

Gateway User Interface Design for Distributed Wireless Monitoring Platform using Raspberry Pi (DWMP)

Muhammad Mirza Amsyar Noor Azeb¹, Faiz Asraf Saparudin^{1*}, Ahmad Afif Aiman Mohd Redzuan¹, Nor Shahida Mohd Shah¹, Muhamad Khairi Azizi Shamsuddin¹

¹Department of Electrical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

DOI: <https://doi.org/10.30880/peat.2021.02.01.049>

Received 12 January 2021; Accepted 01 March 2021; Available online 25 June 2021

Abstract: Distributed Wireless Monitoring Platform (DWMP) is the system that available to collect data of water quality in several of places within range of large distance for research purposes with the aim of improving collect and monitor operations. There are two important aspects for the operations which is data collection and management. Without data management system, it is hard for user to interpret their data efficiently and presenting the data clearly. One of the main components of the system is to design a fully functional web-based server using Linux, Apache, MySQL, PHP (LAMP) architecture in Raspberry Pi platform that can display accurate data obtained from sensor in real time. This project focuses on providing attractive and responsive user interface to the end user to help in collect and monitor process which can be accessed through smartphone, tablets, or personal computer. The data are stores in concept of centralized storage that one of the simplest data storage strategies. There are three crucial data collected and displayed in this web server. Timestamp, water quality index, are obtained from sensor nodes while the signal strength is obtained from the LoRa. Besides that, the user interface also being evaluate using system usability scale (SUS) which is to improve the design and functionality. The user interface design is based on HTML which is lightweight while providing crucial information to the researchers or authorities such as water quality index versus timestamp graph, signal strength indicator, and data table which consist of timestamp, water quality index and signal strength of the sensor nodes in real time. Based on system usability scale (SUS), the user interface of the system has been evaluated which improve the capability of the website and also user-friendly. The users are confidently to use and understand the functionality of the website without having a technical person. Overall, the design implementations able to generate a feasible system that can be used in collect and monitor operation in the future in order to save keep the health of river.

*Corresponding author: faizs@uthm.edu.my

2021 UTHM Publisher. All right reserved.

penerbit.uthm.edu.my/periodicals/index.php/peat

Keywords: DWMP, LAMP Server, User Interface

1. Introduction

Large amounts of human waste have been produced by rapid growth, including residential, agricultural, commercial and transportation waste, which eventually ends up in the water. For instance, in 2018, due to ammonia leakage in Sungai Langat, the state of Selangor suffered serious river pollution, which affected the operations of the sewage treatment plant and took almost two months to heal [1]. Data collection and management are very important aspects for the collect and monitor system for Distributed Wireless Monitoring Platform (DWMP). Therefore, to provide a good management of data and analyst should be have a good user interface. The design will be made according to the expectations of the user and thus will be utilized [2]. In order to represent the intended message of the website or app, it is essential that the design of the UI achieves the aims of the website or software under consideration [3].

The main focus of this paper is to design a user interface or user experience using LAMP server that can provide real time data that needed by Raspberry Pi. In collect and monitor operation, it is crucial to have access to all of the important data in real time since it involves humans live and natural environment. The latest sensor data from the database also can be downloaded from the website. The website can be accessed from personal computer, tablets and smartphones.

1.1 Problem Statement

In collect and monitor operation, there are several of aspects that must be consider such as the system must be easily to implement, low power consumption and also low maintenance. As data is very important aspect, a platform needs to be designed to ensure the all data that receives will be saved and organize effectively. The system that without a good user interface will give bad experience to the user and also the data cannot be presented in efficient way. In addition, these systems have been made affordable to people at nearly every level of society by lowering prices and improving the functionality of these digital devices. Thus, the number of users has grown considerably. With ever increasing number of diversified users, the challenges in designing user interfaces for these systems have become complex and important issues.

1.2 Project Objective

There are 3 main objectives which are firstly is to design distributed wireless monitoring platform website using LAMP that can display the accurate data obtained from sensor in real time. Second, to develop attractive and responsive user interface to the end user to help in water quality monitoring. Lastly, to evaluate user interface performance in terms of system usability scale (SUS).

1.3 Scope of the Study

This project will consist of establishing web server using LAMP connected through Raspberry Pi which is a part of Distributed Wireless Monitoring Platform (DWMP) project, which will contribute in water quality monitoring process. HTML code and CSS code will be as based for the layout of the website to make it responsive and attractive for the user. The website's content will be based on data from MySQL database which is connected to the sensor nodes in real time. Data from sensor nodes is saved into MySQL database and PHP communication engine is used to connect it to HTML file.

The CSS, PHP and Javascript will be used on the website to make it more attractive and friendly user. This project more focus on developing software. The user can monitor real-time data from the sensor nodes which also can be penetrated using personal computers or smartphones. This project will precisely collect and store the data obtained by the sensor nodes into MySQL database and perform it in interactive ways and friendly-user in the website.

