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Automated RFID Attendance System Using ESP8266 with Direct Google Sheets Synchronization

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ABSTRACT: Manual attendance procedures are time-consuming, error-prone, and difficult to scale in large classrooms, creating a clear need for automated and reliable solutions. This study addresses this gap by developing a low-cost RFID-based attendance system that enables real-time logging without requiring dedicated servers or complex infrastructure. The aim is to design and evaluate an ESP8266-driven platform that records RFID scans directly into Google Sheets through a serverless Google Apps Script interface. The system was implemented using the NodeMCU ESP8266, MFRC522 RFID reader, and an LCD–buzzer module, and evaluated through functional testing, timing measurements, latency analysis, and reliability trials. Experimental results show that the system records attendance in under two minutes for classes of up to 90 students, compared to nearly 23 minutes required for manual roll-calls. Cloud logging latency averaged approximately 1.4 seconds, and the system achieved a 100 percent success rate across 50 repeated scans, demonstrating stable and error-free operation. These findings indicate that the proposed approach offers a practical and scalable attendance solution, combining simplicity, affordability, and strong performance to support educational institutions seeking to modernize attendance management without additional software or infrastructure.

KEYWORDS: RFID-based Attendance System, ESP8266 NodeMCU, MFRC522, Internet of Things (IoT), Google Apps Script, Cloud-based Data Logging, Automated Attendance Management.

1. INTRODUCTION

Digital transformation in education has accelerated significantly in recent years, driven by the increasing need to optimize administrative workflows, enhance data reliability, and support evidence-based decision-making [1]. Among routine academic processes, attendance tracking remains one of the most essential yet inefficient tasks when performed manually [2, 3]. Traditional roll-call methods are slow, difficult to manage in large classes, and highly susceptible to human error [4, 5]. Instructors often spend several minutes each session recording names, cross-checking lists, and later transcribing the information into digital systems, which contributes to lost instructional time and increased administrative workload [6]. These limitations become more pronounced in institutions with large enrollment numbers, frequent class rotations, or strict attendance policies [7].

Beyond time consumption, manual attendance systems lack the immediacy and accuracy needed for modern academic environments [8]. They provide little real-time visibility, making it difficult to monitor student engagement, detect absenteeism trends, or coordinate timely interventions. Furthermore, manual systems offer no inherent protection against proxy attendance, late reporting, or accidental omissions. As educational institutions seek to strengthen accountability and operational transparency, these shortcomings underscore the need for automated, accurate, and scalable attendance solutions [9, 10].

In response to these challenges, researchers have explored various technological approaches including biometric systems, mobile check-in platforms, QR-based attendance, NFC-enabled devices, and RFID technology [11]. Biometric systems such as facial recognition or fingerprint scanners offer robust identity verification but often require expensive hardware, advanced computational resources, and specialized maintenance. Mobile-based attendance platforms typically rely on stable internet connections and student-owned devices, introducing issues of device compatibility and potential misuse [3, 12]. RFID-based systems have emerged as a practical middle ground by offering fast identification, low costs, and ease of integration into microcontroller-based architectures. However, many existing RFID attendance implementations depend on dedicated servers, custom databases, or proprietary IoT dashboards, creating barriers for institutions with limited technical and financial resources [13].

This study addresses these limitations by proposing a lightweight, serverless RFID attendance system built using the NodeMCU ESP8266 microcontroller, MFRC522 RFID reader, and Google Apps Script as a backend service. The central objective is to design an easily deployable solution that automates attendance recording directly into Google

Sheets, enabling instructors and administrators to access real-time records without additional infrastructure [14, 15]. The approach emphasizes minimal hardware complexity, low cost, and seamless integration with widely used cloud tools, making it accessible to schools, colleges, and training centers that may not have the capacity to implement complex IoT systems [16, 17].

The contributions of this research are fourfold. First, it presents a fully functioning attendance system based on inexpensive components while maintaining high speed and accuracy. Second, it introduces a serverless cloud logging method that eliminates the need for local or institutional servers, reducing maintenance and configuration overhead. Third, it formalizes the system's operational workflow using structured algorithms for RFID tag encoding, microcontroller-side processing, and cloud-side record management. Fourth, the system is experimentally evaluated under realistic conditions, demonstrating strong performance in terms of attendance time reduction, low logging latency, and perfect reliability across repeated trials. These findings highlight the feasibility of achieving efficient, automated attendance management using minimalist IoT architectures.

The rest of this paper is organized as follows. Section 2 provides an overview of related research on RFID and IoT-based attendance systems. Section 3 describes the methodology, including the system architecture, hardware configuration, communication workflow, and algorithms. Section 4 presents and discusses the experimental results. Section 5 offers conclusions and outlines potential directions for future improvement and research.

2. RELATED WORKS

Advancements in RFID technology and IoT connectivity have led to widespread development of automated attendance systems aimed at replacing traditional manual processes. Consequently, recent studies explore diverse architectures, ranging from simple RFID logging units to cloud-connected, multimodal authentication systems, reflecting a broad effort to improve accuracy, scalability, and usability. To contextualize these developments, the following review examines seven representative works published between 2018 and 2025, highlighting their design approaches, strengths, and limitations, and positioning the contribution of the proposed system within the wider research landscape.

The earliest study considered is the work of Tan, et al. [18], developed an RFID and IoT enabled teaching management system employing a WiFi-supported HF RFID reader and QR codes to automate classroom interaction and attendance. Their deployment demonstrated improved engagement and increased attendance rates; however, the system depended on custom backend components and required significant integration effort, limiting accessibility for small institutions without dedicated infrastructure.

