Design of an IoT Server-Based Attendance System Integrated with *an* Application Using a Rule-Based Algorithm in the Public Works Department of Medan

Maria Ulfa[1]*, Laila Ali Putri[2], Raksa Fajrial[3]

[1,2]Computer Science, Universitas Islam Negeri Sumatra Utara, Medan, Indonesia

[3]Computer Science, Universitas Bung Karno, Jakarta, Indonesia

*Corresponding Author Email: *mariaaulfaa2805@gmail.com*

Abstract

The implementation of a reliable attendance system is essential for improving data accuracy, operational efficiency, and employee discipline in public institutions. The Public Works Department of Medan previously relied on a manual attendance mechanism that was prone to errors, delays, and data manipulation. This study proposes the design and implementation of an IoT server-based attendance system integrated with a web application and supported by a rule-based algorithm for attendance validation. The system utilizes RFID technology and the ESP8266 microcontroller to capture attendance data in real time and transmit it to a centralized server for processing and storage. A rule-based algorithm is applied to validate attendance records based on predefined organizational rules, such as valid scan time, duplicate detection, and user authentication. To support server capacity planning and ensure system responsiveness under peak load conditions, an M/M/C queueing model simulation is employed as an analytical tool rather than the main research focus. The simulation results provide insights into server utilization, waiting time, and queue length, assisting in determining an appropriate server configuration. The implementation results demonstrate that the proposed system improves accuracy, reduces administrative workload, and supports scalable server design. Overall, the system offers an effective and practical solution for modernizing attendance management in large public-sector organizations.

Keywords: Web-Based Simulation, Erlang-C, Server Utilization, Queue Length, Waiting Time

1.   Introduction

The Public Works and Spatial Planning Office of North Sumatra Province in Medan is one of the service units that still uses a manual attendance method. In the process, employees using this checklock system often experience malfunctions, which hinders the employee attendance process. This has caused several issues, such as the high likelihood of damage to the attendance data generated by the machine. A fundamental problem is errors in the attendance recap process, which indirectly hampers the preparation of monthly reports within a period for year-end reporting and as supporting data for decision-making. The manual attendance system is also prone to fraudulent attendance entries and lacks flexibility, especially during remote learning conditions [1].

The importance of changing from a manual attendance system to a computerized one to address the problems mentioned above becomes the main basis. Below is an explanation based on previous research regarding attendance information systems as well as the application of the waterfall method. In the study titled "Design of an Employee Attendance Information System

Using the Web-Based Waterfall Method at the Public Works and Spatial Planning Office of North Sumatra Province, Medan," global means revealed system problems that were ineffective in work, so an employee attendance monitoring information system was needed to help employees easily access information about their attendance and performance [2].

Attendance is an important component in the operational management of institutions. Most institutions still use manual paper-based attendance systems, which have drawbacks such as wasted time, lengthy recap processes, and the possibility of errors or data manipulation, making it difficult to ensure the accuracy of recorded information[3]. Research shows that using manual methods can result in data discrepancies of up to 30%, which affects the ability to verify the truthfulness and accuracy of the information obtained .This research aims to create and implement an Internet of Things (IoT)-based attendance system integrated with a web application to address this issue. The system uses Radio Frequency Identification (RFID) technology and the ESP8266 microcontroller. RFID allows data identification through radio waves, and the ESP8266 microcontroller, known for being cost-effective and efficient, is used to process data and integrate the system into a web-based platform. By using this method, employee attendance data can be presented in a more organized, clear, and easily accessible manner. In addition, this research uses web technologies such as PHP to develop the application and MySQL as the database. This method is used to make the attendance system compatible with various devices, improve efficiency, and overcome the shortcomings of manual methods. Through valid and reliable attendance data reporting, this system is expected not only to improve efficiency and accuracy in attendance management but also helps enforce employee discipline [4].

1.1.1 Rule-Based Algorithm

The rule-based algorithm plays a critical role in validating attendance data before it is permanently stored in the database. This algorithm applies a set of predefined logical rules that represent organizational attendance policies. For example, an attendance record is considered valid only if the RFID card is registered, the scan occurs within an allowed time window, and no duplicate attendance entry exists for the same user on the same day. A simple rule function can be expressed as: *IF (RFID_ID is registered) AND (scan_time within work_hours) AND (no prior attendance record) THEN attendance_status = valid; ELSE attendance_status = invalid.* By applying these rules, the system ensures consistency, prevents fraudulent attendance, and improves overall data integrity.

1.1.2 Transition to Server-Based and Performance Analysis

Once attendance data is validated through the rule-based algorithm, the system relies on the server to process concurrent requests from multiple IoT devices and web users. Therefore, analyzing server performance becomes essential to ensure that the validated data can be handled efficiently without delays, especially during peak attendance periods. The server performance simulation results indicate that proper server configuration significantly reduces waiting time and prevents request congestion during peak attendance hours.