2. Related Studies

V.S.Arumuga and K.Baskaran in Implementation of Effective and Low-Cost Building Monitoring (BMS) using Raspberry Pi [4], use LAMP architecture in the design. The system consists of sensors, controller and Raspberry Pi. Besides that, this article used 2.4Ghz Zigbee protocol in order to move the status of the sensor from the gateway. The sensor data can be downloaded from the web interface. This system is low-cost, compact, scalable, easy to customize, easy to deploy, and easy to maintain.

J.Fletcher and W.Malalasekera in their paper for Development of a User-Friendly, Low-Cost Home Energy Monitoring and Recording System [5], design the website based on HTML and CSS. The database engine that used is MySQL for store the data. While for live communication between the client and the server, AJAX is used. Furthermore, in order to provide graphing and display the data, Highcharts are their selection.

In the design of the Wireless Sensor Network System Design using Raspberry Pi and Arduino for Environmental Monitoring Applications [6], Sheikh Ferdoush and Xingrong Li use the LAMP architecture. With HTML, CSS, Javascript, Ajax, jQuery, and Flot, the User interface is introduced. There are three components to the system; the sensor nodes, the base station, and the web interface. Flot is used to include the opportunity to refresh the map with new data that is collected from the server regularly.

For the web-based Rapeseed-Mustard Germplasm Database [7] by Vinod Kumar, K. H. Singh, K. K. Chaturvedi and J. Nanjundan, they also use the LAMP server. Along with PHP for server-side scripting and Javascript for client-side scripting, the website was designed using HTML code. It comprises three layers: the database layer that holds the data, the logic layer of the framework that provides the user-database interface, and the layer of the user interface that contains the browser. This web server allows users without any training or knowledge of (SQL) to perform record searches, insertions, updates, and deletions.

Tan Chia Chee also use LAMP architecture in system for Water Quality Monitoring System for High Density Aquaculture [8]. The architecture of the website is based on Wordpress with PHP code to retrieve data from the database as a communication engine. As users can access it from laptops, tablets and personal computers, the web server is cross-platform. It is user-friendly and quick to incorporate as well.

The LAMP server is the most servers used by web designers to build a website because of open source and low-cost. For the website design, the design for paper [7] is only compatible for laptop or personal computer use. For [5] and [6], both of the systems use Ajax as their live communication between client and server, both of the system has less functionality in data visualization which limits the user experience in viewing the data. The interaction between websites to database, all the system used `mysql_connect` since it easier for access via raspberry pi using python code. From the paper comparison, it shows that the developers use different ways in designing the website but the architecture of the websites generally are same because the use of LAMP server.

3. Methodology

The methodology covers the main aspects of the project flow, the overall system overview of DWMP, user interface architecture and system usability scale (SUS). The methodology contains reports and explanations to produce evidence that can support a conclusion.

3.1 Flow of the project

Figure 1 shows the flow of the project from the start until its completion. After the title discussion, it followed by the software setup which is Raspberry Pi is used for developing the LAMP server. The creating of MySQL database is to store all the data from the sensor node. The synchronization of

DWMP database with HTML will allowed the information represent on the website. Lastly, all the data from the database will displayed in the website in interactive ways.

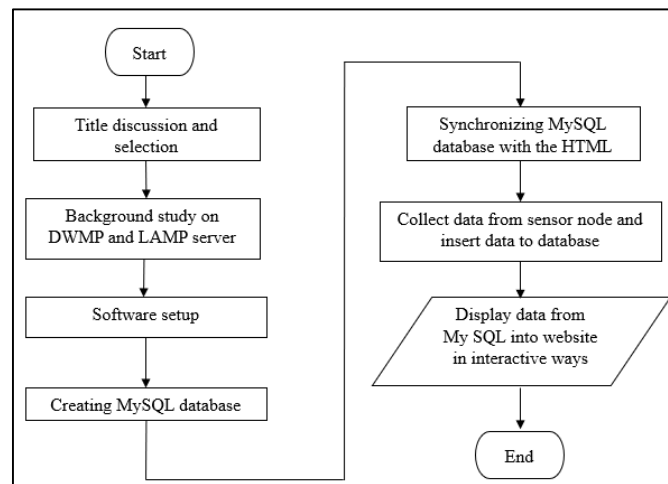


Figure 1: Flow of Project

3.2 DWMP System Architecture

This distributed wireless monitoring platform (DWMP) contains of three main parts; the sensor nodes, the LoRa, and the server. For the sensor nodes, it consists of only one component; which is the sensor. The next part is the base station which are consists of a gateway that connected to the raspberry pi. The base station is function to gather the data from the sensor node and it will receive by the gateway. For the server, it acts to store the data obtained from other parts of sensor nodes in the database. The data from the server is then presented on the website to be accessed in real time by the user. The block diagram of the system is shown in Figure 2.

