Mobile Sensor Node for Real Time Monitoring of pH Level in Domestic Water Resources

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Abstract: With increased levels of environmental pollution, access to clean water is hampered all over the world. As typical laboratory experiments and official water quality tests take considerable amount of time to obtain results, demand for real time monitoring of pH value in household water is ever increasing. Moreover, incidents of serious nature had occurred in the past where people's lives, especially in rural areas, have been lost due to issues pertaining to pH value in drinking water. This happens mainly due to non availability of a simple device that can measure such water quality parameters in real time. This paper presents a technique implemented based on wireless sensor networks and mobile technologies to measure pH value in water in a domestic environment in real time. It consists of a sensor node that measures pH and transmit the values to a mobile device, such as a mobile phone, using wireless communication principles. The proposed system facilitates storing of monitored records that can be viewed graphically on a mobile phone. Real time measurements taken using three water samples indicate that the system performed with a high accuracy and low transmission delays between the sensor node and the mobile device. The system can be readily implemented as a low cost consumer device that can be used even by non-technical persons.

Keywords: pH in water, wireless sensor network, water quality measurements

1. INTRODUCTION

Water is a limited and precious resource not only for human existence but also for flora, fauna and aquatic life. As such, maintaining its quality is essential in order to consume freshwater in day-to-day life. With the industrial development in the modern world, disposal of waste into clean water resources is critically responsible for the reduction of quality of water. Also, pesticides and fertilizers in agriculture too contribute for the destruction of the natural balance, not only in surface water, but also in ground water [1,8]. The quality of water can be measured using several conditions and constituents. These conditions are defined using chemical, physical and biological characteristics of water. One of the main water quality parameter is 'pH', a chemical characteristic used to measure the acidity level of water. It is an indicator of contaminants in water as pH level varies according to the amount of native substances [3].

The process of assuring the quality of water is called water quality monitoring and there are standards for water quality defined by authorized organizations with respect to usage of water [14]. Water quality monitoring is recommended in many situations. Water wells around factories and sites that dump hazardous waste should be regularly monitored [13] as well as water sources in agricultural areas [6, 7]. Moreover, soon after natural disasters such as floods, landslides, tsunami, etc., water sources in the affected area should be tested whether it is suitable for consumption or not [4, 5].

To assure the quality of water, tests can be performed on actual sites and in laboratories [2]. When few measurements are taken at sites, most of the tests are carried out in laboratories by collecting water samples from a particular site and transporting them into different locations. Taking readings in a different environment other than the native environment of the samples will produce error reports hampering accurate monitoring [9].

Although most of these tests are done by authorized organizations having expertise, contacting them and getting necessary authorization involve bureaucracy and cost both time and money. A delay in obtaining the required measurements makes tracking sudden changes in water difficult. In order to prevent disasters based on poor water quality, a technique to monitor water quality in real time over a prolonged time interval is essential. Future risks can only be identified by observing the patterns of collected data over time by keeping a proper storage system.

In Sri Lanka, we have experienced unfortunate incidents where lives of people were lost due to protests over anomaly in pH value in drinking water. This happened because a technique to monitor pH value in real time is not available among an average citizen. Therefore, citizens demand real time information about the quality of water they consume, especially drinking water [1, 2].

In order to solve this national problem, a mobile application based on wireless sensor networks is designed and developed to take real time measurements of pH level in water. It consists of a sensor node that measures pH level in water and communicates with a mobile device via Wi-Fi. An ad-hoc network is setup to send sensed data to a mobile application. Further, the mobile application dynamically displays sensor data in real time and allows us to visualize past data in a graphical form.

2. METHODOLOGY

The initial idea of the proposed system stems from inspirations of wireless sensor networks and ad-hoc networking in mobile computing. The proposed device contains two nodes, one sensor node and a sink node. The sensor node takes measurements and sends them to the sink node which is the mobile phone.

The sensor node has three major components: the pH sensor, WiFi module and a microcontroller board. An Atlas Scientific pH meter is used as the pH sensor as it comes with a pH probe. The HLK-RM04 is used as the WiFi module that can be configured as a WiFi client or an access point while at the same time, behaving as a TCP/UDP client or server. An Arduino-uno is used as the microcontroller board having an ATmega 328 microcontroller because both the sensor and the WiFi module are compatible with Arduino-uno.

