JOURNAL LA MULTIAPP

VOL. 07, ISSUE 02 (434-454), 2026
DOI: 10.37899/journallamultiapp.v7i2.2836

Implementation of Automated Attendance System Using Fingerprint with Wemos D1 R32 and WhatsApp Notifications

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Article Info

Article history:
Received 26 November 2025
Received in revised form 17 December 2026
Accepted 3 February 2026

Keywords:
Internet of Things (IoT)
Fingerprint
Wemos D1 R32
WhatsApp
Attendance System

Abstract

The manual attendance system often leads to inefficiencies, such as input errors, delayed data recap, and slow delivery of information to parents. This study aims to design and implement an automated attendance system based on the Internet of Things (IoT) using the AS608 fingerprint sensor and Wemos D1 R32 microcontroller integrated with attendance notifications via WhatsApp. The research method includes the stages of design, implementation, and testing using the black box approach and system performance evaluation. The results show that the system functions properly, successfully reads fingerprints, displays attendance information on the LCD, and sends WhatsApp notifications with an average response time of under 3 seconds. Black box testing confirmed that all main features, such as login, registration, fingerprint verification, and data export, work as expected. The sensor test results indicate a very high success rate under normal finger conditions but decreased accuracy when the finger is dusty, wet, or wrinkled. Overall, this system improves the efficiency, accuracy, and transparency of the student attendance process and is ready for implementation in a school environment.

Introduction

Student attendance is widely recognized as a fundamental indicator in the educational process, serving not only as a measure of student participation but also as a reflection of discipline, responsibility, and engagement in learning activities (Büchele, 2021). Accurate attendance records are crucial for educational institutions because they form the basis for multiple administrative and academic decisions, including awarding recognition for consistent attendance, imposing sanctions for frequent absences, and assessing students' overall academic performance (Selvan & Vardhini, 2025).

Moreover, precise attendance data facilitates teachers and school administrators in identifying students who may require additional guidance or support, enabling more individualized attention and intervention strategies. In this sense, attendance management is not merely a bureaucratic task; it is a core component that impacts educational quality, operational efficiency, and student outcomes (Childs & Lofton, 2021).

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Despite the widespread acknowledgment of its importance, many schools, particularly in developing regions, continue to rely on traditional, manual attendance methods. SD Kedungjambal 4, for example, still uses paper-based logbooks for recording attendance. While this method is simple and low-cost, it is associated with multiple inefficiencies. Manual recording often results in delays in data recapitulation, errors in entry, reduced data accuracy, and limited accountability for administrative processes (Sabrina & Rizal, 2026; Saputra & Musyafa, 2025; Maheswari & Fitriani, 2025).

Additionally, delayed reporting of attendance information to parents hinders their ability to intervenes efficiently when students exhibit irregular attendance patterns, potentially affecting both the student's academic performance and behavioral development (Marliza et al., 2025). Such inefficiencies demonstrate the urgent need to adopt technological solutions that can streamline attendance management while maintaining reliability and accountability.

The rapid advancement of digital technologies, particularly the proliferation of the Internet of Things (IoT) and biometric systems, offers substantial opportunities to improve attendance management. IoT enables devices to communicate seamlessly over networks, allowing real-time data collection, processing, and dissemination. Biometric systems, such as fingerprint recognition, offer enhanced security and authentication, minimizing the risk of fraudulent attendance records. Combining these technologies in an educational setting can transform manual attendance systems into automated platforms that improve operational efficiency, data integrity, and transparency (Arisandi & Fatmawati, 2023; Tiwari et al., 2025; Bhat, 2023; Jayaram & Bhat, 2022).

Fingerprint-based attendance systems are particularly valuable in ensuring that each recorded entry corresponds to the correct student, eliminating the possibility of proxy attendance. When integrated with low-power, internet-enabled microcontrollers such as the Wemos D1 R32, these systems provide reliable connectivity for data transmission with minimal energy consumption. Additionally, modern attendance platforms can incorporate communication APIs, such as WhatsApp messaging, to automatically deliver attendance notifications to parents.

This feature not only enhances transparency but also strengthens parental engagement and allows for timely interventions when students are absent or late (Aiyshwariya Devi, 2025; Dedi Jubaedi et al., 2023; Katel & Katel, 2024). The literature indicates that IoT-based attendance systems have experienced rapid development over the past decade. Various studies demonstrate different approaches, hardware configurations, and integration methods. For example, (Sotyohadi, 2021) developed a system integrating a fingerprint sensor with a non-contact MLX90614 temperature sensor, enabling simultaneous monitoring of student attendance and body temperature during the COVID-19 pandemic.

This system transmitted data in real time, demonstrating that IoT-based biometric attendance systems can be adapted for multifunctional purposes, including health monitoring. This study highlights the potential of integrating biometric attendance with real-time monitoring systems to create holistic solutions that can meet various school management needs. Similarly, (Yadav et al. 2025; Alfiyya et al., 2024; Prastya & Misbah, 2024) implemented an ESP32-based fingerprint system that automatically sent attendance data to a server and displayed the results through a web application.

Their approach significantly reduced errors associated with manual input and ensured real-time monitoring capabilities, highlighting the advantages of IoT in streamlining

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administrative processes. Furthermore, the system operated with low latency and maintained data integrity, reinforcing the suitability of ESP32 microcontrollers for real-time biometric applications in schools. (Hercog et al. 2023) extended this approach by designing a portable ESP32-based fingerprint attendance system capable of cloud integration. The system verified fingerprints, stored attendance records, and displayed results via a web interface, even under limited network conditions.

This research illustrates the feasibility of portable biometric systems that provide reliable operation in environments with variable connectivity, expanding the flexibility of IoT-based attendance management solutions. The study conducted by (Nirsal & Aminah, 2024; Sitompul et al., 2024) at Cokroaminoto Palopo University focused on designing a student attendance interface system based on IoT with fingerprint sensors. The researchers applied a User Centered Design (UCD) approach that prioritizes user interaction comfort through a UI design that was functionally tested and validated.

