server.
5. The data uploaded on server is stored on the database.
6. The stored data is then routed to the front end web applications and mobile applications.

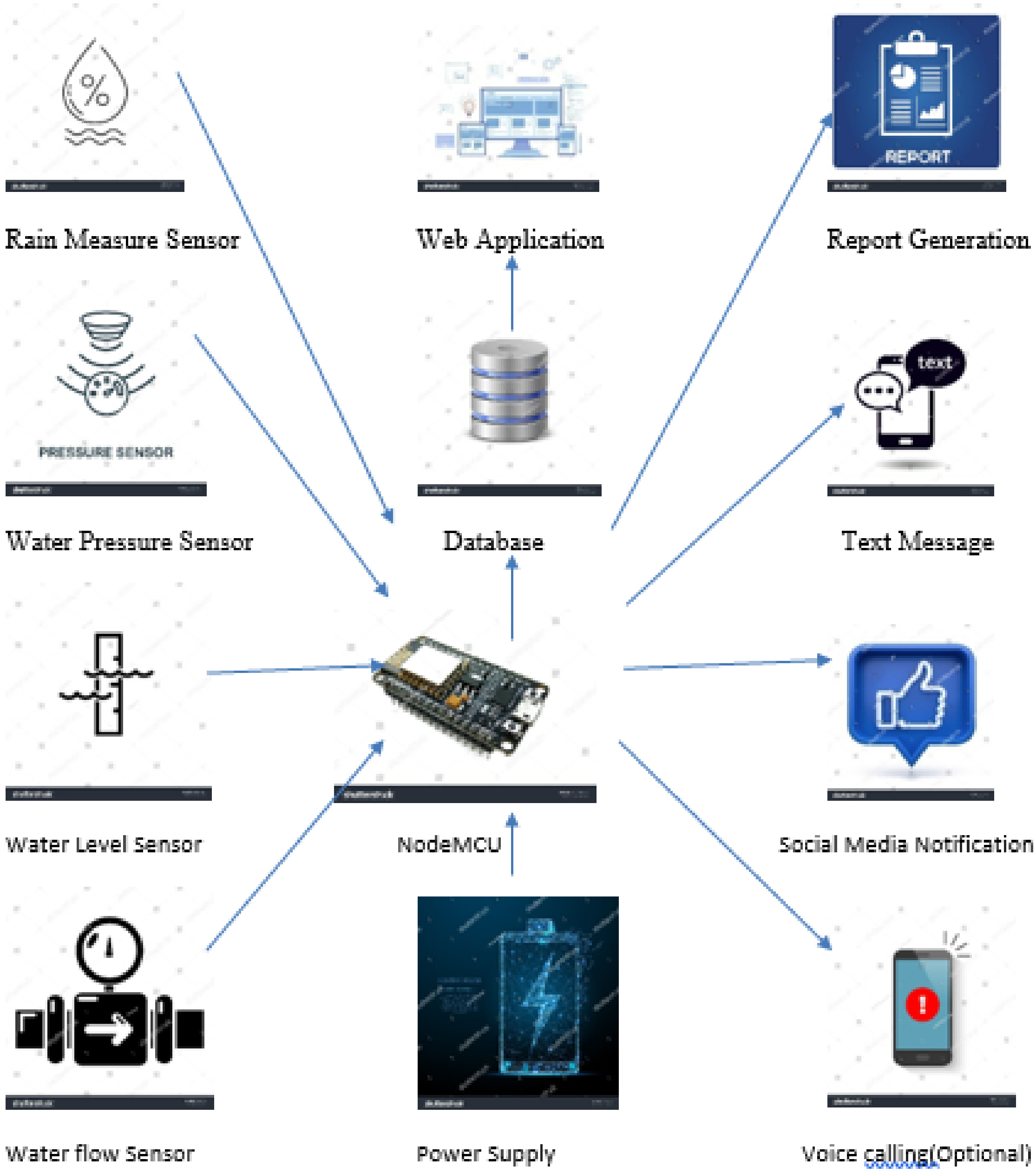


Figure 4.1: System Architecture

4.2 Working of the Proposed System

IoT technologies give benefits in terms of monitoring, tracking, controlling and sensing the environment using real time data. An introduction of the use of IoT to improve environmental monitoring and management tasks [11]. The results from their case study demonstrate that the Integrated Information System

(IIS) based on IoT is valuable and efficient for complex tasks in environmental monitoring and management. The use of IoT technologies in tackling the complexity in monitoring the flood specifically using rain gauges [12]. IoT provides an interface for data streaming management in real time and at the back end provide data analysis. In this approach the data collected will be continuously transmitted via the Internet communication infrastructure, to the software components. The software components are designed to compute the stream flow and to quantify the spatial distribution of flood risk. Use of IoT and machine learning based embedded system to predict the probability of floods in a river basin.

Some Features we are going to implement in the proposed system are as follows: -

1) We are doing continuous monitoring of the river water level and record its data into relevant database.

2) Also we are monitoring the water level of the dam which is concerned with that particular region or provinces.

3) If due to heavy rain fall into that particular region or continuous rain into that region the administration authority release or discharge the water from the dam (Measures mostly in Cusec and Cumec); Then with the help of proposed system, we can calculate approximate level that is going to up rise into normal water level.

4) When heavy quantity of water discharged from the dam at that time warning message will be delivered to those people who having residence nearby river bank as well as the government authority who is responsible for help and relieve duties like municipal corporation and fire and rescue department.

5) If a consider a situation where a flood zone having active electricity supply or the flood water contains high voltage electricity (greater than 440 volts A.C.) then we deliver a message to the victims as well as the help and rescue department along with the local government like municipal corporation.
6) An advance module we are going to add into proposed system is that we are going to collect acknowledgement from the victims or the people to them we are going to deliver the warning message. Acknowledgement is collected by receiving and measuring the reply message that we have broadcasted. By comparing both data we an easy find out who is trapped into and need evacuation and help.
7) This acknowledgement report is going to submit to government authorities to help them start them relieve operation for the flood victims.
8) An additional module is going to add is to detect land movement to nearby to high climbed or ridge zones to detect landslides. This used to help rescue lives before such disaster occur. Each city contains such kind of zones which needs to monitor on continuous basis. In heavy rainfalls landslides can be occur without any kind of warning and causes very big impact in the form of lives and wealth casualties.
9) If water increases rapidly and it is going higher than he road level of the bridge or the water level goes higher than the bridge then the alert message is delivered that the particular that bridge closed for vehicles and to the government authorities as well as on the social media platforms.
10) When that bridge is closed for vehicle then alter alternate road availability message is going delivered.

4.3 Implementation Details (Modules)

4.3.1 Hardware module

In this project, some hardware is used that are Microcontroller, sensors, components required for power supply. The Hardware collects the water level, Pressure of water, Rainfall measure to detect the levels of the flood. The hardware consists of Wi-Fi enabled controller which connects to the server and allows to share the data to through internet.

1. NodeMCU ESP8266 12E :- The ESP8266 module is developed by the espressif company to transfer the data wireless. The ESP8266 consists of the Wi-Fi module with integrated TCP/IO protocol stacks. ESP8266 is a low-cost wireless system which works on the AT commands.

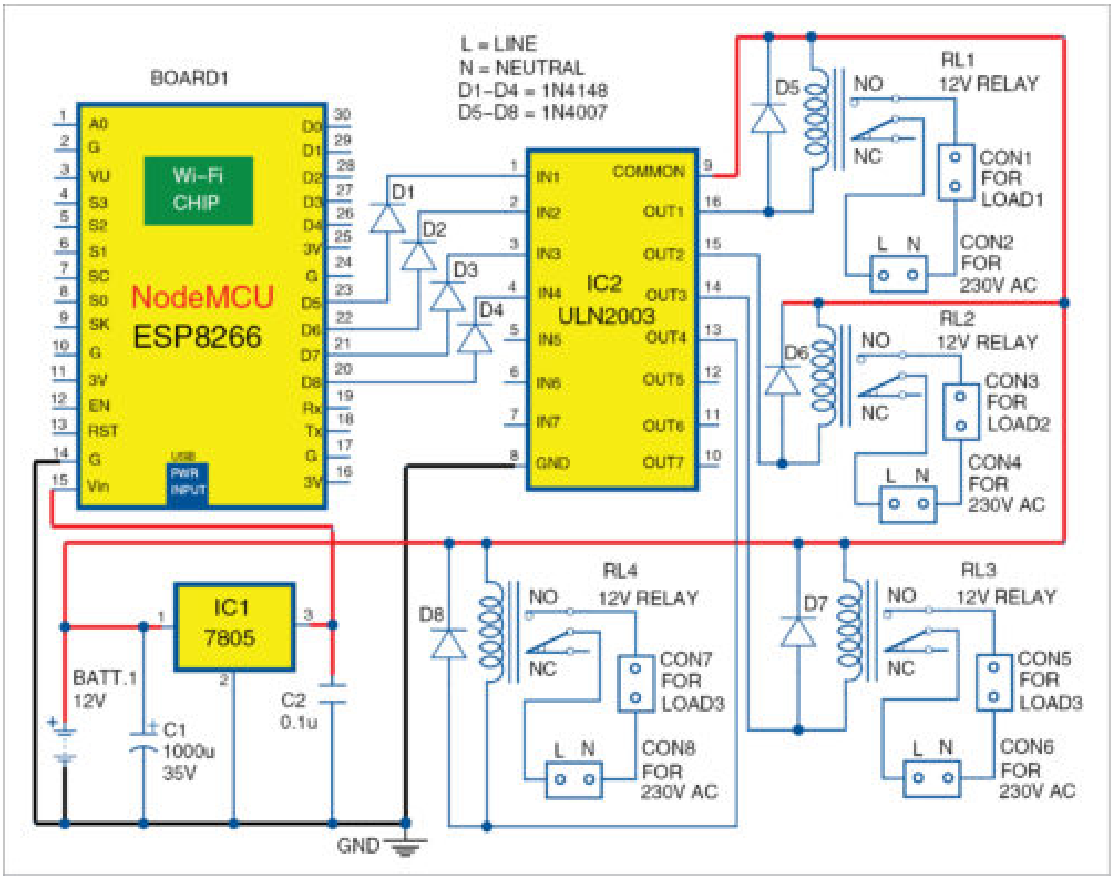


Figure 4.2: NodeMCU Circuit Diagram-1

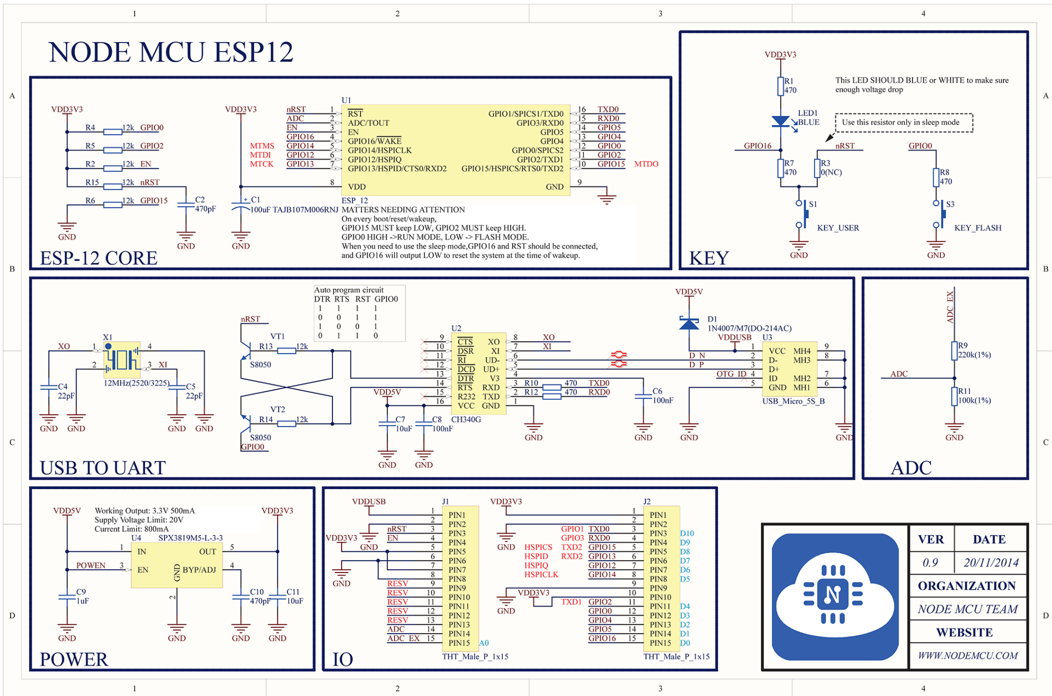


Figure 4.3: NodeMCU Circuit Diagram-2

2. Sensors: -This will collect the information from the particular nodes which are located at certain site. There are four sensors we are going to use in this project.
They are as follows:

- **Ultrasonic Sensor :-** Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules include ultrasonic transmitters, receiver and control circuit. The basic principle of work Using IO trigger for at least 10us high level signal. The Module automatically sends eight 40 kHz and detect whether there is pulse signal back. IF the signal back, through high level, time of high output IO duration is the time from sending ultrasonic to returning.

