University of Peradeniya

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Department of Computer Engineering

Final Project Design

REAL TIME WATER QUALITY MEASUREMENT SYSTEM

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Abstract

Real Time Water Quality measurement (RTWQ) is a technique used by environmental authorities all around the world. RTWQ system is basically using sensors to detect parameters of water such as pH, conductance, turbidity, temperature, Biological Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, concentrations of organic and inorganic substances etc. continuously and update a web server and make data available real time. Current manual system is **time wasting, expensive, require higher labour with expertise** and **difficult to maintain logs and records of data**. Hence, our solution is to develop a power efficient system that is capable of measuring water quality real-time at an affordable cost which can be used from a remote location and having proper security features.

The system consists of several sensors located in remote locations to measure the water quality real time. The information received by sensors are sent to a centralized system which is monitoring the water quality measurement through GSM modules. These information can be sent at a predefined interval of time and they can be analysed from the central monitoring system. The system is secured with access restrictions and only authorized personnel can access.

Sensors include LM35 temperature sensor, turbidity sensor, conductivity sensor, and pH sensor and they are controlled by an ATmega32 microcontroller at the end node and recorded data is sent via a SIM808 GSM module. As the networking part a RESTful application will be created with the help of HTML, CSS, Bootstrap, java script, and AJAX as frontend technologies and Node.js, MongoDB, Mongoose, PHP as backend technologies. In addition, modern encryption techniques will be used to secure data.

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Chapter 1:

a. Introduction and Background

Real Time Water Quality (**RTWQ**) measurement is a technique used by environmental authorities and different companies involved with water testing which came into light after 1950s. This RTWQ refers to measurement of water quality and making them available on the web in real time. Although this process is said to be real time, in practice what is done is recording data in small intervals varying typically from every five minutes to hourly, and these recording data is considered to be continuous. The process of uploading the data to web servers may also have pre-defined intervals. These data come handy in when making decisions regarding the level of pollution of water, public safety for the consumption of water etc.

Real Time Water Quality is made possible because of improvements of sensors and data recording technology. Today, with the evolving computers that are capable of processing a large amount of data simultaneously, it is possible to measure several qualities of water simultaneously. Further, there are sensors that are developed even to measure chemical properties of water.

Water Quality measurement is vital because water is consumed by every human being and animals on a daily basis, and we should have a guarantee that water we are consuming are not harmful to health. Further, it is important in order to maintain a proper eco system without polluting the existing water resources.

Usual parameters measured in water quality testing are **conductance, pH, water temperature, turbidity, BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand) and constituents of the dissolved chemicals.**

Usually, these kinds of systems will cost a lot, and the idea of this project is to deploy a system which is capable of at least giving a rough idea about the quality of water based on several properties selected from the above list. For that purpose, we are thinking of measuring the **conductance, pH, water temperature, and turbidity.** The rest of the parameters may require a deep chemical analysis of the samples and hence may require manual work or else the system should contain sensors measuring chemical constituents of water which would increase the cost of production of such kind of system.

b. Problem Statement

Major drawbacks of the current manual system of collecting samples and measuring them are as follows:

i) In order to measure quality of water at a certain location, it may require to go to the site to collect samples and analyse them.
ii) Repetition of taking samples from sites is difficult.
iii) Cost of collection of samples for several times may be higher because the sampling tools has to be prepared every time sampling is done.
iv) Higher risks to field officers who actually go to sites as these water resources can be hazardous in some cases.
v) Inability to analyse several sites simultaneously.
vi) Higher labour cost.
vii) Time wasting as it takes a lot of time to collect, analyse and finalize samples.
viii) Data logging and report generation over space and time is very difficult using manual methods, especially when a large amount of data is available.
ix) Training of field officers is required, and those personnel should have a certain technical knowledge regarding the field work.

c. Objectives

Proposed Solution

The main objective of the project is to develop a power efficient system that is capable of measuring water quality real-time at an affordable cost which can be used from a remote location and having proper security features.

Specific Objectives

i) Low power consumption end node with the help of the circuit design.

ii) Easier Report Generation over space and time.

iii) Higher security through encryption of data and access levels to web server through via the front-end design

iv) Update database at the central server frequently at a predefined interval.

v) Cost effective product through the design by using components that are not too much expensive.

Chapter 2:

a. Description of design components and the Technical & Theoretical background

2.1) Temperature Sensor (Waterproof)

As the temperature sensor, LM35 which is a semi-conductor IC was used. This device is incredibly straight-forward when it comes to its basic connection scheme. There's a **+V pin, GND, and output**. When connected to +V and GND it delivers an analogue voltage through its output pin linearly proportional to the current temperature, where each 10mV translate into 1°C.

It couldn't possibly be any simpler, but it has an immediately obvious drawback; the **smallest temperature** it can report when wired this way is **0°C** (corresponding to a 0V output). For sub-zero readings this IC needs to be connected in "full-range mode", which involves getting a negative-voltage power supply, making things really complicated all of a sudden. Whatever approach that it is required, we want to use to "feed" this device the negative voltage it needs, will require additional circuitry, which makes it immediately less convenient to use unless the rest of the project already has a negative voltage line.

But for this project it can be assumed that the temperature of water won't go below as typically below zero degrees Celsius is ice, not water.

The following is a brief description of the device found in the data sheet of the LM35.

> "The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼ °C at room temperature and ±¾ °C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the water level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range."
>
> Source: Data Sheet of LM35 Link: http://www.ti.com/lit/ds/symlink/lm35.pdf

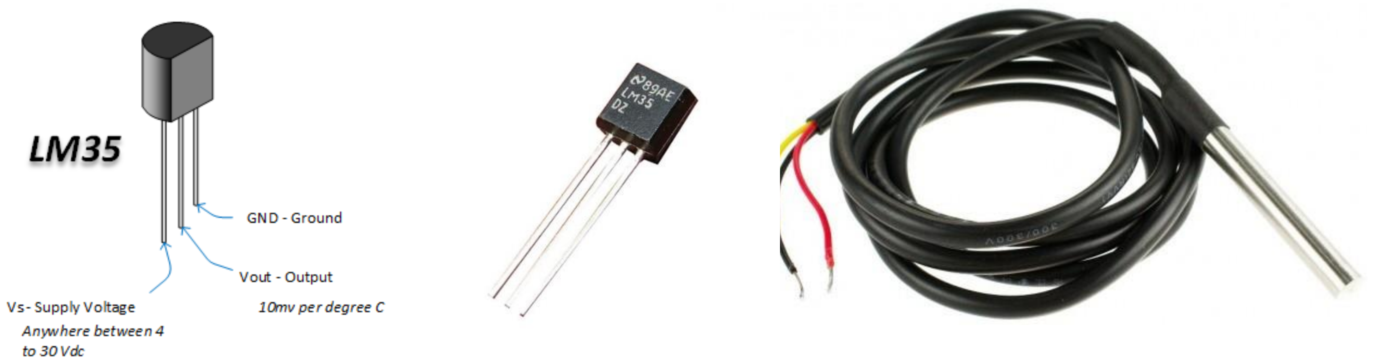


Figure 1: LM35 pin configuration & LM35 actual sensor (left) and Waterproof temperature sensor (right)

2.2) GSM Module

GSM module is used to transfer data from an end node to the central server via GPRS. The model we are hoping to use is SIM808 GSM module. SIM808 module is a GSM and GPS two-in-one function module. It is based on the latest GSM/GPS module SIM808 from SIMCOM, supports GSM/GPRS Quad-Band network and combines GPS technology for satellite navigation. It features ultra-low power consumption in sleep mode and integrated with charging circuit for Li-Ion batteries, that make it get a super long standby time and convenient for our project and it can even be used with rechargeable Li-Ion battery. The module is controlled by AT command via UART and supports 3.3V and 5V logical level. The following are the key features of this GSM module

Features

- Supports multiple frequencies (Quad-band 850/900/1800/1900MHz)
- GPRS multi-slot class12 connectivity: max. 85.6kbps(down-load/up-load)
- GPRS mobile station class B
- Controlled by AT Command (3GPP TS 27.007, 27.005 and SIMCOM enhanced AT Commands)

