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Remote Sensing Kit for Contamination Event Detection in Water

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***Abstract*—Here, we propose an Internet of Things (IoT) enabled remote sensing kit for multipara-meter based water quality monitoring and contamination event detection. The proposed kit is able to collect real-time data from household reservoirs, analyze and display them on an easy to use platform for monitoring purpose. It can measure Temperature (T), pH, Electrical Conductivity (EC), and Turbidity (Tb), as vital indicators of water quality. It can also preprocess acquired data by the onboard processor (NodeMCU) and transfer to the cloud (Firebase) for determining the water quality. Users can monitor water quality regularly as a graph and other means by logging in their web account. The kit has been tested thoroughly to ensure its accuracy and usefulness. The proposed remote sensing kit can be seamlessly integrated into the water management system of the metropolitan area and can be considered as an important part for the future smart city concept.**

Keywords— contamination detection, IoT, real-time monitoring, smart city, water quality monitoring

I. INTRODUCTION

Water is one of the most important natural resources in our daily life. Consumption of clean water is vital for the soundness of our health. However, water can easily be contaminated as well. Water pollution has become growingly prominent in the urban areas of the developing countries in Asia and Africa [1-3]. Development of a water management system should be high priority in these regions as the supply water are heavily polluted by the poor infrastructure of sanitation, natural calamity such as rain and flood and industrial development [4]. The effect of such contamination is huge as it can have both short and long term immeasurable impact on the health and environment [5-7].

People in general are neither aware of the source of water they are consuming or using in other household purpose nor they have knowledge about the level of contamination it contains. The recent advent of information and communication technology brings new hope as it enables the data measurement, transmission, storage and analysis in real-time at a low cost and in an easier fashion [8, 9]. With the help of IoT, it is possible to build a plug and play prototype that can be placed at a particular supply point of the resource [10], do some measurement of important indicators, perform analysis and represent the information in a way that even a non-technical person would be able to understand. Such kind of technological solution will be good for increasing the awareness, as users will be able to learn about the impact or risk of the consumption of a resource.

In this study, an IoT enabled kit has been proposed that is equipped with carefully selected sensor modules and can measure valuable indicators of contamination level of water. The kit is able to float on water surface, so the users can easily place it in the water tanks, or reservoirs commonly used in urban areas for storage purpose. This feature also allows it to be used in open reservoirs such as small lakes and ponds if required. It also contains a processing unit to enable preprocessing of the data collected from the sample and transmission to the server in real-time. An easy to use website and mobile application have also been developed to facilitate users with monitoring the quality of water, checking the log as well as accessing the raw data (sensor values). We believe this device will play a very important role to increase awareness and safety by informing them about the contamination level before consumption.

II. RELATED WORK

Smart water concept as part of future Smart City has been popularized over the last decades [3, 5, 11]. Therefore, different smart solutions regarding water management, monitoring and treatment have been proposed in the recent years. There are several works where authors proposed a solution for monitoring supply water in the pipeline. [12-14] proposed the design of smart sensors for real time water quality monitoring inside the pipe during the supply. The solution uses ZigBee for communication purpose and LED display for the result which user needs to check manually. A low-cost system for real time monitoring and assessment of potable water quality at consumer sites has been proposed by [8] for the same application as the previous work. One disadvantage with solution proposed in these works is that monitoring water in the supply line requires assistance and permission from the metropolitan authority. Our proposed approach, on the other hand, is more concerned about monitoring of water in the reservoirs. The product we propose is consumer focused means consumers themselves can buy it and setup without much technical knowledge. In [15], authors proposed a water quality monitoring sensor box that is suspended from a floating platform and can measure certain parameters from the rivers and transmit them to the shore. They used bidirectional Wi-Fi to send data to the server at the shore. Such kind of design requires high manual intervention for data collection. In our case, floating mechanism has been embedded into the device itself. Wang Yuanyuan [16] discusses the concept of overall framework of smart water that includes sensing layer, transport layer, processing layer, application layer and unified portal layer. In our design we have closely followed this concept.