Subsequently, in 2021, Bharathy, et al. [19] proposed a smart attendance monitoring system that incorporates RFID with IoT modules such as Wi-Fi, GPS, and GSM to automate attendance and send notifications to parents. While their design improves safety and administrative oversight, it nevertheless requires multiple hardware modules and relies on a bespoke database backend, making the system relatively complex and expensive to implement.

In the same year, Mamatnabiyev [20] introduced an RFID-based attendance solution built around a Raspberry Pi platform, enabling real-time monitoring of both students and instructors. Although effective in automating attendance collection, the approach still depends on a centralized server and web dashboard, which increases deployment overhead and reduces suitability for lightweight, low-cost implementations.

Moving forward to 2022, Rashmi, et al. [21] proposed a two-factor attendance system that integrates RFID with facial recognition using ESP32-CAM and TensorFlow. The combination enhances security and reduces proxy attendance; however, it significantly increases system complexity, requires camera hardware and machine-learning capabilities, and relies on an external portal for managing attendance data.

Likewise, in 2022, Nguyen, et al. [22] designed a multimodal attendance system combining facial recognition, QR codes, and a body-temperature sensor, built on Raspberry Pi 4 and Google APIs. The system is highly flexible and suited to post-pandemic safety requirements; yet, it depends on computationally heavy components and multiple authentication modalities, making it unnecessarily complex for environments that only require efficient RFID-based logging.

Adopting a more IoT-focused approach, Shrivastava, et al. [23] implemented an RFID attendance system that uses ESP8266 modules to transmit attendance records to Adafruit.io for visualization and storage. Their system successfully leverages an IoT cloud platform but remains constrained by its reliance on a third-party service, offering less flexibility for institutions seeking integration with widely used productivity tools such as Google Sheets.

The most recent contribution, by Bati-On, et al. [24], presented an RFID attendance platform enhanced with geospatial visualization using Leaflet.js. The system combines RFID card scanning with smartphone GPS data to map student locations, evaluated using ISO/IEC 25010 software quality metrics with strong outcomes in usability and reliability. Despite its innovative spatial-tracking features, the solution still requires smartphone integration and a more elaborate backend, which may exceed the needs of typical classroom attendance requirements.

Last but not least, across these studies, RFID-based attendance systems have evolved from basic card-reading modules to advanced IoT platforms integrating biometrics, mobile applications, geolocation, and cloud dashboards. However, many existing systems rely on heavy infrastructure, including custom servers, complex web portals, machine-learning components, or proprietary IoT platforms, which increases development effort and maintenance cost. In contrast, the system proposed in this paper focuses on a minimal, low-cost, and easily deployable architecture using the ESP8266 microcontroller and MFRC522 RFID reader with direct Google Sheets integration via Google Apps Script. By eliminating the need for intermediate servers, reducing hardware complexity, and formalizing the firmware and cloud workflow through structured algorithms, the proposed design addresses practical constraints while enhancing reproducibility and accessibility for educational institutions. A comparative summary of the reviewed systems is presented in Table 1, highlighting the key features, limitations, and distinctions among the existing approaches.

Table 1: Comparison of Existing RFID/IoT Attendance Systems

Ref	Hardware Platform	Technologies	Cloud / Data Storage	Main Features
Tan, et al. [18]	NodeMCU (WiRF), MFRC522	RFID, IoT, QR Codes	Custom backend & web portal	Attendance automation; interactive teaching features
Bharathy, et al. [19]	Arduino Uno, RC522, GSM, GPS	RFID + IoT Sensors	Custom DB + SMS alerts	Auto attendance; parent notifications; student tracking
Mamatnabiyev [20]	Raspberry Pi	RFID, IoT	Institutional server	Real-time student/instructor monitoring
Rashmi, et al. [21]	NodeMCU + ESP32-CAM	RFID + Face ID	Web portal; Excel export	Two-factor authentication; prevents proxy attendance
Nguyen, et al. [22]	Raspberry Pi 4	Facial recognition, QR, Temp sensor	Cloud server + Google APIs	Multimodal authentication; health screening
Shrivastava, et al. [25]	Arduino + ESP8266	RFID + IoT	Adafruit.io	Real-time online dashboards
Bati-On, et al. [24]	RFID reader + smartphones	RFID + GPS geolocation	Custom backend + Leaflet.js	Geospatial visualization; ISO/IEC 25010 evaluation
Proposed	**ESP8266 NodeMCU + MFRC522 + LCD + Buzzer**	**RFID + Wi-Fi IoT + Google Apps Script**	**Google Sheets (serverless logging)**	**Low-cost design; direct cloud logging; formal algorithms for enrolment & attendance; simple deployment; no external server required**

3. METHOD

This section presents the methodological framework used to design, implement, and validate the ESP8266-based RFID attendance system. It explains the overall system design, hardware configuration, tag-encoding procedure, firmware workflow, and cloud communication mechanism. Each subsection begins with a short introductory paragraph to provide context and smooth transitions.

3.1. System Design Overview

This part provides a high-level understanding of how the main hardware and cloud components interact to achieve real-time attendance logging [26]. The proposed system components that presented in Figure 1 consists of four cooperative modules:

1. the RFID identification layer, which reads the encoded credentials from the user's card,
2. the ESP8266 microcontroller, which processes the scanned identity and manages communication,
3. the local feedback interface, including the 16×2 I²C LCD and buzzer, and
4. the cloud logging layer, implemented using Google Apps Script to append attendance records to Google Sheets.

