WSN-BASED INTELLIGENT WATER QUALITY MONITORING SYSTEM FOR AQUATIC LIFE PRESERVATION IN VOLCANIC TAAL LAKE

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ABSTRACT

The existing need for effective water quality monitoring system of BFAR Region IV-A in 16 sampling stations of Taal Lake enlivens the proponent. The proponent introduces the use of wireless sensor network based on Zigbee in resolving the manual method of water quality monitoring system. The local Zigbee network is capable of acquiring various water quality parameters as identified by BFAR quality experts. Through this WSN-based system, the users can easily observe the current or historical water quality status. It introduces intelligent alarm generation system and decision support system for continuous monitoring of logged data for quality assurance, raise alerts using automated notification to predefined and authenticated staffs via SMS, pop-up and e-mail. Detection of alarm and notification is in terms of OOC/OOS occurrences for Physical (Temperature and Turbidity), Chemical (Dissolved Oxygen, Ammonia, Nitrite and Hydrogen Sulfide) and Micro-Bacteriological (Fecal Coliform) characteristics of water. The over-all water status will be assed as well using Fuzzy Logic. The proponent will implement the system, by creating a Wireless Sensor Network Zone using Crossbow Imote2 sensor nodes. The standard Zigbee 802.15.4 protocol is used for communication. Excel VB macro program and Matlab will be used for simulation purposes.

Keywords — Wireless Sensor Network, Zigbee, OOC/OOS, Cross Imote2, Excel VB, Matlab

INTRODUCTION

Basically, there are three methods in the assessment of water quality. This includes discrete, mechanical, and automated. Of the three methods, the most commonly used is discrete. This method is also known as the traditional manual method. In this manual method, the operator takes samples of water for laboratory analysis. Mechanical method, on the other hand, makes use of container, which contains sample bottles. This container is left at the water body and it mechanically obtains water samples. The water samples will then be sent for laboratory analysis. Today, automated water quality monitoring is used. Automated monitoring places water quality sensors into the water body. It reads and measures the values and store the information in the memory as well (Chaamwe, 2010).

The entire monitoring process is complex, which includes water quality sampling, sample transportation and preservation. In spite of its complexity, still majority of domestic water quality monitoring systems make use of the manual method. Also, the traditional method of artificial regular or irregular sampling is time-consuming, tedious, and difficult for a comprehensive and an objective response to abrupt water quality changes (Wang, Wang & Hao, 2009).

Recently, technology advances in the fields of networking, information and communication. Moreover, research endeavors on water quality monitoring system at home and abroad evolved from the manual monitoring to on-line monitoring system. The latter system offers real-time data transmission. It runs stably and reliably. However, metrologies under this method require complicated wiring connections, difficult network maintenance, and utilization of lot of resources (Wang, Ran & Wu, 2011).

Wireless Sensor Network (WSN) offers solution in these drawbacks. Considering that this technology becoming an ideal platform for environmental remote monitoring system as it offers low power consumption and cost, smaller scale of size, networking, sensing flexibility, and mobility of nodes (Nasirudin, Za'bah & Sidek, 2011).

Background of the Study

Ensuring safe and clean water delivery to end users is an important undertaking to consider. In same importance is monitoring and controlling physical, chemical and biological characteristics of water to protect aquatic life resources. However, it is vital to represent the entire population of the bodies of water thru data sampling for underground and surface water at many data points and different locations (Chaamwe, 2010).

The water quality monitoring methods in Zambia are mostly sparse and manual (Chaamwe, 2010). At North Carolina A&T University's farm, data loggers and sensors are used to monitor pH levels, dissolved oxygen and water temperature. In this system, the sensors at the ponds are connected by cables to a data logger, which is located in nearby laboratory (Mustafa, Kim, Kelly, et al., 2009).

In the Philippines, it is alarming that most Filipinos suffer from tragic loss of livelihood due to ineffective water quality monitoring system (Caldo & Dadios, n.d.). In Taal Lake, the metrologies used by the analysts are the following: meter/probe for Temperature, Sechi-disk for Turbidity, DO meter for Dissolved Oxygen and Laboratory Test for Chemical and Bacteriological parameters. There are sixteen sampling stations (Palsara Mounth, Palsara River, Lumang

Lipa Cage Area, Lumang Lipa Open Water, Aya, Quiling, Tumaway, Sampaloc, Berinaya, Leviste, Buso-buso, Bañaga, Bilibinwang, Manalaw, Poblacion and Ambulong). These stations are covered by Balete, Lipa City, Talisay, Laurel, Agoncillo and San Nicolas respectively. Water quality experts have identified seven critical parameters for defining lake water quality for monitoring and surveillance — Temperature, Turbidity, Dissolved Oxygen (DO), Ammonia (NH3), Nitrite (NH2), Hydrogen Sulfide (H2S) and Fecal Coliform (FC) (Caldo & Dadios, 2012).