III. SYSTEM ARCHITECTURE

The system architecture has been given in Fig. 1. Sensing kit, is at the core of this system that is able to perform data acquisition, preprocessing and data transmission to the cloud independently without any manual intervention.

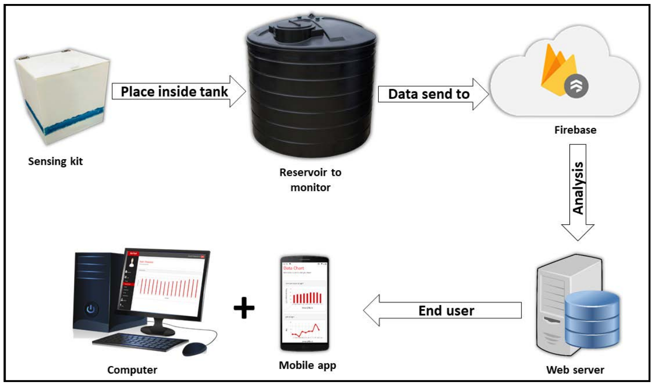

Figure 1: Simplified architecture of the overall system

The sensing kit has a dimension of 20 x 20 x 23 cm, and the overall weight is 876 gram. The box is made of acrylic plastic and can easily fit inside a water tank. Users need to power on the device, set up a mobile application in their mobile phone with a user credentials provided to them. This same credentials has been preprogrammed inside the device to ensure the security. Once the kit is powered on, set up by the mobile app and placed inside the water reservoir, it can automatically send the sensors' reading to the cloud. In firebase, the raw data coming from four different sensors are stored as JSON format, separated by date and time. The web server processes those data; make a decision on contamination level before displaying it to the end users who can observe these via web browser or android application.

IV. DETAIL DESIGN

A. Hardware Architecture

The hardware of the remote sensing kit can be sliced into two parts: sensors connected with analog front-end circuit (AFE), and processing unit (ESP8266), shown in Fig. 2. Four sensors that have been used are Temperature Sensor (DS18B20), pH sensor (SEN0161), Electrical Conductivity Sensor (DFR0300), and Turbidity Sensor (SEN0189). Temperature sensor detect the temperature in °C. The pH sensor is specifically designed to measure the pH of the solution and reflect the acidity or alkalinity. Turbidity sensor is able to detect suspended particles in water by measuring the light transmittance and scattering rate, which changes with the amount of total suspended solids (TSS) in water. The sensors take readings in a specific sequence one at a time to ensure data integrity, and NodeMCU is responsible for ensuring the order. Each sensor take multiple readings to ensure the validity of the data and ESP8266 does the preprocessing of these readings before sending them to the cloud. One limitation with the processing unit, that we are using, is it has only one analog input pin to cover four sensors. This is solved by adding an analog 8x1 multiplexer (74HC4051) which is also part of control circuit. Fig. 3 shows the complete picture of the remote sensing kit.

B. Data Transfer to Cloud

NodeMCU takes multiple readings from each of the AFE circuit, discards the first few readings as part of sensor calibration and stores the averages into an array. The interval between each measurement is set to 2s. The repeated switching

