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SmartTrack: Advanced Attendance System Using LR RFID

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Abstract

This project presents the design and implementation of a long-range (LR) radio frequency identification (RFID) attendance system aimed at transforming how educational institutions track attendance by making the process faster, more accurate, and completely contactless. Traditional methods, whether manual roll calls or short-range RFID scanners, often interrupt class routines and leave room for errors or proxy attendance. To address these issues, the proposed system integrates LR RFID readers, beam sensors, and ESP32 microcontrollers to automatically detect and record attendance as students and faculty naturally walk through designated entry points. RFID readers capture unique identification tags from several meters away, eliminating the need for users to stop or interact with the system, while beam sensors validate movement and reduce false readings. The ESP32 processes the collected data, filters duplicates, associates each detection with the correct subject and session period, and transmits the information wirelessly via Wi-Fi to a centralized web server. A user-friendly web dashboard allows administrators, faculty, and students to view real-time attendance records, filter by presence or absence, and download reports in comma-separated values (CSV) or Excel formats, with role-based access ensuring appropriate data visibility. The system's architecture includes RFID hardware optimized for long-range, contactless identification through non-metallic barriers and supports bulk tag recognition, making it suitable for busy entry points. Secure database management ensures persistent storage of attendance logs, while modular web applications provide analytics, usage logs, and period-wise tracking to support academic decision-making. Extensive testing under various environmental and network conditions confirms the system's reliability and accuracy. By automating the entire workflow, this solution minimizes time wastage, reduces human error, and provides institutions with consistent, trustworthy attendance data that enhances operational efficiency and supports timely interventions to improve student performance.

Keywords: Attendance system, ultra-high frequency (UHF) reader, RFID-based monitoring, long-range RFID, precision attendance system

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INTRODUCTION

The proposed project introduces an innovative long-range attendance system aimed at automating the process for both students and faculty in educational institutions. Unlike traditional attendance marking that relies on manual radio frequency identification (RFID) card scanning, this system leverages long-range (LR) RFID readers and beam sensors integrated with ESP32 microcontrollers, enabling seamless identification as individuals pass through designated doorways without any direct interaction [1]. By automatically logging attendance and associating it with the current subject period, the solution not only streamlines student monitoring but also marks

faculty presence while tracking the subjects they teach in real time. All attendance data is instantly posted to a web-based interface, which provides comprehensive dashboards for faculty, students, and administrators, allowing for secure login, attendance review, filtered downloads by presence or absence, and dynamic tracking of class periods including start and end times, complete with timestamped logs for further analysis and export in CSV or Excel format [2]. This project aims to enhance institutional efficiency, reduce human error, and provide robust analytics for academic management.

Manual attendance tracking in schools and colleges can lead to inaccurate records, increased administrative workload, and issues such as proxy attendance, where someone marks attendance for another person. Initially, systems migrated to contact-based RFID cards, but these still required users to actively scan their cards, which did not fully eliminate queues or manual intervention [3]. The introduction of Internet of Things (IoT) devices like the ESP32 opened the door to more advanced, automated solutions that combine long-range RFID readers with beam sensors, so attendance can be marked simply by walking past a sensor-equipped doorway without card scanning or extra effort.

These systems upload real-time data to a centralized web dashboard, allowing administrators to track not just presence or absence, but also subject-wise logs, faculty periods, and detailed timestamped attendance analytics for both operational and educational improvement [4]. With the ability to export data in multiple formats (CSV, Excel) and filter by attendance status, modern systems offer an efficient, scalable, and secure replacement for legacy methods, providing immediate value in monitoring, auditing, and decision-making.

RELATED WORK

Over the past decade, significant research has been conducted in the field of automated attendance systems, particularly focusing on RFID, IoT, and wireless identification technologies. The evolution of these systems clearly shows a transition from manual and semi-automated approaches to fully intelligent and real-time monitoring solutions [5]. Figure 1 shows a flowchart of the LR RFID attendance system. Early work in this domain, such as the IEEE-based study on RFID attendance systems (2009), highlighted the inefficiency of traditional methods, such as roll calls and paper-based registers. These methods were found to be time-consuming and vulnerable to manipulation and inaccuracies.

