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Smart Water Quality Monitoring System using IoT

M. Deva Priya
Assoc. Professor, Sri Krishna College of Technology /CSE Department, Coimbatore, Tamil Nadu, India
Email: m.devapriya@skct.edu.in

Abstract: **The normal method of testing or analyzing water is by collecting water samples manually and sending them to lab tests where they are tested for various chemical compounds consuming much time and manpower. This challenge can be overcome by using Internet of Things (IoT). In the proposed method, Temperature, pH value, Conductivity, Chemical Oxygen Demand (COD) and Total Dissolved Solids (TDS) of water samples are collected using respective sensors. A Microcontroller is interfaced with the sensors and data is forwarded to a Personal Computer (PC) for processing. The data is also stored on the Cloud using IoT based ThingSpeak. The resources involved in water quality monitoring are greatly reduced and the parameters are analyzed in real-time. The information is also sent to a smartphone or laptop/PC. This quick process is beneficial as it aids in analyzing and saving water bodies that are at the verge of becoming completely unusable.**

Index Terms: **Water Quality, PH, Conductivity, Temperature, Turbidity, IoT, Wi-Fi**

I. Introduction

Water is the most important source for the survival of humankind. This resource is greatly polluted by the current urbanization and revolution in other fields [1]. The drastically affected resource is water. Many stations are established by the government to save water from becoming contaminated and unusable. These stations are established and maintained by the Central Pollution Control Board (CPCB). These stations analyze the water body assigned to them for monitoring and a report is generated and shared to the officials through GPRS/3G/4G networks for necessary action [2].

Internet of Things (IoT) is the integration of internet and devices. The idea of automating and meeting daily needs through devices via internet established IoT has become common. This technology is greatly helpful in achieving many useful innovations of current generation needs. A study says that there are more than a Billion "Things" that use IoT [3].

Determining water quality is the need of the hour as contamination leads to various daring diseases. In this Paper, water quality is monitored by collecting, processing data and transferring the result to the rightful person. Data is collected and stored on the cloud for further processing. Nowadays, smartphones are universally used as they have all the inbuilt features. This has led to a dramatic increase in the number of mobile applications. The mobile features support sending and receiving data by enabling the IoT devices to connect and transfer data [4]. In a ubiquitous network, smart things have become a part of the internet. Authorized users can upload data derived from smart things on the cloud. Applications can be created with sensor logging, location tracing and social network of things with status updates using ThingSpeak. Application Programming Interface (API) of ThingSpeak enables handing of numeric data [5, 6]. The ThingSpeak channel provisions inclusion of fields like elevation, latitude, longitude and status. The data collected from the sensors are sent to the cloud, where they are stored as a channel.

Cloud enables easy access of the stored data. Channel data can be examined, envisaged and new data can be computed. It is possible to interact with web sites and social media. This feature enables finding new data and visualizing data in the form of plots, charts etc., using analytical tools. It can access MATLAB to provide sensor data [7]. Tools are employed for communication among devices. Actions can be taken for both raw and new data in a channel. It aids the devices to operate by queuing commands.

The investment depends on the number of parameters that are to be measured. The fluctuations in the water quality have to be rapidly recognized and sent to higher officials. A novel method is proposed for sensing real-time data and sharing it through smart phones or PC/Laptop. The proposed system measures the quality of water using various IoT sensors and sends digital data to the devices eliminating manual intervention. In this Paper, Section 2 discusses about the work done by various researchers in monitoring the water quality while Section 3 discusses on IoT. Section 4 discusses about the implementation of monitoring water quality system and the results obtained are discussed in Section 5. Section 6 gives the conclusion.

II. Related Work

The water resources are getting depleted and deteriorated due to increase in population, demand for water in agriculture, industries and other personal needs of humans. Water quality is also affected greatly due to pesticides and other chemicals that are used in agriculture. Major river bodies are greatly affected by discharges from industries and untreated sewages. To deal with the issues that are associated with manual water monitoring, CPCB planned to establish real-time Water Quality Monitoring (WQM) network across the Ganga basin. Papageorgiou (2003) [8] have dealt with designing localized algorithms and have used direct diffusion as a collection of concepts that define the communication patterns primary to such algorithms. The design characteristics vary from outmoded wireless networks and are data and application based. Le et al (2007) [9] have deployed sensors for monitoring water quality in terms of salinity and level of underground water in northern Australia in real-time.