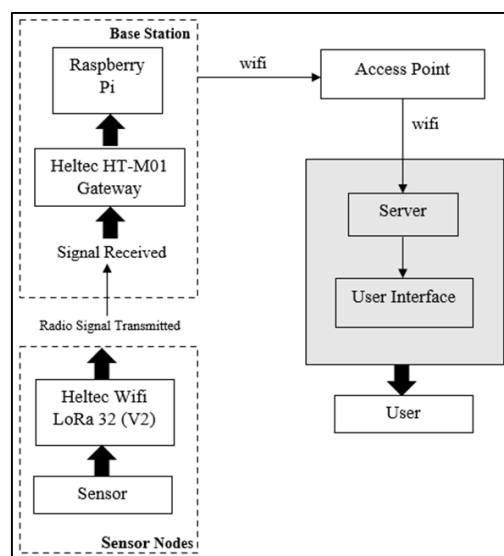


Figure 2: Overall DWMP Block Diagram

3.3 Architecture of User Interface System

The architecture of user interface system consists of three tiers; the database tier, application tier and presentation tier. Figure 3 illustrates the system layer.

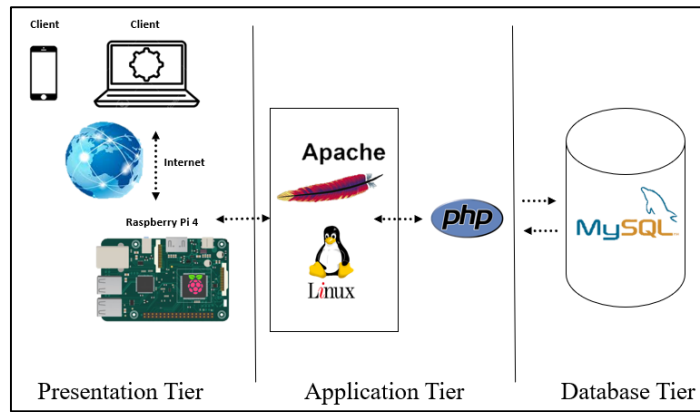


Figure 3: Web Server Architecture

3.3.1 Database Tier

The database tier consists of a database cloud platform and a data access layer. The database tier is the location whereas all the information is stored. We use a LAMP server that consists of a Linux operating system, an Apache web server, a MySQL database and also a PHP scripting language to build this database layer.

According to the DWMP structure, centralized storage is the most efficient to collect data. One of the most straightforward data storage techniques is centralized storage. Each node transmits to the base station (sink node) the captured perception data for storage, and data access gathers the data immediately from the station. Data can be stored for a long time as a result of the unlimited energy and storage capacity of the base station, and data access would not drain the energy of the nodes in the network. The block diagram of the centralized storage technique is shown in Figure 4.

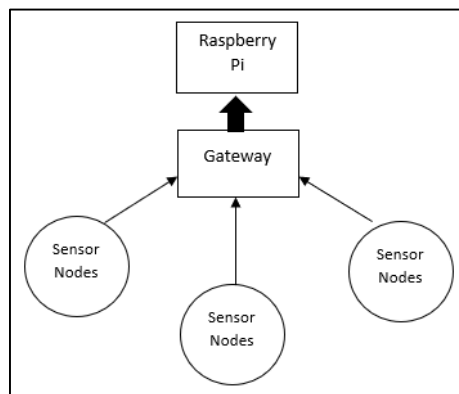


Figure 4: Centralized Storage Block Diagram

3.3.2 Application Tier

The application tier serves as the link between the presentation layer and the database tier. By doing extensive processing, it manages the site features [7]. This tier is where the right of access has also been defined. Often, this application tier is the one that writes and reads information into the tier of the database.

- Open Connection to MySQL using PHP

The PHP language are used for extract data from a database tier to be shown in the presentation tier as shown in Figure 5.