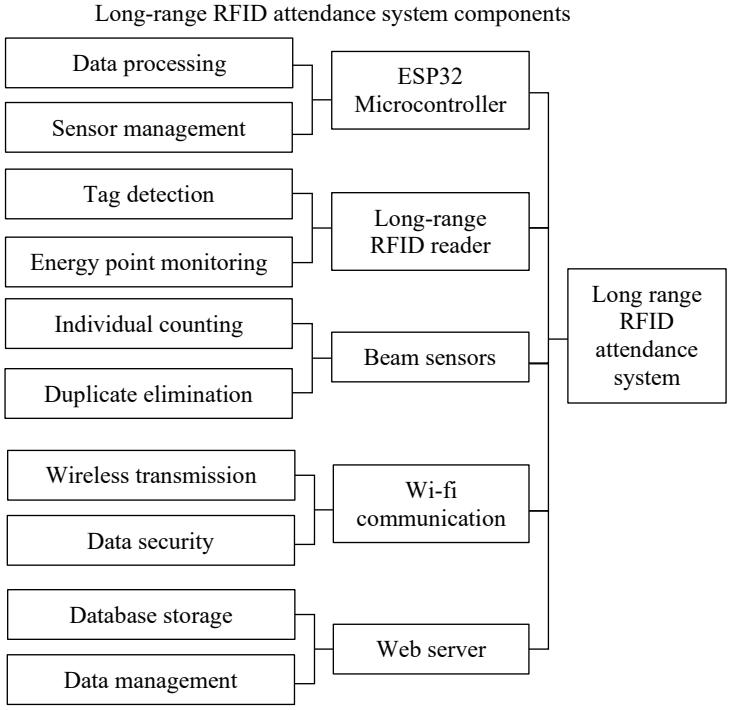

Figure 1. Flowchart of LR RFID attendance system.

This study proposed the use of RFID cards and readers to automate attendance marking, thereby reducing human intervention and improving reliability. As RFID technology matured, researchers began focusing on improving its efficiency and scalability [6]. Several studies have demonstrated that RFID-based attendance systems can significantly reduce administrative workload while ensuring accurate identification of individuals. These systems typically consist of RFID tags, readers, and microcontrollers, which enable automatic data capture and storage. However, most of these early implementations relied on short-range RFID, which required users to manually scan their cards [7].

With the emergence of IoT, attendance systems have undergone a major transformation. Recent literature reviews indicate that RFID systems integrated with IoT platforms allow real-time data transmission, cloud storage, and remote monitoring [8]. For example, a systematic review of IoT-based RFID attendance systems analyzed more than 20 research works and concluded that IoT integration significantly enhances system capabilities by enabling live tracking, automated record keeping, and improved accessibility for administrators [9].

Another important research direction is the use of active RFID and long-range systems. Unlike passive RFID, active RFID systems can detect tags over larger distances, enabling contactless and seamless attendance marking [10]. Research shows that such systems are particularly useful in environments where users are moving continuously, such as entry gates and corridors. However, these systems are often more expensive and require careful calibration to avoid false readings [11].

In summary, the literature clearly indicates that while RFID- based attendance systems have evolved significantly—from basic card scanning systems to IoT-enabled smart platforms there is still a need for systems that provide long-range detection, real-time processing, and high accuracy without user intervention [12]. This gap motivated the development of the proposed system, which combines long-range RFID, ESP32, and sensor-based validation to deliver a more efficient and reliable attendance solution.

SYSTEM DESIGN AND ARCHITECTURE

Design Philosophy

The design philosophy of the SmartTrack system focuses on simplifying, automating, and ensuring the reliability of attendance. It is designed to work in the background without interrupting users and seamlessly capture attendance as individuals pass through an entry point. Simultaneously, it ensures accuracy by using validation mechanisms to prevent errors [13]. The goal is to reduce manual effort while providing a smooth and trustworthy attendance system for real-world applications.

