Comparison on Scorecard and Dashboard in Smart Water Monitoring Application

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***Abstract*—The Smart Water has been a part of the Internet of Things (IoT) which evolves drastically and their involvement in the Smart Home make it a complete infrastructure. Smart Water is a term commonly used to define an automatic water quality monitoring system that is capable of measuring pH and turbidity value through sensor by using Smart Devices. The importance of Smart Water is the way of its data, such as pH and turbidity value will be presented to users. The way of data presentation can be varied depends on the platform that used by users and roles. This paper is based on the comparison made on the data presentation types used in Smart Water technology. Data presentation types such as scorecard and dashboard are compared based on research result to show their relevancy towards real-time data presentation and interactive to human in the Smart Water environment. Critical evolution towards data presentation types shows that dashboard is suitable in order to achieve real-time data presentation and interactive data visualization to human which help in data analysis and decision making. This paper, then discusses the implementation of the data visualization in the Smart Water testbed. The Smart Water testbed specifically developed to test data visualization in real time.**

I. INTRODUCTION

The development of the Internet of Things (IoT) has increased align with the numbers of mobile users [1]. This evolution has been in research to help people in making their life better [2]. It has been involved in lots of areas such as Smart Grid, Smart Cities, and others Smart Industries. For example, Smart Home is a system that use to support human decision which include health and make it easier for their day-to-day life environment. One of usual Smart Devices used in a Smart Home, is Smart Door that helps users to open and lock their door using Smart Phone. Another system that usually installed in a Smart Home is Smart Water, where the quality of the water monitored to ensure it is suitable for human usage to ensure healthiest lifestyle. Throughout this paper, Smart Water will be referred to as a system that specifically developed to monitor the quality of water. This paper will discuss on the Smart Water features that help in monitoring the water pH status and ensuring the water is perfectly suitable for human usage.

A clean water supply is a need to support daily needs such as drinking, washing, bathing and cooking. It is crucial to ensure the water supply is free from any harmful germ and chemical for human consumption [3]. Without clean water supply, domestic use will be disabled for everyone. A research has discovered that inadequate clean water supply is the main factors of health issues in many developing countries [4].

Most of the home water tanks are placed higher than ground to ensure the water supply chain is higher pressure. Indirectly, this condition makes it hard for water tank monitoring by the owner. The water tank owner is responsible to ensure the water supply is in good condition. In some cases, the water tank owner needs to climb up to reach the home water tank for checking the condition of water and record the water pH for water quality monitoring. In general, water undergoes treatment before being stored in water tanks through the pipeline [5]. However, in some cases, water pollution can happen regardless of time and place.

In the world with greater technologies, the way data being captured, save and analyze has been evolving [6]. Earliest days, data were managed through paper as a medium to store it [7]. All the data in some areas have been managed using paper, since it is the most appropriate way at that point of time.

File management is the crucial part of keeping the paper structurally. Despite the structural system for paper, this kind of data storage is likely to produce many problems, since it requires lots of time to find a specific kind of data. The probabilities of losing the file due to natural disaster or any kind of disaster are high. Other than that, the data are exposed to an authorized user if it's not being kept in a safe place. The important part despite way of data been keep is how the data will be analyzed for users' interpretation.

Using paper, manual way will be used to determine the results from the data. For example, water quality used to be checked manually and all the pH results will be written down on a paper. The analyzer needs to compare all the data from a stack of papers. Time taken to analyze the data will be longer depending on the analyzer capabilities. The crucial part is the way of the data to be interpreted on a paper. Analyzer need to transform all the data into a graph or bar chart and present it to the users. Users are required to read the bar chart or graph to understand the results. Mistake in analyzing the data will create a bigger problem where the results are not reliable. The ability for users to understand the graph and bar chart should be taken under consideration. For example, sometimes when the data become larger and the analyzer is required to prepare more than one paper to present the bar chart or graph. This will make it difficult for users to compare all the data simultaneously in real time.

