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Water Quality Monitoring by Implementing ZigBee Network Wireless Sensors

Munara Moldobaeva and Naresh Kumar Appadurai

Abstract--- *Water quality is an extremely valuable condition to all forms of life. Due to the technological development and industrialization during last decades the water quality is drastically dropped down and additional issue as water pollution was raised up. However, the same technology has high capability to resolve the problem with water pollution, manual monitoring and make water quality research efficient by providing more accurate results. Hence, the technology I want to propose in this research paper is the ZigBee based wireless sensor network. ZigBee technology has capacity to measure temperature and water turbidity in real time by sending data to a laboratory station. By implementing Zigbee, it enables to collect water quality monitoring results in remote areas and pass that data wirelessly to laboratory or research centre. The application of wireless system will widely help to reduce the monitoring system expenses and give adjustability in terms of location and distance. And one of the main strength features of ZigBee wireless system is in low cost, reliable data transmission, efficient data collection and ease of use. Water quality monitoring includes analyzing river and marine water resources.*

Keywords--- *ZigBee, Water Quality Monitoring, Wireless Sensor Network.*

I. INTRODUCTION

Water is limited resource which has essential role for life existence on Earth. The whole flora and fauna depend on water, especially, on water quality and its' characteristics. Deterioration of water quality may carry negative affect on environment including people and damage the entire ecosystem. Therefore, water quality monitoring carries crucial value by providing information about water condition and its designed use.

Collected data about water quality can be used to determine whether water meets the designed use or not and forwards to further actions. For instance, there are specific states to characterize the drinking water which should not contain any toxins or harmful chemical elements; marine or river water should not involve any inorganic chemicals which may cause negative effect to a biodiversity of marine life. In this case, water monitoring helps to prevent water pollution or detect it on early stages without letting it reach big scales.

The main parameters for water quality monitoring gathered from lake, river and marine are temperature of water, its' turbidity and pH.

And proposed solution for current issue is in networking technology called Zigbee - IEEE 802.15.4 supported technology for a suite of high level transmission protocols which used to provide personal area networks with small area, in a use of home automation, medical equipment data gathering, and other low bandwidth usages, designed for projects which need wireless connection (Alliance, Z. (2019)).

Munara Moldobaeva, Asia Pacific University of Technology and Innovation, Technology Park Malaysia, Bukit Jalil, Kuala Lumpur, Malaysia. E-mail: munara.moldo@gmail.com
Naresh Kumar Appadurai, Asia Pacific University of Technology and Innovation, Technology Park Malaysia, Bukit Jalil, Kuala Lumpur, Malaysia. E-mail: naresh@apu.edu.my

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The purpose of this research is to design and implement ZigBee technology based on Wireless Sensor Network (WSN) to make water quality monitoring highly efficient and enable to gather more accurate results from monitoring. The data gathered from wireless sensors submerged in water are helps to keep quality standards of water and register pollution without letting it damage the environment (Luo, 2015).

In addition, current project enables to forward manual water monitoring method to automated monitoring by applying Wireless Sensor Network. The application of many wireless distributed sensors allows the making of a clearer map of the water condition and permits the permanent process of monitoring station in locations of far access, without usage of manual data gathering.

Detecting water quality is time-consuming and complicated process which mostly will be done manually by researchers. It takes long period of time to retrieve the results from manually taken water samples and the results are not always accurate. Consequently, shifting to the automated monitoring by using ZigBee technology would truly improve whole procedure. For instance, in cases when marine oil spills occur immediate actions should be taken. But manual water monitoring method cannot immediately notify about these emergencies. Therefore, proposed machine application allows to detect any changes and inform in time to base station, what will be highly useful in water quality protection.

II. RESEARCH BACKGROUND

Water quality monitoring mainly relied on manual data gathering and water analysis from 1960 to 2000s. In manual approach researchers are required to travel long distances for conducting the measurement of water condition. Thus, this process is very time consuming, expensive and not flexible. Moreover, manual method does not allow to get information of water in short period of time and cannot be conducted locations with a real-time connection (Allegretti, 2014).

