IoT based Real-Time Water Quality Monitoring System using smart Sensors

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Abstract – *This paper is describes on design and development of water quality monitoring system based on Internet on Things(IoT) using smart sensor networks. With the objective of notififying the user in real time water quality parameters. According to world health organization (WHO) around 76 million people in our country not access to safe drinking water and 21% diseases are water related. To reduce water related diseases we need to measure water parameters such as pH, conductivity, turbidity, temperature etc. these parameters are used to detect the water containments. The sensors are designed and connected to microcontroller which have inbuilt ADC circuit to convert the signal, also processes and analyses the data. In this design Wi-Fi protocol is used to send the data to cloud. The projected water quality observation interfaces sensor with quality observation with IoT setting. WQM selects parameters of water like temperature, pH level, turbidity by multiple different device nodes. This methodology sends the information to the web server. The updated data into the server may be retrieved or accessed from any place within the world in real time. Also the system predicts the status of water based on machine learning algorithm. Classification using decision tree algorithm is used to predict the classes of water.*

***Key Words*: pH sensor, turbidity sensor, temperature sensor, Wi-Fi protocol, internet on things(IoT), machine learning, Decision tree algorithm**

1. INTRODUCTION

In the 21st century providing pure drinking water is becoming a major challenge worldwide. International governing bodies such as United Nations (UN) and World Health Organization (WHO) also recognized human right to sufficient, continuous, safe, and acceptable, physically accessible, and affordable water for personal and domestic use. According to research of WHO 844 million people lack even a basic drinking water service; impure drinking can cause life threatening disease such diarrhea, cholera, dysentery, typhoid, and polio. The research alarmingly estimates that every year diarrhea alone is causing around death of five lakh people. Hygienic water is one of the most important resources required to sustain life and the quality of drinking water plays a very important role in the well-being and health of human beings [1]. Water supply to taps at urban homes and water sources available in more rural areas, is however, not necessarily safe for consumption. It is thus paramount to monitor the quality of water which will be used for consumption. The monitoring is defined as the collection of information at set locations and at regular intervals in order to provide data which may be used to define current conditions. Traditional water quality monitoring methods involve sampling and laboratory techniques. These methods are however time consuming (leading to delayed detection of and response to contaminants) and not very cost effective. There is thus a need for more extensive and efficient monitoring methods.

Quality monitoring can be achieved through physiochemical measurements as well as microbial measurements. Physiochemical parameters include electrical conductivity, pH, oxidation reduction potential (ORP), turbidity, temperature, chlorine content and flow. These parameters can be analyzed quickly and at less cost than the microbial parameters. Monitoring with sensor technology [11] is still not very effective, as they do not always meet the practical needs of specific utilities; although cheaper than traditional equipment, cost, reliability and maintenance issues still exist; and data handling and management can also be improved. In this paper the development of a low-cost, wireless, multi-sensor network for measuring the physicochemical water parameters; enabling real-time monitoring, is presented. The system implements temperature, turbidity and pH sensors from first principles. All the data from the sensors are processed and analyzed, and transmitted to cloud and stored data in cloud is downloaded and analyzed using classification based decision tree algorithm.

2. LITERATURE REVIEW

The literature review involving the implementation of water quality monitoring systems using wireless sensor network (WSN) technology can be found in literature. In [8] a distributed system for measuring water quality is designed and implemented. Temperature, conductivity, pH and turbidity sensors are connected to a field point, wherefrom and transferring the measured value via GSM technology to work station. In [11] [8]a Zigbee based WSN water quality monitoring and measurement system is presented. The system enables remote probing and real-time monitoring of the water quality parameters and also enables observation of current and historical water quality status. data is sent using a GSM (global system for mobile communications) network to a land based station. The focus of this study is however on the processing of the sensor data using Kohenen maps (auto-associative neural networks). In [9] WSN-based water environment system which consist of three part :Data monitoring nodes, video base station and remote monitoring center of key areas and water parameters such as temperature, turbidity, pH, dissolved oxygen and conductivity is presented the measured parameter processed by ARM-DSP and for communication purpose CDMA and Zigbee technology is used. Data is sent from the data monitoring nodes and data video base station to a remote monitoring center using Zigbee and CDMA (code division multiple access) technology. The water environment monitoring system implemented in [10] analyses and processes water quality parameters (pH, conductivity, dissolved oxygen and temperature), and also sounds an alarm when there is a water contamination is above the standard value mentioned from the WHO, or change in water quality. The whole water environment monitoring system presents useful characteristics as large network capacity. The parameters are measured with off-the shelf sensors and data is sent to a base station via GPRS (general packet radio service).