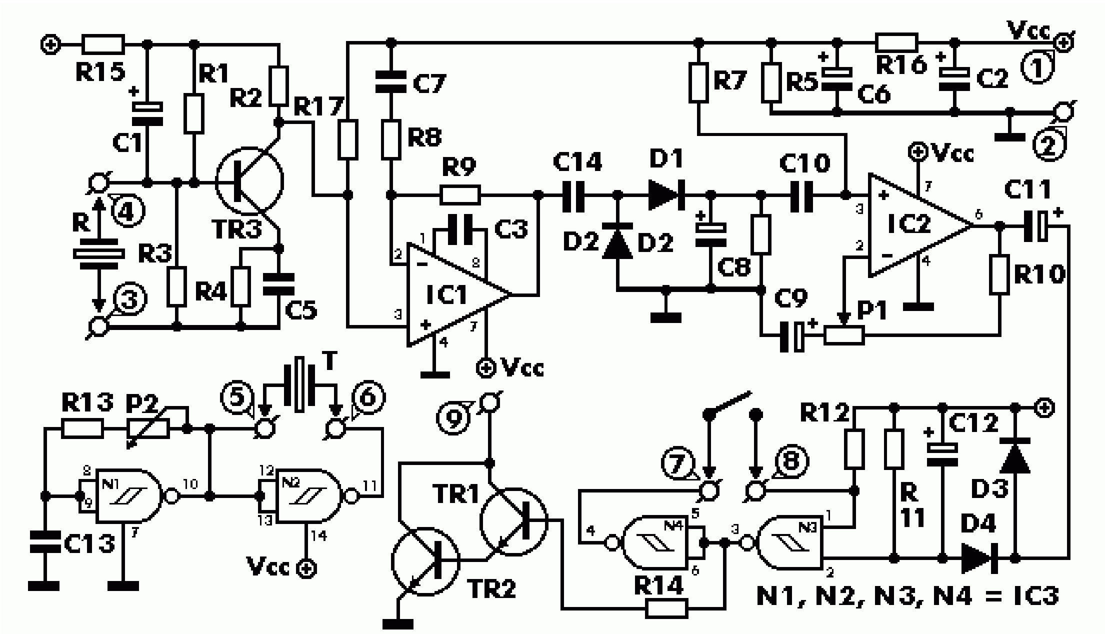
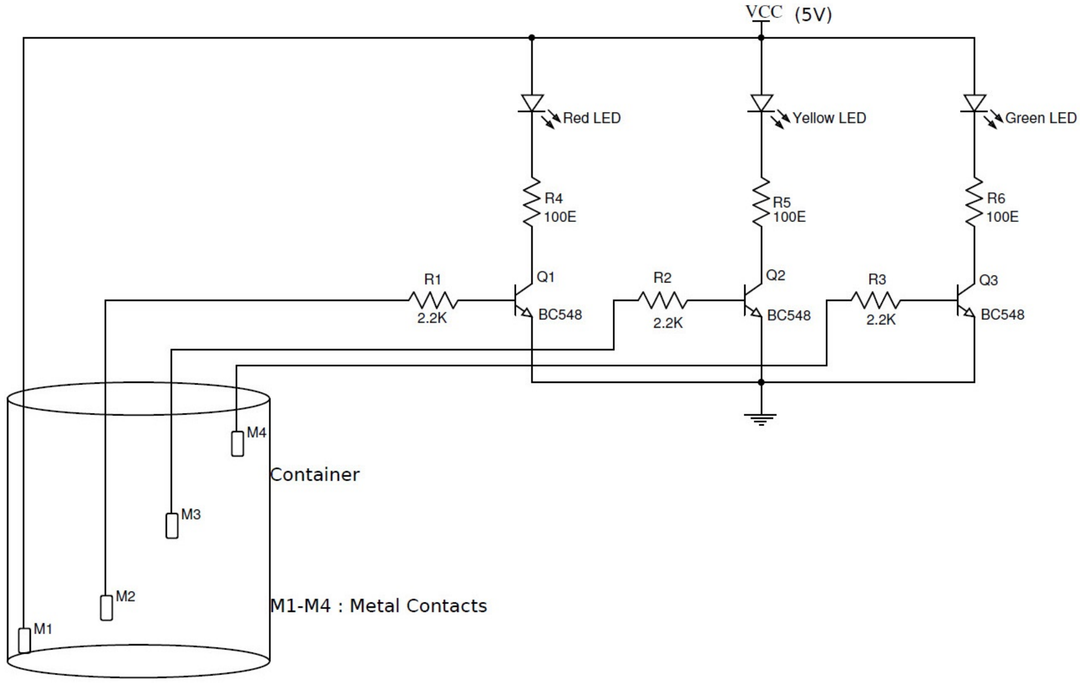


Figure 4.4: Ultrasonic Sensor circuit Diagram

- **Water Level Sensor :-** Level sensors detect the level of liquids and other fluids and fluidized solids. The level measurement can be either continuous or point values. Continuous level sensors measure level within a specified range and determine the exact amount of substance in a certain place, while point-level sensors only indicate whether the substance is above or below the sensing point. Generally, the latter detect levels that are excessively high or low.



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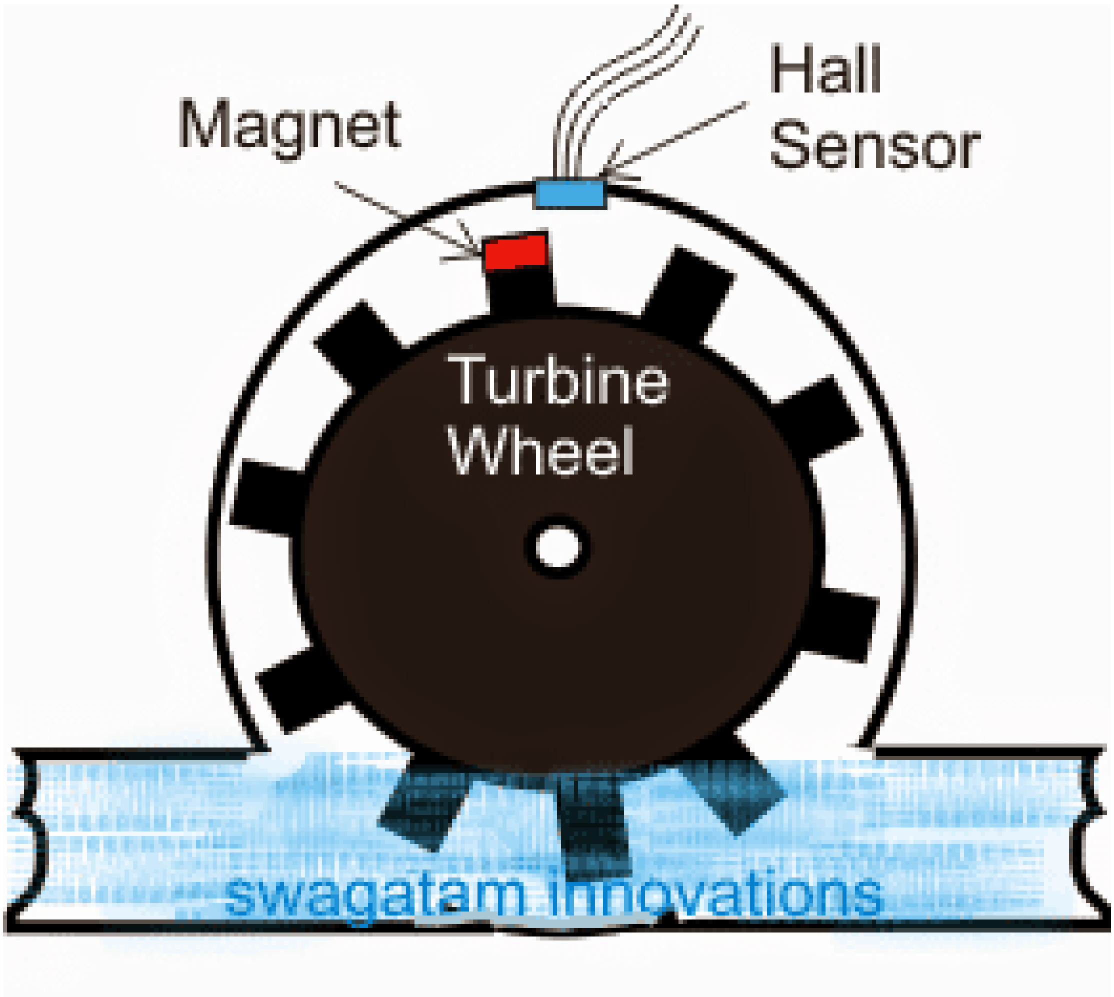

Figure 4.6: Waterflow Sensor Circuit Diagram

- **Temp Sensor :-** This sensor is used to measure change in atmospheric temperature and humidity. For this we are using sensor which works on one wire protocol and gives digital output.

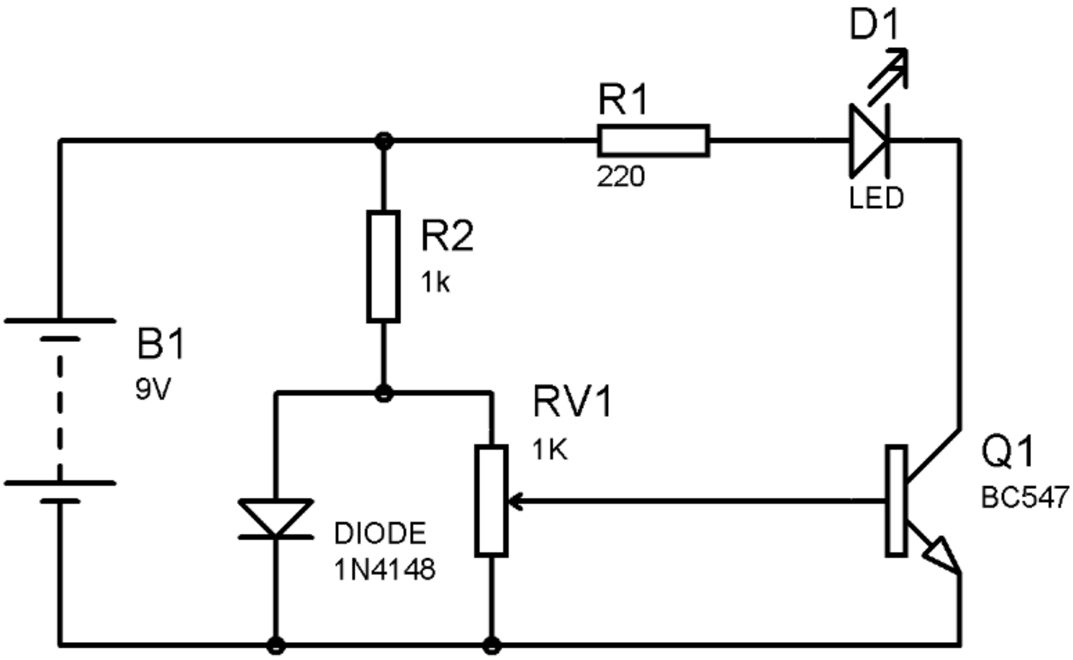

Figure 4.7: Temperature Sensor Circuit Diagram

3. Power Supply: - In real time we get 230v AC, in actual project we do not need this amount of power supply so we convert this AC power supply to DC power supply.

4.3.2 Software Module

In this module, we have done an android application as well as the Website application for this project. Admin web page will contain and display the information like Login, Registration, Number of users registered to the app, status of the sensor, safe places near flood affected area where people can migrate and that places are shown on the Map. The Android application will be used by the users who are register. After registration the user can login with aunique username and password. And then user can access all facilities provided by application. Application is provided the information like current status of water level and temperature etc. This app contain map which are show the safe places near the user and also the current place where the user is.

4.3.3 Database Module

Microcontroller will send the values measured by the sensors to the server. This will contain the number of users registered to App; this will also show the safe places through the Map. The data uploaded on server is stored on the database. The stored data is then routed to the front end web applications and mobile application.