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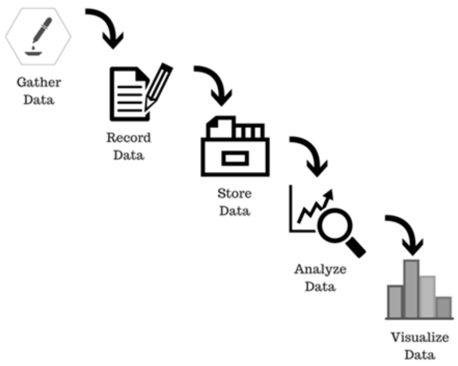

Fig. 1. File Management Structure

The world has changed the way it managed data, using technologies the data can be kept and analyze swiftly without any compromise attack. Moreover, using technologies, data can be gathered easily and rapidly. Functionality of system application such as update, delete and read can be executed with no restriction. Besides that, system application can improve the innovation, collaboration, compliance, and audit results [8]. Technologies such as system, servers and internet communication help in storing the data. For example, Smart Water will use a sensor to produce the data which will be sent to the servers through a system for water monitoring process. This kind of storing data is much better than using paper based in terms of data reliability and accuracy. In the system environment, the data will be kept securely which only authorized users can access it.

The aim of this paper is to determine the most suitable data presentation in Smart Water to aid homeowners in monitoring water supply and safety of water tap in their home. The pH probe is used as the input to the system. The data collected from the pH sensors will be sent to the cloud for data analysis and present the output in data visualization on their devices later. This paper will elaborate on the way to present the data, so that it can be easily interpreted by a non-IT literate users. Data presentation is very important in Smart Water, where users can understand if the quality of the water has been compromised when they saw the pH status is in certain level. This paper, then discusses the implementation of the data visualization in Smart Water testbed. The Smart Water testbed specifically developed to test data visualization in real time an on actual environment. The objective is to investigate data visualization implementation in real environment and not rely only on data simulation.

II. Literature Review

A. Data Presentation

This study, conducted a survey to find the most appropriate data presentation for Smart Water Application by comparing two types of common data presentation which are scorecard and dashboard. This comparison is based on certain criteria such as purpose of presentation, timeliness of data, users and linked to systems to simplify the perspective area for data presentation [9]. According to Cheng, et. Al. 2011, a good data presentation requires a prompt and concise information retrieval, organized information to support meaning, usability, less distraction and avoid clichés and unnecessary information that could create confusion among users. This is crucial to ensure users have a pleasant viewing experience and easy for data comparison process [10].

B. Scorecard

The first data presentation proposes is the scorecard. Scorecard emerged in the early 1990s as a new approach of key performance indicators (KPIs) which introduced by Robert S. Kaplan and David P. Norton as Balanced Scorecard (BSC) [11]. The BSC is a performance management system that enables organizations to clarify vision, determine strategy and translate all of them into action [12]. Based on the research made by [13], Balanced Scorecard (BSC) is the most prominent performance management system used by over 60% of organizations worldwide.

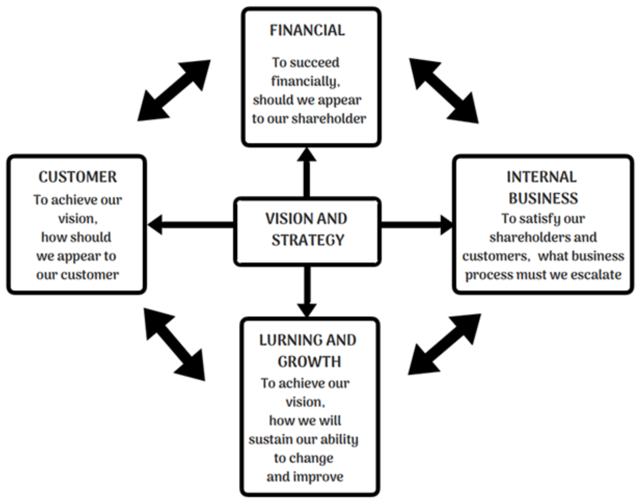

Fig. 2. Balance scorecard structure

Fig. 2 shows a Balance Scorecard structure which preserves financial metrics as the ultimate outcome measure for company success supported by three additional perspectives which are customer, internal process and learning and growth [12]. These three additional perspectives used for creating long-term shareholder value [13]. The main purpose of BS is to measure the organization performance from different angles and incorporate the necessary key performance indicators [12].