Qiao & Song (2010) [10] have developed an online system for monitoring water quality based on General Packet Radio Service (GPRS)/ Global System for Mobile

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Communications (GSM) features. The information is transferred using the GPRS network that helps to remotely analyze the water quality parameters. Silva et al (2011) [11] have presented a web dependent water monitoring system by deploying sensors using ZigBee and WiMAX. The parameters are measured, collected, processed and directed through the ZigBee gateway to the web server using WiMAX. The water quality is analyzed remotely in real-time. Bhardwaj (2011) [12] has clearly stated the route of river Ganga and the amount of waste dumped in it along the path. It is clearly understood that even the most important water resource of our nation is severely affected by pollutants.

He & Zhang (2012) [13] have designed a water quality measuring system based on sensors. The remote sensor is based on ZigBee. The parameters and the data are sent to the Web using GPRS. With the help of the Internet, the information is gathered at the remote server. Amruta & Satish (2013) [14] have designed a solar powered water quality network that utilizes a Remote Sensor Network (RSN). The Base Station (BS) gathers the information from a remote sensor. The BS associated with the ZigBee module is powered by the sunlight baseboard from where the energy for the system is harvested.

Wang et al (2015) [15] have focused on a novel research using IoT. Starting from the viewpoint of correlative technologies depending on time to assess the evolutionary process of IoT, they have dealt with the associations among the correlation methods that are widely absent in the existing literature. They have highly focused on the overview and association of prevailing technologies and less on challenges describing the evolutionary process of IoT. Cloete et al (2016) [16] have focused on designing and developing a water quality monitoring system with an aim of informing the details of the related parameters in real-time. The system is capable of measuring the physicochemical parameters of water quality which include flow, temperature, pH, conductivity, and oxidation reduction potential. Das & Jain (2017) [17] have used Thing speak to store and analyze data collected from sensors related to water quality. This is time efficient and effective in analyzing data.

III. Proposed Smart Water Quality Monitoring System using IoT (SWQMSI)

The proposed system includes 3 phases namely, Pre-processing, Feature Extraction and Classification.

A. Preprocessing

In this phase, it is ensured that the collected data in the right form so it can be further processed. Handling missing data is the greatest challenge. The missing value can be replaced using data loss prevention algorithms that are employed in statistical data. The missing value is substituted with the median of the data available. In a histogram, the data is transformed into a graph. The median is found using the following formula.

$$\text{Median} = L_m + \left(\left(\frac{\frac{N}{2} - F_{m-1} - 1}{F_m}\right) . c\right) \quad (1)$$

Here,

L - Median bar lower limit
N - Total count of observations
F_{m-1} - Cumulative frequency of the bar
f - median bar frequency
c - median bar width

In this approach, IoT sensors are used to obtain the pH level, conductivity, Turbidity and temperature of the water. These data are in the form of analog signals that are converted to digital signals using an Analog to Digital converter. Then the converted digital signals are sent through Wi-Fi to the microcontroller. When data from the sensors is received by the microcontroller, it is further processed and sent to the Smartphone or Laptop/PC. The data flow is from sensors to the webpage that is accessed at the end user device via microcontroller. These processes are carried out by programs that are written using Embedded-C in Arduino IDE.

B. Feature extraction

The most prominent information is extracted from the dataset for analysis. It involves simplifying the amount of information required to represent a large set of data accurately.