4.4 Data Flow Diagrams

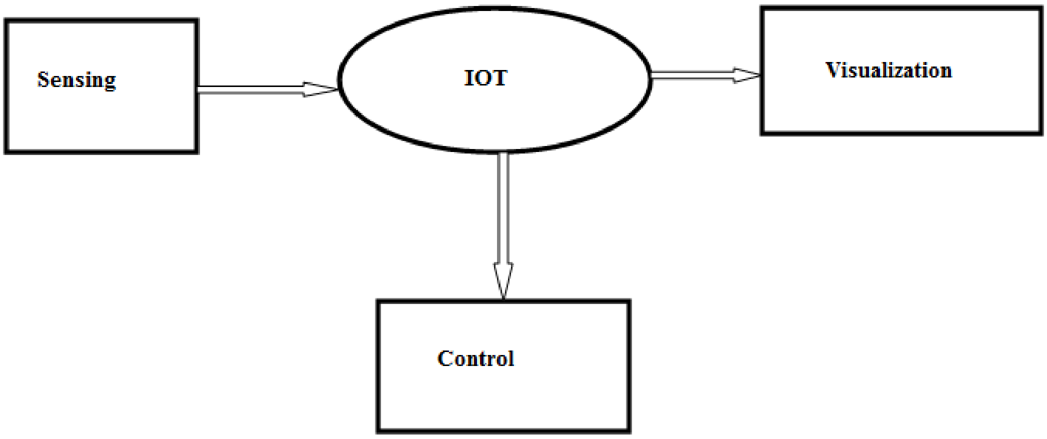

Figure 4.8: DFD: Level 0

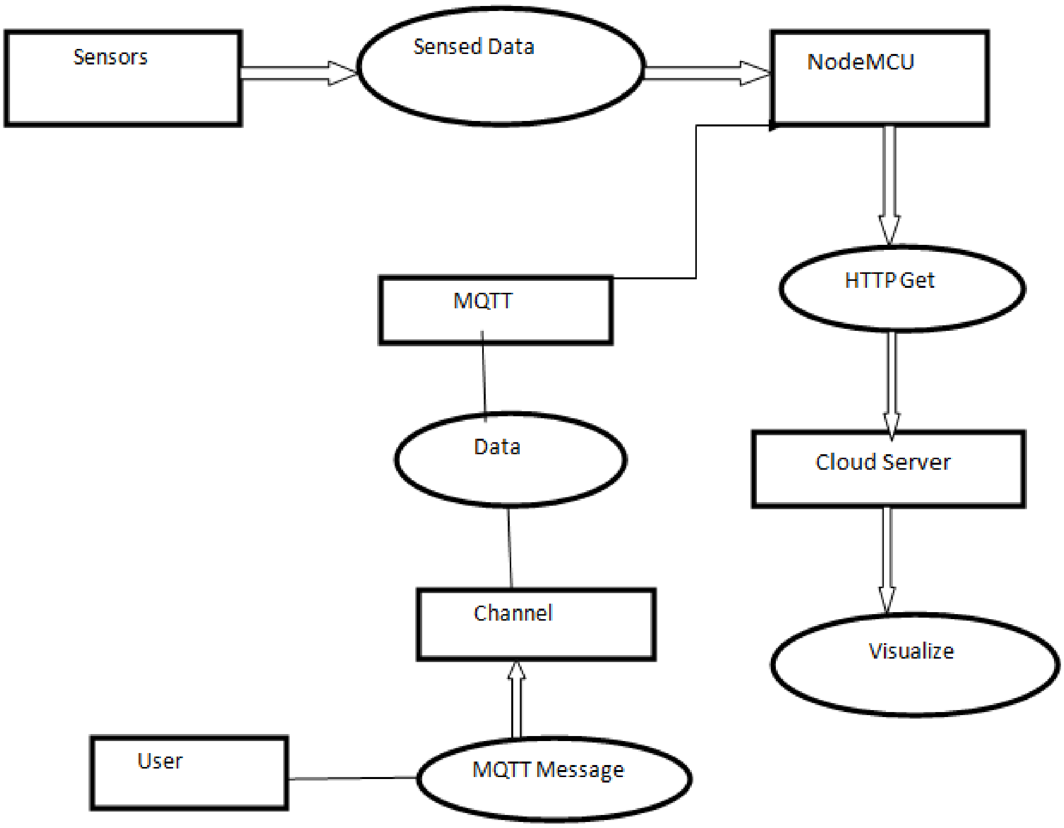

Figure 4.9: DFD: Level 1

4.5 Use Case Diagram

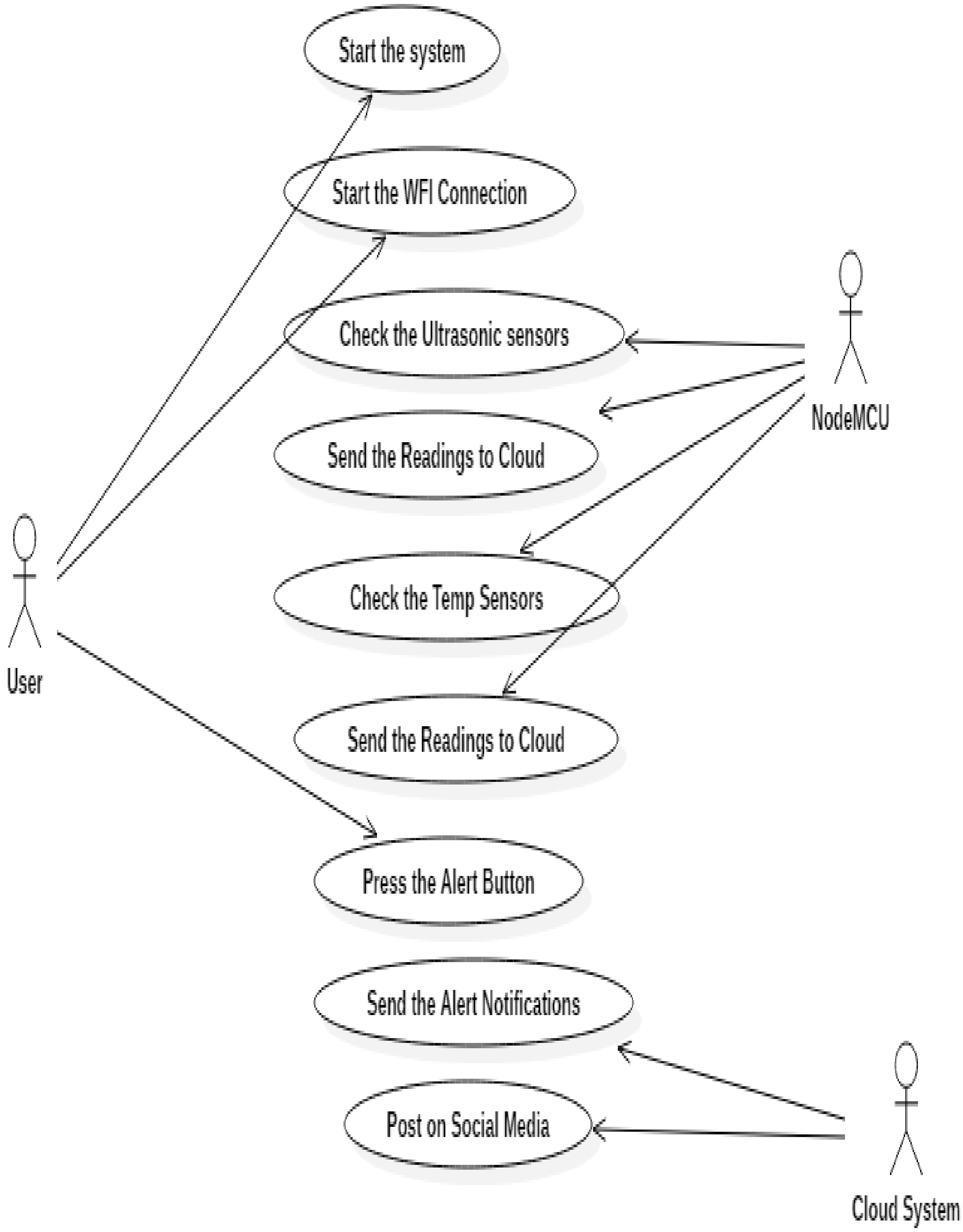

Figure 4.10: Use Case Diagram

4.6 Activity Diagram

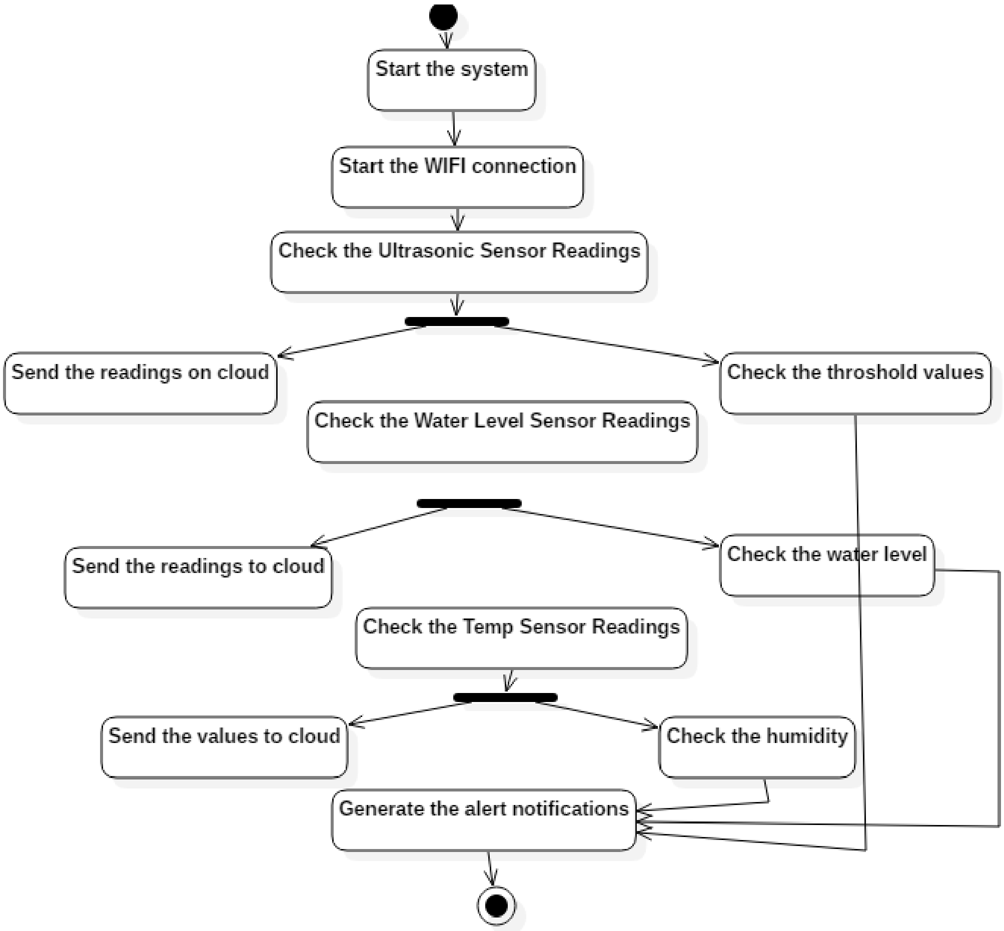

Figure 4.11: Activity Diagram

4.7 Class Diagram

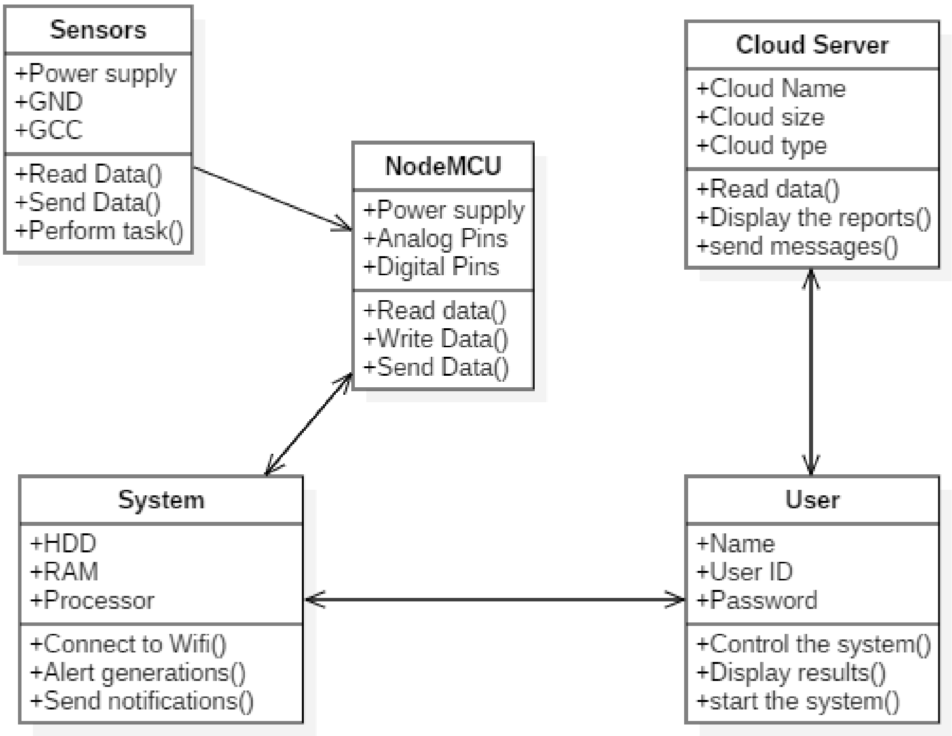

Figure 4.12: Class Diagram

4.8 Sequence Diagram

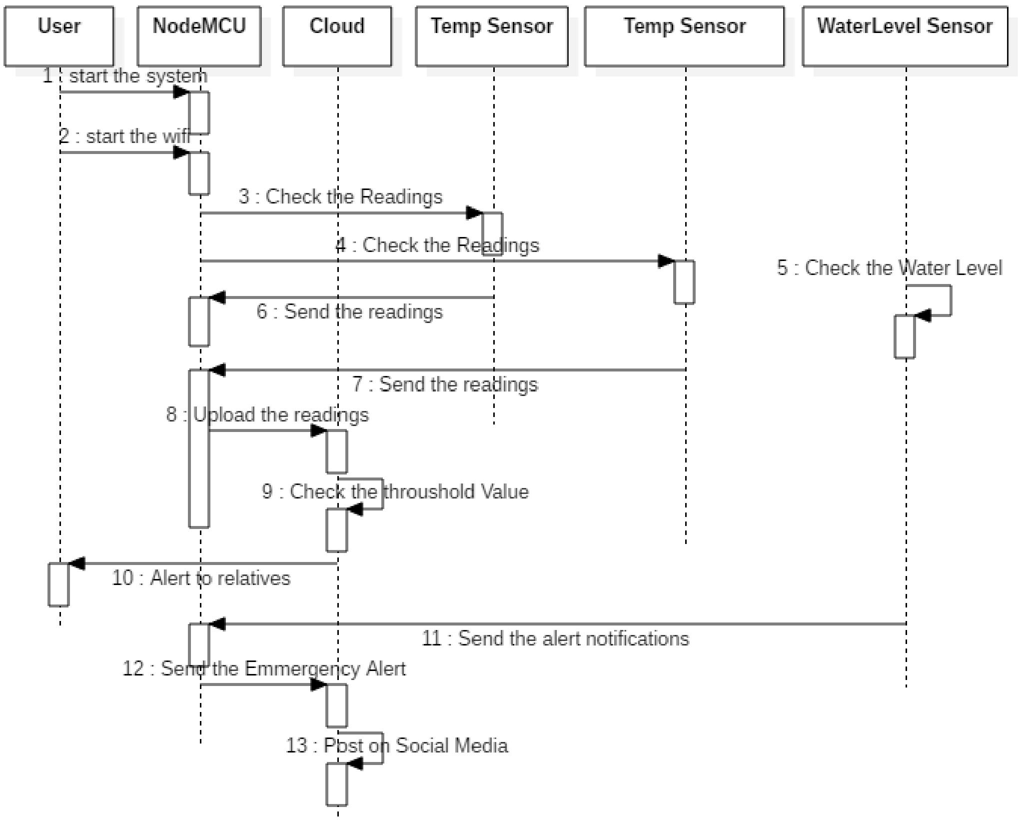

Figure 4.13: Sequence Diagram

4.9 Component Diagram

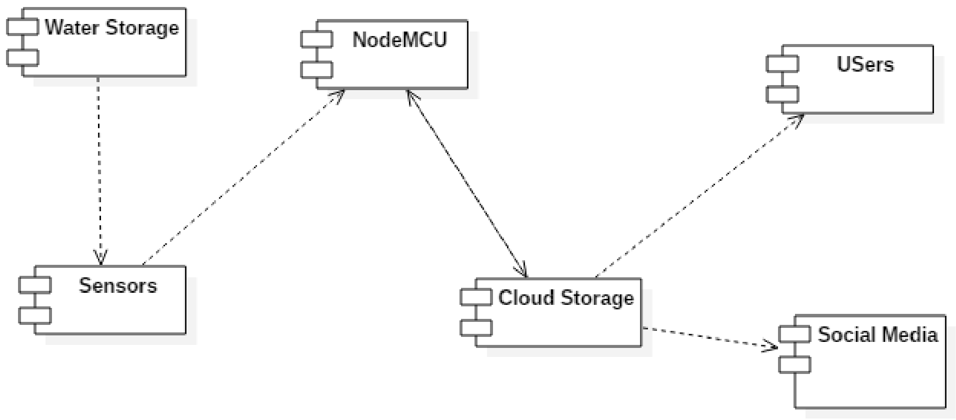

Figure 4.14: Component Diagram

4.10 Deployment Diagram

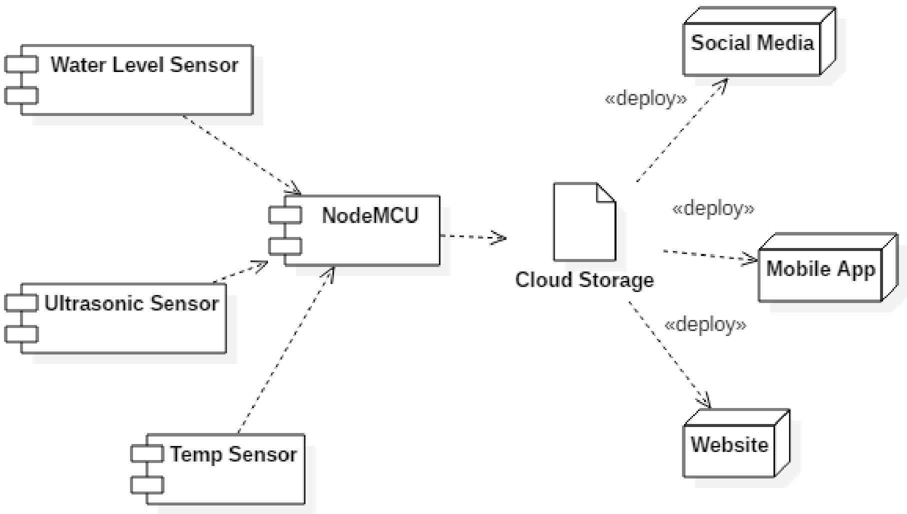

Figure 4.15: Deployment Diagram

Chapter 5

Project Plan

5.1 Project Estimate

The basis of estimates is an important tool in project management. It involves estimators and project managers to calculate the total cost needed for the entire project. It is used to support proposals, bidding and executing a project.In a nutshell, the basis of estimates is a method of documenting different important aspects of the project cost estimate to mitigate the cost risk of the project. It should be a clear document so that those involved in project management will be able to understand as well as assess the estimate. It will make it easier for those in project management to determine the cost, funding options, pricing basics, cost risk, allowances, opportunities and many others using the standard practices. The basis of estimates requires attachments which include the estimate deliverable checklist, reference documents, benchmarking reports, risk analysis and reconciliation reports among many others. It is important to take note that the basis of estimates is concise, factual and should describe techniques used to create the cost estimate. A well-written basis of the estimate can help determine both the risks and opportunities involved in the project management blueprint.

5.1.1 Reconciled Estimates

The model followed is the Constructive Cost Model (COCOMO) for estimating the effort required in completing the project.Like all the estimation models, the COCOMO model requires sizing information. This information can be specified in the form of :

- Object Point
- Function Point(FP)
- Lines of Source Code(KLOC)

For our project,we use the sizing information in the form of Lines of Source Code.

- Total Lines of Code for our project , KLOC=6k(approx).
- Cost of each person per month, Cp=Rs.200 /- (per person-hour)

Equations

The initial effort (E_i) in man months is calculated using the equation:

$E = a * (KLOC)^b$

Where,

a = 3.0, b = 1.12, for a semi-detached project

E=Efforts in person-hour

$D = a * (E)^b$

Where, a = 2.5 ,b = 0.32, for a semi-detached project

D=Duration of project in months

Cp = Cost incurred per person-hour

Hrs = hours

Efforts

$E = 3.0 * (5.2)^{1.12}$

E = 22.31 person-months

Total of 22.31 person-months are required to complete the project successfully.

Duration of project

$D = 2.0 * (E)^{0.32}$

D = 6.75 months

The approximate duration of project is 7 months.

Number of people required for the project

$N = 22.31/7$

N = 3.83

N = 4 people

Therefore 4 people are required to successfully complete the project on schedule.

Cost of project

$C = 4 * 200 * 210 = 168000$ Therefore, the cost of project is 168000/-(approx.)

5.1.2 Project Resources

A resource is a necessary asset whose main role is to help carry out a certain task or project. A resource can be a person, a team, a tool, finances, and time. Most projects require many different resources in order to be completed. Resources should be assessed and allocated before a project begins. Poor resource planning can result in running out of resources midway through a project, delaying deadlines, and delivery of the final product or service.

People:- 4 Group Members as a developer/Tester.

Hardware:

Hard Disk 40gb and above.

Ram 512 and above.

Processor P4 and above.

Software:

Software: Ardiuno IDE.

Tools: Google API for location .

Other resources: Cloud Storage for database storage.

5.2 Risk Management

5.2.1 Risk Identification

