IoT-Based Fingerprint Attendance System with Real-Time Monitoring and Notifications

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***Abstract*—Over the past few years, technology has contributed significantly in simplifying routine activities, including attendance management. The conventional attendance recording and management methods like manual registers and card based systems consume more time, are susceptible to human error, tampering of stored attendance records, proxy attendance and also leads to delays and inconsistencies in consolidating the attendance records. To address these problems, this work presents the development and implementation of an IoT-based smart attendance system that combines fingerprint authentication with real-time attendance status notification features. The developed system utilizes an ESP8266 microcontroller, an R307 fingerprint sensor, and an OLED display for user interaction and attendance data processing. Fingerprint data will be collected from the users and during the session while marking the attendance, users will be authenticated and the attendance details will be uploaded to cloud storage through the internet for further processing and record maintenance. By the incorporation of biometric authentication, the system ensures unique identification of individuals and improves attendance accuracy. A web based dashboard is also provided to faculty and administrators to access and monitor student attendance remotely. Further, the system also includes automated email notification feature to communicate attendance information efficiently. The implemented system has a compact and portable design, making it suitable for use in educational institutions where secure and reliable attendance management is essential.**

***Index Terms*—Biometric Authentication, Cloud Storage, ESP8266, Fingerprint Recognition, IoT, Real-Time monitoring, Smart Attendance System, Web-Based Dashboard.**

I. INTRODUCTION

Attendance management plays a vital role in educational institutions, as it aids in maintaining records, monitoring participation, and evaluating overall performance of the student. In the scenarios where the number of students is high, conventional attendance methods such as roll calls, paper registers, and manual entry sheets are difficult to manage and consume considerable time. Also, traditional methods are vulnerable to human error, proxy attendance, and record tampering, which affect the accuracy of attendance data and increase the workload of faculty and administrative staff. Recent developments in IoT and biometric technologies have made it possible for developing automated attendance systems that are more secure and consistent. This research focuses on incorporating fingerprint based biometric authentication to uniquely identify individuals and prevent identity fraud commonly observed in card based or password based systems. This paper presents an attendance system that combines IoT technology, fingerprint authentication, and automated email notifications to provide a secure and accurate attendance management solution. The developed system uses an ESP8266 microcontroller, and R307 fingerprint sensor, and an OLED display. During attendance marking, the fingerprint sensor captures and verifies the user's fingerprint, while the ESP8266 module processes the data and uploads the authenticated attendance records to cloud storage through the internet. The stored data can be accessed and monitoring through a web based dashboard for further processing and reporting.

The system also sends automated email notifications to registered parents, guardians, or authorized personnel and ensures timely communication regarding attendance status. The compact and portable design of the device makes it suitable for classroom environments. By reducing manual effort and improving data security, the developed system provides a practical and scalable solution for real-time attendance management.

II. LITERATURE SURVEY

Anagha Jadhav et al., in [1] proposed an IoT-based fingerprint attendance system to replace manual