Hardware Layer

1. *RFID tags:* An RFID tag is a small electronic device that contains a unique identification code and communicates wirelessly with an RFID reader using radio waves. In attendance systems, RFID tags are issued to students and faculty members as cards or key fobs, enabling automatic and contactless identification when they come within the reading range of a compatible RFID reader.
2. *ESP32 microcontroller:* An ESP32 is a small, powerful microcontroller designed for smart devices and IoT applications. It has built-in Wi-Fi and Bluetooth, making it easy to connect wirelessly to the Internet or other devices [14]. It's energy- efficient and equipped with a fast processor, plenty of memory, and multiple input/output pins for connecting sensors and other hardware; this makes it a great choice for projects like an RFID system, home automation system, etc.
3. *CHAFON MU922 UHF RFID:* The CHAFON MU922 UHF RFID reader is a compact and efficient long-range reader designed for quick, contactless tag detection. It operates in the UHF frequency range and can read multiple RFID tags simultaneously from a short distance, making it suitable for applications such as attendance systems and access control [15]. The module is easy to interface with microcontrollers such as ESP32 using serial communication, and it provides fast and reliable performance, which helps in capturing data smoothly in real-time

environments. CHAFON MU922 UHF RFID integrated module, 865–868 MHz, 100 tags/s, built-in 3 dBi antenna, distance: 0 to 100 cm.

4. *Adjustable infrared (IR) sensor switch:* The E18-D80NK mini-adjustable IR sensor is a simple and reliable proximity sensor used to detect nearby objects without physical contact. It works by emitting infrared light and sensing the reflected signal when an object comes in front of it [16]. One useful feature is its adjustable range, which allows control of the distance at which an object can be detected. Because of its quick response and easy setup, it is commonly used in automation projects for tasks such as object detection and movement sensing. It has a range of 0 to 80 cm, which is adjustable.

Software Layer

1. *Microcontroller programming environment:* The microcontroller software plays an essential role in managing sensors, reading RFID tags, and facilitating wireless communication [17]. This is typically implemented using embedded programming tools such as Arduino IDE or ESP-IDF, with C or C++ code to handle real-time data capture and processing on the ESP32 microcontroller.
2. *Backend server:* The backend server software is responsible for securely receiving, storing, and managing the attendance data. It typically uses robust web frameworks such as Node.js, Django, or Flask, accompanied by databases such as MySQL, PostgreSQL, or MongoDB to maintain detailed attendance logs and user profiles.
3. *Web-based dashboard:* The user interface software provides real-time monitoring and reporting capabilities through a web-based dashboard. This front-end application was developed using HTML, CSS, and JavaScript frameworks, such as React or Angular, equipping administrators and educators with tools for filtering attendance records, visualizing trends, and exporting reports.
4. *Database:* A database for the long-range RFID attendance system is an excellent choice. Firebase provides a cloud-based NoSQL database solution called Firebase Realtime Database or Cloud Firestore, which allows real-time data synchronization and easy integration with web and mobile applications. This enables the attendance data captured by the ESP32 microcontroller to be instantly sent via Wi-Fi and updated in the database [18]. Firebase also offers built-in authentication, ensuring secure access control for administrators and users to access attendance records.

System Architecture Overview

Figure 2 shows the system block diagram for the long-range RFID attendance system, which comprises several critical components integrated for automated attendance tracking. The core of the system is the ESP32 microcontroller, which acts as the central processing unit coordinating all operations. Long-range RFID readers are positioned at entry points to detect unique RFID tags carried by students and faculty as they pass by, enabling contactless identification.