To solve current obstacles, starting from 2000s new technologies been introduced to address monitoring limitations. One of the core developments in this area was coming of new sensors that covered fiber optics, laser technology, biosensors, optical sensors, and microelectronic mechanical systems (MEMS) to find different water quality parameters (K.S. Adu-Manal et. al., 2017). New monitoring technology was used not only in water monitoring industry but also in air quality, climatology and energy source monitoring. (Journal of Applied Research and Technology, 2017). In early 2000s by new advent of ZigBee wireless sensor network (WSN) monitoring system been improved and got wide attention by supporting very effective analysis and environmental data transmission.

Zigbee is a networking device with low-cost, energy-sufficient used in wireless control and monitoring applications. Zigbee works in the industrial, scientific and medical radio waves:

2.4 GHz. Zigbee-style digital network self-organized ad-hoc radio were represented in the 1990s. The IEEE 802.15.4-2003 Zigbee specification was ratified on December 14, 2004. The Zigbee Alliance announced availability of Specification 1.0 on June 13, 2005, known as the Zigbee 2004 Specification (Adu-Manu et al., 2017).

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Fig. 1: Zigbee Sensor Node

Table 1: Parameters of Zigbee

International Standard	*IEEE 802.15.4*
Industry	*Scientific, Industrial and Medical*
Developed by	*Zigbee Alliance*
Physical range	*10-20 meters*

2.1) Zigbee Sensors

A sensor unit includes several sensors which can to detect the predesigned parameters that indicate the quality of water (Alliance, Z. (2019)). In this work, three types of water sensors been represented; pH sensor that senses the pollution of the water, temperature sensor and turbidity sensor (Tuna et al., 2014). Sensors for operation work by using battery. The information being detected by the sensors are later translated into electrical signal (digital signal) and pass through the signal circuit that works to ensure the voltage or current produced by the sensors is equivalent to the actual values of parameters being sensed. Then it is passed to a microcontroller or microprocessor that processes it to the value understandable by human Luo, R. (2015).

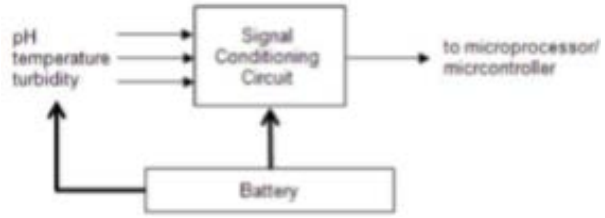

Figure 2.0: Diagram of Sensor Unit

2.2) (WSN) Wireless Sensor Node

Wireless sensor node is device which is capable for performing some processing, gathering sensory information and data transmission processes with other connected nodes inside of the network.

In order to monitor quality of water in various sites, future works can be focused on establishing a system with more sensor nodes and more base stations. Nodes and base stations are connected as wireless sensor network (WSN), the different base stations system and get a real time water quality data faraway (Shu et al., 2012).

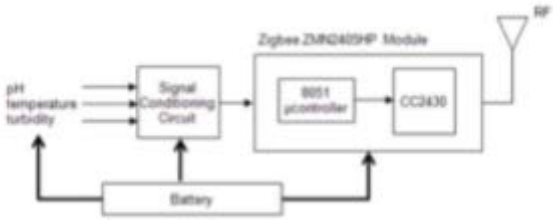

Figure 2.1: Sensor Unit Block Diagram

2.3) Base Station and Monitoring

The base station including same Zigbee module which programmed as a transmitter that receives the data which sent from the sensor nodes (end devices and routers) wirelessly. Data gathered from the end device nodes is transmitted to the base station computers then data taken is represented by using graphical user interface (GUI) on the laboratory station. (Zulhani, 2019). This interface contains real time water monitoring results for each specific water quality parameter as turbidity, chemical solution etc. In addition, the system architecture of water monitoring infrastructure requires full time access to internet and strong database system.

Hence, strong security and firewall applications need to be applied. And overall, the whole design of the system should be well designed and secured from any possible failures, security attacks and damages.