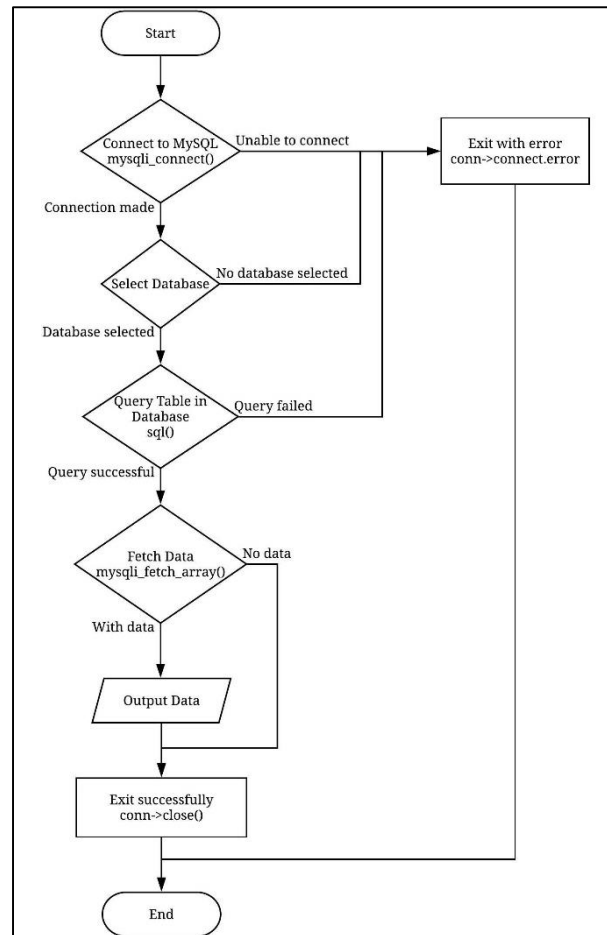


Figure 5: Database Connection

- Download data from MySQL into excel (.csv) file

Obtaining data to be export into MySQL file in users’ personal computer or smartphones is also under application layer. User can download latest data from the database by clicking the download data button and the data will be downloaded in excel (.csv) file. The downloaded data then can be used for further analysis.

3.2.3 Presentation Tier

The presentation tier of the 3-tier framework is the front-end layer which consists of the user interface. With the inclusion of CSS code to make it interactive and look good, the website is built using the basic approach of using HTML code, and PHP and Javascript make it more interactive for the user. The website is built on HTML code from scratch. This website consists of three key page view websites and two types of page view data display types.

- The Web Pages Design

Essentially, Javascript, CSS and PHP code are the foundation of the main website. This shows the DWMP information and has a location1 button that will guide the user to the next page when it is pressed. PHP code are the based for the second and third page. This page will have a water quality index versus timestamp, signal strength indicator, data table, and a button for download data. Figure 6 shows the website mapping. Web Design (Wireframe) for each page are shown in Figure 7 and 8 respectively.

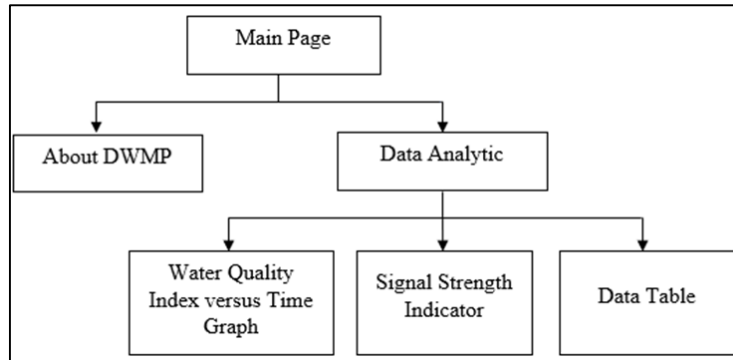


Figure 6: Website Mapping

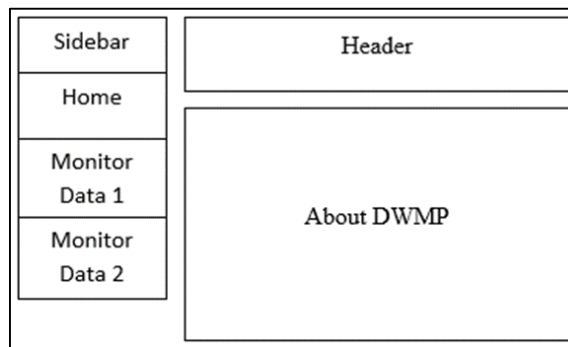


Figure 7: Main Page Layout

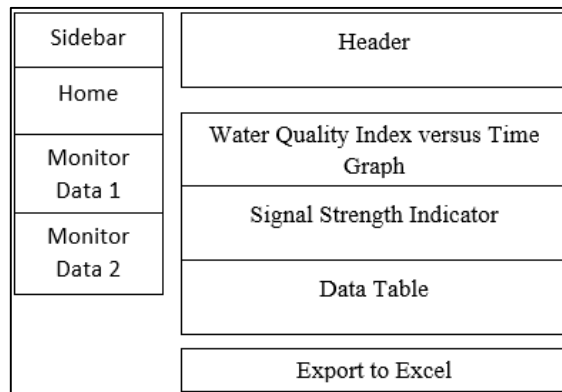


Figure 8: Second Page Layout and Third Page Layout

The website can also be used as a native application on smart phones without downloading it on the phone device. This is carried out using the manifest format. Manifests allow the website to be placed on the home screen of the device.