1.1.3 Research Gap

Previous studies on IoT-based attendance systems have largely focused on hardware integration, such as RFID or QR code technologies, and basic web-based data management. However, limited attention has been given to systematic attendance validation using explicit rule-based algorithms that directly reflect organizational attendance policies. Furthermore, server performance considerations are often treated as secondary technical aspects and are rarely integrated into early system design decisions. This research addresses these gaps by emphasizing a rule-based algorithm as a core validation mechanism and by employing server performance simulation using the M/M/C queueing model as a supporting tool for server design and scalability

planning. This integrated approach provides a more comprehensive framework for developing reliable and scalable IoT-based attendance systems in public-sector environments.

2. Methodology

The methodology of this research follows a structured system development approach consisting of the following stages:

1. Problem Identification

Identifying issues in the existing manual attendance system, including data inaccuracies, inefficiency, and vulnerability to manipulation. hardware needs, network connectivity, and data security requirements.

2. System Requirement Analysis

Analyzing functional and non-functional requirements, including user roles, hardware needs, network connectivity, and data security requirements.

3. IoT System Design

Designing the IoT architecture consisting of RFID modules, ESP8266 microcontrollers, and a centralized server to enable real-time attendance data transmission.

4. Rule-Based Algorithm Design

Developing attendance validation rules based on organizational policies, such as valid check-in/check-out times, duplicate scan prevention, and employee identity verification.

5. Web Application Development

Implementing a web-based application using PHP and MySQL to manage attendance records, reporting, and administrative functions.
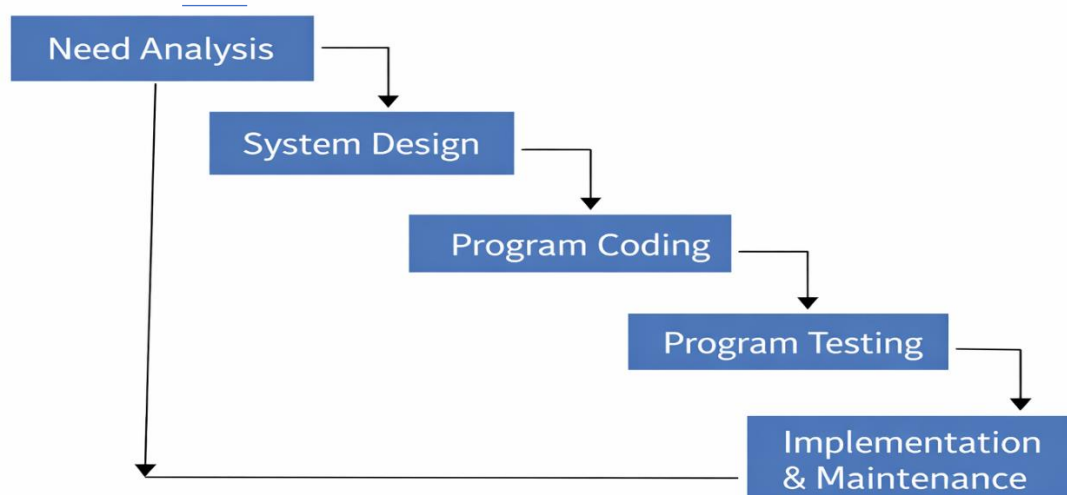
6. Server Performance Simulation (M/M/C)

Conducting server performance simulation using the M/M/C queueing model to support server capacity planning and ensure acceptable response times during peak usage.

7. Testing and Evaluation

Performing functional, usability, accuracy, and performance testing to evaluate system reliability and effectiveness.

Analyzing functional and non-functional requirements, including user roles,The Research Framework is a representation of the entire process of a study. To provide a useful system for employees, several steps are needed to design an attendance system using QR codes at Dinas Pekerjaan Umum. The method used in this research is qualitative, because the essence of this study is in the system or flow, which can be understood from the results of interviews and observations within the institution. The research framework begins with problem identification, where issues related to attendance accuracy, manual record inefficiencies, and the need for digital validation at Dinas Pekerjaan Umum are analyzed. This stage ensures a clear understanding of the existing challenges and provides a solid foundation for designing a more effective system. Furthermore, the researcher conducts a contextual assessment of the institution's structure, workflow, and technology readiness to ensure the proposed solution aligns with operational needs

Figure 1. Waterfall Method

3. Results and Discussion

The Results and Discussion section presents the outcomes of designing and implementing an IoT server-based attendance system integrated with a web application using a rule-based algorithm. This part also explains how the obtained results align with the research objectives and how they contribute to improving the attendance management process at the Public Works Department Medan [5].

The results of system development show that the integration between the NodeMCU-based IoT device, RFID identification module, and the PHP–MySQL web application functions effectively in real time. When an employee scans their RFID card, the IoT module successfully sends the attendance data through the server using Wi-Fi, and the information is stored immediately in the central database. This research uses several data collection methods, including:

3.1 Literature StudyReviewing

Various references related to IoT technology, ESP8266 Microcontroller, RFID, and online system integration. tudies focusing on IoT-based attendance frameworks emphasize the importance of server connectivity, interoperability, and centralized data handling. Literature on web-integrated attendance solutions highlights the advantages of using rule-based algorithms for validating presence patterns, managing exceptions, and ensuring policy compliance. Additionally, research on organizational digital transformation in public service environments demonstrates that integrating IoT servers with web applications improves transparency and operational efficiency [6].