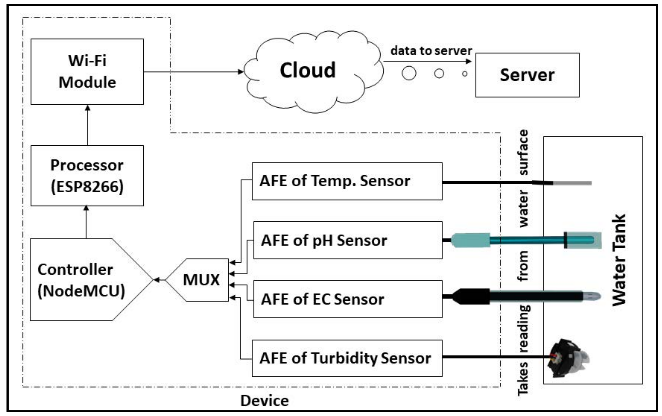

Figure 2: The flow of data from sensors to server

during measurements is done by the NodeMCU with the help of NPN transistors (2N3904). Finally, the array with one round of dataset is converted into a JSON format text with current date and time. The date and time is taken from Network Time Protocol (NTP) server "*asia.pool.ntp.org*" accessed by NodeMCU. To parse data and push into firebase database, JSON library has been used. NodeMCU finally transfers that JSON format data to the Firebase, shown in Fig. 4. Firebase stores the data as REST tree which have API endpoint to facilitate easy fetch of data as user requires. The website fetch those raw texts; from the firebase, to display it to the end users. Chartist.js has been used to plot graph and chart from firebase data, along with HTML, CSS.

C. End User Access

The details about the user access has been shown in the flowchart in Fig. 4. A website has been developed so that users can access the data from the cloud with ease. The website connects the firebase, and fetches raw data from the database system. Firebase is a free web server provided by Google. Firebase follows No-SQL format, therefore, fetching those data are different compared to normal database system with Structured Query Language (SQL). Users needs to provide the credentials, user id & password to access the data collected by their device. Fig. 5 shows the UI of the website. An android based mobile application has also been developed considering the flexibility and comfort of the users. An UI of the android application has been shown in Fig. 6. To keep things simple, there are only few options in the app. The first option is to connect the kit with an internet connection. Once the internet connection is established the users can use their credentials for login to access the firebase data for observation. Here, users will able to monitor the quality of water through graphs, stats and meaningful comments.

V. METHODS AND FEATURES

The kit has been designed with a consideration to the users utmost comfort. Users only need to power the device on, put it into the reservoir and start enjoying the blessings of IoT.

A. Hardware Implementation

The major decision behind making the sensing kit floating type on the water surface is to reduce the manual intervention,

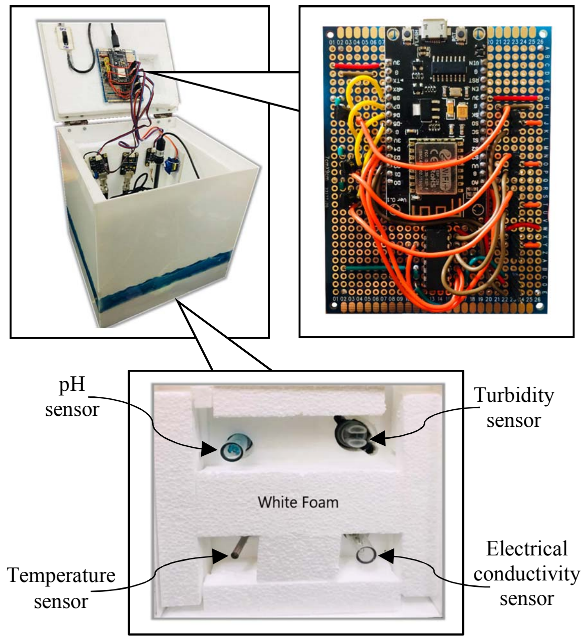

Figure 3: Showing inside the kit, the IC board & sensors' position below the device

power consumption caused by the external motor to pull the entire device up and down to the water surface during the measurements, the additional cost caused by the sensors required to identify the level of the water surface before bringing it down for measurements. White foam has been placed on the bottom of the device (Fig. 3) for floating purpose. Before placing it on any water surface, the user have to turn on the device by using the slider switch inside the device. After turning it on, the user can manually check whether all the sensors are working by checking the blue LED indicators on the AFE circuit board. For connecting the sensing kit with the internet, one can preprogram it with internet access point (AP) details or can manually set it up through the app. In the first case, the kit can start scanning for known connections after the power is ON. As for the second, users can use their mobile phone to set the access points for the kit. This is done by first connecting to the Wi-Fi hotspot, *purewater* created by the communication module inside the device and then providing the respective Wi-Fi credentials when asked.