There are multiple sources of risk. For risk identification, the project team should review the program scope, cost estimates, schedule (to include evaluation of the critical path), technical maturity, key performance parameters, performance challenges, stakeholder expectations vs. current plan, external and internal dependencies, implementation challenges, integration, interoperability, supportability, supply-chain vulnerabilities, ability to handle threats, cost deviations, test event expectations, safety, security, and more. In addition, historical data from similar projects, stakeholder interviews, and risk lists provide valuable insight into areas for consideration of risk.

Risk identification is an iterative process. As the program progresses, more information will be gained about the program (e.g., specific design), and the risk statement will be adjusted to reflect the current understanding. New risks will be identified as the project progresses through the life cycle.

5.2.2 Risk Analysis

A risk is a probability that some adverse circumstance will occur. It is potential problem- it might happen or it might not. But, regardless of outcome, it is really a good idea to identify it, assess its probability of occurrence, estimate its impact and establish a contingency plan should the problem actually occur. For good software project management, understanding the risks and taking proactive measures to avoid or manage them is a key element. Risk Management is concerned with identifying risks and drawing up plans to minimize their effects on the project.

Table 5.1: Risk Table

ID	Risk Description	Probability	Impact		
1	Harware Failure	Low	Low	High	High
2	High Voltage	Low	Low	High	High

Table 5.2: Risk Probability definitions

Probability	Value	Description
High	Probability of occurrence is	$> 75\%$
Medium	Probability of occurrence is	$26 - 75\%$
Low	Probability of occurrence is	$< 25\%$

5.2.3 Overview of Risk Mitigation, Monitoring, Management

Risk Mitigation, Monitoring and Management mean risk avoidance. Avoidance is the best strategy by adapting the proactive strategy to

Table 5.3: Risk Probabilty Definitions

Impact	Value	Description
Very High	>10%	Schedule impact or Unacceptable quality
High	5-10%	Schedule impact or Unacceptable quality
Medium	<5%	Schedule impact or Barely noticeable degradation in quality Low Impact on schedule or Quality can be incorporated

risk. The project manager should monitor i.e. keep a check on the project to see whether the risk is becoming more likely or not. Risk management comes into play when the mitigation efforts have failed and the risk has become a reality.

Risk 1

- Sophistication of the end user's application program
- Mitigation-Develop a front end that is both user friendly and covers all needs.
- Monitor-Test the application with novice, expert and intermediate users.
- Management-Customer should be noticed about the limitations and the scope of the API.

Risk 2

- Delay in completion of modules due to member being sick.
- Mitigation-Keep work of all members documented.
- Monitor-Review is made between members and ideas, thought, plans are discussed in meetings.
- Management-Shift one or more members to sick member's module.

Risk 3

- Schedule might slip due to inexperience
- Mitigation-The planned schedule should be followed strictly.
- Monitor-Check whether work is going according to time.
- Management-Add more members to the project or increase the working hours of already working people.

Risk 4

- Resources might prove insufficient
- Mitigation-Gather all the resources that are required and check whether they are feasible.
- Monitor-Check at any point of time whether the resources allocated are less and whether more resources will be required.
- Management-Increase the fund that is allocated to the resources or try and adjust with the existing resources.

Table 5.4: Risk Impact Definition

Risk ID	1
Risk Description	Hardware Connectivity
Category	Development Environment
Source	System will require hardware connectivity
Probability	Low
Impact	High
Response	Mitigate
Risk Status	Occurred

5.3 Project Schedule

5.3.1 Project task set

Major Tasks in the Project stages are:

- Task 1: Water Level Sensor.
- Task 2: Ultrasonic Sensor.
- Task 3: Social Media Connect.
- Task 4: Location Detection.

5.3.2 Task network

Project tasks and their dependencies are noted in this diagrammatic form.

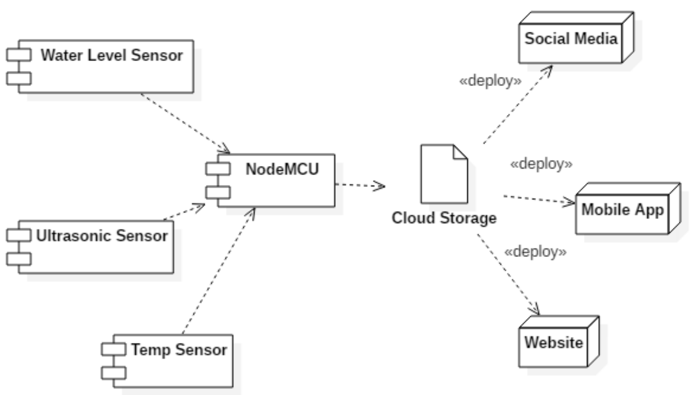

Figure 5.1: Project Task Network.