- Supports charging control for Li-Ion battery
- Supports Real Time Clock
- Supply voltage range 3.4V ~ 4.4V
- Integrated GPS/CNSS and supports A-GPS
- Supports 3.0V to 5.0V logic level
- Low power consumption, 1mA in sleep mode
- Supports GPS NMEA protocol
- Standard SIM Card
- Operating Temperature range -40^0C ~ 90^0C

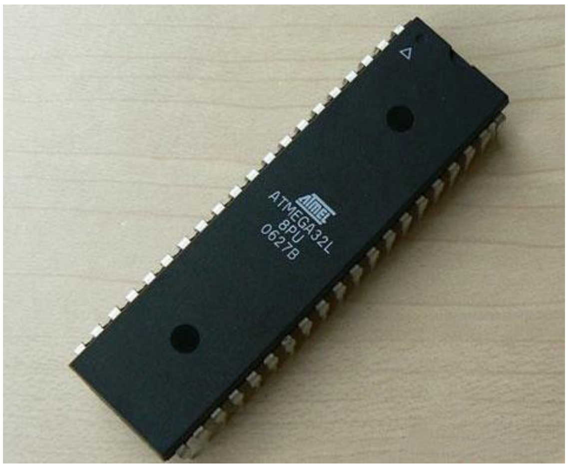
Figure 2: SIM808 GSM module

2.3) ATmega MCU

ATmega32 will be used as the embedded platform for this project. ATmega32 is an 8-bit high performance microcontroller of Atmel's Mega AVR family. Atmega32 is based on enhanced RISC (Reduced Instruction Set Computing) architecture with 131 powerful instructions. Most of the instructions execute in one machine cycle. Atmega32 can work on a maximum frequency of 16MHz. ATmega is easier in setting up in a shorter time. Since it contains **in-built internal pull up resistors** to avoid floating of pins, an extra circuitry is avoided. Further, it consists of a variety of on-chip peripherals such as **3 timers** (two 8-bit and one 16-bit timers), 8 channel 10 bit **ADC**, **PWM** mode, **I^{2}C** bus, **USART**, **SPI serial interface, sleep modes** (watchdog timers) and many more. It consists of a reasonable size of RAM and ROM which help to process data and store codes conveniently. The following are the key features of the ATmega32 MCU.

Key Features:

- 32 x 8 general working purpose registers.
- 32K bytes of in system self-programmable flash program memory
- 2K bytes of internal SRAM
- 1024 bytes EEPROM
- Available in 40 pin DIP, 44 lead QTFP, 44-pad QFN/MLF
- 32 programmable I/O lines
- 8 Channel, 10 bit ADC
- Two 8-bit timers/counters with separate pre-scalers and compare modes
- One 16-bit timer/counter with separate pre-scalers, compare mode and capture mode.
- 4 PWM channels
- In system programming by on-chip boot program
- Programmable watch dog timer with separate on-chip oscillator.
- Programmable serial USART
- Master/slave SPI serial interface



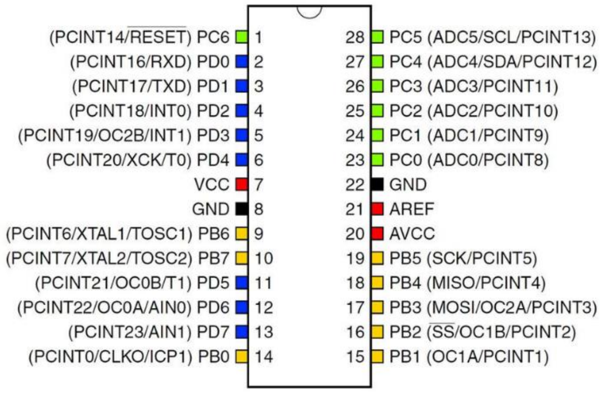


Figure 3: ATmega 32 IC (left) and ATmega32 pin configuration (right)

2.4) pH Probe

A pH Electrode can be compared to a battery in that an electrical voltage is generated between two points that is a function of water chemistry. In the case of a pH electrode the voltage potential is a function of the free acidity or free alkalinity of the solution in which it is immersed.

The pH element is a thin glass membrane that is permeable by H+ ions. The electrode is filled with a neutral solution, which by definition contains an equal number of H+ and OH- ions. When the probe is immersed in an H+ rich environment (acidic) the glass membrane is permeated by the H+ ions which exert a positive potential on the sensing electrode. This potential difference is measured by a pH meter and converted to a pH output.

Likewise, when the probe is immersed in an alkaline environment there exists within the probe a higher H+ concentration than outside of the probe. This causes H+ ions within the probe to migrate outside of the probe which leaves an excess of OH- ions within the probe. A negative potential is thus sensed by the pH meter.

The following are the features of the pH probe we are expecting to use.

Features

- 100% Brand new and high quality
- BNC connector, suitable for most pH meter and controller with BNC connector.
- Suitable for wide range of application: Aquariums, Hydroponics, Laboratory etc.
- Measurement range: 0.00~14.00 PH
- Zero-point: 7 +- 0.5PH
- Alkali Error: 0.2PH
- Theoretical Percentage Slope: 98.5%
- Internal Resistance: 250M
- Response Time: 1min
- Operating Temperature: 0-60ºC
- Terminal Blocks: BNC plug
- Cable length: Approx. 70cm

Figure 4: pH probe

2.4) Conductivity sensor (Hand-made)

A conductivity sensor which is already available on the market could have been used instead of a handmade one which will in turn provide more accuracy than the hand-made one. But the conductivity sensor available in the market will cost about (9$ = Rs. 1400 approx.) which is relatively high. Since the final product is meant to be economical, and the conductivity probe could be made easily with a reasonable accuracy using components which are really cheap, it was decided to use a hand-made conductivity sensor in the project.

Materials used:

- laptop or desktop computer with USB cable and Internet access
- 2 x 20 cm lengths of 22 gauge single-strand insulated copper wire
- 2 x 10 cm lengths of 32 gauge nicrome wire
- wire stripper
- plastic barrel from a disposable pen, such as a BIC pen
- electrical tape
- several plastic cups, for the several test solutions
- half-size or larger breadboard
- assorted jumper wires
- 470 Ω resistor
- 9V battery/ can use Arduino board 5V
- Arduino UNO

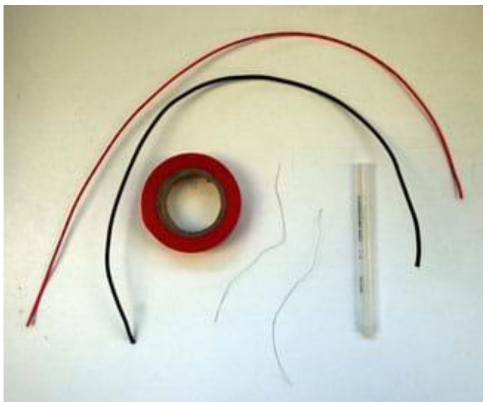


Figure 5: Material for conductivity probe

Working principle:

The measurement of conductivity is typically a measure of how easily electrical current is able to move through a solution. The higher the conductivity of a solution, the less resistance to the flow of electrical current. This is the basis for the conductivity probe that is used in the project. The probe measures resistance and translates the resistance as an indicator of conductivity. Hence, if the solution has a high resistance, such as with a non-electrolytic solute, the conductivity will be very low and if the solution has a low resistance, such as with an electrolytic solute like table salt, the conductivity will be very high. The conductivity probe uses simple electrical circuits to communicate the measurement to the user.

Hence, resistance of solutions to conduct electricity is used as a measure of conductivity and converted in to a voltage. Then depending on the voltage levels obtained and using a pre-calibrated scale conductivity of a solution can be known. Note that here pre-calibration refers to using the test solutions with known conductivities and compare with the actual voltages obtained and scale them manually. Here, the conductivity obtained is actually relative to the conductivities of the known solutions.

