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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. 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. 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.

***Key words*: pH in water, wireless sensor network, water quality measurements**

I. 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.

A. Recent work

A prototype of a wireless sensor network for water quality monitoring consisting of three layers; sensor board layer, wireless sensor board layer and a gateway layer is presented in [10]. The sensor board consists of 90-FLT series E sensor having the ability to measure pH, conductivity, TDS (total dissolved solids), dissolved oxygen, turbidity and the temperature. The board layer has two components; a wireless sensor node and a base station. The wireless sensor node fetches the most recent data from the 90-FLT sensor and passes them to a base station via Zigbee technology. The base station is connected to the gateway via a USB interface. The gateway collects all the information received from the base station and stores them in a database to be accessed via the Internet.

A Zigbee based wireless sensor network [11] is developed to monitor the quality of water polluted by industries. The system consists of a sensor unit, a wireless sensor node (WSN), a base monitoring station and a graphical user interface (GUI). Sensors to measure pH, temperature and the turbidity are placed inside the node. The Zigbee module acts as a router between the sensor node and the gateway. The base station, which coordinates operations of the network, is responsible for setting up the channel, assigning network addresses to routers and end-devices and maintaining the routing tables to route data from one end to another in the same Zigbee network. Finally, measured data is transmitted to a computer to be displayed using the GUI platform.

A wireless sensor network is developed for agriculture purposes [12] that comprises of a self-organizing WSN endowed with sensing capabilities, a GPRS gateway which gathers data and provides a TCP/IP based connection towards a remote server and a web application. The GPRS embedded gateway provides a transparent bi-directional wireless TCP/IP connectivity. The gateway subsystem, having a 12 V rechargeable battery and a 20 W solar panel, can be operated unattended in outdoor environments.

II. 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. Figure 1 shows how these components are connected together while Figure 2 depicts the actual device setup.

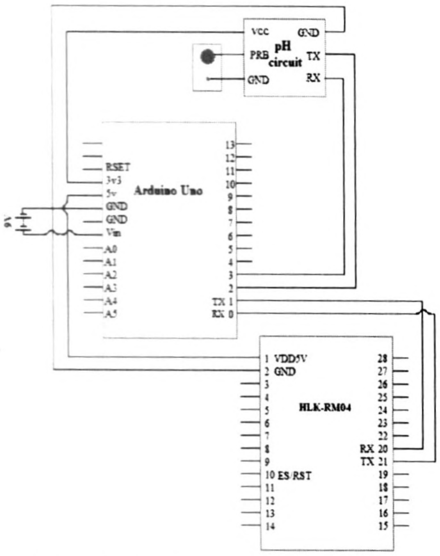


Fig. 1: Circuit diagram for the sensor node

The communication between the two nodes is handled by an ad-hoc network created by accessing WiFi functionality of the mobile device. An interface is provided to the user to change the network name (SSID) and network settings in the mobile application. The network can be adjusted using two settings; one to hide the SSID by disabling the broadcast and the other to use an encryption method for security. The sensor node is connected to this ad-hoc network with necessary authentication.

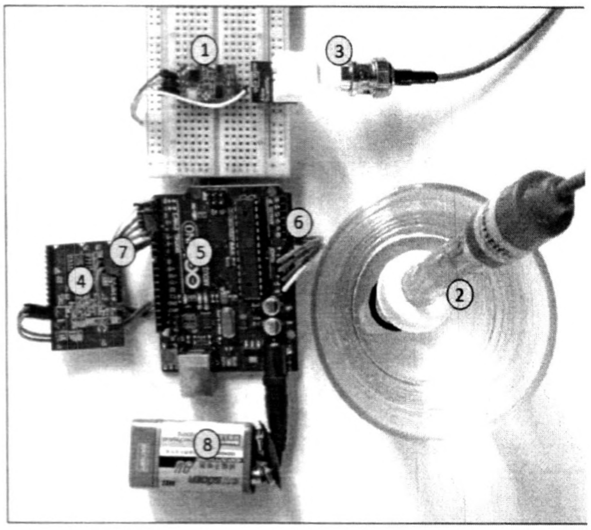


Fig. 2: Device setup of the sensor node. 1-Atlas Scientific pH circuit, 2-Atlas Scientific pH probe, 3-BNC connector, 4-HLK-RM04 Wi-Fi module, 5-Arduino Uno board with 32-bit Atmel ARM Microprocessor, 6-Analog pins, 7-Digital TX and RX pins, 8-9.0v battery

The 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.