5.3.3 Timeline Chart

A project timeline chart is presented. This include a time line for the entire project. Remaining points should be covered in Project Planner as Annex C %and you can mention here Please refer Annex C for the planner

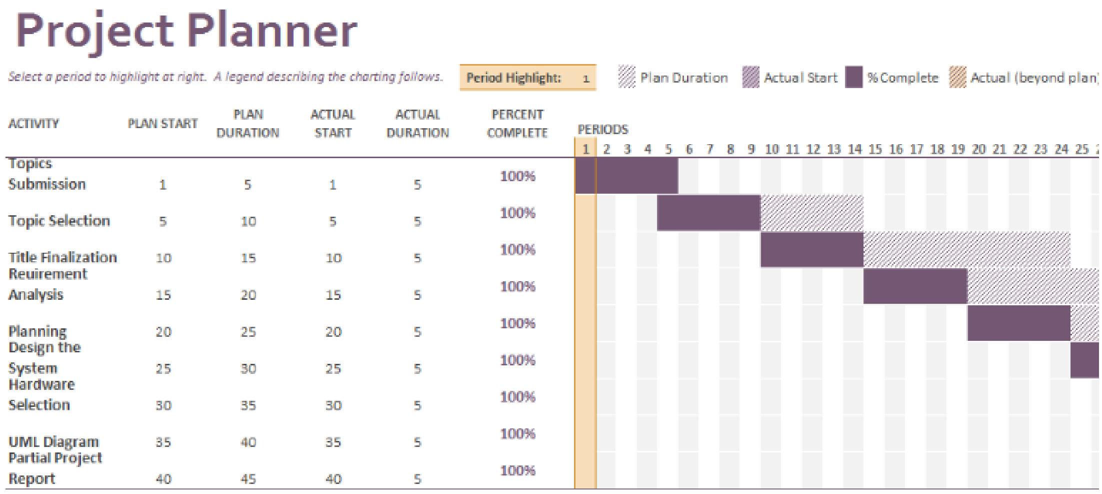

Figure 5.2: Software Project Plan

5.4 Team Organization

5.4.1 Team Stucture

1. Mayur Tajane :- Project Leader
2. Harshal Chaudhari :- Software Developer
3. Monali Sonawane :- Software Developer and Testing
3. Mayuri Sonavane :- Software Developer and Testing

Chapter 6

Project Implementation

6.1 Overview of Project Modules

1. Water Level Detection
2. Social Media Alerts
3. Cloud Database
4. Alert Notifications to officials

6.2 Tools and Technologies Used

1. Ardiuno Uno IDE
2. Google API
3. Text Messages API
4. 000webhostapp.com Hosting
5. Php myAdmin

6.3 Algorithm Details

6.3.1 Naives Bayesian Algorithm

Naive Bayes is the most straightforward and fast classification algorithm, which is suitable for a large chunk of data. Naive Bayes

classifier is successfully used in various applications such as spam filtering, text classification, sentiment analysis, and recommender systems. It uses Bayes theorem of probability for prediction of unknown class.
Naive Bayes is an eager learning classifier and it is much faster than K-NN. Thus, it could be used for prediction in real time. Typically, email spam filtering uses Naive Bayes classifier. It takes a probabilistic estimation route and generates probabilities for each class. It assumes conditional independence between the features and uses a maximum likelihood hypothesis. The best part with this classifier is that, it learns over time. In a spam filtering task, the type of spam words in email evolves over time. In the same way, the classifier also calculates probability estimates for the newly occurring spam words in a "bag of words" model and makes sure it performs well. This feature of the classifier is due to the inherent nature of the algorithm being generative and not discriminative.

What is Naive Bayes Classifier?
Naive Bayes is a statistical classification technique based on Bayes Theorem. It is one of the simplest supervised learning algorithms. Naive Bayes classifier is the fast, accurate and reliable algorithm. Naive Bayes classifiers have high accuracy and speed on large datasets. Naive Bayes classifier assumes that the effect of a particular feature in a class is independent of other features. For example, a loan applicant is desirable or not depending on his/her income, previous loan and transaction history, age, and location. Even if these features are interdependent, these features are still considered independently. This assumption simplifies computation, and that's why it is considered as naive. This assumption is called class conditional independence.

$$P(h|D) = \frac{P(D|h)P(h)}{P(D)}$$

Figure 6.1: Naive Bayes Formula

- **P(h):-** the probability of hypothesis h being true (regardless of the data). This is known as the prior probability of h.
- **P(D):-** the probability of the data (regardless of the hypothesis). This is known as the prior probability.
- **P(h/ D):-** the probability of hypothesis h given the data D. This is known as posterior probability.
- **P(D/h):-** the probability of data d given that the hypothesis h was true. This is known as posterior probability.

Naive Bayes classifier calculates the probability of an event in the following steps:-

- **Step 1:-** Calculate the prior probability for given class labels.
- **Step 2:-** Find Likelihood probability with each attribute for each class.
- **Step 3:-** Put these value in Bayes Formula and calculate posterior probability.
- **Step 4:-** See which class has a higher probability, given the input belongs to the higher probability class.

Chapter 7

Software Testing

Software testing is defined as an activity to check whether the actual results match the expected results and to ensure that the software system is Defect free. It involves execution of a software component or system component to evaluate one or more properties of interest. Software testing also helps to identify errors, gaps or missing requirements in contrary to the actual requirements. It can be either done manually or using automated tools. Some prefer saying Software testing as a White Box and Black Box Testing. In simple terms, Software Testing means Verification of Application Under Test (AUT).

7.1 Types of Testing

Testing for IoT devices broadly revolves around Security, Analytics, Device, Networks, Processors, Operating Systems, Platforms and Standards.

1. Usability Testing: There are so many devices of different shape and form factors are used by the users. Moreover, the perception also varies from one user to other. That's why checking usability of the system is very important in IoT testing. Usability testing is a way to see how easy to use something is by testing it with real users. Users are asked to complete tasks, typically while they are being observed by a researcher, to see where they encounter problems and experience confusion. If more people encounter similar problems, recommendations will be made to overcome these usability issues.Usability testing is a method used to evaluate how easy a website is to use. The tests take place with real users to measure how 'usable' or 'intuitive' a website is and how easy it is for users to reach their goals.

2. Compatibility Testing: There are lots of devices which can be connected though IOT system. These devices have varied software and hardware configuration. Therefore, the possible combination are huge. As a result, checking the compatibility in IOT system is important. Compatibility is nothing but the capability of existing or living together. In normal life, Oil is not compatible with water, but milk can be easily combined with water. Compatibility Testing is a type of Software testing to check whether your software is capable of running on different hardware, operating systems, applications, network environments or Mobile devices. Compatibility Testing is a type of Non-functional testing

3. Reliability and Scalability Testing: Reliability and Scalablity is important for buidling an IOT test enviorment which involves simulation of sensors by utilzing virtualization tools and technolgoies.Reliability testing is defined as a software testing type, that checks whether the software can perform a failure-free operation for a specified period of time in a specified environment. Reliability means "yielding the same," in other terms, the word "reliable" mean something is dependable and that it will give the same outcome every time. The same is true for Reliability testing. Reliability testing in software assures that the product is fault free and is reliable for its intended purpose.

4. Data Integrity Testing: It's important to check the Data integrity in IOT testing as it involves large amount of data and its applcaiton.Data integrity corresponds to the quality of data in the databases and to the level by which users examine data quality, integrity and reliability. Data integrity testing verifies that the data in the database is accurate and functions as expected within a given application.

5. Security testing: In the IOT environment, there are many users are accessing a massive amount of data. Thus, it is important to validate user via authentication, have data privacy controls as part of security testing. IoT Security challenges: IoT is data centric where all the devices/system connected operate based on the data that is available. When it comes to the data flow between devices, there is always a chance that the data can be accessed or read when getting transferred. From a testing standpoint, we need to check if the data is protected/encrypted when getting transferred from one device to the other.Wherever, there is an UI, we need to make sure there is a password protection on it.

6. Performance Testing: Performance testing is important to create strategic approach for developing and implementing an IOT testing plan.When we are talking about a system for a healthcare domain, we need to make sure the system is scalable enough for the whole hospital. When the testing is carried out, it is done for 2-10 patients at a time and the data is propagated to 10-20 devices. When the whole hospital is connected and 180-200 patients are connected to the system, the data that is propagated is much bigger than the tested data. As testers, we need to make sure the system performs the same even though the added data is propagated. We should also test the monitoring utility to display the system usage, power usage, temperature etc.

7.2 Test Cases and Test Results

Defining test cases for IoT devices can be considered as a uphill task. Other than testing the real life scenarios there are a few common test scenarios you need to consider while testing IoT devices and the network.

7.2.1 Test Cases for Website Module

Test Id (No)	**Test Description**	**Expected Result**	**Actual Result**	**Test Status (Pass/Fail)**
1	Login Check	Only authorised users should logged in	Only authorised users can logged in	Pass
2	Invalid user	Invalid user shouldnot logged into system	Invalid User cannot logged in	Pass
3	Google-Map location check	Correct location should be displayed	Doesnot show correct location	Fail
4	Water level in the river basin	Water level of river basin should display	Accurate water level of the river basin is displayed	Pass
5	Water level in the Dam	Water level of the dam should display	Accurate water level of the Dam is displayed	Pass

Table 7.1: Test Cases for Website

7.2.2 Test Cases for Hardware

Test Id (No)	**Test Description**	**Expected Result**	**Actual Result**	**Test Status (Pass/Fail)**
1	Water level sensor (River)	Accurate water level should detect	Accurate water level is detected	Pass
2	Water level sensor (Dam)	Accurate water level should detect	Accurate water level is detected	Pass
3	Voltage Check	NodeMCU should work on low voltage	NodeMCU worked on low voltage	Pass
4	Data transfer	Sensor data should transfer to cloud	Sensor data transfered to cloud	Pass
5	Location Tracking	Locate the accurate location	Doesnot locate accurate location	Fail