C. Classification

The pH value of water should be in the range 6.5 to 8.5. If the value is below 6.5, then it is acidic; If it is greater, then it is alkaline, else neutral. The acceptable temperature range is 28 - 44 degree centigrade. Distilled water can have a conductivity of 0.5 to 3 µmhos/cm, while that of rivers ranges from 50 to 1500 µmhos/cm, and that of inland fresh waters specify that streams with mixed fisheries are between 150 to 500 µmhos/cm. Similarly, the Total Dissolved Solids (TDS) in milligrams per unit (mg/L) for drinking water can have a maximum concentration level of 500 mg/L EPA. As said by WHO recommends, the Chemical Oxygen Demand (COD) of drinking water is 10 ppm. When the values of each parameter exceed the limits, they are confirmed to be contaminated.

IV. System Design

The data collected by the sensors are processed using the LPC2148 microcontroller module and are sent via the ESP8266 Wi-Fi module to the webpage in the end device. The overall collection, processing, analyzing and transfer of data are done in real-time. Fig.1. shows how the components are connected to each other.

The system uses the following sensors namely, pH, temperature, conductivity and ultrasonic [18], microcontroller unit as the predominant processing module and a data communication module (ESP8266 Wi-Fi module). The microcontroller unit plays a predominant role designed for water quality measurement as it consumes less power and is smaller in size. It includes a chip ADC that interprets the analog signals into digital values for investigation. Based on the nature of output, the sensor's analog outputs are connected to the microcontroller's analog pins, and digital outputs are connected to the digital pins. The microcontroller processes the data and sends to the

ThingSpeak server through the Wi-Fi module (NodeMCU) [19].

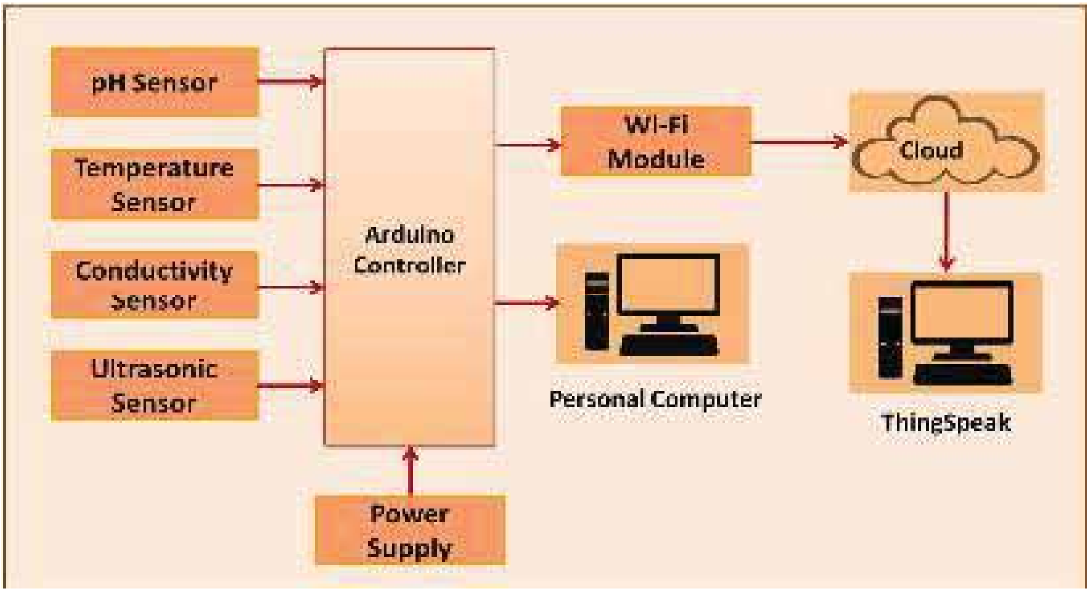

Figure 1. Block diagram of component integration

Arduino UNO microcontroller is used in this system as it has many merits. It has a faster flash memory, consumes less power and is smaller in size. This microcontroller helps in reducing the consumption of power and space. The Wi-Fi module is connected through the [Tx/Rx] pin through which transferring and receiving of data is done. The ESP8266 Wi-Fi provides easy connectivity with any microcontroller, enabling it to be a great Wi-Fi module for IoT devices. This system uses Attention Commands to connect and open the Transmission Control Protocol (TCP) connection through the Wi-Fi network instead of using TCP/IP stack. So communication from the microcontroller to the ESP8266 Wi-Fi module is enough to push the processed data to the web.