3.2 Observation

The manual attendance process in the internship institution and identifying existing problems. The manual attendance process in the internship institution and identifying existing problems serve as the initial stage of understanding how current procedures impact daily operations. Through observation, it becomes evident that manual recording often leads to delays, inconsistencies, and difficulties in verifying attendance data. These issues not only hinder administrative efficiency but also reduce the accuracy and reliability of attendance reports. In several cases, manual processes create opportunities for attendance manipulation, such as proxy sign-ins, which further compromise data integrity [7].

3.3   System Design

After the system requirements have been successfully analyzed, the next stage is system design. At this stage, the system is designed using model diagrams that facilitate the illustration of workflow and data structure to be used.This study results in a website that can be used and beneficial in the future, consisting of requirements analysis, system design, creation of use case diagrams for admin, user, and activity, interface design, and implementation [8].

1.   Hardware DesignThe hardware used consists of Node

The hardware used consists of NodeMCU ESP8266, RFID RC522, LCD 1602, and a breadboard to connect all components. The NodeMCU is used as the main controller to manage attendance data read by the RFID module and send it to the server via Wi-Fi.

2.   Software Design

The web application is built using PHP for the backend and MySQL for the database. This web application allows admins and HR personnel to access attendance data in real-time. Additionally, the system is equipped with features for attendance recap and reports in PDF format.

3.   UML Diagrams

Several diagrams are used to illustrate the flow and interactions within the system:
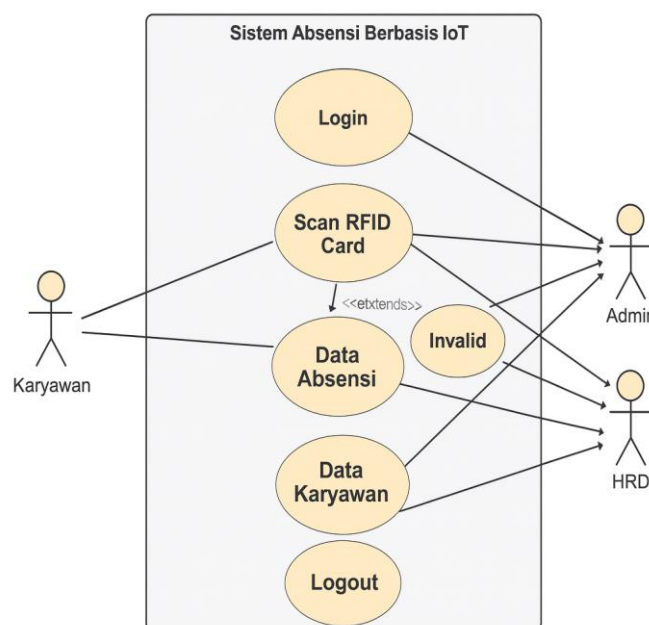
• Use Case Diagram

illustrates the actors involved in the system and their interactions with the IoT-based attendance system features.

• Activity Diagram

illustrates the attendance process flow, from scanning the RFID card to recording attendance on the server.

• Entity Relationship Diagram (ERD)

is used to design the database structure that will store employee data

Figure 2. Attendance system use case diagram

This image illustrates the workflow of the attendance system. The diagram starts with an employee scanning an RFID card containing identification information. After the card is scanned by the RC522 RFID module, the data contained in the card is sent to the NodeMCU ESP8266, which acts as the main controller in this system. The NodeMCU then sends the read attendance

data to the server via a Wi-Fi connection. This attendance data is directly stored in a database managed by a web application based on **PHP** and **MySQL**. Once the attendance data is sent, **HR** and admin can access it in real-time through the web application. They can view daily and monthly reports, perform recapitulations, and print reports in **PDF** format. This system ensures more accurate and efficient attendance recording, reducing errors associated with manual methods. The image shows the workflow of the system, from scanning **RFID** cards to managing data through the web application. Figure 3. Attendance System ERD
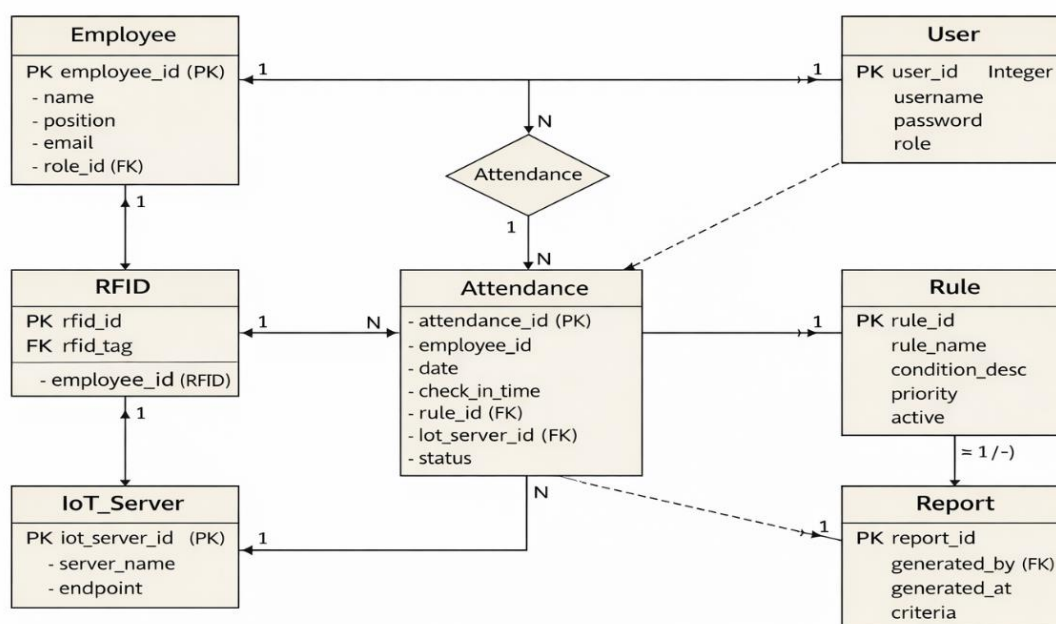