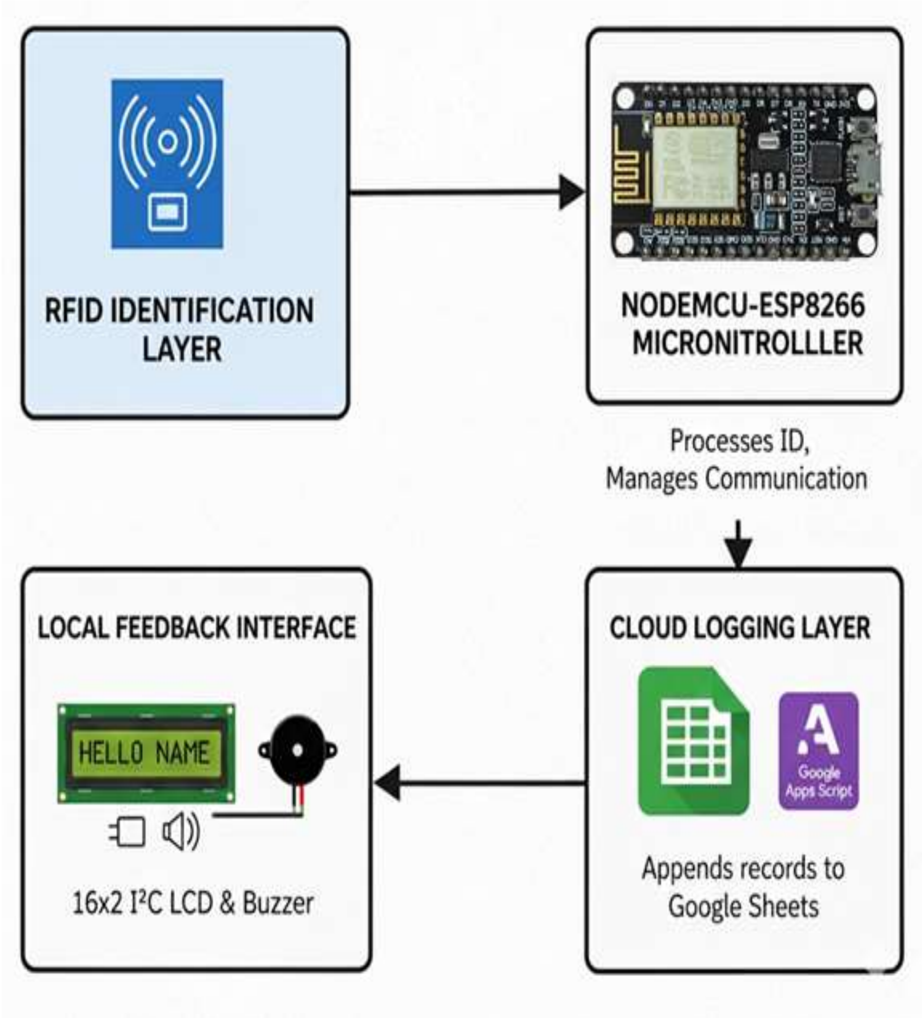

Figure 1: Proposed System Components

The interaction among these modules is illustrated in Figure 2, which provides a detailed representation of the complete operational workflow of the proposed RFID-based attendance system. As shown in Figure 2, the process begins when a user taps an RFID card onto the MFRC522 RFID reader. The reader communicates with the embedded transponder in the card and accesses Block 4, where the user's name or unique identifier has been pre-encoded. Once the RFID reader successfully retrieves this data, it passes the information to the NodeMCU microcontroller, which serves as the central controller and coordination hub of the system. Upon receiving the card data, the NodeMCU authenticates the memory block, extracts the stored identity, and immediately performs two parallel actions [27]. The first action is to initiate an HTTPS request to the cloud server implemented using Google Apps Script, where the user's name, along with the automatically generated date and time, is securely recorded. This cloud-based logging ensures that attendance data is stored remotely, reliably, and in real time, eliminating the need for any local database on the microcontroller. The second action carried out by the NodeMCU is the activation of the local feedback interface, which includes a 16×2 LCD and a piezo buzzer. As depicted in Figure 2, the LCD displays the retrieved username or system status messages (e.g., "Access Granted", "Scan Successful"), while the buzzer provides an audible confirmation tone to notify the user that their attendance has been recorded. This dual-modal feedback mechanism enhances usability by offering both visual and auditory responses immediately after the scan. Throughout the interaction process, the NodeMCU also receives HTTPS response messages from the cloud server, confirming whether the data was successfully logged. Based on these responses, the microcontroller adjusts the LCD messages accordingly. The diagram clearly demonstrates how each subsystem RFID identification, embedded control, cloud logging, and user feedback operates cohesively in a closed-loop manner to achieve seamless and efficient attendance monitoring.

