2023 International Conference Advancement in Data Science, E-learning and Information Systems (ICADEIS)
ISBN: 979-8-3503-0341-4

2023 International Conference on Advancement in Data Science, E-learning and Information System (ICADEIS) | 979-8-3503-0341-4/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICADEIS58666.2023.10271044

Smart Dashboard on an Internet of Things-Based Automatic Water Meter Reading System

[1st]Luthfi Fitra Musyaffa
School of Industrial Engineering
Telkom University
Bandung, Indonesia
luthfimusafa@student.telkomuniversity.ac.id

[2nd]Dita Pramesti
School of Industrial Engineering
Telkom University
Bandung, Indonesia
ditapramesti@telkomuniversity.ac.id

[3rd]Muhammad Rizal Bimantoro
School of Industrial Engineering
Telkom University
Bandung, Indonesia
rebimantoro@student.telkomuniversity.ac.id

[4th]Hanif Fakhrurroja
School of Industrial Engineering
Telkom University
National Research and Innovation Agency
Bandung, Indonesia
haniff@telkomuniversity.ac.id

Abstract: **Water scarcity and non-revenue water (NRW) are major issues faced by water companies worldwide, with Indonesia ranking fifth in the Asia-Pacific region for the highest NRW value. Reduction of NRW has been a challenging task for water companies due to several reasons. However, the integration of smart dashboard and smart home technologies provides a streamlined and convenient solution for managing water usage and payments. The development of a smart dashboard system that integrates with an automatic water reading device presents several challenges, including the manual recording of water meter readings and handling unpaid customer bills. The implementation of a smart dashboard water meter application has proven to be a beneficial solution for the water company's financial issues, resulting in cost savings from reduced field staff and improving service quality to customers. The results from testing the smart dashboard water meter application have provided concrete evidence of its effectiveness, further supporting its implementation as a solution to water companies' financial issues.**

Keywords: water, automated meter reading, Internet of Things, smart dashboard

I. INTRODUCTION

Water is a vital resource, but its availability and distribution are often a challenge in many countries. In Indonesia, the issue is exacerbated by high levels of non-revenue water (NRW), which refers to water that is lost due to leaks, theft, poor metering, and corruption. The Asian Development Bank has reported that more than 32 billion m3 of water are lost each year due to leaks in the distribution network, and an additional 16 billion m3 are given to customers without being billed [1]. The total annual cost borne by water companies worldwide is estimated to be $14 billion. Indonesia is ranked fifth in the Asia-Pacific region for the highest NRW value.

Reducing NRW has been a challenging task for water companies due to several reasons include a lack of understanding of the problem (magnitude, source, cost), insufficient capacity (lack of trained staff), inadequate funding to replace infrastructure (pipes, meters), a lack of commitment from management and employees, and a weak performance-supporting environment and incentives [2]. Currently, Indonesia is attempting to reduce its NRW by using an Internet of Things (IoT)-based automatic water meter reading system, which reduces human error in the billing process. At present, there is no reliable smart dashboard technology available that can fully support the smart home concept by utilizing an IoT-based automatic water meter reading system in Indonesia.

The integration of smart dashboard and smart home technologies is increasingly prevalent, especially in the context of monitoring water usage and paying water bills. A smart dashboard is a centralized platform that provides real-time information and analytics on various aspects of a user's life, including water usage. By integrating this technology with a smart home system that uses IoT devices to control various aspects of the home, users can easily monitor and control their water usage and make payments from a single interface [3]. For instance, users can monitor their water consumption through the smart dashboard and adjust their smart home system to conserve water and reduce their bills. Overall, the integration of smart dashboard and smart home technologies provides a streamlined and convenient solution for managing water usage and payments.

The study conducted in Vietnam at 2022 showed that a digital application integrated with an automatic water meter reading system could remotely collect statistics, detect and adjust abnormal water usage, and reduce NRW by up to 20% [4]. Furthermore, a digital application integrated with an automatic reading system is needed by water supply companies to improve the effectiveness of their business processes. Water company faces two main problems: water company need to handle unpaid customer bills manually, and the suboptimal control of water reading device location and status one by one. Improvements are necessary to alleviate the

time-consuming and labor-intensive nature of manual readings, as well as the negative effects of unpaid bills on the company's financial stability.

II. LITERATURE REVIEW

Internet of Things can be defined as a connection of people and things at any times and in any places . Internet of Things is an Internet-based large dynamic network which consists of many wired/wireless technologies, all types of information devices such as scanners, infrared devices, radio frequency identification devices, wireless sensor and actuator networks, smart cell phones (to identify, connect, communicate, and manage things and objects), and the Internet [5].