This research is relevant because it integrates UCD principles with fingerprint technology in a web-based attendance system, thereby supporting an automated and efficient attendance process. Further research by (Jamil et al., 2025; Raysa & Nasir, 2025) utilized a Raspberry Pi–based fingerprint system equipped with an LCD display and email notifications. The system achieved a high recognition rate of 97.7% and securely stored attendance data in a web database. This study highlights the critical role of biometric security and demonstrates how automated notification systems can enhance the effectiveness of attendance monitoring.

Overall, existing literature indicates that IoT and biometric technologies have significantly contributed to the automation of attendance systems. However, most studies still primarily focus on recording accuracy, data transmission, and cloud integration, while fully functional real-time notification systems remain limited. A comparison of these studies reveals several important findings: hardware selection plays a crucial role in overall system performance, biometric sensors such as the AS608 provide reliable authentication, data delivery methods vary across implementations from web dashboards to email notifications and messaging platform APIs while fully integrated real-time notification features remain limited in previous research.

Based on these identified gaps, the present study focuses on designing and implementing an automated attendance system that integrates fingerprint biometric authentication, IoT connectivity via the Wemos D1 R32, and real-time WhatsApp notifications. This system ensures data authenticity, reduces manual recording errors, provides rapid reporting to parents, and enhances student discipline through improved accountability. By synthesizing insights from the literature and addressing existing limitations, this study aims to contribute to the development of practical, technology-driven solutions for school attendance management.

In conclusion, the integration of IoT and biometric technologies in attendance systems represents a transformative step toward modernizing school administrative practices. Although previous studies have demonstrated significant progress in automated recording, cloud integration, and multifunctional monitoring, there remains an opportunity to develop a more comprehensive system that combines accuracy, efficiency, portability, and real-time parental communication.

The proposed system leverages the strengths of fingerprint recognition, low-power microcontrollers, and widely used messaging platforms to create a holistic solution. Its

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implementation is expected to improve operational efficiency, enable real-time attendance monitoring, enhance parental involvement, and ultimately foster a culture of discipline and accountability among students.

Methods

This research adopts the Design and Implementation approach, aiming to produce a functional and integrated prototype of a fingerprint-based attendance system. The approach emphasizes the integration of both hardware and software development aspects. The software development method employed is the Waterfall Model, a structured and sequential development process that progresses from requirements analysis to system testing. This model was chosen because it is suitable for systems with well-defined requirements and requires a systematic and well-documented development process (Rachma & Muhlas, 2022).

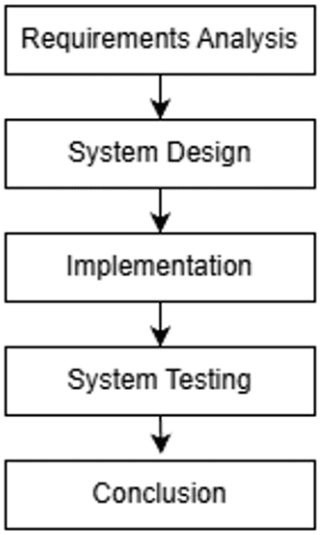

Figure 1. Waterfall Model of Fingerprint Attendance System

Requirements Analysis

This stage focuses on analyzing and determining the detailed requirements that must be fulfilled by the automated attendance system. The analysis process combines the results of observation and interviews conducted at SD Kedungjambal 4 to understand the existing attendance process, along with a literature review obtained from books, scientific articles, journals, and online sources.From this process, the functional requirements include fingerprint recording and verification, automatic attendance recording, real-time data storage in the database, and attendance report generation for teachers and parents. The non-functional requirements emphasize system responsiveness, data security through encryption, and ease of access to reports via a web-based dashboard. This combination of field findings and technical references ensures that the designed system operates efficiently and aligns with the school's operational needs.

To meet these requirements, specific hardware and software specifications are determined as a reference for the design and implementation phases. In developing the system, several technologies and electronic components are integrated to support automation and data accuracy. The system applies the concept of the Internet of Things (IoT), which connects physical devices to the internet to enable automatic communication and control (Situmorang,

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2024). The main controller used is the Wemos D1 R32, a microcontroller based on the ESP32 chip that supports Wi-Fi and Bluetooth connectivity, making it ideal for IoT applications (Maulana et al., 2023). The AS608 fingerprint sensor functions as the main input device for student identification, providing high accuracy through biometric authentication (Andre, 2023).

The LCD 16x2 I2C module is used to display attendance status and user information, while the buzzer acts as an audio indicator when the fingerprint is successfully verified (Oktodinata et al., 2024). The push button is utilized to select operational modes such as registration, check-in, or check-out (Martin & Dewanto, 2023). Supporting components such as the breadboard and jumper cables are used during prototyping to connect circuits without permanent soldering (Alrasyid et al., 2025). Power to the system is supplied using a 5V power adapter, ensuring stable operation. Meanwhile, the backend and database are developed using PHP and MySQL, integrated with the WhatsApp Bot API to provide real-time attendance notifications to parents. Programming and testing of the microcontroller are carried out using the Arduino IDE platform.

Table 1. Components List along with The specifications

No.	Component	Specifications & Functions
1	WEMOS D1R32	microcontroller with built-in Wi-Fi module, plays a role in sending data to the server and integration with the WhatsApp API.
2	FINGERPRIT AS608	Module for reading student fingerprints.
3	16x2 I2C LCD	Shows student information when the finger is successfully read.
4	Push Button	Used to select the mode: attendance in, going home, or register.
5	Buzzer	Gives a sound signal when the finger is successfully read.
6	Breadboard	Used as a medium for assembling electronic circuits without a soldering process.
7	Jumper Cable	Connecting components in a circuit on a breadboard and microcontroller.
8	Power Supply / 5V Adapter	Provides electrical power for all system components.
9	PHP & MySQL	Used to build WHATSAPP dashboard and API
10	WHATSAPP BOT API	Used as a medium for sending student attendance information to parents automatically and in real- time.
11	Arduino IDE	Used as programming software to write, upload, and test code on the Wemos D1 R32.