methods. It uses a NodeMCU ESP8266 with Wi-Fi and an R307 fingerprint sensor to authentic students. Attendance data is sent to a central server and stored in a database, while a Windows-based dashboard enables faculty to manage sessions and monitor records. The system achieved about 80% accuracy, with errors mainly due to improper finger placement and sensor issues. It enhances reliability, minimizes false attendance, and automates classroom attendance management. Ramgopal A. et al., in [2] proposed a secure and resilient attendance system integrating fingerprint biometrics, IoT, and cloud technologies. It uses a GT521F52 fingerprint sensor and ESP32 microcontroller to authenticate students and send data to Google Firebase in real time. An offline caching mechanism ensures data storage during network failures and synchronizes it later. Security is enhanced with AES-256 encryption, while role-based web portals allow students and faculty to access and monitor attendance. The system ensures transparency, data integrity, and efficient academic management. Sayed AI Amin et al., in [3] proposed an integrated attendance and security system combining fingerprint authentication, IoT, and an ultrasonic sensor. It uses a GT511C3 fingerprint scanner with an Arduino Mega and ESP32 to authenticate users and send encrypted data to a web server. An ultrasonic sensor verifies physical entry, while a solenoid-based door lock controls access. A touch LCD supports user interaction, and a Laravel-based portal enables remote monitoring. The system eliminates proxy attendance and significantly reduces time during classes. Work by Roshani Memane et al., in [4] proposed a fingerprint-based attendance system using an R307 sensor with a Raspberry Pi to replace manual roll calls. The system authenticates students, stores attendance digitally, and automatically generates and emails reports. It also analyzes limitations of existing methods like RFID, barcode, and biometric approaches. The model reduces proxy attendance, improves accuracy, enables real-time monitoring, and ensures a cost-effective, scalable solution. Prof. M. P. Mahajan et al. [5] proposed a portable fingerprint-based attendance system using a GT-511C3 sensor with an Arduino Nano and NodeMCU (ESP8266) for Wi-Fi and cloud integration. Data is temporarily stored in SPIFFS during connectivity loss and later uploaded to an AWS-based MySQL database via HTTP. The system includes an LCD interface, battery-powered hardware, and a web portal for real-time monitoring. It reduces proxy attendance, minimizes manual effort, ensures secure storage, and enhances portability over conventional systems. Prajwal Gujarkar et al., in [6] developed a portable fingerprint-based attendance system for industrial and organizational use. It uses an ESP8266 NodeMCU, R307 fingerprint sensor, and OLED display to capture and transmit data over Wi-Fi. Fingerprints are processed using filtering techniques and authenticated with a >=75% similarity threshold. A web dashboard using HTML, CSS, JavaScript, PHP, MySQL supports registration, tracking, and report generation. Testing on 100 users showed 7.86 seconds average marking time, 99.9% accuracy, low FAR (0.01%), and FRR (0.1%), indicating high efficiency, security, and cost-effectiveness. Suhas D. et al., An IoT-enabled attendance system integrating an ESP8266 NodeMCU, Arduino Uno, and R307 optical fingerprint sensor for real-time attendance monitoring was proposed in [7]. Fingerprints are authenticated against stored templates, and attendance data is sent via Wi-Fi to Google Sheets (PushingBoxAPI) and the ThingsBoard platform. A 16X2 LCD and serial monitor provide user feedback. The system enables real-time visualization, remote access, and efficient analysis, demonstrating a cost-effective and reliable solution for secure automated attendance management. Mary A. Adedoyin et al., in [8] presented a scalable and cloud-integrated fingerprint attendance system using NodeMCU (ESP8266), R305 sensor, 12C interface, and a 16X2 LCD with a web application that incorporates HTML, CSS, JavaScript, PHP, MySQL. The system supports secure enrollment and verification with remote access via devices. A dynamic template matching method handles variations in orientation and skin condition, while encryption ensures data security. Testing on 100 students achieved 98-100% accuracy with ~4 seconds verification time, outperforming traditional methods. It offers low power consumption, high security, fast processing, portability, and improved functionality over existing systems. Swarnendu Ghosh et al., [9] proposed a portable biometric attendance system using an Arduino Uno, R305 fingerprint sensor, HC-05 Bluetooth module, and 16X2 LCD. Fingerprints are enrolled with unique IDs, and attendance is recorded upon successful matching. The verified data is displayed and sent to an Android app via Bluetooth for monitoring. The system significantly reduces attendance time, saving

