Digital Transformation of Student Attendance: Backend Design Based on IoT Technology with RFID

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Abstract

This study aims to design and implement a student attendance system based on the Internet of Things (IoT) using Radio Frequency Identification (RFID) technology at SMP Negeri 35 Palembang. The main issue addressed is the manual attendance process, which is time-consuming, error-prone, and difficult in terms of managing and accessing student attendance data. The proposed system is expected to improve efficiency and accuracy in attendance recording while providing real-time data management convenience. The methodology employed includes system design, hardware (RFID) and software (web-based application) development, and system implementation in the school environment. The research results indicate that the IoT-based attendance system successfully replaces the manual system, enhancing the speed and accuracy of attendance recording, as well as facilitating data management for the school and providing accessibility for parents. However, challenges related to user adaptation and reliance on internet connection stability still need to be addressed. As a suggestion for future research, it is recommended to develop the system with additional features such as attendance analytics and integration with the school's academic system to support data-driven decision-making.

Keywords*: Digital Transformation, Internet of Things, Radio Frequency Identification, Student Attendance System*

1. Introduction

Education serves as the primary foundation for developing high-quality human resources. In its process, education in schools is not only focused on knowledge transfer but also on fostering students' discipline and responsibility [1]. One approach to supporting this development is through the implementation of an effective and organized attendance system. Attendance systems play a vital role in monitoring student presence, which serves as an indicator of their discipline and responsibility toward the teaching-learning process. However, many educational institutions, including Palembang Public Junior High School 35 (SMP Negeri 35 Palembang), still rely on manual attendance systems, which come with various limitations. Manual attendance systems often face significant challenges, such as recording errors caused by human mistakes, the risk of data loss due to physical files that are not integrated with digital systems, and time-consuming recapitulation processes that demand extra effort from administrative staff. These issues not only hinder efficiency but also reduce transparency in managing student attendance data [2].

In today's digital era, technology has rapidly advanced, offering innovative solutions for school administrative systems. One relevant technology is the Internet of Things (IoT), which enables devices to connect, share information, and provide real-time data [3]. In the context of student attendance, IoT can automate attendance recording, improve data accuracy, and enhance accessibility for both schools and parents [4]. Various studies have examined the implementation of IoT and RFID in student attendance systems. Research by Ardana et al. [7] demonstrated that an IoT- and RFID-based attendance system improves efficiency and real-time accuracy in attendance recording. Another study conducted at SMK Negeri 1 Cileungsi found that this system provides instant attendance monitoring and automated reporting for schools and parents [8]. Additionally, research by Sutarti et al. [9], which utilized an RFID sensor with an ESP8266 microcontroller and web integration, showed that this automated system not only enhances school operational efficiency but also simplifies attendance data management for administrative staff. RFID technology has been proven reliable across various industries, including logistics, banking, and security, making it highly suitable for student attendance systems [10]. With RFID, students only need to tap a card embedded with an RFID chip on a reader device, and their attendance information is automatically recorded in an IoT-based system [11]. This replaces manual methods prone to errors and significantly enhances school operational efficiency [5]. Other studies indicate that implementing an IoT-based attendance system

can replace manual attendance tracking with a more accurate and efficient automated system. Therefore, to improve efficiency and transparency, the development of an IoT-based attendance system using RFID is necessary at Palembang Public Junior High School 35. This system allows students to record their attendance automatically, making it easier for schools to manage attendance data and provide faster information to parents [6].

This study aims to design and implement an IoT-based attendance system with RFID technology at SMP Negeri 35 Palembang. The proposed system is expected to address various challenges previously encountered, such as reducing recording errors caused by human mistakes, minimizing the risk of losing attendance data, and speeding up the process of recapitulation and reporting. Additionally, the system provides real-time access to attendance data for both schools and parents, thereby achieving transparency and efficiency in managing student attendance. The utilization of IoT and RFID technologies in this attendance system fosters a more modern, integrated, and efficient learning environment. The implementation of this system aligns with the digital transformation efforts prioritized across various sectors, including education. Furthermore, the results of this study can serve as a model for other schools seeking to adopt similar technologies to enhance the quality of their administrative services.