System Design

The system design phase follows the requirements analysis. At this stage, the identified functional and non-functional requirements are translated into technical designs, including hardware architecture, database structure, and software logic. The main objective is to form a structured blueprint that guides system implementation, ensuring all components microcontroller, fingerprint sensor, and WhatsApp-based notification mechanism are optimally integrated to support automated attendance recording.

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System Architecture Model

The system architecture is designed to ensure all parts work collaboratively, enabling efficient and real-time attendance operations.

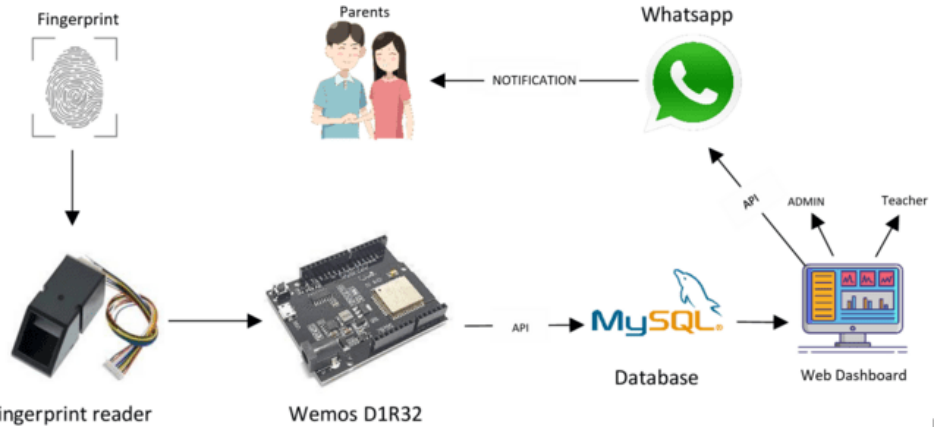

Figure 2. Architectural Model of Fingerprint Attendance System with WhatsApp integration

All hardware and software components are interconnected to ensure smooth identification, data recording, and information delivery. The fingerprint technology serves as the biometric authentication method, while the WhatsApp API provides automatic attendance notifications to parents enhancing transparency and engagement between school and parents.

Dashboard Design

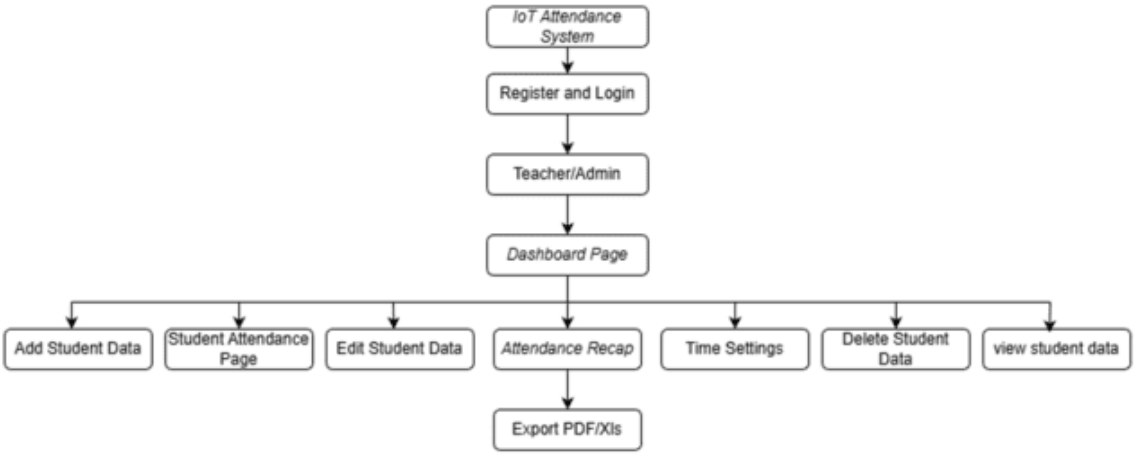

Figure 3. Dashboard Menu Structure

This section describes the dashboard design of the IoT-based student attendance system. The dashboard serves as the main interface for teachers to efficiently manage student and attendance data. The menu structure is designed to be simple and user-friendly.

Teachers log in as main users to access the dashboard, where they can view, add, update, and delete student data, as well as monitor attendance recaps directly. The system also supports data export to PDF or Excel (XLS) formats for archiving or reporting purposes.

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Unified Modeling Language (UML) Design

The Unified Modeling Language (UML) is a standardized modeling language in software engineering that helps describe object-oriented system designs (Koç et al., 2021; Lupasc, 2021). UML serves as a visual modeling tool to make the system design more structured and easier to understand.

Use Case Diagram

The attendance system involves three main parties: teachers, students, and parents. Teachers serve as the primary users who manage student and class data, as well as monitor attendance results through the system. Students record their attendance directly using devices connected to IoT technology. Meanwhile, parents automatically receive notifications of their child's attendance via WhatsApp messages, allowing them to monitor attendance activities more easily and quickly.

Figure 4. Use Case Diagram of Attendance System

Activity Diagram

This system is represented through two integrated activity diagrams that describe the overall workflow of student attendance management and the delivery of attendance notifications to parents. These diagrams are designed to illustrate how data flows between users, system components, and external communication platforms in a structured and transparent manner.

Figure 5 presents the sequence of activities related to the teacher's login and system access process. As the primary user, the teacher must first authenticate through the login interface to ensure data security and authorized access. After successful verification, the teacher is directed to the main dashboard, which serves as the central control panel for managing academic and administrative information. Through this dashboard, the teacher is granted full authority to manage student profiles, class assignments, attendance schedules, and daily attendance records. In addition, the system enables the teacher to generate attendance summaries and reports, which can be used for academic evaluation, administrative monitoring, and communication with school management.

Figure 6 illustrates the attendance recording process conducted by students using RFID technology. In this stage, students register their presence by tapping their RFID cards on the reader device installed at designated locations. The reader automatically scans the card and

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transmits the identification data to the central system. This process minimizes manual input, reduces human error, and ensures faster and more accurate attendance recording. Once the data is successfully captured, the system immediately stores it in the attendance database and updates the student's attendance status in real time.