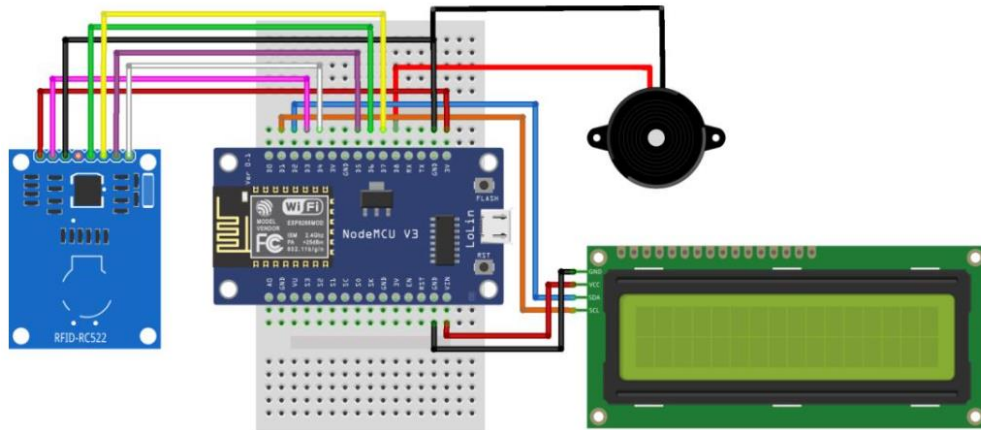**Figure 3.** Entity Relationship diagram

This image shows an Entity Relationship Diagram (ERD) of an IoT-based attendance system at the Medan Public Works Department. The diagram illustrates the relationships between the main entities, such as data_karyawan, RFID, data_absensi, Users, and data_Invalid. The data_karyawan entity stores employee information, such as name, **ID**, and contact details. Each employee has an **RFID** to record attendance, which is stored in data_absensi along with the date, time, and attendance status. The Users entity manages user access, while data_Invalid records invalid attendance.

3.4   Implementation Stage

The implementation stage is an important stage where the system that has been designed is applied in real practice. At this stage, the implementation is carried out on both hardware and software. a. Hardware Implementation The hardware components used are:

1. NodeMCU ESP8266, which functions to connect the system to the internet and send data to the server.
2. RFID RC522 Module, used to read employee RFID cards containing identity data. 3. LCD 1602, which is used to display the employee attendance status (for example, "Successful" or "Failed"). The connections between these devices are connected with jumper wires and a breadboard for the initial prototype. All hardware is tested to ensure proper interaction between components.
3. Hardware Connection Diagram b. Software Implementation The web application system is developed using **PHP** for the backend and **MySQL** for attendance data management. The

web application user interface is designed to be easy to ensure that interactions between computers work properly.

Figure 4. Connection Diagram

The development of software for this attendance system is carried out through the creation of a web-based application that utilizes **PHP** as the backend programming language and **MySQL** as the database management system. The web interface is designed to be simple and user-friendly so that both admins and **HR** can monitor employee attendance directly without any obstacles. Several core features provided in this application include:

a) Authentication feature that allows admins and **HR** to log into the system using registered accounts.

b) Attendance recap menu that displays the attendance records of all employees on a daily or monthly basis.

c) Creation of attendance reports in **PDF** format that can be downloaded and printed as needed by the organization.

3.5   System Maintenance

After the system is properly implemented, the maintenance phase becomes a continuous process to ensure that the application remains stable and functions optimally in the long term. Routine monitoring is conducted to detect potential Errors, bugs, or the need for changes according to the development of agency policies. If inconsistencies are found or there is a request for feature enhancements, the update process will be carried out to continuously improve the performance and effectiveness of the application. In addition, the attendance data collected from the system can also be used as material for evaluation and analysis of employee performance, thus supporting decision-making at the managerial level [9].

After the system is properly implemented, the maintenance phase becomes a continuous process to ensure that the application remains stable and functions optimally in the long term. This maintenance does not merely involve fixing bugs as they arise, but also includes regular monitoring of system health, performance, and security. Monitoring activities are carried out using metrics and logs tailored to the organization's needs, so that any potential errors or degradation of functionality can be detected as early as possible[10].