Table 7.2: Test Cases for Hardware

Chapter 8

Results

8.1 Outcomes

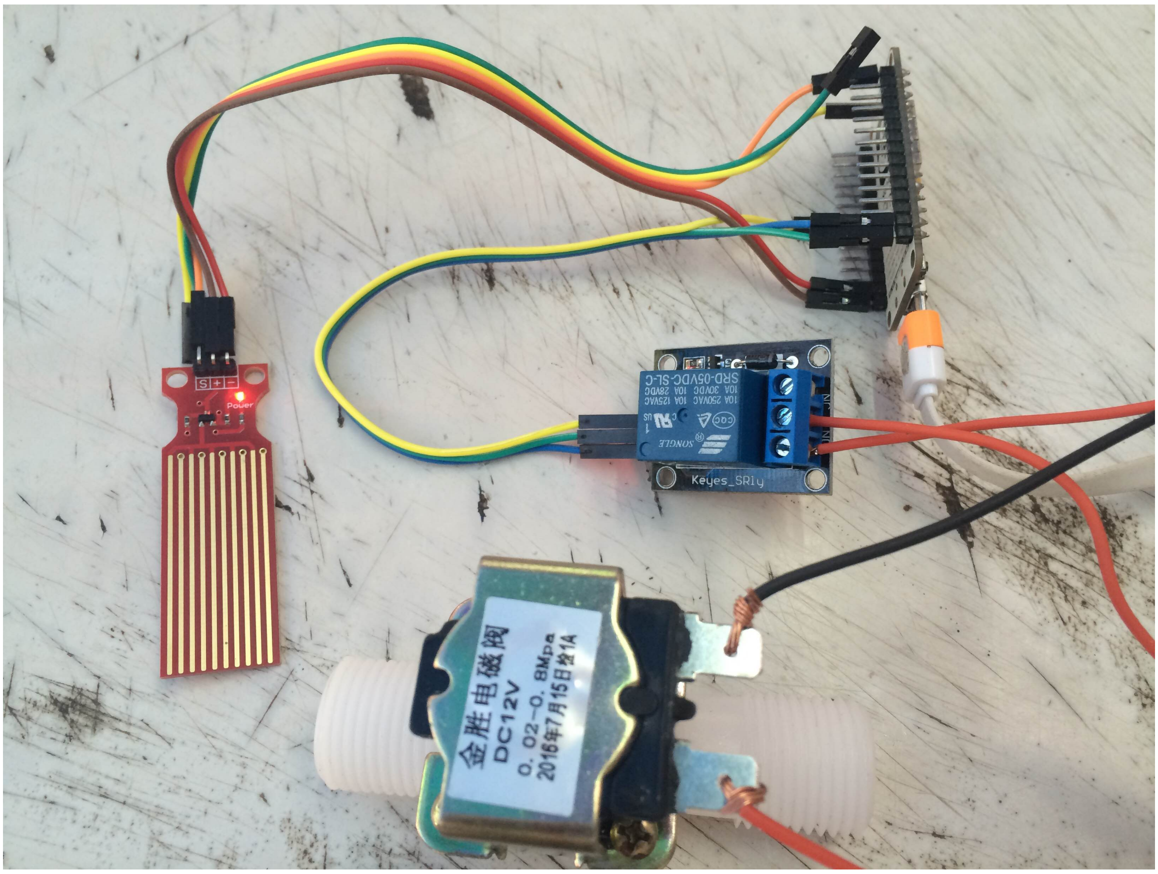

Figure 8.1: Waterlvel Sensor with NodeMCU

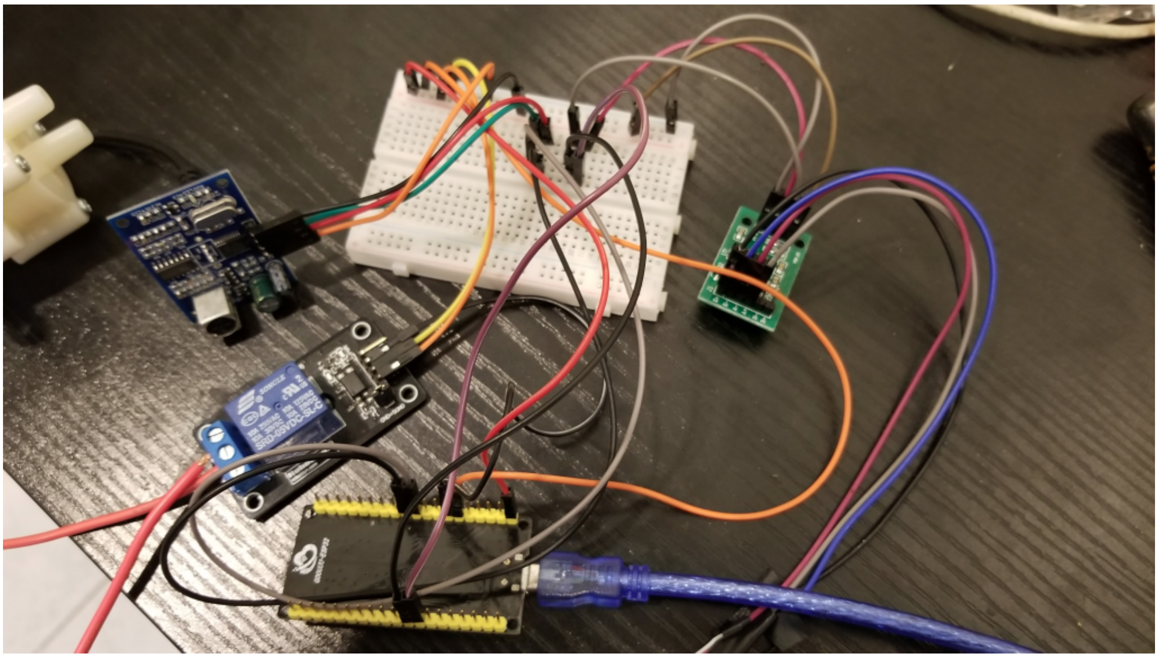

Figure 8.2: Ultrasonic Sensor With NodeMCU

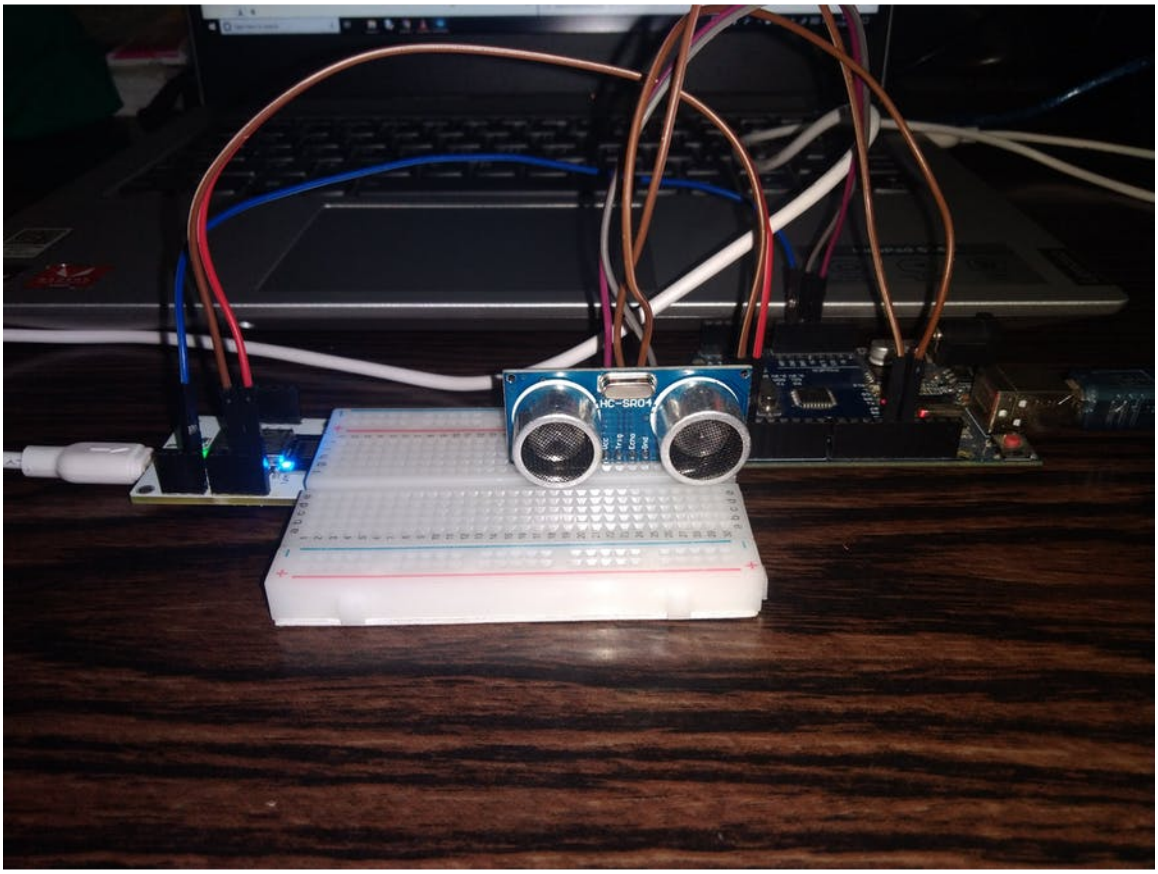

Figure 8.3: Ultrasonic Sensor With NodeMCU

8.2 Screenshots

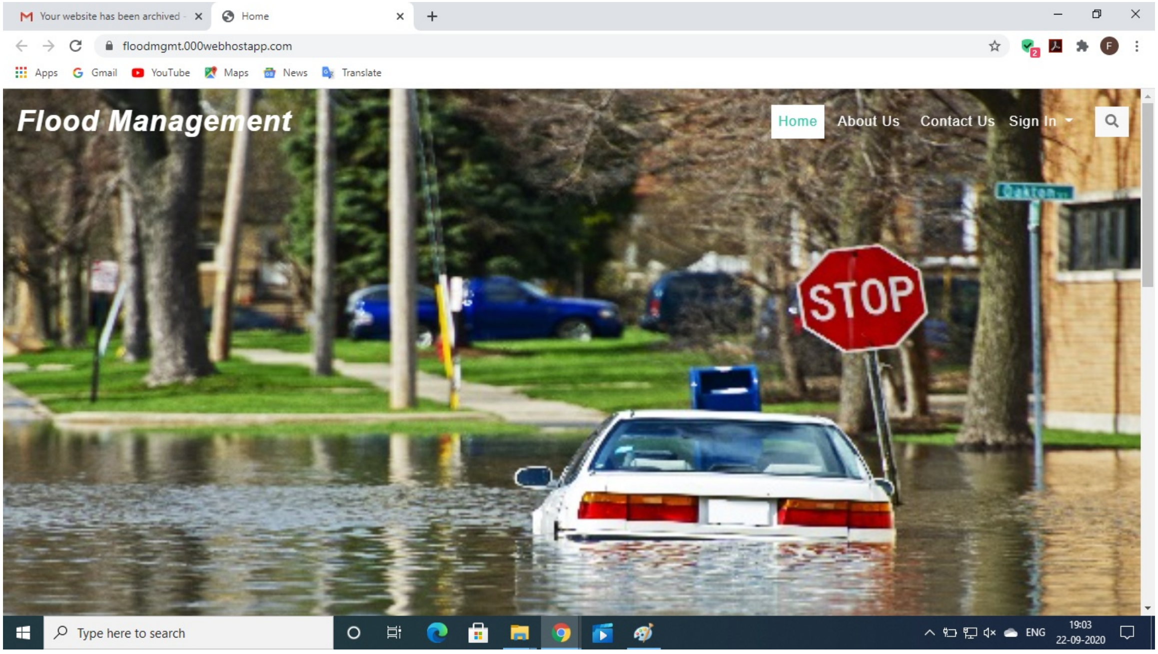

Figure 8.4: Screeshot No: - 1

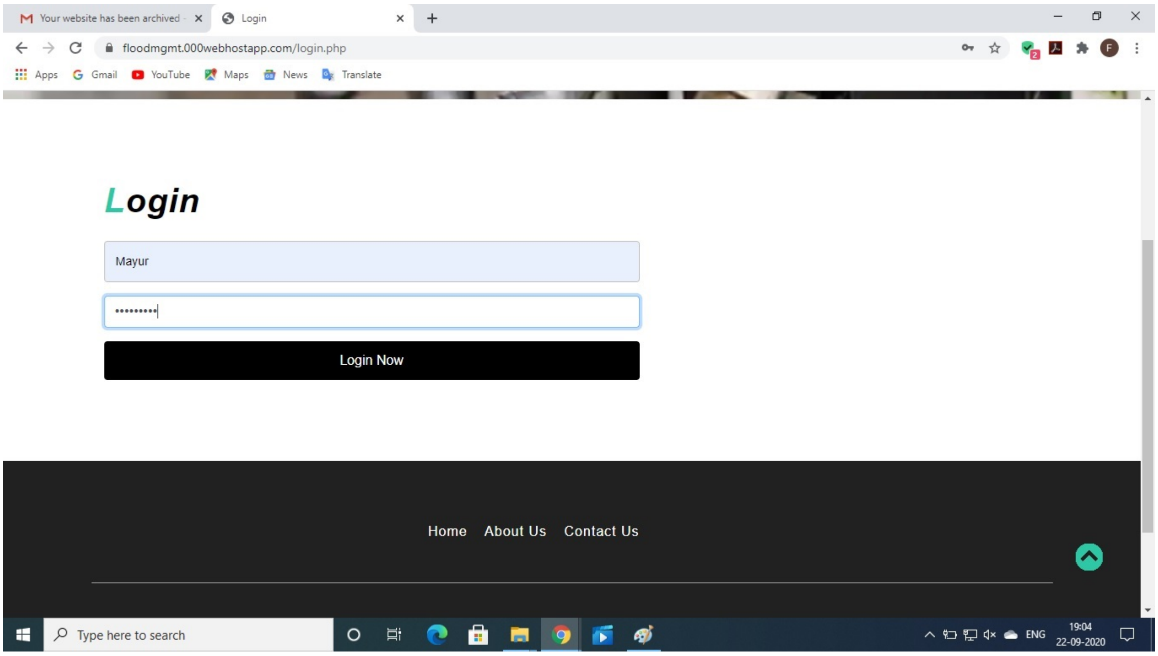

Figure 8.5: Screeshot No: - 2

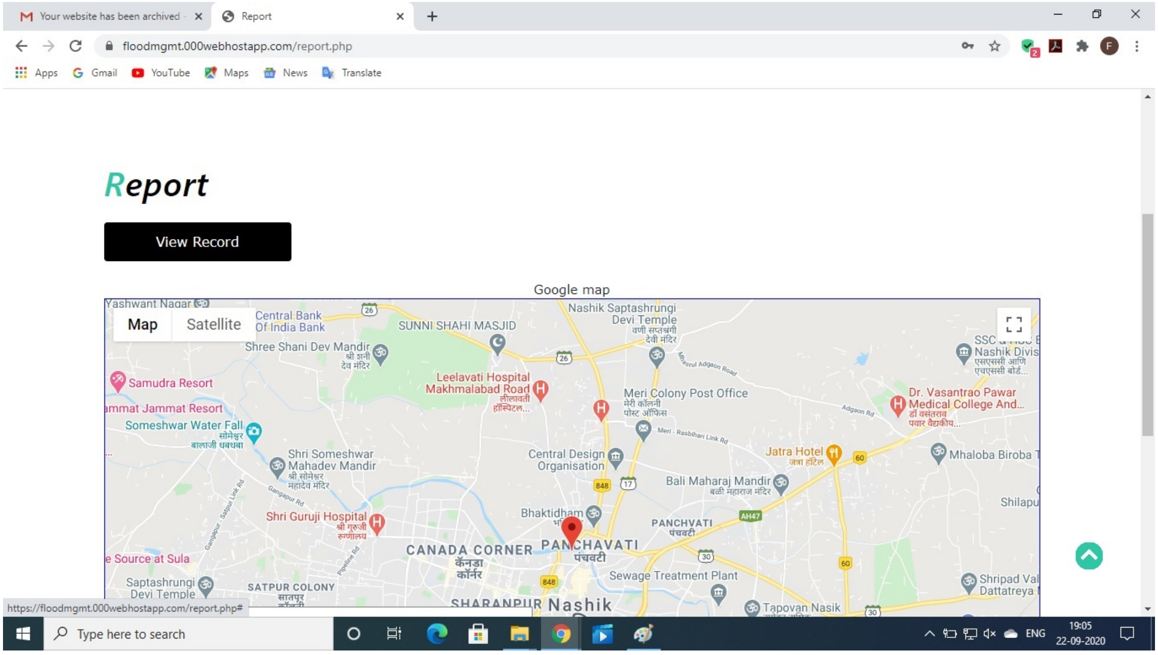

Figure 8.6: Screeshot No: - 3

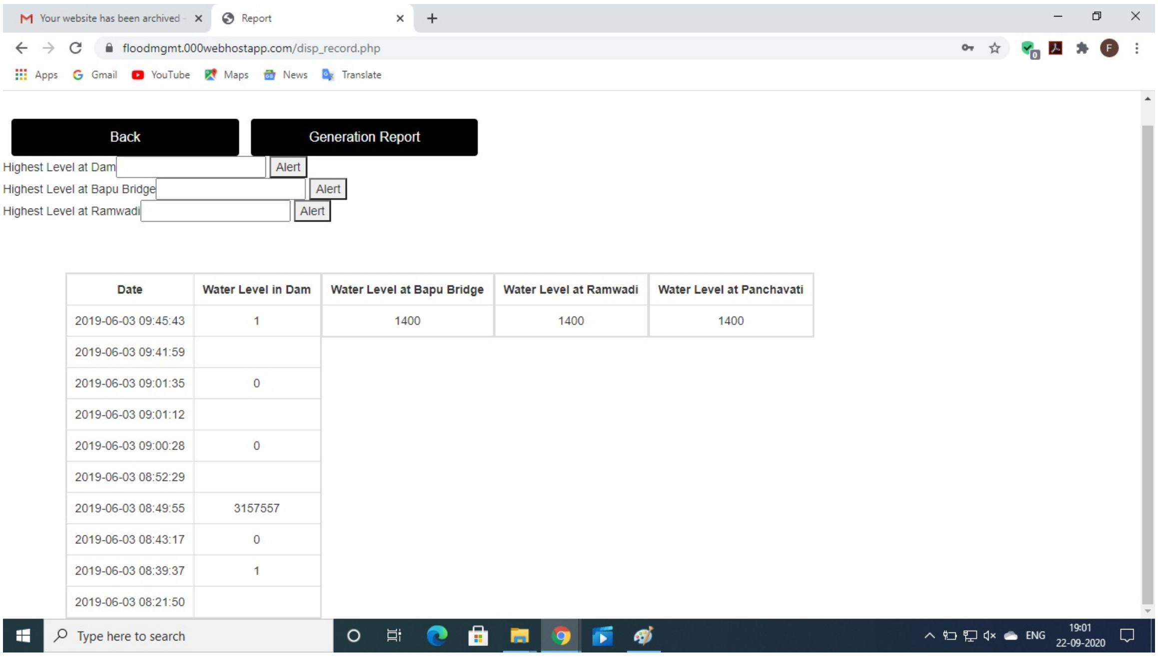

Figure 8.7: Screeshot No: - 4

Chapter 9

Conclusion

9.1 Conclusion

The success of flood disaster management depends largely on how well flood related data can be collected, managed and utilized. Due to this importance, the use of IoT to facilitate flood data management is seen as a step in the right direction. With the proposed architecture, future research works on flood that makes use of IoT will have a reference to specify how the work can fit within the larger flood management system.