After the attendance data has been recorded, the system initiates an automated notification process. The recorded information is synchronized with the communication module, which is connected to the WhatsApp messaging service. As a result, parents or guardians receive instant notifications containing information about their child's attendance status, including the time and date of arrival. This real time communication mechanism strengthens collaboration between schools and parents, enhances transparency, and enables early intervention in cases of absenteeism or irregular attendance.

Overall, the integration of teacher management functions, RFID based attendance recording, and automated WhatsApp notifications creates an efficient and reliable attendance monitoring system. The activity diagrams demonstrate how each component operates sequentially and interactively, ensuring data accuracy, operational efficiency, and effective communication among teachers, students, and parents.

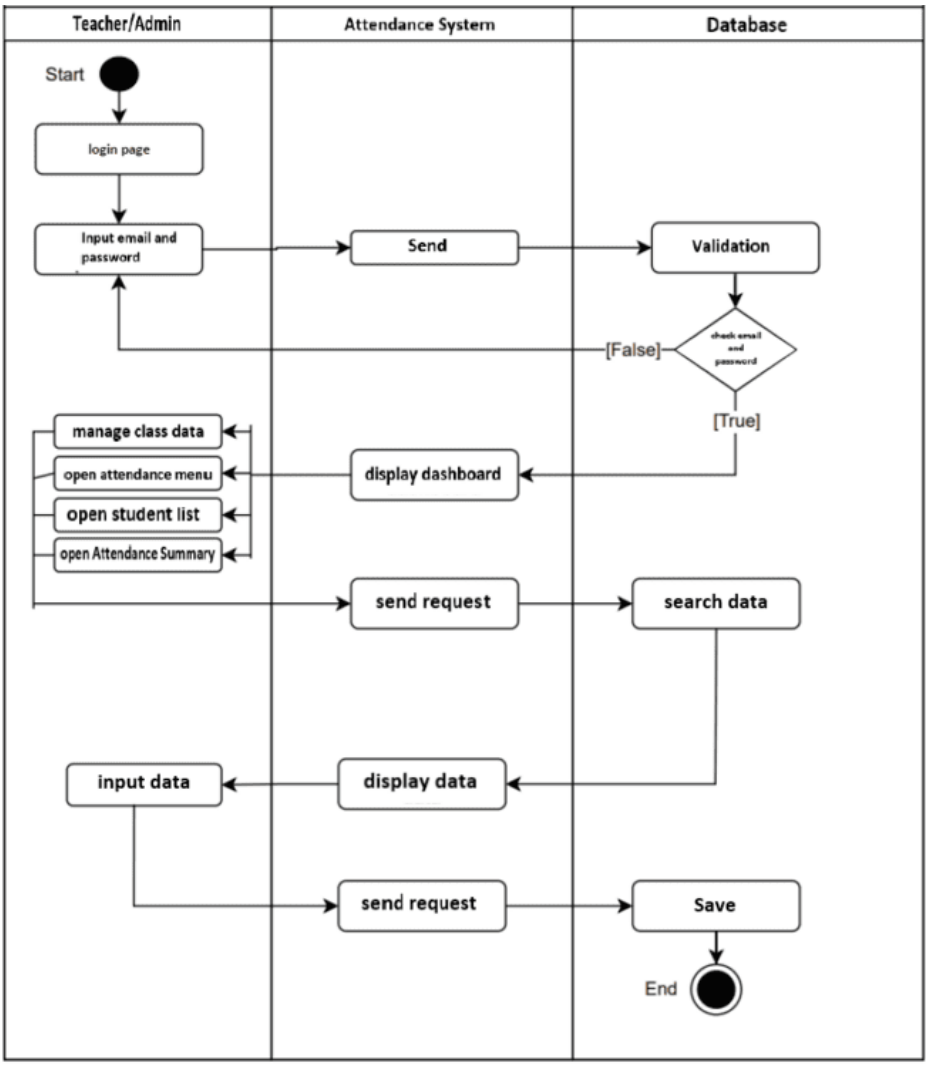

Figure 5. Teacher Activity Diagram

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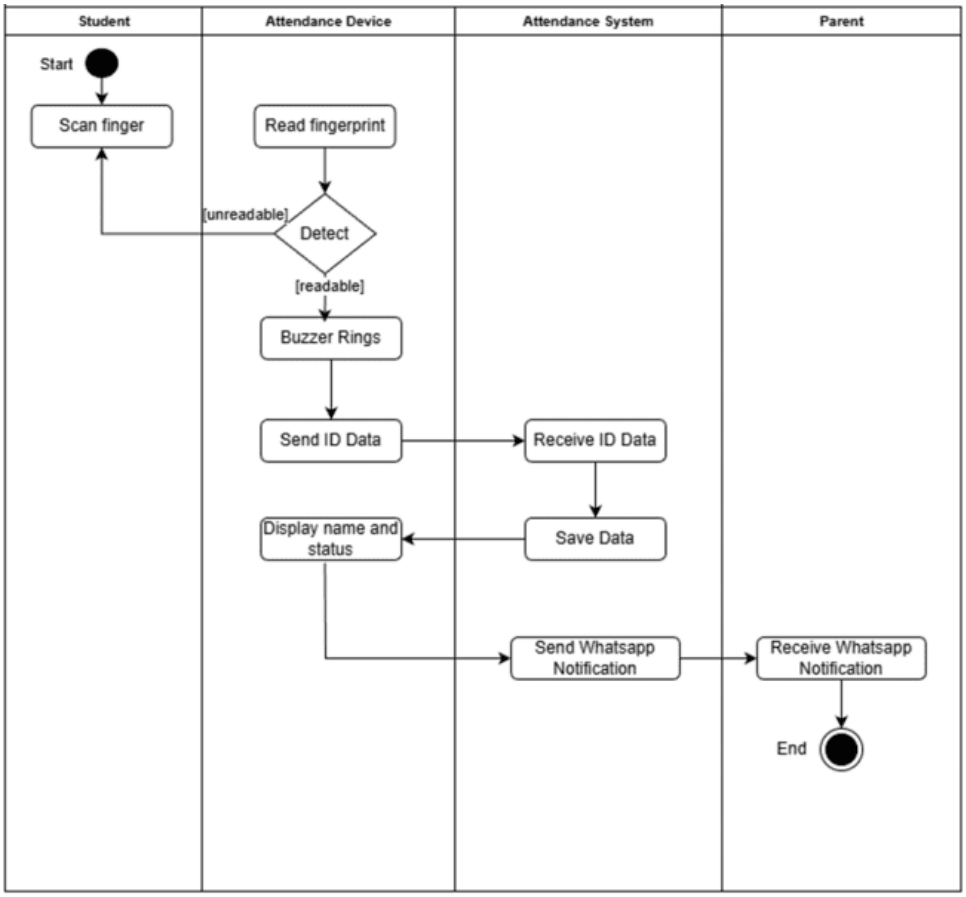

Figure 6. Student and Parent Activity Diagram

Conceptual Database Design

The Entity Relationship Diagram (ERD) models the structure of the attendance system's data, showing relationships among entities such as students, attendance records, fingerprints, and schedules.

