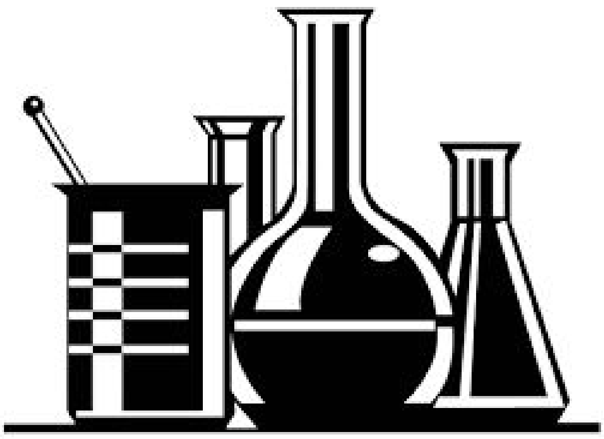
AUTOMATED WATER QUALITY MONITORING SYSTEM

Design Manual



Group Members: E/15/077-Dilhani K.P.W.A.K.K.

E/15/211- Maduwanthi S.A.I.

E/15/279-Premathilake L.S.W.S.

Content

1. Abstract

The water quality monitoring plays an important role in water contamination surveillance and guides the water resource protection for safe and clean water. A flexible automated real-time water quality monitoring and alarm system based on the wireless sensor network for a water treatment plant is proposed. This system is built in accordance with node MCU communication protocol, which consists of the sensor nodes, route nodes and coordinator node. The sensor nodes based on cheap and efficient sensors (pH sensor and turbidity sensor) are collected.Then those data are transmit to the server with encryption process with the help of wifi module and display the data on the web site.

The time synchronous algorithm is adopted to wake up all the nodes in the network to improve the stability and reliability of the communication. The long-time measurement results verify the real time and accuracy in data acquisition and stability and reliability in communication. The system meets the requirements of water quality monitoring, and has great practical value.

2. Introduction

Water is one of the most critical resources for human well-being and vital for industry and agriculture. With the rapid development of economy, the illegal discharge of toxic chemicals and untreated domestic waste water leads to the water pollution. The fishery resources decreases, and the aquatic species significantly reduce. The ecological environment is damaged, and human health is endangered. It is imminent to effectively protect the aquatic environment and comprehensively improve the water quality. The water quality monitoring, the quantifiable measurement of water quality variables over time, plays an important role in reflecting the water quality. It is an important basis of environmental protection measures for safe and clean water. Higher and higher requirements on water quality monitoring system are put forward.

The traditional manual method of water quality monitoring of a water treatment plant involves the collection of water samples at various stages and at different time(hourly basis), which are transported to a chemical laboratory for analysis. It is too slow to protect the public health in real time. Some pollution might be missed. The kind of approach is no longer efficient.

The modern integrated automated monitoring systems can provide the comprehensive chemical and biological analysis of the water quality. However, only a small number of locations are sampled and analyzed, which can not obtain the critical decisions of water protection. An automated real-time water quality monitoring system without visiting the places where the relevant stage is proceed is required.

This is a wireless sensor network which uses sensors and microcontrollers with wifi module to process signal and communicate with database.It is easy to use wireless system to achieve the rapid and flexible deployment in a variety of stages. It empowers us for continuous monitoring of water quality. Two types of sensors are incorporated in one sensor node and three sensor nodes are distributed in one treatment plant to measure the water parameters. The data collected by the sensor nodes are transmitted to the microcontroller and check the variation with standard values and after encrypting the values those are transmitted to the server and display on the website . A timely alert is triggered when the parameters go beyond the restricted range. That appropriate steps will be taken. The data communication is based on TCP protocol using node MCU module. It can accommodate five TCP connections to communicate mutually.

3.Design Manual

3.1 Implementation

3.1.1 System design

The choice of system architecture needs to consider the requirements of efficiency, dependability, security and safety requirements for the automated water quality monitoring system. The network topology is also an important problem to be considered carefully. It has a direct effect on the latency, robustness, capacity of the network and the complexity of data routing.

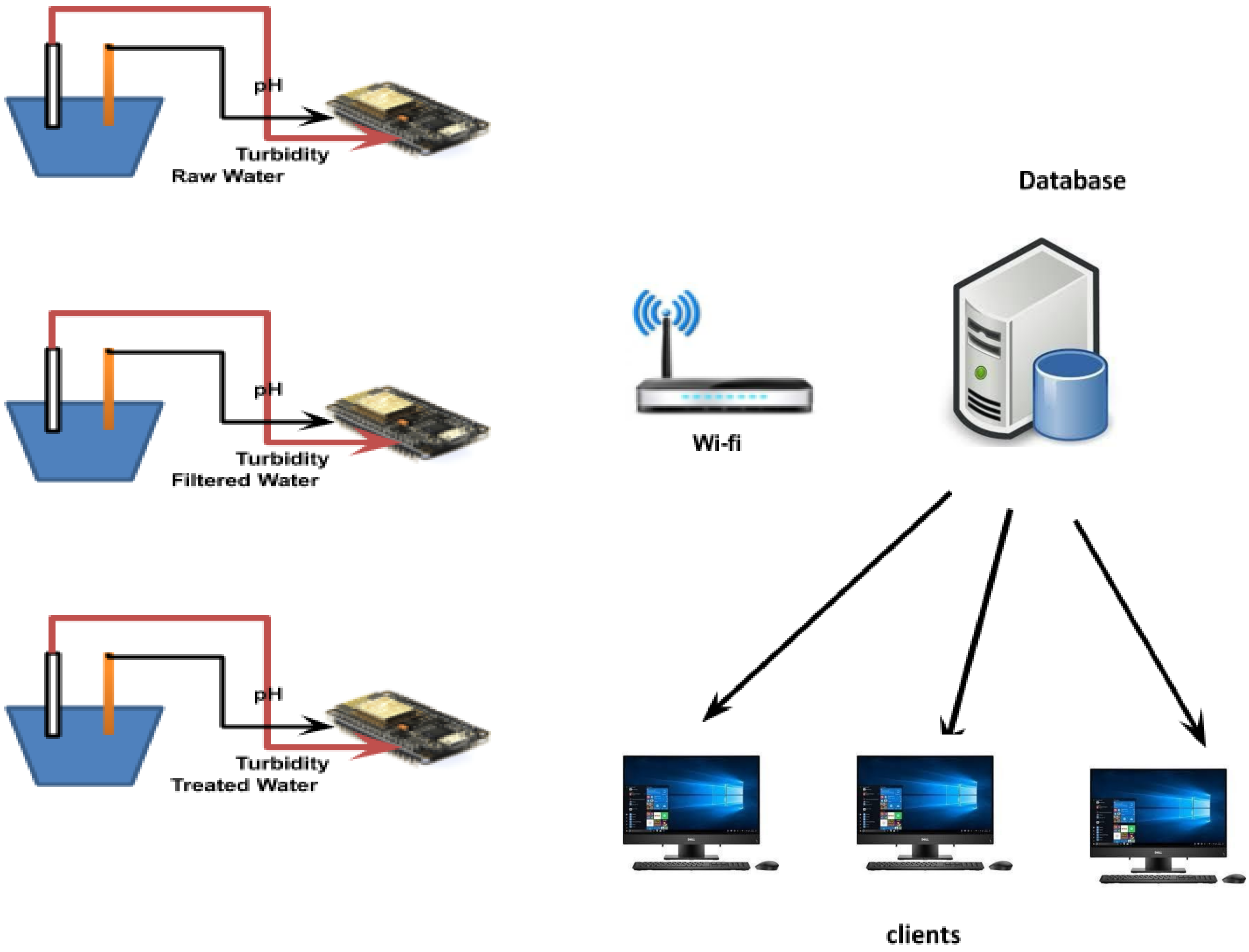


Figure: Network topology of the system

Our system is basically consist of sensor nodes, wifi network and data center. The sensor node is made up with one pH sensor,one Turbidity sensor and only one node MCU module which has in built wifi module. We have connected similar three sensor nodes for a particular plant which is monitoring raw water, filtered water and treated water.