A river basin scale WSN for agriculture and water monitoring, called Soil Weather is implemented in [12]in this high quality sensors are used for water and soil to calibrate the sensor to monitor data quality and automatic cleaning sensors in water by compressed air. The network uses GSM and GPRS technology for transmission of sensor data. A turbidity system is proposed in [13], operation is based on the principle that the intensity of the light scattered by the suspended matter is to its concentration.. Turbidity can be interpreted as a measure of the relative clarity of water and often indicates the presence of dispersed, suspended solids; particles not in true solution such as silt, clay, algae based on passing the UV rays. Which is low powered [14], small-sized, easy-to-use, light weight and inexpensive. In [15], the DEPLOY project is introduced to monitor the spatial and temporal distribution of water quality and environmental parameters of a river catchment. It is intended to demonstrate that an autonomous network of sensors can be deployed over a wide area and the system measures parameters such as pH, temperature, depth, conductivity, and turbidity and dissolved oxygen. A microcontroller-based WSN system is proposed in [16] to measure pH, chlorine concentration and temperature in a pool. Data is transmitted using GSM and in sleep mode the sensor nodes are shown to consume 27 μA. Besides, the input voltage is 3.0V, so TB88-30 is idle and no power loss. When the input voltage descends, the current consumption is getting to increase. In [17] a WSN system is used to measure the water quality of fresh water and uses solar daylight harvesting for optimized power management. The data collected from the various sensor nodes are sent to a sub-base node and from there to a monitoring station using a GSM network. The system powered by PIC16F886, RF ZIGBEE 802.15.4 ISM 2.4G Hz module for each node, integrated with GSM/GPRS modem, to solve power issue Li-PO battery is used. A low-cost, real-time, in-pipe sensor node with a sensor array for measuring flow, pH, conductivity, ORP and turbidity, is designed and developed in [18]. Contamination event detection algorithms are also developed to enable sensor nodes to make decisions and trigger alarms when contaminants are detected.

3. METHODOLOGY AND IMPLIMENTATION OF SYSTEM

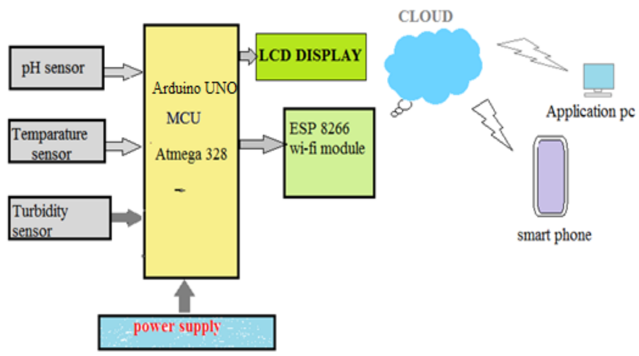

Figure 1: Block diagram of water quality monitoring system

This paper presents the theory on real time monitoring of water quality in IoT environment. The overall block diagram of the proposed method is explained. Each and every block of the system is explained in detail.

In this proposed block diagram consist of several sensors (temperature, pH, turbidity) is connected to core controller. The core controller are accessing the sensor values and processing them to transfer the data through internet. Ardunio is used as a core controller. The sensor data can be viewed on the internet Wi-Fi system. The pure water should be within the specified WHO standard range shown in below table.

Table1: water quality physical parameter standard value table

Sl.No	Parameter	Range	Unit
1	Temperature	15-30	°C
2	pH	6.5-8.5	pH
3	Turbidity	0-5	NTU

a) pH sensor: The pH of a solution is the measure of the acidity or alkalinity of that solution. The pH scale is a logarithmic scale whose range is from 0-14 with a neutral point being 7. Values above 7 indicate a basic or alkaline solution and values below 7 would indicate an acidic solution. It operates on 3.3V power supply and it is easy to interface with arduino. The normal range of pH is 6 to 8.5

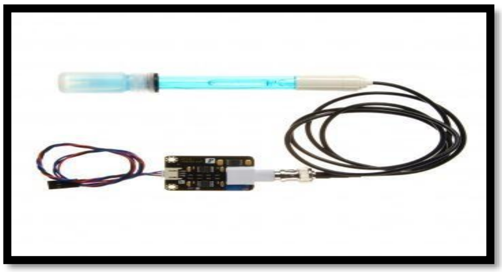

Figure2: pH sensor

b) Turbidity sensor: Turbidity is a measure of the cloudiness of water. Turbidity has indicated the degree at which the water loses its transparency. It is considered as a good measure of the quality of water. Turbidity blocks out the light needed by submerged aquatic vegetation. It also can raise surface water temperatures above normal because suspended particles near the surface facilitate the absorption of heat from sunlight.