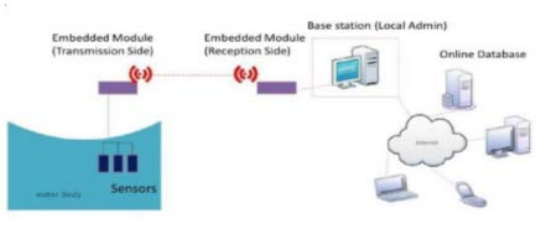

Figure: 2.1 System Architecture

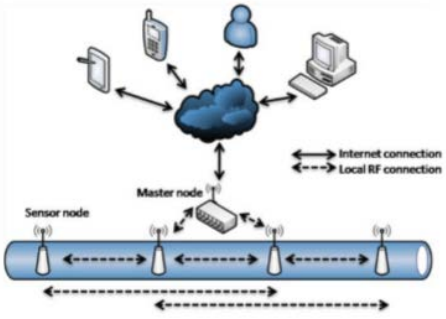

Figure 2.2: Base Station Data Transmission Design

To solve the issue of the manual monitoring method used in water quality detection, this review introduces a remote water quality measuring and monitoring system. It has implemented wireless sensor network based on the ZigBee to demonstrate the water quality and enable real-time monitoring function. This paper proposes the network method which works through sensor levels and data transmission to the central station through a wireless network. (Luo, 2015).

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Over the past decade, online water quality monitoring has been widely used in many countries known to have serious issues related to environmental pollution. In my proposed system water quality parameters are measured by the different water quality monitoring sensors such as turbidity, conductivity and dissolved oxygen (Adake, 2019). After doing my review from various resources, I found lots of authors who conducted research works on the same topic about water quality monitoring and implementation of ZigBee technology. One of the main core topics that authors have been debating about is as below:

2.4) Advantages & Disadvantages of Integrating Zigbee Technology with Water Quality Monitoring Process

According to (Shruti Sridharan, 2014) who claimed about importance of this monitoring system where monitoring task can be easily conducted by any staff in research centre with little training at the starting of the system installation stage. In addition to this idea (Dr.K.Karuppasamy et. al., 2016) he agrees with first author and also mentions about low-cost implementation of current system and its' capability to continuously measure water quality with real-time data transmission.

Alternatively, (K.S. Adu-Manu et al., 2017) proposes that underwater communication in marine water sources is challenging because GPS signals and other communication technologies, such as Zigbee, do not propagate well through water. In addition, same author considering the node and data security concerns as vulnerability of system. He also talks about nodes that can be tampered with or destroyed by intruders at the water site. Once compromised, these nodes able to lure other nodes to pass data to them (e.g., wormhole type attack).

As per (Pule, Yahya and Chuma, 2017), they believe that implementing such a technology in locations with huge bandwidth would not be the right choice, due to the coverage difficulties of the sensors and Zigbee network within such a distance. They also stated that having this kind of technology might generate some issues from the sensor's sides, because more sensors are required to maintain high sensibility and accuracy. Nonetheless, this debate seems to be continued between authors and scientists, however, the system to be proposed have way more advantages than its disadvantages, which in future development can be solved with more advanced features.

III. PROBLEM STATEMENT

Lack of existing network technology systems designed for water monitoring causing various difficulties to conduct scientific researches, strength environment protection and healthcare methods. In order to stop water pollution and prevent poor water quality causing health related issues wide number of researches and solutions been conducted by many authors. Despite, strong background and existing knowledge on this topic, there are still gaps and unanswered questions which need more further investigation.

Challenges that arise are security, privacy and data confidentiality which still remain as a vulnerable part of the system. Moreover, arising issues to this current technology are in complex management process after data from wireless node sensors been taken. In other words, end user system design and graphical user interface should be implemented in a way that it will be easy manageable, interactive and simple. The resolution of current problems will lead current system to smooth and effective performance, strong security and good manageability.

The main aim of this research paper is to provide better quality of water and environment that would provide

better healthcare for humans through implementing Zigbee wireless network monitoring which works with sensor system and provide a real-time alert or early warning for whom concerned to take an action.

IV. OBJECTIVES OF RESEARCH

Proposed objectives, which are:

- To establish strong wireless network which will work efficiently and smoothly during water monitoring process.
- To implement powerful sensors and neat network architecture which enables to increase the monitoring range and overall performance.
- To simplify the monitoring process and facilitation of wireless network.
- To transit from manual to automated water quality monitoring.
- To add strong security design for data transmission and protect system from security attacks.