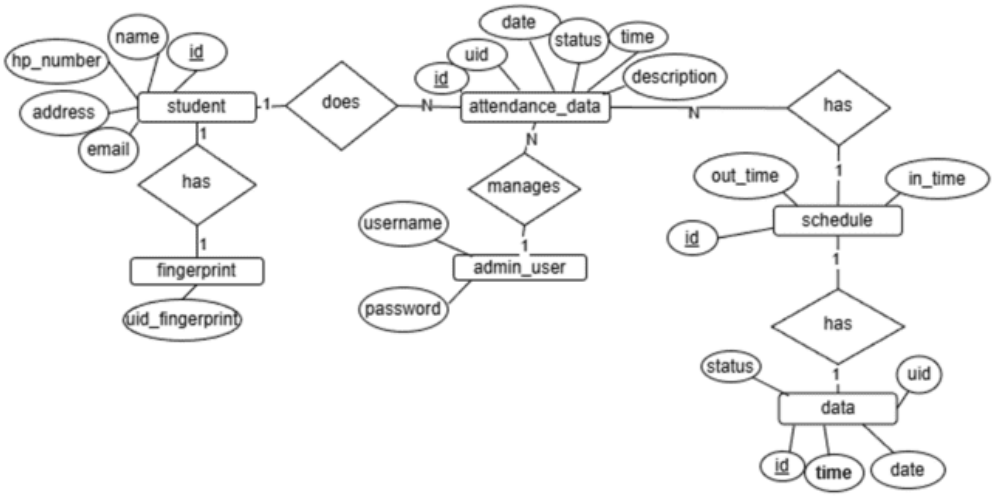

Figure 7. Design of ERD Database for Student Attendance System

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System flowchart design

The flowchart is used as a fundamental step for implementing the IoT-based attendance prototype (Rijanandi et al., 2023).

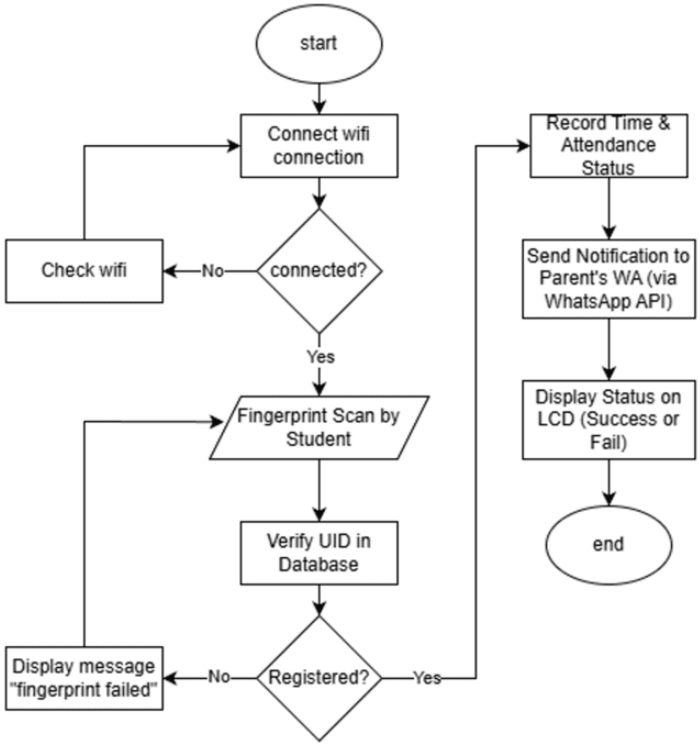

Figure 8. Flowchart of the Fingerprint Attendance System with WhatsApp Notifications

The attendance process begins when the system is powered on, where it immediately attempts to establish a Wi-Fi connection and will recheck if the connection fails. Once successfully connected, students scan their fingerprints using the sensor. The UID (unique identification number) obtained from the scan is then verified against the data stored in the database. If the fingerprint is not registered, the system will display a “fingerprint failed” message. However, if the UID is found, the system records the time and attendance status, then automatically sends an attendance notification to the parent’s WhatsApp via an integrated API. Finally, the attendance status is displayed on the LCD screen as confirmation to the user, completing the process.

Hardware Design

The hardware design of the system was carried out by assembling all the main components including the Wemos D1 R32 microcontroller, AS608 fingerprint sensor, 16x2 LCD with I2C module, buzzer, and input buttons using a breadboard and jumper wires. The primary purpose of this temporary setup is to ensure that all hardware connections function properly before permanent implementation. The designed system detects student attendance through fingerprints, sends the attendance data to the database server, and then automatically delivers notifications to parents via WhatsApp.