The first perspective in BS is financial which include the financial growth, profitability and risk [14]. Second, customers whereby services are the main insight towards the organization [14]. Third, internal process which focuses on the business process to fulfill stakeholder and customer needs and wants [14]. Last but not least is the innovation and growth; the process of creating new ideas to create value for the organization [14].

After identifying a company vision, management has to come out with a specific strategy on what the company wants to drive and ensure intangible assets managed effectively. The implementation of BSC by using the combination of relevant literature and practical experience helps to overcome problems in strategy implementation [15]. Therefore, the BSC is used for monitoring progress over time. Using the top-down approach in balance scorecard that allows management to implement its strategy by aligning performance with goals [9].

Scorecard requires to analyze data for a long period of time, which mean it will gather data day by day to be able to produce the results [16]. The data will compare overall data that's been gathered, this is likely to get an average or to compare data on monthly basis [16][13]. Another part is the type of users for score card, which is used for upper level managers. The last part in the Scorecard is linked to the systems occasionally which means only when they require to send data then it will connect to the server. The main objectives of balance scorecard is to generate the improvement of performance rather than instruments for measurement and diagnosis [17].

Apart from the fact that Balance Scorecard (BS) is the performance indicators for an organization, there are other advantages associated as well. As the timeliness of data are collected periodically, BS can provide stakeholders an overview of the health of organization in short, intermediate and long terms [13]. Besides, organizations can ensure every strategic action will produce the desired outcomes [18]. As an example, if the process of creating the product is in a high quality, the customer will be satisfied.

On the other hand, there are certain limitations of BS. One of the disadvantages of using BS is it is a massive process; requires a proper planning before implementation. BS is not suitable to solve a quick span of time problems without a proper plan. The organization should focus on improving quality, reducing cycle times and deliver excellent customer services [19].

Besides, another drawback is limited understanding on how the BS works and what is it. The limited understanding and knowledge led the initiative in the wrong direction at the very start of its implementation [20]. It is really recommended that all employees should involve in the BS implementation to ensure it works effectively. If they do not know how the BS works and what is the outcomes, they definitely may not invest in it [21]. Thus, it is crucial to gain acceptance from stakeholders by providing training for them.

C. Dashboard

The second data presentation proposes is the dashboard. The dashboard is popular as a unique and powerful tool for data visualization, which consolidate and arrange crucial data on a single screen and monitor the information at a glance [11]. The concept of dashboard started in the 1980s with the name of Executive Information System (EISs) which used to display static interfaces for business purposes. In 1990s, digital dashboard was first introduced. The digital dashboard established the consumption of data and made it available to all stakeholders. This development made it easier to grasp data and broadened the scopes for collecting and synthesize data from all relevant sources [11]. Due to technology developments, it is much easier to retrieve data regardless of time and place. Thus, modern dashboard was introduced which provide up-to-date information to users. This kind of data visualization requires online connection where data is sending and retrieve concurrently [9]. Besides, it also overcome the limitations of EIS which is lack of interactivity.

Previously, users had no option to explore the data and their understanding of data was limited to the macro picture [10]. On the other hand, modern dashboard provides the capabilities for users to drill down into data, zoom into it, and even slice and dice the dashboard. Thus, it is easier for users to customize the data that have been display based on they needed.

A dynamic dashboard can be made interactive and user-friendly by allowing extraction of information from different perspectives and context [10]. Nowadays, the modern dashboard can be found in different kind of approach and commonly used to perform daily tasks such as personal finance management (Mint) and fitness tracing (Fitbit) [13].