Limitations:

The conductivities obtained are relative to the conductivities of original solutions. Hence, a precise calibration is required in order to obtain a higher accuracy from the conductivity sensor. But having a precise calibration may be somewhat difficult leading to less accuracy of the conductivity sensor. Number of levels of calibration of the conductivity depends on the user requirements, higher the number of levels, higher the accuracy. But having higher number of levels is not always possible as voltage (electrical resistance) may change depending on the other factors such as temperature, pH etc. and it is really difficult to maintain them constant while calibrating. Hence, we have to use lesser number of levels which is optimum for our application.

Chapter 3:

a. Implementation of the project

The following chapter describes how we are going to implement the project.

i. Embedded Systems Design

1) What will you be measuring and/or controlling?

Temperature – It will be measured using a waterproof temperature sensor
pH – It will be measured using the pH probe
Conductivity – It water will be measured with the help of two electrodes
Turbidity – It will be measured by sensing the amount of light passing through water

2) What embedded systems platform(s) will you be using, and why?

ATmega32 – (probably an Arduino – Arduino also contains this IC) the reason for using this is because it comes with already in-built peripherals which can be really useful in this project. They are;

ADC – To convert analog inputs taken from sensors in to digital signals
32 General Purpose Working Registers – Can manipulate a lot of I/O s.
Built in pull up resistors – Extra circuits are not required reducing power consumption
3 timers – Can be used to build events which trigger when certain conditions are met
1KB EEPROM, 2KB SRAM, 32KB self-programmable flash memory – Higher amount of code and data can be stored in the memory

3) How does the system connect to the network?

SIM808 GSM module – This GSM module is used to communicate with the server using GPRS via Internet

4) What peripheral components will you be using, and how do they work?

DS18B20 waterproof temperature sensor –

Why?

Usual temperature sensors are RTDs (Resistance Temperature Detectors), Thermistors, Thermocouples, and semi-conductor IC sensors.

The following table shows the comparison between these sensors.

Criteria	RTD	Thermistor	Thermocouple	IC Sensor
Temperature Range / ^0C	-250 to 750	-100 to 500	-267 to 2316	-55 to 200
Accuracy	Best	Depends on calibration	Good	Good
Linearity	Good	Worst	Good	Best
Sensitivity	Less	Best	Worst	Good
Circuitry	Complex	Depends on accuracy/power requirements	Complex	Simplest
Power Consumption	Higher when taking measurements		Low to high	Low
Relative system cost	$$-$$$	$-$$$	$$-$$$	$

Table 1: Comparison between the temperature sensors

From the comparison given in the above table, it is evident that semi-conductor ICs are optimum for low power consuming, low cost projects with a reasonable accuracy, linearity, temperature range and sensitivity.

5) How do you interface those components?

Temperature sensor, turbidity sensor, pH probe, conductivity electrodes will be connected to the end node via microcontroller unit. Then the entire end node will be connected to the central server.

6) What are the limitations of those components?

- Temperature sensor– Inability to measure negative temperature under the simple circuit design and will require a much more complex circuit.
- pH probe – Not responding quick changes in the pH of water.
  Will not work properly above 70 ^0C
- ATmega32 – Memory limitations for storing data and the program together.

7) What workarounds can you come up with in order to deal with those limitations?

- It is actually not required to worry about negative temperatures as the temperature of water is typically above zero most of the time as below zero is basically ice
- Have to restrict the time interval of recording data more than the response time of the pH probe.

- Typically, we won't find water resources having temperatures closer to 100^0C unless it is a hot water well as found in Trincomalee. Excluding such extreme cases, most of the time temperature of water will lie below the operation temperature of the pH probe.
- Has to limit the amount of code stored in the memory of the microcontroller and regarding the data stored in the memory of the microcontroller they have to be cleared immediately after they are successfully sent to the web server, to gain memory space.

ii. Web and Network Application Design

1) What network protocols and middleware will you use, why, and how do they work?

MQTT (Message Queuing Telemetry Transport) is a messaging protocol that works on top of TCP/IP. It is designed for connections with remote locations where a "small code footprint" is required or the network bandwidth is limited. It is mostly suitable for sensing applications and mobile applications. Moreover, it supports low power usage, minimised data packets, and efficient distribution of packets among several clients.

GTP – GPRS Tunnelling protocols are a set of IP based protocols that are used to send GPRS packets via GSM (Global System for Mobile Communications), UMTS (Universal Mobile Telecommunications System) and LTE (Long Term Evolution) networks. This is used when packets are sent to the telecommunication tower from the GSM modules.

In addition, typical TCP/IP protocols are used as the rest of the communication, since after the telecommunication towers the remaining part of the packet transfer is done via the Internet.

2) What back-end and front-end technologies will you use, and how do they work?

Front end – HTML, CSS, Bootstrap, Java script, AJAX, Vue js
Back end – mySQL, PHP

- HTML, CSS will be used to generate static context of the front end.
- Bootstrap will be used to make the front end responsive, so that it supports various resolutions and various views on different devices such as laptops, desktop PCs, mobile devices etc.
- AJAX and java script will be used to generate the dynamic contents of the pages.
- mySQL is the database type which is used to store data. It is querying language which supports php finely.
- PHP used as the backend language since mySQL is used as the database and php can handle mySQL better than other languages.

3) What APIs will you use when connecting different parts of the system?

REST API - A RESTful API is an application program interface (API) that uses HTTP requests to GET, POST data.

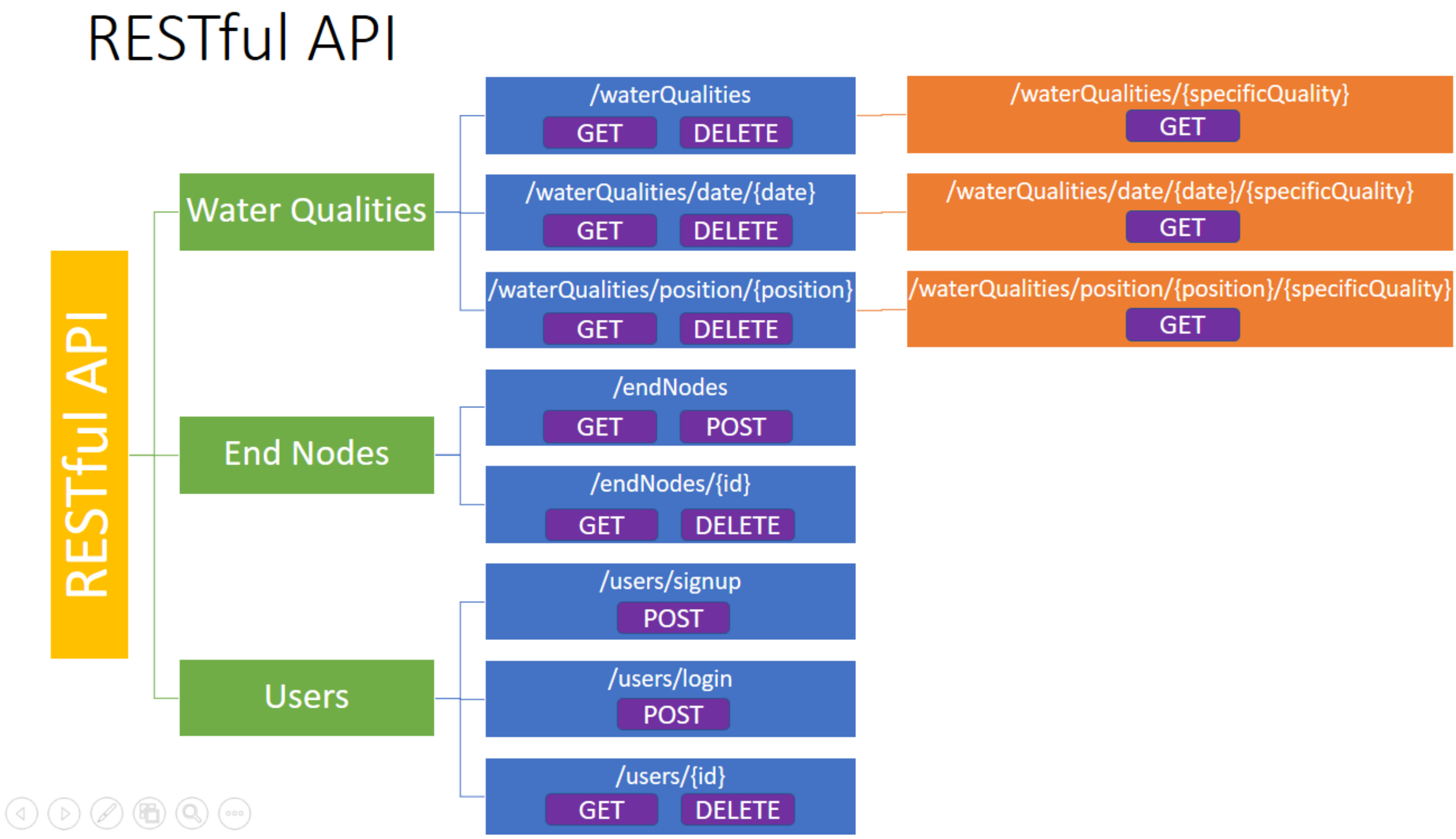


Figure 6: RESTful API

iii. Computer and Network Security

1) Are there any sensitive data in your system that need to be secured?