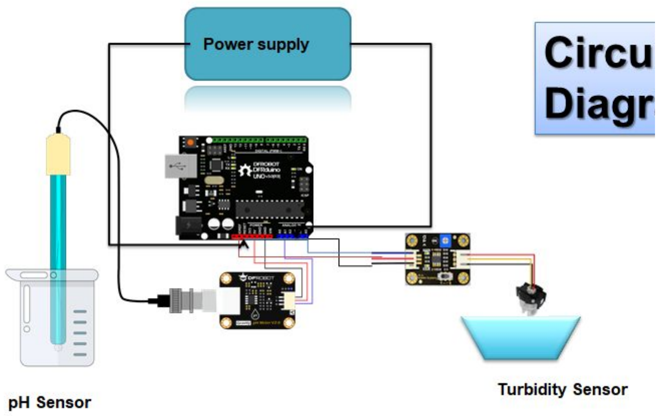


Figure: Circuit diagram for one sensor node

pH and Turbidity sensors are getting their readings and send it to the node MCU microcontroller to process.It compares with the standard values of pH and turbidity values of each stages.

	pH value	Turbidity Value(NTU)
NODE1 (raw water)	-	-
NODE2 (filtered water)	6.9	4
NODE3 (treated water)	7	1

Table: Standard values for pH and Turbidity water quality parameters

Then the sensor data is encrypted and send them to server through wifi network. When retrieving data from the database the data is decrypted and data values on the web application is updated real time.

We use following hardware components to implement this system.They are ESP8266 microcontroller(node MCU),pH sensor,Turbidity sensor,LCD display,12 channel analog to digital multiplexers.Then sensors are calibrated separately before used them in the circuit.According to figure above,the circuit diagram is built for all three nodes.Then using Arduino IDE ,ESP8266 microcontroller is programmed to obtain the sensor readings by every 30 minutes and encryption method is applied to the data.To send this data through wifi network first we have to establish TCP connections with both sides(between microcontroller and database).

3.1.2 Database Handling

3.1.2.1 Setting up nodeMCU with Firebase

We have used firebase real time database to store our sensor data and user authentication data.Firebase is Google's database platform which is used to create, manage and modify data generated from any android application, web services, sensors etc. To work with firebase first we will set up the NodeMCU ESP8266 Wi-Fi Module and then set up Google Firebase. For that initially you should download and install firebase-arduino-master library in Arduino IDE.

In setting up the NodeMCU ESP8266 Wi-Fi Module, once you are all set with components you should follow simple steps mentioned below:

1. Connect NodeMCU with Computer.
2. Open Arduino IDE.
3. Goto 'Tools' and Select 'Boards'.
4. In board's section, select 'NodeMCU V1.0 (ESP-12E Module)'.
5. Also select appropriate COM Port.
6. Find the "FIREBASE_HOST" and "FIREBASE_AUTH"

Programming NodeMCU ESP8266 for using Google Firebase

Firstly include the libraries for using ESP8266 and firebase.

#include <ESP8266WiFi.h>

#include <FirebaseArduino.h>

Then download and install the libraries by following the below link:

https://github.com/FirebaseExtended/firebase-arduino/blob/master/src/Firebase.h

While compiling, if you get error that ArduinoJson.h library is not installed then please install it using link given below.

https://github.com/bblanchon/ArduinoJson

These two parameters are very important to communicate with firebase. Setting these parameters will enable the data exchange between and ESP8266 and firebase. To find these parameters for your project, follow the steps given in later section (Setting Up Firebase) below.

FIREBASE_HOST "your-project.firebaseio.com" // the project name address from firebase id **#define FIREBASE_AUTH "06dEpqanFg**************qAwnQLwLI"** // the secret key generated from firebase

After successfully finding the credentials, just replace in the above code. Below parameters are used to connect to your Wi-Fi network or the network that you setup. Replace SSID and password with your network SSID and password. Also internet is required in order to communicate with firebase.

#define WIFI_SSID "xxxxxxxxxxxxx" // input your home or public wifi name

#define WIFI_PASSWORD "xxxxxxxxxxxxxx" //password of wifi ssid

This statement tries to connect with your entered Wi-Fi network.

WiFi.begin(WIFI_SSID, WIFI_PASSWORD); //try to connect with wifi

This statement tries to connect with firebase server. If the host address and authorization key are correct then it will connect successfully

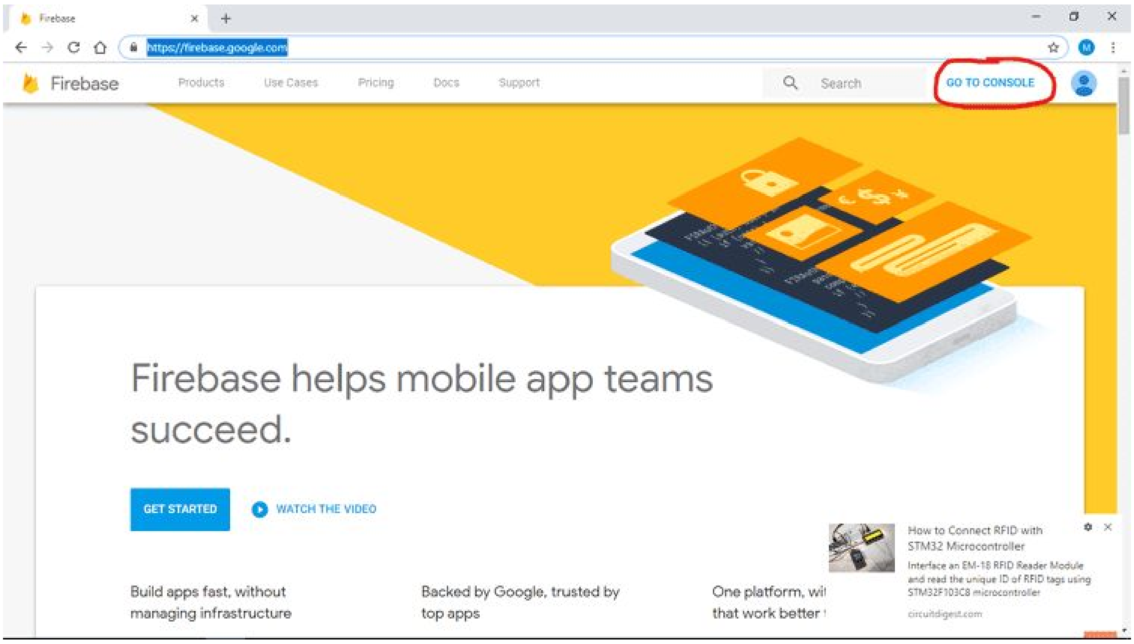
Firebase.begin(FIREBASE_HOST, FIREBASE_AUTH); // connect to firebase

3.1.2.2 Setting Up Firebase Console

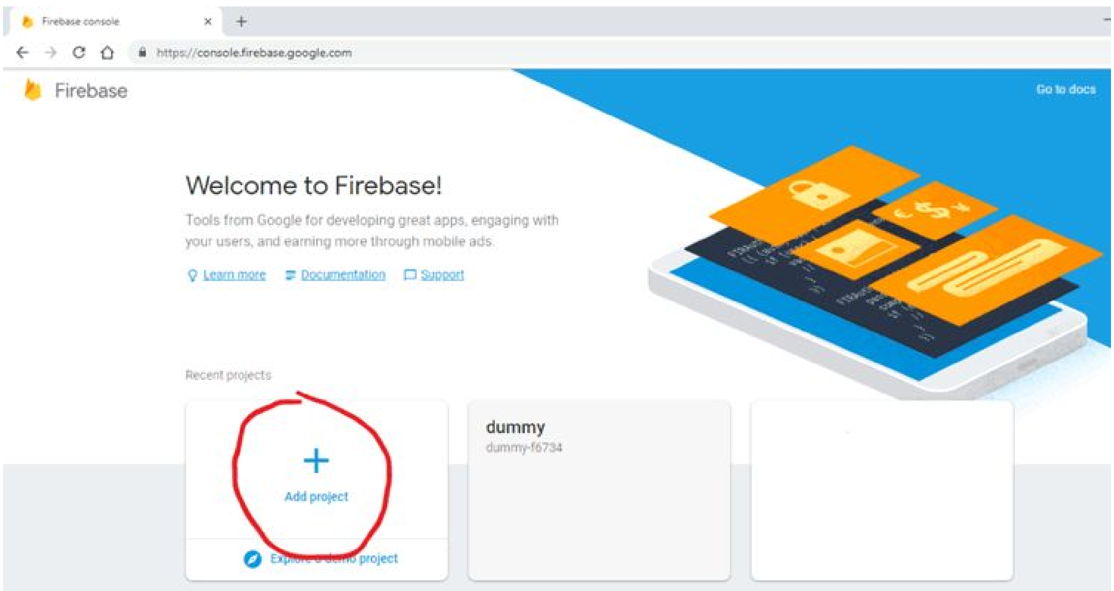
If you have Gmail id then you don't need to Sign Up for firebase, if you don't have Gmail id then Sign Up for one and then you can go to next step.