about 11 minutes per class and 57 minutes daily compared to traditional methods. It is low-cost, portable, secure, and improves overall teaching efficiency. Wang Jingli, [10] proposed an IoT-enabled teaching management system integrating biometric identification for automated attendance and performance tracking. It uses fingerprint and vein recognition with a portable device featuring a touch LCD and ARM-based controller for real-time logging. Data is transmitted via IoT and stored in an SQLite database for monitoring. The system reduces faculty workload, improves data accuracy, and enhances student performance tracking. Ms. Ashvini H. Kale et al., in [11] proposed an IoT-based biometric attendance framework using an ESP32 and fingerprint sensor for automated classroom management. Fingerprints are stored and verified, with results displayed on a 16X2 LCD. Upon successful authentication, attendance data such as ID, name, date, time is sent via IFTTT webhooks to Google Sheets for real-time monitoring. The system follows enrollment, verification, and logging processes, reducing manual effort, preventing proxy attendance, and improving accuracy and efficiency. Dhaval Sarode et al., in [12] presented an IoT-based biometric attendance system designed using an Arduino Uno, R307 fingerprint sensor, and 16X2 12C LCD for student authentication. A Python script connects the hardware to cloud services, uploading data to Google Sheets via API for real-time monitoring. The system follows enrollment, verification, and cloud logging stages, achieving about 98% accuracy. It reduces proxy attendance, minimizes manual errors, and improves efficiency, transparency, and data accessibility. Prof. Sheetal Patil et al., proposed an automated attendance system in [13] combining fingerprint biometrics, RFID, and IoT. It uses a fingerprint scanner and RFID reader for authentication and identification, with an ESP8266 enabling data transfer to a web database. After enrollment, fingerprints are verified during sessions, and attendance is recorded. The system also sends SMS and email notifications to parents and provides a web portal for administrators. It reduces manual effort, prevents proxy attendance, and improves accuracy, security, and efficiency. Temilola M. Adepoju, et al., proposed an automated attendance monitoring system in [14] that integrates fingerprint biometrics with SMS notifications. Fingerprints are captured and stored during enrollment, then verified during sessions to record attendance. The system includes a fingerprint scanner, computer processing unit, and SQLite database, with a Java-based application and eBulkSMS API for alerts. It achieved 90% accuracy, reducing impersonation and improving monitoring through automated notifications. Ankit Barua et al. [15] proposed a smart biometric attendance system using an R307 fingerprint sensor and ESP8266 for real-time data transmission. Attendance data is stored in a MySQL database and accessed through a web interface. The system includes an OLED display and portable design, along with analytics for monitoring attendance patterns. It improves accuracy, reduces manual effort, and provides a cost-effective and scalable solution. Nilotpal Dwivedi [16] proposed a hybrid attendance system combining RFID and fingerprint authentication to improve accuracy and prevent proxy attendance in rural schools. The system uses an offline-first architecture with Raspberry Pi/Arduino and local SQLite storage, synchronizing data to the cloud when connectivity is available. A web/mobile dashboard enables monitoring, while SMS/WhatsApp notifications inform parents in real-time. The system improves efficiency, reduces manual effort, and enhances accountability, making it a cost-effective and scalable solution for rural environments. Mohammed Alhothaily et al. [17] proposed a fingerprint-based attendance system using biometric authentication recording. The system stores data in a database and provides web-based access with email reporting for monitoring. It improves accuracy, reduces time consumption, and prevents proxy attendance while offering a low-cost solution.

As in [1], the proposed system also utilizes an ESP8266 microcontroller with a fingerprint sensor to automate attendance and reduce manual intervention. The use of cloud platforms such as Firebase for real-time data storage and monitoring, as discussed in [2], [7], and [11], is similarly adopted to ensure instant data synchronization and remote accessibility. Studies [3] and [13] emphasize enhanced security through biometric authentication and multi-level verification, which aligns with the proposed system's focus on preventing proxy attendance. The concept of integrating additional features such as automated notifications and report generation, as highlighted in [4], [12], and [14], is incorporated in the system through email-based alerts to improve communication efficiency. Portable IoT-enabled attendance solutions discussed

in [5], [6], and [15] are reflected in the proposed design, which ensures flexibility, scalability, and ease of deployment. Hybrid and advanced authentication approaches, including RFID and multimodal systems presented in [13], and [16], support the need for enhanced reliability, although the proposed system focuses on fingerprint-based authentication for simplicity and cost-effectiveness. Real-time dashboards and web-based monitoring systems described in [6], [8], and [17] are also implemented to provide administrators with efficient access to attendance records. Furthermore, the importance of data security, cloud integration, and scalability highlighted in [2], [8], and [16] is addressed through the use of Firebase and MySQL for secure and structured data management. The overall concept of IoT- enabled automated attendance systems discussed across [9], [10], and [17] directly aligns with the proposed work, which aims to provide a reliable, secure, and real-time attendance management solution.

III. PROBLEM STATEMENT

The existing attendance management methods lack secure authentication, real time data synchronization, and automated communication features, which can lead to inefficiency and security issues. This research addresses the limitations of traditional attendance systems by developing an IoT based biometric attendance system that integrates embedded hardware, cloud storage, and automated notification features. The designed attendance system supports accurate attendance recording, real-time data synchronization, and efficient monitoring while also provides a scalable solution suitable for educational institutions.

IV. METHODOLOGY

The smart attendance system is designed using an IoT based architecture that incorporates biometric authentication, embedded hardware, cloud technology, and automated communication features. Initially, the fingerprint details of the users are enrolled and stored in the centralized along with the unique identification information. During the attendance marking, the fingerprint sensor captures the user's fingerprint and verifies it with the stored templates, and the ESP8266 microcontroller processes the authentication data.

After successful verification, the attendance data is uploaded to the cloud platform through Wi-Fi for real-time synchronization and monitoring. The attendance records are also stored in a backend database for future access and analysis. At the end of each session, the system compares the list of enrolled users with the recorded attendance data to identify absentees, and automated email notifications are sent accordingly. A web based dashboard is also provided to help administrators and faculty members view, manage, and analyze the records.