2.1 Smart Dashboard in Water Meter Reading

Smart dashboard technology has a critical role in the automated water meter reading system based on the Internet of Things (IoT) [6]. One of the main functions of smart dashboard technology is to provide real-time insights and analytics on water usage to end-users. By integrating IoT devices, smart dashboard technology can collect and analyze data from water meters in real-time, providing users with accurate and timely information on their water usage. This data empowers end-users to monitor their water consumption patterns and make necessary adjustments, leading to lower water bills and reduced wastage. Additionally, smart dashboard technology can notify users of potential leaks or abnormal water consumption patterns, allowing them to take prompt corrective action and prevent significant damage.

Another crucial role of smart dashboard technology in water meter reading is to offer end-users a user-friendly interface to access and manage their water usage data. With an intuitive user interface, end-users can conveniently view and analyze their water usage data, including historical usage patterns, daily usage, and even real-time usage data. This data can help end-users make informed decisions about their water consumption, allowing them to optimize their water usage and reduce wastage. Furthermore, smart dashboard technology can enable users to set up alerts and notifications for any issues related to abnormal water consumption patterns, leaks, or other problems, ensuring quick and effective responses. Overall, the use of smart dashboard technology in water meter reading provides end-users with powerful tools to monitor and manage their water consumption, resulting in more efficient usage, reduced waste, and cost savings.

2.2 Monitoring Water in Smart Dashboard

In the implementation of smart dashboard technology in an automatic water meter reading system based on the Internet of Things, IoT technology will be integrated with a conventional water meter embedded in the water supply pipe (Linflow water meter), which will then be added as a retrofit to be able to read the water meter value. Once successfully integrated, the IoT device will send water usage data for each customer with a different device ID using Lorawan technology to the PT Telkom Lorawan Gateway and store it on the PT Telkom Lorawan network server named Antares. The data sent is still encrypted, so decryption is required first using Node JS. When the data is successfully decrypted by Node JS, the data is stored in cloud servers (Id Cloud Host). The React JS framework is used to display the data on the smart dashboard. Figure 1 provides an overview of data communication.

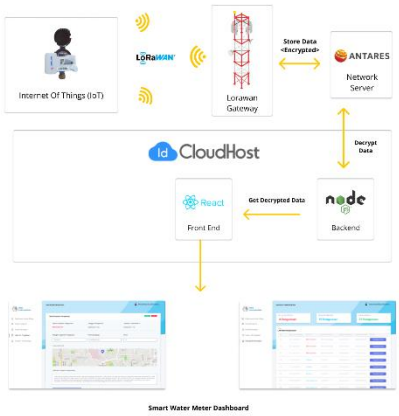

Figure 1 Data Flow on Smart Dashboard

III. RELATED WORK

In recent years, the development of smart dashboards for water management has progressed rapidly. Existing technologies enable quick monitoring of water usage and remote assessment of water quality. This research introduces a novel approach to water usage control by leveraging a smart dashboard, which allows water customers to directly monitor and pay their water bills through the application. Table 1 presents a comparative analysis of relevant works related to smart dashboards for water monitoring.

Table 1 Comparison Analysist for Smart Dashboard

Reference	Water Use Management	Water Billing Payment	Water Meter Reading Accuracy
Nguyễn et All [4]	Yes	No	High
Maulana et All [6]	Yes	No	High
Putra et All [7]	Yes	Yes	High
Harika et All [8]	Yes	No	High
Pablo et All [9]	Yes	No	High
Li et All [10]	Yes	No	High
Bassir et All [11]	Yes	No	High
Hasibuan et All [12]	Yes	No	High
Ray et All [13]	Yes	No	High
Rapelli et All [14]	Yes	No	High
Herath et All [15]	Yes	No	High

IV. PROBLEM STATEMENT

The issue of water scarcity is a major concern in numerous countries, which is further aggravated by the high levels of non-revenue water (NRW) resulting from leaks,

theft, inaccurate metering, and corrupt practices. As a result, the development of a smart dashboard system that integrates with an automatic water reading device presents several challenges, including:

1. The process of manually recording water meter readings requires a significant number of field staff, which is having a negative impact on the company's finances,
2. Handling unpaid customer bills is also contributing to the financial instability of the water company. The more unpaid bills there are, the worse the situation becomes.