The pH circuit produces an output, one in every 15 seconds, based on ASCII characters representing the pH or status messages terminating with a carriage return. It takes approximately 378 milliseconds to complete a command. Subsequently, the pH value is sent to the serial port of the microcontroller. The WiFi module is used to connect the sensor node to the ad-hoc network. It is configured as a WiFi client who should be able to connect to an existing network and a TCP client who is able to send requests. The baud rate of the microcontroller, WiFi module and the pH circuit need to be the same. The SSID and the network type must be compatible with the target network.

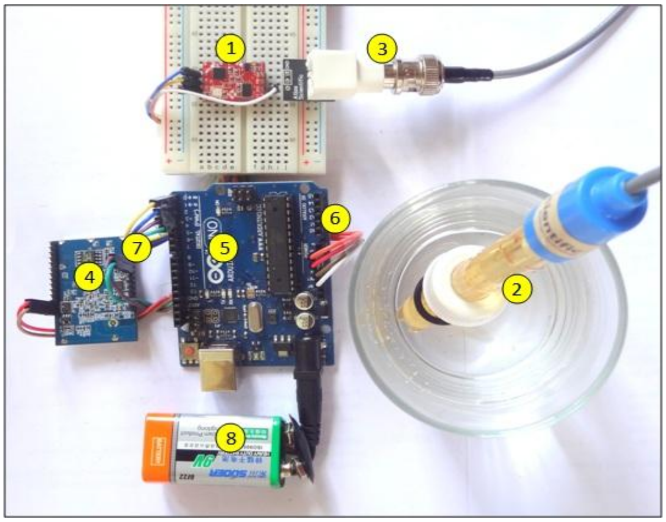
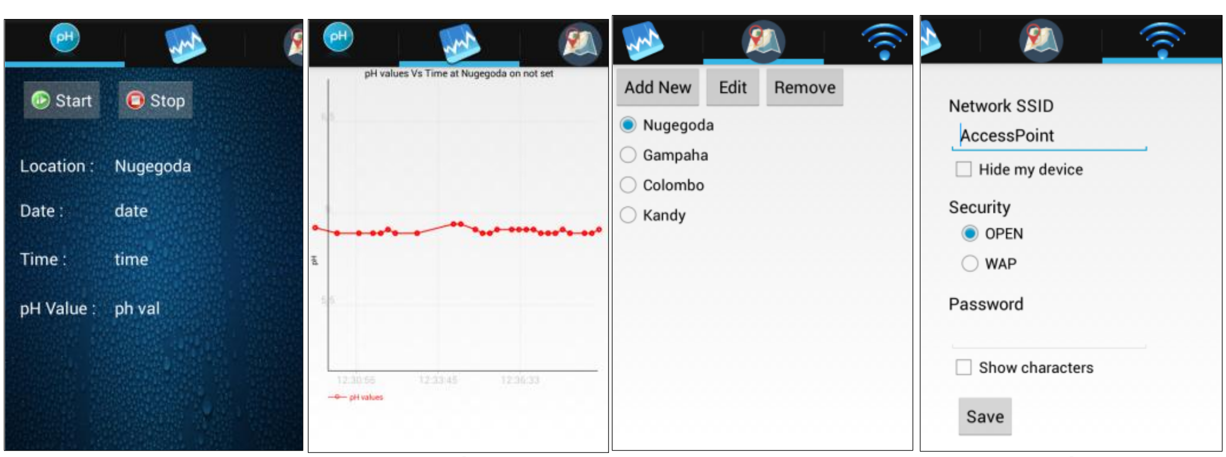


Fig. 2: Device setup of the sensor node. 1-Atlas Scientific pH circuit, 2-Atlas Scientific pH probe, 3-BNC connector, 4-HLK-RM04 Wi-Fi module, 5-Arduino Uno board with 32-bit Atmel ARM Microprocessor, 6-Analog pins, 7-Digital TX and RX pins, 8-9.0v battery