The major benefit of the dashboard is it can be used by any different users. The integration of visual and functional features improves the cognition and interpretation of user [22]. Dashboard makes it possible to be used by any user level from front-line workers to top management [13]. It communicates complex data to the decision maker through the visualization process; interactive visual representation of non-physical based data to amplify cognition [22].

Besides, the dashboard also offers different functional purposes such as monitoring, consistency, planning and communication. Monitoring is a day-to-day action of collecting and analyzing information towards reaching its objectives [10]. It is also the most fundamental used of dashboard [13]. Consistency refers to the procedures used across departments and business units. Besides, the dashboard is also useful for planning and communications.

However, the greatest challenge of dashboard involves squeezing information on a single screen in a way that does not result in a cluttered mess. As dashboard is known as a visual display to portray crucial information, it must be super interactive and concise for users [11]. Besides, a careful and informed dashboard makes it communicate clearly, accurately and efficiently [10].

TABLE I. COMPARISON BETWEEN DASHBOARD AND SCORECARD [10]

	Dashboard	Scorecard
Purpose	Performance at a glance	Managing performance
Timeliness of data	Current (often real time)	Periodic (often monthly)
Data freshness	Depends on sensor's accuracy	Depends on frequency of data collection
Users	Lower level managers	Upper level managers
Linked to system	Almost always	Sometimes

Many times, dashboards are set up without the user in mind. It can be either extremely complicated to set up or the measurement metrics irrelevant to the user [22]. As the result, incorrect data are presented to the user. Therefore, a dashboard should present relevant data to users either in real time or any time whenever data are needed. Thus, a well-designed and user-friendly dashboard is critical for business development.

Table I summarizes the difference between scorecards and dashboard.

Table I is the comparison table of data visualization between dashboard and scorecard. The first criteria show the purpose of both data visualization methods. Dashboard usually uses to present current performance data and scorecard works to manage performance. The crucial part of the table is the timeliness of the data presented. The dashboard is presenting real time data and scorecard is more towards periodic data or monthly data. The third criteria are the type of users that related to which data visualization. For the dashboard, the lower level managers are more likely use this kind of data visualization and top level managers are suitable with the scorecard method. The last part is the frequency of data visualization to link with the system. The dashboard is linked frequently and the data will update in no time and scorecard is almost certainly will update the data less frequent or on a monthly basis.

While comparison has been made between scorecard and dashboard to achieve the goals for this paper which are presenting a real-time data and interactive to human there are limitation that this paper does not cover which are 3D presentation or even virtual interfaces. Since this paper is written to compare only two data presented and to emphasize which is better to be implemented in Smart Water testbed than 3D presentation or virtual interfaces are not included. However, in further research these two areas can look into either, which one is suitable to be implemented in the dashboard.

III. DATA IN SMART WATER

In the previous section, we have discussed that Smart Water is about monitoring water quality based on pH value and turbidity of the water [23]. Smart water uses sensors to detect water quality and send it to the servers for data analysis. The pH sensor will send the value between 0-14 and the system will conclude either it is acidic or non-acidic. Backend system is the crucial part when it plays an important role to analyze data from pH sensor. The way system analyzing the data by dividing it into three classes that are acidic, normal, and alkaline.

The acidic water can be caused by the leaking of heavy metal ion such as iron, copper, lead and zinc which comes from the old plumbing and piping system [24]. Therefore, water with low pH could contain contaminated metals which will affect human health and causes damage to piping systems [3]. Meanwhile, alkaline water can lead to aesthetic issues which are pressure of water is disturbed, precipitate on piping and many more [3]. Therefore, the system will determine either water quality is good for users or not based on the information collected from the pH probe.