B. Software Implementation

Using Bootstrap, CSS, and HTML a template was created first. Then using JavaScript and a firmware of JavaScript - JQuery, a retrieving program from firebase has been implemented. After getting the data using JavaScript, its session option is called. All the information come from the firebase are stored in their respective array. The last value of each array represents the pH, turbidity, temperature, or EC value. In the graph page, session function is called further to get those data. To plot graph, another JavaScript library named Chartist.js is used (Fig. 4) that takes two parameters, label, and data to plot the graph. time of measuring the quality of water has been label in this case which is placed into the x-axis. y-axis represents sensor values at that point of time received from data array as the data parameter.

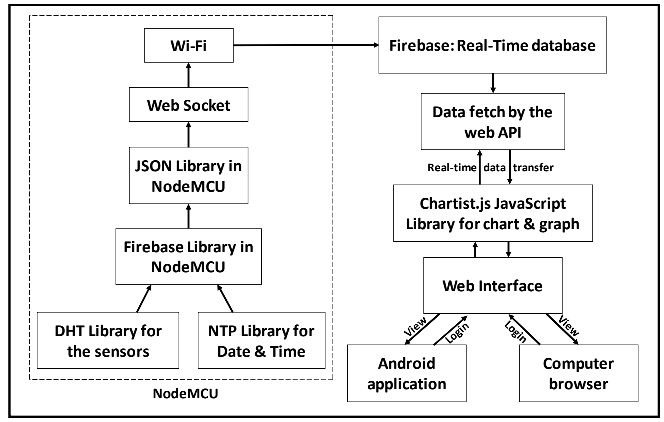

Figure 4: Flowchart showing the Software architecture of the project

There are two options in the android app: LOGIN, and WIFI SETUP. "WIFI SETUP" option will direct the user to connect the device to home Wi-Fi connection, as shown in Fig. 6. After the device is successfully connected to the home WIFI connection, the user can use "LOGIN" option to access his/her user dashboard, as shown in Fig. 5.

VI. EXPERIMENT AND RESULT

Before the experiments were done with the final device, all the sensors and their measurements were experimentally verified. For example, pH sensor was tested with different solutions Mineral water, Mineral Water + Detergent, Tap Water from WASA, Tap Water + Detergent, Mineral Water + Lemon, Coca-Cola. EC and temperature sensor was tested with tap water. Turbidity sensor was tested in clean and dirty water. Finally the sensing kit was assembled and the complete IoT system was tested.