The Bureau of Fisheries and Aquatic Resources (BFAR) Region IV-A makes use of the conventional water quality monitoring method in 16 sampling stations of Taal Lake for data collection and analysis. Considering that Taal Lake is the third largest lake in the Philippines, manual process is becoming a waste of manpower, material resources and time. In addition, achieving overall monitoring for different sampling stations for large likes like Taal is indeed difficult. Also, in this setting, analysts would need to travel in many distant sites to collect and to analyze water samples. It is inconvenient for them due to its impracticality and laborious tasks, especially if the data will have be collected at regular time intervals in uncontrolled volcanic environment (Silva, Nguyen, Tiporlini & Alameh, 2011).

Statement of the Problem

Considering that BFAR Region IV-A makes use of manual system in water quality monitoring using log sheets. The proponent intends to study the entire process of monitoring, surveillance, control and management of Taal Lake. Computing tools will be used to develop an early warning system in predicting fish kill event. In addition, the proponent will develop software, which incorporates the use of statistical process control and statistical tools and analysis, so as to provide effective monitoring and control system of volcanic Taal Lake. The critical parameters shall be identified and it will be monitored using control charts in a real-time basis. The specification limits shall be established; and the control limits review, computation and disposition shall be done automatically. The proponent will then design, develop, simulate and implement a model of Taal Lake in a controlled environment.

Major consideration of this study is how wireless sensor network would apply to effective risk assessment and mitigation of environmental policies. It makes use of a case study assessment of water quality in Lake Taal of Batangas to illustrate this evaluation. The ultimate goal of the study is to use wireless sensor network and consider how much this approach can be applied more broadly for environmental assessments.

WSN-Based Intelligent Water Quality Monitoring System for Aquatic Life Preservation in Volcanic Taal Lake is an attempt to develop a WSN-based monitoring system, which can collect, monitor, analyze and assess critical water quality parameters automatically. This paper proposes monitoring water quality using cheap, effective and efficient sensors that have the ability to sense, process and transmit the sensed data.

Objectives of the Study

The prime objective of this study is to design a WSN-based intelligent water quality monitoring system for aquatic life preservation in volcanic Taal Lake.

Specifically, this study aims to:

a) measure physical, chemical and micro-biological status of water using available sensors at remote place,
b) create a system, which is capable of retrieving the data for water quality analysis,
c) collect data from various sensor nodes and send it to base station by wireless channel,
d) analyze identified critical water parameters for quality control (graphical and numerical records using Visual Basic and Matlab),
e) assess the physical, chemical, bacteriological and over-all status of water using fuzzy logic,
f) notify parties affected through pop-up, SMS, e-mail and alarm system,
g) simulate and verify the performance of WSN-based intelligent system

METHODOLOGY

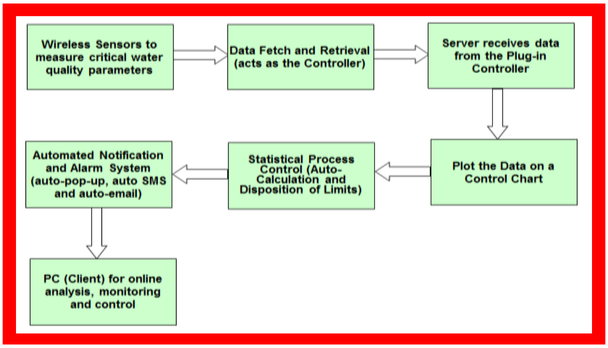

Figure 1. Block diagram

Figure 1 shows the block diagram of the WSN-based water quality monitoring system which consists of seven (7) blocks that shows the steps on which the system will go.

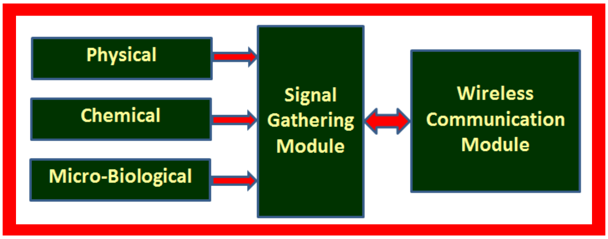

Figure 2. Schematic diagram of sensor node (Wang, Wang & Hao, 2009)

As shown in Figure 2, the sensor node is composed of the water quality sensor, signal gathering module and wireless communication module. The water quality sensors may convert water quality parameters of physical and chemical volume to electrical signals, the signal may be voltage signal or current signal; but in general it is a very small signal.