To enable the function, a link tag to the webmanifest file need to be included in the head of the index.html file. The signal strength versus time graph and signal strength indicator are represented using Javascript code. For this website, charts from ZingChart.com has be used. ZingChart’s flexible data handling allows direct data usage from a database. By using PHP to query a MySQL database, the data can be converted into JavaScript variables to be used in the charts. PHP while loops has been used to loop through data to create JavaScript arrays from the result set.

3.4 System Usability Scale (SUS)

The following 10 items are with odd-numbered items worded positively and even-numbered items worded negatively as shown in figure 9. When a SUS is used, participants are asked to score the

following 10 items with one of five responses that range from Strongly Agree to Strongly disagree. The questionnaire was created through the google form for the respondents to answer each question based on their experiences using the user interface of Distributed Wireless Monitoring Platform (DWMP) website. Before the respondents answer the questionnaire, the respondents will browse the website and experience the functionality of the DWMP website.

SUS	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I think that I would like to use this website frequently.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. I found the website unnecessarily complex.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. I thought the website was easy to use.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. I think that I would need the support of a technical person to be able to use this website.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. I found the various functions in this website were well integrated.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. I thought there was too much inconsistency in this website.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. I would imagine that most people would learn to use this website very quickly.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. I found the website very cumbersome / awkward to use.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. I felt very confident using the website.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. I needed to learn a lot of things before I could get going with this system.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 9: Table of Questionnaire for System Usability Scale (SUS) [9]

4. Results and Discussion

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

4.1 Collected Data

The system constructed to monitors the water quality and signal strength of the sensor nodes in exact time. This database table consists of three kinds of data; the time stamp, water quality index and signal strength. The timestamp, water quality index and signal strength data are originated from the sensor nodes that connected with LoRa. The timestamp is the exact time whereas the data is collected. The water quality index enables the users to notice the quality of water in certain areas. The signal strength is depending on the weather either in good or bad condition. Figure 10 shows data obtained from sensor nodes.

TIME STAMP	WATER QUALITY INDEX	SIGNAL STRENGTH
2020-06-20 12:00:00	50	-40
2020-06-19 12:00:00	55	-40
2020-06-18 12:00:00	60	-40
2020-06-17 12:00:00	55	-40
2020-06-16 12:00:00	45	-40
2020-06-15 12:00:00	40	-40
2020-06-14 12:00:00	45	-40
2020-06-13 12:00:00	60	-40
2020-06-12 12:00:00	55	-40
2020-06-11 12:00:00	55	-40

Figure 10: Data obtained from sensor nodes

4.2 Data Representation

The website contains of three forms of data visualization which is the water quality index versus timestamp graph, the signal strength indicator, and data table. These data presentations will help users to have good experiences when using the website. The water quality index versus timestamp and signal strength indicator are designed based on Javascript code while the data table is using CSS code. All data represented in the webpage is obtained from database using PHP code. PHP code gives an advantage during the development because it can be coded in between the HTML and Javascript code.

The indicator in Figure 11 makes it easy for the user to see the strength of the signal because it provides colorful range depending on the strength.

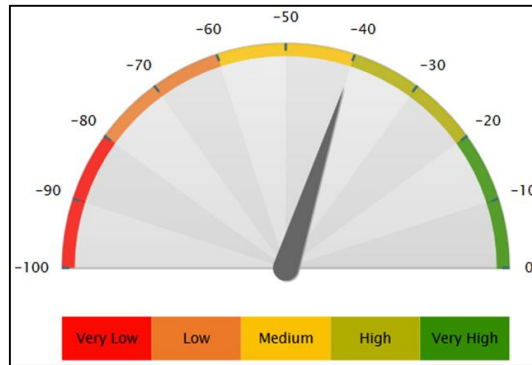


Figure 11: Signal strength indicator

The Figure 12 below shows that the graph provides the users with a way to track the water quality index versus the timestamp. It also helps users to monitor the consistency of their water in exact time. The ten most recent data will be included in the graph.