1.Open your browser and go to "firebase.google.com".

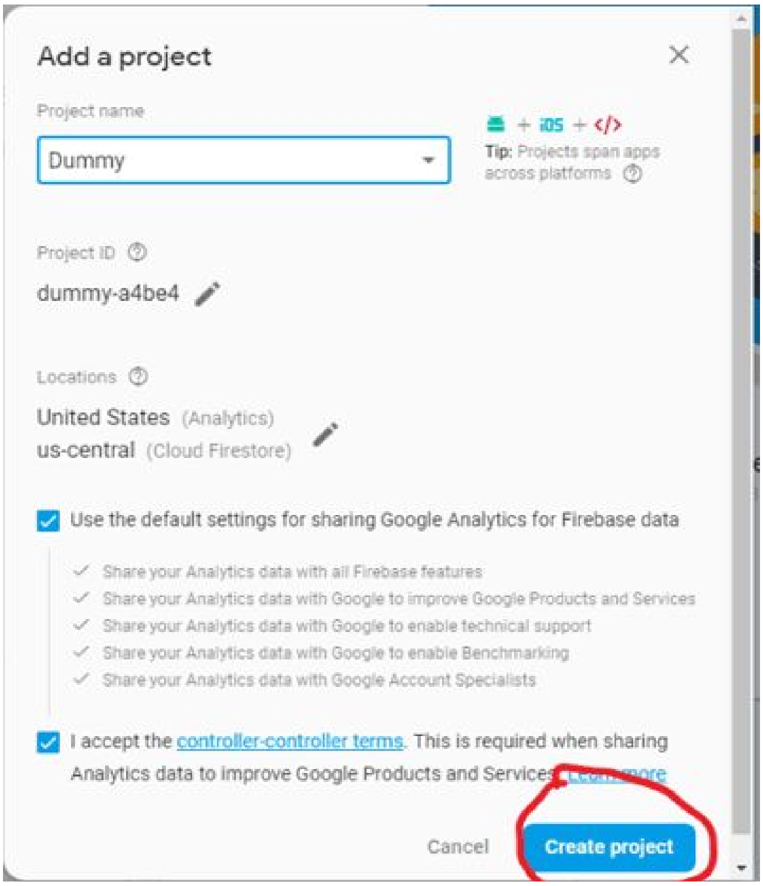
2.The right top corner go to "Go to Console".



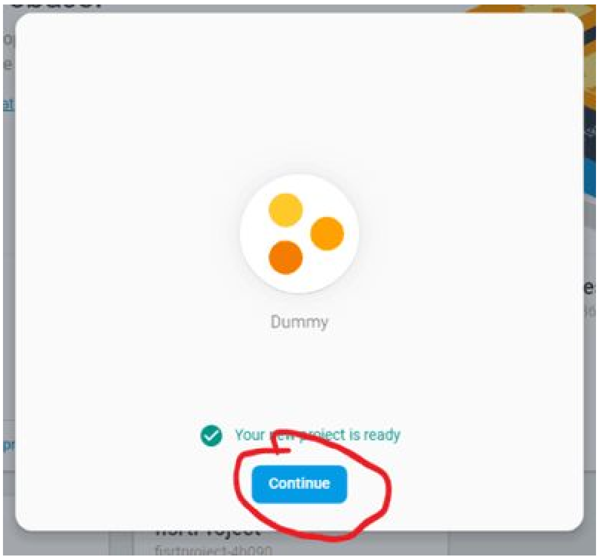
3.Click on "Add project".



4.Input your Project Name.

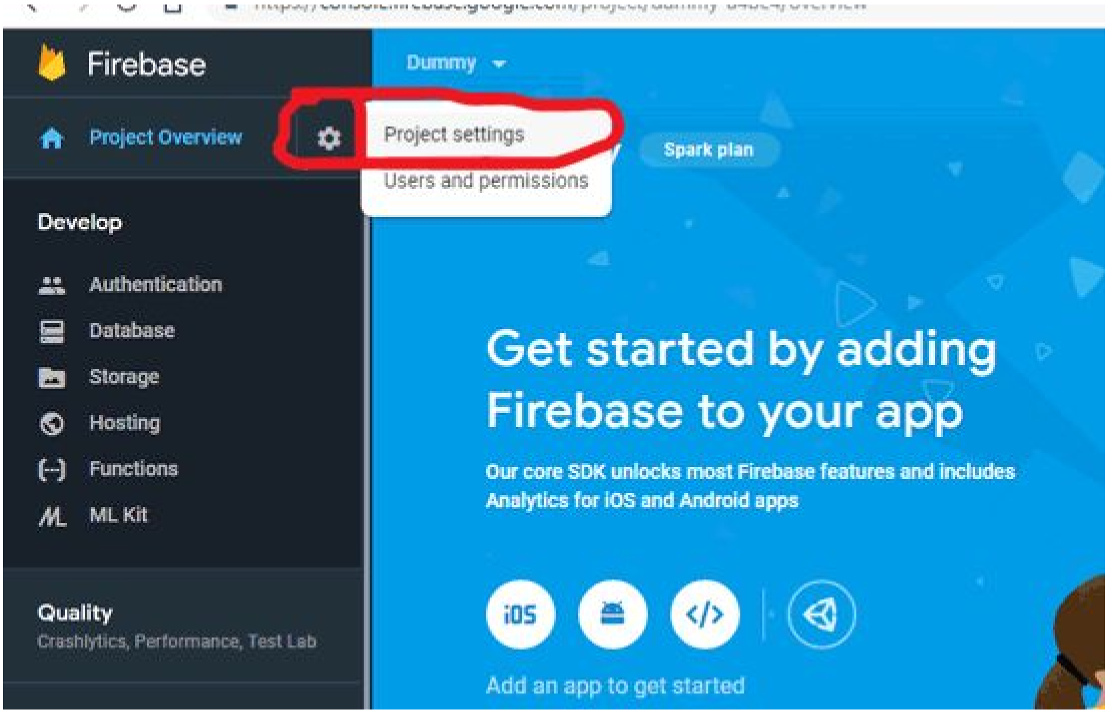


5.Accept the terms and condition, Create project and click on “Continue”

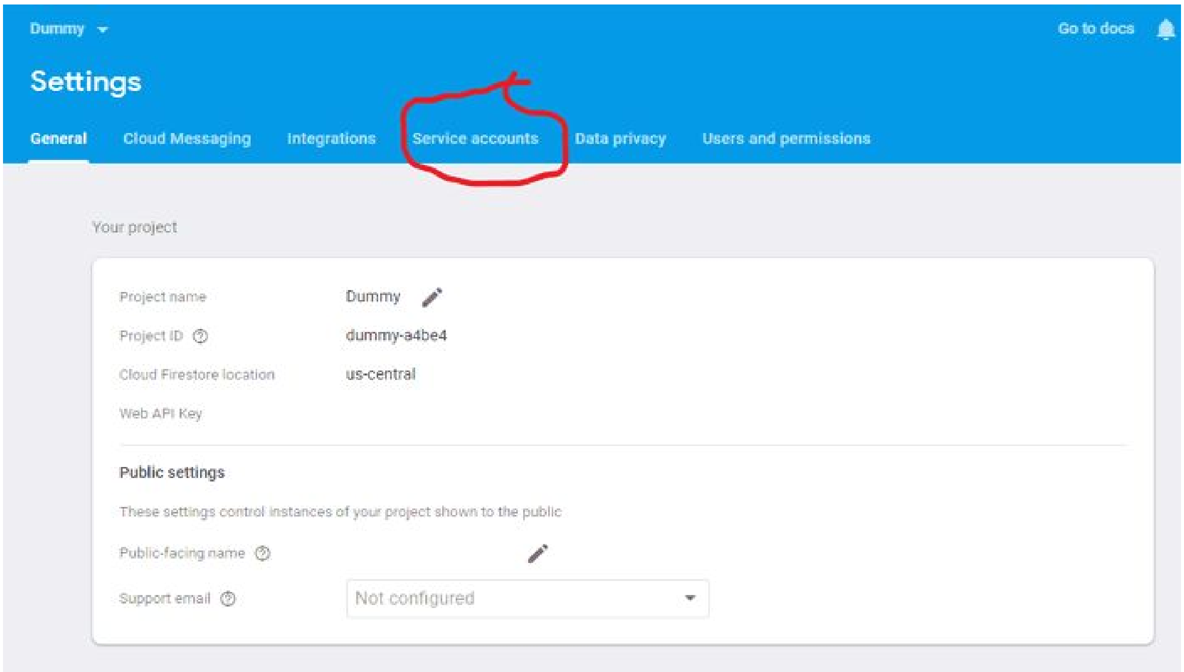


You have successfully created your project. Look for the Host Name and Authorization Key also known as Secret Key. For this, follow steps given below:

6. Go to Settings Icon(Gear Icon) and click on “Project Settings”



7. Now click on “Service Accounts”

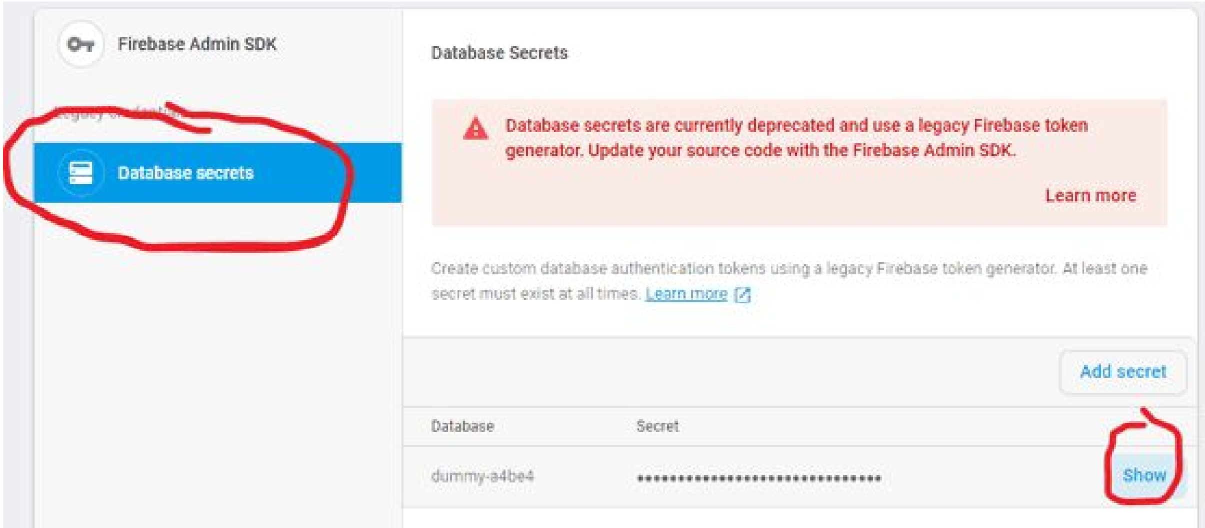


8. You can see two options “Firebase admin SDK” and “Database Secrets”

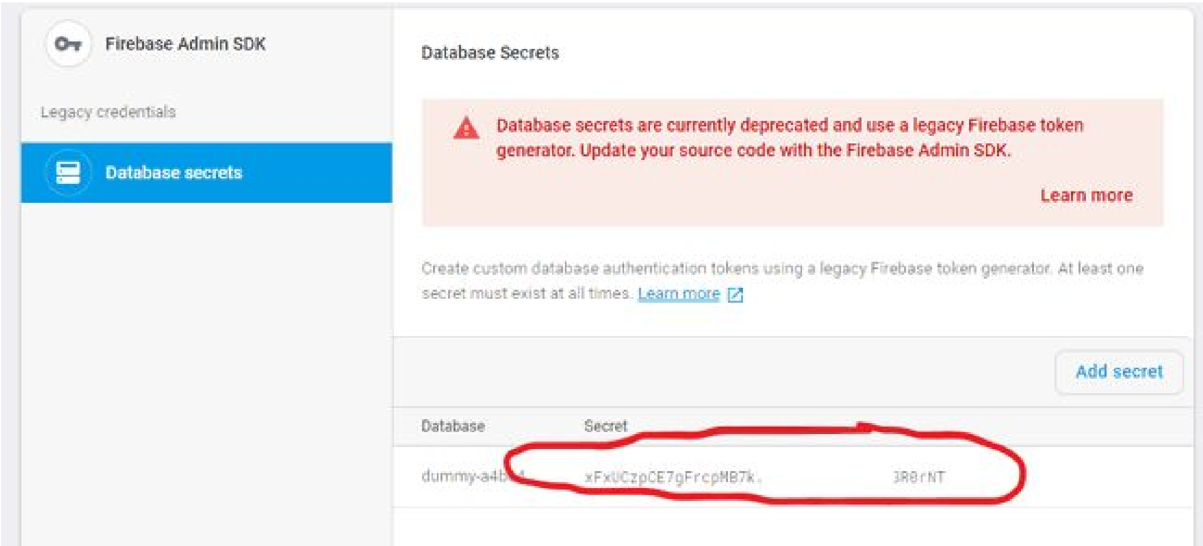
9. Click on “Database Secrets”

10. Scroll on your project name and ”Show” option appears at right side of your project

11. Click on “Show” and now you can see secret key created for your project

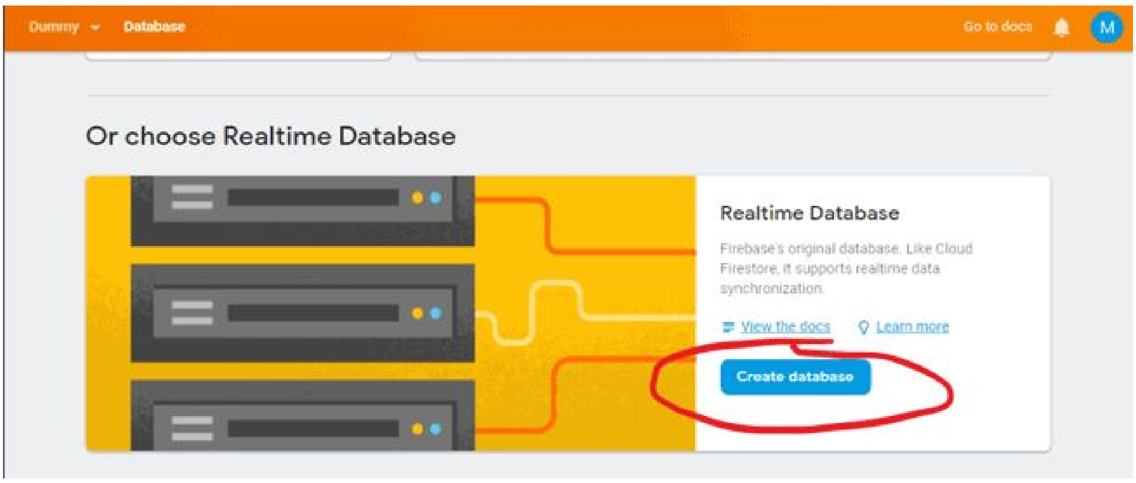


13. Copy the secret key and save it to notepad. This is your "FIREBASE_AUTH" string which we have written in Arduino program above.