2. Research Methodology

his study employs a qualitative method with a descriptive approach to describe and analyze the development process of an IoT-based attendance system with RFID technology at Palembang Public Junior High School 35, as illustrated in Figure 1. The Prototyping Model was adopted as the system development methodology to guide the stages of development. Activities in the Prototyping Model include [12]:

1. Defining the main objectives comprehensively and identifying the known requirements.
2. Quickly creating an initial design as the basis for prototyping.
3. Testing and evaluating the prototype, followed by adjustments and improvements based on evaluation results.

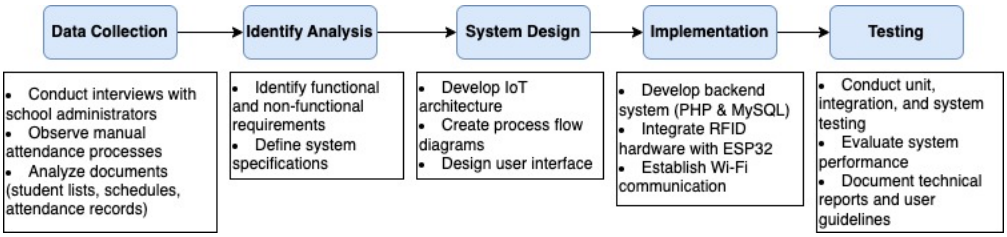

Fig. 1 Research flow

2.1 Data Collection

The study utilizes qualitative methods with a descriptive approach, aiming to describe and analyze how the development of a web-based information system at Palembang Public Junior High School 35 can enhance operational efficiency, transparency, and the quality of services to the community [13]. Data were collected using various techniques, including interviews, observations, and document reviews.

Interviews were conducted with school administrative staff to gather in-depth information about system requirements and challenges in managing student attendance data. Direct observations were carried out to examine the manual attendance process at the school, enabling a detailed understanding of the existing workflow. Additionally, document reviews were performed by analyzing related data, such as student lists, class schedules, and attendance records, to obtain a comprehensive picture of the current processes and potential improvements [14].

The research process began with initial data collection using these three techniques to gain a complete understanding of system requirements. Based on the collected data, a needs analysis was conducted to formulate system specifications, including both functional and non-functional requirements. The subsequent step involved system design, encompassing the development of IoT architecture, process flows, and user interfaces.

After completing the system design, the implementation phase began with developing the backend software, integrating RFID hardware, and ensuring that all system components functioned cohesively. The developed system underwent several testing stages, including unit testing, integration testing, and overall system testing, to ensure it met the specified requirements.

The final stage of the study involved evaluating system performance based on testing results, creating technical documentation, and preparing a user manual to facilitate system operation by school

personnel. This systematic procedure aims to produce an IoT-based attendance system with RFID technology that is effective, efficient, and tailored to user needs.

2.2 Device Design

The IoT-based attendance system, developed using Arduino IDE, relies on various tools and components to support its functionality. The ESP32 microcontroller serves as the central processing unit, handling data received from the RFID reader and managing communication with other devices. The RC522 RFID Reader module is used to read data from RFID tags, which contain unique identification information. RFID tags, in the form of cards or keychains equipped with unique chips, are used for identification. The system also includes a WiFi communication module, enabling internet connectivity for transmitting attendance data to a server. The schematic design of the RFID and ESP32-based attendance device is shown in Figure 2.

Figure 1 illustrates the schematic design of the IoT-based attendance device, incorporating the RFID module, ESP32 microcontroller, buzzer, and an LCD display for feedback. The RFID Reader reads data from RFID cards, which the ESP32 processes. The results are displayed on a 16x2 LCD, providing users with attendance status information. A buzzer serves as an indicator, notifying users of successful or unsuccessful attendance processes. All components are connected via a breadboard and powered by a 5V adapter, ensuring smooth integration for automated attendance.