Besides pH value, turbidity is another crucial aspect to define water quality [25] as it is interpreted as a measure of the relative clarity of water [26]. Turbidity is a measurement to indicate the presence of suspended and dissolved matter. These particles could be silt, clay, algae, organic matter and other minute particles. It can obstruct the transmittance of light through water [25][26]. The major used of turbidity is to measure if water has been pollute or not [27]. It is measured by shining light through a sample and quantifying the suspended particle concentration. The more particles that are in a solution, the higher the turbidity. The best way to measure the turbidity is by using a turbidity meter which measured in nephelometric turbidity units (NTU) or turbidity tube in Jackson turbidity units (JTLJ). Thus, the system gets the result from turbidity sensors and analyze by the servers.

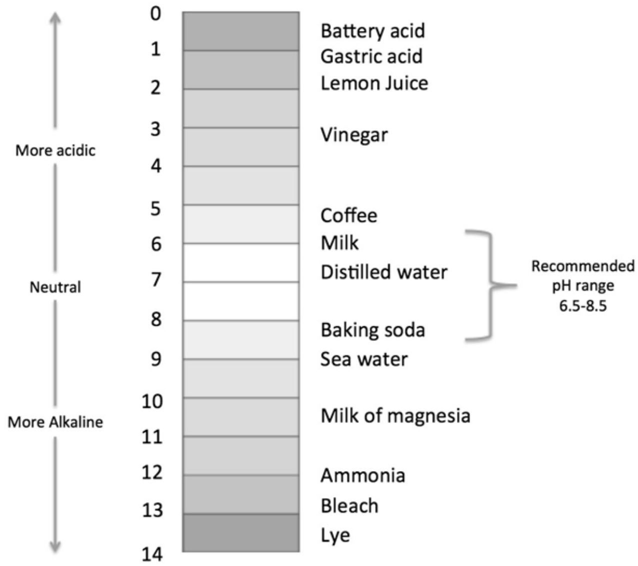

Fig. 3. Illustration of pH scale [24]

Fig. 3 illustrates the pH scale. The normal range for pH value is from 6.5 to 8.5. Therefore, water with the pH less than 7 classified as acidic. On the other hand, water with the pH more than 7 is alkaline. Therefore, based on all requirements discussed in the previous sections, it shows that for this paper, the development of the Smart Water testbed requires data freshness and accuracy of the data monitored. Therefore, it is concluded that Dashboard approach is required for the development of the Smart Water testbed. Users will be able to make the decision based on real time data. Users will be able to execute their decision using a smart application, whether thru Smart Phone or PC or any other Smart Devices that provide access to the cloud.

IV. SMART WATER TESTBED

This paper has successfully surveyed on data visualization for Smart Water. However, this paper will not have discussed in detail of the Smart Water testbed develop specifically for Smart Home implementation. The Smart Water testbed developed was discuss in detail in Rahman et. al. 2017 [28]. The setup used in the paper, is a Sensor to Cloud setup in an actual environment as shown in Fig. 4 [28], [29], [30]. The development of the Smart Water testbed designed in minimal weight, miniature form-factor, limited processing power using 2 AA batteries, storage, nRF24L01 operating on 2.4GHz ISM (Industry Scientific and Medical) bandwidth and standard based interface protocols [28]. In the paper, the prototype of Smart Water testbed deployed, designed with the details as shown in Table II [28], [29].

TABLE II. SMART WATER TESTBED [28]

No	Components	Description
1	Antenna	1dBi built in antenna
2	Rate	Transmitting up to 250kbps of data
3	AA size Battery Power	1.5 volts Zinc-Manganese Dioxide (Zn/MnO_2)
4	Sensor's Weight	20g of weight
5	Wireless	nRF24L01 operating on 2.4GHz ISM bandwidth
6	Turbidity Sensor	IR Optical sensor with optical fiber Accuracy 5% (around 1 NTU) Range 0-4000NTU
7	Oxidation Reduction Potential	Combination Electrode Range 0-1999mV
8	Dissolved Oxygen Sensor	Galvanic Cell Accuracy: ±2% Range 0-20mg/L
9	pH Sensor	Combination Electrode Range 0-14pH Response Time <1 min