- The recorded data sent to the server from each node has to be secured. For instance, one might be able to change/modify the actual data sent to the server by intercepting.
- The personal details of the members logging in to the system through the frontend UI.
- Login requests to the central server.

2) How might an unauthorized third party obtain data from your system?

- A third party may intercept the actual data sent to the server while packets are transmitted via GPRS or Internet and then modify the data and send the modified data to the server.
- Personal details of the members logging in to the system can be retrieved by hacking the server database.
- Sending replay attacks by listening to logging in of members to the server.

3) How might an unauthorized third party manipulate your system?

- A third party may send modified data to the server hiding the real data.
- A third party may take over the system by hacking the central server.

4) What security features are you able to implement, and how?

- Modern encryption techniques can be used when sending data from an end node to the server.
- Validation of access to the central server.
- Maintaining initial password protected login and having access levels to access the system.
- Add SSL in Transport layer to ensure the safety of packet transfer via Internet.

User Authentication

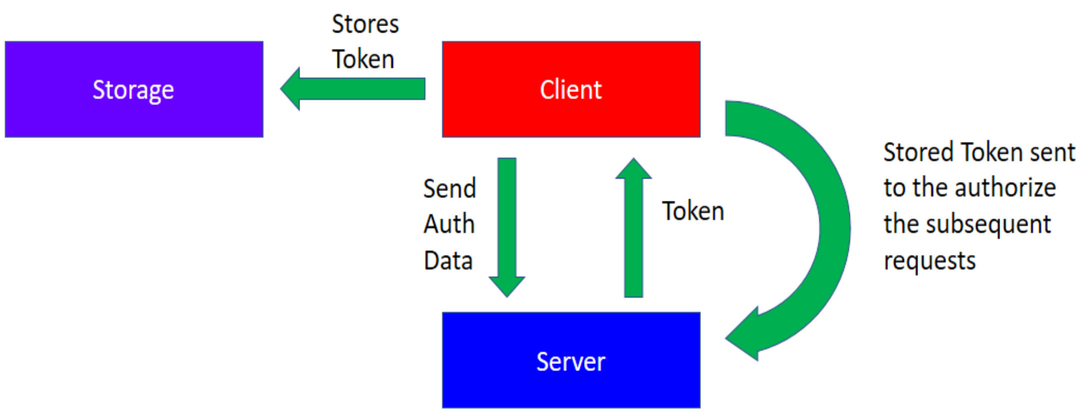


Figure 7: User authentication diagram

b. Block diagrams & Circuit diagrams

b.1. pH Sensor

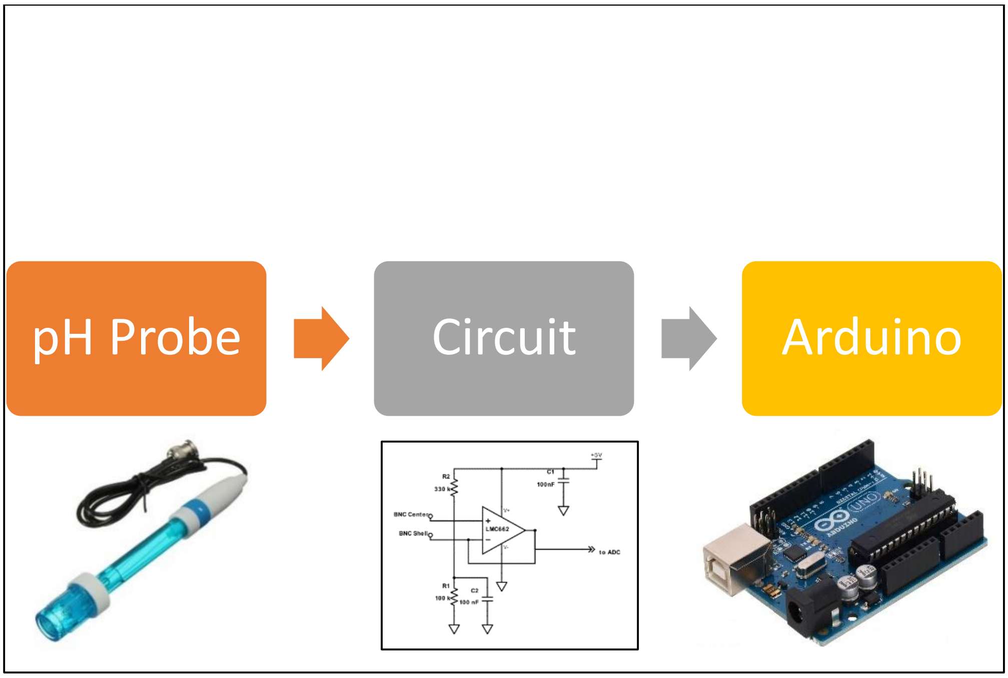


Figure 8: Block Diagram of pH sensor

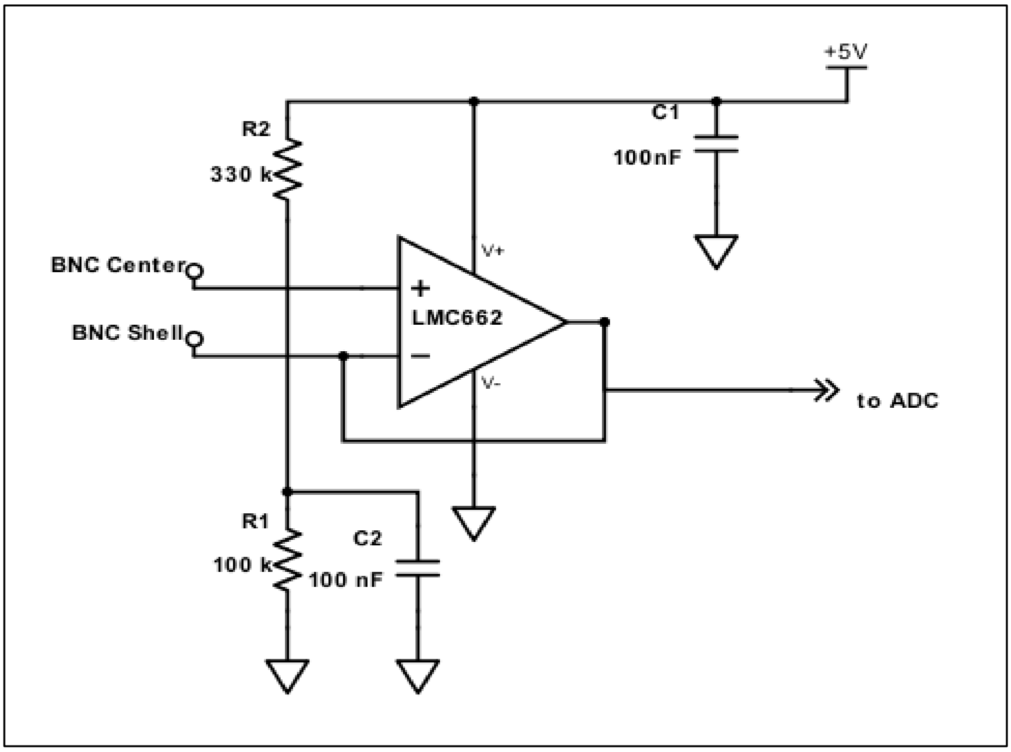


Figure 9: Circuit which is using to connecting the pH probe

pH probe plug is a BNC. Therefore to connect the pH probe to the Arduino there should be some intermediate connection. This is the circuit that using to connect the pH probe to the micro controller.