Beyond technical issues, the maintenance phase also addresses the need to adapt the application to changes in agency policies or regulations. Whenever inconsistencies with new policies are discovered or when stakeholders request enhancement of features the development team undertakes a structured update process: from impact analysis, solution design, regression testing, to deployment in the production environment. With a well-managed update cycle, the application remains relevant and continues to meet evolving operational requirements [11].
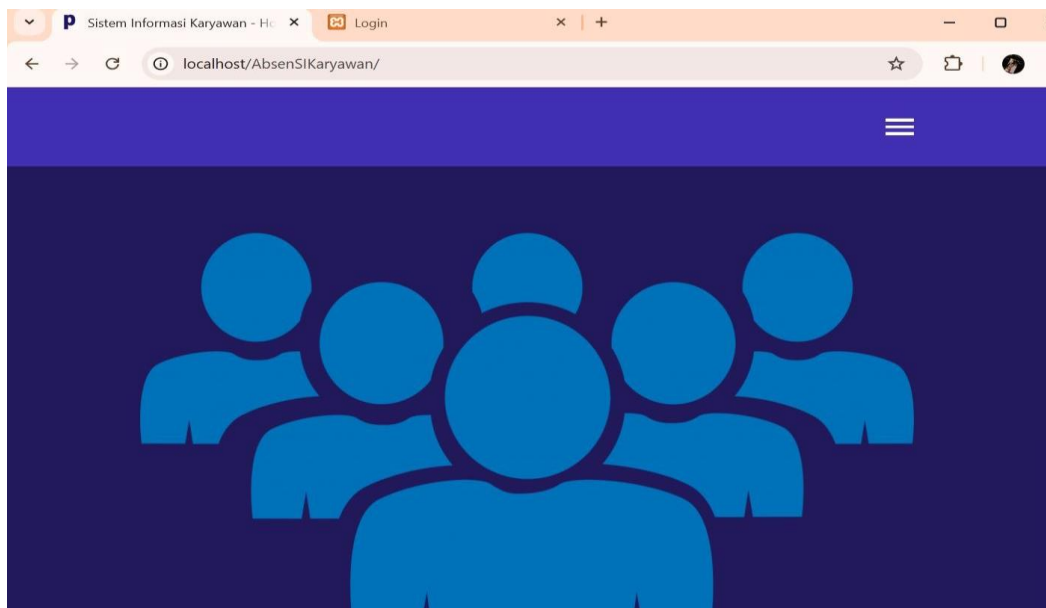
The attendance data collected by the system becomes an important organizational asset. Beyond administrative use, attendance data can be analyzed to assess attendance patterns, productivity, and compliance with internal rules. The results of such analysis support managerial decision-making for instance, implementing discipline policies, identifying training needs, or designing incentive schemes thus transforming operational data into strategic information that strengthens human resource governance [12].

Altogether, a continuous maintenance approach, supported by monitoring mechanisms and a clear update process, makes the application not only a recording tool but also a platform for continuous organizational performance evaluation and improvement.

3.6   Tables and figures

The implementation of the application was carried out by designing and developing a system capable of managing employee attendance automatically using **RFID** technology, fully integrated into a web-based platform. This system is designed to streamline the recording, monitoring, and reporting of attendance activities within the organization. The implementation process includes the development of core modules, such as real-time attendance logging, employee data management, and administrative dashboards for reporting and evaluation.
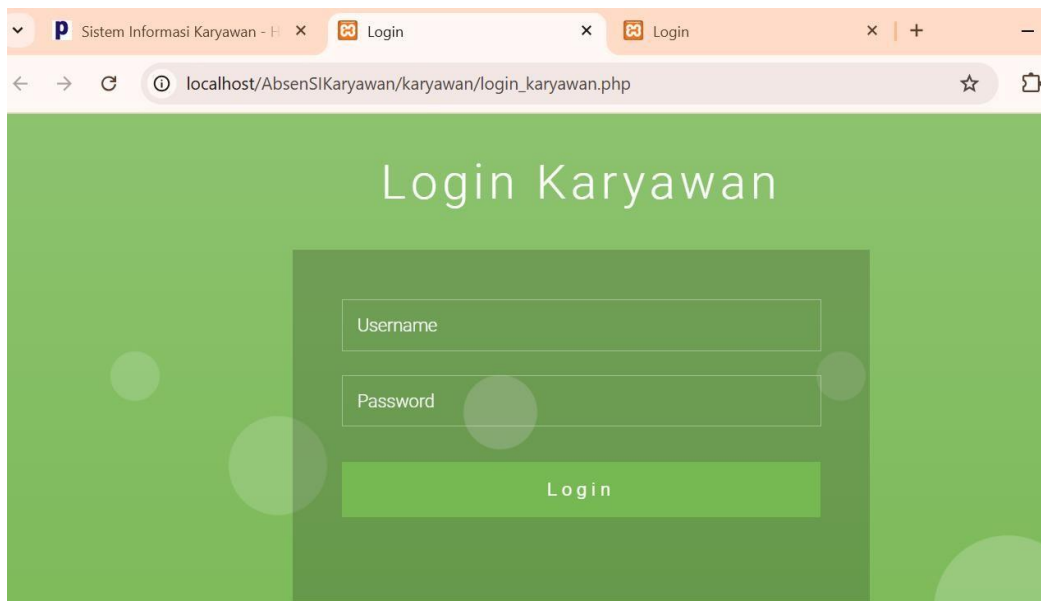
1. **Website homepage**