Smart Water testbed that been introduced by Rahman et. Al. 2017 [28] consist of 9 items which are antenna with the rate of transmitting up to 250kbps of data. Battery use for this testbed is an AA size Battery power that supply 1.5 volts Zinc-Manganese Dioxide. The sensor's weight is 20g and wireless used in the testbed is nRF24L01 operating on 2.4GHz ISM bandwidth. The specification for turbidity sensor is an IR Optical sensor with optical fiber with an accuracy of 5% and the range is from 0 to 4000 NTU. Oxidation Reduction Potential (ORP) used to measure water's ability for chemical reaction with a range from 0 to 1999mV. Dissolved Oxygen Sensor has been used to determine changes in dissolved oxygen level, for this testbed galvanic cell type with an accuracy of ±2% And range between 0 to 20mg per litre. For pH Sensor it is a combination of electrode with the range from 0 to 14pH and it can response with less than 1 minute.

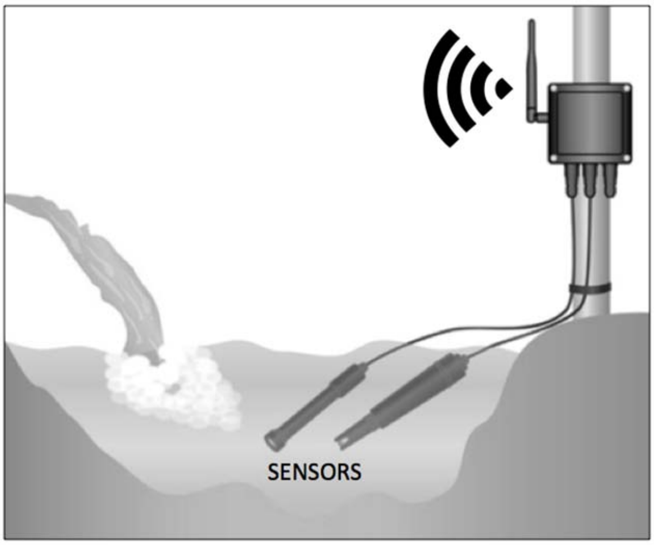

Fig. 4. Smart Water testbed using Wireless 2.4GHz [28]

The testbed reads the value of a battery, time, pH, oxidation, turbidity and a dissolved oxygen sensor every 5 minutes and sends it to Cloud server listening on TCP port 80 as shown in Fig. 5 and Fig. 6 [28]. The Cloud server will listen for communications on port 80 and print out data received in the standard output [28]. The Smart Water testbed is using Wi-Fi IEEE 802.11 that widely uses in cloud architecture and based on the environment implementation.

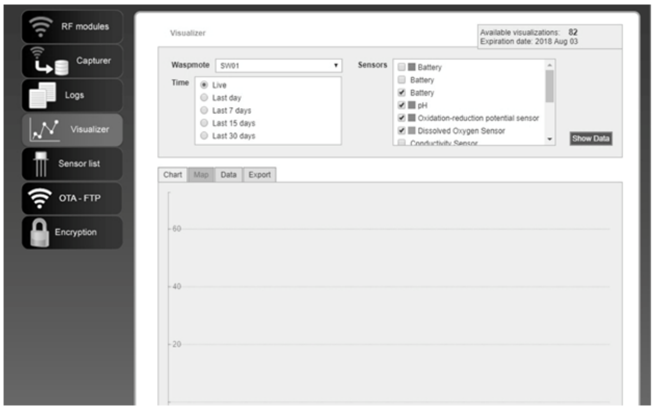

Fig. 5. Smart Water testbed using Wireless 2.4GHz [28]