9.2 Future Scope

In future we want to develop the flood and earthquake monitoring as well as management system that will alerts the people before the it take place. This will be lead to minimize the money and human loss due to dissasters.

9.3 Applications

1)Municipal Corporations: -

The Municipal Corporation has The Emergency Response Team which faces natural and human involved disasters. By using proposed system an automated message is going to deliver to those Respond Teams to help victims.

2)Fire And Rescue Department: -

The Fire Department is responsible to help the victims who are trapped into such flood situation where they can have at least information regarding upcoming disaster which going to prevent human casualties.

3)Smart City Management : -

If such ideas included into smart city development then it could improve the impression of that city over other cities regarding early warning relive support.

Annexure A

Laboratory assignments on Project Analysis of Algorithmic Design

A.1 Introduction to IDEA Matrix:

- To develop the problem under consideration and justify feasibilty using concepts of knowledge canvas and IDEA Matrix. IDEA Matrix is represented in the following form. Knowledge canvas represents about identification of opportunity for product. Feasibility is represented w.r.t. business perspective.

I	D	E	A
Increase	Drive	Educate	Accelerate
Improve	Deliver	Evaluate	Associate
Ignore	Decrease	Eliminate	Avoid

Table A.1: IDEA Matrix

A.2 Introduction to Knowledge of Canvas:

Knowledge is a familiarity, awareness or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning.

A.3 NP Hard - NP Complete Analysis:

Classification of Algorithms Class of computational problems for which a given solution can be verified as a solution in polynomial time by a deterministic Turing machine.

A.3.1 P

Informally the class P is the class of decision problems solvable by some algorithm within a number of steps bounded by some fixed polynomial in the length of the input. Thus P is a robust class and has equivalent definitions over a large class of computer models. Here we follow standard practice and define the class P in terms of Defect Tracking.

A.3.2 NP-hard

Class of problems which are at least as hard as the hardest problems in NP. Problems in NP-hard do not have to be elements of NP, indeed, they may not even be decision problems.

A.3.3 NP-complete

Class of problems which contains the hardest problems in NP. Each element of NP-complete has to be an element of NP.

A.3.4 NP-easy

At most as hard as NP, but not necessarily in NP, since they may not be decision problems.

A.3.5 NP-equivalent

Exactly as difficult as the hardest problems in NP, but not necessarily in NP.

Our system comes in NP Complete convention.

Annexure B

Base Paper

Smart river monitoring and early flood detection system in Japan developed with the EnOcean long range sensor technology

1) *Dalibor Purkovic: EnOcean GmbH, Oberhaching, Germany, dalibor.purkovic@enocean.com*
2) *Lee Coates: EnOcean GmbH, Oberhaching, Germany*
3) *Marian Hönsch: EnOcean GmbH, Oberhaching, Germany*
4) *Dirk Lumbeck: EnOcean GmbH, Oberhaching, Germany*
5) *Frank Schmidt: EnOcean GmbH, Oberhaching, Germany*

***Abstract*—Smart city is a term which is heard very often nowadays. It is a synonym for a variety of IoT solutions integrated into the daily city life, for the benefit of its inhabitants. One of these solutions, presented in this paper, is a river monitoring and early flood detection system. The proposed solution consists of an ultrasonic sensor adapted to the EnOcean solar-powered, long range sensor module. This maintenance free, self-powered sensor module was deployed in a couple cities in Japan to monitor river water level. The specially designed generic sensor interface allowed the adoption of the off-the-shelf MaxBotix ultrasonic sensor with a 10 meter measuring range. This can then be turned into a flood detection system which satisfies the standards prescribed by the Japanese River Bureau under the Ministry of Land, Infrastructure, Transport and Tourism. The detailed communication between the ultrasonic sensor and the sensor module via EnOcean Generic Sensor commands is shown. In addition, the transmission of the measured data over greater distances with the use of the EnOcean long range, low power communication protocol, is outlined.**

***Index Terms*—ultrasonic sensor, water level monitoring, EnOcean, energy harvesting, long range, sensor module.**

I. INTRODUCTION

With today's extreme climate changes and global warning effects, floods are continuously occurring on a global scale. In Japan, this situation is very unique, because the majority of rivers are very steep with a short distance from the source to the sea (Fig. 1). This results in rapid flow of water [1].

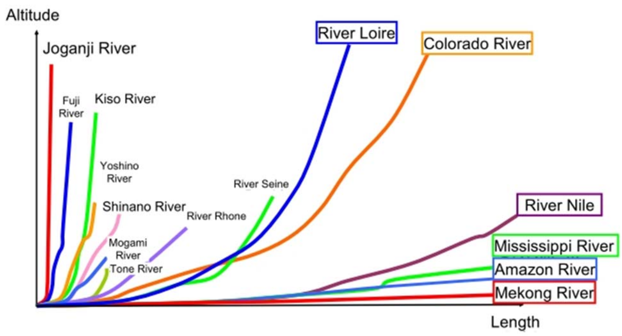

Fig 1. Comparison of different riverbeds from all around the world [1].

Additionally, approximately half of the population and three-quarters of total assets are concentrated in low-lying areas. Major damage is anticipated when flooding occurs. Furthermore, most urban areas are located in low-lying areas that are lower than the water level during floods [1]. Using the early flood detection system would save many assets and moreover, allow prompt evacuation thus, saving human lives.

River level monitoring is not a novelty and different sensors and techniques are used for this purpose. Authors in [2] developed a very large and expensive system based on the horizontal acoustic Doppler current profiler (H-ADCP). Attempts with a cheaper ultrasonic sensor resulted in a very simple prototype. However, it is not completely applicable in outdoor conditions due to lack of robustness and measurement accuracy [3]. Other authors rely on video surveillance systems [4] which require specific infrastructure and a deeper data analysis. There are also solutions with a rainfall sensor network [5], although these are not very applicable as an early flood detection system. Newer solutions include river monitoring with inclined LiDARs [6]. The proposed solution in this paper relies on a very robust and compact ultrasonic sensor. This is then attached to a completely energy independent, self-powered and maintenance free sensor module from EnOcean. Our solution is not expensive, allows easy installation and deployment, and transfer of measured data over larger distances.

This paper is organized into five sections. After the Introduction, Section II describes the ultrasonic sensor used. Section III provides more detail about EnOcean's self-powered module. Section IV describes the measurement protocol and the specifications required when water level is measured on Japanese rivers. Section V. contains experimental results and real use cases of the developed smart river and early flood detection system.

II. ULATRASONIC SENSOR

As a measuring element, the ultrasonic sensor MB7383 from MaxBotix is used [7]. It has a maximum measurement range of 10 meters with a 10 mm resolution. The measurement values are obtained on the serial output pin and

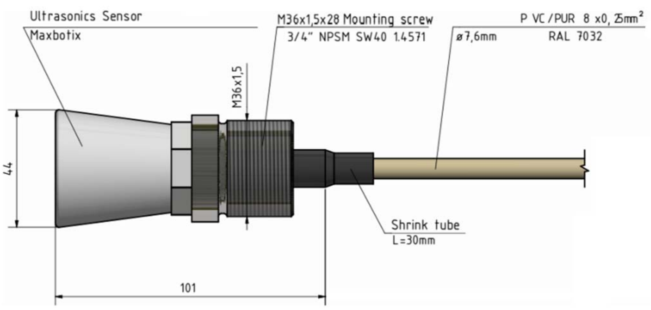

Fig. 2. MaxBotix ultrasonic sensor enclosed in housing with the attached cable.

the data format is TTL (transistor-transistor logic), where +Vcc represents logic 1, and 0 V represents logic 0. The maximum range reported is 9998 mm, while a range value of 9999 corresponds to no target being detected in the field of view. Different supply voltage levels have been tested to obtain the maximum range and accuracy of the ultrasonic sensor. Table I shows how different supply voltages affect ultrasonic sensor performance.

TABLE I. Measurements of the distance from the bridge to the river in mm for different ultrasonic sensor supply voltages. Value 1068 represents false measurement.

	3.6 V			4.0 V			5.0 V	
1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
819	818	823	820	1068	820	823	817	819
817	819	1068	821	820	819	818	818	817
818	819	818	818	821	820	819	818	817
820	820	822	818	818	1068	817	818	818
1068	821	821	1068	819	817	819	817	1068
820	820	823	819	818	818	821	819	821
824	823	822	821	817	819	1068	817	818
824	1068	1068	820	819	821	819	819	817
826	823	822	819	1068	819	1068	817	819
823	1068	1068	821	821	820	823	822	821

Three times 10 measurements of distance have been recorded on a relatively steady river and the measurement success rate is expressed for 3.6 V, 4 V and 5 V. F-measure [8] from the results above gives the following measurement success rate: 80% at 3.6 V, 87% at 4.0 V and 90% at 5.0 V. A compromise can be made between a slightly lower measurement success rate and energy consumption. The ultrasonic sensor supply voltage level is proportional to the sensor`s current consumption. Table II shows the sensor's energy consumption for different supply voltages of 3.6 V and 5 V respectively. Due to the better success rate closer to the maximum measurement range, 5 V was chosen for sensor supply voltage.

A. Generic sensor PCB

To be able to communicate with the existing EnOcean long range sensor module, the ultrasonic sensor needs some additional logic components. A small PCB was built which contains a low power microcontroller STM32L071K and a step-up converter. This ensures a stable 5 V supply voltage to the ultrasonic sensor from the variable input voltage, which can be seen on the block diagram in Fig. 3.

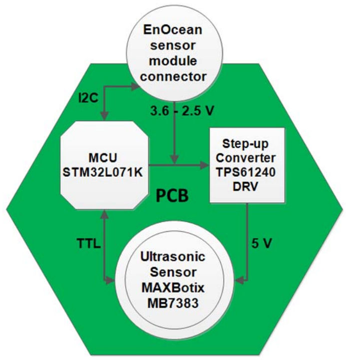

Fig. 3. Generic sensor PCB block diagram.

All the communication between the microcontroller on the generic PCB and the microcontroller on the EnOcean sensor module is done via I^2C lines. The same lines are also used to update the firmware when needed. This is done by triggering the bootloader mode of the STM32L0x microcontroller. The microcontroller on the generic sensor PCB is always powered, but 99% of time it spends in sleep mode. During this time, the ultrasonic sensor is shut down. The entire generic sensor PCB drains a constant current of around 3 μA. After connecting the MaxBotix ultrasonic sensor to the PCB in Fig. 3, the sensor becomes a generic ultrasonic sensor. It is then capable of communicating with the EnOcean sensor module via generic sensor commands described in chapter IV.

III. Solar-Powered EnOcean Sensor Module

The main source of the energy supply and central unit of the water level measurement system, is the EnOcean solar-powered long range sensor module. The sensor module characteristics and its unique communication protocol are described in [9]. Since the sensor module has a limited power supply in the form of a 40 F supercapacitor, the ultrasonic sensor needs to fulfill certain current consumption criteria so to not drain the supercapacitor within one measurement cycle. As it can be seen in Table II, at 5 V the sensor's average energy consumption per one measurement cycle is 8 mWs. The available energy from the supercapacitor (while taking into consideration the operating supply voltage from 3.6 V to 2.5 V) is expressed with (1):

$$Energy = \frac{1}{2}CV^2 = 134.2\ Ws \quad (1)$$

where,

C is the capacity of the supercapacitor (40 F).
V is the difference (1.1 V) between maximum and minimum supply voltage.

Equation (1) shows that the sensor module has enough energy stored to support 20 water level measurements, and three radio transmissions of measurement results per every wake-up cycle. Three radio transmissions need around 67.5 mWs, making it the most consuming operation.

TABLE II. Energy consumption of the MaxBotix ultrasonic sensor when powered with two different supply voltages.