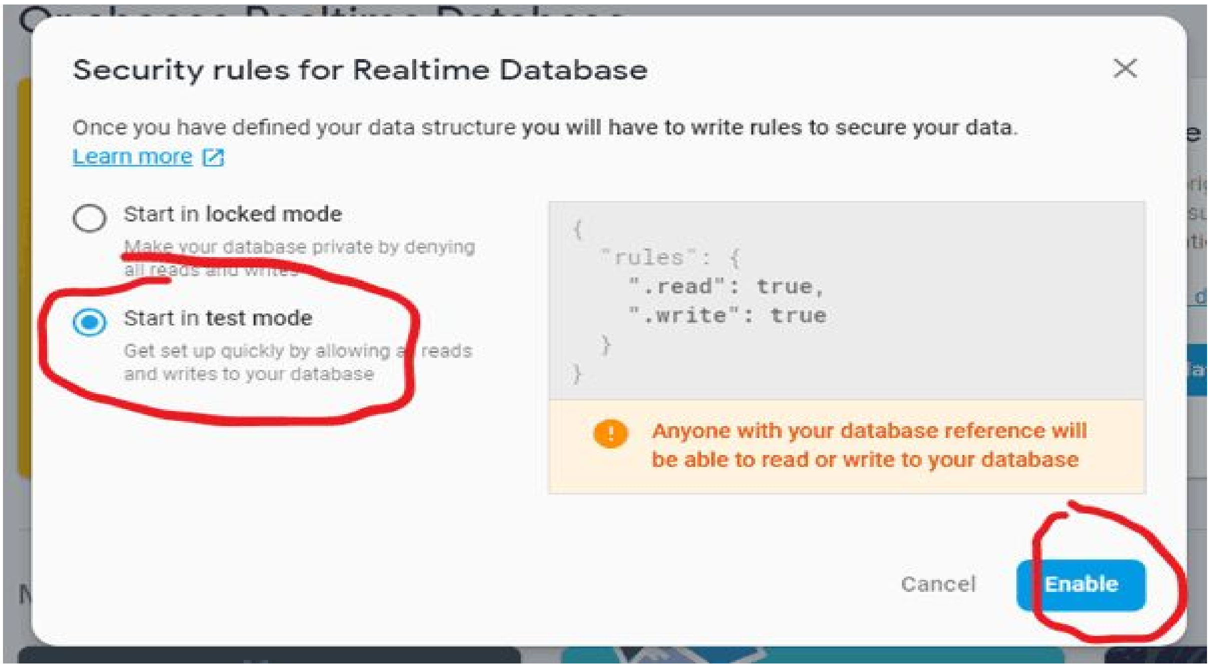


14. Now go to "Database" on left control bar and click on it

15. Scroll down and click on "Create Database"

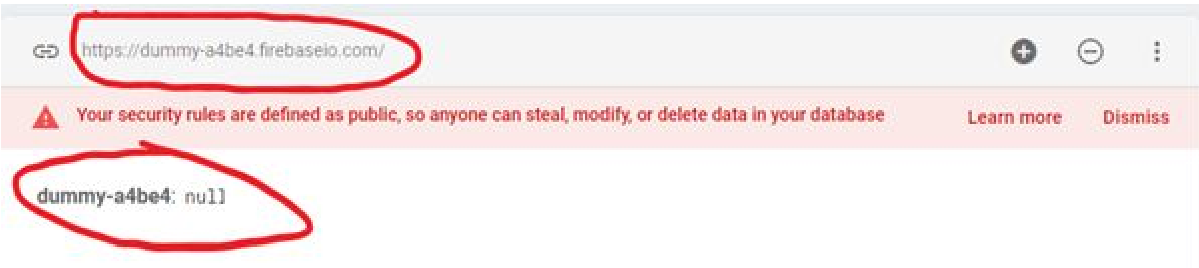


16. Choose “Start in test mode” and click on “Enable”



17. Now your database is created and you will have to come to this section again to control sensors

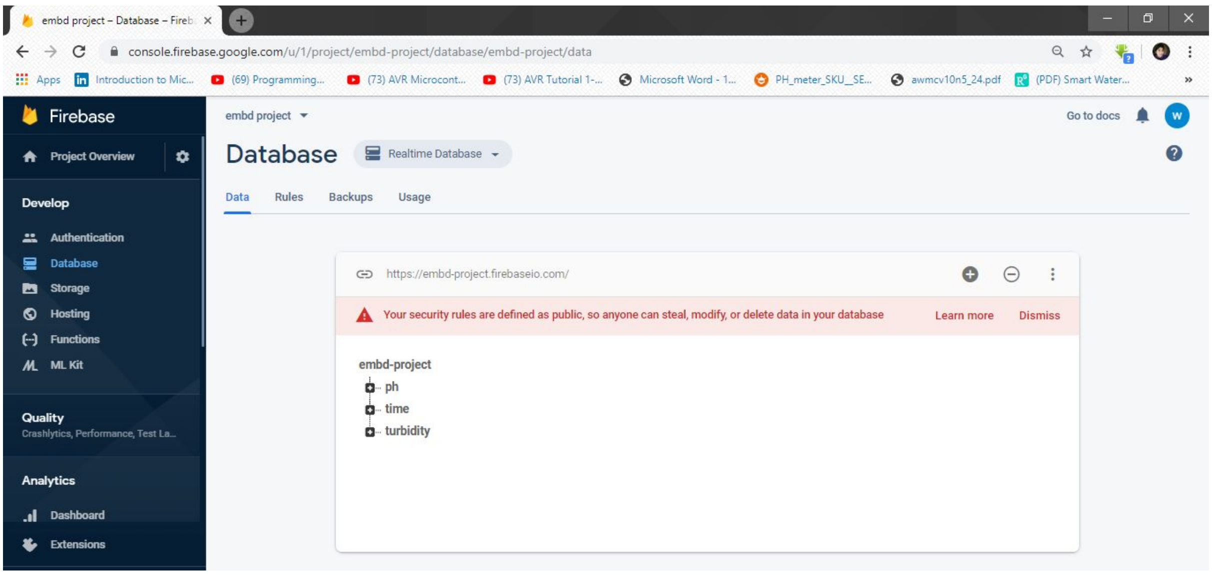
18. Now just above the database you can see “https://your_project_name.firebaseio.com/”



19. Just copy *“your_project_name.firebaseio.com”* without any slash and https and save it again to notepad just you had saved for secret key

20. This is your “FIREBASE_HOST” string which we have written in Arduino program above

Now put “FIREBASE_HOST” and “FIREBASE_AUTH” in Arduino program and upload the sketch.



Then to add host name first click on database and copy that host name and paste in Arduino code given below at line
#define FIREBASE_HOST "fir-app-example.firebaseio.com"

To add Database Secrete Key to Arduino sketch Go to **Setting>Project Setting>SERVICE ACCOUNTS>DATABASE** Secretes. Copy and paste Database Secrets at the line in code
#define FIREBASE_AUTH "examplesd2asdasdasdasd2asd3asd2asd2as32das3d2as2da3"

To add router name and password Change line with your WiFi router name and password

#define WIFI_SSID "Wifi Router Name"
#define WIFI_PASSWORD "Router Password"

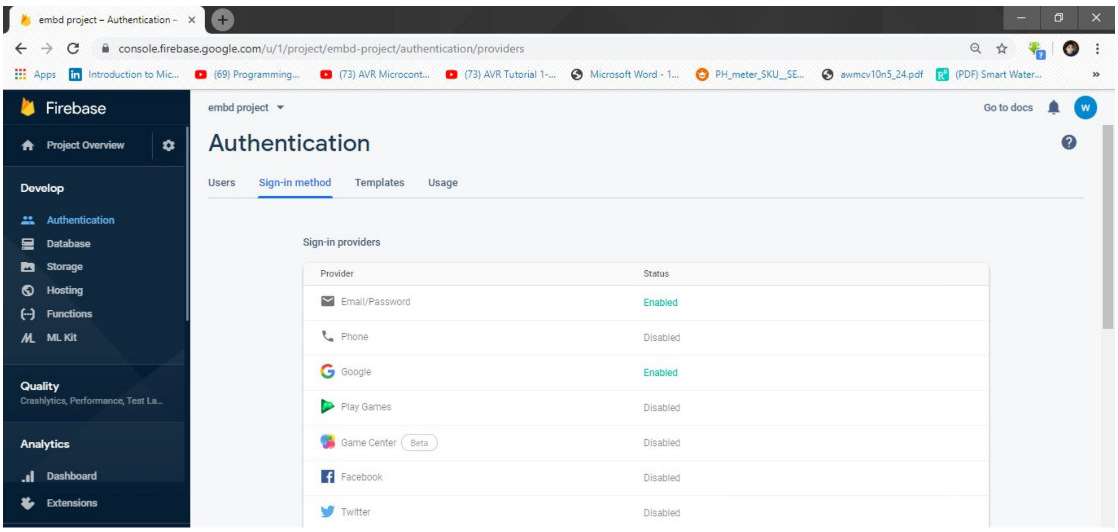
After resetting ESP8266check serial terminal whether the ESP is get connected with your router and got IP address.

Then make connection between web application and database to display data using javascrpts.In our system the web application is designed by using react js.And considering security features the authentication facility is going to given only for authorized people(plant engineer,chemist,technical officer)

3.1.2.3 Setting up Authentication in Firebase

Firebase Authentication provides backend services, easy-to-use SDKs, and ready-made UI libraries to authenticate users to your system. It supports authentication using passwords, phone numbers, popular federated identity providers like Google, Facebook and Twitter etc.So it can be easily integrated with your custom backend.You can sign in users to your Firebase app either by using FirebaseUI as a complete drop-in auth solution or by using the Firebase Authentication SDK to manually integrate one or several sign-in methods into your system.Here the system have been implemented only for Email and password based authentication. Firebase Authentication also handles sending password reset emails.

For email address and password sign-in and any federated identity providers you want to support, enable them in the Firebase console and complete any configuration.



Now, it is able to sign in to the system using valid email and password.