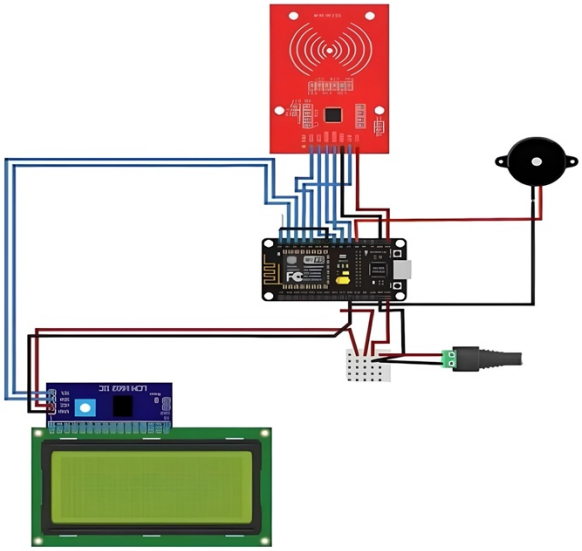

Fig. 2 Attendance Device Schematic

2.3 Backend System Design

The backend system for the attendance application is web-based and developed using PHP programming with MySQL as the database. Communication with IoT devices using RFID is programmed using Arduino language. The system requires a power source, such as an adapter or battery, to operate. Visual and audio indicators, such as buzzers and LEDs, signal when an RFID tag is successfully read. Attendance data collected from the system is stored in the MySQL database for recording and reporting purposes. Internet connectivity is essential to facilitate communication among devices in the IoT system. Supporting documents, such as attendance records, student lists, and class schedules, are used for system testing references. The workflow of the attendance device is shown in Figure 3.

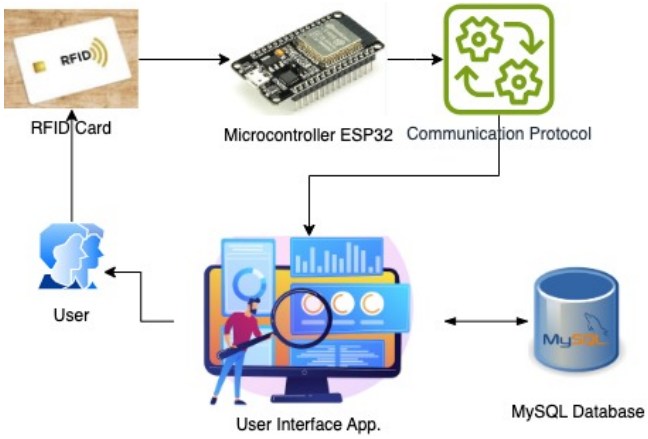

Fig. 3 Workflow Diagram of IoT-Based Attendance Device

The IoT-based attendance system shown in Figure 2 utilizes RFID technology and the ESP32 microcontroller to automatically record user attendance. The process begins when a user places their RFID card near the reader connected to the ESP32. The microcontroller reads the data from the RFID card, processes it, and transmits the information to a web-based application. This application acts as the user interface, enabling the management and monitoring of attendance data. The data received by the application is stored in a MySQL database for recording and reporting purposes. Additionally, the application provides feedback or information to users about their attendance status, ensuring smooth communication between users, hardware components, and the backend system. This system offers an efficient, integrated, and real-time attendance solution.

In the backend process, PHP scripts handle the RFID card UID data through several steps, including validating the card (whether it is registered), recording the attendance time, and checking the user's status (e.g., whether attendance has already been recorded on the same day), as illustrated in Figure 4. The processed data is then stored in the MySQL database for further recording and analysis. The backend also sends responses back to the ESP32, such as "success" for successful attendance or "double" for errors. These responses are processed by the ESP32 to provide feedback to the user via an LCD screen or buzzer. Thus, the backend functions as a central hub that ensures data integrity, process validation, and synchronization between IoT devices and the web-based application.