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.

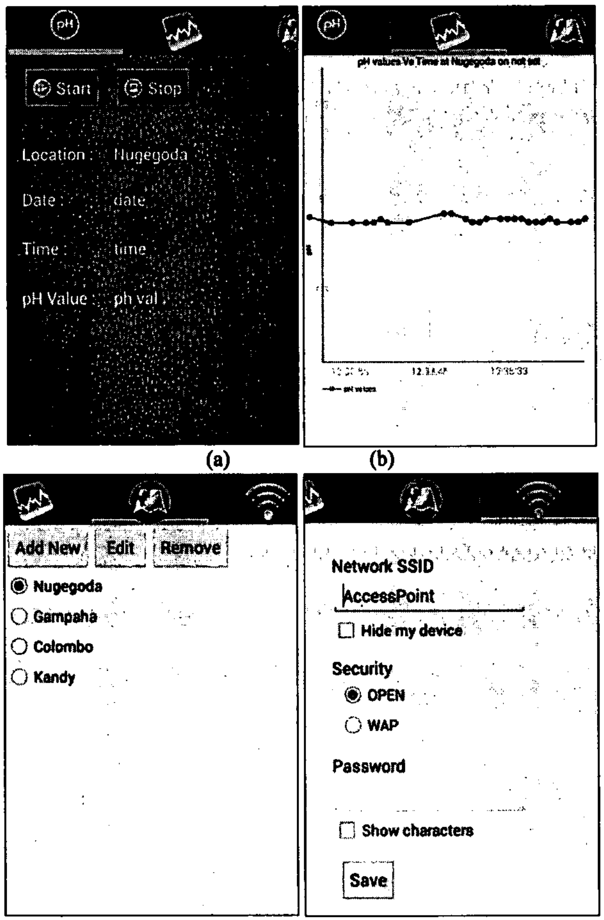
A web server is used to handle incoming requests, i.e. the requests sent by the sensor node. Let the sensor device to be the client for this server. The port 8080 is used to receive requests from the sensor. The server is setup using Jetty, an open-source project providing an HTTP server, HTTP client and javax.servlet container. It supports instantiating a server and running it in the application alternately deploying the application in a server. A request handler is added to the server to examine HTTP requests and to generate a relevant HTTP response.

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.

The settings of the network are depended on the features and the hardware capabilities of the mobile device. If the network settings are changed, the WiFi module should be configured according to the new settings.

An SQLite is used as the database having two tables; one table to store sensor records (phdata) and the other to store the previous status of the application (appstatus – to store previous network and location settings).



Location : Nugegoda

Date : date

Time : time

pH Value : ph val

● Nugegoda
○ Gampaha
○ Colombo
○ Kandy

Network SSID
AccessPoint
☐ Hide my device

Security
● OPEN
○ WAP

Password

☐ Show characters

(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.