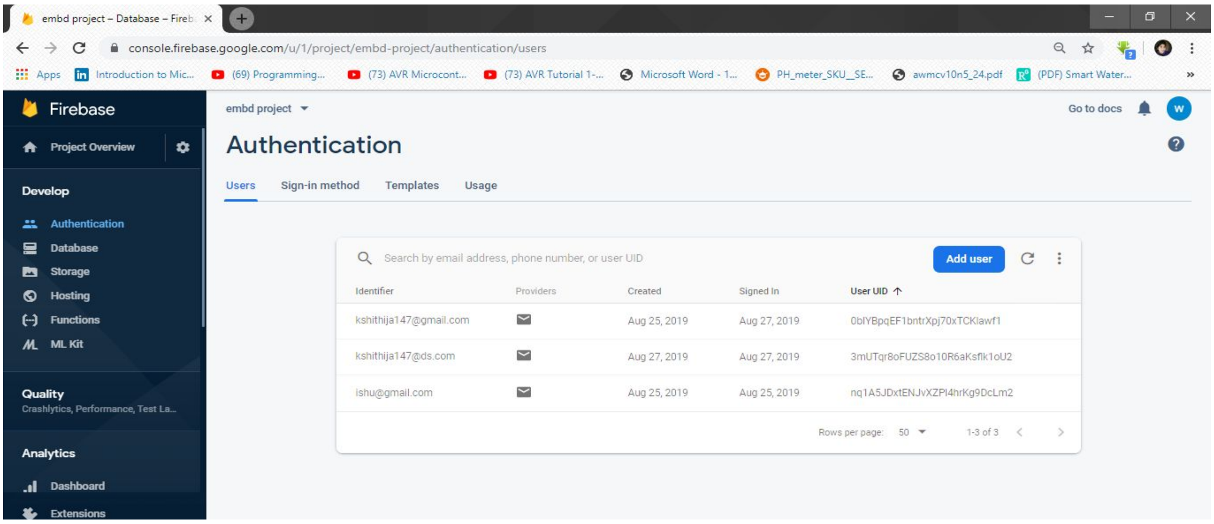


Figure: Firebase Authentication interface

3.2 Methodology

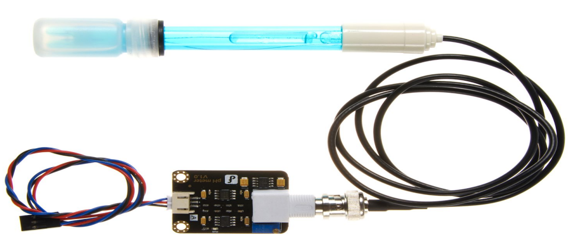
3.2.1 Hardware Architecture

The sensor nodes are an important part of the system. The circuit includes the sensor module, microcontroller module, wireless communication module and power module.

These parts will be considered separately.

3.2.1.1 Sensor module

3.2.1.1.1 pH sensor



The Analog PH Sensor Kit has a built-in simple, convenient and practical connection and features.It has an LED which works as the power Indicator, a BNC connector and PH2.0 sensor interface.The response time is 90% of final reading in 1 second.The accuracy of the sensor is +/- 0.2 pH units and the default calibration values are slope is about –3.838 and intercept is about 13.720. Operating voltage of the sensor is as close as possible to the +5V.After programmed the NodeMCU, and we have to put the pH electrode into the solution then we can get the pH values easily .

To use it, just connect the pH sensor with BNC connector, and plug the PH2.0 interface into the analog input port of any [Arduino controller](). If pre-programmed, you will get the pH value easily. Comes in compact plastic box with foams for better mobile storage.

Attention:In order to ensure the accuracy of the pH probe, you need to use the standard solution to calibrate it regularly.Generally, the period is about half a year. If you measure the dirty aqueous solution, you need to increase the frequency of calibration.

Specifications:

- Module Power : 5.00V
- Module Size : 43mm×32mm
- Measuring Range:0-14PH
- Measuring Temperature :0-60 ℃
- Accuracy : ± 0.1pH (25 ℃)
- Response Time : ≤ 1min
- pH Sensor with BNC Connector
- PH2.0 Interface (3 foot patch)
- Gain Adjustment Potentiometer
- Power Indicator LED
- Cable Length from sensor to BNC connector:660mm

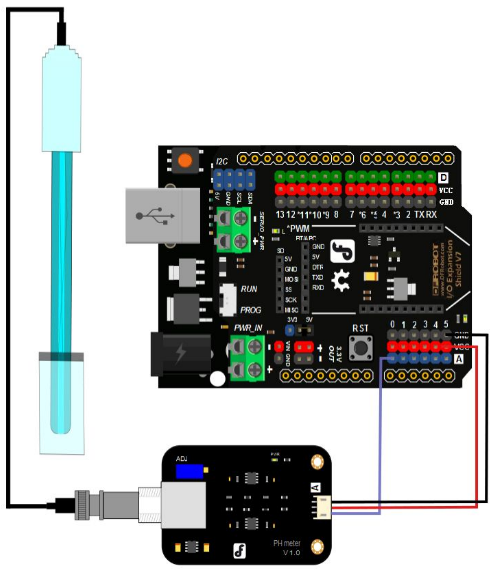


Figure: connection diagram

To calibrate the pH sensor

As we can see that there are two potentiometers in the circuit. Which it is closer to the *BNC* connector of the probe is the *offset regulation*, the other is the *pH limit*.

- Offset: The average range of the probe oscillates between negative and positive values. The 0 represents a pH of 7.0. In order to be able to use it with Arduino this circuit adds an offset value to the value measured by the probe, so the *ADC* will only have to take samples of positive voltage values. Therefore we will force a pH of 7.0 by disconnecting the probe from the circuit and short-circuiting the inside of the BNC connector with the outside. With a multimeter measure the value of *Po pin* and adjust the potentiometer to be 2.5V.

- PH Limit: This potentiometer is to set a limit value of the pH sensor circuit that causes the red *LED* to light up and the *Do pin* signal to turn *ON*.

In addition we have to calculate the voltage conversion that will give us the pH sensor so we will need two pH reference value and measure the voltage returned by the sensor on the *pin Po*. The best thing to do is to use a calibration solution in powders, there are also in liquid but it is easier to preserve the powders. These solutions are sold in different values but the most common are pH 4.01, pH 6.86 and pH 9.18.

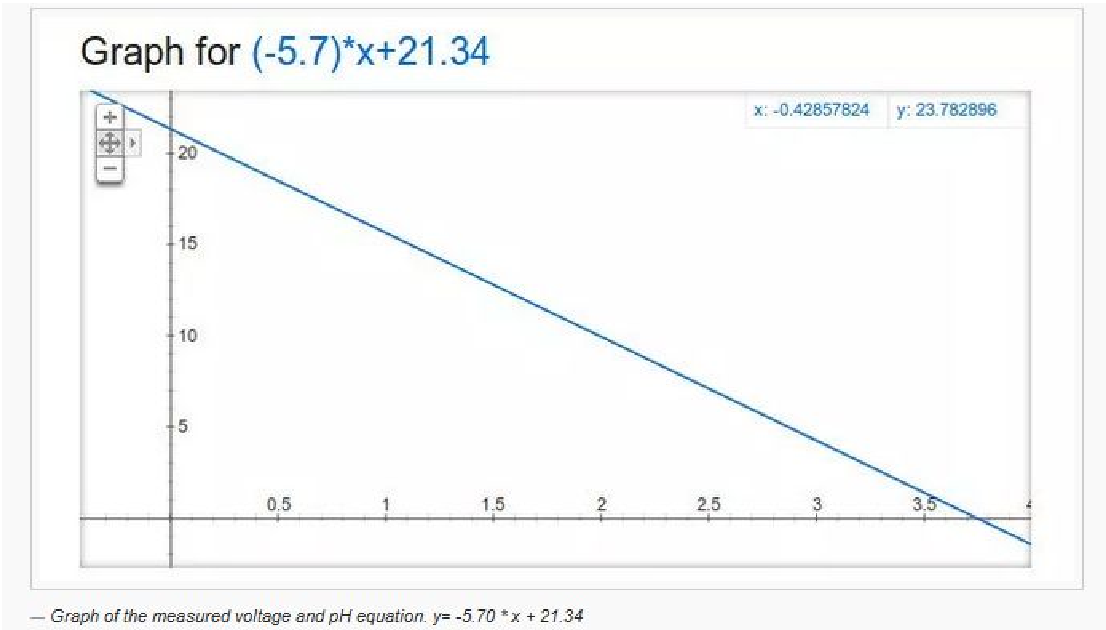


Figure: Graph of the measured voltage and pH equation

Using the powders with *pH 4.01 and pH 6.86* we obtain the voltages on the pin Po *3.04V and 2.54V* respectively. The sensor is linear so by taking two points we can deduce the equation to convert the measured voltage to pH. The general formula would be $y = mx + b$, so we have to calculate m and b since x would be the voltage and y the pH. The result is $y = -5.70x + 21.34$.