IMPLEMENTATION

Software Implementation

The software implementation of the long-range RFID attendance system began with the development of firmware for the ESP32 microcontroller. This firmware is written in C/C++ using the Arduino IDE or ESP-IDF framework, programmed to manage the collection of RFID tag data and beam sensor inputs, ensure data accuracy by filtering duplicate reads, and handle wireless communication protocols. The ESP32 connects to the Firebase cloud database via Wi-Fi, enabling real-time data synchronization, where attendance records are instantly uploaded and stored securely [19].

Interfacing Hardware with Software

The interfacing of hardware with software in the long-range RFID attendance system involves establishing seamless communication between physical devices like the ESP32 microcontroller, RFID readers, and beam sensors with the software components responsible for data processing, storage, and user interaction.

RFID Tag → Long-Range RFID Reader → ESP32 Microcontroller → Wi-Fi Communication → Firebase Database → Web Server Backend → Web Dashboard → Teacher/Administrator. Alongside this, Beam Sensor → ESP32 Microcontroller

Screenshots of Output or Circuits

The dashboard, as shown in Figure 3, displays the total number of students, present and absent counts, faculty attendance status, live scan logs, and the list of absent students for the current day. Key features include cloud synchronization, attendance simulation, and convenient report generation, providing a comprehensive view of real-time attendance data for both students and faculty. You can use this image as an example of the output in your report to illustrate how the system interfaces with users and presents attendance information visually [20]. Figure 4 shows the downloadable report of student attendance from the web server.

Operational Modes

The system supports two operational modes selectable from the dashboard:

1. *Automatic mode:* In the RFID attendance system, two modes can be implemented for marking attendance: auto and manual. In Auto Mode, attendance is automatically marked as students and faculty pass through the RFID readers. When an RFID tag is detected by the reader, the system instantly records the presence of the individual in the Firebase database without requiring any user intervention.
2. *Manual mode:* Teachers or administrators can add or edit attendance entries through a web-based dashboard. This feature is essential in cases where individuals might have missed scanning their RFID tags or in other exceptional scenarios. Teachers can securely log in to the system, view attendance records, and manually mark or correct attendance for specific students or sessions. Combining both modes provides flexibility, allowing the system to automate routine attendance marking while giving educators.

Output Interface

The" Reports" section of your RFID attendance system output provides a user-friendly interface for generating, filtering, and exporting attendance data. Administrators can select specific dates or sessions to review when students or staff are present or absent. Each record includes a timestamp, person type (student), unique ID, name, and subject or session attended, offering clear traceability for compliance or reviews.