b.2. Turbidity Sensor

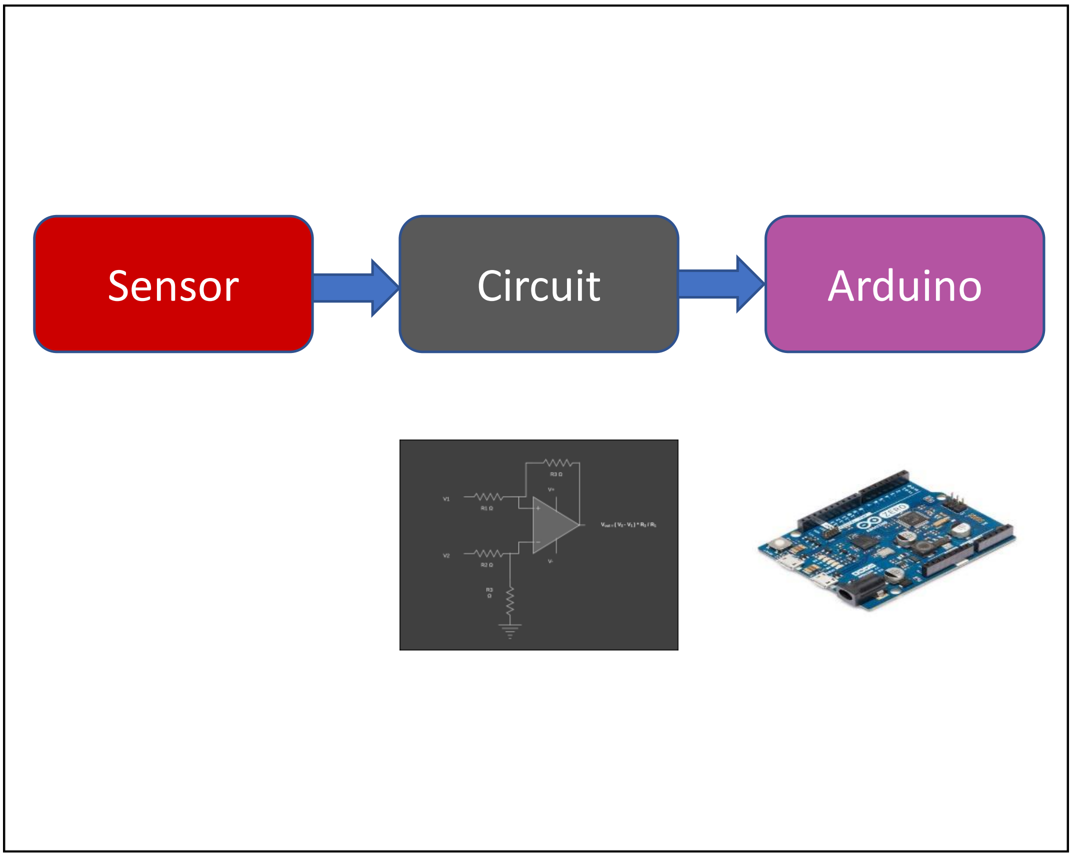


Figure 10: Block diagram of turbidity sensor

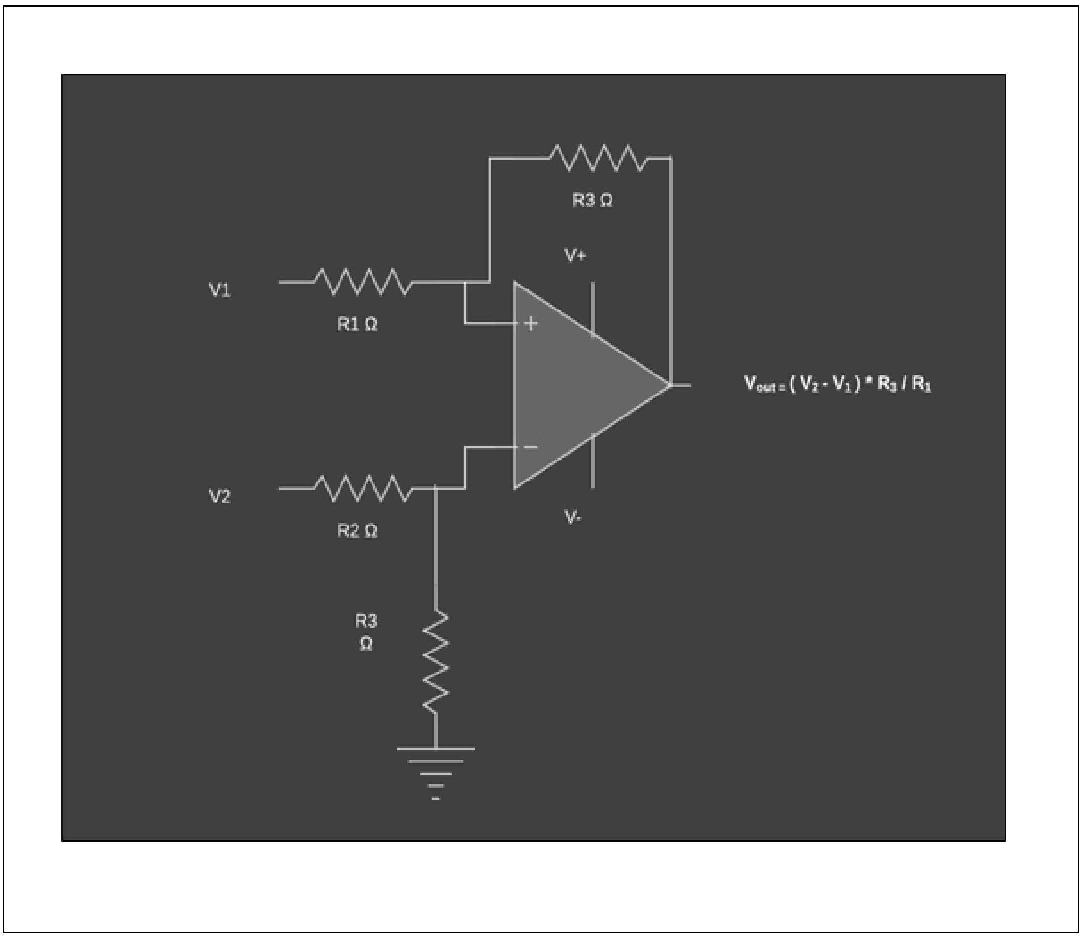


Figure 11: Circuit diagram of the turbidity sensor

b.3. Conductivity Sensor

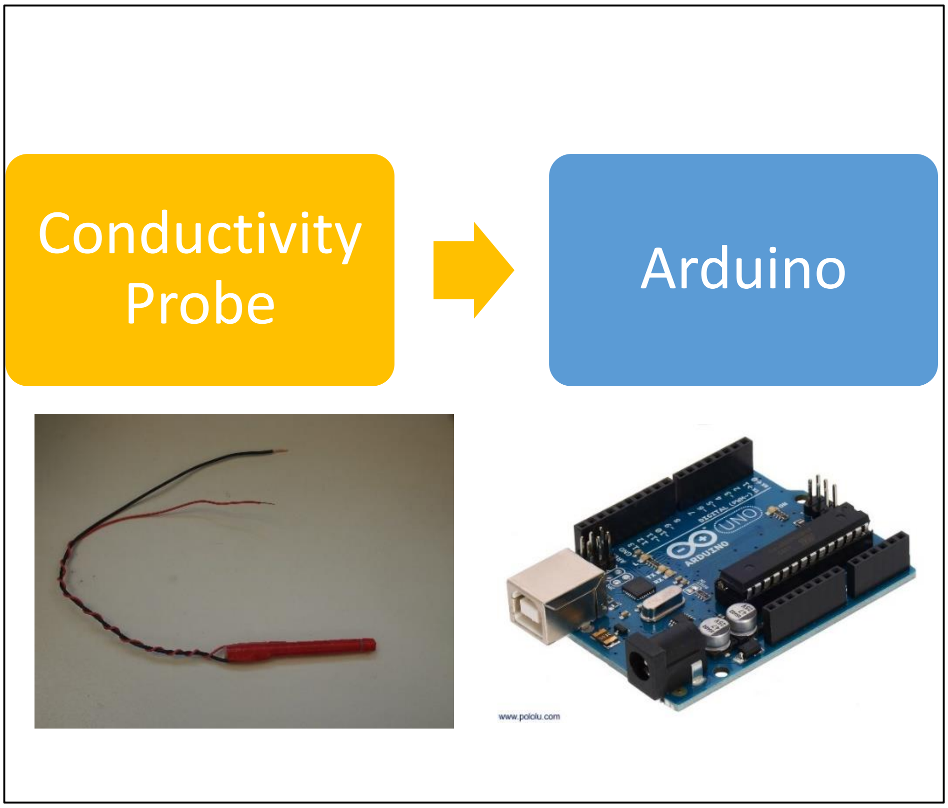


Figure 12: Block diagram of the conductivity sensor

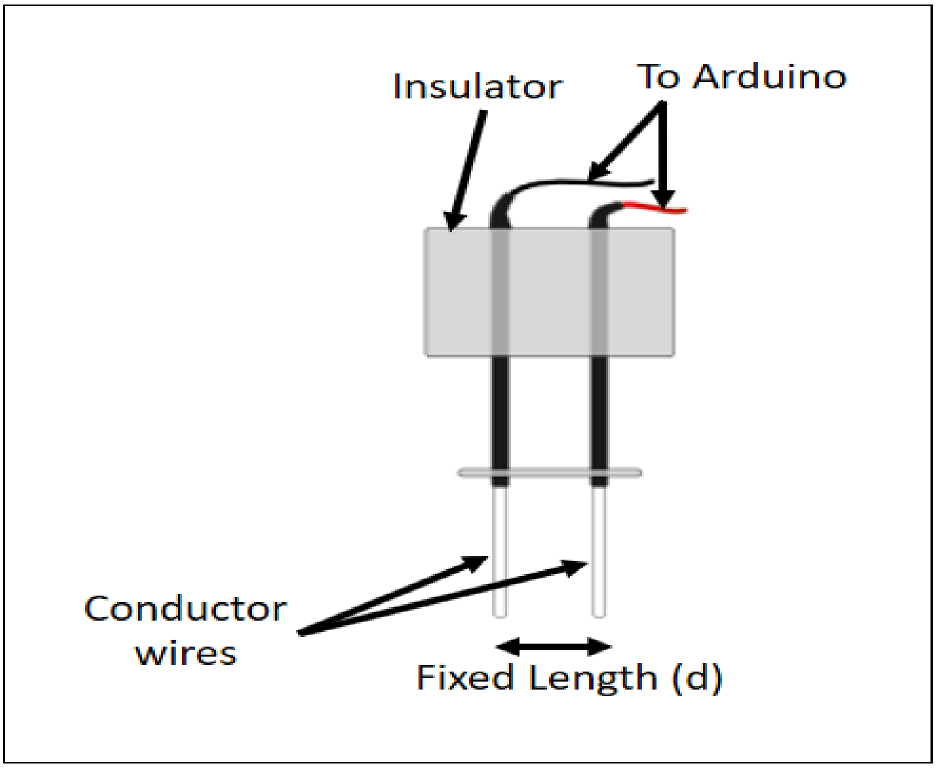


Figure 13: Circuit diagram of the conductivity sensor

b.4. Temperature Sensor

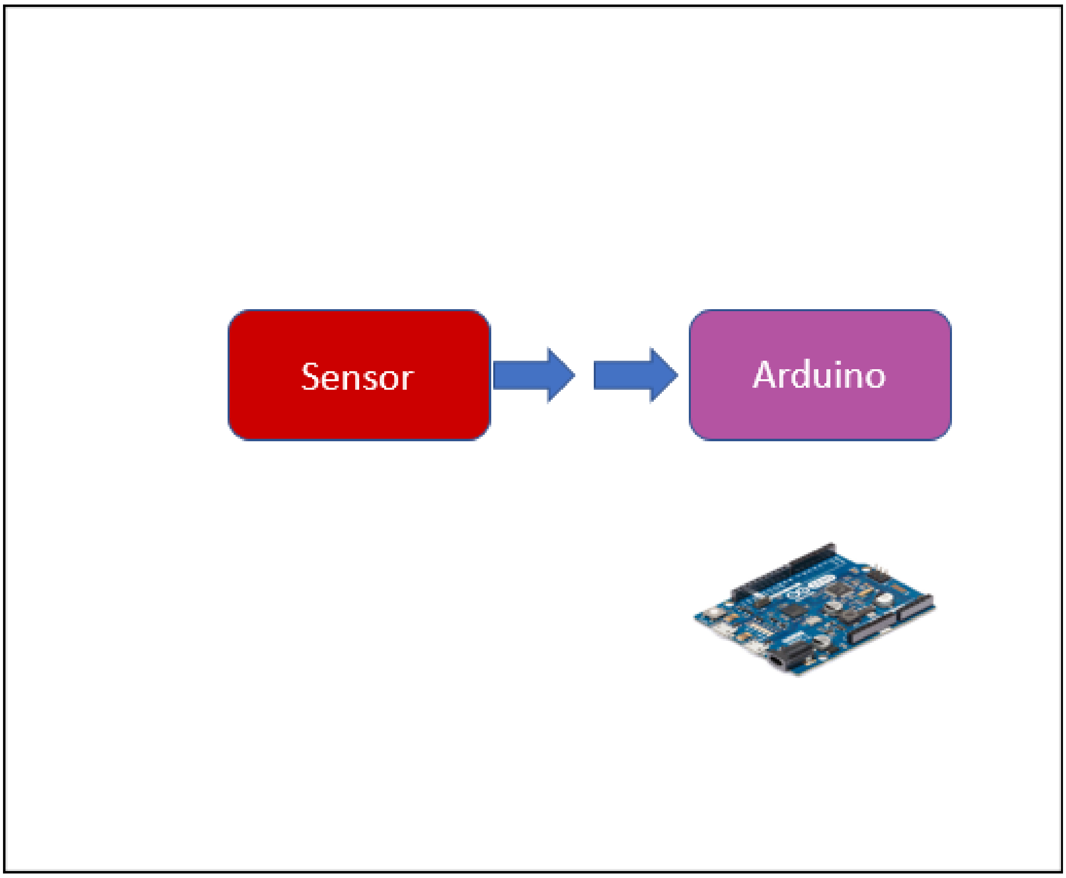


Figure 14: Block diagram of the Temperature sensor

b. Overall design of the system

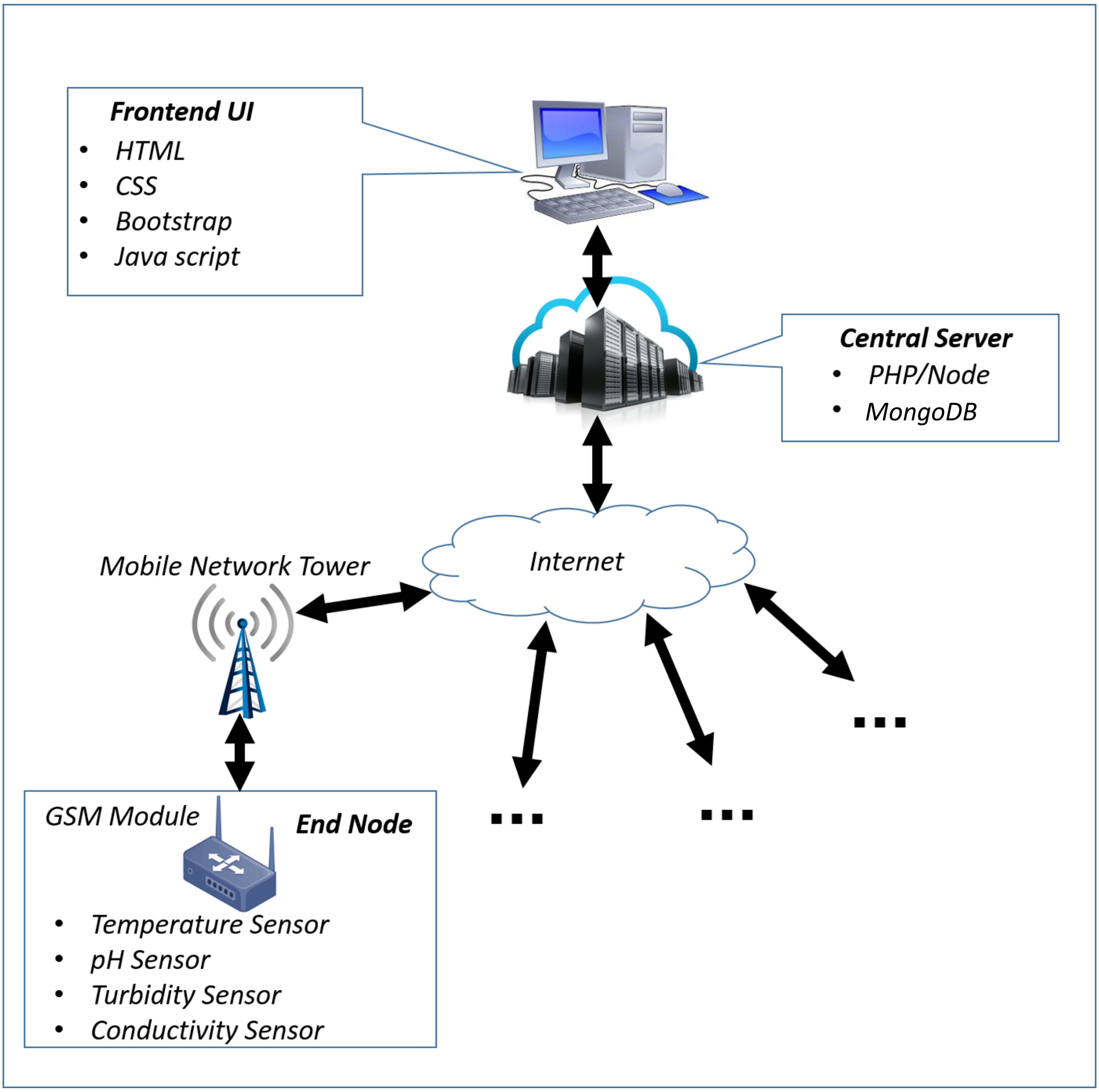


Figure 15: Overall design of the RTWQ system

Server Side Overview

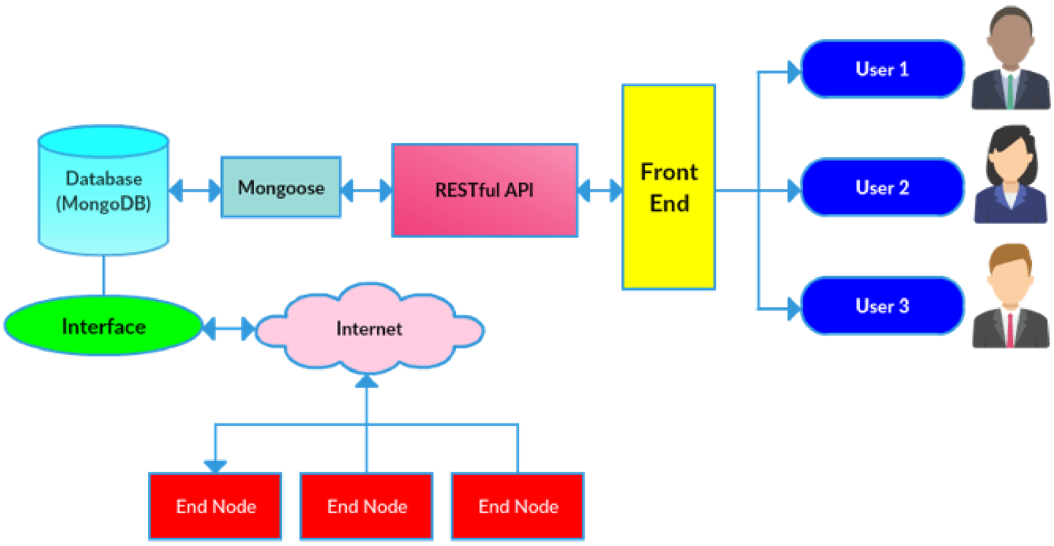


Figure 16: Server-side overview

Database

Temperature	Turbidity	pH	Conductivity	Position	Date

Table: Readings Table