Test sensor with this code

```
const int analogInPin = A0;
int sensorValue = 0;
unsigned long int avgValue;
float b;
int buf[10],temp;
void setup() {
 Serial.begin(9600);
}
```

```
void loop() {
 for(int i=0;i<10;i++)
 {
  buf[i]=analogRead(analogInPin);
  delay(10);
 }
 for(int i=0;i<9;i++)
 {
  for(int j=i+1;j<10;j++)
  {
   if(buf[i]>buf[j])
   {
    temp=buf[i];
    buf[i]=buf[j];
    buf[j]=temp;
   }
  }
 }
 avgValue=0;
 for(int i=2;i<8;i++)
 avgValue+=buf[i];
 float pHVol=(float)avgValue*5.0/1024/6;
 float phValue = -5.70 * pHVol + 21.34;
 Serial.print("sensor = ");
 Serial.println(phValue);
 delay(20);
}
```

3.2.1.1.2 Turbidity Sensor

The Turbidity Sensor emits at its end an infrared light, capable of detecting particles that are suspended in water.It measure the light transmittance and the dispersion rate, which changes according to the Amount of TSS (Total Suspended Solids).As the TTS increases, the liquid turbidity level increases. Turbidity sensors are used to measure water quality in rivers and streams, wastewater and effluent measurements, control instrumentation for settling ponds, sediment transport research and laboratory measurements. This liquid sensor provides analog and digital signal output modes. The threshold is adjustable when in digital signal mode. You can select the mode according to your MCU.

NOTE: The top of probe is not waterproof.

Specifications:

- Operating Voltage: 5V DC
- Operating Current: 40mA (MAX)
- Response Time : <500ms
- Insulation Resistance: 100M (Min)
- Output Method:
    - Analog output: 0-4.5V
    - Digital Output: High/Low level signal (you can adjust the threshold value by adjusting the potentiometer)
- Operating Temperature: 5℃~90℃
- Storage Temperature: -10℃~90℃
- Weight: 30g
- Adapter Dimensions: 38mm*28mm*10mm/1.5inches *1.1inches*0.4inches

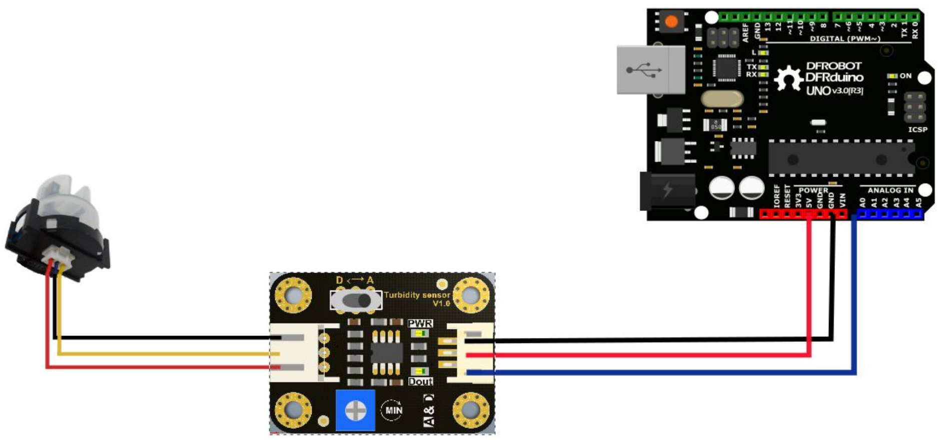


Figure:Turbidity Sensor connection diagram

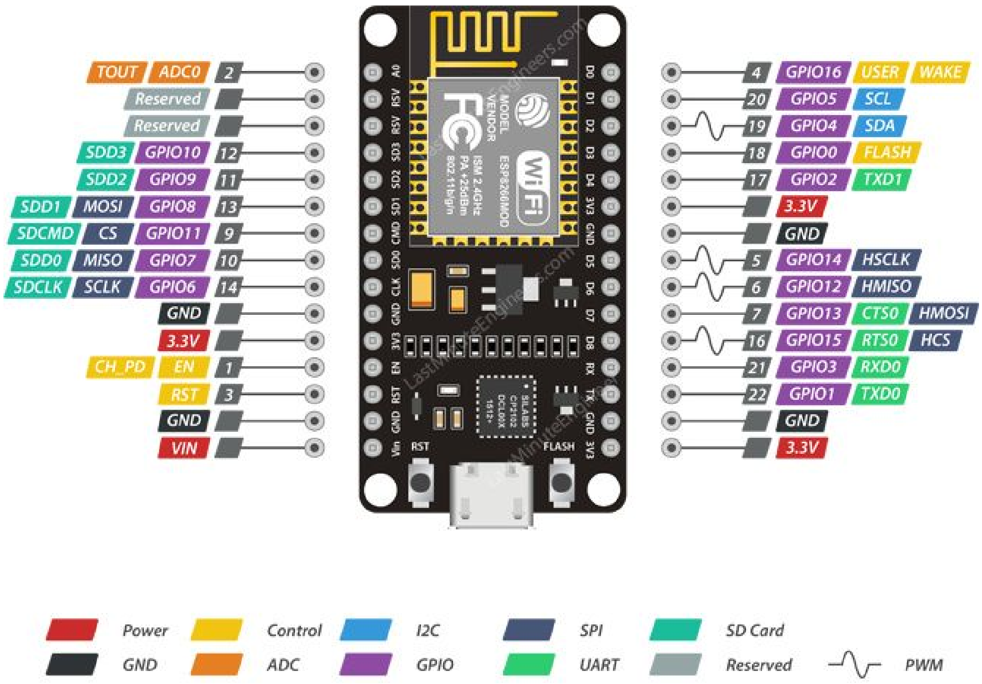
To test turbidity sensor with simple code

```
/*AnalogReadSerial
  Reads an analog input on pin 0, prints the result to the serial monitor.
  Attach the center pin of a potentiometer to pin A0, and the outside pins to +5V and ground.
 This example code is in the public domain. */

// the setup routine runs once when you press reset:
void setup() {
  Serial.begin(9600);  // initialize serial communication at 9600 bits per second:
}

// the loop routine runs over and over again forever:
void loop() {
  int sensorValue = analogRead(A0); // read the input on analog pin 0:
  Serial.println(sensorValue); // print out the value you read:
  delay(1);        // delay in between reads for stability
}
```

3.2.1.2 Node mcu



<u>Figure:The ESP8266 NodeMCU Pinout</u>

The ESP8266 NodeMCU CP2102 board has ESP8266 which offers a complete and self-contained Wi-Fi networking solution.The operating Voltage of the sensor is about 3.3V..The maximum concurrent TCP connections are 5.Power to the ESP8266 NodeMCU is supplied via the on-board MicroB USB connector.