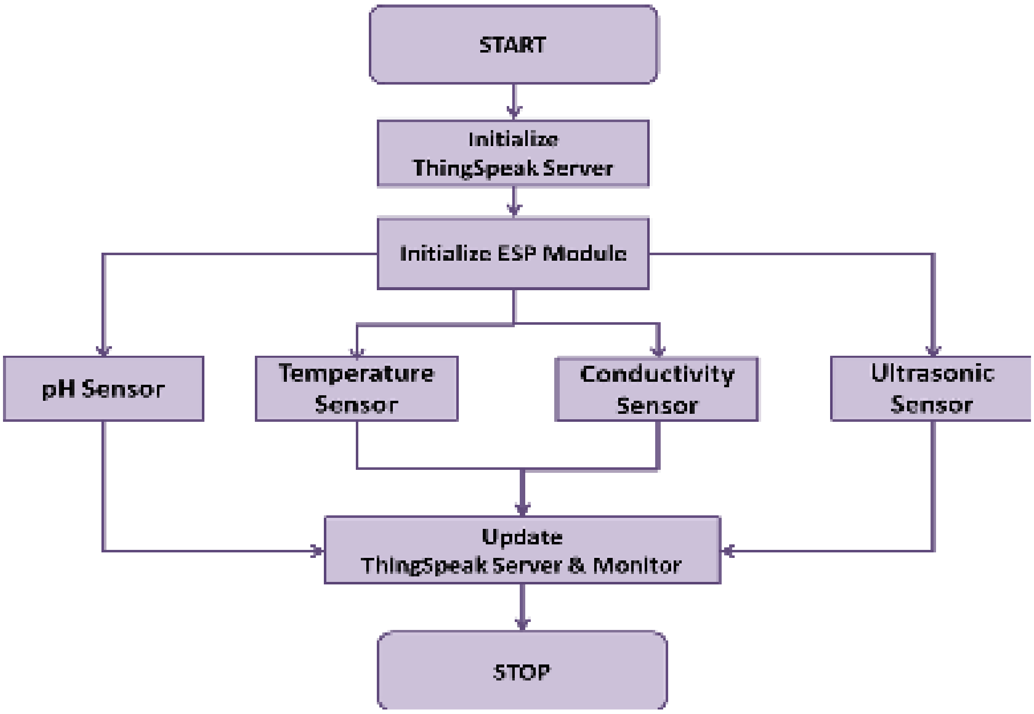

Figure 2. Overall Functioning of the System

The steps are shown in Fig. 2. Primarily, the serial monitor in the Arduino is set to 115200 baud rate, and the Wi-Fi module and the ThingSpeak server are initialized. The values of the sensors are updated on the server. As the ultrasonic sensor deals with digital value, it is taken directly for duration (Seconds). From the duration, distance can be computed as shown in the following equation.

$$\text{Distance} = (\text{Duration}) / 58.8 \quad (2)$$

The DHT 11 Sensor handles the analog values of both temperature and humidity. In case of pH sensor, the analog values of 10 samples are taken into account. The average value is computed. Similarly, the conductivity is also measured. The microcontroller unit with sensors considers samples every 10s and the parameters are shown on the Arduino IDE serial display. The server is updated every 20s.

Based on the Nernst equation, the pH value of water is directly proportional to water voltage.

$$E = E^{\circ} + \left(\frac{RT}{zF}\right).pH \quad (3)$$

where,

E - Cell potential under the prevailing conditions

E° - Cell potential under standard temperature and pressure conditions

R - Universal gas constant

T - Temperature

z - Number of electric moles

F - Constant Faraday

The Turbidity of water is inversely proportional to the voltage in water.

$$T = -1120.4\,x^2 + 5742.3x - 4352.9 \quad (4)$$

where,

x - Voltage

The sensors used and their purpose are detailed in Table I.