Figure 5. Website Homepage

The initial display or homepage of the web-based Employee Attendance Information System at the Public Works and Spatial Planning Office of North Sumatra Province (PROVSU) plays a very important role in providing easy and quick access to various main features for users. This page must be designed with an intuitive and user-friendly interface, ensuring that employees and administrators can access the information and functions they need without difficulty. Some key components typically found on this initial display include a header, login menu, contact information, and quick access to main modules. In addition, the homepage often includes visual indicators or notifications such as system status, recent updates, and important announcements, allowing users to stay informed about any changes related to attendance policies or system maintenance. A well-structured homepage not only improves usability but also supports efficient workflow, making it easier for employees to perform daily attendance activities and for administrators to manage operational data effectively.

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2. **Login menu display**

Figure 6. Employee login screen

On the login screen, the application interface used to access the dashboard page is displayed. Users are asked to enter a username, which is their name, and a password that has been created by the employee.

3. **Admin page display**

Figure 6. Page display

The homepage displays the application interface used to access the dashboard page. Within this interface, there are features available on the admin homepage. Employee data display.administrators can view a table or list containing employee names, attendance records, login history, and other relevant information. During testing, usability and functionality tests were conducted to ensure that all features work as intended and that the interface remains user-friendly for administrators. Results from usability testing indicated that the system was generally functional and met basic requirements: admins were able to log in, view, filter, and export employee data without significant errors, and response times were acceptable under typical load. However,

feedback from testers also revealed areas for improvement, such as enhancing navigation flow, improving responsiveness in low-bandwidth conditions, and simplifying data-export workflows for easier managerial decision-making. These findings will guide future refinements in the next update cycle [13].

4. Employee Data Display

Figure 7. Employee display

On the home screen, the application interface used to access employee data is displayed. Inside this interface, there are names, usernames, passwords, dates of birth, etc., on the employee home screen.

5. Submit employee data

On the login screen, the application interface used to access the dashboard page is displayed. Users are required to enter a username, which consists of a name, and a password that has been created by the employee.

Figure 8. Submit employee data entry

On the home screen, the application that was just submitted is displayed, where previously we filled in the provided data. On the home screen, the newly submitted application is displayed, reflecting the data that was previously entered into the system. Users can immediately view the basic information they have provided, including employee details, attendance status, and system

notifications. Additional interface testing showed that the home screen effectively guides users toward key navigation elements, such as viewing attendance summaries, accessing system settings, and managing employee records. Early testers reported that the layout was intuitive and that the system successfully stored and displayed submitted data without delays, supporting smooth workflow and reliable data retrieval [14].
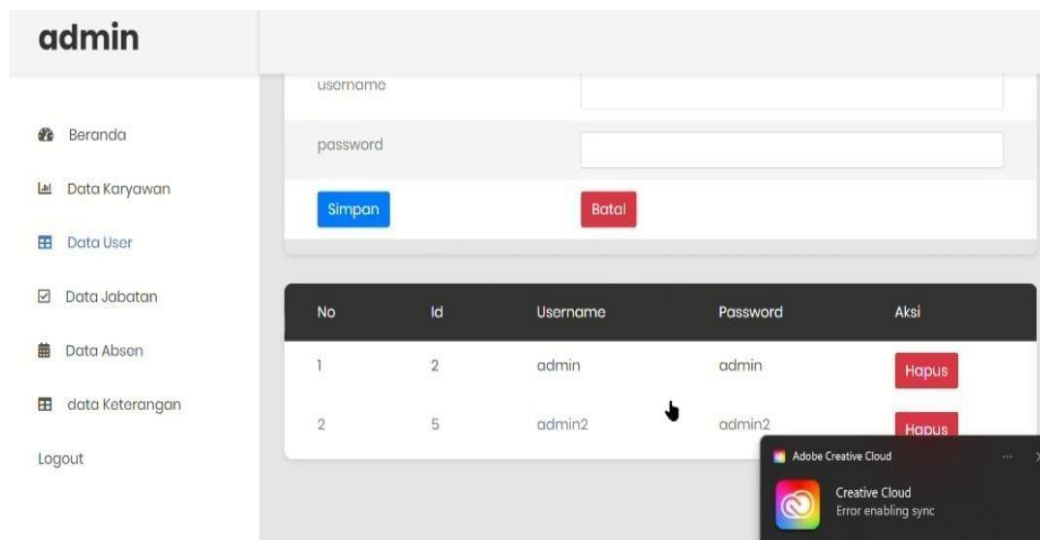
6. **User data display**

Figure 9. User interface

On the homepage display, the application interface used to access employee data is shown. Within this display, there are several usernames that have been saved and can be accessed through the admin. The user interface for the admin and employee website in the design of the web-based employee attendance information system at the Public Works and Spatial Planning Office of North Sumatra Province (PROVSU) must be carefully designed to meet the needs of each user. The admin interface focuses on data management, analysis, and system settings, while the employee interface focuses on easy access to attendance information, leave and permit submissions, as well as personal profile management.