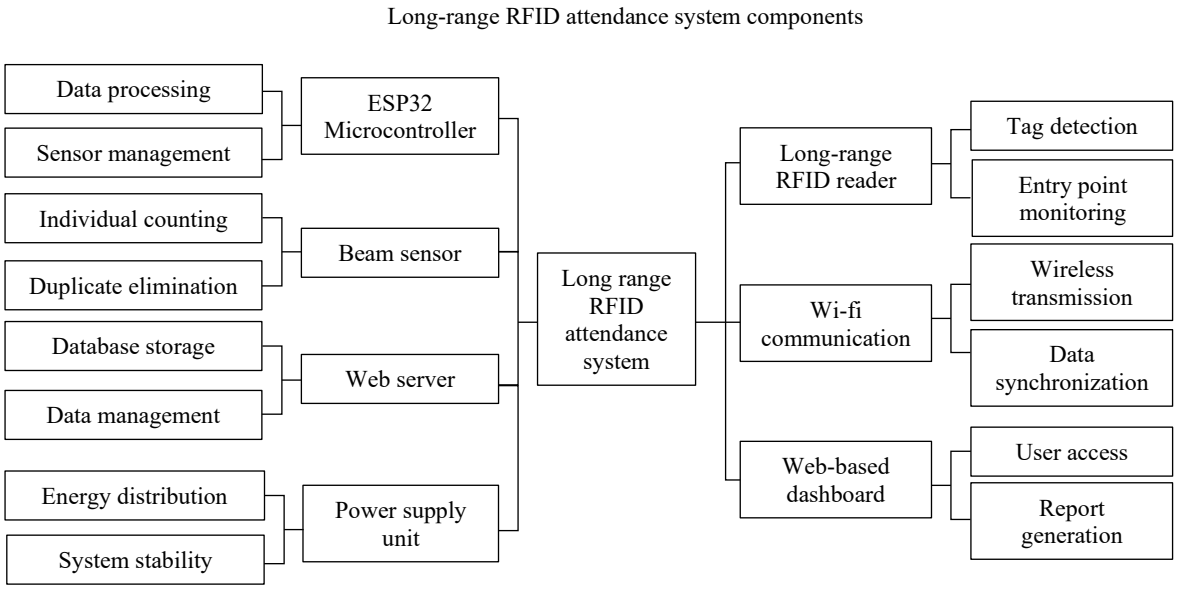

Figure 2. System block diagram of LR RFID attendance system.

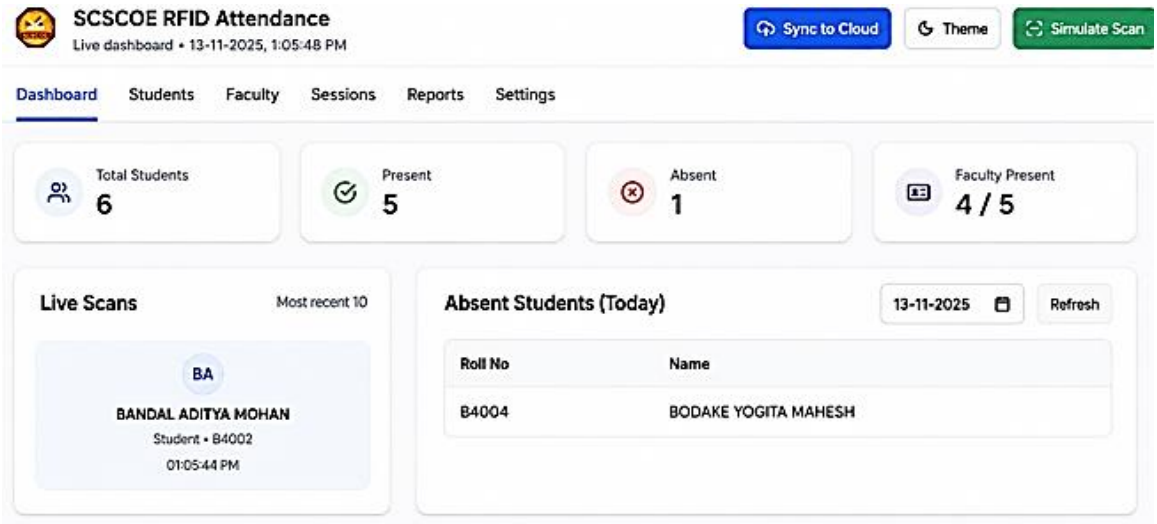

Figure 3. Dashboard of LR RFID attendance system.