TABLE I.
SENSORS AND THEIR DESCRIPTION

Sensors	Description
pH Sensor	Used to find the pH value which is the level of acidic or alkaline level of the water. If the value is below 7, then it is acidic; If it is greater, then it is alkaline, else neutral.
Electric Conductivity Sensor	Used to measure the electric conductivity. Salts generally have positive and negative ions which are good conductors of electricity. This ability of ions in water with dissolved salt to conduct electricity is called Electric conductivity.
Turbidity Sensor	Used to measure the turbidity which is the measure of particles suspended in the water
Temperature Sensor	Used to measure the temperature which is the measure of heat or chillness around

V. IMPLEMENTATION

The system is designed in Embedded-C and simulated using Arduino IDE. Authorized users have access to the data stored on ThingSpeak server [20]. The data is collected, stored, examined and conveyed in real-time. Users with access to Thingspeak can login as shown below (Fig. 3). The real-time values are shown in the form of graphs [21].

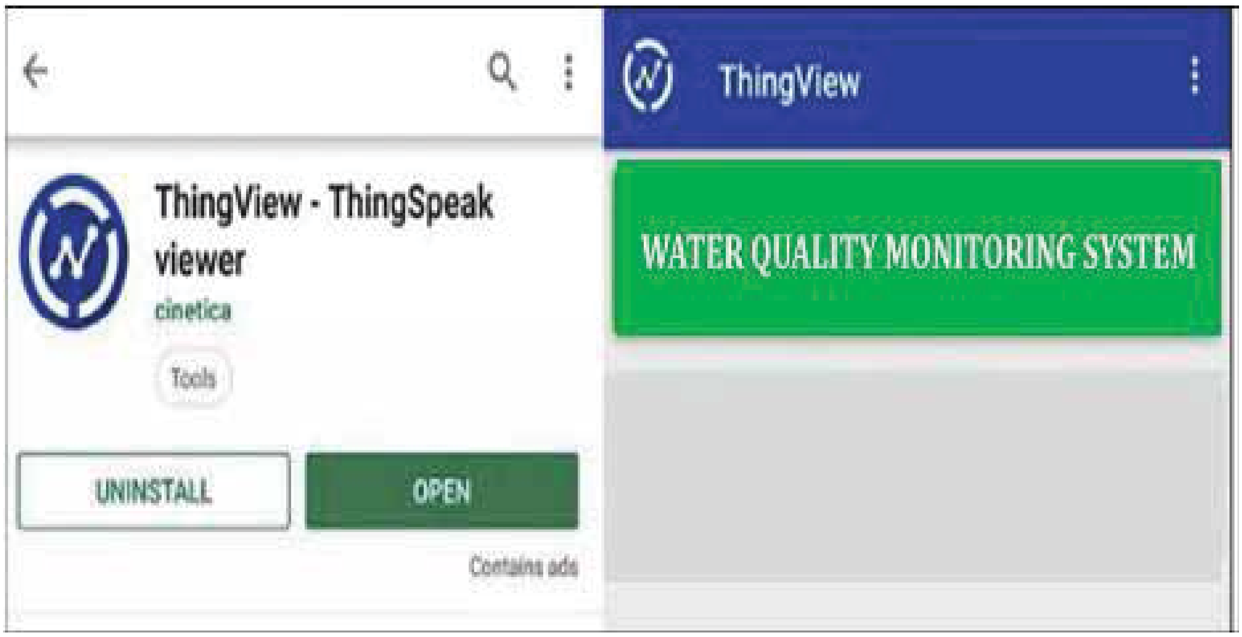

Figure 3. ThingSpeak Application

ThingSpeak supports analysis of IoT data collected from edge node devices [22, 23]. The channel with data and status fields are the primary components. Once a channel is developed, data can be altered, handled and inferred using MATLAB [24, 25]. The following table (Table 2) shows some sample data of raw values collected and the graphs generated from these values for different Stations. Fig. 4 shows the hardware setup of the Project. Figure 5 to Figure 9 show the Temperature, pH value, Conductivity, Chemical Oxygen Demand (COD) and Total Dissolved Solids (TDS) obtained at different stations.