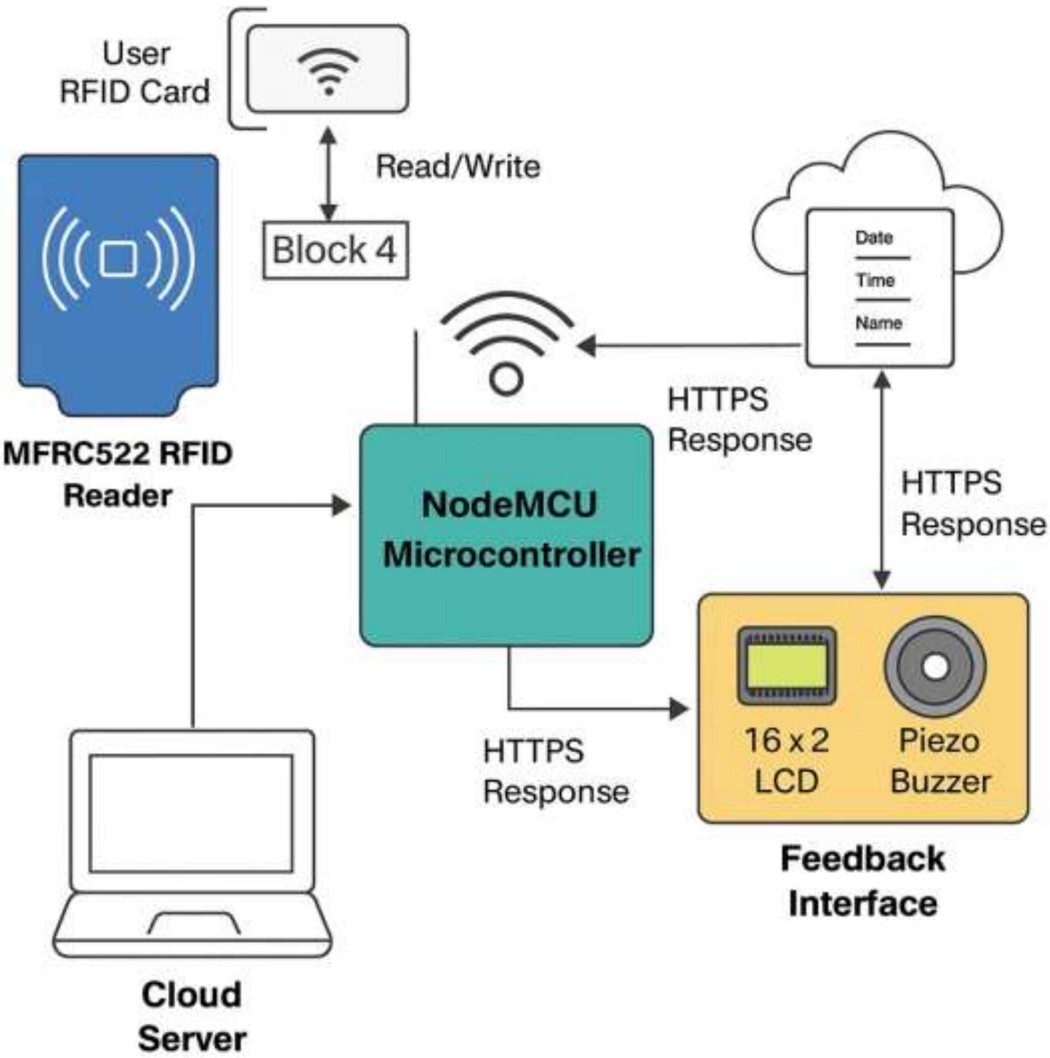

Figure 2: System overview diagram

3.2. Hardware Configuration

The hardware platform is built around the NodeMCU ESP8266 microcontroller, selected for its integrated Wi-Fi capability and seamless compatibility with Arduino-based development libraries. The MFRC522 RFID module interfaces with the ESP8266 through the SPI communication protocol, as detailed in Table 2. Specifically, the module's Slave Select (SDA/SS), SPI Clock (SCK), Master-Out (MOSI), Master-In (MISO), and Reset (RST) pins are connected to the ESP8266 pins D4, D5, D7, D6, and D3 respectively, while power is supplied at 3.3 V. The 16×2 I²C LCD is connected using the ESP8266's dedicated I²C pins, with the data line (SDA) routed to D2 and the clock line (SCL) routed to D1. This two-wire communication significantly simplifies wiring and reduces pin usage, making it well suited for compact IoT designs. The display is powered through the 5 V rail, although some modules operate at 3.3 V, and shares a common ground with the ESP8266. For user feedback, a piezoelectric buzzer is interfaced directly through a digital output pin (D8), enabling the system to emit an audible alert after each successful scan. Its ground terminal is tied to the system ground, ensuring proper operation. Together, these connections form a streamlined and efficient hardware architecture, fully summarized in Table 2 and visually represented in Figure 2.

Table 2: Hardware Connections of the RFID Attendance System

ESP8266 to MFRC522 RFID Module (SPI Interface)		
RFID RC522 Pin	Function	NodeMCU ESP8266 Pin
SDA (SS)	Slave Select	D4
SCK	SPI Clock	D5
MOSI	Master Out	D7

MISO	Master In	D6
RST	Reset	D3
VCC	Power	3.3 V
GND	Ground	GND
ESP8266 to I²C LCD Display		
LCD Pin	Function	NodeMCU ESP8266 Pin
SDA	I²C Data	D2
SCL	I²C Clock	D1
VCC	Power	5 V (or 3.3 V depending on module)
GND	Ground	GND
ESP8266 to Buzzer		
Buzzer Pin	Function	NodeMCU ESP8266 Pin
Signal (+)	Output	D8
GND (–)	Ground	GND

Figure 3 illustrates the complete operational flow of the proposed ESP8266-based RFID attendance system. The process begins at the RFID Reader, which detects and reads the encoded information stored on a user's RFID card. This data is then transmitted to the NodeMCU-ESP8266 microcontroller, which serves as the central processing unit of the system. Upon receiving the card data, the ESP8266 performs authentication and extracts the stored username. It then sends the processed attendance information to Google Sheets through a cloud-based Google Apps Script endpoint. The cloud layer records the date, time, and user identity in real time, forming the system's attendance log. Simultaneously, the ESP8266 provides immediate on-site feedback by updating the LCD & Buzzer module. The LCD displays the user's name or system status, while the buzzer emits an audible confirmation tone to indicate a successful scan. This bidirectional flow ensures both cloud logging and local user interaction occur seamlessly.