Figure 3: turbidity sensor

c) Temperature sensor: Water Temperature indicates how water is hot or cold. The range of DS18B20 temperature sensor is -55 to +125 °C. This sensor is digital type which gives accurate reading.

Figure 4: Temperature sensor

Arduino Uno: Arduino is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller. Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past or outdated boards see the Arduino index of boards

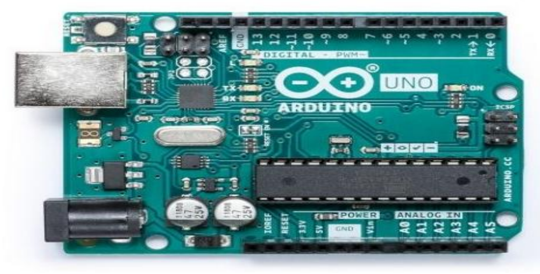

Figure 5: arduino uno platform

Wi-Fi module: The ESP8266 Wi-Fi Module is a self contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware. The ESP8266 module is an extremely cost effective board with a huge, and ever growing, community.

Figure 6: ESP8266 Wi-Fi module

Implementation: The whole design of the system is based mainly on IOT which is newly introduced concept in the world of development. There is basically two parts included, the first one is hardware & second one is software. The hardware part has sensors which help to measure the real time values, another one is arduino atmega328 converts the analog values to digital one, & LCD shows the displays output from sensors, Wi-Fi module gives the connection between hardware and software. In software we developed a program based on embedded c language. Classification based decision tree algorithm is used to predict the water quality classes using matlab.

Once the all hardware is interfaced to the core we need to program for sensor and communication devices. power the module to measure water parameters from sensor, each sensor value is measured at different interval time and displayed on LCD alternatively accumulate the measured value and send to cloud using ESP8266 wi-fi module. Here Thingspeak is used as a cloud server. User can view the real time measured value by login the account, where we can monitor the real time water parameters in graphical view.

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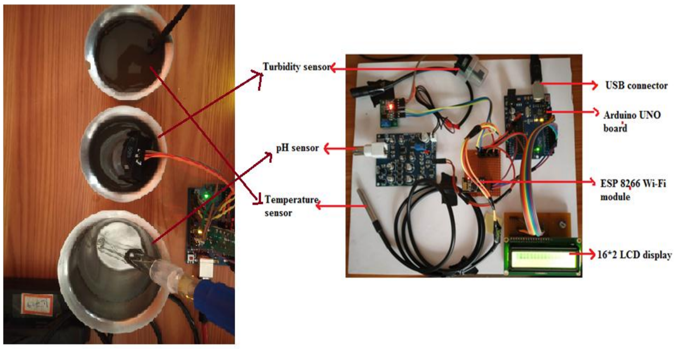

Figure7: System design model of water quality monitoring system using IOT

4. RESULT AND DISCUSSION

The water quality monitoring is impartment for several applications such as drinking water distribution and measurement and environment monitoring of pond and eco system etc. The proposed real- time water monitoring system having three different sensors which are connected to a core. Which are senses or read the water parameter by using microcontroller and send to the cloud using Wi-Fi module, here we can monitor the water quality parameter on the internet by using cloud computing. We use thing speak as a cloud server to store the water parameters these parameters can be obtained in graphical manner.

While turning ON the system initialization takes place and display the system name on LCD display as we code shown in following picture1.Alternatively once the system is initialized then Wi-Fi module is get connected to a network using IP address and connecting progress display on serial monitor window and also on LCD display like as connecting to Wi-Fi, both serial monitor window and lcd display shown in the Figure8.2. If the Wi-Fi get connected to network shows Wi-Fi connected message on both serial and lcd window or else shows Wi-Fi connected message shown in 8.3.

Figure 8.1 figure: 8.2 figure 8.3

The figure 9 represents the pH value of the water, the X axis is represents the time and Y axis represents the pH value. We took three different samples for demo purpose. One is pure water, second one is drainage water and third one is added acidic water each samples parameters are measured continuously and obtained result is real time on both lcd display and on web. In figure 9 the pH value is range from in between the 7 and 5.5 of three different samples.