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TABLE 1I.
SENSORS AND THEIR DESCRIPTION

Stations	Temperature (○C)	pH	Conductivity (µS/cm)	COD (ppm)	Total Dissolved Solids (mg/L)
1	28.4	6.6	6.6	7.3	5.7
2	29.2	6.1	6.1	8.1	5.91
3	27.6	5.9	5.9	8.5	4.83
4	28.7	6.7	6.7	7.8	5.27
5	29.3	7.1	7.1	8.2	4.72
6	31.4	6.2	6.2	7.7	5.36

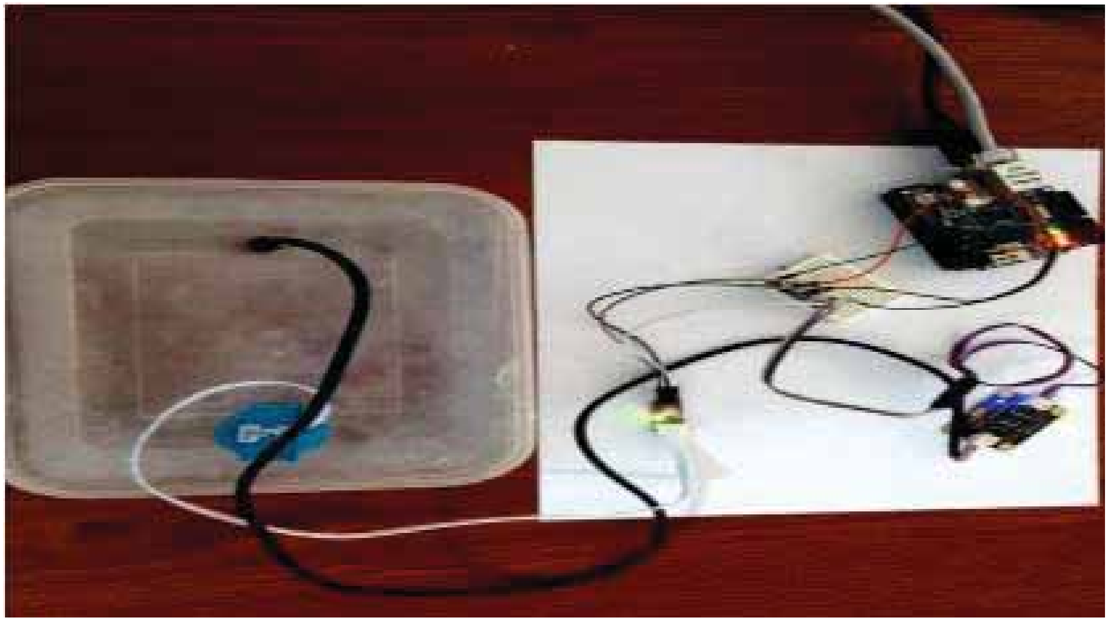

Figure 4. Hardware

B. Working with ThingSpeak

ThingSpeak is an IoT application's open source, wherein data can be stored and retrieved.

Getting started:

- ✓ Sign-up in ThingSpeak
- ✓ Create new channel to store the data obtained from sensors
- ✓ Give the field names as pH, Temperature, conductivity, TDSx
- ✓ If public option is checked, data is available to all

Sending data to Thing Speak:

- ✓ Configure the microcontroller program to the URL that is provided by ThingSpeak
- ✓ Additional data can be added through the link
- ✓ Charts can be generated from data that is sent to the ThingSpeak channel using View Charts option

Both data uploading and graph generation in ThingSpeak takes place in real-time.