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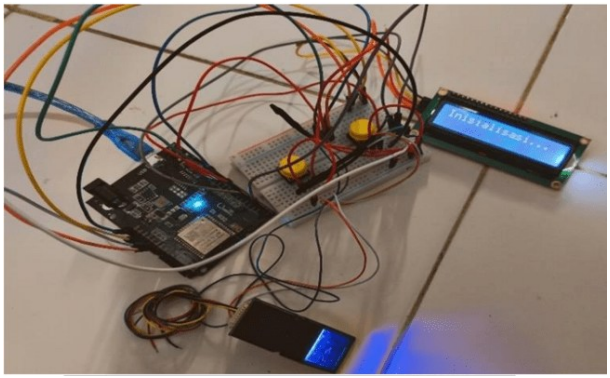

Figure 9. Physical Design of Fingerprint Attendance System Based on Wemos D1 R32

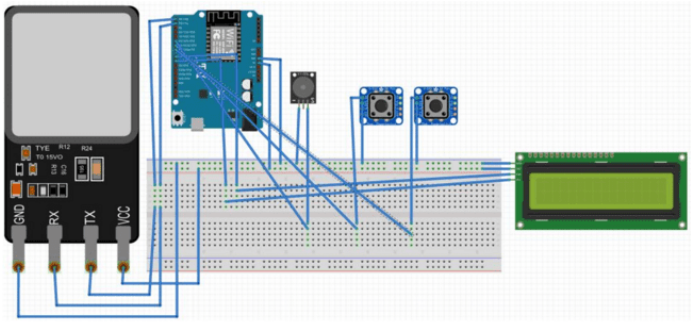

Figure 10. Circuit Schematic of Fingerprint Attendance System Based on Wemos D1 R32

The system components are connected as follows: the 16x2 I2C LCD has its VCC connected to 5V, GND to GND, SDA to GPIO 18, and SCL to GPIO 19. The AS608 fingerprint sensor is connected with VCC to 3.3V, GND to GND, TX to GPIO 16 (RX2), and RX to GPIO 17 (TX2). For input buttons, the Finger button is connected to GPIO 13 and the Absent button to GPIO 14. The buzzer is connected with the positive terminal to GPIO 4 and the negative terminal to GND. The Wemos D1 R32 microcontroller controls the system's logic flow, including reading data from the fingerprint sensor, managing the LCD, handling input from buttons, and establishing a Wi-Fi connection to send attendance data to the server via an API.

Results and Discussion

Implementation System

The outcome of this research is the implementation of a web-based student attendance application integrated with fingerprint scanning and automatic WhatsApp notifications. The system was developed using Laravel (PHP) and MySQL, with an API connected to the Wemos D1 R32 to record attendance in real-time. The main objective of the system is to provide efficient, accurate, and easily monitored attendance management through a web interface. The discussion focuses on system implementation, testing, and evaluation of functionality and reliability, including the analysis of hardware and software integration to improve attendance recording performance. The system consists of two main components: hardware (Wemos D1 R32, AS608 fingerprint sensor, 16x2 I2C LCD, buzzer, buttons, and supporting components) which capture and transmit data in real-time, and software based on Laravel and MySQL which manages student data, attendance records, and notifications. The integration of these two subsystems results in an automatic, comprehensive, and reliable attendance system. The main features of the system include:

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Login and Registration:

This feature serves as the main entry point for both administrators and teachers. The registration process stores user data in the database, while the login module authenticates users based on valid credentials. If login credentials are verified successfully, the system redirects the user to the main dashboard.

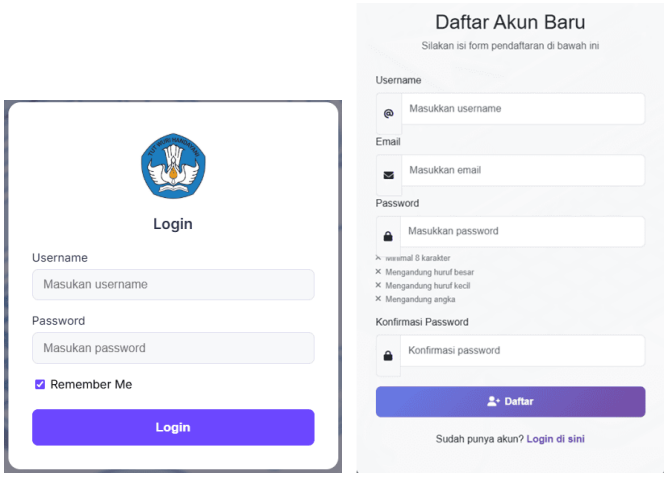

Figure 11. Display Login and Register the Attendance System

Dashboard Real-time Monitoring

The dashboard displays an overview of attendance activity, including the number of students present, absent, or late. Real-time monitoring ensures that administrators can view updates within seconds of each fingerprint scan. The dashboard also provides quick access to data recaps and performance reports.

Figure 12. Real-time Dashboard View

Student Data Management

This feature enables the recording and pairing of fingerprint UIDs with corresponding student identities. Data are stored automatically in the MySQL database after successful registration through the hardware interface. Each fingerprint is uniquely mapped to a student ID, minimizing duplication and false identification.

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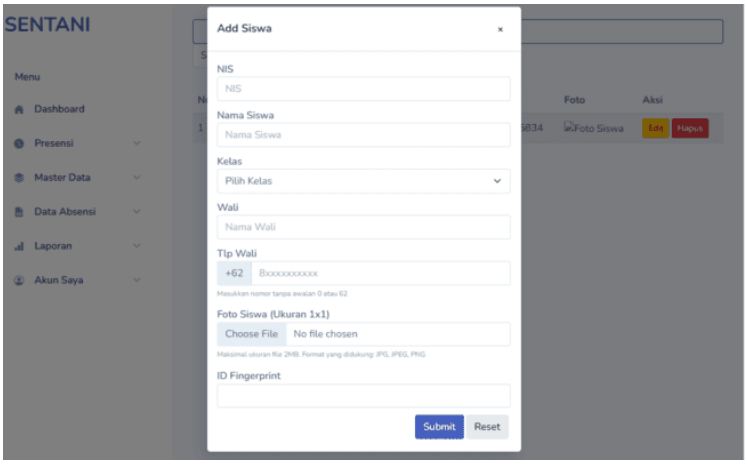

Figure 13. Form View Student Data Input and Fingerprint Registration

Attendance and Departure

The attendance process includes both arrival (check-in) and departure (check-out) functions. Students simply place their registered fingerprints on the AS608 sensor, which identifies them and records the attendance data along with the timestamp. The LCD displays confirmation messages such as “Attendance Successful,” and a buzzer sound indicates the result.