V. PROPOSED SYSTEM

The presented system is an IoT based smart attendance solution that utilizes fingerprint authentication to record the attendance securely and accurately. The system integrates a R307 fingerprint sensor with an ESP8266 Wi-Fi enabled microcontroller to capture and verify user identity in real time. Once the authentication is successful, attendance data is uploaded to Firebase for instant cloud storage and synchronization. The backend system stores the data in a MySQL database to aid in future access.

Attendance records are analyzed further to identify absentees, and automated email notifications are sent accordingly. A web based dashboard is also provided for administrators and faculty members to monitor and manage attendance records efficiently. By combining IoT connectivity, biometric security, and automated communication, the proposed system eliminates proxy attendance, reduces manual effort, and provides a scalable, secure, and real-time attendance management solution suitable for educational institutions.

VI. SYSTEM HARDWARE DESCRIPTION

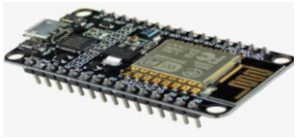

Fig. 1. ESP8266 Microcontroller

Fig.1. represents a low-cost Wi-Fi enabled microcontroller used to process data and transmit it to cloud platforms in IoT applications.

Fig. 2. R307 Fingerprint Sensor

Fig.2. represents an optical biometric device that captures and matches fingerprint patterns for secure user authentication.

Fig. 3. OLED Display

Fig.3. is a compact display module used to show system messages, prompts, and status information in real time.

Fig. 4. Li-ion battery 3.7V

Fig.4. is a rechargeable power source that provides stable voltage supply to the system components

Fig. 5. Buck Convertor

Fig.5. represents a voltage regulator that steps down higher input voltage to a lower stable output required by electronic components.

Fig. 6. Switch

Fig.6. is a basic electrical component used to control the power supply by turning the system ON or OFF.

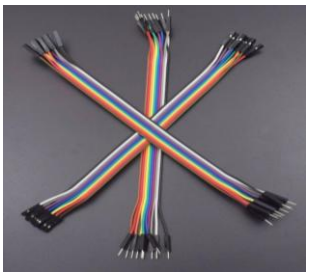

Fig. 7. Jumper Wire

Fig.7. is a flexible connecting wires used to establish electrical connections between components without soldering.

VII. SOFTWARE COMPONENTS DESCRIPTION

Arduino IDE

Arduino IDE is an open-source development environment used to write, compile, and upload code to microcontroller like ESP8266. It provides built-in libraries that simplify hardware control and IoT communication.

Google Firebase

Firebase is used in the system to store the attendance records and update them instantly through the internet. It allows the attendance data to be synchronized automatically and accessed from different devices whenever required.

MySQL

MySQL is integrated into the system to store attendance data in an organized way. It aids in viewing and maintaining records as required.

Visual Studio Code (VS Code)

Visual Studio Code is used for writing and managing backend code in Python. Its debugging features and extension support help simplify the development process.

Python Programming Language

Python is integrated into the backend of the system to handle database operations and automation tasks. It is mainly used to identify absentees and send automated email notifications using attendance data.

C++ Programming Language

C++ is used to develop firmware for the ESP8266 microcontroller using the Arduino framework. It enables efficient hardware control, fingerprint processing, and real-time data transmission.

VIII. SYSTEM EVALUATION

The performance of the proposed IoT-based smart attendance system was evaluated based on accuracy, response time, reliability, and system efficiency. The fingerprint authentication identified users accurately, which helped in preventing false attendance and unauthorized access. While testing the system, minor issues were noticed only when fingerprints were not placed properly on the senor or when fingerprint quality was unclear. The ESP8266 microcontroller transmitted the data to the cloud in real time, enabling records to be updated instantly in

the database. Attendance marking process was completed within a short period of time, making the system suitable even when multiple users accessed it continuously. The integration of Firebase and MySQL helped in storing attendance records securely and retrieving them whenever required. The system was able to identify absentees automatically and send email notifications without requiring manual intervention, which improved communication efficiency. The web based dashboard displayed attendance records clearly and supported easy monitoring. Overall, the developed attendance system reduced manual workload, improved the accuracy of attendance records, and provided a more efficient and transparent alternative to conventional attendance methods.

IX. RESULTS

The designed IoT-based smart attendance system was successfully implemented and tested in real time environments.