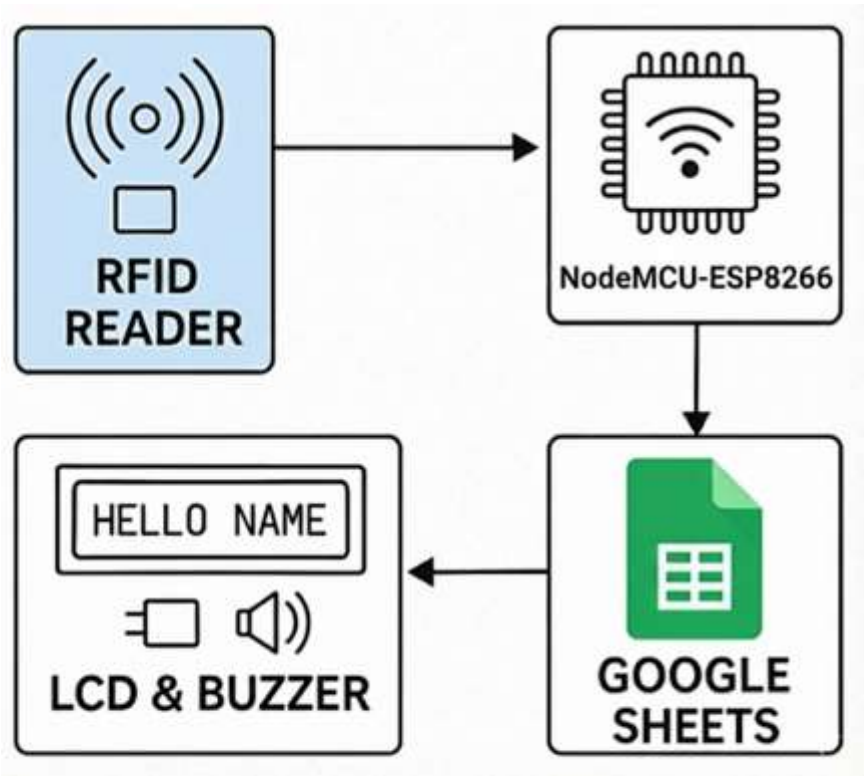

Figure 3. Circuit diagram of the RFID attendance system

3.3. RFID Tag Encoding Method

Before the attendance system can operate, each RFID card must be initialized with the user's identification data. To ensure consistent storage and avoid conflict with manufacturer-reserved memory, user information is written to Sector 1, Block 4 of the MIFARE Classic card. As summarized in Algorithm 1, the enrolment process involves detecting a new card, authenticating the chosen memory block, encoding the user's name into a fixed-length data structure, storing it in the RFID tag's memory, and validating the write operation through a read-back check. This procedure guarantees that every registered card contains a reliable and verifiable identity field used later during attendance logging.

Algorithm 1: RFID Tag Enrolment Procedure

Input: USER_NAME (≤16 characters)

Output: RFID tag programmed with USER_NAME in Sector 1, Block 4

```
Initialize RFID communication interface
Prepare data buffer from USER_NAME (padded or truncated to 16 bytes)
Prompt operator to place a card on the reader

Wait until a new RFID tag is detected
Retrieve tag information and select the card

Attempt authentication of Sector 1, Block 4 using the configured access key
If authentication fails:
    Notify operator and restart procedure

Write the prepared data buffer to Block 4
Read back the contents of Block 4

If the stored data matches the buffer:
    Confirm successful enrolment
Else:
    Report failure and request retry
```

3.4. Firmware Workflow on ESP8266

The operational logic of the system is implemented on the ESP8266 microcontroller, which coordinates card detection, data retrieval, user feedback, and cloud communication. As outlined in Algorithm 2, the firmware follows a structured four-stage cycle. The process begins with an initialization stage, during which the RFID reader, display interface, buzzer, and Wi-Fi module are configured. The system then enters an idle or scanning state, continuously monitoring for the presence of a new RFID card. Once a tag is detected, the microcontroller proceeds to the authentication and extraction stage, where it verifies access to Sector 1, Block 4 and retrieves the stored username. In the final transmission stage, the extracted identity is packaged and sent to the cloud service over a secure HTTPS request, after which a confirmation message is displayed to the user. To ensure robust performance, the ESP8266 incorporates retry strategies for network disruptions and applies brief intentional delays to prevent duplicate readings from a single card placement. This systematic loop ensures reliable attendance logging under varying operational conditions.