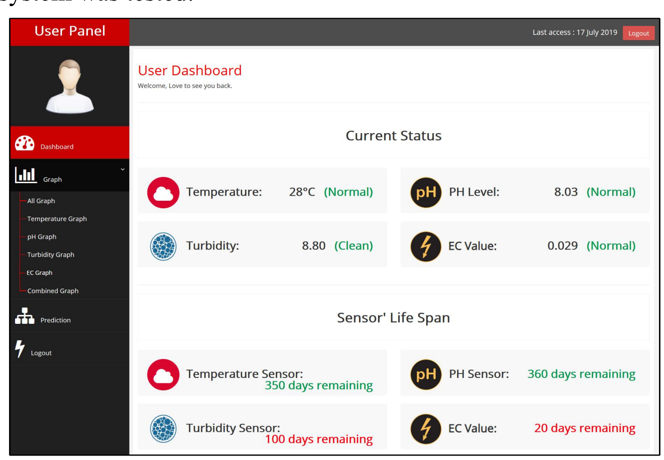

Figure 5: User dashboard with water quality status and sensor details

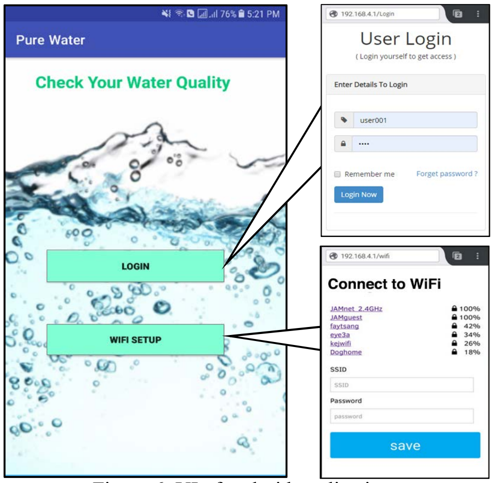

Figure 6: UI of android application

A. *Experiment With Final Device*

This section details the data collected through the complete prototype. Figure 7 and 8 show the real-time graph plotted based on the data collected through the kit. Electrical conductivity is in general directly proportional to temperature of water, considering the surrounding temperature remains constant. This is reflected in Fig. 7, where small dotted line represent temperature (ºC) and long dotted line represent electrical conductivity (mS/cm). The primary vertical axis represent

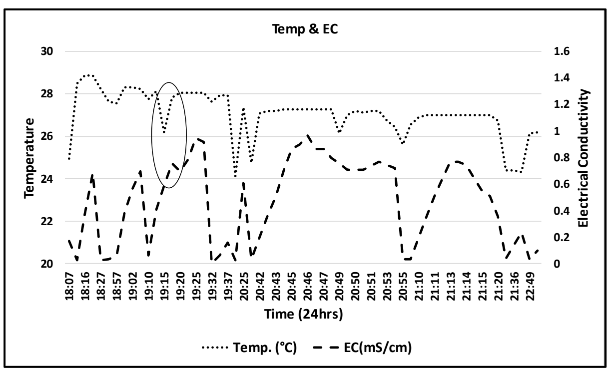

Figure 7: Showing pH and Turbidity in a single graph

temperature, and secondary vertical axis represent the EC and the horizontal axis represent time in 24 hours. Here, we should note that safe water has a range of conductivity from 0 – 1.5 mS/cm, and temperature from 15 – 45 ºC. By analyzing the graph, it can be deduced that the water is safe in perspective to EC and temperature in the time frame 18:07 – 19:05. At 19:15, however the EC sensor is displaying abnormal value, as marked in Fig. 7. The motion of water can cause this type of EC value. After 19:23 the graph shows a symbiosis relation between temperature and electrical conductivity.

There is no direct relation between pH and turbidity. They both are represented in Fig. 8 recorded at the same time frame as the other sensors. The small dotted line represent pH, and its vales are shown in the primary vertical axis. The long dotted line represent turbidity, and its values are shown in the secondary vertical axis. The horizontal axis represent time in 24 hours. The range of pH level is 0 to 14, where 7 indicates a neutral substance. Usable water has a range of pH 6 to 8.5. Any lower

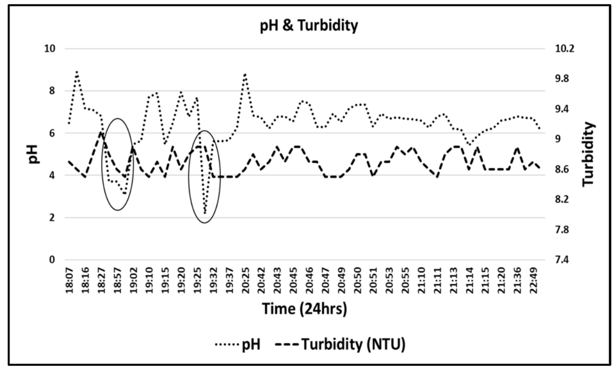

Figure 8: Showing the relation between temperature and EC

value from 6 or higher from 8.5 is considered to be an acidic or alkaline respectively. On the other hand, turbidity has a range from 0 to 11. Where value less than 8 is dirty and greater or equal to 8 is considered to be clean water. After inspection, it can be concluded that turbidity of the experimental water is clean, but few pH readings are closing to danger zone, as pointed in Fig. 8.