V. RESEARCH QUESTIONS

- What are the effects of water pollution and poor water quality?
- How does water quality is currently being measured and monitored?
- How wireless ZigBee technology can improve water quality monitoring industry?
- How to implement ZigBee wireless technology (for industry)?
- What are the data sensing techniques and algorithms that are suitable for collection of data and better monitoring performance?
- How to conduct efficient data collection and data analysis after monitoring process?

VI. RESEARCH SIGNIFICANCE

Water pollution and its' low quality is one of the main global issues which is rising by each decade. It is not a secret that water is fundamental source of life. Therefore, water quality is our absolute interest. The critical situation of the polluted natural water resources in developing countries like Malaysia, India and Indonesia was my major motivation for this research paper. Implementing this proposed system would help people to have healthy life by purifying water that we rely on for all our living activities. Moreover, it is fascinating how nowadays network technologies are been developed to solve existing global issues like environmental pollution and poor monitoring progress in medical, scientific and industrial fields. In order to, expand and contribute a positive impact for further development of networking technology (Zigbee WSN technology) and for sustainable environment, this work been proposed. The essential value and contribution to proposed topic of this research document is in improvement of end-user management interface, system design modifications and security enhancements. All those reasons and more are validly enough for current research paper to be carried out and worth its significance.

VII. RESEARCH METHODOLOGY

After discussing the monitoring problem and proposing system in literature review, it is time to identify which pattern and methodology is suitable to adopt and efficient for data gathering analysis. And the final part is to provide

overview of the system and discuss future enhancements. To decide which methodology framework to use, we need to know some important elements and attributes, such as the source of information (data), what type of data it is, and in which way it would be transformed and interpreted for future results. Literature review had made it clear that the main source of data in the proposed system will be the Zigbee sensors, which will transfer all retrieved data to the base station wirelessly. During research it was identified that the type of data transformed is digital. A methodology framework would be defined as a framework that provides a helping hand to manage, structure, and plan the process of developing an Information System. In order to apply that, it was identified that this research paper should be done in a quantitative manner rather than qualitative, where data collected from different resources would be used, and data transferred (from Zigbee sensors) to the monitoring station would be computed and analyzed based on level of quality for some elements in the water like pH, turbidity and chemical concentration. There are many different types of analysis that can be carried out for data analysis, but in current project the focus would be given to the procedure of descriptive analysis. We will try to understand the received data and hence understand what process is carried in certain locations and areas where monitoring process should be conducted. Diagnostic analysis could be carried out to find the cause of the problems (polluted water) while predictive analysis can be done for the estimation of the affected people in a certain area who have been used the polluted water resource. After being certain that one water source is polluted based on the water quality monitoring test been done, Prescriptive analysis can be carried out to illustrate the different actions that could be implemented to purify polluted water.

Research Methodology Study Design Research methodology study design flow of this research document is represented below. The initial stages of methodology study design include review of literature review and theoretical framework which been carried in initial stage of research. After having strong research and gathered theory relevant to chosen topic different methods and approaches need to be applied. The final stages are data analysis which divide into three categories: descriptive, inferential and content analysis Cyfar.org. (2019).