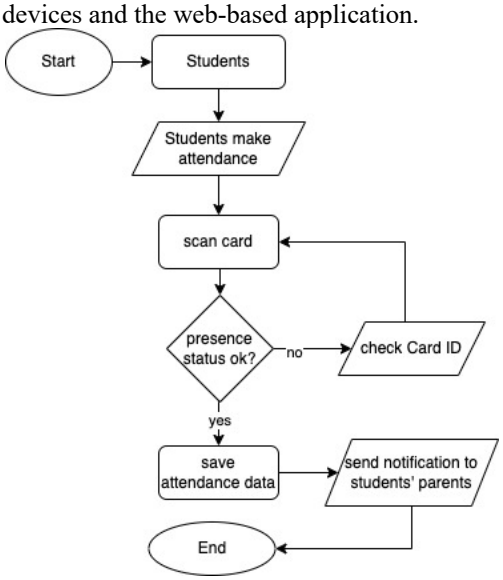

Fig. 4 Attendance Process Flowchart

In implementing the RFID and ESP32-based attendance device, the backend plays a crucial role as the center of data processing and storage. The backend, deployed on a web-based server, receives RFID card UID data sent by the ESP32 via HTTP GET requests. This data is passed to PHP scripts (e.g., *esp_tambah.php, esp_masuk.php,* or *esp_keluar.php*), depending on the device's operational mode. For instance, in the esp_tambah.php script, the line *$tag = $_GET["tag"];* is used to receive data from the

ESP32 in the form of a "*tag*" parameter containing the RFID card's UID. If no record with the same tag exists for the same date, the UID data will be stored in the "*Tambah*" table.

3. Results and Discussion

3.1. Testing Results

This study successfully developed an Internet of Things (IoT)-based student attendance system that functions effectively according to the established goals. The attendance device, built using an RFID Reader, Arduino, and communication modules, successfully recorded student attendance automatically (Figure 4). Visual and audio indicators, such as LEDs and buzzers, provided immediate feedback whenever an RFID tag was successfully read, indicating the proper functioning of the system. Furthermore, the integration of the IoT system with a web-based application was also successfully implemented. The application, developed using PHP and MySQL, effectively stored and displayed attendance data transmitted from IoT devices in real-time (Figure 5). Data transmission to the web-based application via internet communication modules such as ESP32 ran smoothly, ensuring that attendance data remained updated and easily accessible to authorized users.

Fig. 5 IoT-Based Attendance Device

The program was designed to address the issues of manual attendance systems at Palembang Public Junior High School 35 by developing a PHP-based backend and a MySQL database, complemented by a user interface created with Bootstrap. This program integrates RFID devices to record student attendance automatically. The backend serves as the data manager, storing attendance information in the database and providing APIs to support the user interface, which displays attendance data in real time. The system was designed to minimize recording errors, enhance transparency, and accelerate the data recap process.

The backend also provides a RESTful API to integrate attendance data with a web-based user interface designed using Bootstrap, allowing school administrators to view attendance data in an interactive table format (Figure 6). This interface supports searching for data by student name, class, or specific dates, as well as generating reports in PDF or Excel formats. Additionally, the backend is designed to send real-time notifications to parents via email or messages, providing instant updates about their child's attendance at school.