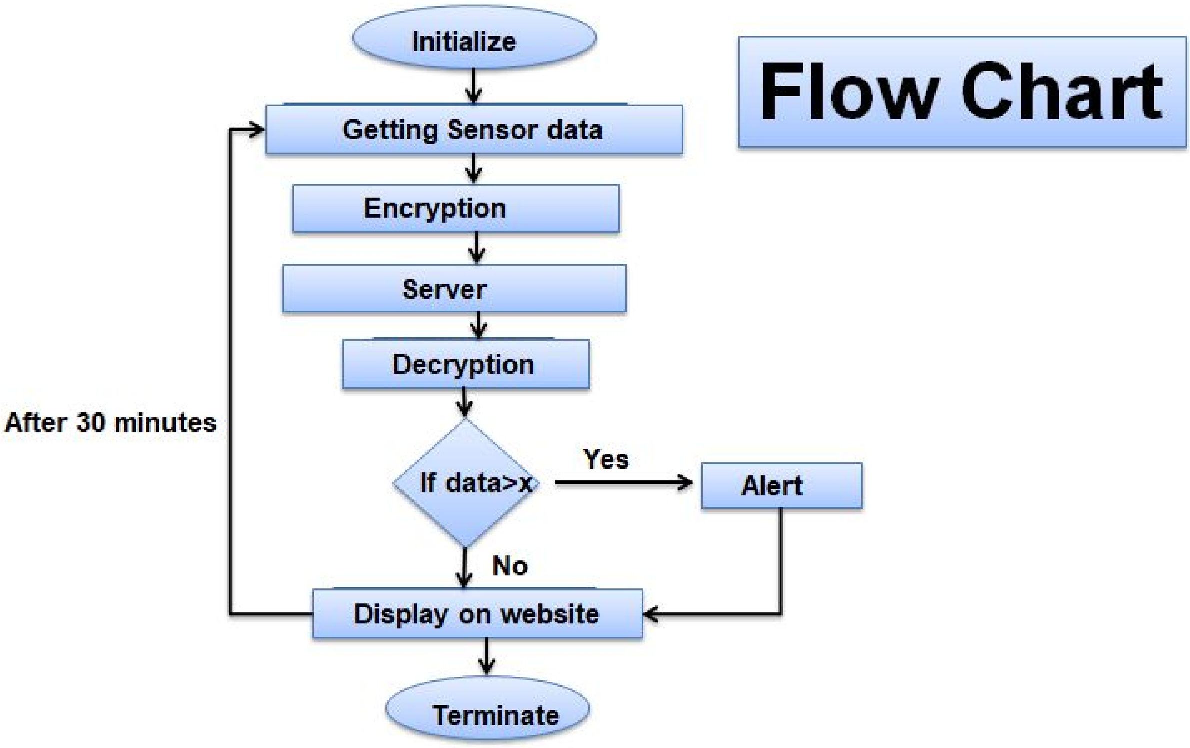
<u>Specifications:</u>

- Embedded with Tensilica Xtensa® 32-bit LX106 RISC micro controller
- operates at 80 to 160 MHz adjustable clock frequency
- 128kB internal RAM
- Flash Memory: 4MB external flash (for program and data storage)
- 802.11b/g/n Wi-Fi transceiver
- operating voltage range:3V to 3.6V
- On-board 3.3V 600mA regulator
- 80mA Operating Current

WARNING:

The ESP8266 requires a 3.3V power supply and 3.3V logic levels for communication. The GPIO pins are not 5V-tolerant! If you want to interface the board with 5V (or higher) components, you'll need to do some level shifting.Otherwise nodeMCU board may burn.

3.2.2 Software architecture



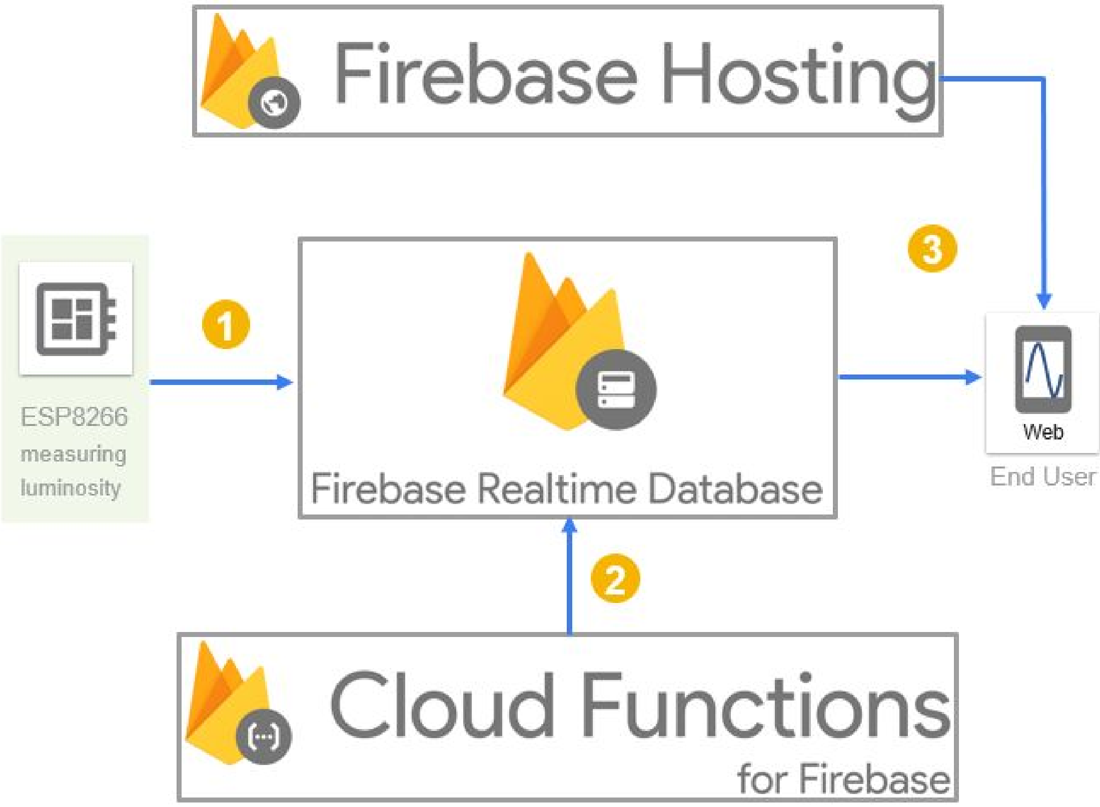
The flow chart of our system is shown in above.This shows how the sensor reading is taken by 30 minutes continuously and those data will go through encryption process to the database.Then by decrypting those data we can retrive in to the web application. when it is needed user can terminate the system.

To implement this we will consider back end and front end technologies what we used.As back end technologies we used firebase real time database to store and retrieve dynamic data and to store authentication details.We have used React js as front end technology.

3.2.2.1 Backend overview

The Firebase Realtime Database is a cloud-hosted NoSQL database that lets us store and sync data between our users in real time. Real time syncing makes it easy for users to access their data from any device: web or mobile, and it helps users collaborate with one another. Firebase provides a realtime database and backend as a service.The service provides application developers an API that allows application data to be synchronized across clients and stored on Firebase's cloud.

The Realtime Database integrates with Firebase Authentication to provide simple and intuitive authentication for developers. We can use our declarative security model to allow access based on user identity or with pattern matching on your data.In the above of manual we have mentioned that how can we setting up firebase console with the project and how to setting up authentication accesses.



3.2.2.2 Frontend overview

We have used React js as front end technology. ReactJS is an open-source JavaScript library which is used for building user interfaces specifically for single page applications. It’s used for handling view layer for web and mobile apps. React also allows us to create reusable UI components. React allows developers to create large web applications which can change data, without reloading the page. The main purpose of React is to be fast, scalable, and simple. It works only on user interfaces in application. This corresponds to view in the MVC template. It can be used with a combination of other JavaScript libraries or frameworks, such as Angular JS in MVC.

Algorithm:

Specially, here we are using **array data structure** to store our data using react js and then those array data will retrieve by the web site. It is fast and efficient to retrieve and insert data and also less space consuming.

```
constructor(props){
   super(props)
   this.ref=firebase.database().ref();
   this.phRef=this.ref.child('ph');
   this.turbRef=this.ref.child('turbidity');
   this.state={
      ph:[],
      turbidity:[]
    }; }
```

This concept is not only for one water treatment plant but this can be scalable among the island wide and control the process. Considering above factor we have implemented our idea and only for authorized people can access the system.

The system has good real-time performance, stable and reliable data transfer. The measurement accuracy and communication distance meet the requirements of water quality monitoring applications. The system can offer long-time observations on the water quality variations which can be analyzed further in the monitoring center.

3.3 Testing

3.3.1 Integration testing

By focusing pH sensor under temperature 25^0C we can give some sort of boundary values to the system and check whether it gives expected output to the clients. Normally pH value of treated water should be in the range of 6.5 – 7.5.Then we are going to test our system using this case. By using soap water ,normal water and leman water it can be tested and except when normal water is using other two solutions should give alert to the system.

3.3.2 Unit Testing

pH value of water is going to be changed by using pH known chemical and expecting their exact pH values using our pH sensor under 25^0C temperature.By doing this test following output is expected.

solution	Expected output
Vinegar	2.2
Milk of Magnesia	10.5
Sodium Hydroxide (NaOH)	14.0

3.3.3 Load Testing

Considering whole system we will increase the number of nodes up to 30 nodes for the system using dummy values .By doing these tests you can test the system.

4. Conclusion

This system is built in accordance with node MCU communication protocol, which consists of the sensor nodes, route nodes and coordinator node. The sensor nodes based on cheap and efficient sensors (pH sensor and turbidity senor) are collected.Then those data are transmit to the server with encryption process with the help of wifi module and display the data on the web site. The time synchronous algorithm is adopted to wake up all the nodes in the network to improve the stability and reliability of the communication. The long-time measurement results verify the real time and accuracy in data acquisition and stability and reliability in communication. The system meets the requirements of water quality monitoring, and has great practical value