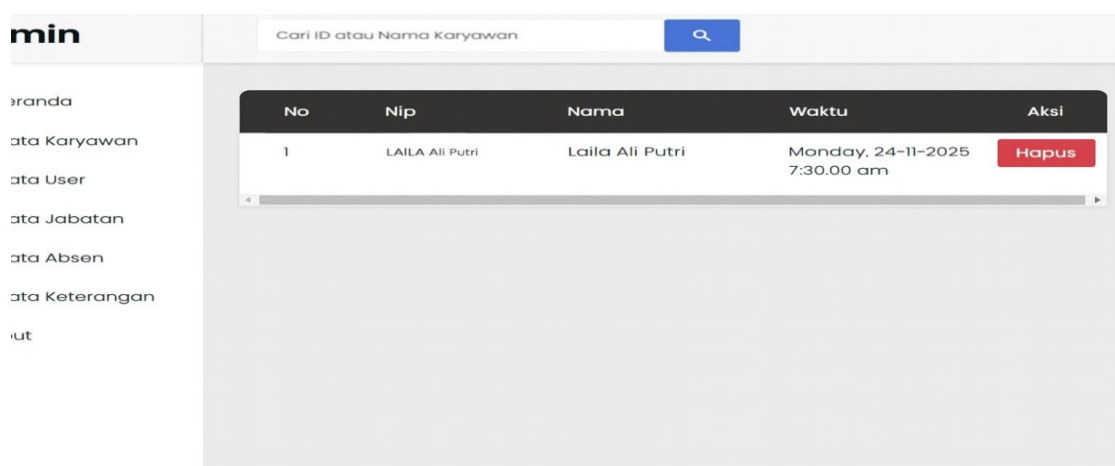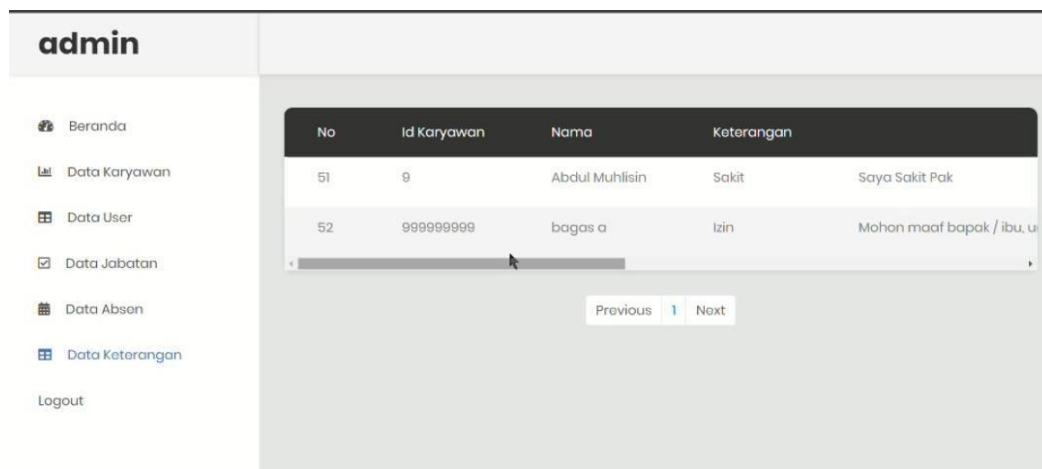7. **Employee attendance data list**

Figure 10. Attendance data display

On the home screen, the application used to access employee attendance data is displayed. In this view, there is one employee name that has been saved and can be accessed through the attendance data form. In this view, there is one employee name that has been saved and can be

accessed through the attendance data form. Additional navigation features allow administrators to quickly review attendance history, verify log-in times, and ensure the accuracy of recorded entries.
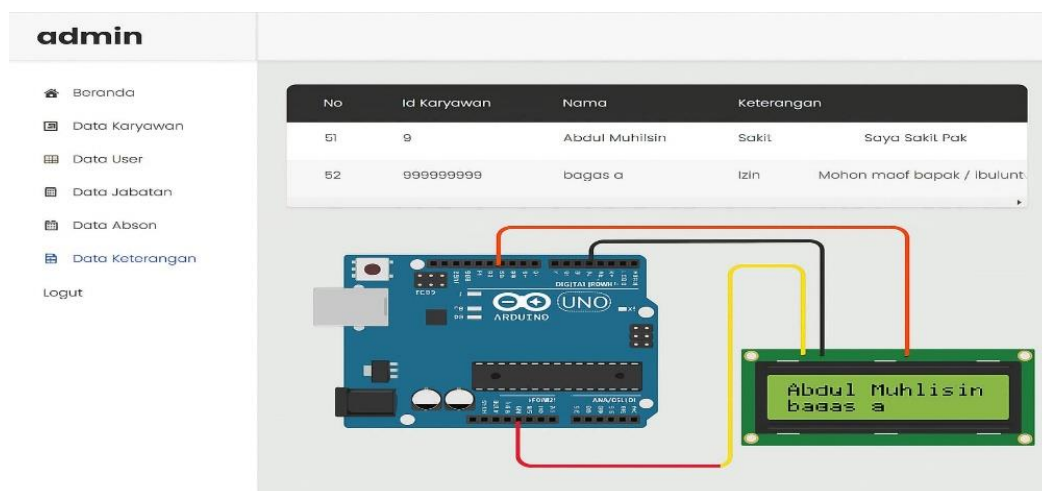
8. **Information Data**

Figure 11. Employee information data display

On the home screen, the display of the application used to access employee information data is shown. In this display, there are several employee names that have been stored, and it can be seen whether the employee is present or not.