V. PROPOSED METHODE

The Smart Dashboard application serves multiple roles with varying priorities. Water customers can log in, request device installations, view water usage reports, make bill payments, and submit complaints. Super Admins have login access and manage various administrative tasks, including billing and account management, water prices, devices, and complaints. Admin Billing handles billing accounts, water prices, devices, and complaints. Field Officers manage device installation requests, devices, and complaints. Overall, the user-friendly Smart Dashboard streamlines water operations, empowering different roles to efficiently manage their responsibilities.

The development of the smart dashboard for (IoT) application-based automated water meter reading system utilizes the design thinking approach to identify problems, create innovative solutions, and ensure a user-centric experience. By embracing design thinking, the team can deeply empathize with the end-users, understand their needs, and design solutions that truly address their pain points. This human-centered approach allows for a more holistic understanding of the problem space, leading to more effective problem definition, ideation, prototyping, and testing. Ultimately, design thinking enables the team to develop a Smart Dashboard that not only meets the functional requirements but also delights the users with an intuitive and seamless experience.

4.1 Empathize Stage

The initial stage of the Smart Dashboard development process for the Internet of Things Application-Based Automated Water Meter Reading System starts with the empathize stage, which involves the development team gathering data by conducting interviews with respondents who have profiles that match the application's target market. The purpose of this empathize stage is to comprehend the problems faced by the target market so that during the development process, each idea generated can effectively address the issues that the target market is experiencing.

4.2 Define Stage

After completing the empathize stage, the development team moves on to the second stage called the define process. At this stage, the team focuses on defining the users' needs and divides them into four different segments in Table 2.

Table 2 Role Type on Smart Dashboard

Role	Description
Water Customers	Water customers are the main users of this application, where they need a way to read water quickly and accurately, and want payments directly within the application.
Super Admin	Super admin is a role that has the function of tying all Admin Billing accounts, and Field Officers so that work is more structured. In addition, Super Admin can access all data in the application.
Admin Billing	Admin billing is a role that has responsibility for managing business processes based on each sub-district that has been owned, including installing devices, recording payment data, and handling complaints.
Field Officers	Field officers are officers who have been plotted based on sub-districts and have the function of installing devices at customer homes and coming directly when there are reports of complaints that need to be resolved directly on the spot.

4.3 Ideate Stage

The third stage, ideation, involves brainstorming ideas for application solutions that can effectively address the problems identified in the previous stages. Table 3 the following list outlines the minimum feature requirements essential for the development of a smart dashboard.

Table 3 Feature Requirements for Smart Dashboard

No	Role	Priority	Feature
1	Water Customers	Med	Login and registration
2		High	Device installation request
3		High	Water usage report
4		High	Water bill payment
5		Med	Complaint report
6	Super Admin	Med	Login
7		High	Admin billing account management
8		High	Water customers account management
9		High	Field officers account management
10		High	Water price management
11		High	Water reader device management
12		Med	Complaint report management
13	Admin Billing	Med	Login
14		High	Water price management
15		High	Water reader device management
16		Med	Complaint report management
17		High	Device installation request management

No	Role	Priority	Feature
18	Field Officers	Med	Login
19		High	Device installation request management
20		High	Water reader device management
21		Med	Complaint report management

4.4 Prototype Stage

At this stage, a physical or digital representation of the solution ideas generated in the previous stage (Ideate) are created. The purpose of creating a prototype is to test the viability of the solution ideas and to obtain feedback from potential users. The following is a high-fidelity display of each smart dashboard user role.

a. Water Customers Dashboard

The water customer dashboard is an all-in-one online platform that simplifies the management of water usage and bills for customers. After logging in and registering, users can access various features, such as requesting the installation of water usage monitoring devices. The platform also offers a real-time water usage report for customers to monitor their consumption. Bill payment is made hassle-free through the dashboard's online payment system. Figure 2 provides an overview of the water customers dashboard interface.

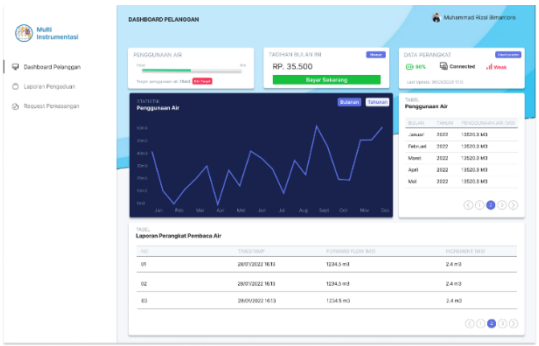

Figure 2 Water Customer Dashboard

b. Super Admin Dashboard

Super admin dashboard is a centralized platform that offers various features to manage and monitor the water management system efficiently. Overall, the super admin dashboard provides a comprehensive view of the water management system, making it easier to manage and monitor different aspects of the system [5] [7]. Figure 3 provides an overview of the super admin dashboard interface.