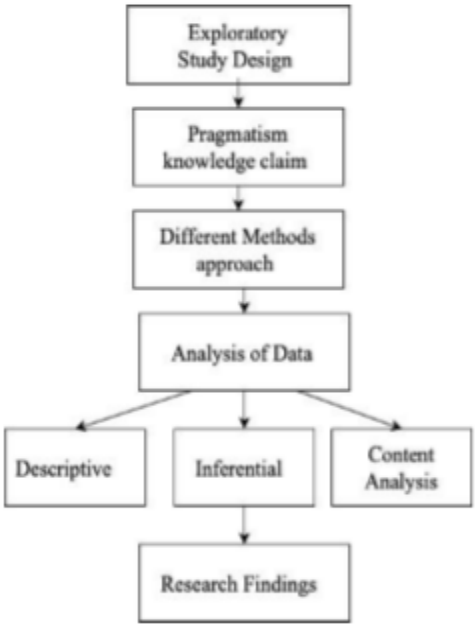

Figure 3: Research Methodology

For the methodology used in this research paper, it was proven that quantitative approach is the best suited, because of the type of data that needed to be collected which is digital data. As for data gathering technique to be used, the decision was made to make real experiments to get water sampling and increase the accuracy. Lastly but not least, the analysis approach that was chosen is descriptive analysis. Due to its' ability to allow understand the received data and hence understand what process should be carried in certain locations and areas. Although, the research paper had some limitation such as challenges of strengthening GPS signals and other communication technologies, like ZigBee sensors, under the water, due to their low-to medium propagation level and so on, but it also suggested some future enhancements that can overcome the limitation and bring the system to next level, one of future enhancements stated was to replace power supply with solar panels. After summarizing this research paper and its' main parts, it is now clear that the system is worth to be carried out to help solving current problems and make a positive impact on our lives.

Then after research methodology strategies of inquiry will follow. In our case quantitative approach been selected through real life laboratory experiment results.

7.1) Data Gathering Techniques

Choosing the right data gathering technique highly depends on what kind of system the data is gathered for. Traditional data gathering techniques such as Interviews, and Surveys are widely popular. However, in this case, to our proposed system is more particular and requires concrete analysis and measurement. And gathered data needs to be very specific and highly accurate.

That is the reason to strongly recommend data collection by organizing real life experiments with water quality of marine areas instead of interviewing. This represents that specific laboratory experiments should be conducted to find out an accurate data sample (water) that can be tested and measured.

VIII. SYSTEM LIMITATIONS

Despite wide number of researches and studies been made previously by many authors on water quality monitoring system by using Zigbee technology, there are still limitations and obstacles remain. Two main limitations been carried out in this research paper are:

1. Challenges in power strengthening of GPS signals and other communication technologies, such as ZigBee, under the water, due to their low-to medium propagation level.
2. High demand of networking infrastructure which requires using lots of sensors underwater to ensure high sensibility and smooth performance. While, it should be possible to decrease number of external sensors while having same level of sensibility.

Future Enhancements and Suggestions:

After implementing system design and getting general view water monitoring using Zigbee technology, following enhancements been proposed:

1. The power supply for Wireless sensors can be replaced by solar panels.

2. The Zigbee has short distance data transmission while CDMA (Code Division Multiple Access) system could be applied for long distance transmission between sensors and the database system.
3. Installing minimal number of sensors with provide highest level of sensibility.
4. Inside of the database and end user monitoring interface data science and AI data analytical system can be used. What would ensure accuracy of data gathered result and provide more statistical and visual output.

IX. OVERVIEW OF THE SYSTEM

Presented Zigbee wireless system which works in combination with WSN technology sensors that put underwater. Hence, these sensors indicate about overall water condition and collect data which is sent in real-time to the base monitoring station, which plays a role of coordination between the nodes. Furthermore, by implementing such a solution, new enhancements can be generated to use the technology to purify river and marine water, instead of difficult and complicated manual monitoring procedure. By application of sensors we can indicate the water quality by use of wireless module. After the system is automatic it means that it is low in cost and does not require manpower. Also, time and operational cost is reduced and been saved. Thus, proposed network technology has widespread usage and significant value to the healthcare and environmental sustainability.

Works of different authors been listed and cited in literature review who addressed to the same topic. Authors had different thoughts and theories about the topic and its' advantages and disadvantages, for example, (Shruti Sridharan, 2014) who has mentioned about importance of this monitoring system is in its' easy installation of the system where the base station can be placed at the local residence close to the target area, whereas, (K.S. Adu-Manu et al., 2017) did not agree with (Shruti Sridharan, 2014) and proposed that underwater communication in marine water sources is challenging because GPS signals and other communication technologies, such as ZigBee, do not propagate well through water. This research paper has as well answered so many frequent questions and clarified some doubts about system implementation.

X. CONCLUSION

I cannot miss fact that chosen topic is big interest of mine, I could expand my view about Zigbee technology and networking field overall. I hope my research in future will grow into bigger scale and will be strong foundation in future academical and career path.

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