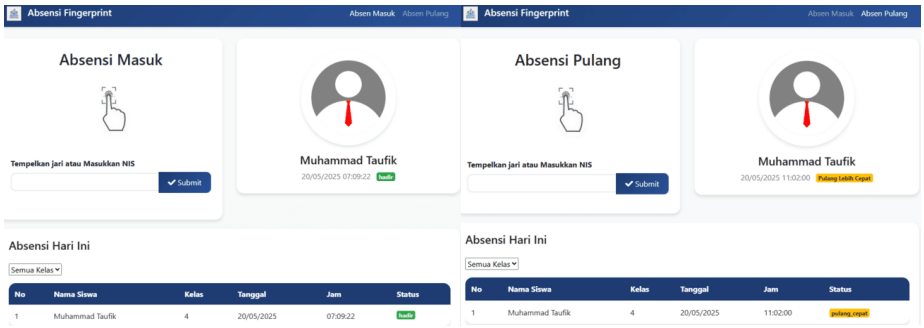

Figure 14. Display of Student Attendance and Exit Features

Attendance Recapitulation

This feature allows filtering based on class, date, and attendance status. Users can also export data to PDF or Excel format for administrative reports. This supports transparency and simplifies the documentation of student attendance records.

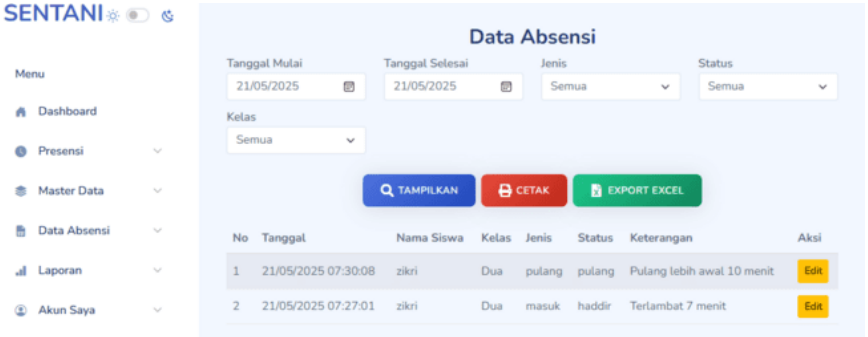

Figure 15. Student Attendance Data Display

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WhatsApp Notification Delivery

After successful verification, the system automatically sends a WhatsApp notification to the parent or guardian. The message includes the student's name, class, and attendance time, ensuring real-time communication between schools and parents.

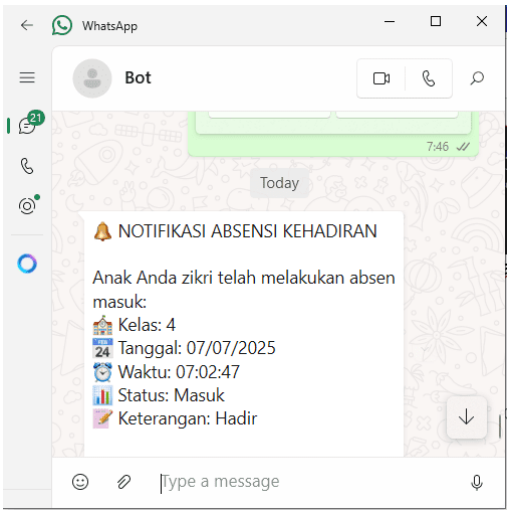

Figure 16. Automatic WhatsApp Message from the Attendance System

Hardware Implementation

The hardware has been assembled into a functional prototype enclosed in a protective casing for safe use within the school environment. This device operates independently and communicates with the database through a Wi-Fi connection using the Wemos D1 R32.

Figure 17. Hardware Circuit Prototype

System Testing

At this stage, the system was tested to ensure all features functioned as intended. Blackbox testing was chosen to evaluate the system from a user's perspective by verifying outputs against input scenarios. The results of blackbox testing on the student attendance system are shown in Table 2.

Table 2. Blackbox Test Results

No	Feature	Testing Scenario	Expected results	Results
1.	Registration	Add a new account via the registration form	New user data is stored in the database.	Succeed
2.	Login	Enter a valid username and password	The system displays the main dashboard.	Succeed

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3.	Dashboard	Admin opens the dashboard page	The system displays the latest attendance list in real- time.	Succeed
4.	Fingerprint Registration	Sticking finger for registration	Fingerprint data is stored and associated with student data.	Succeed
5.	Fingerprint Verification Failed	Attaching an unregistered fingerprint	Displays the message "Fingerprint not recognized on LCD" and does not record attendance.	Succeed
6.	Fingerprint Verification (Attendance)	Attaching the registered fingerprint	Displays student name, attendance time, and "Entered" status.	Succeed
7.	Fingerprint Verification (Return Attendance)	Attach fingerprints when coming home from school	Displays student name, home time, and "Home" status.	Succeed
8.	LCD display	Fingerprint successfully detected	The LCD displays "Attendance Successful" along with the student's name.	Succeed
9.	Indicator Buzzer	Fingerprint read successfully	The buzzer sounds once as a sign of success.	Succeed
10	Attendance Recapitulation	Admin selects date/class filter	Attendance data is displayed according to the filter.	Succeed
11.	Export Attendance Data	Admin presses the Export (PDF/Excel) button	File successfully downloaded.	Succeed
12.	WhatsApp Notifications	Students successfully took attendance	Parents receive an automatic message on WhatsApp containing attendance time.	Succeed

Blackbox testing results indicate that all features of the fingerprint-based attendance system with WhatsApp notifications function correctly and reliably without errors. Core processes, including login, account registration, fingerprint registration and verification for check-in and check-out, and WhatsApp notifications, operate as expected. The system displays attendance data in real-time, provides feedback via LCD and buzzer, and accurately stores records in the database. Data recap and export features to PDF and Excel also work optimally. Testing of WhatsApp notifications confirmed that the system can deliver real-time attendance information to parents, as shown in Table 2.