Sensor@3.6V	Start-up time [s]	Average current [A]	Peak current [A]	Capacitance [F]	Measure time [s]	Energy [Ws]
MB7383-100	1.60E-01	2.30E-03	4.90E-02	4.70E-05	1.66E-01	**3.54E-03**
	34.32%		22.85%	7.23%	35.60%	**100.00%**
Sensor@5.0V	**Start-up time [s]**	**Average current [A]**	**Peak current [A]**	**Capacitance [F]**	**Measure time [s]**	**Energy [Ws]**
MB7383-100	1.60E-01	3.10E-03	9.80E-02	4.70E-05	1.66E-01	**8.09E-03**
	30.65%		30.28%	7.26%	31.80%	**100.00%**

The sensor module communicates with the ultrasonic sensor via the above mentioned generic PCB, and the specially developed GSI (Generic Sensor Interface) commands described in the next chapter. Fig. 4 shows the generic ultrasonic sensor attached to the EnOcean self-powered sensor module, with compact housing and small integrated solar cell.

Fig. 4. EnOcean self-powered sensor module with the attached generic ultrasonic sensor.

IV. Measurements and Communication

To satisfy the measurement criteria prescribed by the Japanese government [10], the developed river monitoring sensor system has to adapt its operation to the type of the river as shown in Table III.

TABLE III. Definition of measurement intervals and number of the observations for different types of rivers [10].

River size	Interval	Duration	# of observation
Great river	10min	24hrs	Ca 150
Mid and small	5min	12hrs	Ca 150
River with a rapid rise in water level	2min	5hrs	Ca 150

Besides measurement interval, it is also defined that the minimum measurement resolution has to be 1 cm and that water level should be measured in the following way:

1. One measurement sampling is done within 1 second.
2. Total measurements per cycle should last min. 20 seconds.
3. 2 maximum values or 2 minimum values can be neglected to minimize the influence of incorrect measurement data.

The generic ultrasonic sensor has two modes of operation: "monitoring" mode and "critical" mode. In monitoring mode, the measurements will be taken by default every 10 minutes, but only transmitted every 2 hours (default value). If the water level rises and the measured distance drops below a certain threshold level, the device will enter critical mode. In critical mode, measurements are taken by default every 5 minutes and every measurement will transmitted. After 150 (default value) measurements, if the distance to the surface of the water rises above the threshold level, the sensor system will return to normal mode. If the water level doesn't drop enough, the device will remain in critical mode and take another 150 measurements before checking again. Each measurement cycle performed by the ultrasonic sensor will last for 20 seconds. During this time, the distance will be measured by the ultrasonic sensor every second. At the end of the measurement cycle, the median value will be selected and used as the result of the measurement.

It is intended that the ultrasonic sensor controls when the measurements are performed and when they should be transmitted. Interrupts will be generated to inform the EnOcean sensor module that a new measurement is available. If the sensor module requests a measurement, the last measured value will be reported, instead of starting a new measurement. If a measurement is requested before a measurement has been taken, a measurement value of 0 meters will be reported. This will happen when the generic ultrasonic sensor is for the first time connected to EnOcean sensor module. After start-up, the generic ultrasonic sensor will start a measurement cycle and then generate an interrupt. Before emitting an ultrasonic wave and measuring distance, the ultrasonic sensor, for about 120 ms on the UART line transmits factory stored data relevant to sensor identification. This is not optimal behavior of the MaxBotix ultrasonic sensor, as this action is consuming energy and it is not relevant for the measurement process. Current peaks, as well as UART communication and supply voltage level after ultrasonic sensor is powered, can be seen in Fig. 5.

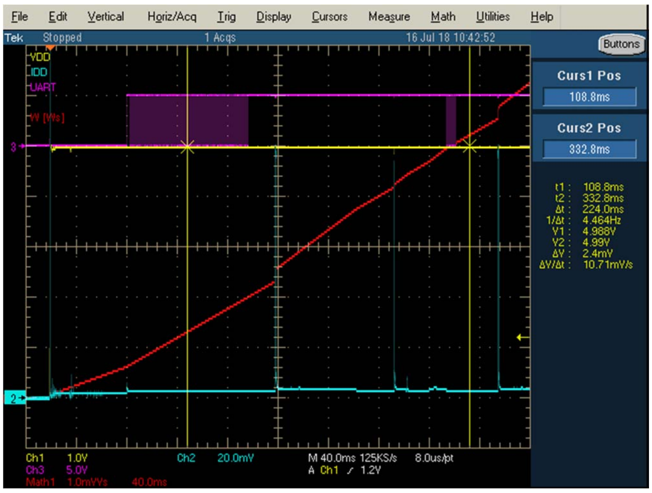

Fig. 5. Start-up of the ultrasonic sensor and measurement data transfer (purple line) together with the current peaks (blue line) and calculated energy consumption (red line).

A. *Generic Sensor Interface commands and communication protocol*

The main aim of the interface is to enable the connection of different sensors to the EnOcean sensor module with no additional effort inside the sensor module itself. The protocol is specified on all OSI (Open System Interconnection) layers [11]. On the lower layers, it incorporates the I^2C standard with dedicated lines for interrupt handling. The Generic Sensor Interface defines the communication between the EnOcean long range sensor module and a generic sensor, which is in this case an ultrasonic water level sensor [12]. The flow of the data between the ultrasonic sensor and the EnOcean sensor module, is based on the exchange of the GSI commands (Tables IV-VII) and it runs using the following algorithm:

1. Sensor module wakes up generic ultrasonic sensor by pulling separate power-on line high.
2. The generic ultrasonic sensor creates an interrupt on the interrupt line. This tells the sensor module that it is ready for operation.
3. The sensor module sends a Start Measurement Request (SMS) via I^2C lines to the generic ultrasonic sensor.
4. After the measurement is done, the generic ultrasonic sensor creates an interrupt on the interrupt line. Then the sensor module receives the measurement result with the Get Measurement Result (GMS) command.

At the end of every command, the 16 bit cyclic redundancy check (CRC) ‘CCITT-FALS’ is used. Generator polynomial is 0x1021 with an initial value of 0xFFFF [12].

TABLE IV. Request command structure [12].

REQUEST					
	Offset	Size	Value		Description
	0	1	Add + Op	0xC4	I2C Slave Address: 0x62, Operation: Write
	1	1	Length	0xnn	Specifies length of DATA_PL
Data_PL	2	1	**Packet Type**	0b0XXX XXXX	
	3	x	Content	0x...	Contains the actual data payload with topics: - Data (e.g. settings) - Function codes x = variable length of Content
	3+x	2	CRC16	0xnnnn	Data integrity check over Data_pl

TABLE V. Response command structure [12].

RESPONSE					
	Offset	Size	Value		Description
	0	1	Add + Op	0xC5	I2C Slave Address: 0x62, Operation: Read
	1	1	Length	0xnn	Specifies length of DATA_PL
Data_PL	2	1	**Packet Type**	0b1XXX XXXX	
	3	1	Return Code	0x00	Return code of the requested command.
	4	X	Additional content	0x...	Additional content returned by the requested operation if available. Can be also none. If included or not is defined by REQUEST type, actual Return code value. It is also signalized by LENGTH of DATA_PL.
	4+x	2	**CRC16**	0xnnnn	Data integrity check over Data_pl

TABLE VI. Examples of the request packet types [12].

Type	Name	Description
0x00	NA	Reserved
0x01	INFO_SIGNAL	Detecting presence of the slave by a default and short request message.
0x02	INTERRUPT_SIGNAL	Detecting & confirmation of interrupt by sensor signal.
0x03	START_MEASUREMENT	Triggering measurement.
0x04	GET_MEASUREMENT	Receiving measurement results
0x05	TUNNEL_COMMAND	Tunnels a command to another connected Sensor
0x06-0x0F	RESERVED	Reserved for future versions
0x10	SET_PARAMETER	Overall parameterization command to set parameters.
0x11	GET_PARAMETER	Overall parameterization command to get parameters.
0x12-0x1F	RESERVED	Reserved for future versions
0x20-0x2F	DEBUG	Debugging commands manufacturer specific
0x30-0x7F	RESERVED	Reserved for future versions

TABLE VII. Examples of the response packet types [12].

Type	Name
0x80	NA
0x81	INFO_RESPONSE
0x82	INTERRUPT_SIGNAL_RESPONSE
0x83	START_MEASUREMENT_ RESPONSE
0x84	GET_MEASUREMENT_RESPONSE
0x85	TUNNEL_COMMAND_RESPONSE
0x86-0x8F	Reserved for future versions
0x90	SET_PARAMETER_RESPONSE
0x91	GET_PARAMETER_RESPONSE
0x92-0x9F	Reserved for future version
0xA0-0xAF	DEBUG_ RESPONSE
0xB0-0xFF	Reserved for future versions

V. EXPERIMENTAL RESULTS

Before the developed sensor system was installed in the field, dark time run operation had to be tested. Dark time operation represents the sensor module operation time with the attached generic ultrasonic sensor and without the supercapacitor being recharged via the solar cell. During this test, one generic ultrasonic sensor was set in critical mode by changing the distance threshold to 2 meters. The solar cell of the EnOcean sensor module was also covered to prevent recharging of the supercapacitor. Measurements and the transmission of the measurement results over the air occurred every 5 minutes. The entire sensor system ran until the voltage on the supercapacitor dropped to 2.5 V. This is when the sensor module shuts down automatically until is recharged again. In parallel, another sensor module ran with another generic ultrasonic sensor, but now set in the monitoring mode. In this mode, measurements were triggered every 5 minutes while the transmission of the data over the air occurred every 2 hours. Fig. 6 compares the dark time operation for these two different operation modes.

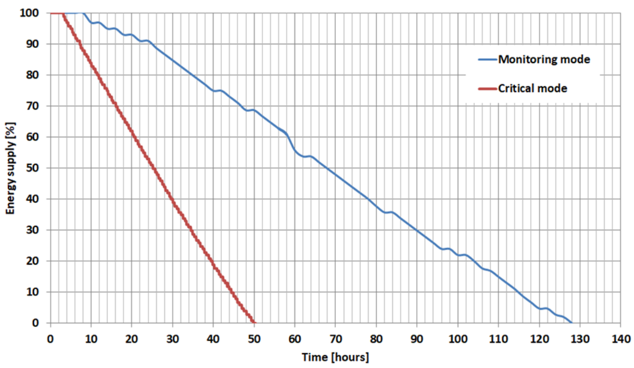

Fig. 6. Dark time operation of the sensor system for two different surveillance modes.

It can be seen when the generic ultrasonic sensor operates in critical mode, its dark time operating life is 57% shorter. This needs to be taken into the consideration so that entire sensor system has enough energy to operate, even in the worst case conditions.

After energy consumption is defined, different types of 3D printed cones for the ultrasonic sensor, were tested above different river flow variations. Table VIII summarizes the measurement success rate depending on the cone used and the river conditions. In Fig. 7 the different types of cones used are depicted and Fig. 8 shows an example of "calm" and "very wild" river flow respectively.

TABLE VIII. Measurement success rate for different cone types and different river flow.

Cone type	River type and the distance to the bridge		
	Calm (9.1 m)	Wild (9.6 m)	Very wild (8.5 m)
No cone	**100%**	**38%**	**14%**
Extended cone	100%	97%	24%
Cylinder cone	**100%**	**56%**	**4%**
Spy cone	100%	100%	69%

Fig. 7. Different 3D printed cone types used during water level measurements.

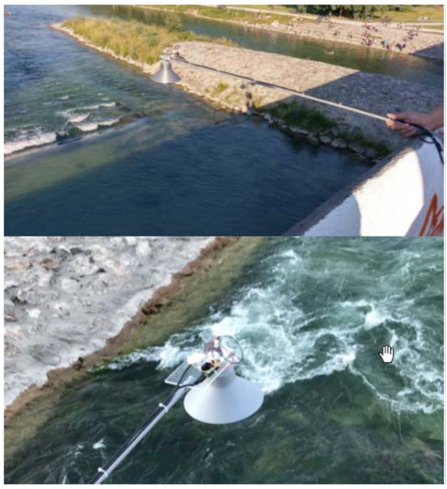

Figure 8. Measurements with the spy cone on a "calm" river flow and a "very wild" river flow.

The complete system installed above the river in Hyogo prefecture in Japan can be seen in Fig. 9. All the benefits of the EnOcean self-powered sensor module are exploited; compact size, self-powered, maintenance free and long-range transmission. The closest receiver is 2 km away from the EnOcean sensor module itself.

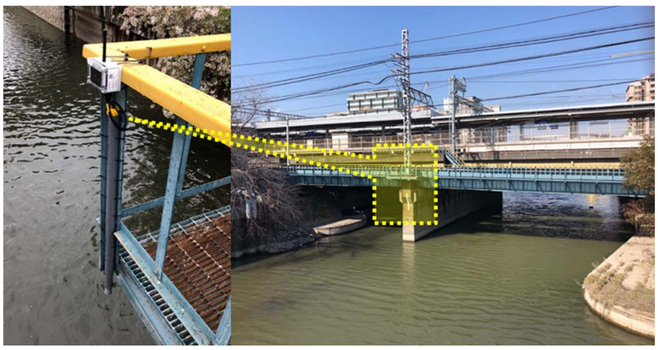

Fig.9. Complete smart river monitoring and early flood detection system installed above the river in Hyogo prefecture, Japan.

ACKNOWLEDGMENT

Special thanks to Tobias Meyer for his contribution to the Generic Sensor Interface specification development and to Rajdeep Deo for the paper review and the grammar check.

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Annexure C

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