Signal conditioning module takes collected voltage signal or current signal with amplification treatment to make it more suitable for A/D conversion and ease of MCU processing. Wireless communication module is responsible for wireless communications between sensor nodes and other nodes. Because of battery-powered sensor nodes, the low-power design becomes a major consideration. Sensor node in the system enters the sleep mode when it does not collect the data, at the time the microprocessor work under the 32.168 kHz.

A prototype system using Crossbow iMote2 sensor nodes that uses Zigbee protocol standard for communication will be implemented. ZigBee offers a standard for wireless sensing and control that is based on a well-known 802.15.4 specification. While the 802.15.4 document describes PHY and MAC layers of the protocol stack only, ZigBee builds on top of 802.15.4 to offer a network and application layer specifications also.

The wireless sensor network zone is established by using Crossbow Imote2 sensor nodes. It is built around the lowpower PXA271 XScale processor and integrates an 802.15.4 radio (CC2420) with a built-in 2.4GHz antenna.

The Imote2 is a modular stackable platform and can be expanded with extension boards to customize the system to a specific application. Through the extension board connectors sensor boards can provide specific analog or digital interfaces.

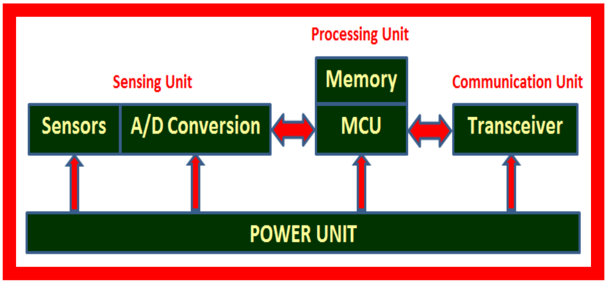

Figure 3. Hardware elements of sensor node (Hua, Zhao, Xia, et al., 2010)

Composition of sensor node's hardware elements is shown in Figure 3. It includes five units namely: sensing unit, processing unit, communication unit, time synchronization unit and power unit. A sensing node includes several functions such as water quality parameters sensing, signal amplifying and reshaping, data processing and storing, wireless transmission and power supply.

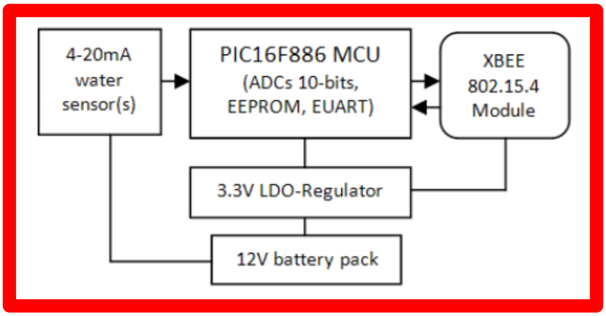

Figure 4. Circuit block diagram for sensor node platform (Nasirudin, Za'bah & Sidek, 2011)

The proposed system is the first model platform built for this project that can perform a multi-sensor interface with 8 or 10 Bits ADC resolution. The PIC16F886 is the main MCU for this board version that drives the logical task such as the EUSART serial data, Analog-to-Digital (ADC) conversion and logical processing. The Microchip PIC16F866 offers best in class with its nanoWatt™ technology, wide range of input voltage 2V-5.5V, 20nA standby current packaged with 28-pin CMOS 8-bits which can reduce the power consumption significantly compared to previous PIC16F87XA series (Mustafa, Kim, Kelly, et al., 2009).

The platform in Figure 4 initially used XBEE 802.15.4 RF module for data transportation and it is interchangeable with XBEE Pro or XBEE PRO Series 2 ZNet 2.5(mesh network). It operates by 2.8-3.4V voltage supply and gives 3.3v TTL serial output (DIN, DOUT pins) for data and programming terminals. The current XBEE module used for this platform has a maximum range up to 30 meter distance line of sight (1mWatt, 0dBm) and only support point-to-point and point-to-multi-point networks topology.

At a Coordinator device board, it also can be connected by an optional 4x20 Alpha Numeric LCD for direct real-time data readings or directly connected to PC via RS232 COM Port for saving data in system database. That setup is applicable if the database server PC locally networked within the XBEE RF coverage. Otherwise, an alternative way to extend the network is via Global System for Mobile (GSM), a payable mobile phone networks using GSM 900Mhz modem. The communication between MCU and GSM 900/1800Mhz (Wavecom Fastrack M2406B) device is done through Serial RS232 level by AT commands at 9600 baud, 8 bits data and no parity.