First Name	Last Name	Email	ID	Password	Contact No

Table: Users Table

ID	Position

Figure 17: Database overview

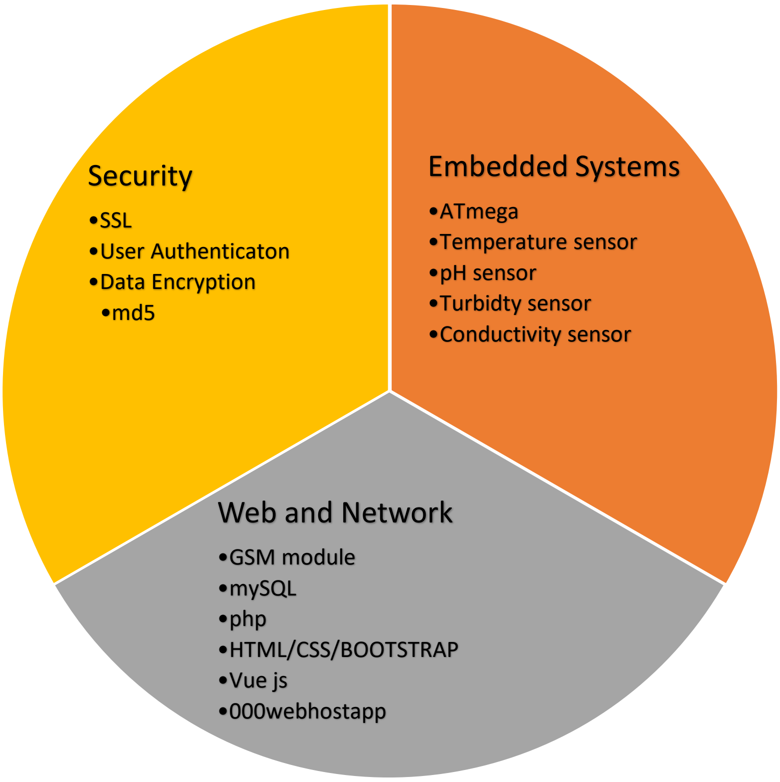


Figure 18: Aspects of the system relevant to the courses

d.Designed GUI

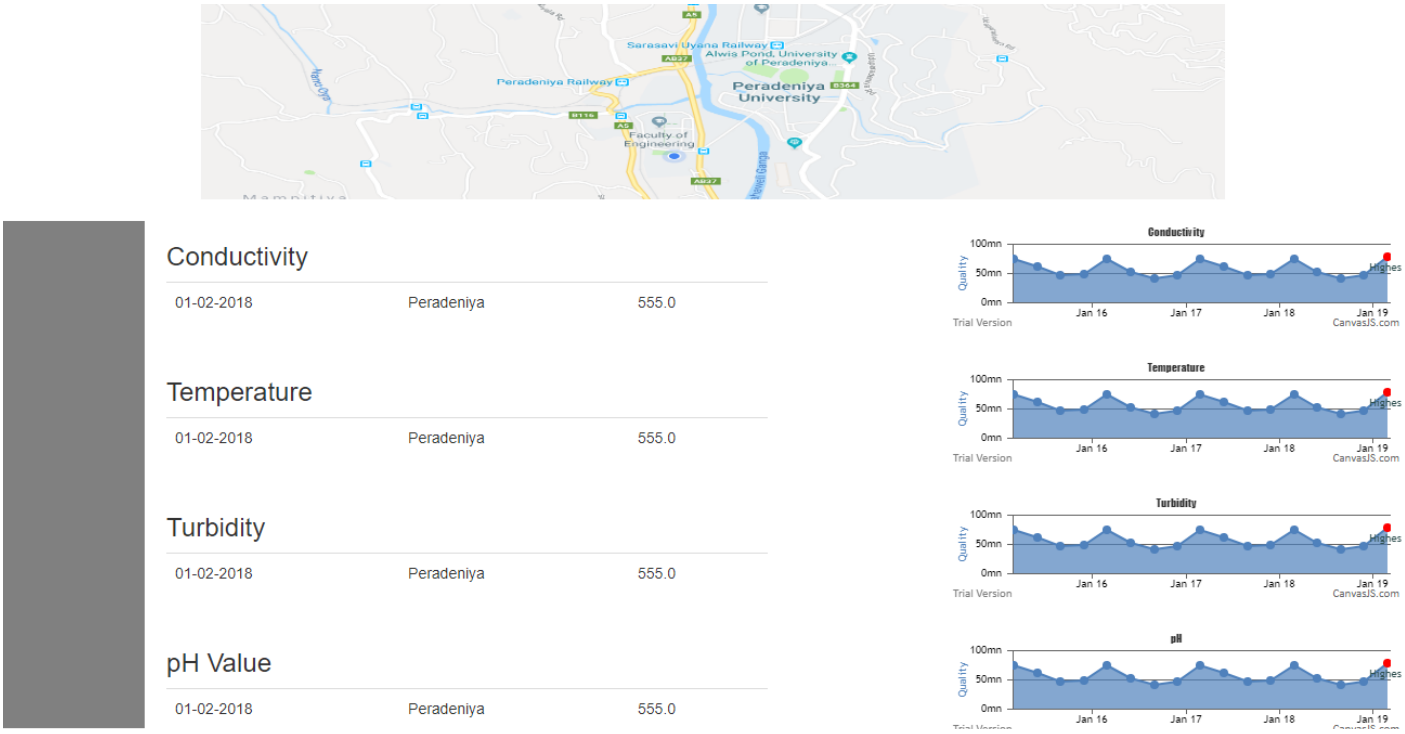


Figure 19: Designed GUI

e.List of third party software tools

- Vue js
- Bootstrap
- Javascript
- Git,Github
- mySQL
- 000webhostapp – this used for free web hosting

f.Source Code

API using PHP and mySQL -

https://github.com/eranthaWELIKALA/RealTimeWaterQualityMeasurementSystem.git

Arduino Code –

https://github.com/AmilaIndika789/RTWQMS

For further development API using node js –

https://github.com/AmilaIndika789/RTWQ-Measurement-System.git

Chapter 4:

a. Project Information

Expenses

Description	Qty.	Unit Price/Rs.	Amount	
Sensors and components required for sensors				
1) LM35 Temperature sensor	1	390.00	390.00	