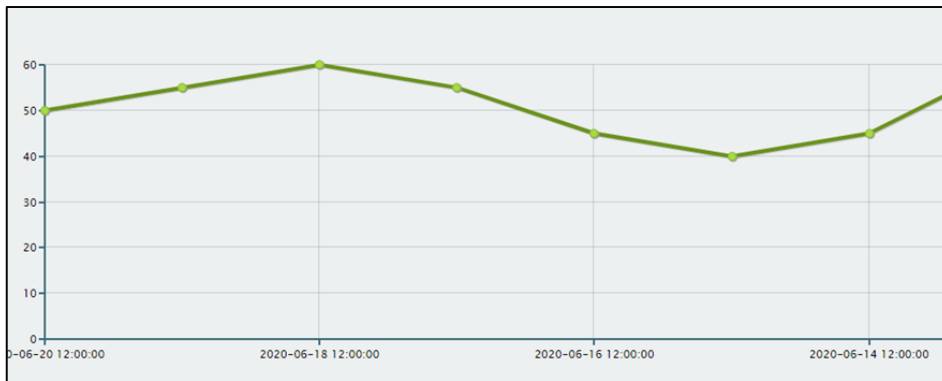


Figure 12: Water quality index versus timestamp graph

The last data presentation in the table consists of all three main data types in this DWMP system. The table collects all the data obtained from the sensor nodes into a single table that can then be downloaded from the.xls file to allow the user to further analyze the data. The table are shown in Figure 13.

TIME STAMP	WATER QUALITY INDEX	SIGNAL STRENGTH
2020-06-20 12:00:00	50	-40
2020-06-19 12:00:00	55	-40
2020-06-18 12:00:00	60	-40
2020-06-17 12:00:00	55	-40
2020-06-16 12:00:00	45	-40
2020-06-15 12:00:00	40	-40
2020-06-14 12:00:00	45	-40
2020-06-13 12:00:00	60	-40
2020-06-12 12:00:00	55	-40
2020-06-11 12:00:00	55	-40

Figure 13: Data table

Browsers used on personal computers, smartphones and tablets are compliant with the website interface. The interface adapts its view to the browser resolution of the computer used. Every five seconds, new data will be shown to allow the user to obtain the latest data to keep up with the data obtained by the sensor nodes. Figure 14, 15 and 16 shows the interface for browsers in personal computer.

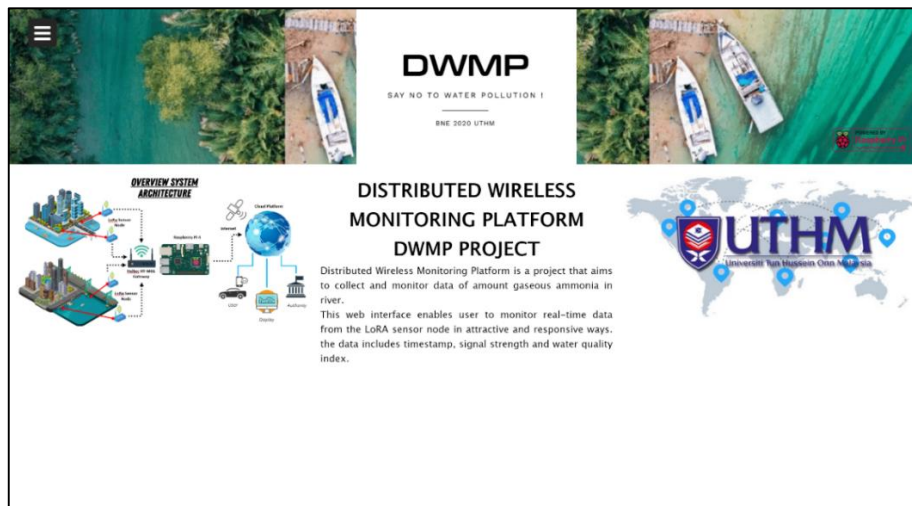


Figure 14: Homepage view in personal computer without sidebar



Figure 15: Homepage view in personal computer with sidebar



Figure 16: Data monitor page view through personal computer

In order to make this website are user-friendly, by adding it to the home screen, the website can also be used as a mobile application on the user's smartphone or tablet. This feature allows the web application to run independently from the web browser on its own windows and also hides elements of the standard user interface (UI) including URL and bar. It also had its own icon on the home screen like native application which make it easier for the user to access the web application instead of opening the browser every time user need to access the web. Figure 17 shows the web application manifest detected by the browser.

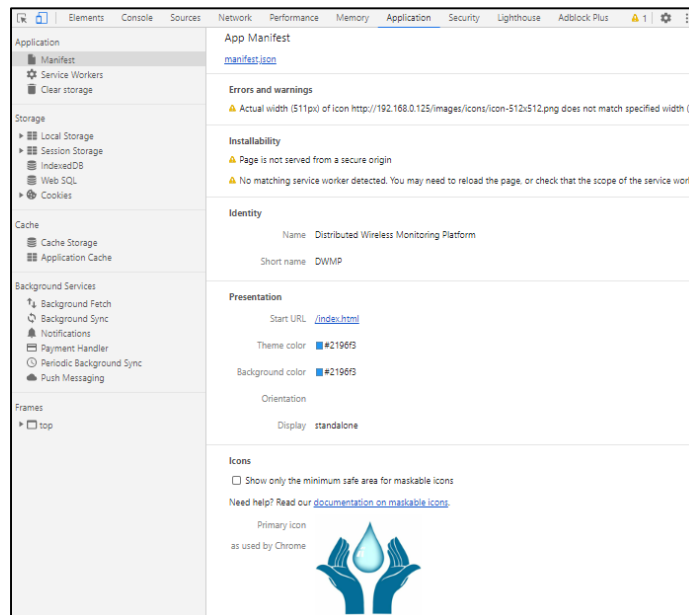


Figure 17: Application Manifest detected in browser

Figure 18 below shows the website being added into the user’s home screen together with the natives’ application.