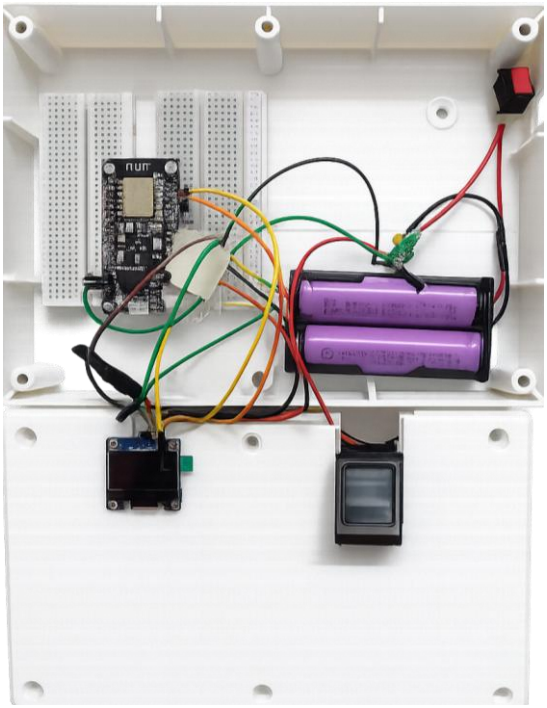

Fig. 8. Hardware Prototype of the IoT-based Smart Attendance System

The system accurately captured and verified fingerprint data using the R307 sensor, ensuring reliable user authentication and effectively eliminating proxy attendance. Attendance records were generated immediately after fingerprint verification and uploaded to the cloud database through the ESP8266 microcontroller without much delay. The records consisted of user details, attendance status, and date information, which were automatically synchronized and made available through the web based dashboard for monitoring. This showed that the system was capable of maintaining accurate and organized attendance data in real time.

Firebase supported quick synchronization of attendance information, while MySQL helped in storing records securely for future access. The backend module also identified absentees automatically by analyzing the attendance data. Email notifications were sent to the registered email addresses of absentees, which improved communication efficiency.

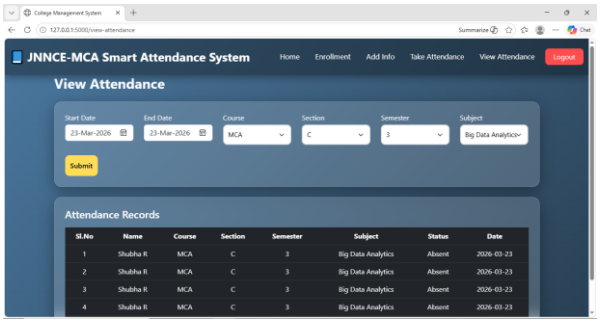

Fig. 9. Web-based Attendance Monitoring Dashboard

The dashboard displays attendance records with filtering options based on date, course, section, semester, and subject, enabling efficient monitoring and report generation.

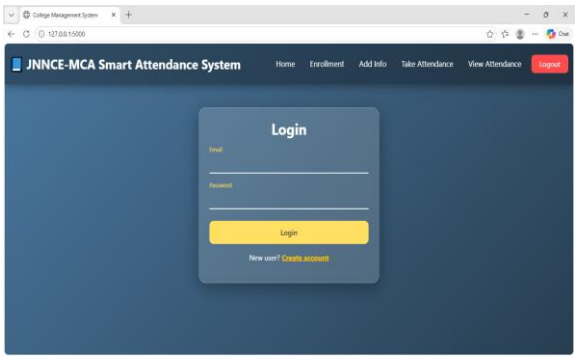

Fig. 10. Login Interface of the Smart Attendance System.

Overall, the developed attendance system showed accurate performance, quick response during attendance marking, and reliable operation real time environments. The results showed that the system can provide a secure and automated approach for managing attendance records more efficiently.

X. CONCLUSIONS

This work presents an IoT-based smart attendance system that integrates fingerprint authentication, cloud storage, and automated communication features. The developed system addresses the drawbacks of traditional attendance methods by reducing manual work, preventing proxy attendance, and ensuring secure user identification. The implementation uses an ESP8266 microcontroller, R307 fingerprint sensor, Firebase cloud platform, and MySQL database to support real-time attendance recording, secure storage of records, and remote access to attendance information.

The system also includes an automated email notification feature that sends absentee alerts without manual intervention. The implementation results showed that the system performed reliably in real-time environments and managed attendance records efficiently. With its compact design, ease of use, and IoT integration, the developed attendance system provides a practical and cost-effective solution for attendance management in educational institutions and organizations.

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