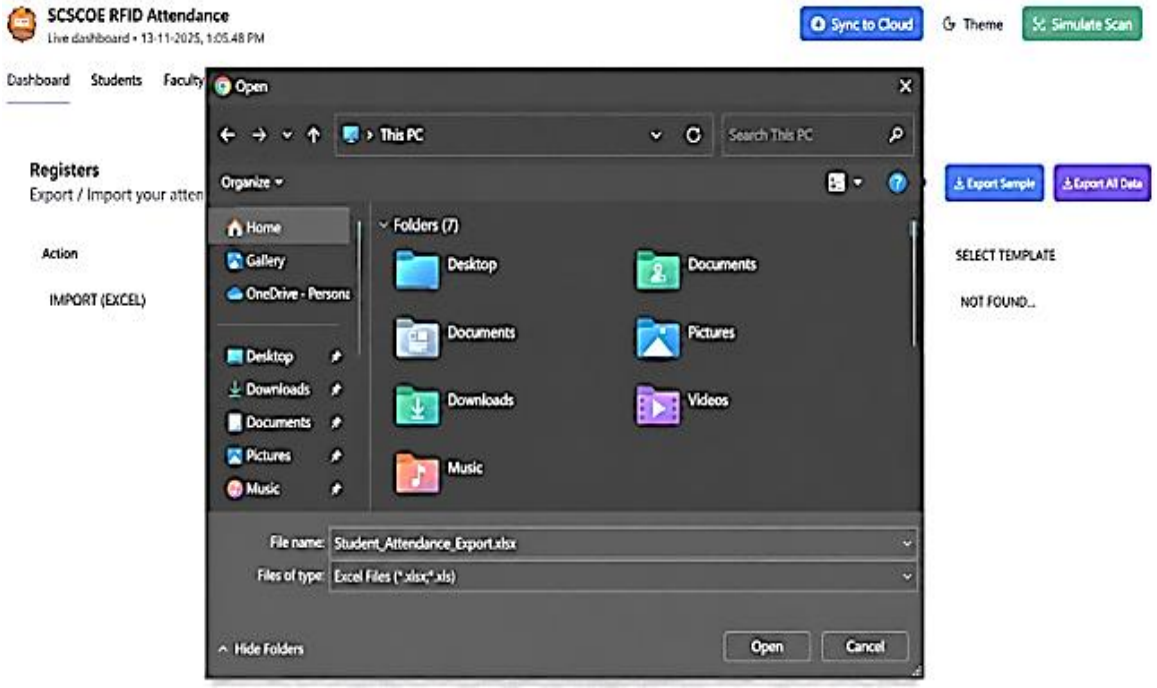

Figure 4. Downloadable report of student attendance from the web server.

RESULTS AND DISCUSSION

Quantitative Performance

Table 1 summarizes the parameters and values of the proposed attendance system. The expected efficiency and accuracy of the RFID attendance system are extremely high compared with manual attendance processes. The system is designed to record each student's attendance within seconds as they pass an RFID reader, with actual implementations demonstrating the rapid processing of hundreds of attendees nearly instantaneously. This eliminates the bottlenecks associated with manual roll calls and minimizes the administrative workload [21].

The 98.00% accuracy figure remained reasonably steady owing to the proper setup of the UHF RFID for a single classroom. The main reason for using the UHF RFID reader is to get contactless attendance, i.e., when you just walk through the door carrying the RFID tag in your pockets as well as your bag, the RFID reader scans the tag from long range, so we do not have to tap the card.

Table 1. System performance summary.

Parameter	Value
Read range	Typically, 1 to 10 meters (typical for long-range UHF)
Read rate	Up to hundreds of tags per second
Attendance accuracy	98% to 100% (high accuracy with proper setup)
Data transmission	Real-time via Wi-Fi/GSM/Firebase Cloud
Recall	94.2%
RFID tag type	Passive UHF (common), sometimes active
Microcontroller	Passive UHF (common), sometimes active
Power supply	5 V–12 V regulated DC supply

Table 2. LR RFID system versus traditional method.

Parameter	LR RFID system	Traditional method
Data capture speed	Instantaneous	Time-consuming
Accuracy	High (98%–100%)	Moderate to low
Proxy attendance	Difficult due to unique RFID tags	Paper-based
Data storage	Digital, cloud synchronization	Large area per file
Real-time monitoring	Yes	No
Reporting physical effort	Automated, facilitated via manual overrides	Manual, difficult, manual cross-verification

Comparison with Traditional Methods

The RFID attendance system offers significant benefits over traditional methods by automating attendance marking, providing real-time data updates, and utilizing cloud-based storage solutions. It eliminates manual errors, speeds up the process, and ensures transparency with instant data availability for analysis and decision-making. The system is flexible, allowing for both automated RFID scans and manual entries to handle exceptions. The use of a cloud database, such as Firebase, ensures reliable storage, scalability, and easy reporting for institutional management. Overall, the proposed system is highly accurate and efficient.