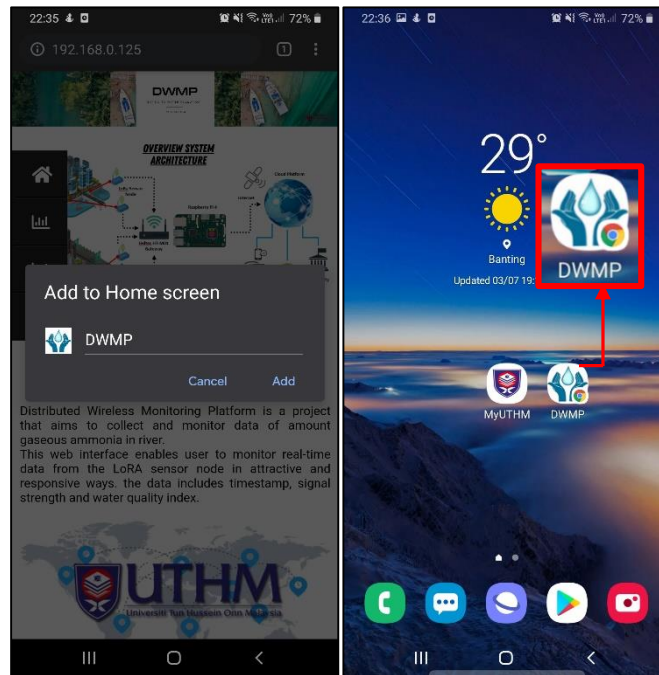


Figure 18: Web Application added to home screen and Web Application with other natives’ application

The website interface for smartphones is shown in figure 19 below.

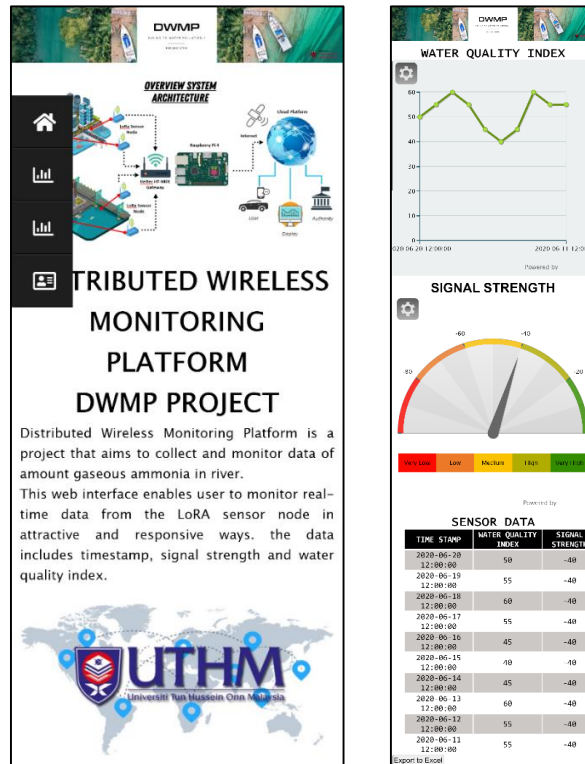


Figure 19: Homepage view through smartphone and Data monitor page view through smartphone

4.2 Evaluation Result of System Usability Scale (SUS)

The questionnaire had been responded by 30 respondents among students. The evaluation result of system usability scale (SUS) is shown in the figure 20. Each question is evaluated by the respondents based on their experiences using the website. From the graph, it shows that the users are getting easy to use and discovers about the functionality of website such as the presentation of data are very simple and organize efficiently.