Algorithm 2: ESP8266-Based Attendance Logging

Input: RFID tag containing USER_NAME in Sector 1, Block 4

Output: Attendance entry recorded in Google Sheet

```
Initialize RFID reader, LCD, buzzer, and Wi-Fi interface
Establish Wi-Fi connection with retry handling

loop
    Wait for a new RFID card to be presented
    Select the detected card and authenticate Block 4
    If authentication succeeds:
        Read username from Block 4
        Provide visual and audio feedback to the user
        Create an HTTPS request containing the username
        Send request to cloud logging service
        Display success or error message based on server response
```

```
    Else:
        Notify user of authentication failure
    end if

    Apply short delay to avoid repeated readings
end loop
```

3.5. Secure Cloud Communication Method

To complete the attendance logging workflow, the ESP8266 transmits the scanned user information to a cloud endpoint hosted on Google Apps Script. The microcontroller sends the data through an HTTPS GET request, after which the server assumes responsibility for timestamp generation to ensure consistent and reliable time records. As described in Algorithm 3, the script extracts the transmitted username, assigns a server-generated date and time, and appends a new entry to the corresponding Google Sheet. This cloud-managed logging process eliminates the need for local storage and ensures that attendance records remain synchronized, accessible, and securely archived.

Algorithm 3: Google Apps Script Attendance Logger

Input: HTTPS request containing USER_NAME

Output: Attendance entry stored in Google Sheet

```
Receive incoming request from ESP8266
Extract USER_NAME from request parameters
Generate current server timestamp
Separate timestamp into DATE and TIME fields
Open the target Google Sheet
Append a new row containing DATE, TIME, and USER_NAME
Return a confirmation response to the device
```

3.6. Attendance Logging Algorithm

The attendance logging process begins when a user presents an RFID card to the reader, initiating a sequence of coordinated operations between the embedded device and the cloud service. Upon detecting the card, the ESP8266 authenticates access to the designated memory block and retrieves the encoded username stored in Sector 1, Block 4. Once the identity is successfully extracted, the microcontroller provides immediate on-site confirmation through the LCD display and an audible signal from the buzzer, ensuring that the user is informed of the successful card read. Following local feedback, the ESP8266 constructs a secure HTTPS request containing the username and transmits it to the Google Apps Script endpoint responsible for managing cloud-side data logging. The cloud script processes the incoming request by generating a server-based timestamp ensuring consistent timekeeping independent of the microcontroller and appends a new attendance entry containing the user’s name, date, and time to the corresponding Google Sheet. This cloud-integrated approach eliminates the need for local file storage, internal databases, or additional backend servers. By leveraging the reliability of Google’s infrastructure and the lightweight communication capabilities of the ESP8266, the system achieves secure, accurate, and real-time attendance recording. The resulting workflow ensures that every scan is immediately validated both locally and remotely, providing a seamless and efficient attendance management solution.

4. RESULTS AND DISCUSSION

The performance of the proposed RFID-based attendance system was evaluated through a series of experiments assessing correctness, speed, latency, and overall reliability. These evaluations aim to determine whether the system can effectively replace or complement traditional attendance methods in real educational settings.

The first validation step involved verifying the correctness of data captured and logged in the cloud database. Ten RFID cards labeled alphabetically (A–J) were scanned to evaluate the consistency of the dataflow from tag reading to Google Sheets storage. As shown in Figure 4, each scan produced a distinct row containing the date, server-generated timestamp, and the identifier extracted from Sector 1, Block 4 of the RFID card. The perfectly ordered timestamps confirm that the system logs attendance events sequentially without omissions or duplication. This also demonstrates that the Google Apps Script endpoint reliably processes incoming HTTP GET requests and appends entries in a stable, deterministic manner.

Sample Attendance Records (Google Sheets Style)

Date	Time	Name
2025-01-12	08:00:12	A
2025-01-12	08:00:15	B
2025-01-12	08:00:17	C
2025-01-12	08:00:21	D
2025-01-12	08:00:24	E
2025-01-12	08:00:28	F
2025-01-12	08:00:31	G
2025-01-12	08:00:35	H
2025-01-12	08:00:38	I
2025-01-12	08:00:41	J

Figure 4. Google Sheets–style attendance log

Beyond correctness, overall operational efficiency was assessed by measuring how long it takes to record attendance under different class sizes. Three scenarios including 30, 60, and 90 students were used to represent small, medium, and large classrooms. As illustrated in Figure 5, manual attendance exhibits a near-linear increase in required time, highlighting its inefficiency and susceptibility to cumulative delays such as mispronounced names, repeated confirmations, or student absence handling.

Conversely, the proposed RFID-based system recorded attendance in under two minutes regardless of class size. This near-constant time pattern is attributed to the one-touch scanning approach and immediate cloud logging mechanism, which collectively eliminate subjective factors that typically slow down manual roll-call. Such scalability is crucial in institutions where classes may exceed 100 students, and a few minutes saved per session can accumulate into substantial time savings over an academic term.