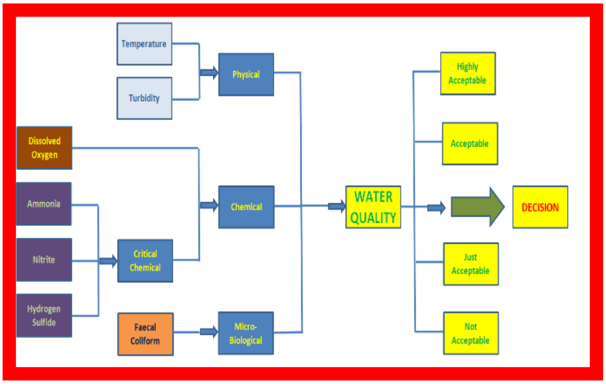

Figure 5. Hierarchical structure for water quality classification
(Nasirudin, Za'bah & Sidek, 2011)

A hierarchical structure was constructed for the simulation of the water quality system, Refer to Figure 5. The third level characterizes the characteristics of water as physical, chemical and biological to obtain an acceptable water quality assessment for monitoring and surveillance purposes (Dimayuga, Jaron, Montero, et al., 2015; Diocales, Gulle, Nuñez, et al., 2015)

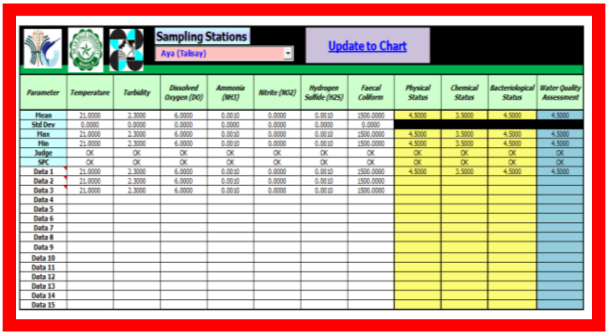

Figure 6. System Page (Caldo & Dadios, 2012)

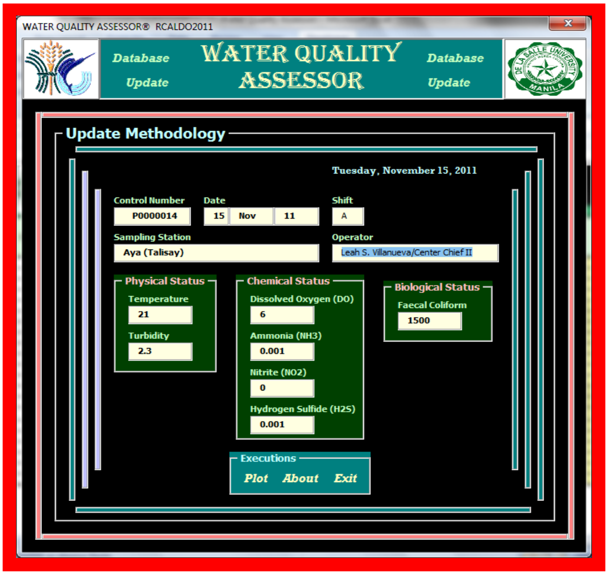

Figure 7. System homepage (Caldo & Dadios, 2012)

Figures 6 and 7 show the main screen of the system, the system page and system homepage respectively. These figures show the manual updates of the status of the lake from different sampling made by certain operator.

CONCLUSION

The use of WSN based on Zigbee in the resolution of the manual method of water quality monitoring in Taal Lake shows promising results if ever the said system will be implemented. The system was able to acquire various water quality parameters by means of Zigbee and shows that the network was efficient. The system is still under development but once finished, it will be a great data logging and monitoring in the Taal Lake.

RECOMMENDATION

Considering that the proponent only introduces a model using wireless sensor network for water quality assessment in Taal Lake, it is strongly recommended to briefly mention and discuss the different sensors to be used for the monitoring of the water quality. Moreover, the method of validation from the data acquired from the wireless transmission will be done. The proponent will include manual retrieval operation set of data and compare it against the wirelessly transmitted data to see if they both agree. In addition, considering that Wireless Sensor Network is not really a new concept, but it will be applied to Taal Lake; the novelty of this work would fall on the validity of data obtained from the system. Lastly, aside from emphasizing too much on the use of PIC microcontroller and Zigbee features, a block diagram containing the different sensors and their interface to the server with corresponding discussion on the method of communication or protocol used will be provided, as it helps the reader in understanding the design part of the paper.

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