2) LDR	2	10.00	20.00	
3) Laser LED	1	75.00	75.00	
4) LED	2	2.00	10.00	
5) pH sensor(pH probe/pH pen meter + circuit)	1	1400.00	1400.00	
6) BNC Jack	1	50.00	50.00	
GSM module	1	3750.00	3750.00	
Sub Total				**5695.00**

Table 2: Expenses

Chapter 5:

Testing Styles

- SMOKE TESTING –

    1. TURN POWER ON AND SEE IF SMOKE POURS OUT
    2. CAN FIND HARDWARE FAULTS

- EXPLORATORY TESTING –

    LOOK SPECIFICALLY FOR STARNGE BEHAVIOURS IN THAT ARE NOT IN REQUIREMENTS

- BLACK BOX TESTING –

    TEST FOR FUNCTIONALITY OF THE EMBEDDED DESIGN WITHOUT CONSIDERING INTERNAL IMPLEMENTATION

- WHITE BOX TESTING –

    TEST FOR FUNCTIONALITY OF THE EMBEDDED DESIGN WITH THE KNOWLEDGE OF IMPLEMENTATION

Testing Situations

Unit Testing for the product

TEST CASE	QUALITY	EXPECTED	ACTUAL
1. Distilled Water	PH	7	6.95
	TEMPERATURE	25-30	27
	CONDUCTIVITY	0	1.05