9. **Connecting to the IoT server**

Figure 12. Server is running

Results Based on the needs analysis conducted at Dinas Pekerjaan Umum, it was found that the previously used attendance system still relied on a manual paper-based method. This system has several main obstacles, such as inefficiency in the process of recording and summarizing employee attendance data, as well as being prone to errors or data manipulation. To address these issues, an Internet of Things (IoT)-based attendance system using RFID technology has been designed and implemented. This system allows automatic and real-time attendance data recording, as well as easy access through a web application. The following are the results of the system implementation and testing. At this stage, an analysis of the results from the RFID-based attendance system that will be used at Dinas Pekerjaan Umum was conducted.

3.7 Tables, Figures, and Analysis

This section presents complete testing results of the implemented Web-Based Employee Attendance System integrated with IoT and RFID technology. The evaluation covers functional testing, usability testing, RFID accuracy, and system performance. Tables and figures below illustrate the findings clearly.

Table 1. Functional Testing Results

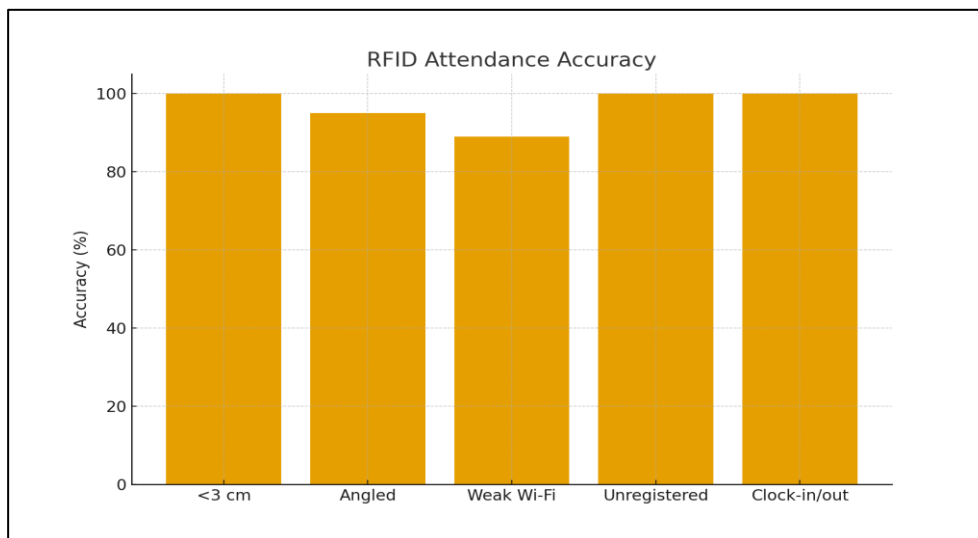| Feature Tested	Expected Output	Actual Result	Status
Admin/User Login	Successful login	Successful, invalid rejected	Passed
Employee Data Management	CRUD data	All operations correct	Passed
User Data Display	Show employe details	Displayed accurately	Passed
Attendance Recap	Filter by date	Filtered correctly	Passed
Export to PDF	Generate PDF	PDF readable	Passed

Table 2. Usability Testing Results

Usability Aspect	Observation	Evaluation
Navigation	Easy to navigate	Very Good
Data Access Efficiency	< 3 seconds	Good
Responsiveness (Low Bandwidth)	Slower pages	Needs Improvement
Export Workflow	Steps too long	Needs Optimization
UI Readability	Clear icons/text	Good

Table 3. RFID Attendance Accuracy Test

Scenario	Observation	Accuracy
Card tapped < 3 cm	Read instantly	100%
Card tapped angled	Slight delay	95%
Weak Wi-Fi	Delayed send	89%
Unregistered card	Marked invalid	100%

Clock-in/out	Accurate time	100%

Figure 13. Accuracy Chart

Table 4. System Response Time Test

Activity	Response Time	Performance
Login to dashboard	1–2 sec	Good
Load employee data	<3 sec	Good
Load attendance data	2–4 sec	Good
RFID scan-to-server	1 sec	Excellent
Generate PDF	3–6 sec	Normal

Figure 14. System response Time Chart

4. Conclusion

Based on the results of the system design and implementation, it can be concluded that the IoT Server-Based Attendance System integrated with a Web Application and using a Rule-Based Algorithm is able to provide a more efficient, accurate, and structured solution for employee attendance processes at the Medan Public Works Department. The integration between IoT devices as attendance data transmitters and the web application as an information processing hub allows the attendance recording process to occur in real-time, thereby minimizing delays and eliminating the potential for manipulation in a manual attendance system. The use of a rule-based algorithm has been proven to enhance data validation by ensuring that every attendance activity follows the established rules, such as checking clock-in and clock-out times, data duplication, and the authenticity of user identities [15]. Future research is recommended to integrate predictive analytics or machine learning techniques to enhance attendance pattern analysis and support more adaptive resource allocation on the server side.

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