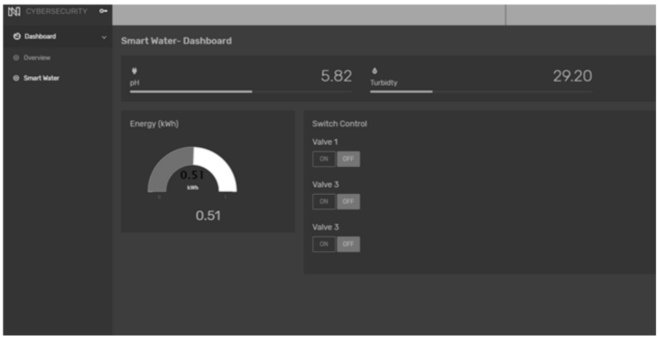

Fig. 6. The Cloud shows Sample Data from Smart Water testbed in real time

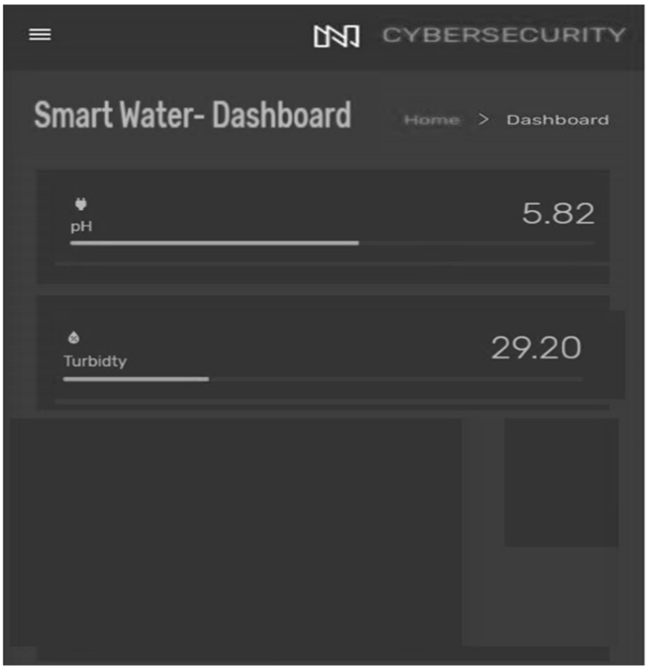

Fig. 7. The Cloud shows Sample Data from Smart Water testbed in mobile browser

The real time data from the Smart Water testbed were uploaded to the cloud and presented in the dashboard shown in Fig. 6. As shown in Fig. 6, the real time data presented in dashboard will significantly improve the way of water monitoring compared to an outdated scorecard approach. Any slight changes to the quality of water shall be updated to the dashboard and alert system administrator if any anomalies arise. The Fig. 7 shown that the dashboard is mobile ready, where the water monitoring shall be viewed in a mobile browser. This approach is to support multiple OS such as iOS and Android.

This paper will not discuss the details of the Cloud development setup such as the language used and the protocol used to communicate between the cloud and Smart Water testbed. However, the Cloud was set up just to receive data without any optimization or security installed and configured. Since the approach of this paper is to show the impact of data visualization for Smart Water Monitoring testbed without any security mechanism or optimization. Fig. 8, Fig. 9 and Fig. 10 shows the Smart Water Monitoring testbed that been used during this research. There are 3 main components for the Smart Water Monitoring System. The first component is a glass water tank fills with tap water used as testbed. Second is the Smart Water Monitoring device that consist of all the electrical circuits and sensors, transmitting real time data to the cloud via wireless 2.4GHz ISM Bandwidth. Third is the cloud that enables system administrator to monitor water quality via mobile phone, tablet or laptop.

Since the objective of this paper is on investigating and comparing an outdated scorecard approach to monitor water quality with a dashboard approach, this paper shall not investigate the impact of the different type of water quality. This paper only tests a single type of tap water quality from a single source.