	TURBIDITY	0	20
2. Sugar Solution	PH	6.94-7.84	7.05
	TEMPERATURE	25-30	28
	CONDUCTIVITY	2.5	3.05
	TURBIDITY	10	26
3. Salt Solution	PH	7.5-8.4	7.2
	TEMPERATURE	25-30	26
	CONDUCTIVITY	5	4.5
	TURBIDITY	20	20
4. Normal Water	PH	6.5-7.5	6.95
	TEMPERATURE	25-30	29
	CONDUCTIVITY	3	2
	TURBIDITY	0	16

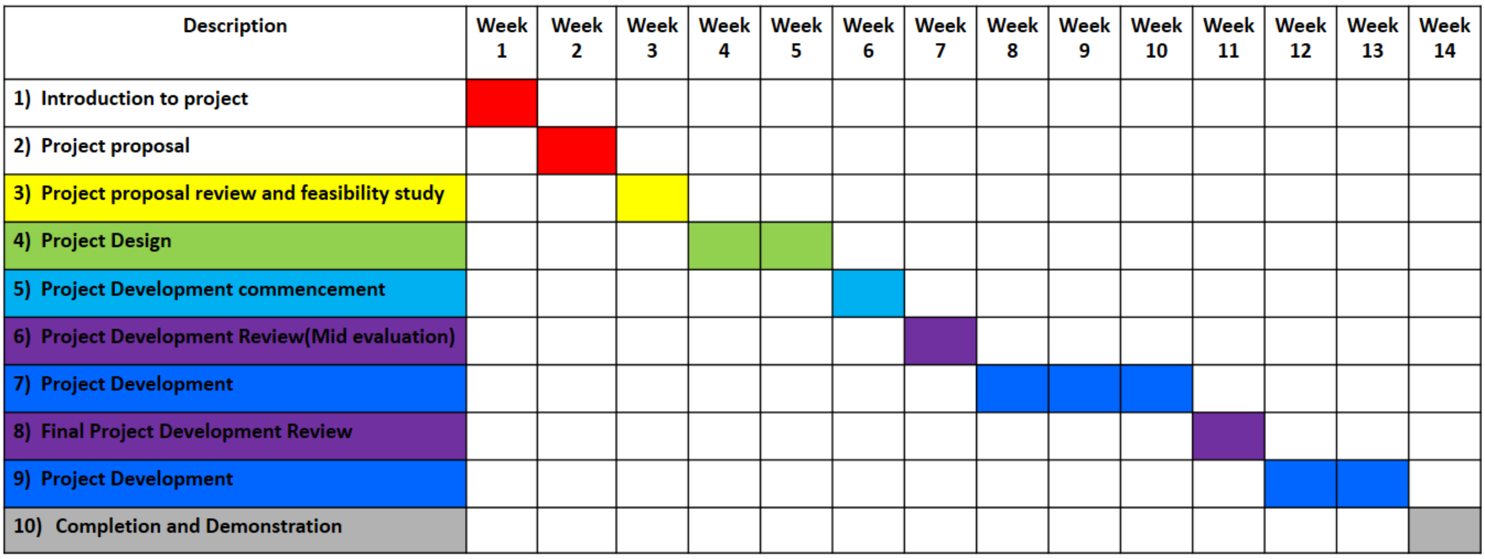


Figure 19: Timeline of the project

References

1) Waterproof temperature Sensor DS18B20 (1 Wire Digital Thermometer) Data sheet https://cdn.sparkfun.com/datasheets/Sensors/Temp/DS18B20.pdf1
2) https://www.itead.cc/wiki/SIM808_GSM/GPRS/GPS_Module
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9) Steven Silva, Hoang N ghia Nguyen, Valentina Tiporlini and Kamal Alameh, "Web Based Water Quality Monitoring with Sensor Network: Employing ZigBee and WiMax Technologies", IEEE Conference on Local Computer Networks, IEEE 2011.