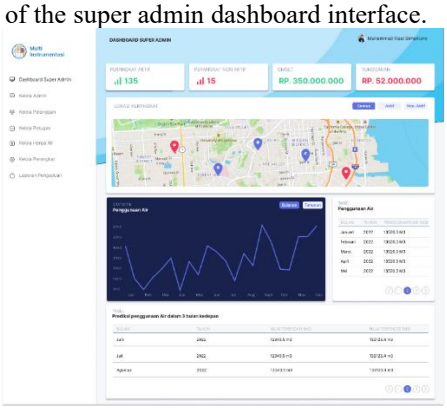

Figure 3 Super Admin Dashboard

c. Admin Billing Dashboard

Admin billing is a web-based platform designed to manage water billing activities. With these features, super admin billing provides a comprehensive solution for managing water billing activities. Figure 4 provides an overview of the admin billing dashboard interface.

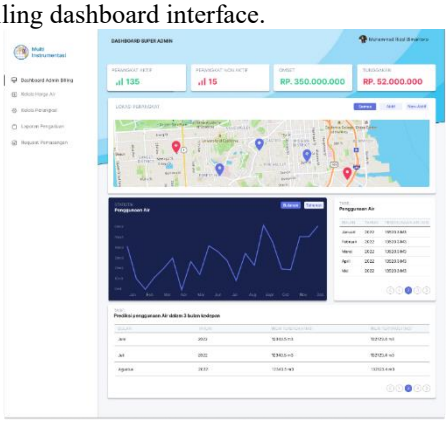

Figure 4 Admin Billing Dashboard

d. Field Officers Dashboard

Field officer dashboard is an online platform designed for field officers who are responsible for managing and monitoring the water supply network. The platform provides various features that allow field officers to efficiently manage their tasks. The dashboard can be accessed through a login process, which ensures that only authorized personnel can access the platform. Overall, the field officer dashboard is a powerful tool that helps field officers manage and monitor the water supply network more efficiently. Figure 5 provides an overview of the field officers dashboard interface.

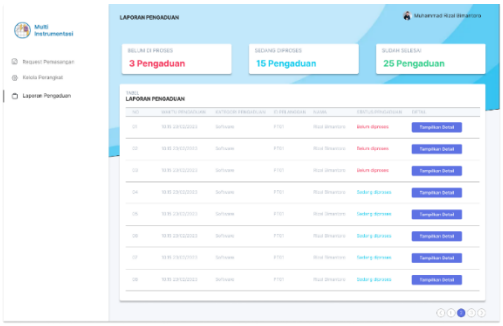

Figure 5 Field Officers Dashboard

In addition to the smart dashboard interface display device, in the development process, the backend part of the smart dashboard generates encrypted data from the AMR unit. Encryption is done to maintain data security so that it is not easily broken into by irresponsible parties. In the process of decrypting the data available at Antares, a javascript-based framework, namely Node JS, is used. The decryption results are stored in a cloud-based database, which is then displayed on the smart dashboard. Figure 6 provides an overview of the data sent into Antares

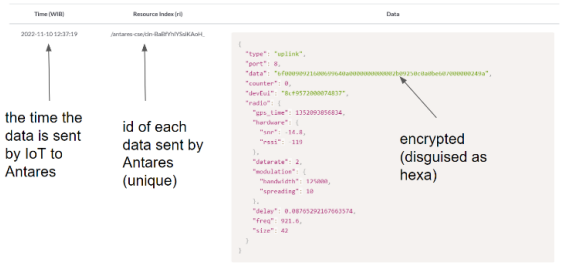

Figure 6 Data on Antares

Encrypted data has a reading pattern before being reversed, found in Figure 7.

Start	Water Number	Forward Flow	Backward Flow	Water Unit	Timestamp	Status Byte	Battery Voltage	Check Byte
6f	99066021090900	00000a64	00000000	2b	07e60b0a0c2509	000000	24	9a

Figure 7 Encrypted Data Before Reversed

After finding a pattern in the encrypted data, a hexadecimal transformation (forward flow, backward flow, water unit, timestamp, byte status, and battery voltage) is performed on Figure 8.