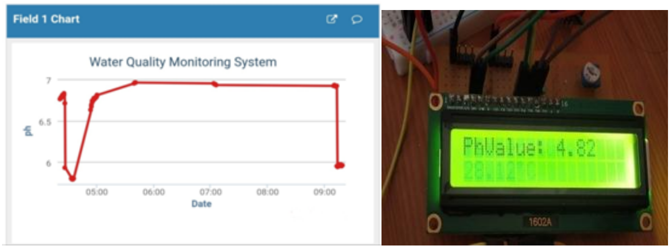

Figure 9: Measurement of pH value

The voltage output from the pH electrode which ranges from -430 mV to 430 mV is represented by measured voltage. The resolution is 60mV/pH. Figure 9 shows the different water sample results but in LCD display 4.82 is the lemon pH.

Similarly the temperature is also a one of parameter of water quality .which is to be sensed by temperature sensor and obtained the live temperature data on thingpeak window in the form of graph shown in below figure. Where X axis represents the time slot and Y axis represents the temperature value of water sample. The expected output from the op-amp U1 should read from 0 to 2.85V as specified in the design. The resultant output displayed in integer on LCD.

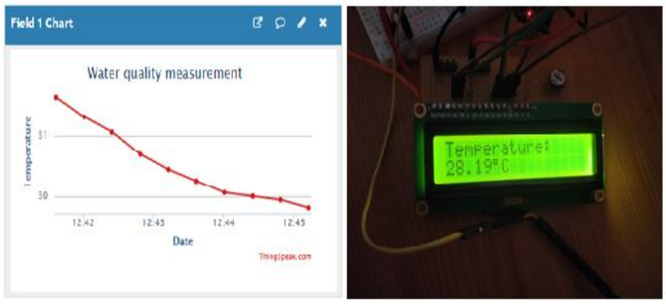

Figure 10 : Measurement of water temperature using temperature senor

Likewise the turbidity is also a one of parameter of water quality .which is to be sensed by turbidity sensor and obtained the live result data on thingspeak window in the form of graph shown in below figure. Where X axis represents the time slot and Y axis represents the turbidity in NTU and which is in the range of 0-3000 NTU of water sample.Turbidity causes cloudiness or decrease in transparency of water the direction of transmitted light path will undergo changes when the light hits the particles in the water column and microcontroller gets the digital signal from inbuilt ADC circuit and display the results along with all above mentioned parameters shown in figure 11.

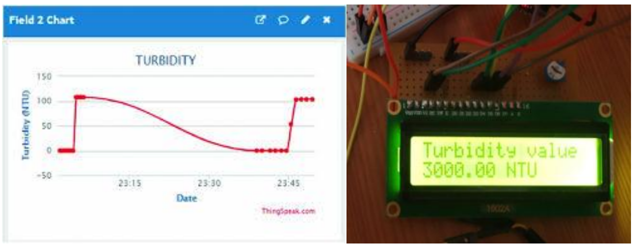

Figure 11: Measurement of water turbidity using turbidity sensor senor

Once the sensed data from sensor by all three sensor is sent to cloud, that data sample means last obtained data is downloaded using MAT lab code and analyzes or predict quality of water. Here we used decision tree classification algorithm to predict the water parameter. The decision tree algorithm is preferred and GUI window is created to show the predicted result on MAT lab.

The GUI is created as the measured data can be in used to predict in either on IoT or manual mode. In manual mode we entered the data manually where we get from on either LCD window which is connected to circuit or where we get from cloud. Based on those data algorithm is predicts water pH value is either acidic or alkaline, and temperature is COOL, HOT, and NORMAL, and Turbidity level is BAD, MODERATE, POOR. Shown in figure12.

The IoT mode operates based on live stream data is downloaded automatically from the cloud and predicts the result and measure the accuracy of the water sample shown in following figure In IoT mode operation, initially we train the model based on data sets and then read the data from cloud where last measured value is fetched from cloud as Excel file. That data is used to predict the water quality using trained data set and measures the acidity level, Turbidity level and Temperature of water. The following tree is formed based on decision tree algorithm .The figure 12 shows the proposed model decision tree diagram.

Here we considered three different parent nodes each node having three child nodes. The child node is formed based on the information Gain. Which decides feature to split on at each step in building the tree? The split with the highest information gain will be taken as the first split and the process will be continue until all children nodes are pure, or until the information gain is 0.