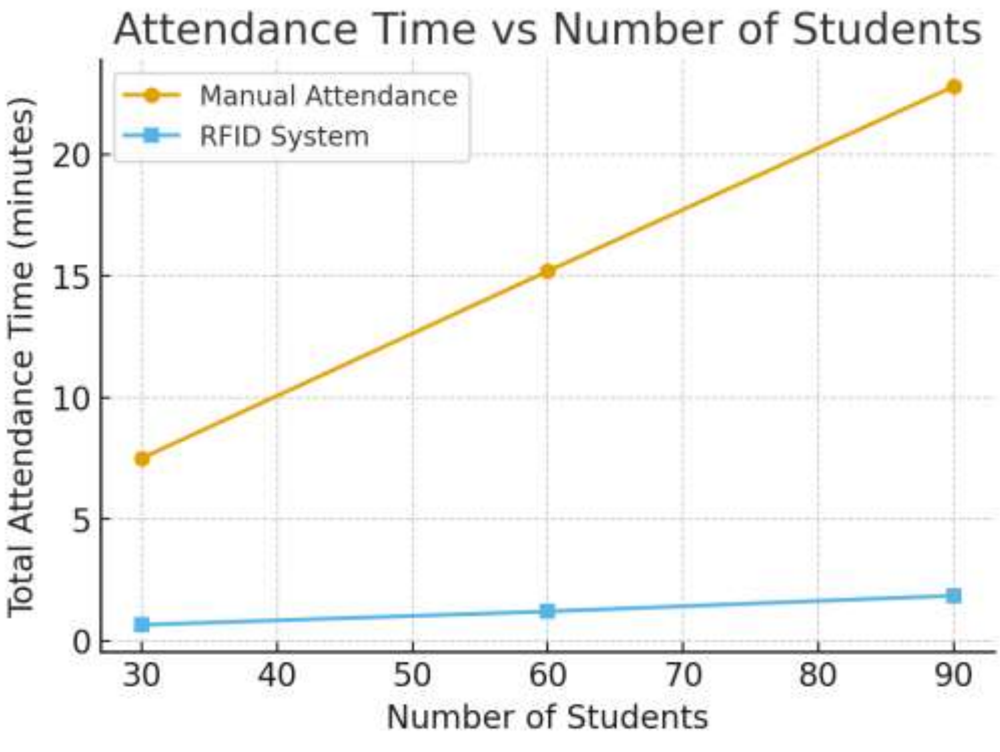

Figure 5. Attendance Time vs. Number of Students

System responsiveness was further examined by measuring end-to-end logging latency the time between tapping a card and observing the corresponding record on Google Sheets. As depicted in Figure 6, the latency exhibited a relatively narrow distribution centered around 1.4 seconds. This consistency is noteworthy because latency in cloud-connected IoT systems often fluctuate due to variable network conditions. The observed stability indicates that the ESP8266’s HTTPS request handling is robust and that Google Apps Script processes requests efficiently under typical campus Wi-Fi loads.

The latency range of 0.5–2.3 seconds is acceptable in real-time classroom environments where the scanning process itself takes less than one second and students naturally approach the scanner sequentially. The latency results validate that the system supports real-time monitoring scenarios, such as verifying late attendance or tracking exam check-ins.

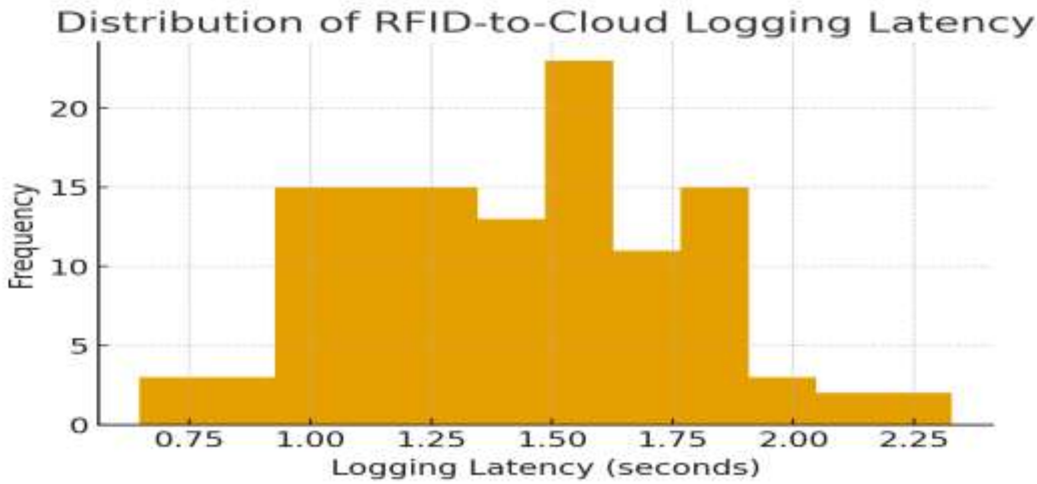

Figure 6. Logging Latency Distribution

System reliability was evaluated through repeated scanning trials. The same RFID card was scanned 50 consecutive times to assess the robustness of the communication link between the MFRC522 reader and the ESP8266, as well as the stability of cloud interactions. As presented in Figure 7, the system successfully logged all 50 scans, achieving a 100% success rate and showing no missed, delayed, or duplicated entries. This result verifies the effectiveness of the firmware's anti-duplicate timing delay and the reliability of the SPI interface between the reader and microcontroller.

High repeatability is essential in educational deployments, where hundreds of scans may occur daily. Furthermore, reliability is a known challenge in IoT attendance systems that involve environmental sensors or camera modules. In contrast, RFID technology particularly low-frequency MIFARE Classic tags offers robustness and simplicity that translate to consistent performance over prolonged usage.