Sensor Testing

Fingerprint sensor testing was conducted to assess the capability of the AS608 sensor in recognizing biometric patterns under various finger surface conditions. The objective was to evaluate the sensor's sensitivity to changes in skin texture and environmental factors commonly encountered during daily use. A total of 12 participants, including the researcher, took part in the testing, with each performing trials under four different conditions: normal, dusty, wet, and wrinkled fingers.

Table 3**.** Fingerprint Sensor Testing

No.	Participant	Normal Finger	Dusty Finger	Wet Finger	Wrinkled Finger
1	Participant 1	✓	×	✓	✓
2	Participant 2	✓	×	✓	✓
3	Participant 3	✓	✓	×	×

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4	Participant 4	✓	✓	✓	✓
5	Participant 5	✓	×	✓	×
6	Participant 6	✓	✓	×	✓
7	Participant 7	✓	×	×	✓
8	Participant 8	✓	×	×	✓
9	Participant 9	✓	✓	✓	✓
10	Participant 10	✓	×	✓	×
11	Participant 11	✓	×	×	×
12	Participant 12	✓	×	×	×
Success Percentage (Average)		100%	33%	50%	58%

Table 3 shows the results of the AS608 fingerprint sensor testing under four finger surface conditions: normal, dusty, wet, and wrinkled, based on trials conducted with twelve participants. The success rate reached 100% under normal conditions, indicating that the sensor performs optimally when fingerprint patterns are clean and clearly detectable. However, the success rate dropped sharply to 33% for dusty fingers due to dirt obstructing the sensor's optical reading of the fingerprint ridges and valleys. For wet fingers, the success rate was only 50%, caused by light reflections and surface moisture interfering with scanning. For wrinkled fingers, the sensor still performed reasonably well with a success rate of 58%, although skin pattern deformations affected matching accuracy. Overall, the AS608 sensor is most effective with clean, dry fingers, while its accuracy decreases when the finger surface is dirty, moist, or altered. Further evaluation was conducted to assess the AS608 sensor's performance in a real-world context within the student attendance system. This testing focused on the registration (enrollment) and verification processes using the right thumb. A total of 17 fourth-grade students participated to evaluate the sensor's response to fingerprint patterns in daily operational scenarios. The results are presented in Table 4.

Table 4**.** Fingerprint Registration And Attendance Testing

No.	Student Name	Registration Attempt	Attendance Attempt
1	Akbar	Success	Success
2	Akmal	Success	Success
3	Aldo	Success	Success
4	Anggita	Success	Success
5	Annisa	Success	Success
6	Arjuna	Success	Success
7	Azizan	Success	Success
8	Berlian	Success	Success
9	Hana	Success	Success
10	Keisha	Success	Success
11	Latep	Success	Success
12	Luqman	Success	Success
13	Nabila	Success	Success
14	Nayla	Failed	Failed
15	Pembayun	Success	Success
16	Renata	Success	Success

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17	Risqi	Success	Success

Based on the test results, only one student experienced a failure during both the registration and attendance processes. This failure was caused by an unreadable fingerprint pattern or suboptimal finger surface conditions during scanning. When the system fails to recognize the fingerprint, the device displays a "not recognized" notification on the LCD screen, indicating that the fingerprint data cannot be verified.

Table 5. Fingerprint Sensor Error Rate Testing

No.	Test Type	Number of Trials	Number of Errors	Error Percentage (%)	Description
1	False Acceptance Rate (FAR)	50	0	0%	System accepts unregistered fingerprints
2	False Rejection Rate (FRR)	50	2	4%	System rejects registered fingerprints

As shown in Table 5, the fingerprint sensor system demonstrates good performance. A FAR of 0% indicates that the system does not accept unregistered fingerprints, ensuring security. The FRR of 4% shows that only a small portion of registered fingerprints failed to be recognized.

Table 6. Fingerprint Sensor Error Rate Testing

No.	Test Scenario	Number of Trials	Average Response Time	Description
1	Fingerprint Registration	10	3.1 s	Time from placing finger to data saved
2	Attendance Check-In	10	1.8 s	Time from placing finger to "Check-In" status displayed
3	Attendance Check-Out	10	2.0 s	Time from placing finger to "Check-Out" status displayed
4	Unregistered Fingerprint	10	1.2 s	Time from placing unregistered finger to "unrecognized" message

The results in Table 6 indicate that the Wemos D1 R32 with the AS608 module provides fast and consistent response times across scenarios. Registration takes an average of 3.1 seconds, while check-in and check-out verification take 1.8 and 2.0 seconds, respectively. In the case of unregistered fingerprints, the system displays an "unrecognized" message in 1.2 seconds on average. These results demonstrate that the Wemos D1 R32 and AS608 sensor combination can handle attendance efficiently and responsively, providing a fast and reliable user experience.

WhatsApp Notification Testing

Table 7. WhatsApp API Notification Performance

No.	Condition	Notification Platform	Average Delivery Time	Notification Success

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1	Check-In	WhatsApp API	1.8 s	Yes
2	Check-Out	WhatsApp API	2.0 s	Yes
3	Failed Attempt	WhatsApp API	–	No

According to the results in Table 7, WhatsApp API notifications performed well for check-in and check-out, with average delivery times under 3 seconds. This demonstrates the system's capability to provide rapid feedback to users. For failed attendance attempts, notifications were not sent, as the system only issues messages for successful identification. Overall, the WhatsApp API notification system proves responsive and reliable in supporting the IoT-based attendance process.

Conclusion

Based on the results of the conducted testing, it can be concluded that this IoT-based attendance system functions effectively and meets its intended objectives. The AS608 fingerprint sensor is capable of recognizing biometric patterns with high accuracy under normal finger conditions, while its performance decreases on dusty, wet, or wrinkled fingers, as confirmed by testing. The student registration and attendance processes run efficiently, with only one failure case among 17 students. Error rate testing shows a FAR of 0% and an FRR of 4%, confirming the system's security and accuracy. Furthermore, WhatsApp API notifications successfully delivered real-time attendance information, with an average delivery time of under 3 seconds. These testing results indicate that the system provides accurate and responsive attendance data, supporting efficient student attendance management and ensuring reliability for school implementation. Future developments may include the utilization of cloud databases, enhancement of the biometric module, and integration with academic and school management systems to improve operational capability and interoperability.

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