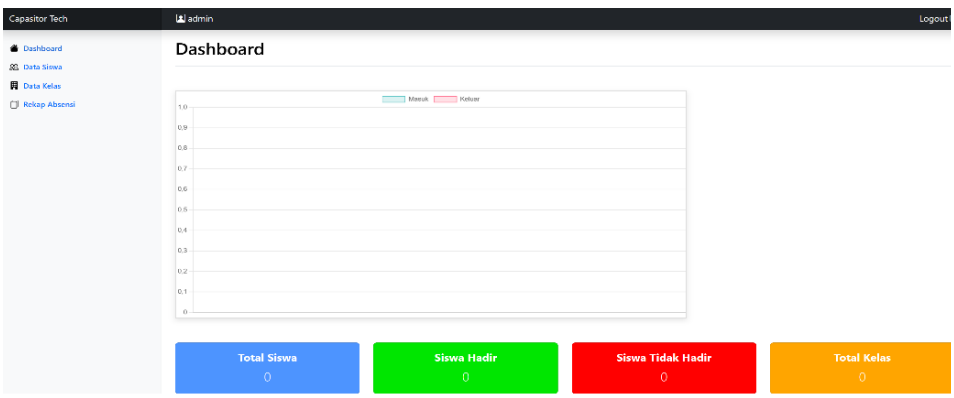

Fig. 6 Web-Based Attendance Application Dashboard

3.2. Discussion

The success of this IoT-based student attendance system lies not only in its ability to record attendance automatically and efficiently but also in the digital transformation it offers. By replacing manual attendance systems that are prone to errors and time-consuming, this RFID-based attendance tool has significantly improved attendance data management at Palembang Public Junior High School 35. Integration with a web-based application that enables real-time data management provides convenience for the school in monitoring student attendance, generating reports, and sending notifications to parents.

One of the main advantages of this system is the improvement in operational efficiency. The attendance process, which previously required time and effort for recording, correcting, and organizing data, can now be done automatically with a high degree of accuracy. Additionally, the system allows for better data accessibility, enabling the school and parents to access student attendance information anytime through the web-based application. This enhances transparency in student data management, facilitating the school in making more accurate data-driven policies.

However, despite its success in overcoming many challenges of manual systems, several issues remain to be addressed. One of these is user adaptation, both from the school staff and parents, to the new technology. Therefore, it is essential for the school to provide training to system administrators and parents to ensure optimal use of the system. Training can be conducted through face-to-face sessions, online tutorials, and user manuals that are easy to understand. Scheduled training sessions and continuous monitoring will ensure that all parties can fully utilize this technology. Furthermore, the system's success heavily relies on the stability of the internet connection, a crucial factor in ensuring seamless communication between devices. Thus, infrastructure that supports network stability is necessary to maintain system performance. As a mitigation measure, the school may consider using backup systems or offline communication technologies that allow devices to temporarily store data if the connection is disrupted [15]. The data can then be automatically synchronized when the internet connection is restored.

This system also has great potential for integration with other existing systems in the school, such as academic or student management systems. Automatically recorded attendance data can be linked to other information, such as academic scores or student schedules. This allows the school to gain a more holistic view of student development. Such integration will enhance data management efficiency and minimize information duplication. Data security is another critical aspect [16]. The system must ensure that student attendance data is well-protected, both in terms of access and storage. The use of encryption technologies and restricted access policies for authorized personnel are essential steps to safeguard student data privacy. This will also increase parents' trust in the implemented system. Overall, the digital transformation achieved by implementing this IoT-based attendance system demonstrates the significant potential of technology in improving efficiency, transparency, and accessibility in school administration management. This system not only simplifies attendance procedures but also supports the broader goal of digital transformation in education by creating a more modern, efficient, and integrated system.

4. Conclusion

This study successfully developed and implemented an IoT-based student attendance system using RFID technology at Palembang Public Junior High School 35. The system replaced the error-prone and time-consuming manual attendance method by providing an efficient and accurate automation solution. The application of RFID technology enabled real-time recording of student attendance, significantly improving operational efficiency while enhancing transparency and data accessibility for both the school and parents.

The system also effectively addressed common issues found in manual systems, such as recording errors, data loss, and time-intensive data recap processes. However, challenges related to user adaptation and reliance on stable internet connections remain areas of concern. Therefore, training for system administrators and parents, along with the development of infrastructure to support stable networks, is crucial to ensure smooth system operations. In conclusion, this IoT-based attendance system not only simplifies attendance procedures but also aligns with the goals of digital transformation in education by creating a more modern, efficient, and integrated system. The implementation of this system is expected to serve as a model for other schools to adopt, thereby improving the quality of administrative management in educational settings

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