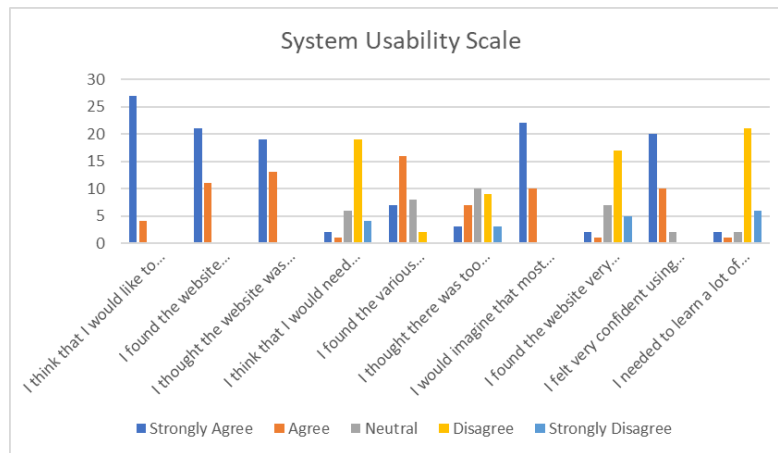


Figure 20: Evaluation Result of System Usability Scale (SUS)

The calculation had been done by through excel based on the step calculation in section 3.4. The SUS score for the Distributed Wireless Monitoring Platform (DWMP) website achieve the effectiveness and credibility of a good website with adjective rating is good. It shows that the website is well organized, simple and user-friendly navigation. The respondents are easily to access and understand the functionality of the website without having a technical person.

5. Conclusion

In this paper, web interface for DWMP have been presented. The DWMP website is important because it can make an immense contribution to the nature especially in order to keep river health at an adequate level for optimal operation to sustain living beings. In our own natural environment, the real-time data generated by this website can have a huge effect. There are a variety of appealing features in the system, including affordable, lightweight, extensible, easy to configure, easier to deployed and also easier to manage. As a conclusion, the objectives of the paper had been achieved. The website can display the accurate data obtained from sensor in exact time. Users are also able to use personal computers, smartphones or tablets to navigate the website. The data from the sensor can be easily downloaded for analysis purposes from the website. The user interface performance of this website had been observed through the System Usability Scale (SUS) and the DWMP website provides a good experience for the user. The users are confidently to use and understand the functionality of the website without having a technical person. Overall, the design implementations proved to generate a feasible system that can be used in collect and monitor operation in the future.

4.1 Recommendation

The system architecture outlined in this paper can be applied in a variety of different ways as future work such as functionality and reliability. There are some recommendations that might to be considered to increase effectiveness project in the future to change the collect and monitor scenario to a better one:

- Implement more features to include a user - friendly interface and enhanced user experience in data visualization, management, and analysis.

- Implement a second database server on the Internet or on the cloud computing infrastructure since there is insufficient space in the raspberry pi.
- Integrate real time weather forecast in the website to allows for data to be gathered to build up a more detailed data of water quality.
- Use web socket to enable data collection in the background, without the web interface intervening.

Acknowledgement

The research was made possible by funding from MDR research grant number vot-H470. The authors would like to thank the fellow lecturers for the guidance and also the support from the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia.

References

- [1] M. Z. Abidin, A. A. Kutty, T. Lihan, and N. A. Zakaria, "Hydrological change effects on Sungai Langat water quality," *Sains Malaysiana*, vol. 47, no. 7, pp. 1401–1411, 2018, doi: 10.17576/jsm-2018-4707-07.
- [2] T. Mandel, *The Elements of User Interface Design*. USA: John Wiley & Sons, Inc., 1997.
- [3] R. Chandra and C. Guntupalli, "User interface design: methods and qualities of a good user interface design.," p. 37, 2008.
- [4] V. S. Arumuga Perumal, K. Baskaran, and S. K. Rai, "Implementation of effective and low-cost Building Monitoring System (BMS) using raspberry PI," *Energy Procedia*, vol. 143, pp. 179–185, 2017, doi: 10.1016/j.egypro.2017.12.668.
- [5] J. Fletcher and W. Malalasekera, "Development of a user-friendly, low-cost home energy monitoring and recording system," *Energy*, vol. 111, pp. 32–46, 2016, doi: 10.1016/j.energy.2016.05.027.
- [6] S. Ferdoush and X. Li, "Wireless sensor network system design using Raspberry Pi and Arduino for environmental monitoring applications," *Procedia Comput. Sci.*, vol. 34, pp. 103–110, 2014, doi: 10.1016/j.procs.2014.07.059.
- [7] V. Kumar, K. K. Chaturvedi, and J. Nanjundan, "Design and implementation of web-based database of rapeseed-mustard germplasm using Linux - Apache - MySQL - PHP (LAMP) technology," *African J. Agric. Res.*, vol. 8, no. 22, pp. 2733–2743, 2013, doi: 10.5897/AJAR2013.6945.
- [8] F. A. Saparudin, T. C. Chee, A. S. Ab Ghafar, H. A. Majid, and N. Katiran, "Wireless water quality monitoring system for high density aquaculture application," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 13, no. 2, pp. 507–513, 2019, doi: 10.11591/ijeecs.v13.i2. pp507-513.
- [9] J. Brooke, "SUS: A quick and dirty usability scale," *Usability Eval. Ind.*, vol. 189, 1995.