The most significant practical difference is not accuracy in isolation but a combination of accuracy, speed, and automated follow-on advice. A farmer who receives a detection result on their phone along with dosage instructions can begin treatment the same morning the drone flies. Under manual inspection with expert consultation, the same cycle typically takes two–three days.

Qualitative Observations

The qualitative evaluation of the long-range RFID attendance system showed that the integrated RFID reader, beam sensors, and ESP32 microcontroller operated reliably in real conditions, enabling smooth, contactless detection as individuals passed through the entry point. The system consistently minimized duplicate readings and maintained accurate person counting even during high-traffic moments, demonstrating strong synchronization between hardware components. Real-time data transmission to the web server ensured that the dashboard reflected attendance updates immediately, and users found the interface to be intuitive for reviewing records and generating reports. Overall, the system exhibited stable performance, reduced manual effort, and delivered a more efficient and error-resistant alternative to traditional attendance methods. Table 2 shows the comparison between the LR RFID system and the traditional method.

LIMITATIONS AND FUTURE SCOPE

Current Limitations

- *Cost:* Deploying RFID systems, especially with long-range readers and cloud integration, involves a significant initial investment in hardware and infrastructure, which may not be feasible for all institutions.

- *Privacy and security concerns:* RFID attendance data can be vulnerable to unauthorized access or hacking attempts without robust encryption and authentication mechanisms. Ensuring data security and user privacy remains a challenge in this field.
- *Technical limitations:* RFID signals may be affected by environmental factors such as electromagnetic interference, metal objects, or adverse weather conditions, which can reduce reading reliability.
- *Tag malfunction or loss:* RFID tags may malfunction or be lost, resulting in missed attendance marks unless manual overrides are consistently used.
- *User resistance:* Users may initially resist adopting new technology due to unfamiliarity or skepticism, which can impact the effective implementation and data accuracy.

Future Directions

The future scope of this RFID attendance system is exciting and full of possibilities. It can be upgraded with biometric or facial recognition technology to enhance security and eliminate proxy attendance. Integration with mobile apps could allow students and faculty to conveniently access attendance records, notifications, and reports. Advanced analytics can provide insights into attendance trends, helping institutions identify patterns and take proactive measures to improve student engagement and performance. Additionally, expanding the system to support multi-campus institutions or workplaces would make it more versatile. With these enhancements, the system has the potential to become a comprehensive tool for efficient attendance management and institutional development.

CONCLUSION

The RFID attendance system represents a significant advancement in automating and improving attendance tracking in educational institutions and workplaces. By leveraging RFID technology integrated with microcontrollers such as ESP32 and cloud services such as Firebase Realtime Database, the system offers a fast, reliable, and accurate solution. It eliminates the errors and inefficiencies associated with manual attendance methods, providing real-time monitoring, instant data synchronization, and user-friendly web-based dashboards for administrators and teachers. The contactless nature of the system also enhances hygiene and convenience, which is particularly relevant in today's health-conscious environments. Additionally, the ability to manage multiple RFID cards dynamically supports the scalability of large institutions without extensive customization.

It significantly reduces administrative workload, boosts accuracy, enables transparent reporting, and improves institutional workflow. Future enhancements could include biometrics or facial recognition for added security, mobile application integration, and advanced data analytics to maximize attendance management efficiency. The successful implementation of this RFID-based attendance management system demonstrates the transformative potential of combining the IoT, cloud computing, and automation to modernize institutional operations effectively. The current system can be further enhanced by integrating advanced features such as GPS- based autonomous navigation for automated field coverage, cloud-based data storage for long-term disease tracking, and AI-driven analytics for predictive health assessment. Future upgrades may also include extending flight time with improved batteries, adding night vision or multispectral cameras for low-light and thermal analysis, and developing a dedicated mobile application for better accessibility. Expanding the dataset to include diverse crop types and regional diseases will further improve the model's performance and adaptability. With these advancements, the system has strong potential to evolve into a completely smart farming solution, assisting farmers in making data-driven decisions and ensuring higher yields with minimal losses.

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