VII. Conclusion

Here, we propose an IoT enabled easy to use prototype for real-time water quality monitoring. Four sensors were used to identify important parameters as meaningful indicator of water quality. Physical condition of water was measured by using temperature, and turbidity sensors, and the chemical condition was measured by using pH, and EC sensors. The sensing kit, a self-independent hardware device has been designed that can float on the water surface, take measurements at a regular interval and send them to the cloud without any manual intervention. The sensors were verified experimentally and the complete product was setup and tested to confirm its ability in real-time monitoring. The user can use the Android app, or web browser not only to access the data but also to configure the NodeMCU, the main processing board of the kit. The proposed solution have many applications starting from water quality monitoring by non-technical people in day to day household activities, long data collection from a particular area like river, pond etc., monitoring of water in industrial zone where waters are highly polluted by the wastes and many more. We believe this kit will be useful for increasing the water related awareness in the society.

References

[1] U. Shafi, R. Mumtaz, H. Anwar, A. Qamar and H. Khurshid, "Surface Water Pollution Detection using Internet of Things." *2018 15th International Conference on Smart Cities: Improving Quality of Life Using ICT & IoT (HONET-ICT)*. IEEE, 2018.

[2] K. Soni, D. Waghela, R. Shah and M. Mohan, "Smart Well Monitoring System." *2018 International Conference on Smart City and Emerging Technology (ICSCET)*. IEEE, 2018.

[3] K. Mohammed Shahanas and P. Bagavathi Sivakumar, "Framework for a smart water management system in the context of smart city initiatives in India." *Procedia Computer Science* 92 (2016): 142-147.

[4] A. Prasad, K. Mamun, F. Islam and H. Haqva, "Smart water quality monitoring system." *2015 2nd Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE)*. IEEE, 2015.

[5] Y. Chen and D. Han, "Water quality monitoring in smart city: A pilot project." *Automation in Construction* 89 (2018): 307-316.

[6] Y. Qina, A. Alama, S. Panc, M. Howladera and R. Ghoshc, "Integrated water quality monitoring system with pH, free chlorine, and temperature sensors." *Sensors and Actuators B: Chemical* 255 (2018): 781-790.

[7] R. Nageswara, Ch. Mukesh and V. Sagar, "Water quality monitoring system using IoT." *2018 Fourth International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB).* IEEE, 2018.

[8] T. Lambrou, C. Panayiotou and C. Anastasiou, "A low-cost system for real time monitoring and assessment of potable water quality at consumer sites." *SENSORS, 2012 IEEE.* IEEE, 2012.

[9] B. O'Flynn, F. Regan, A. Lawlor, J. Wallace, J. Torres and C. O'Mathuna, "Experiences and recommendations in deploying a real-time, water quality monitoring system." *Measurement Science and Technology* 21.12 (2010): 124004.

[10] R. Yue and T. Ying, "A novel water quality monitoring system based on solar power supply & wireless sensor network." *Procedia Environmental Sciences* 12 (2012): 265-272.

[11] A. Mickelson, and D. Tsvankin, "Water quality sensors for smart cities." *Proceedings of the 2017 International Conference on Smart Digital Environment.* ACM, 2017.

[12] S. Kavi Priya, G. Shenbagalakshmi and T. Revathi, "IoT Based Automation of Real Time In-Pipe Contamination Detection System in Drinking Water." *2018 International Conference on Communication and Signal Processing (ICCSP).* IEEE, 2018.

[13] N. Cloete, R. Malekian and L. Nair, "Design of smart sensors for real-time water quality monitoring." *IEEE Access 4* (2016): 3975-3990.

[14] M. Carminati, V. Stefanelli, G. Ferrari and M. Sampietro, "Smart pipe: A miniaturized sensor platform for real-time monitoring of drinking water quality." *2017 IEEE Workshop on Environmental, Energy, and Structural Monitoring Systems (EESMS).* IEEE, 2017.

[15] G. Surendran, G. Udupa and G. Nair, "Design and modelling of cable suspended sonde for water quality monitoring." *2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT).* IEEE, 2017.

[16] W. Yuanyuan, L. Ping, S. Wenze and Y. Xinchun, "A new framework on regional smart water." *Procedia Computer Science* 107 (2017): 122-128.