Start	Water Number	Forward Flow	Backward Flow	Water Unit	Timestamp	Status Byte	Battery Voltage	Check Byte
6f	99066021090900	2660	0	1L	9s 37m 12j 10 - 11 - 2022	0	36	9a

Figure 8 Encrypted Data After Reversed

The data is converted to JSON format with the help of the Node JS framework found in Figure 9.


```
{
  "startValue": "9f",
  "waterNumber": "99066021090900",
  "forwardFlow": "2.66 m3",
  "backwardFlow": "0 m3",
  "waterUnit": "1L",
  "timeStamp": "10-11-2022 12:37:9",
  "statusByte": "0",
  "batteryVoltage": "3.6V",
  "checkByte": "9a"
}
```


Figure 9 Decrypted Data

The json formatted data is then displayed in the smart dashboard application using the React JS framework. Figure 10 provides an overview of the displayed data on dashboard interface.

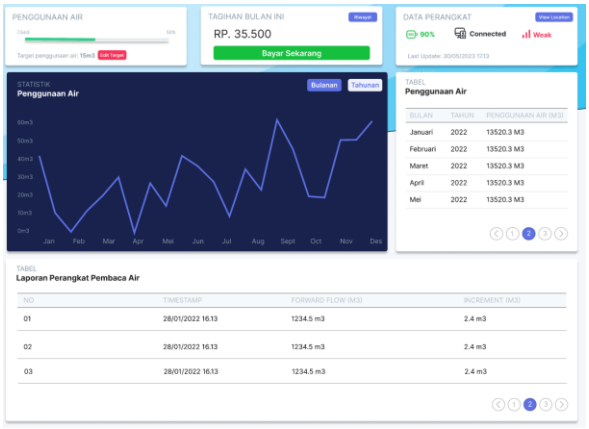

Figure 10 Data Transformation into Graphics

4.5 Testing Stage

The final stage is the testing phase, which evaluates the user interface's ease of application for each user role in the smart dashboard. This testing process involved four test scenarios for each role, utilizing the usability testing method with the maze tool. The measurement method for the tests employed a system usability scale. The following are the performance results of the website interface based on registered user roles [8].

The overall average score of the system usability scale is 89,5. When interpreting this overall average value, we can observe that a score of 89,5 falls under the "Acceptable" category in terms of acceptability aspect. Referring to the grading scale, this score is equivalent to a "B" grade. Furthermore, on the adjective scale, the rating falls under the "Excellent" category. These findings indicate that overall, the assessed interfaces or features received a favorable rating from the respondents. Figure 11 depicts the results of the SUS test.

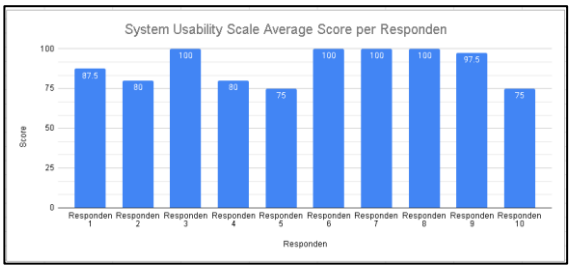

Figure 11 System Usability Scale Result

In addition to testing the smart dashboard interface, we also checked the accuracy of the water meter reader, which showed a difference of only 0.02 m^3 with evidence as water meter and screenshot of data reception on Figure 12.

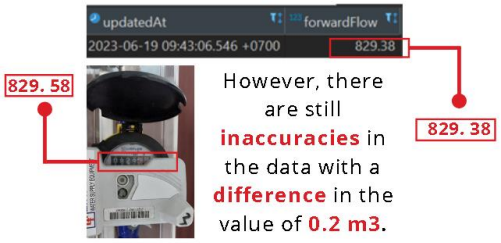

Figure 12 AMR Reader Result

VI. Conclusion

The smart dashboard water meter application has proven to be a beneficial solution for the water company's financial issues by eliminating manual water meter reading and reducing field staff costs. The integration of features such as water usage monitoring, online bill payment, and complaint reporting can help reduce unpaid bills and provide a convenient experience for customers. The application can improve financial stability and enhance service quality. Results from testing show the effectiveness of the dashboard interfaces, with scores above 8.95, and accuracy testing on the water meter reader demonstrated a low difference of only 0.2 m3, providing further support for the implementation of the smart dashboard water meter application.

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