The main purpose of the WiFi module is to transmit pH values to the sink node. To accomplish this task, an HTTP GET request is used where the pH value is included in the URL as a parameter. The IP address of the mobile device and the port number is included in the request to find its way to the relevant mobile device. A web server is used to handle incoming requests, i.e. the requests sent by the sensor node. Let the sensor device to be the client for this server. When a request is received at the server, the handler extracts the parameters relevant to a pH value and stores them in a database. The mobile device too displays these measurements on a GUI in real time which is updated dynamically upon receiving requests by the node The mobile application, as depicted in Fig. 3, contains four main GUIs, namely, the pH monitor, pH history, location settings and network settings. The pH monitor displays in real time the pH values with time, date and the location. The pH history allows a user to view the past records graphically for a selected location. The readings are plotted using a line chart. The location settings show the locations where the measurements are taken.

3. RESULTS AND DISCUSSION

The performance of the system is evaluated by measuring the accuracy of the readings taken from the pH sensor, the response time of the pH sensor, the data transmission delay and the performance of the mobile application.



(a) (b) (c) (d)

Fig. 3: Screen shots of the mobile display: (a) pH monitor, (b) pH history, (c) location settings and (d) network settings.

3.1 Accuracy of readings

The readings obtained by the sensor are compared with values taken by a standard pH meter simultaneously. Three water samples are collected from different water sources, namely, distilled water, tap water and well water. The sample having distilled water is used to calibrate the sensor because the pH value is already known. Figure 4 shows the results obtained for the three water samples.

As a standard practice, measurements are taken after about 30 minutes after powering up a pH meter. This helps us to obtain measurements at a high precision and ensures stability of readings. However, at the laboratory setup, this initial stabilization period may differ from machine to machine. Based on the results, an average difference of 0.572 between the proposed system and the standard pH meter is calculated. A precautionary note to take at this point is that every pH meter must be calibrated after a certain time period. As different chemicals come in contact with the probe, accuracy of the meter decreases over time. Without proper calibration mechanism, a pH meter can show erroneous readings. According to the data sheet of the Atlas Scientific pH probe and the circuit, an error of +/- 0.02 is expected and calibration is required only once a year.

3.2 Transmission Delay over the network

Initially, the transmission delay is measured by varying the distance between the WiFi module and the mobile device without the pH sensor to ensure that external factors do not interfere with the measurements. As seen in Table I, the distance between the WiFi module and the mobile device did not have any profound effect on the transmission time. As the main requirement of the proposed system is to develop a mobile application for consumer use, it is assumed that a user stays close to the source of water (approximately 3m) in a domestic environment.

3.3 Performance of the mobile application

The mobile application is tested on a Samsung Galaxy S Duos 2 mobile phone (Android version 4.2.2, Wi-Fi 802.11 b/g/n, hotspot). The external nodes are able to connect to the network setup in the mobile phone which acts as an access point. The mobile application to monitor the pH values runs in the background and receives the values in real time.

TABLE I
MEASUREMENT OF TRANSMISSION DELAYS

Reading No.	Distance between Wi-Fi module and mobile device (m)	Delay (s)
1	0.1	-
2	0.1	0
3	0.1	0
4	0.1	0
5	0.1	0
6	0.1	0
7	3.0	-
8	3.0	0
9	3.0	0
10	3.0	0
11	3.0	0
12	3.0	0

4. CONCLUSION

The proposed system facilitates monitoring of pH value of water in real time. It provides a user friendly graphical interface to visualize relevant information on the screen of a mobile phone. Moreover, the system contains a storage mechanism to archive previous records and analyze them through an auto-generated graph. This allows users to track sudden changes in pH value (eg. when a factory dumps waste into a water resource, the pH value in a nearby well may change rapidly) and identify its patterns over time. As the proposed system has many advantages over standard pH meters, it is a versatile and practical solution to the issue of real time water quality monitoring in both urban and rural areas.

The proposed mobile framework is only a prototype designed to implement interaction between a sensor node and a mobile device over a wireless network. The accuracy of the pH sensor can be tested further by varying the acidity level of water samples. Multiple sensors can also be added to the node to measure more water quality parameters. In a rural setup, solar energy can be utilized to power up the sensor node attached to a water resource for prolonged and continuous monitoring of water quality.

5. REFERENCES

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