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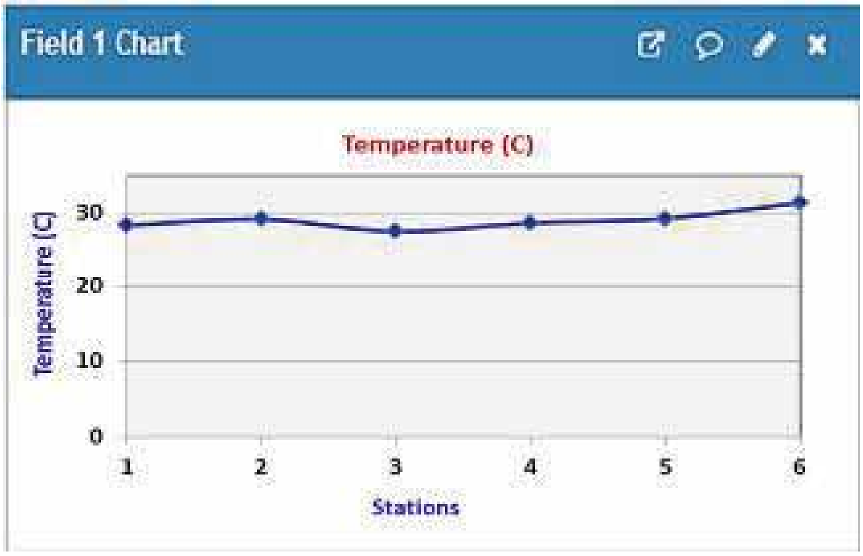