V. Conclusion

Based on the data comparison between dashboard and scorecard, we conclude that dashboard is the most appropriate way to present data on the Smart Water application. The first point is that Smart Water requires real time data to be used in their application. A dashboard can deliver real time data based on its criteria. The ability of dashboard to connect 24/7 to the system makes it reliable to receive real time data. Based on table 1 the environment of the dashboard which is always online, using real time data the accuracy and reliability can be assured. Another one is the requirement of data freshness. The users shall make decisions based on real time data and with minimum time and latency. The dashboard is suitable for all levels of users from technical assistant, manager as well as general users. Based on the implementation of Smart Water testbed, this paper concluded that Dashboard is the most suitable approach to visualize real time data for Smart Water compared to the scorecard. Despite this paper has concluded that dashboard is the most suitable for data presentation in Smart Water testbed, a few limitations in this paper has been found such as the other data visualization methods that can be compared and Smart Water testbed is not discussed in details. The way forward towards this paper is that, other data visualization such as 3D presentation or virtual interfaces can be discussed more and how it can work well with the dashboard.

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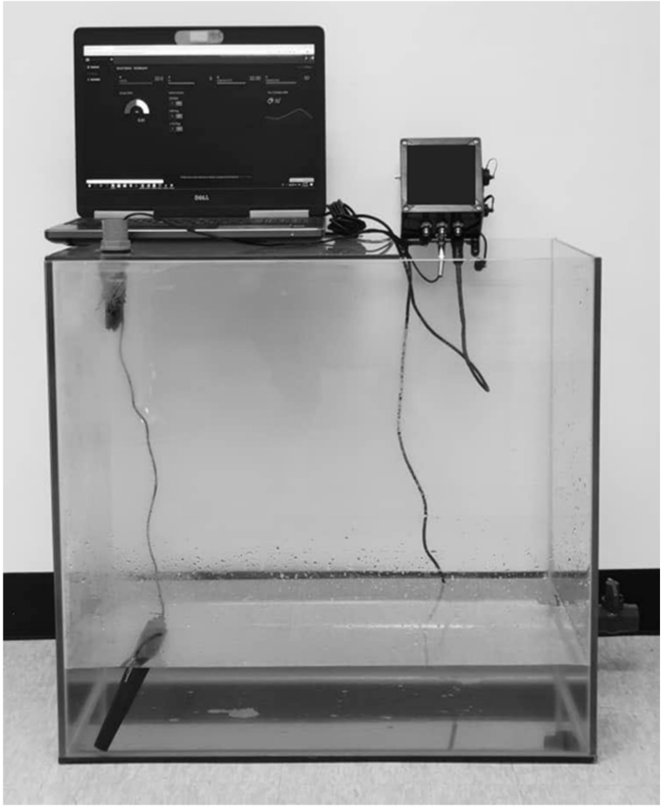

Fig. 8. Front View of the Smart Water Testbed

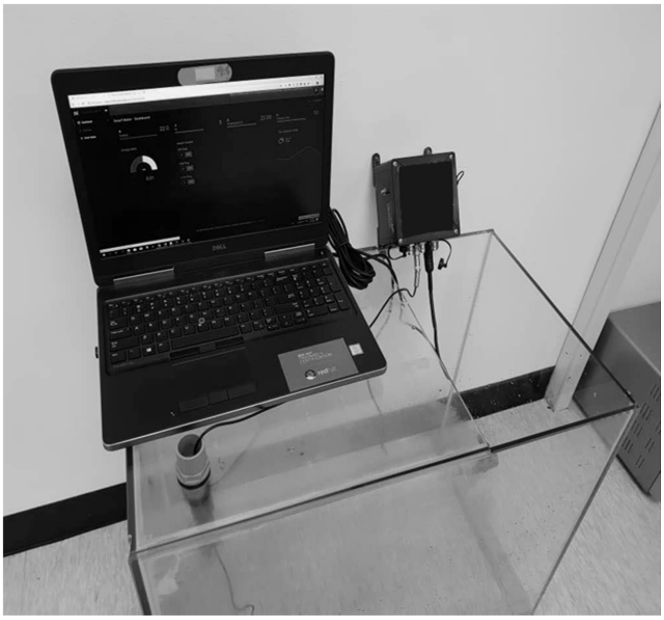

Fig. 9. Side View of the Smart Water Testbed

Fig. 10. Top View of the Smart Water Testbed

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