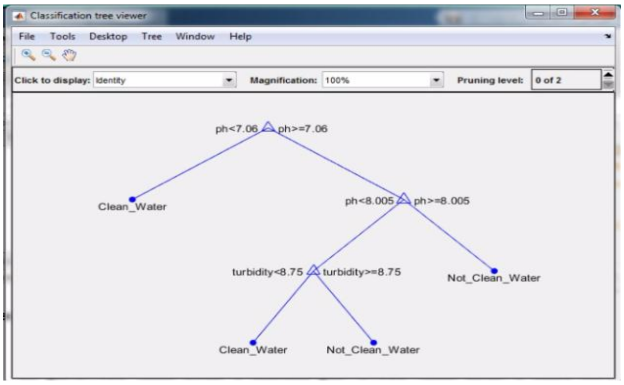

Figure 12: Decision tree of proposed model

The Graphic user interface (GUI) window is prepared in MATLAB for viewing the water parameters based on run the model. Which is also known as Apps, provide point and click control of our software application.

Its an interactive environment that integrates the two primary tasks of App building: laying out the visual components and programming the Apps behavior. It allows us to quickly move between visual design in the canvas and developing code in MATLAB editor.

The following GUI window having two blocks of operation. first one is IoT mode and Manual mode, initially we train the model just click on the "train the model" button then read the data from cloud after that click on "predict the water quality" then following empty block will show a quality of water

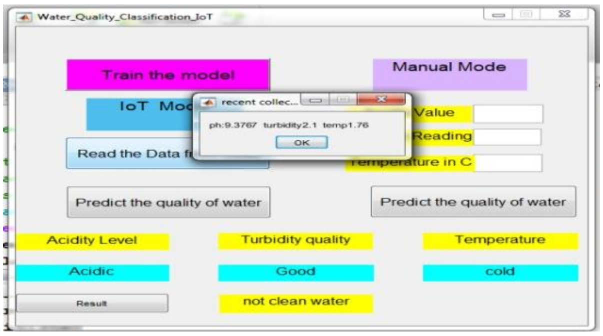

Figure 13: GUI window of water quality

5. CONCLUSION AND FUTURE SCOPE

Based on study of existing water quality monitoring system and scenario of water we can define that proposed system is more suitable to monitor and analysis of water quality parameters in real time. The smart water quality meter is automatic and does not require human interface, thereby reducing the errors, a sensor node with a temperature, pH, and turbidity sensors was designed and constructed on a Vero-board. The proposed system having wireless sensor networking using Wi-Fi module, which makes sensor network is simple low cost and reliable and more efficient. The temperature sensor was completed using a thermistor based design. The pH sensor made use of a glass electrode and yielded acceptable results. The Turbidity sensor based light transmission and reception yields acceptable result.

The microcontroller is used as heart of this module, which process the received signal from different sensors then transmitted the measurements wirelessly to the cloud via the wireless Wi-Fi modules. A wireless node was implemented using ESP8266 Wi-Fi modules configured for peer-to-peer communication. IoT in recent computing paradigms consist of three sensor or objects. The objects surround us to connect to a network. And exchange information to advances in semiconductor and communication technology lead to development of tiny computing devices and the object get smaller as embedded system; they become a sensor as actuators system. They are deployed in on sample water and generate numerous data. The network connected to server in the cloud through gateway, thus a lot of data is delivered to the sever and server gathers data from the objects and then analyze it for intelligent services. The number of cloud server available for store the data on cloud. The presented system uses Thingspeakwebservice for MATLAB analysis and MATLAB visualization this runs automatically run matlab code that makes it easier to gain insight our data Depend on the analyzed information of the server different behavior can be obtained in the services. They approach decision making through the collected data from the objects in the physical domain. Thus a data analysis is an impartment part in the IoT services. The current**0**plan can show the boundaries continuously, To analyze the data which stored in cloud, first we need to download the data from cloud then we used Decision algorithm for predicting the data, where we need data set for train the model here we took around 114 different data set and predicted parameter is shown on GUI window.

Due to limitation0of time and budget we focus on0measuring quality of water parameters. This project can be extended into efficient water management system of a local area and other parameters is not on scope of this project such as chemical oxygen demand and dissolved oxygen can also be quantified. So additional budget is required for further improvement of overall system. We can also work on making a mobile application for remote water monitoring which user can download and install in his or her device and can get real time notification.

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