III. 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. 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.

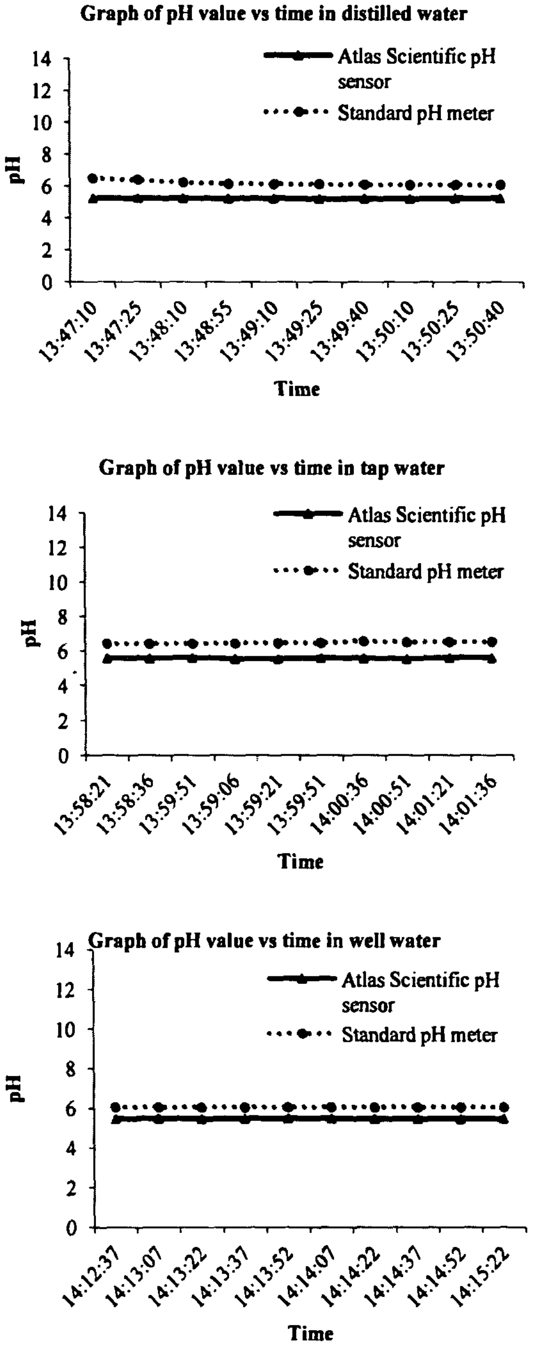


Fig. 4: Readings from standard pH meter and Atlas Scientific pH sensor for (top) distilled water, (center) tap water and (bottom) well water.

B. Response time of the pH circuit

The response time of the pH circuit is tested using the time gap between two consecutive readings. A command to take a measurement is sent in every 15 seconds by expecting a 15-second gap between two consecutive readings in the mobile application. Accordingly, 66.67% of the readings did not report a delay. However, 33% of the readings exhibit a delay when the time gap is between 30 and 45 seconds. This delay is due to the absence of a measurement when data is requested. As such, due to non-availability of data, the microcontroller waits for another 15 seconds to obtain the next reading.

C. Transmission Delay over the network

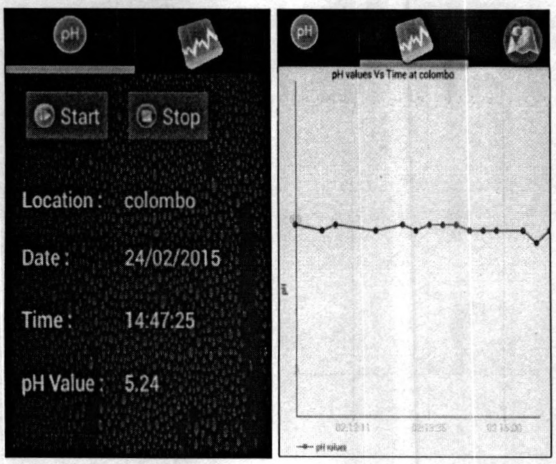
Initially, the transmission delay is measured by varying the distance between the WiFi module and the mobile device without the pH sensor to ensure that external factors do not interfere with the measurements. As seen in Table I, the distance between the WiFi module and the mobile device did not have 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.

D. 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. Whenever the server receives a request, the UI designed for the pH monitor updates dynamically showing the history of pH reading in a chart as shown in Figure 5.

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



Location : colombo
Date : 24/02/2015
Time : 14:47:25
pH Value : 5.24

Fig. 5: pH monitor (left) and pH history (right) for a sample of water taken from a well.

IV. 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.

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