Figure 5. Temperature measured at Different Stations

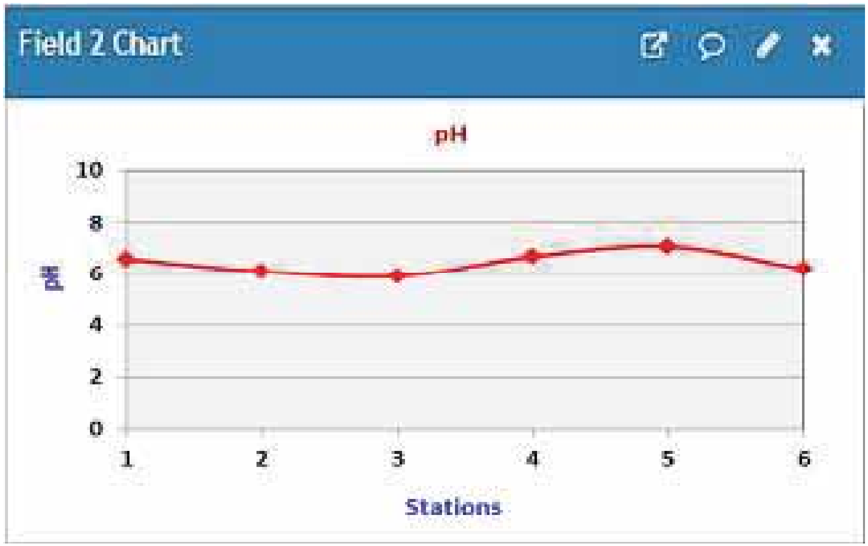

Figure 6. pH Value measured at Different Stations

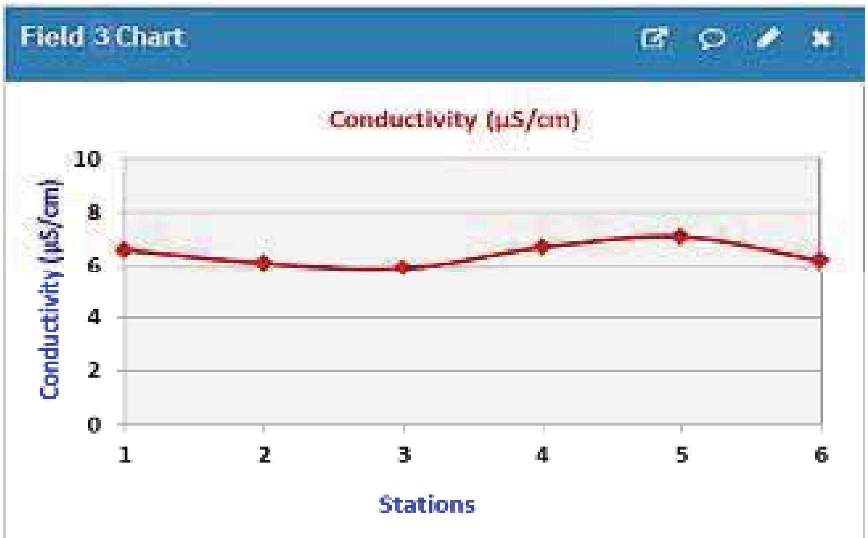

Figure 7. Conductivity measured at Different Stations

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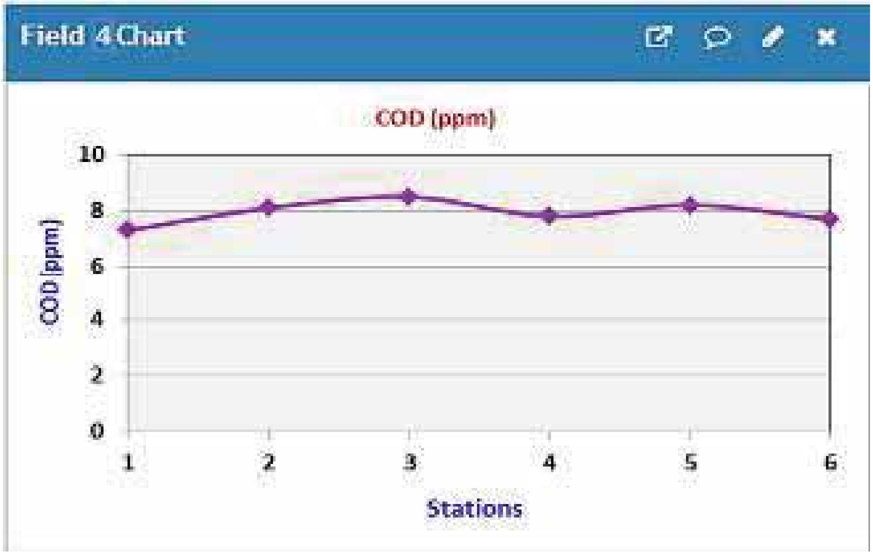

Figure 8. Chemical Oxygen Demand (COD) measured at Different Stations

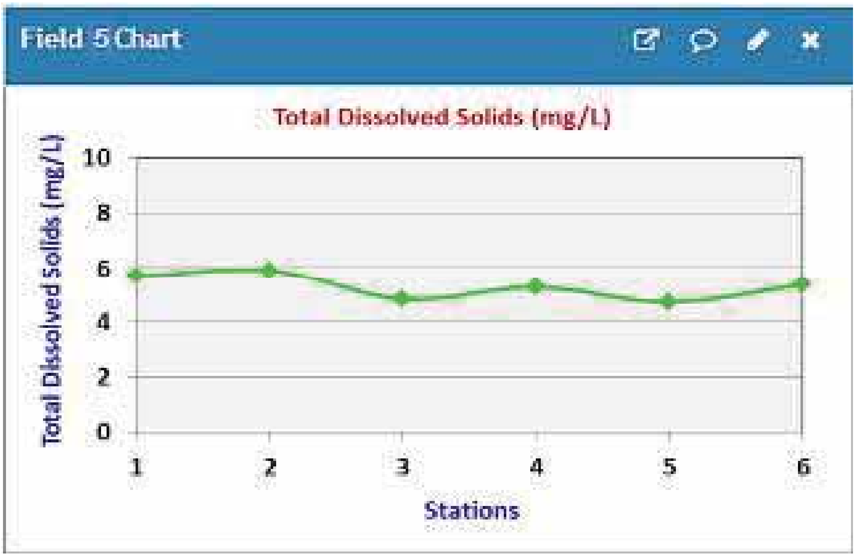

Figure 9. Total Dissolved Solids (TDS) measured at Different Stations

VI. Conclusions

The system propounded for water monitoring is an efficient and low-priced IoT solution for real-time water quality monitoring. The micro controller and sensors are interfaced. An effectual algorithm is designed to track water quality. ThingSpeak is used to observe the Temperature, pH value, Conductivity, Chemical Oxygen Demand (COD) and Total Dissolved Solids (TDS) of water at different stations through the webserver. These parameters are also observed in the ThingSpeak mobile application.

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