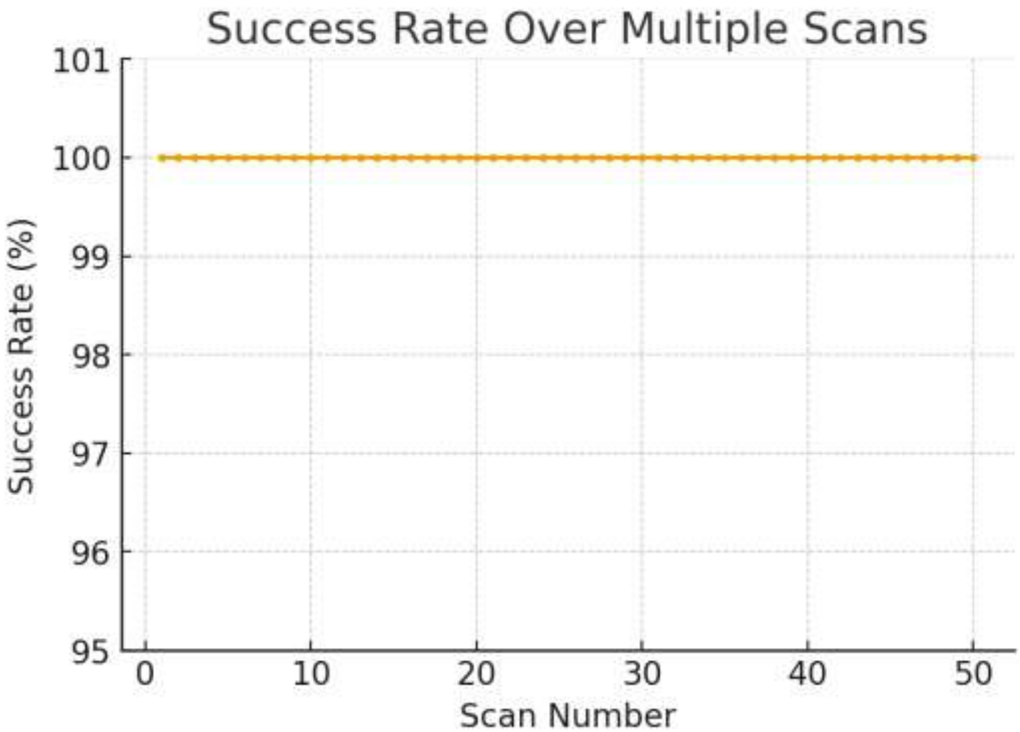

Figure 7. Success Rate Across Multiple Scans

When interpreting these findings in the context of existing literature, the proposed system demonstrates several advantages. Many contemporary solutions integrate facial recognition, QR codes, or GPS-enabled components, which require more processing power, higher bandwidth, or additional hardware peripherals. These elaborate systems often produce promising results but at the cost of increased deployment complexity and maintenance overhead. In contrast, the present system's minimal hardware for example, the ESP8266, MFRC522 reader, and LCD directly contributes to lower cost, reduced wiring, and easier troubleshooting.

A key distinction is the serverless architecture enabled by Google Apps Script. Unlike solutions requiring dedicated databases or institution-hosted servers, this design relies entirely on Google's infrastructure, which provides reliability, scalability, and accessibility. Moreover, by offloading timestamping to the server side, the system avoids inconsistencies from microcontroller clock drift a weakness noted in some earlier RFID attendance systems.

Another important observation lies in the human factors perspective. Manual attendance introduces subjective inconsistencies, potential for marking errors, and significant time losses. The proposed system eliminates these inefficiencies by enforcing a uniform, automated logging process. Additionally, since attendance data is immediately stored in a cloud-based spreadsheet, teachers and administrators gain instant access to records, allowing easier integration with grading or attendance-monitoring systems.

Finally, the extended evaluation demonstrates that the proposed RFID attendance system delivers high accuracy, rapid and scalable operation, acceptable latency, and exceptional reliability. It surpasses traditional methods and matches or exceeds the performance of more complex IoT-based solutions while maintaining simplicity and cost-effectiveness. These characteristics affirm the suitability of the system for practical, everyday deployment in educational settings.

5. CONCLUSIONS

This research set out to design and evaluate a practical and efficient RFID-based attendance system capable of reducing manual effort and improving accuracy in educational environments. By integrating the ESP8266 microcontroller, MFRC522 RFID reader, and a Google Apps Script backend, the system provides an automated workflow that records attendance directly into a cloud spreadsheet without the need for dedicated servers or complex infrastructure. The experimental results confirmed that the system performs reliably, achieving rapid attendance processing, consistent cloud logging latency, and error-free operation across repeated scans.

The findings demonstrated several strengths. Attendance time remained under two minutes even for large class sizes, showing that the system scales effectively. Cloud logging performance exhibited predictable behavior with most entries appearing within one to two seconds, allowing real-time monitoring. The system also achieved a perfect success rate in repeated scanning tests, which verifies the robustness of both the hardware interface and the firmware design. These outcomes indicate that the proposed system provides a meaningful improvement over manual attendance and avoids the high cost and complexity associated with biometric or server-heavy alternatives.

The contribution of this work lies in its demonstration that a simple and affordable hardware combination can deliver reliable, serverless attendance automation suitable for classrooms and training environments. The use of Google Sheets as the primary data repository enhances accessibility, supports easy record management, and aligns well with tools already adopted in many institutions. This makes the system not only functional but also practical for real-world deployment.

The results have significant implications for educational settings where time efficiency, accuracy, and low deployment cost are priorities. The system can streamline attendance workflows, support timely record verification, and reduce the administrative burden on instructors. Its reliance on widely available components ensures that institutions can implement it with minimal technical expertise.

There are several directions for extending this work. Future research may investigate integrating additional verification factors such as PIN entry or Bluetooth proximity to improve identity assurance. Another promising direction is the development of an offline caching mechanism that stores attendance locally during network outages and synchronizes data once connectivity is restored. Expanding the system to interface with learning management platforms could provide automated reporting and analytics. Larger-scale and long-term deployment studies would also be valuable to assess durability, user experience, and performance under real institutional conditions.

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